

# BQ2969T Overvoltage and Overtemperature Protection for 2-Series, 3-Series, and 4-Series Cell Li-Ion Batteries with LDO Output and Control / PTC Input

#### 1 Features

- 2-series, 3-series, and 4-series cell overvoltage protection (OVP)
- Factory programmed OVP threshold (3.6V to 5.2V) with ±12mV accuracy
- Fixed delay timer to trigger FET drive output (0.25s to 6.5s options)
- Control input pin, which can implement cell overtemperature protection (OT) using external PTC thermistor
- Integrated 3mA regulated output programmable to 3.8V, 3.3V, 3.15V, 3.0V, 2.5V, 1.8V, or 1.5V
- Factory programmed undervoltage (UV) detection threshold (1V to 4.15V) to disable regulator
  - OVP and OT remains operational even in undervoltage condition
- Output pin options:
  - Active high
  - Open-drain active pulldown
  - Open-drain inactive pulldown
- Multiple power modes:
  - NORMAL mode no OV or UV: I<sub>CC</sub> ≅ 1.23µA
  - Undervoltage or disable mode UV detected or control input low: I<sub>CC</sub> ≅ 0.25µA
  - Overvoltage mode OV detected: I<sub>CC</sub> ≅ 15µA
- Low leakage current per cell input < 100nA</li>
- Small package footprint
  - 8-Pin WSON (2mm × 2mm)

## 2 Applications

- Notebook PC
- Ultrabooks
- · Portable medical electronics
- UPS battery backup systems

## 3 Description

The BQ2969T family is a high-accuracy, low-power overvoltage protector with a 3mA regulated output supply and control / PTC input for Li-ion and LiFePO<sub>4</sub> (LFP) battery pack applications.

Each cell in a 2-series to 4-series cell stack is individually monitored for an overvoltage condition. An internal fixed-delay timer is initiated upon detection of an overvoltage condition on any cell. Upon expiration of the delay timer, the output pin is triggered into an active state to indicate that an overvoltage condition has occurred.

The regulated output supply delivers up to 3mA output current to drive always-on circuits, such as a real-time clock (RTC) oscillator. The BQ2969T family has a self-disable function to turn off the regulated output if any cell voltage falls below a programmable undervoltage threshold, thereby preventing drain on the battery.

The BQ2969T family includes a CTL pin which can be used to assert the OUT pin upon demand. The device also supports overtemperature (OT) protection when a PTC thermistor is attached between the CTL and VDD pins on the device.

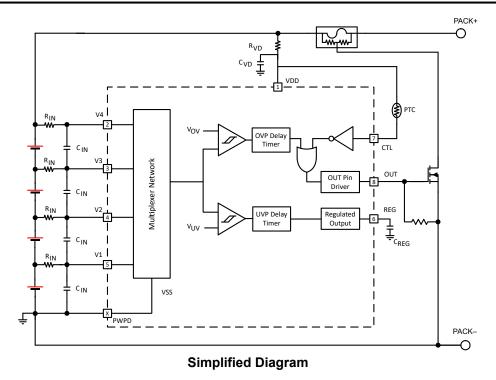
The BQ2969T family provides exceptionally low power operation, drawing only 1.23µA during normal operation (excluding regulator load current), and dropping to 0.25uA when in an undervoltage condition. Even when in the undervoltage state, the device can still detect an overvoltage condition on any other cell (which can occur in an imbalanced pack) and can assert the output pin.

## **Package Information**

PART NUMBER <sup>(1)</sup>	PACKAGE <sup>(2)</sup>	PACKAGE SIZE <sup>(3)</sup>		
BQ2969xxT	DSG (WSON, 8)	2.00mm × 2.00mm		

- (1) See the Device Comparison Table.
- (2) For more information, see Section 11.
- (3) The package size (length × width) is a nominal value and includes pins, where applicable.







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## **4 Device Comparison Table**

## **BQ2969T Device Options**

BQ2969T Device	OVP (V)	OVP DELAY (s)	OVP HYSTERESIS (mV)	UV (V)	LDO (V)	OUT PIN MODE	LATCH OUT	CTL PULLDOWN (Ω)
BQ296900T	4.65	5.5	150	2.5	3.0	active high	No	10M
BQ296901T	3.90	5.5	150	2.5	3.0	active high	No	10M
BQ296906T	4.35	5.5	150	2.5	3.0	active high	No	10M
BQ2969xxT <sup>(1)</sup>	3.6 – 5.2	0.25, 0.5, 1, 2, 3, 4, 5.5, 6.5	150, 300	1 – 4.15	1.5, 1.8, 2.5, 3.0, 3.15, 3.3, 3.8	active high, open-drain active pulldown, open-drain inactive pulldown	Yes, No	500k, 1M, 2M, 10M

<sup>(1)</sup> Product Preview (not Production Data). Contact TI for more information.

## **5 Pin Configuration and Functions**

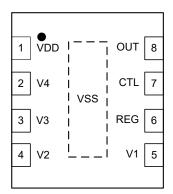


Figure 5-1. 2-Series to 4-Series BQ2969T (Top View)

Table 5-1. Pin Functions

PIN		TYPE(1)	DESCRIPTION			
NAME	BQ2962	ITPE	DESCRIPTION			
VDD	1	Р	Power supply input			
V4	2	IA	Sense input for positive voltage of the fourth cell from the bottom of the stack			
V3	3	IA	Sense input for positive voltage of the third cell from the bottom of the stack			
V2	4	IA	Sense input for positive voltage of the second cell from the bottom of the stack			
V1	5	IA	Sense input for positive voltage of the lowest cell from the bottom of the stack			
REG	6	OA	Regulated supply output. Requires an external ceramic capacitor for stability			
CTL	7	IA	Analog input control signal to assert OUT. An external PTC thermistor can be connected between CTL and VDD to implement overtemperature (OT) protection.			
OUT	8	OA	Analog output drive for an overvoltage fault signal; CMOS output high or opendrain active pulldown or open-drain inactive pulldown			
PWPD	-	Р	Electrically connected to integrated circuit ground and negative terminal of the lowest cell in the stack			

(1) IA = Analog input, OA = Analog Output, P = Power connection

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## **6 Specifications**

## 6.1 Absolute Maximum Ratings

Over operating free-air temperature range of -40°C to 110°C (unless otherwise noted)(1)

	PARAMETER	MIN	MAX	UNIT
Supply voltage range	VDD – VSS	-0.3	30	V
	VDD – V4	-0.3	30	V
Input voltage range	V1 – VSS, V2 – VSS, V3 – VSS, V4 – VSS, CTL – VSS	-0.3	30	V
Output voltage range	REG – VSS	-0.3	5.0	V
Output voltage range	OUT – VSS	-0.3	30	V
Storage temperature, T <sub>stg</sub>		-65	150	°C

<sup>(1)</sup> 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 may affect device reliability, functionality, performance, and shorten the device lifetime.

#### 6.2 ESD Ratings

PARAMETER			VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>	2000	V
V <sub>(ESD)</sub>	Electrostatic discharge	Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup>	500	V

- (1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
- 2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

#### **6.3 Recommended Operating Conditions**

Typical values stated where  $T_A = 25^{\circ}\text{C}$  and VDD = 15.2V, MIN/MAX values stated where  $T_A = -40^{\circ}\text{C}$  to 110°C, and  $V_{DD} = 3\text{V}$  to 22V (unless otherwise noted).

	PARAMETER	MIN	TYP M	X UNIT
	Supply voltage, V <sub>DD</sub> (REG ≤ 2.5V)	3		22 V
	Supply voltage, V <sub>DD</sub> (REG ≤ 3.3V)	4		22 V
Supply voltage, V <sub>DD</sub>	Supply voltage, V <sub>DD</sub> (REG ≥ 3.8V)	7.5		22 V
- 00	Normal operation, V <sub>DD</sub> – V4 <sup>(1)</sup>	-0.2	(	.2 V
	Customer test mode, V <sub>DD</sub> – V4		10	V
Innut valtage renge	V4 – V3, V3 – V2, V2 – V1, V1 – VSS	0		.5 V
Input voltage range	CTL - VSS	0		22 V
Operating ambient temperature range, T <sub>A</sub>	Operating ambient temperature range, T <sub>A</sub>	-40	1	10 °C

<sup>(1)</sup> Specified by design

#### 6.4 Thermal Information

		BQ2969T	UNIT
THERMAL	THERMAL	SON	UNIT
		(8 PINS)	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	80.0	°C/W
R <sub>0</sub> JC(top)	Junction-to-case(top) thermal resistance	102.5	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	46.5	°C/W
Ψлт	Junction-to-top characterization parameter	6.1	°C/W
ΨЈВ	Junction-to-board characterization parameter	46.5	°C/W
R <sub>0</sub> JC(bottom)	Junction-to-case(bottom) thermal resistance	22.7	°C/W



## **6.5 Electrical Characteristics**

Typical values stated where  $T_A$  = 25°C and VDD = 15.2V, MIN/MAX values stated where  $T_A$  = -40°C to 110°C, and  $V_{DD}$  = 3V to 22V (unless otherwise noted).

PARAMETER	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Voltage Protect Thresholds	tion					
V <sub>OV</sub>	V <sub>(PROTECT)</sub> Overvoltage Detection	$R_{IN} = 1k\Omega$		Applicable Voltage: 3.6V to 5.2V		V
\/	OV Detection Hystorogic	Nominal setting of 150mV	100	150	200	mV
V <sub>OVHYST</sub>	OV Detection Hysteresis	Nominal setting of 300mV	250	300	350	mV
V <sub>OA</sub>	OV Detection Accuracy	T <sub>A</sub> = 25°C	-12		12	mV
		$T_A = -40$ °C	-40		40	mV
	OV Detection Accuracy	T <sub>A</sub> = -10°C	-22		22	mV
OADRIFT	OV Detection Accuracy Across Temperature <sup>(1)</sup>	T <sub>A</sub> = 55°C	-24		24	mV
		T <sub>A</sub> = 85°C	-37		37	mV
		T <sub>A</sub> = 110°C	-50		50	mV
Supply and Leakage Curre	nt					
	Supply Current in NORMAL	$(V_n - V_{n-1}) = (V1 - V_{SS}) = 3.8V$ , n = 2, 3, 4, VDD = 15.2V, $I_{REG} = 0$ mA, $T_A = -10^{\circ}$ C to $60^{\circ}$ C		1.23	2	μΑ
	mode	$(V_n - V_{n-1}) = (V1 - V_{SS}) = 3.8V$ , $n = 2, 3, 4$ , VDD = 15.2V, $I_{REG} = 0$ mA, $T_A = -40^{\circ}$ C to 110°C			2.5	μA
DD	Supply Current in UV	$(V_n - V_{n-1}) = 3.8V$ , n = 2, 3, 4, and $V_{UVQUAL} < (V1 - V_{SS}) < V_{UVREG}$ , VDD = 11.4V, $T_A = -10^{\circ}$ C to 60°C		0.25	0.5	μΑ
	cappi, canonium c	$(V_n - V_{n-1}) = 3.8V$ , n = 2, 3, 4, and $V_{UVQUAL} < (V1 - V_{SS}) < V_{UVREG}$ , VDD = 11.4V, $T_A = -40^{\circ}$ C to 110°C			0.7	μΑ
	Supply Current in OV	$(V_n - V_{n-1}) = 3.8V$ , n = 2, 3, 4, and $V_{OV} < (V1 - V_{SS})$ , VDD = 15.2V, $T_A = -40$ °C to 110°C		15		μΑ
IN	Input Current at V <sub>n</sub> Pins	$V_{n} - V_{n-1} = (V1 - V_{SS}) = 3.8V, n = 2, 3, 4, VDD = 15.2V,$ $V_{A} = 25^{\circ}C$	-0.1		0.1	μΑ
nput Voltage						
V <sub>CTL</sub>	CTL Input Voltage Threshold	$VDD - CTL$ , $VDD \ge 5V$ , $T_A = -40$ °C to 85°C	2.55	2.8	2.95	V
		$VDD - CTL$ , $VDD \ge 5V$ , $T_A = -40$ °C to 110°C	2.55	2.8	3.37	V
CTLDELAY	CTL Delay <sup>(3)</sup>	VDD ≥ 5V	5.2	6.5	7.8	S
R <sub>PD</sub>	CTL internal pulldown resistance	CTL = VDD; $500k\Omega$ , $1M\Omega$ , $2M\Omega$ , $10M\Omega$ options	-30		30	%
R <sub>PDH</sub>	CTL hysteresis internal pulldown resistance	VDD – CTL > $V_{CTL}$ ; $R_{PDH} \approx R_{PD} / 2$ , VDD ≥ 5V		±30		%
OUT Pin Driver	•					
		OUT pin configured in active high mode, $(V_n - V_{n-1})$ or $(V1 - V_{SS}) > V_{OV}, n = 2, 3, 4, l_{OH} = 100 \mu A, VDD \ge 7.5 V$	5.5		8	٧
Vout	Output Drive Voltage	OUT pin configured in active high mode, $(V_n - V_{n-1})$ or $(V1 - V_{SS}) > V_{OV}, n$ = 2, 3, 4, $I_{OH}$ = 100 $\mu$ A, 3V < VDD < 7.5V	VDD – 1.5	VDD – 1.1	VDD	V
		OUT pin configured in active high mode, $(V_n - V_{n-1})$ and $(V1 - V_{SS}) < V_{OV}$ , $n = 2, 3, 4$ , $I_{OL} = 100\mu A$ flowing into OUT pin.		190	400	mV
ОИТН	OUT Source Current (during OV)	OUT pin configured in active high mode, $(V_n - V_{n-1})$ or $(V1 - V_{SS}) > V_{OV}$ , $n = 2, 3, 4$ , OUT = 0V, current measured sourced from OUT pin.	0.6		5.2	mA
OUTL	OUT Sink Current	OUT pin configured in active high, open-drain active pulldown, or open-drain inactive pulldown. Device output in pulldown state, OUT driven to 0.5V, current measured into OUT pin.	0.2		4	mA

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Typical values stated where  $T_A$  = 25°C and VDD = 15.2V, MIN/MAX values stated where  $T_A$  = -40°C to 110°C, and  $V_{DD}$  = 3V to 22V (unless otherwise noted).

PARAMETER	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
		Internal fixed delay, 0.25 second delay option <sup>(3)</sup>	0.14	0.25	0.38	s
		Internal fixed delay, 0.5 second delay option <sup>(3)</sup>	0.34	0.5	0.68	s
t <sub>DELAY</sub>		Internal fixed delay, 1 second delay option <sup>(3)</sup>	0.74	1	1.28	s
	OV D 1 T (2)	Internal fixed delay, 2 second delay option <sup>(3)</sup>	1.54	2	2.48	s
	OV Delay Time <sup>(2)</sup>	Internal fixed delay, 3 second delay option <sup>(3)</sup>	2.4	3	3.6	s
		Internal fixed delay, 4 second delay option <sup>(3)</sup>	3.2	4	4.8	s
		Internal fixed delay, 5.5 second delay option <sup>(3)</sup>	4.4	5.5	6.6	s
		Internal fixed delay, 6.5 second delay option <sup>(3)</sup>	5.2	6.5	7.8	s
t <sub>DELAY_CTM</sub>	OV Delay Time in Test Mode	Internal fixed delay		15		ms
t <sub>DELAY_RESET</sub>	OV Delay Reset Time	With one cell voltage above $V_{OV}$ , others cells below $V_{OV}$ , minimum time the high cell voltage must fall below $V_{OV}$ to reset OV Delay Timer <sup>(3)</sup>	0.1			ms
Regulated Supply Output,	REG					
		$VDD \ge 7.5V$ , $I_{REG} = 10\mu A$ , $C_{REG} = 0.47\mu F$ , $V_{REG} = 3.8V$ , $T_A = 25^{\circ}C$	3.724	3.8	3.876	V
		VDD ≥ 4V, $I_{REG}$ = 10 $\mu$ A, $C_{REG}$ = 0.47 $\mu$ F, $V_{REG}$ = 3.3V, $T_{A}$ = 25°C	3.234	3.3	3.366	V
	REG Supply	VDD ≥ 4V, $I_{REG}$ = 10 $\mu$ A, $C_{REG}$ = 0.47 $\mu$ F, $V_{REG}$ = 3.15V, $T_{A}$ = 25°C	3.087	3.15	3.213	V
$V_{REG}$		VDD ≥ 4V, $I_{REG}$ = 10 $\mu$ A, $C_{REG}$ = 0.47 $\mu$ F, $V_{REG}$ = 3.0V, $T_{A}$ = 25°C	2.94	3.0	3.06	V
		VDD $\geq$ 3V, I <sub>REG</sub> = 10 $\mu$ A, C <sub>REG</sub> = 0.47 $\mu$ F, V <sub>REG</sub> = 2.5V, T <sub>A</sub> = 25°C	2.45	2.5	2.55	V
		$VDD ≥ 3V$ , $I_{REG} = 10 \mu A$ , $C_{REG} = 0.47 \mu F$ , $V_{REG} = 1.8 V$ , $T_{A} = 25 ^{\circ} C$	1.764	1.8	1.836	V
		$VDD ≥ 3V$ , $I_{REG} = 10 \mu A$ , $C_{REG} = 0.47 \mu F$ , $V_{REG} = 1.5 V$ , $T_A = 25 ^{\circ} C$	1.470	1.5	1.530	V
		VDD ≥ 7.5V, $I_{REG}$ = 3mA, $C_{REG}$ = 0.47 $\mu$ F, $V_{REG}$ = 3.8V	3.58	3.8	3.88	V
		VDD ≥ 4V, $I_{REG} = 3mA$ , $C_{REG} = 0.47\mu F$ , $V_{REG} = 3.3V$	3.12	3.3	3.39	V
		VDD ≥ 4V, $I_{REG} = 3mA$ , $C_{REG} = 0.47\mu F$ , $V_{REG} = 3.15V$	2.98	3.15	3.23	V
$V_{REG}$	REG Supply	VDD ≥ 4V, $I_{REG} = 3mA$ , $C_{REG} = 0.47\mu F$ , $V_{REG} = 3.0V$	2.84	3.0	3.08	V
		VDD ≥ 3V, $I_{REG}$ = 3mA, $C_{REG}$ = 0.47 $\mu$ F, $V_{REG}$ = 2.5V	2.35	2.5	2.57	V
		VDD ≥ 3V, $I_{REG}$ = 3mA, $C_{REG}$ = 0.47 $\mu$ F, $V_{REG}$ = 1.8V	1.70	1.8	1.85	V
		VDD ≥ 3V, $I_{REG} = 3mA$ , $C_{REG} = 0.47\mu F$ , $V_{REG} = 1.5V$	1.42	1.5	1.56	V
I <sub>REG_SC_Limit</sub>	REG Output Short Circuit Current Limit	REG = V <sub>SS</sub> , C <sub>REG</sub> = 0.47µF	3.2		25	mA
R <sub>REG_PD</sub>	REG pull-down resistor	Activated when REG is disabled	20	30	40	kΩ
	oly Undervoltage Self-disable				'	
V <sub>UVREG</sub>	Undervoltage detection accuracy	Factory Configuration: 1.0V to 4.15V in 50mV steps, T <sub>A</sub> = 25 °C	-50		50	mV
V <sub>UVHYS</sub>	Undervoltage detection hysteresis		250 300 350		350	mV
t <sub>UVDELAY</sub>	Undervoltage detection delay <sup>(3)</sup>		5.2	5.2 6.5 7.8		s
V <sub>UVQUAL</sub>	Cell voltage to qualify for UV detection		0.45	0.5	0.55	V

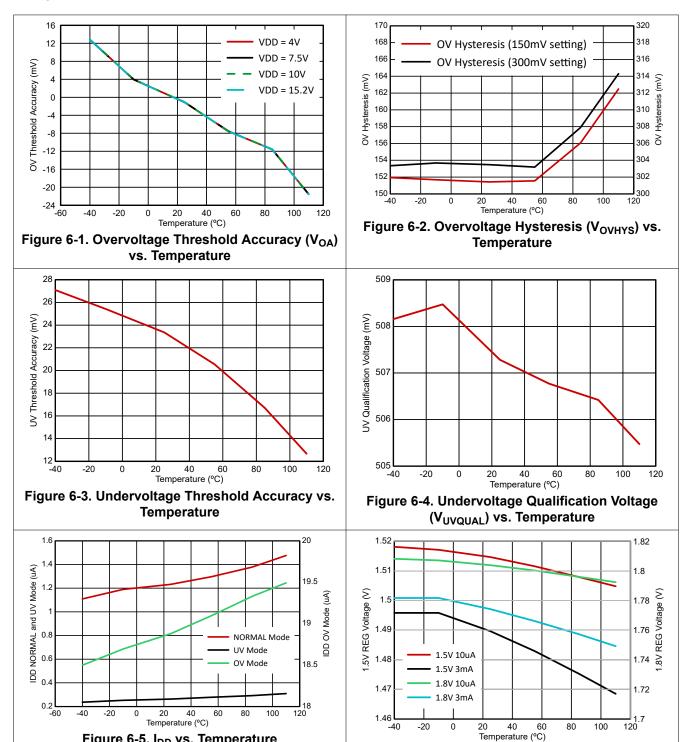
<sup>(1)</sup> Specified by a combination of characterization and production test

<sup>(2)</sup> Delay values specified when transitioning from NORMAL mode to OVERVOLTAGE mode. While device is in UNDERVOLTAGE mode, the delay can increase by a value between 0 and 1.2 seconds.

<sup>(3)</sup> Specified by a combination of design and production test



#### **6.6 Typical Characteristics**



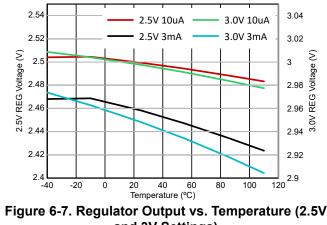
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Figure 6-5. I<sub>DD</sub> vs. Temperature

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Figure 6-6. Regulator Output vs. Temperature (1.5V and 1.8V Settings)

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and 3V Settings)

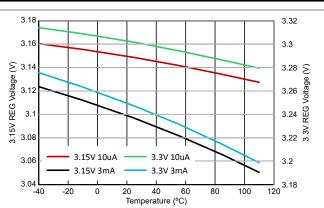


Figure 6-8. Regulator Output vs. Temperature (3.15V and 3.3V Settings)

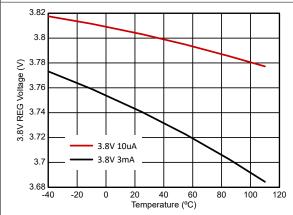


Figure 6-9. Regulator Output vs. Temperature (3.8V Setting)

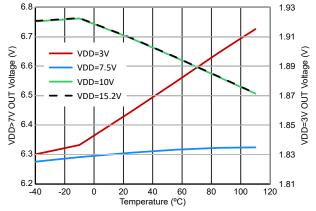


Figure 6-10.  $V_{\text{OUT}}$  vs Temperature, with 100 $\mu\text{A}$  Load **Current on OUT** 

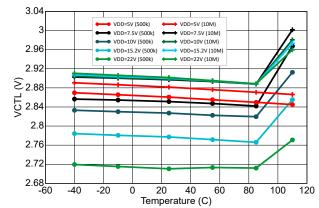


Figure 6-11. CTL Voltage Threshold Accuracy (V<sub>CTL</sub>) vs. Temperature

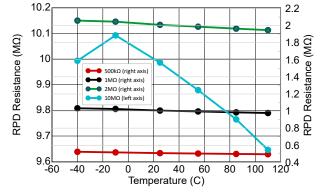


Figure 6-12. CTL Pulldown Resistance (RPD) vs. **Temperature** 



## 7 Detailed Description

#### 7.1 Overview

The BQ2969T family is a high-accuracy, low-power second-level overvoltage and overtemperature protector with a 3mA regulated output supply and control / PTC input for Li-ion and LiFePO₄ (LFP) battery pack applications.

Each cell in a 2-series to 4-series cell stack is individually monitored for an overvoltage condition by comparing the actual cell voltage to an overvoltage threshold  $V_{OV}$ . The overvoltage threshold is preprogrammed at the factory, with a range between 3.6V to 5.2V. The device initiates an internal fixed-delay timer when an overvoltage condition is detected on any cell. Upon expiration of the delay timer, the output pin is triggered into an active state to indicate that an overvoltage condition has occurred. The output pin can be configured as active-high, open-drain active pulldown, or open-drain inactive pulldown. The device recovers from the overvoltage condition when all cell voltages are detected below the overvoltage threshold by a hysteresis level, which can be programmed to 150mV or 300mV. Alternatively, the output pin can be programmed to latch and not recover whenever the output pin is activated.

The regulated output supply is programmable from 1.5V to 3.8V and delivers up to 3mA output current to drive always-on circuits, such as a real-time clock (RTC) oscillator. The BQ2969T family has a self-disable function to turn off the regulated output if any cell voltage falls below a programmable undervoltage threshold, thereby preventing drain on the battery. This undervoltage threshold can be programmed over a range from 1V to 4.15V.

The BQ2969T family includes a CTL pin which can be used to assert the OUT pin upon demand. The device also supports overtemperature (OT) protection when a PTC thermistor is attached between the CTL and VDD pins on the device.

The BQ2969T family provides extremely low power operation, drawing only 1.23µA during normal operation (excluding regulator load current), and dropping to 0.25uA when in an undervoltage condition. Even when in the undervoltage state, the device still monitors cell voltages and can detect an overvoltage condition on any other cell (which can occur in an imbalanced pack) and assert the output pin. Similarly, in the undervoltage state, the device still monitors the CTL pin voltage and can detect an overtemperature condition when a PTC is used, and assert the output pin.

**Table 7-1. Programmable Parameters** 

OVERVOLTAGE RANGE (V)	OVERVOLTAGE DELAY (s)	OVERVOLTAGE HYSTERESIS (mV)	UNDERVOLTAGE RANGE (V)	OUT PIN MODE	LATCHED OUT	REGULATOR (V)	CTL PULLDOWN (Ω)
3.6 to 5.2 in 1mV steps	0.25, 0.5, 1, 2, 3, 4, 5.5, 6.5	150, 300	1.0 to 4.15 in 50mV steps	active high, open- drain active pulldown , open- drain inactive pulldown	yes, no	1.5, 1.8, 2.5, 3.0, 3.15, 3.3, 3.8	500k, 1M, 2M, 10M

Product Folder Links: BQ2969T

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#### 7.2 Functional Block Diagram

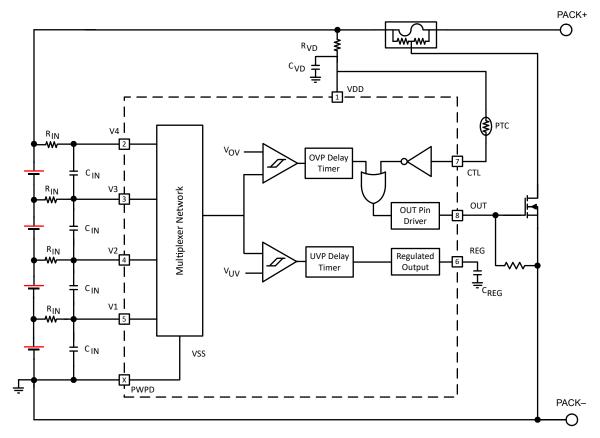


Figure 7-1. BQ2969T Block Diagram

### 7.3 Feature Description

#### 7.3.1 Pin Details

#### 7.3.1.1 Input Sense Voltage, Vx

These inputs sense each battery cell voltage. A series resistor and a capacitor across the cell for each input is required for noise filtering and stable voltage monitoring.

## 7.3.1.2 Output Drive, OUT

This terminal serves as the fault signal output whenever an overvoltage condition on any cell is detected. The pin can be configured as active high, open-drain active pulldown, or open-drain inactive pulldown. The pin can also be programmed to latch asserted when an overvoltage condition occurs, or to recover after the maximum cell voltage drops 150mV or 300mV below the overvoltage threshold.

#### 7.3.1.3 Supply Input, VDD

This terminal is the unregulated input power source for the device. A series resistor is connected to limit the current, and a capacitor is connected to ground for noise filtering.

## 7.3.1.4 Control / PTC Input Pin, CTL

The CTL pin can be used as a control input to assert the OUT driver upon demand by driving the pin low. This pin can also be used to implement cell overtemperature (OT) protection by connecting a PTC thermistor between the CTL and VDD pins. The device includes a pulldown resistance on the CTL pin which is configured by TI with options ranging from  $500k\Omega$  to  $10M\Omega$ .

Using the CTL pin functionality requires a VDD voltage of 5V or above. If the device is to be used in an application with VDD < 5V, then connect the CTL pin to VDD.

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#### 7.3.1.5 Regulated Supply Output, REG

The BQ2969T provides a regulated supply on the REG pin, which can be used to power external circuitry such as a real-time clock or other function. The REG output includes current limit protection circuit and also detects and protects for excessive power dissipation due to short circuit of the external load. This pin requires a ceramic 1µF capacitor connection to VSS for stability, noise immunity, and ESD performance of the supply output. This capacitor must be placed close to the REG and VSS pins for connection.

#### 7.3.2 Overvoltage Sensing for OUT

Each cell in the BQ2969T device is monitored independently for an overvoltage condition. Overvoltage is detected by comparing the actual cell voltage to a protection voltage reference, V<sub>OV</sub>. If any cell voltage exceeds the programmed V<sub>OV</sub> value, an internal timer circuit is activated. After the timer completes a fixed, pre-programmed delay, the OUT pin transitions from an inactive state to the active state.

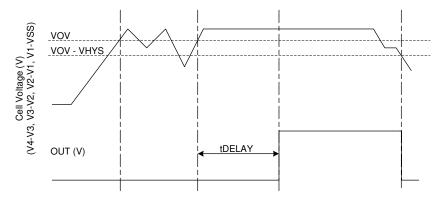


Figure 7-2. Timing for Overvoltage Sensing for OUT

#### 7.3.3 Regulator Output Voltage

At power up, the regulator output in the BQ2969T is on by default. If any cell voltage is below V<sub>UVREG</sub> at device power up, the regulator output remains on until the t<sub>UVDELAY</sub> time has passed, then the device disables the regulator output.

During discharge, if any cell voltage falls below the V<sub>UVREG</sub> threshold for t<sub>UVDELAY</sub> time, the regulator output is self-disabled. The regulator output turns on again when all the cell voltages are above V<sub>UVREG</sub> + V<sub>UVHYS</sub>.

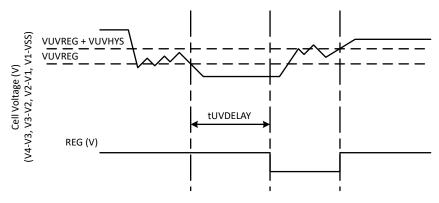


Figure 7-3. REG Output Timing

#### 7.4 Device Functional Modes

#### 7.4.1 NORMAL Mode

When all of the cell voltages are below the V<sub>OV</sub> threshold AND above the V<sub>UVREG</sub> threshold AND the CTL pin voltage is above V<sub>DD</sub>-V<sub>CTI</sub>, the device operates in NORMAL mode. The device regularly monitors the CTL pin

voltage (CTL-VSS) and differential cell voltages connected across (V1-VSS), (V2-V1), (V3-V2), and (V4-V3). The OUT pin is inactive in this mode, and the regulated output is enabled.

#### 7.4.2 OVERVOLTAGE Mode

OVERVOLTAGE mode is detected if any of the cell voltages exceed the overvoltage threshold,  $V_{OV}$ , for a configured OV delay time. The OUT pin is activated after a delay time pre-programmed at the factory. This pin is typically used to then enable an external FET and blow a fuse to disable the pack. When all of the cell voltages fall below ( $V_{OV} - V_{HYS}$ ) and remain above the  $V_{UVREG}$  threshold, the device returns to NORMAL mode if the output is not configured to latch when asserted. The regulated output remains enabled in this mode if all cell voltages are above  $V_{UVREG}$ .

#### 7.4.3 UNDERVOLTAGE Mode

The UNDERVOLTAGE mode is detected if any of the cell voltage across (V1–VSS), (V2–V1), (V3–V2), or (V4–V3) is below the  $V_{UVREG}$  threshold for  $t_{UVDELAY}$  time. In this mode, the regulated output is disabled. To return to NORMAL mode, all the cell voltages must be above ( $V_{UVREG}$  +  $V_{UVHYS}$ ) and below  $V_{OV}$ .

If the device is used in a system with fewer than 4 cells,  $V_n$  pin can be shorted to the  $(V_{n-1})$  pin. The device ignores any differential cell voltage below the  $V_{UVQUAL}$  threshold for undervoltage detection.

Even when in the UNDERVOLTAGE mode, the device continues to regularly monitor the CTL pin voltage and each cell voltage, checking if CTL falls below  $V_{DD}-V_{CTL}$  or if any cell voltage exceeds the  $V_{OV}$  threshold. If a condition occurs whereby a cell voltage is above  $V_{OV}$  and another cell voltage is below  $V_{UVREG}$ , such as can happen in a heavily imbalanced pack, then the OUT pin is activated and the regulator is disabled.

#### 7.4.4 CTL / OVERTEMPERATURE Mode

The CTL / OVERTEMPERATURE mode is entered if the voltage on the CTL pin falls below the  $V_{DD}-V_{CTL}$  threshold for the  $t_{UVDELAY}$ . The OUT pin is asserted after the  $t_{UVDELAY}$ , which is pre-programmed by TI. The OUT pin is typically used to then enable an external FET and blow a fuse to disable the pack.

The CTL pin can be used as a control input from external circuitry to cause the OUT pin to be asserted. The pin can also be used to implement cell overtemperature protection by connecting a PTC thermistor between the VDD and CTL pins of the device. The device includes an internal pulldown resistance from the CTL pin to VSS, with a resistance configured by TI. The pulldown resistance is enabled periodically when the CTL pin level is evaluated by the device. As the PTC resistance increases, this resistive divider with the internal pulldown resistance causes the CTL pin voltage to fall below the  $V_{DD}$ – $V_{CTL}$  threshold, resulting in the CTL / OVERTEMPERATURE mode being triggered and the OUT pin being asserted.

When the CTL / OVERTEMPERATURE mode is triggered, the OUT pin remains asserted until the CTL pin voltage rises above the  $V_{DD}$ – $V_{CTL}$  threshold. While in CTL / OVERTEMPERATURE mode, the internal pulldown resistance is reduced to half the normal value. When a PTC is used for cell overtemperature protection, this causes a temperature hysteresis, so the CTL / OVERTEMPERATURE mode only exits when the PTC thermistor reduces to a lower resistance.

If the latch option is configured in the device, then the OUT pin latches asserted when the CTL / OVERTEMPERATURE mode is triggered. The Undervoltage Detection Delay used to trigger the CTL / OVERTEMPERATURE mode is reduced to  $t_{DELAY\ CTM}$  while the device is in Customer Test Mode.

When the CTL pin voltage rises above the  $V_{DD}$ – $V_{CTL}$  threshold, the device returns to NORMAL mode if the output is not configured to latch when asserted. The regulated output remains enabled in this mode if all cell voltages are above  $V_{UVREG}$ .

#### 7.4.5 CUSTOMER TEST MODE

The Customer Test Mode (CTM) helps to reduce test time for checking the OV Delay Timer parameter once the circuit is implemented into the battery pack. To enter CTM, the VDD pin must be set at least 10V higher than V4 (see Figure 7-4). In this mode, the OV Delay Timer is reduced to approximately 20ms, considerably shorter than the timer delay in normal operation. To exit CTM, reduce the VDD voltage to below V4 + 10V, which causes

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the device to exit this mode. This reduction in OV Delay Timer also affects the time required to enter CTL / OVERTEMPERATURE mode as well as UNDERVOLTAGE mode.

#### **CAUTION**

Avoid exceeding any Absolute Maximum Voltages on any pins when placing the device into CTM. Also avoid exceeding Absolute Maximum Voltages for the individual cell voltages (V4–V3), (V3–V2), (V2–V1), and (V1–VSS). Stressing the pins beyond the rated limits can cause permanent damage to the device.

Figure 7-4 shows the timing for the Customer Test Mode.

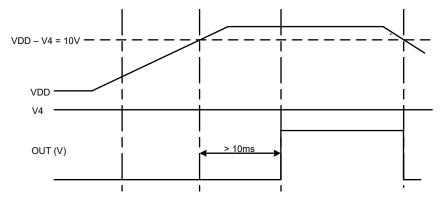


Figure 7-4. Timing for Customer Test Mode

Figure 7-5 shows the measurement for current consumption of the product for VDD and the cell input pins.

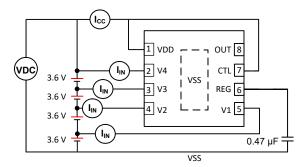


Figure 7-5. Configuration for Integrated Circuit Current Consumption Test



## 8 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.

## 8.1 Application Information

The BQ2969T family of second-level protectors is used for overvoltage and overtemperature protection of the battery pack in the application. A regulated output is available to drive local external circuitry. The device OUT pin can be configured in one of 3 drive types and is asserted whenever the device enters the overvoltage mode or overtemperature mode. The pin is typically used to drive an NMOS FET that blows a fuse in the event of a fault condition, thereby disconnecting the pack power path.

#### 8.2 Typical Application

Figure 8-1 shows a simplified application schematic using the BQ2969T together with the associated passive components and external NFET to flow a high-side fuse.

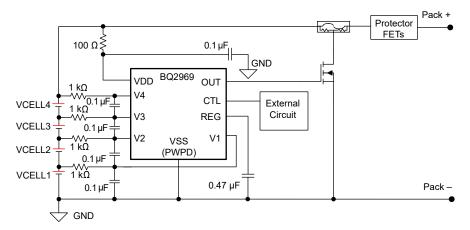


Figure 8-1. BQ2969T 4-Series Cell Typical Implementation (Simplified Schematic)

A full schematic of a basic circuit based on the BQ2969T for a 4-series battery pack evaluation module is shown below. Figure 8-11 and Figure 8-12 show the board layout for this design.

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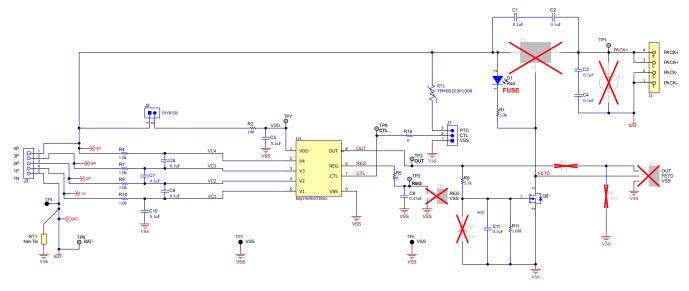


Figure 8-2. BQ2969T 4-Series Cell Schematic Diagram - Protector and Fuse Blow Circuitry

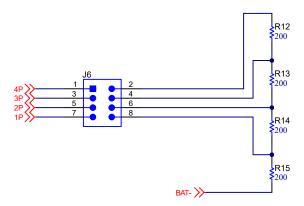


Figure 8-3. BQ2969T 4-Series Cell Schematic Diagram - Cell Simulator Circuitry

#### 8.2.1 Design Requirements

#### Note

Changes to the ranges shown in Table 8-1 can impact the accuracy of the cell measurements.

**Table 8-1. Parameters** 

PARAMETER	EXTERNAL COMPONENT	MIN	NOM	MAX	UNIT
Voltage monitor filter resistance	R <sub>IN</sub>	900	1000	4700	Ω
Voltage monitor filter capacitance	C <sub>IN</sub>	0.01	0.1	1.0	μF
Supply voltage filter resistance	R <sub>VD</sub>	100	_	1000	Ω
Supply voltage filter capacitance	C <sub>VD</sub>	_	0.1	1.0	μF
REG output capacitance	C <sub>REG</sub>	0.47	1	_	μF

#### Note

The device is calibrated using an  $R_{\text{IN}}$  value =  $1000\Omega.$  Using a value other than the recommended value changes the accuracy of the cell voltage measurements and V<sub>OV</sub> trigger level.

#### 8.2.2 Detailed Design Procedure

- 1. The device allows a random cell connection to the VSS, V1, V2, V3, and V4 pins. The device does not require VSS to connect first and does not require cells connected in a particular order. However, the OUT pin being temporarily asserted during cell attach is possible, depending on the timing of the attachment and the external circuitry connected to the device. The user can want to take measures to check that the OUT pin assertion at this point does not cause issues on the production line.
- 2. If fewer than 4 cells are used, then short an unused cell input pin V<sub>n</sub> to the next lower cell input pin (V<sub>n-1</sub>).
- 3. It is recommended to place the cell input capacitors, supply pin capacitor, and REG output capacitor close to the device, minimizing trace length on the PCB.

## 8.2.3 Application Curves

The scope plots below show the response of the device transitioning among the different states. Figure 8-4 shows the device detecting an overvoltage event and asserting the OUT pin to blow an external fuse after the overvoltage delay period. Figure 8-5 displays the device recovering from the overvoltage event when all cell voltages have fallen below the overvoltage threshold by the required hysteresis level, and the OUT pin deasserting. Figure 8-6 shows the device detecting an undervoltage condition and disabling the REG LDO output after the undervoltage delay period. Figure 8-7 then depicts the device recovering from the undervoltage condition and re-enabling the REG LDO when all cell voltages have risen above the undervoltage threshold by the required hysteresis level.

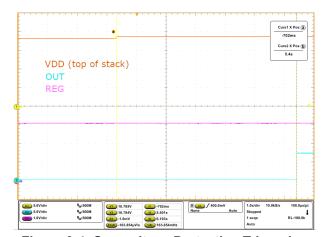


Figure 8-4. Overvoltage Protection Triggering

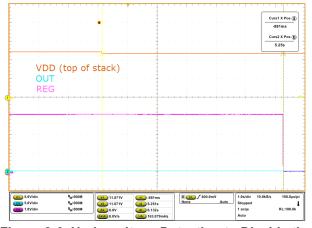


Figure 8-6. Undervoltage Detection to Disable the Regulator



Figure 8-5. Overvoltage Protection Recovery



Figure 8-7. Undervoltage Recovery to Re-enable the Regulator



#### 8.2.4 CTL for PTC Thermistor Protection

The CTL pin of the BQ2969T family can provide overtemperature (OT) protections when a PTC thermistor is attached between the CTL and VDD pins of the device. The CTL pin has a factory programmable internal pulldown resistance ( $R_{PD}$ ) with  $500k\Omega$ ,  $1M\Omega$ ,  $2M\Omega$ , and  $10M\Omega$  options. In all operational modes  $R_{PD}$  is pulsed at a low duty cycle, making a higher effective resistance of  $R_{PD}$ , to avoid drawing significant additional current from the supply.

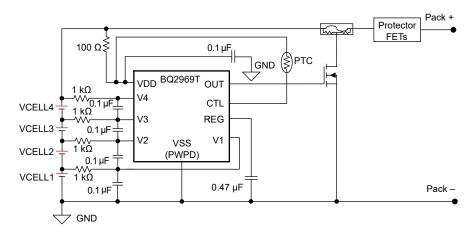


Figure 8-8. BQ2969T PTC Configuration Reference Schematic

The overtemperature mode is entered when the voltage of the CTL pin falls below the  $V_{DD}$  -  $V_{CTL}$  threshold for  $t_{UVDELAY}$ , in this mode the OUT pin is then asserted. The OUT pin is typically used to then enable an external FET and blow the fuse to disable the pack. Figure 8-9 shows an example of CTL being used for overtemperature protection. The OT voltage trip threshold is defined as the voltage  $V_{DD}$  minus  $V_{CTL}$ . For example assume a  $V_{DD}$  of 16V and typical  $V_{CTL}$  of 2.8V, to calculate the OT voltage trip threshold, 2.8V is subtracted from 16V, which provides a nominal OT trip voltage threshold of 13.2V. The voltage across the PTC is nominally always  $V_{CTL}$ , when the OT voltage trip threshold is met.

Overtemperature hysteresis is implemented with the  $R_{PDH}$  resistance. After the overtemperature protection triggers, the  $R_{PD}$  resistance halves, for example if using the  $10M\Omega$  option, the new resistance ( $R_{PDH}$ ) is now  $5M\Omega$ . The new lower resistance means that to recover from an overtemperature condition a lower resistance from the PTC is needed, to cause the CTL pin voltage to rise above the OT voltage trip threshold. When the temperature drops, the PTC resistance lowers to allow OT recovery as the CTL pin voltage again increases in voltage.

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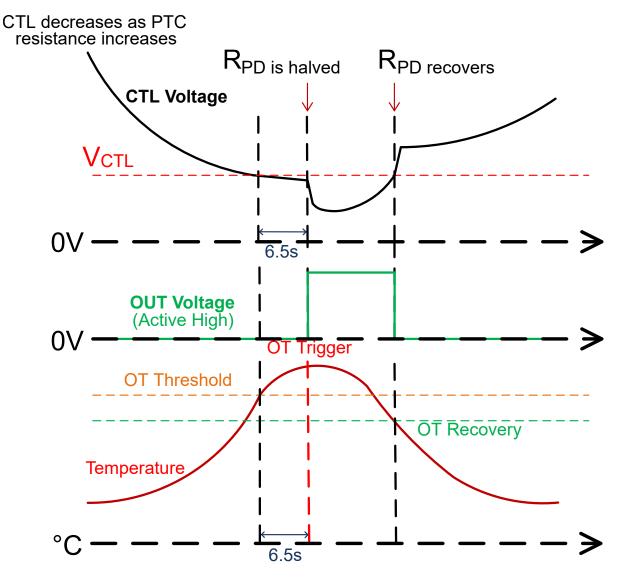


Figure 8-9. Overtemperature protection

#### 8.2.5 CTL for External OUT Overdrive

In the BQ2969T control of the OUT pin can be achieved with external circuitry. The CTL pin can be used as a control input from an external circuit to force the OUT pin to be asserted. OUT Overdrive control is achieved when the CTL pin falls below  $V_{DD}$  -  $V_{CTL}$ , for the  $t_{UVDELAY}$ . This can be achieved with simple circuits, like the N-Channel MOSFET shown in Figure 8-10. The OUT pin remains asserted until the CTL pin voltage rises above the OT voltage trip threshold.

In all operational modes  $R_{PD}$  is pulsed at a low duty cycle, making a higher effective resistance of  $R_{PD}$ , to avoid drawing significant additional current from the supply.



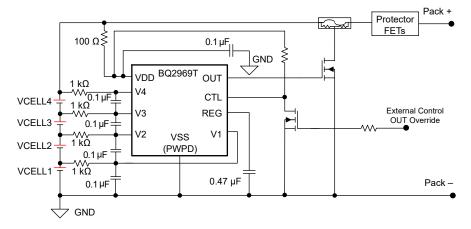


Figure 8-10. BQ2969T External OUT Overdrive Configuration Reference Schematic

#### 8.3 Power Supply Recommendations

Connect a series resistor between the top of the cell stack and the VDD pin on the BQ2969T. Connect a capacitor between the VDD pin and the VSS powerpad connection on the device, positioned close to the device on the PCB. Connect the VSS powerpad to the bottom of the cell stack.

#### 8.4 Layout

## 8.4.1 Layout Guidelines

Use the following layout guidelines:

- 1. Verify that the RC filters for the cell input pins (V4, V3, V2, V1, VSS) and VDD pin are placed as close as possible to the target pin, reducing the tracing loop area.
- 2. Place the regulator output capacitor between REG and VSS, keeping the capacitor close to the device pins.
- 3. Confirm that the trace connecting the fuse through the NFET to the Pack– is sufficient to withstand the expected current during a fuse blow event.

#### 8.4.2 Layout Example

An example circuit layout using the BQ2969T device in a 4-series cell design is described below in Figure 8-11 and Figure 8-12. The design implements the schematic shown in Figure 8-2 and Figure 8-3, and uses a 2-layer circuit card assembly with cell connections on the left edge and pack connections on the right edge of the board.

Care must be taken to place the RC filter components close to the VC pins of the device. Be sure to use a sufficiently wide trace for the NFET source and drain connections to support the maximum current that flows during a fuse blow event.

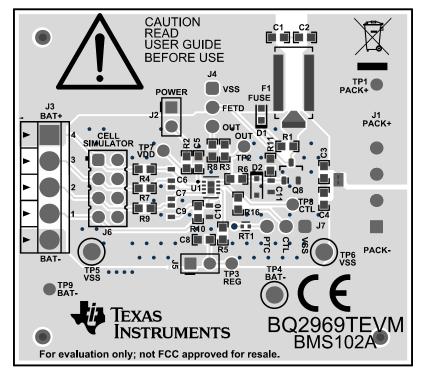


Figure 8-11. BQ2969T Two-Layer Board Layout - Top Layer

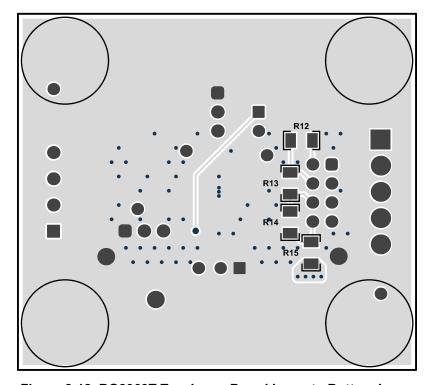


Figure 8-12. BQ2969T Two-Layer Board Layout - Bottom Layer



## 9 Device and Documentation Support

## 9.1 Device Support

#### 9.1.1 Third-Party Products Disclaimer

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## 9.2 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.

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#### 9.5 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.

## 9.6 Glossary

TI Glossary

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

#### 10 Revision History

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

## Changes from Revision A (May 2025) to Revision B (June 2025) Changed BQ296906T to active in the Device Comparison Table

С	hanges from Revision * (December 2024) to Revision A (May 2025)	Page
•	Added BQ296906T in the Device Comparison Table	4
•	Updated the Test Conditions for the OV Delay Reset Time in <i>Electrical Characteristics</i>	5
•	Added clarification information in <i>Detailed Design Procedure</i>	17
	•	



## 11 Mechanical, Packaging, and Orderable Information

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

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#### PACKAGING INFORMATION

Orderable part number	Status	Material type	Package   Pins	Package qty   Carrier	RoHS	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking
	(1)	(2)			(3)	(4)	(5)		(6)
BQ296900TDSGR	Active	Production	WSON (DSG)   8	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 110	690T
BQ296900TDSGR.A	Active	Production	WSON (DSG)   8	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 110	690T
BQ296901TDSGR	Active	Production	WSON (DSG)   8	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 110	6T01
BQ296901TDSGR.A	Active	Production	WSON (DSG)   8	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 110	6T01
BQ296906TDSGR	Active	Production	WSON (DSG)   8	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 110	6T06

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

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

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

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

<sup>(4)</sup> Lead finish/Ball material: Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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

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

## **PACKAGE MATERIALS INFORMATION**

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## TAPE AND REEL INFORMATION





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

#### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



#### \*All dimensions are nominal

Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
BQ296900TDSGR	WSON	DSG	8	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q3
BQ296901TDSGR	WSON	DSG	8	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q3
BQ296906TDSGR	WSON	DSG	8	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q3

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## \*All dimensions are nominal

Device	Device Package Type		Pins SPQ		Length (mm)	Width (mm)	Height (mm)	
BQ296900TDSGR	WSON	DSG	8	3000	210.0	185.0	35.0	
BQ296901TDSGR	WSON	DSG	8	3000	210.0	185.0	35.0	
BQ296906TDSGR	WSON	DSG	8	3000	210.0	185.0	35.0	

2 x 2, 0.5 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

This image is a representation of the package family, actual package may vary. Refer to the product data sheet for package details.





PLASTIC SMALL OUTLINE - NO LEAD



#### NOTES:

- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- 2. This drawing is subject to change without notice.
- 3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



PLASTIC SMALL OUTLINE - NO LEAD



NOTES: (continued)

- 4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
- Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



PLASTIC SMALL OUTLINE - NO LEAD



NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.



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