BQ77216 Voltage and Temperature Protection for 3-Series to 16-Series Cell Li-Ion Batteries with Internal Delay Timer

1 Features

- 3-series cell to 16-series cell protection
- High-accuracy over voltage protection
  - ± 10 mV at 25°C
  - ± 20 mV from 0°C to 60°C
- Overvoltage protection options from 3.55 V to 5.1 V
- Undervoltage protection with options from 1.0 V to 3.5 V
- Open-wire connection detection
- Overtemperature protection
- Random cell connection
- Functional safety-capable
- Fixed internal delay timers
- Fixed detections thresholds
- Fixed output drive type for each of COUT and DOUT
  - Active high or active low
  - Active high drive to 6 V
  - Open drain with ability to be pulled up externally to VDD
- Low power consumption I_{CC} ≈ 1 µA ($V_{CELL(ALL)} < V_{OV}$)
- Low leakage current per cell input < 100 nA with open wire detection disabled
- Package footprint options:
  - Leaded 24-pin TSSOP with 0.65-mm lead pitch

2 Applications

- Protection for Li-ion battery packs used in:
  - Handheld garden tools
  - Handheld power tools
  - Cordless vacuum cleaners
  - UPS battery backup
  - Light electric vehicles (eBike, eScooter, pedal assist bicycles)

3 Description

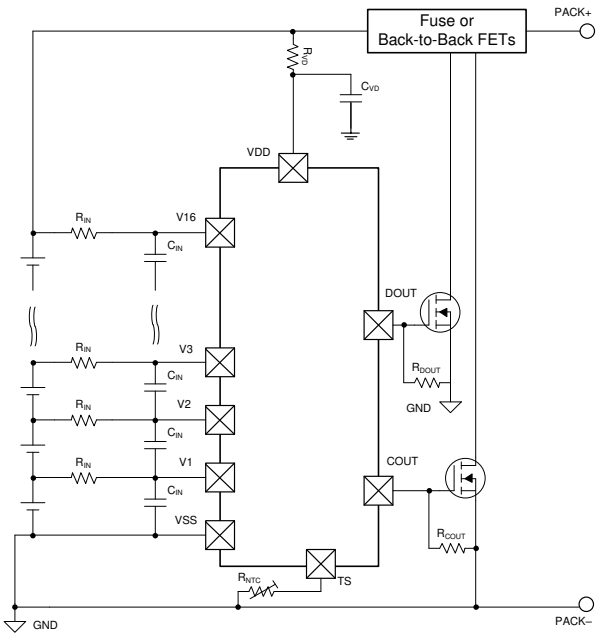
The BQ77216 family of products provides a range of voltage and temperature monitoring including overvoltage (OVP), undervoltage (UVP), open wire (OW), and overtemperature (OT) protection for Li-ion battery pack systems. Each cell is monitored independently for overvoltage, undervoltage, and open-wire conditions. With the addition of an external NTC thermistor, the device can detect overtemperature conditions.

In the BQ77216 device, an internal delay timer is initiated upon detection of an overvoltage, undervoltage, open-wire, or overtemperature condition. Upon expiration of the delay timer, the respective output is triggered into its active state (either high or low, depending on the configuration).

Device Information Table

PART NUMBER	PACKAGE	BODY SIZE (NOM)
BQ7721600(1)	TSSOP (24)	4.40 mm × 7.80 mm (6.40 mm × 7.80 mm, including leads)

(1) For available catalog packages, see the orderable addendum at the end of the data sheet and the *Device Comparison Table*.



Simplified Schematic

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4 Revision History

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

Changes from Revision H (March 2023) to Revision I (July 2023)	Page
• Updated the *Device Comparison Table*	3

Changes from Revision G (July 2022) to Revision H (March 2023)	Page
• Updated the *Device Comparison Table*	3

Changes from Revision F (June 2022) to Revision G (September 2022)	Page
• Updated the *Device Comparison Table*	3

Changes from Revision E (April 2022) to Revision F (June 2022)	Page
• Changed the UVP entry for the BQ7721609 device in the *Device Comparison Table*	3

Changes from Revision D (January 2022) to Revision E (April 2022)	Page
• Moved the BQ7721609 and BQ7721610 devices from PRODUCT PREVIEW to Production Data in the *Device Comparison Table*	3

5 Description (continued)

The overvoltage triggers the COUT pin if a fault is detected, and undervoltage triggers the DOUT pin if a fault is detected. If an overtemperature or open-wire fault is detected, then both the DOUT and COUT will be triggered. For quicker production-line testing, the BQ77216 device provides a Customer Test Mode (CTM) with greatly reduced delay time.

6 Device Comparison Table

Table 6-1. BQ77216 Device Comparison

PART NUMBER	T_A	PACKAGE	PACKAGE DESIGNATOR	OVP (V)	OV HYSTERISIS (V)	OVP DELAY	UVP (V)	UVP DELAY
BQ7721600	–40°C to 110°C	24-Pin TSSOP	PW	4.325	0.100	1 s	2.25	1 s
BQ7721602	–40°C to 110°C	24-Pin TSSOP	PW	4.325	0.100	1 s	2.25	1 s
BQ7721603	–40°C to 110°C	24-Pin TSSOP	PW	4.3	0.100	2 s	2	2 s
BQ7721605	–40°C to 110°C	24-Pin TSSOP	PW	4.225	0.100	1 s	2.6	1 s
BQ7721606	–40°C to 110°C	24-Pin TSSOP	PW	4.275	0.100	1 s	2.5	1 s
BQ7721607	–40°C to 110°C	24-Pin TSSOP	PW	4.25	0.100	4 s	2.5	2 s
BQ7721609	–40°C to 110°C	24-Pin TSSOP	PW	4.35	0.200	4 s	Disabled	
BQ7721610	–40°C to 110°C	24-Pin TSSOP	PW	4.25	0.100	4 s	2.5	2 s
BQ7721611	–40°C to 110°C	24-Pin TSSOP	PW	3.8	0.200	4 s	1.5	1 s
BQ7721612	–40°C to 110°C	24-Pin TSSOP	PW	3.6	0.200	2 s	2.0	2 s
BQ7721613	–40°C to 110°C	24-Pin TSSOP	PW	4.25	0.100	4 s	2.0	2 s
BQ7721614	–40°C to 110°C	24-Pin TSSOP	PW	3.9	0.100	4 s	1.85	2 s

Table 6-2. BQ77216 Device Comparison (continued)

PART NUMBER	UV HYSTERISIS (V)	OTC (°C)	UTC (°C)	OW	LATCH	OUTPUT DRIVE	TAPE AND REEL
BQ7721600	0.100	70	NA	Enabled	Disabled	Active Low	BQ7721600PWR
BQ7721602	0.100	70	NA	Enabled	Disabled	Active High, 6-V Drive	BQ7721602PWR
BQ7721603	0.100	75	NA	Enabled	Disabled	Active High, 6-V Drive	BQ7721603PWR
BQ7721605	0.200	75	NA	Disabled	Disabled	Active High, 6-V Drive	BQ7721605PWR
BQ7721606	0.200	75	NA	Disabled	Disabled	Active High, 6-V Drive	BQ7721606PWR
BQ7721607	0.100	83	–30	Enabled	Disabled	Active High, 6-V Drive	BQ7721607PWR
BQ7721609	Disabled	83	NA	Enabled	Disabled	Active High, 6-V Drive	BQ7721609PWR
BQ7721610	0.100	83	NA	Enabled	Disabled	Active High, 6-V Drive (COUT) Active Low (DOUT)	BQ7721610PWR
BQ7721611	0.200	70	NA	Disabled	Disabled	Active High, 6-V Drive	BQ7721611PWR
BQ7721612	0.200	75	NA	Disabled	Disabled	Active Low	BQ7721612PWR
BQ7721613	0.100	83	–30	Enabled	Disabled	Active High, 6-V Drive	BQ7721613PWR
BQ7721614	0.100	75	–30	Enabled	Disabled	Active High, 6-V Drive	BQ7721614PWR

7 Pin Configuration and Functions

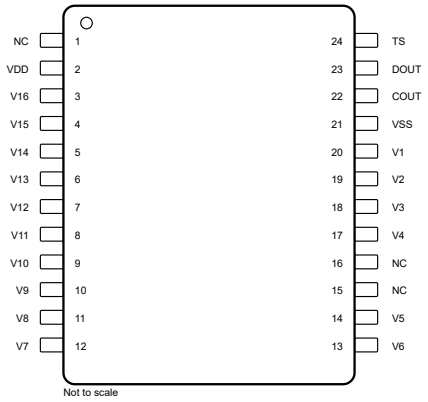


Table 7-1. 24-Lead Pin Functions

NO.	NAME	TYPE	DESCRIPTION
1	NC	—	Not electrically connected and can be left floating
2	VDD	P	Power supply
3	V16	I	Sense input for positive voltage of the sixteenth cell from the bottom of the stack
4	V15	I	Sense input for positive voltage of the fifteenth cell from the bottom of the stack
5	V14	I	Sense input for positive voltage of the fourteenth cell from the bottom of the stack
6	V13	I	Sense input for positive voltage of the thirteenth cell from the bottom of the stack
7	V12	I	Sense input for positive voltage of the twelfth cell from the bottom of the stack
8	V11	I	Sense input for positive voltage of the eleventh cell from the bottom of the stack
9	V10	I	Sense input for positive voltage of the tenth cell from the bottom of the stack
10	V9	I	Sense input for positive voltage of the ninth cell from the bottom of the stack
11	V8	I	Sense input for positive voltage of the eighth cell from the bottom of the stack
12	V7	I	Sense input for positive voltage of the seventh cell from the bottom of the stack
13	V6	I	Sense input for positive voltage of the sixth cell from the bottom of the stack
14	V5	I	Sense input for positive voltage of the fifth cell from the bottom of the stack
15	NC	—	Not electrically connected and can be left floating
16	NC	—	Not electrically connected and can be left floating
17	V4	I	Sense input for positive voltage of the fourth cell from the bottom of the stack
18	V3	I	Sense input for positive voltage of the third cell from the bottom of the stack
19	V2	I	Sense input for positive voltage of the second cell from the bottom of the stack
20	V1	I	Sense input for positive voltage of the lowest cell in the stack
21	VSS	P	Electrically connected to IC ground and negative terminal of the lowest cell in the stack
22	COUT	O	Output drive for overvoltage, open wire, and overtemperature. It can be left floating if not used.
23	DOUT	O	Output drive for undervoltage, open wire, and overtemperature. It can be left floating if not used.
24	TS	I	Temperature sensor input. If not used, leave it NC.
I = Input, O = Output, P = Power Connection			

8 Specifications

8.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Supply voltage range	VDD - VSS	–0.3	85	V
Input voltage range	Vn - VSS where n = 1 to 16	–0.3	85	V
	TS	–0.3	1.5	V
Output voltage range	COUT - VSS, DOUT - VSS	–0.3	85	V
Functional temperature,T_{FUNC}		–40	110	°C
Storage temperature, T_{STG}		–65	150	°C

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If 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.

8.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1)	±2000	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002, all pins	±500	

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

8.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{DD}	Supply voltage (1)	5		75	V
V_{IN}	Input voltage range of Vn - Vn-1 where n = 2 to 16 and V1 - VSS	0		5	V
	TS	0		1.5	V
V_{CTM}	Customer Test Mode Entry V_{DD} > V16 + V_{CTM}	12		13	V
C_{TS}	Total capacitance on the TS Pin			200	pF
T_A	Ambient temperature	–40		85	°C
T_J	Junction temperature	–65		150	°C

(1) V_{DD} is equal to top of stack voltage

8.4 Thermal Information

THERMAL METRIC(1)		DEVICE PW (TSSOP) 24 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	97.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	40.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	53.1	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	4.3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	52.7	°C/W

THERMAL METRIC(1)		DEVICE	UNIT
		PW (TSSOP)	
		24 PINS	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	NA	°C/W

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

8.5 DC Characteristics

Typical values stated where T_A = 25°C and VDD = 58 V, MIN/MAX values stated where T_A = –40°C to 85°C and VDD = 5 V to 75 V (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OVER VOLTAGE PROTECTION (OV)						
V_{OV}	OV Detection Range		3.55		5.1	V
V_{OV_STEP}	OV Detection Steps			25		mV
V_{OV_HYS}	OV Detection Hysteresis	Selected OV Hysterysis depends on part number. See device selection table for details.		V_{OV} – 100		mV
		Selected OV Hysterysis depends on part number. See device selection table for details.		V_{OV} – 200		mV
V_{OV_ACC}	OV Detection Accuracy	T_A = 25°C	–10		10	mV
	OV Detection Accuracy	0°C ≤ T_A ≤ 60°C	–20		20	mV
	OV Detection Accuracy	-40°C ≤ T_A ≤ 110°C	–50		50	mV
UNDER VOLTAGE PROTECTION (UV)						
V_{UV}	UV Detection Range		1.0		3.5	V
V_{UV_STEP}	UV Detection Steps			50		mV
V_{UV_HYS}	UV Detection Hysteresis	Selected OV Hysterysis depends on part number. See device selection table for details.		V_{UV} + 100		mV
		Selected OV Hysterysis depends on part number. See device selection table for details.		V_{UV} + 200		mV
V_{UV_ACC}	UV Detection Accuracy	T_A = 25°C	–30		30	mV
	UV Detection Accuracy	-40 ≤ T_A ≤ 110°C	–50		50	mV
V_{UV_MIN}	UV Detection Disabled Threshold	Vn - Vn-1 where n = 2 to 16 and V1 - VSS	450	500	550	mV
OVER TEMPERATURE PROTECTION (OT)						
T_{OT}	OT Detection Range	Available options: 62°C, 65°C, 70°C, 75°C, 80°C, 83°C	62.0		83.0	°C
R_{OT_EXT}	OT Detection External Resistance	62°C		2850		Ω
		65°C		2570		
		70°C		2195		
		75°C		1915		
		80°C		1651		
		83°C		1525		
T_{OT_ACC} (1)	OT Detection Accuracy		–5		5	°C

8.5 DC Characteristics (continued)

Typical values stated where T_A = 25°C and VDD = 58 V, MIN/MAX values stated where T_A = –40°C to 85°C and VDD = 5 V to 75 V (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T_{OT_HYS} (2)	OT Detection Hysteresis			–10		°C
				4186		Ω
				3530		Ω
R_{NTC}	Internal Pull Up Resistor	After TI Factory Trim	19.5	20	20.6	kΩ
OPEN WIRE PROTECTION (OW)						
V_{OW}	OW Detection Threshold	Vn < Vn-1 where n = 2 to 16		–200		mV
		V1 - VSS		500		mV
V_{OW_HYS}	OW Detection Hysteresis	Vn < Vn-1 where n = 1 to 16		V_{OW} +100		mV
V_{OW_ACC}	OW Detection Accuracy	-40 ℃ ≤ T_A ≤ 110℃	–25		25	mV
SUPPLY AND LEAKAGE CURRENT						
I_{CC}	Supply Current	No fault detected.		2	3.5	µA
I_{IN} (2)	Input Current at Vx Pins	Vn - Vn-1 and V1 - VSS = 4V, where n = 2 to 16, Open Wire Enabled	–0.3		0.3	µA
		Vn - Vn-1 and V1 - VSS = 4V, where n = 2 to 16, Open Wire Disabled	–0.1		0.1	µA
OUTPUT DRIVE, COUT and DOUT, CMOS ACTIVE HIGH VERSIONS ONLY						
V_{OUT_AH}	Output Drive Voltage for COUT and DOUT, Active High 6V	Vn - Vn-1 or V1 - VSS > V_{OV}, where n = 2 to 16, VDD = 58 V, I_{OH} = 100 µA measured out of COUT, DOUT pin.	6			V
	Output Drive Voltage for COUT and DOUT, Active High VDD	VDD - V_{COUT} or V_{DOUT}, Vn - Vn-1 or V1 - VSS > V_{OV}, where n = 2 to 16, I_{OH} = 10 µA measured out of COUT, DOUT pin.	0	1	1.5	V
	Output Drive Voltage for COUT and DOUT, Active High 6V	VDD - V_{COUT} or V_{DOUT}, If 15 of 16 cells are short circuited and only one cell remains powered and > V_{OV}, VDD = Vx (cell voltage), I_{OH} = 100 µA,	0	1	1.5	V
	Output Drive Voltage for COUT and DOUT, Active High 6V and VDD	Vn - Vn-1 and V1 - VSS < V_{OV}, where n = 2 to 16, VDD = 58 V, I_{OH} = 100 µA measured into pin		250	400	mV
R_{OUT_AH}	Internal Pull Up Resistor		80	100	120	kΩ
$I_{OUT\_AH\_H}$	OUT Source Current (during OV)	Vn - Vn-1 or V1 - VSS > V_{OV}, where n = 2 to 16, VDD = 58 V, OUT = 0V. Measured out of COUT, DOUT pin			4.5	mA
$I_{OUT\_AH\_L}$	OUT Sink Current (no OV)	Vn - Vn-1 and V1 - VSS < V_{OV}, where n = 2 to 16, VDD = 58 V, OUT = VDD. Measured into COUT, DOUT pin	0.3		3	mA
OUTPUT DRIVE, COUT and DOUT, NCH OPEN DRAIN ACTIVE LOW VERSIONS ONLY						
V_{OUT_AL}	Output Drive Voltage for COUT and DOUT, Active Low	Vn - Vn-1 or V1 - VSS > V_{OV}, where n = 2 to 16, VDD = 58 V, I_{OH} = 100 µA measured into COUT, DOUT pin.		250	400	mV
$I_{OUT\_AL\_L}$	OUT Source Current (during OV)	Vn - Vn-1 or V1 - VSS > V_{OV}, where n = 2 to 16, VDD = 58 V, OUT = VDD. Measured into COUT, DOUT pin.	0.3		3	mA
$I_{OUT\_AL\_H}$	OUT Sink Current (no OV)	Vn - Vn-1 and V1 - VSS < V_{OV}, where n = 2 to 16, VDD = 58 V, OUT = VDD. Measured out of COUT, DOUT pin.			100	nA

(1) Assured by Design. This accuracy assumes the external resistance is within +/- 2% of the R_OT_EXT values for the corresponding temperature threshold.
(2) Assured by Design.

8.6 Timing Requirements

Typical values stated where T_A = 25°C and VDD = 58 V, MIN/MAX values stated where T_A = –40°C to 85°C and VDD = 5 V to 85 V (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{OV_DELAY}	OV Delay Time			0.25		s
				0.5		s
				1		s
				2		s
				4		s
t_{UV_DELAY}	UV Delay Time			0.25		s
				0.5		s
				1		s
				2		s
t_{OT_DELAY}	OT Delay Time			4		s
t_{OW_DELAY}	OW Delay Time			4		s
t_{DELAY_ACC}	Delay Time Accuracy	For 0.25s, 0.5s delays	–128		128	ms
t_{DELAY_ACC}	Delay Time Accuracy	For 1s delays	–150		150	ms
t_{DELAY_DR}	Delay time drift across operating temp	For all delays other than 0.25s, 0.5s, 1s delays	–10%		10%	
t_{CTM_DELAY}	Fault Detection Delay Time during Customer Test Mode	See Customer Test Mode.		50		ms

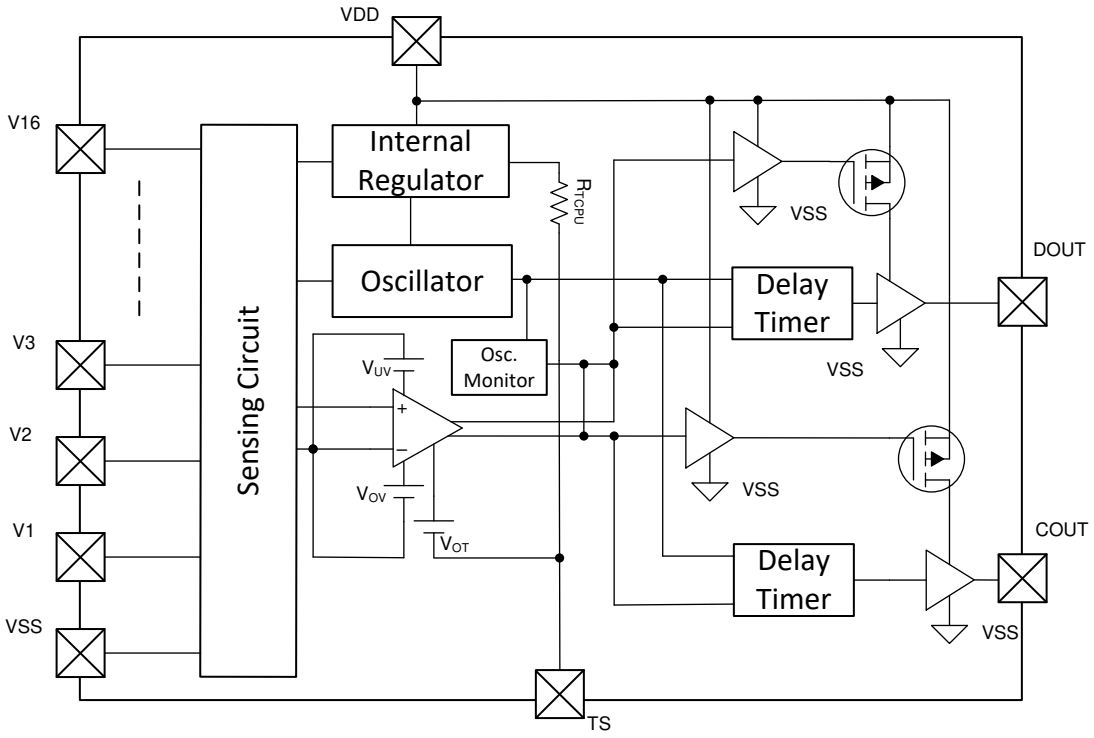
9 Detailed Description

9.1 Overview

The BQ77216 family of devices provides a range of voltage and temperature monitoring including overvoltage (OVP), undervoltage (UVP), open wire (OW), and overtemperature (OT) protection for Li-ion battery pack systems. Each cell is monitored independently for overvoltage, undervoltage, and open-wire conditions. With the addition of an external NTC thermistor, the device can detect overtemperature conditions. An internal delay timer is initiated upon detection of an overvoltage, undervoltage, open-wire, or overtemperature condition. Upon expiration of the delay timer, the respective output is triggered into its active state (either high or low depending on the configuration). The overvoltage triggers the COUT pin if a fault is detected, and undervoltage triggers the DOUT pin if a fault is detected. If an undertemperature, overtemperature, or open-wire fault is detected, then both the DOUT and COUT are triggered.

For quicker production-line testing, the BQ77216 device provides a Customer Test Mode (CTM) with greatly reduced delay time.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Voltage Fault Detection

In the BQ77216 device, each cell is monitored independently. Overvoltage is detected by comparing the actual cell voltage to a protection voltage reference, V_{OV}. If any cell voltage exceeds the programmed OV value, a timer circuit is activated. When the timer expires, the COUT pin goes from inactive to active state. The timer is reset if the cell voltage falls below the recovery threshold ($V_{OV} – V_{OV\_HYS}$). Undervoltage is detected by comparing the actual cell voltage to a protection voltage reference, V_{UV}. If any cell voltage falls below the programmed UV value, a timer circuit is activated. When the timer expires, the DOUT pin goes from inactive to active state. The timer is reset if the cell voltage rises below the recovery threshold ($V_{UV} + V_{UV\_HYS}$).

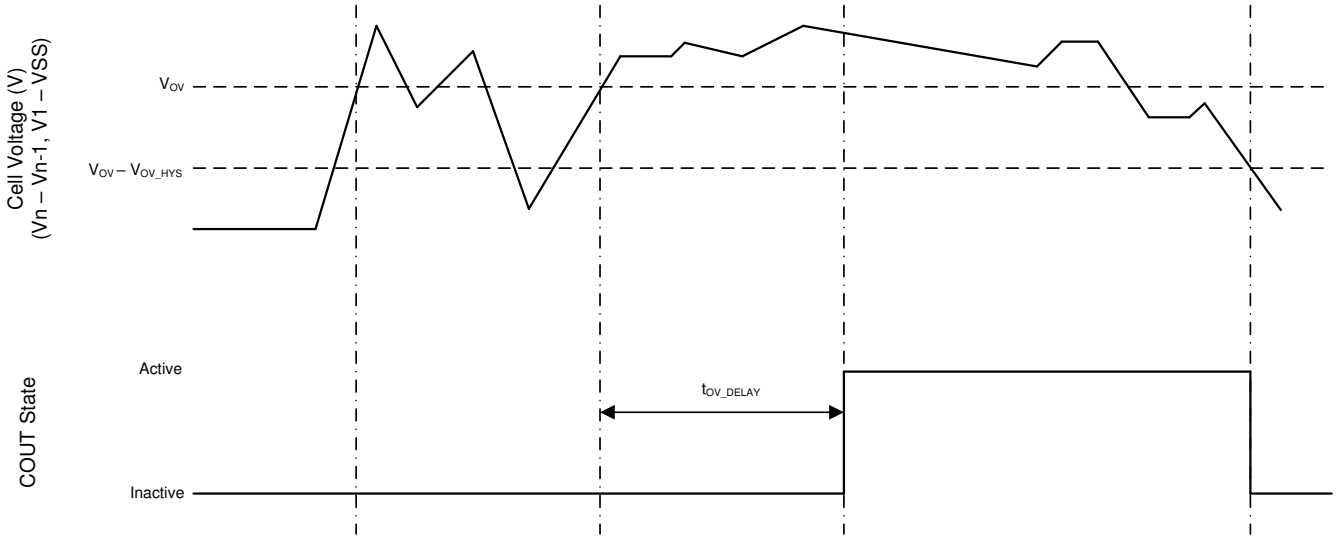


Figure 9-1. Timing for Overvoltage Sensing

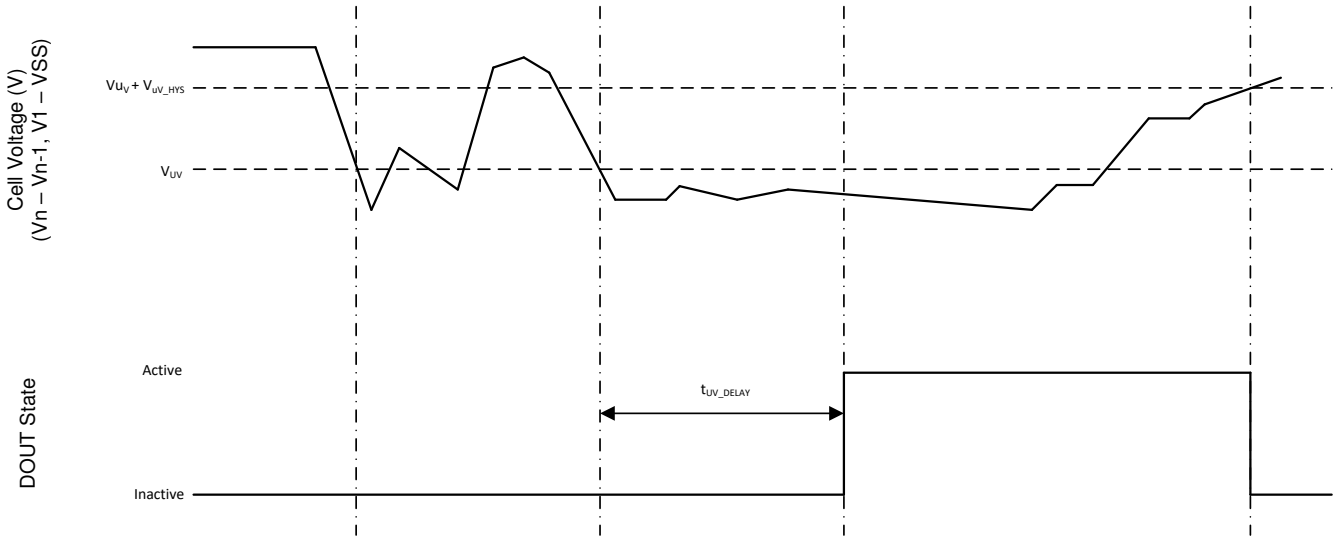


Figure 9-2. Timing for Undervoltage Sensing

9.3.2 Open Wire Fault Detection

In the BQ77216 device, each cell input is monitored independently to determine if the input is connected to a cell or not by applying a 50-µA pull down current to ground that is activated for 128 µs every 128 ms. If the device detects that Vn < Vn-1 – V_{OW} V, then a timer is activated. When the timer expires, the COUT and DOUT pins go from an inactive to active state. The timer is reset if the cell input rises above below the recovery threshold (V_{OW} + V_{OW_HYS}).

9.3.3 Temperature Fault Detection

In the BQ77216 device, the TS pin is ratiometrically monitored with an internal pull up resistance R_{NTC}. Overtemperature is detected by evaluating the TS input voltage to determine the external resistance falls below a protection resistance, R_{OT_EXT}. If the resistance falls below the programmed OT value, a timer circuit is activated. When the timer expires, the COUT and DOUT pins go from inactive to active state. The timer is reset if the resistance rises above the recovery threshold (R_{OT} + R_{OT_HYS}). If external capacitance is added to the TS pin, it needs to be within the spec limit shown in recommended operating conditions.

Note

Texas Instruments does not recommend adding an external capacitor to the TS pin. The capacitance on this pin will affect the TS measurement accuracy if greater than C_{TS}.

9.3.4 Oscillator Health Check

The device can detect if the internal oscillator slows down below the f_{OSC_FAULT} threshold. When this occurs then the COUT and DOUT go from inactive to active state. If the oscillator returns to normal then the fault recovers.

9.3.5 Sense Positive Input for Vx

This is an input to sense each single battery cell voltage. A series resistor and a capacitor across the cell for each input is required for noise filtering and stable voltage monitoring.

9.3.6 Output Drive, COUT and DOUT

These pins serve as the fault signal outputs, and may be ordered in either active HIGH with drive to 6V or active LOW options configured through internal OTP.

The COUT and DOUT will respond per the following table when a fault is detected, if the specific fault is enabled.

Table 9-1. Fault Detection vs COUT and DOUT Action

FAULT Detected	COUT	DOUT
Overvoltage	Active	Inactive
Undervoltage	Inactive	Active
Open Wire	Active	Active
Over Temperature	Active	Active
Oscillator Health	Active	Active

9.3.7 The LATCH Function

The device can be enabled to latch the fault signal, which effectively disables the recovery functions of all fault detections. The only way to recover from a fault state when the latch is enabled is a POR of the device.

9.3.8 Supply Input, VDD

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

9.4 Device Functional Modes

9.4.1 NORMAL Mode

When COUT and DOUT are inactive (no fault detected) the device operates in NORMAL mode and device is monitoring for voltage, open wire and temperature faults.

The COUT and DOUT pins are inactive and if configured:

- Active high is low.
- Active low is being externally pulled up and is an open drain.

9.4.2 FAULT Mode

FAULT mode is entered if the COUT or DOUT pins are activated. The OUT pin will either pull high internally, if configured as active high, or will be pulled low internally, if configured as active low. When COUT and DOUT are deactivated the device returns to NORMAL mode.

9.4.3 Customer Test Mode

Customer Test Mode (CTM) helps to reduce test time for checking the delay timer parameter once the circuit is implemented in the battery pack. To enter CTM, VDD should be set to at least V_{CTM} higher than V16 (see Figure 9-3). The delay timer is greater than 10 ms, but considerably shorter than the timer delay in normal operation. To

exit Customer Test Mode, remove the VDD to a V16 voltage differential of 10 V so that the decrease in this value automatically causes an exit.

CAUTION

Avoid exceeding any Absolute Maximum Voltages on any pins when placing the part into Customer Test Mode. Also avoid exceeding Absolute Maximum Voltages for the individual cell voltages (VCn–VCn-1) and (V1–VSS). Stressing the pins beyond the rated limits may cause permanent damage to the device.

Figure 9-3 shows the timing for the Customer Test Mode.

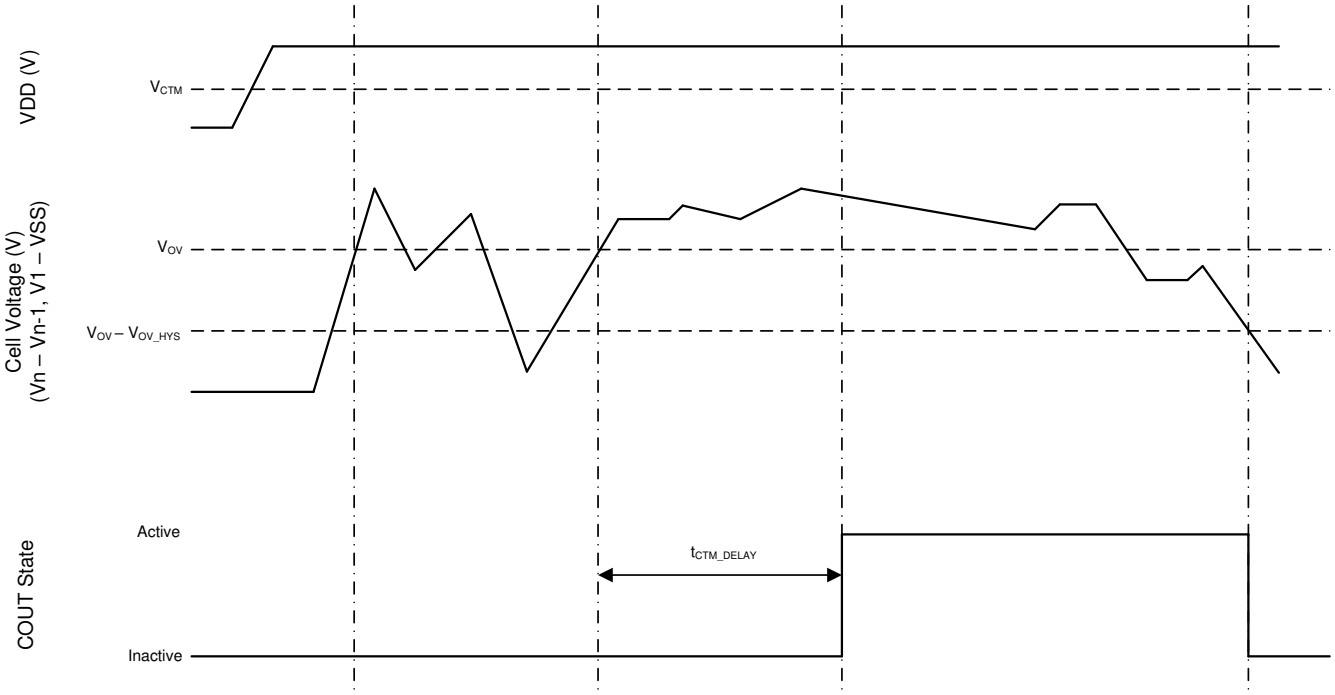


Figure 9-3. Timing for Customer Test Mode

10 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, as well as validating and testing their design implementation to confirm system functionality.

10.1 Application Information

Changes to the ranges stated in Table 10-1 will impact the accuracy of the cell measurements.

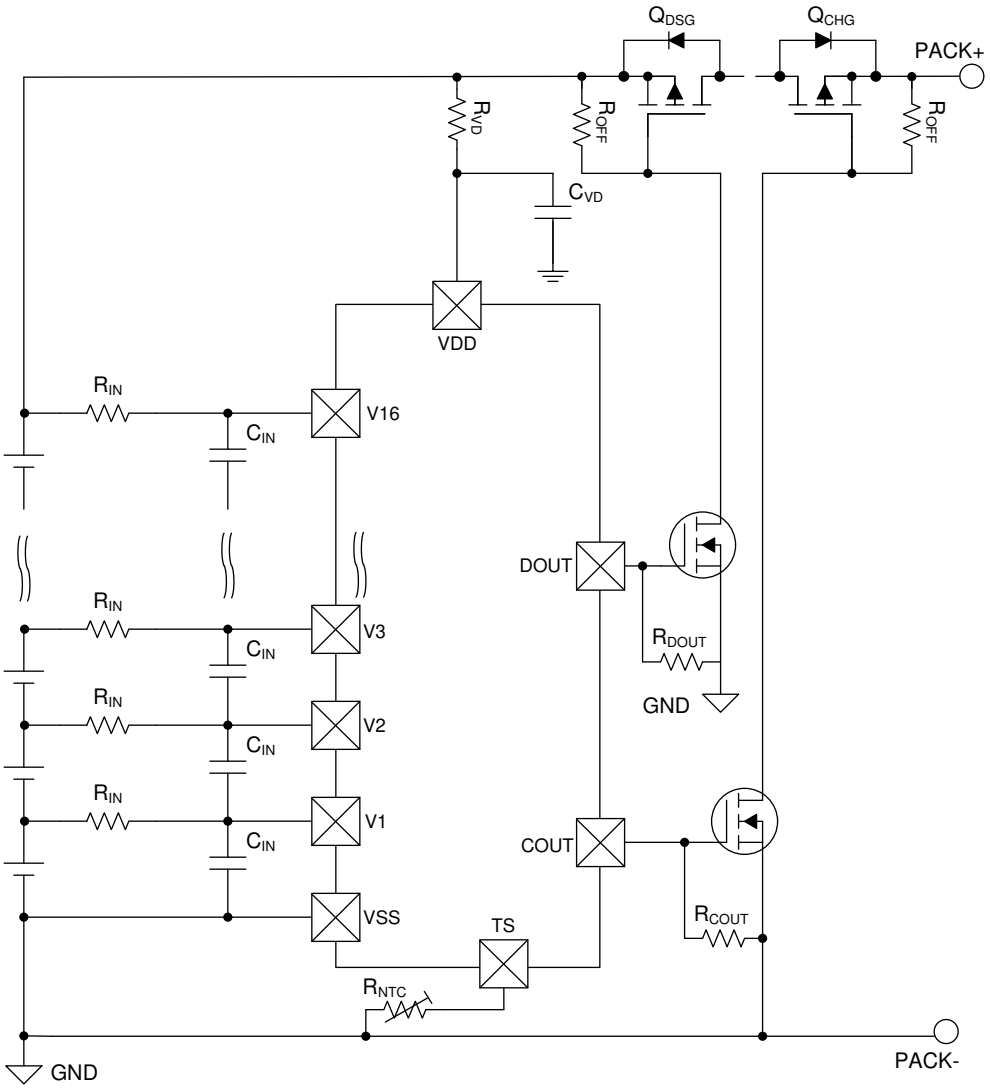


Figure 10-1. Application Configuration

10.1.1 Design Requirements

Changes to the ranges stated in Table 10-1 will impact the accuracy of the cell measurements. Figure 10-1 shows each external component.

Table 10-1. Parameters

PARAMETER	EXTERNAL COMPONENT	MIN	NOM	MAX	UNIT
Voltage monitor filter resistance	R_{IN}	900	1000	1100	Ω

Table 10-1. Parameters (continued)

PARAMETER	EXTERNAL COMPONENT	MIN	NOM	MAX	UNIT
Voltage monitor filter capacitance	C_{IN}	0.01		0.1	µF
Supply voltage filter resistance	R_{VD}	100	300	1K	Ω
Supply voltage filter capacitance	C_{VD}	0.05	0.1	1	µF

Note

The device is calibrated using an R_{IN} value = 1 kΩ. Using a value other than this recommended value changes the accuracy of the cell voltage measurements and V_{OV} trigger level.

10.1.2 Detailed Design Procedure

Figure 10-2 shows the measurement for current consumption for the product for both VDD and Vx.

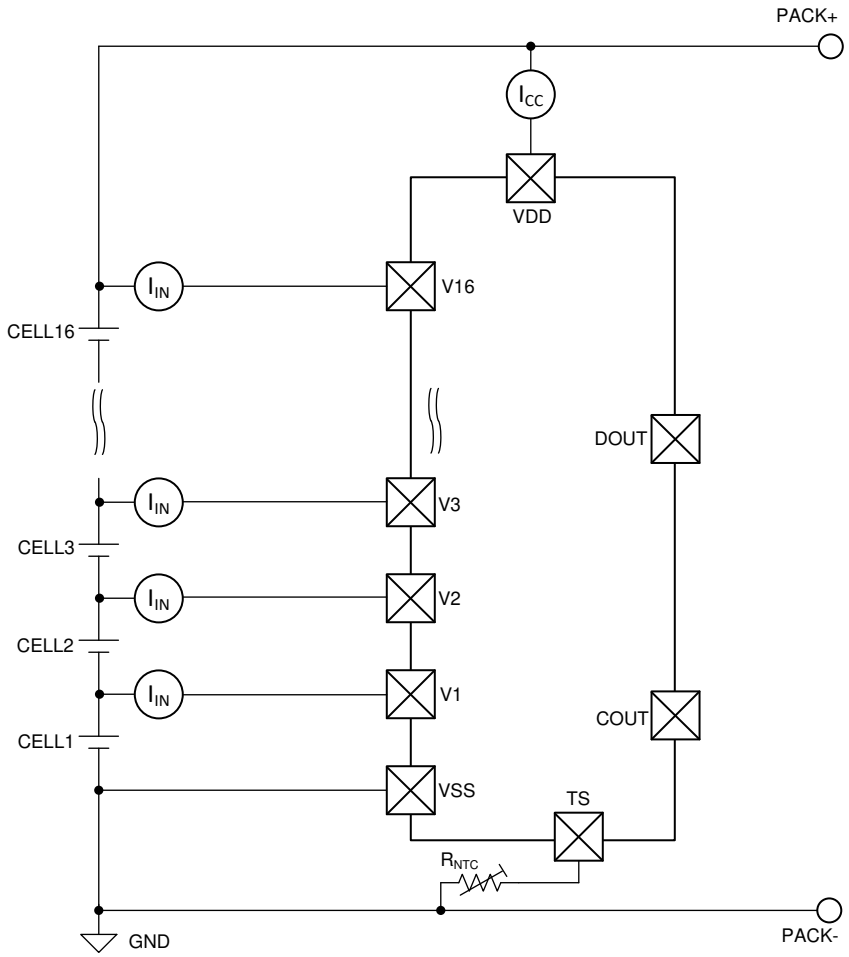


Figure 10-2. Configuration for IC Current Consumption Test

10.1.2.1 Cell Connection Sequence

The BQ77216 device can be connected to the array of cells in any order without damaging the device.

During cell attachment, the device could detect a fault if the cells are not connected within a fault detection delay period. If this occurs, then COUT and/or DOUT could transition from inactive to active. Both COUT and DOUT can be tied to VSS or VDD to prevent any change in output state during cell attach.

10.2 Systems Example

In this application example, the choice of a FUSE or FETs is required on the COUT and DOUT pins—configured as an active high drive to 6-V outputs.

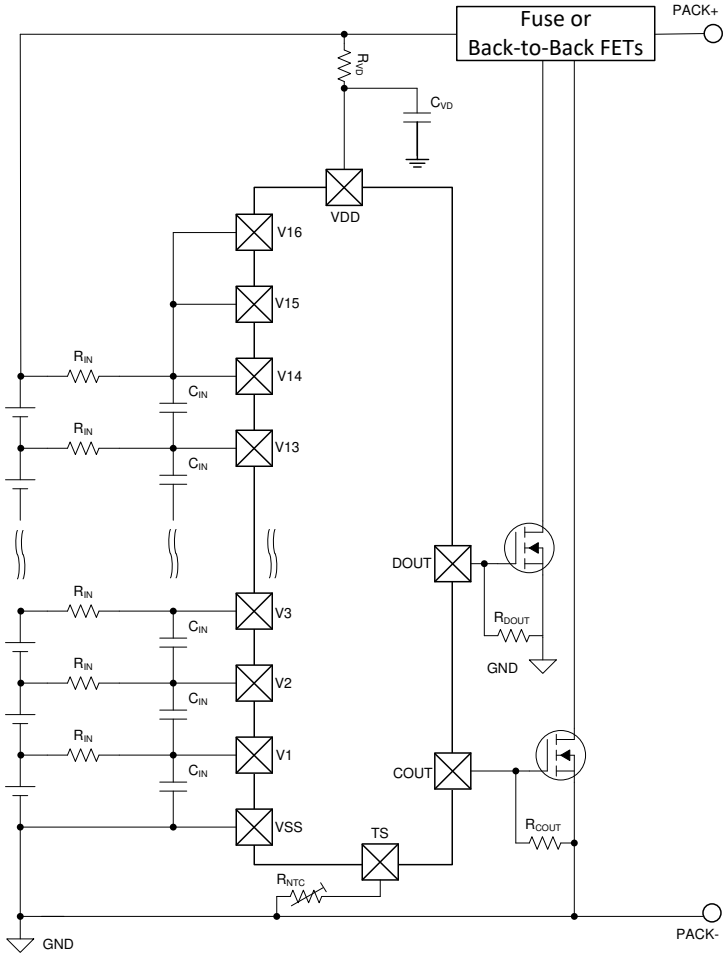


Figure 10-3. 14-Series Cell Configuration with Active High 6-V Option

When paring with the BQ769x2 or BQ76940 devices, the top cell must be used. For the BQ77216 device to drive the CHG and DSG FETs, the active high 6-V option is preferred. Its COUT and DOUT are controlling two N-CH FETs to jointly control the CHG and DSG FETs with the monitoring device. For such joint architecture, the open-wire feature of the BQ77216 device may be affected if the primary protector or monitor device is actively measuring the cells. Care is needed to ensure the V_{OW} spec of the BQ77216 device is met or to choose a version of the BQ77216 device with open wire disabled. When working with a BQ769x2 device, the LOOPSLOW setting of the BQ769x2 device should be set to 0x11 to ensure the BQ77216 V_{OW} spec is met.

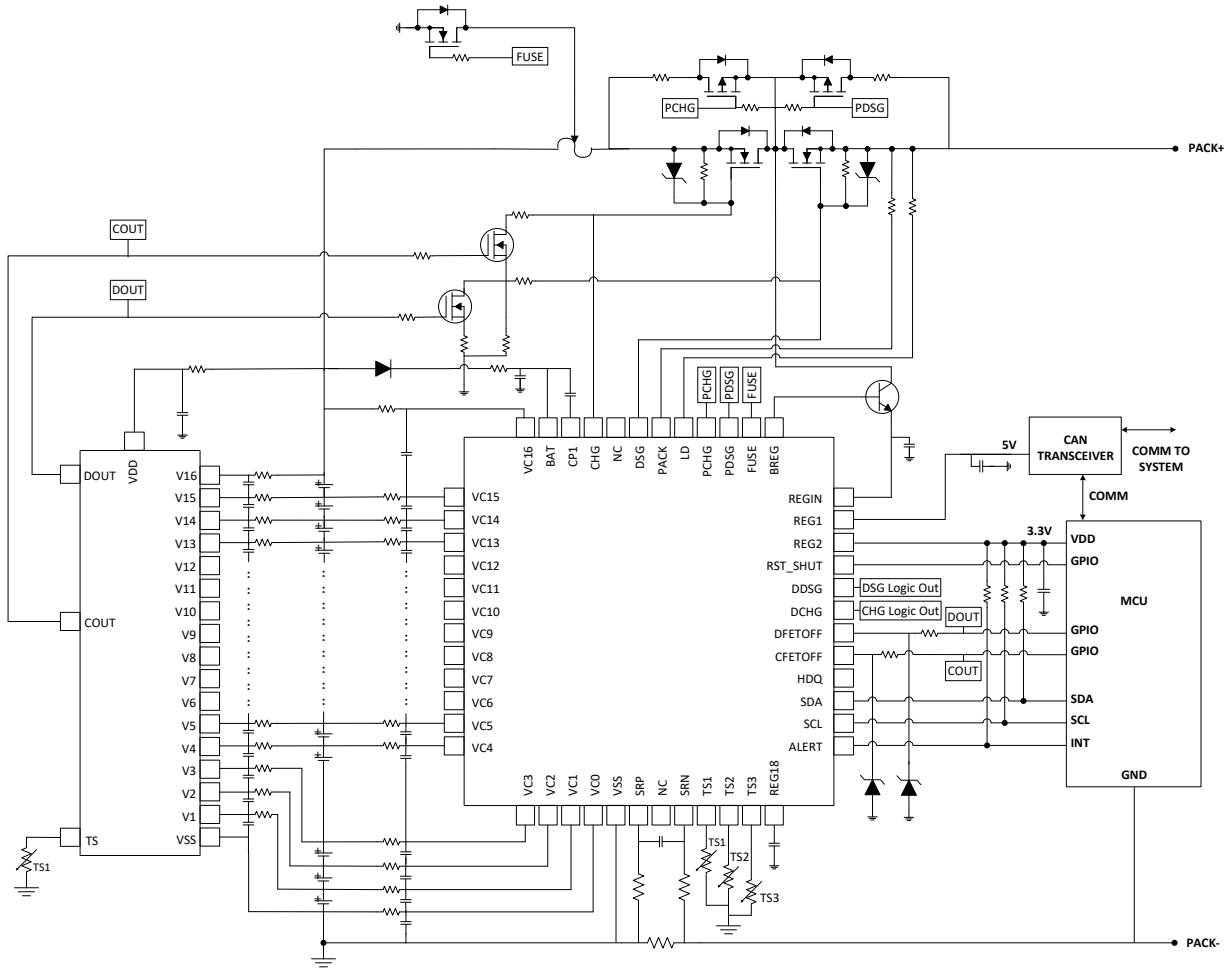


Figure 10-4. BQ77216 with BQ76952

11 Power Supply Recommendations

The maximum power supply of this device is 85 V on VDD.

12 Layout

12.1 Layout Guidelines

- Ensure the RC filters for the Vn and VDD pins are placed as close as possible to the target terminal.
- The VSS pin should be routed to the CELL– terminal.

12.2 Layout Example

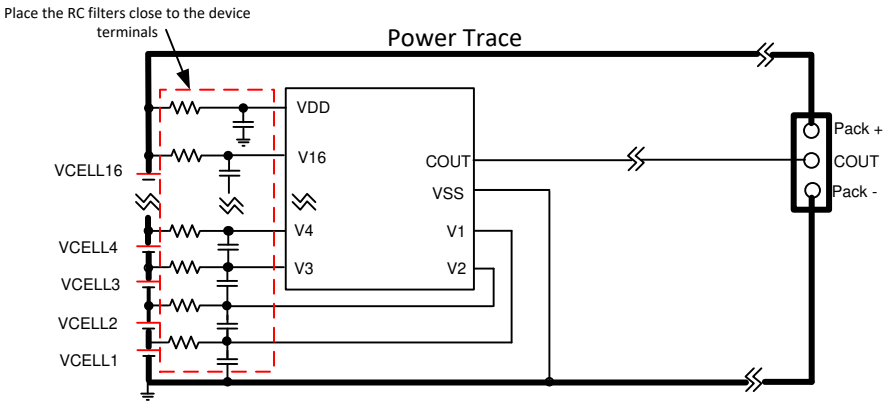


Figure 12-1. Example Layout

13 Device and Documentation Support

13.1 Third-Party Products Disclaimer

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13.2 Receiving Notification of Documentation Updates

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13.3 Support Resources

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

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13.5 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.

13.6 Glossary

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

14 Mechanical, Packaging, and Orderable Information

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

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
BQ7721600PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ7721600	Samples
BQ7721602PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ7721602	Samples
BQ7721603PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ7721603	Samples
BQ7721605PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 110	BQ7721605	Samples
BQ7721606PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 110	BQ7721606	Samples
BQ7721607PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 110	BQ7721607	Samples
BQ7721609PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 110	BQ7721609	Samples
BQ7721610PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 110	BQ7721610	Samples
BQ7721611PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 110	BQ7721611	Samples
BQ7721612PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 110	BQ7721612	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.

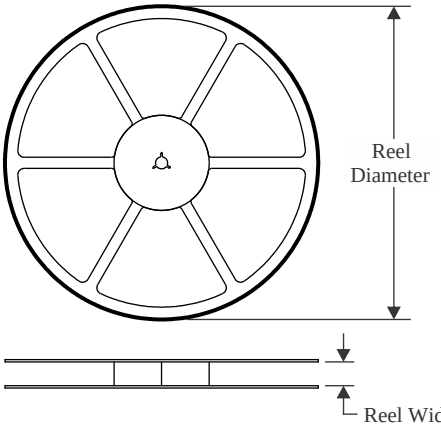
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

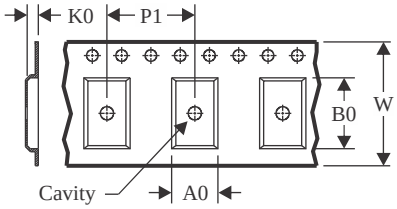
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

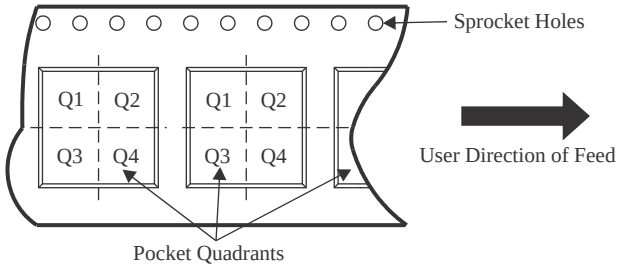


TAPE DIMENSIONS



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

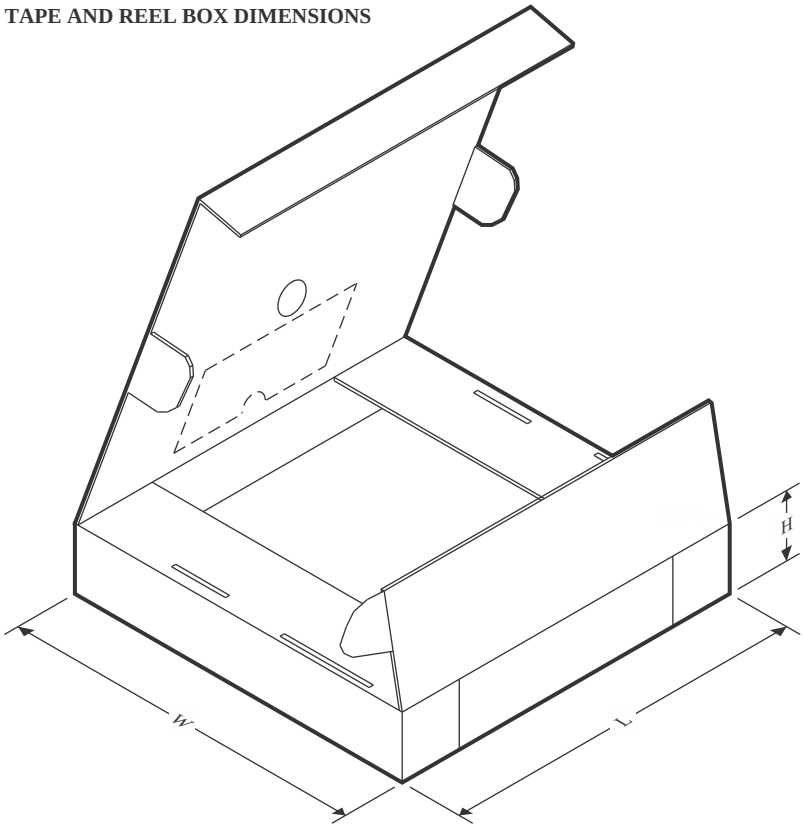
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
BQ7721600PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721602PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721603PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721605PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721606PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721607PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721609PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721610PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721611PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
BQ7721612PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

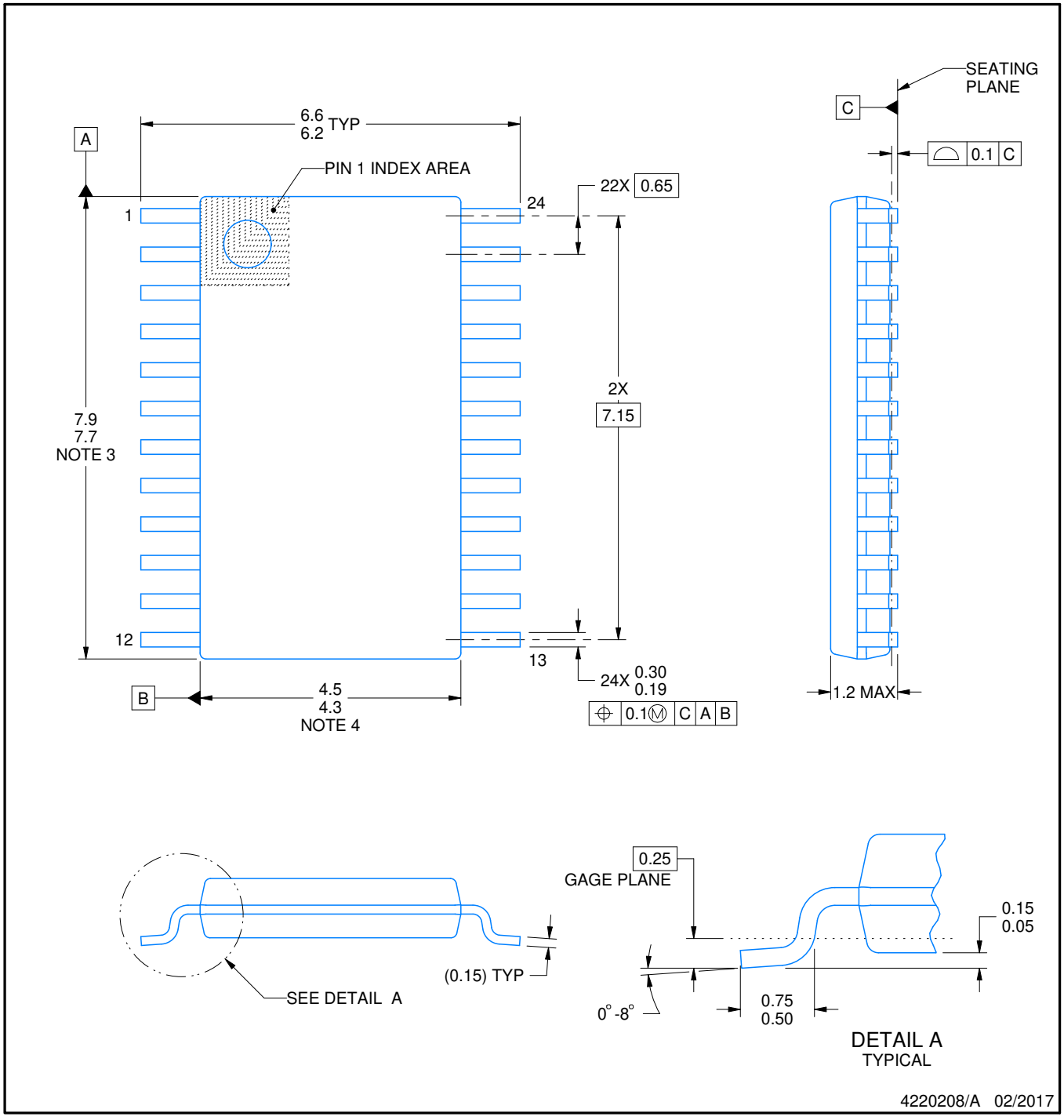
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ7721600PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721602PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721603PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721605PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721606PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721607PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721609PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721610PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721611PWR	TSSOP	PW	24	2000	356.0	356.0	35.0
BQ7721612PWR	TSSOP	PW	24	2000	356.0	356.0	35.0

PACKAGE OUTLINE

PW0024A

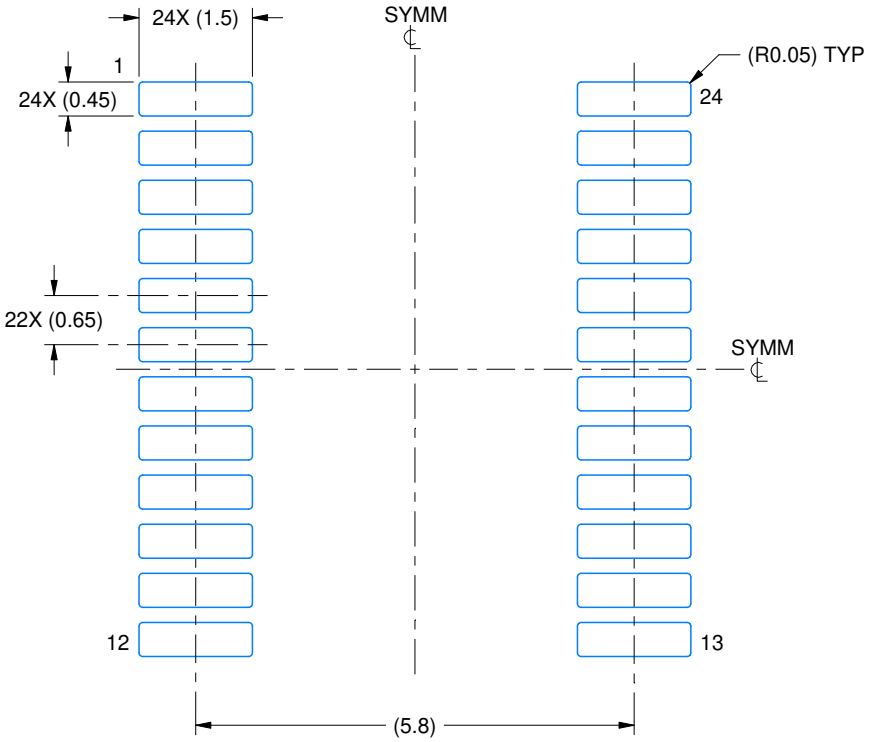
TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

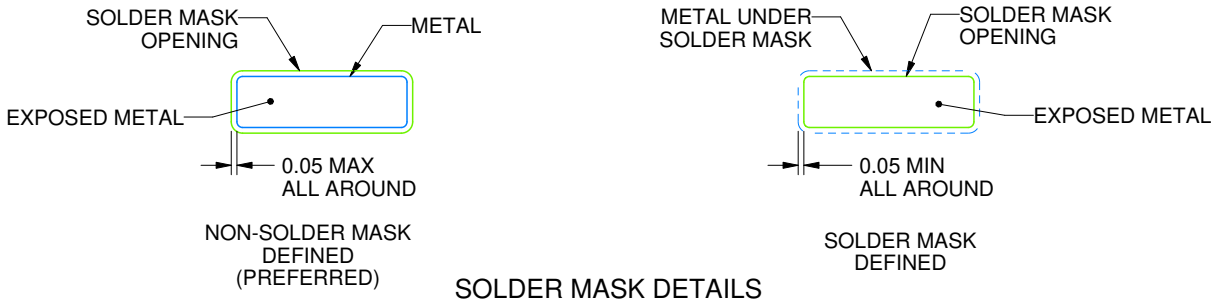


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X

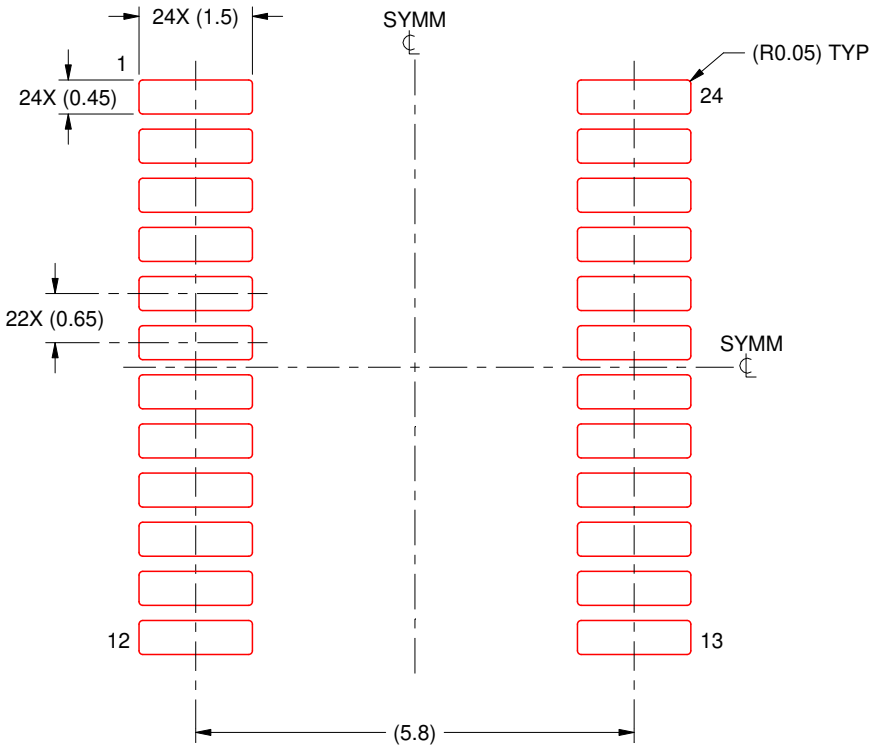


SOLDER MASK DETAILS

4220208/A 02/2017

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 10X

4220208/A 02/2017

NOTES: (continued)

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

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