BQ77904, BQ77905 3-Series to 20-Series Ultra Low-Power Voltage, Current, Temperature, and Open-Wire Stackable Lithium-Ion Battery Protector

1 Features

- NORMAL mode: 6 µA (BQ77904 and BQ77905)
- Full suite of voltage, current, and temperature protections
- Scalable cell count from 3 series to 20 series or more
- Voltage protection (accuracy ±10 mV)
  - Overvoltage: 3 V to 4.575 V
  - Undervoltage: 1.2 V to 3 V
- Open cell and open-wire detection (OW)
- Current Protection
  - Overcurrent discharge 1: –10 mV to –85 mV
  - Overcurrent discharge 2: –20 mV to +170 mV
  - Short circuit discharge: –40 mV to +340 mV
  - Accuracy ±20% for ≤ 20 mV, ±30% for > 20 mV across full temperature
- Temperature protection
  - Overtemperature charge: 45°C or 50°C
  - Overtemperature discharge: 65°C or 70°C
  - Undertemperature charge: –5°C or 0°C
  - Undertemperature discharge: –20°C or –10°C
- Additional Features
  - Independent charge (CHG) and discharge (DSG) FET drivers
  - 36-V absolute maximum rating per cell input
  - Built-in-self-test functions for high reliability
- SHUTDOWN mode: 0.5-µA maximum
- Functional Safety-Capable
  - Documentation available to aid functional safety system design

2 Applications

- Power tools, garden tools
- Start-stop battery packs
- Lead-acid (PbA) replacement batteries
- Light electric vehicles
- Energy storage systems, uninterruptible power supplies (UPS)
- 10.8-V to 72-V packs

3 Description

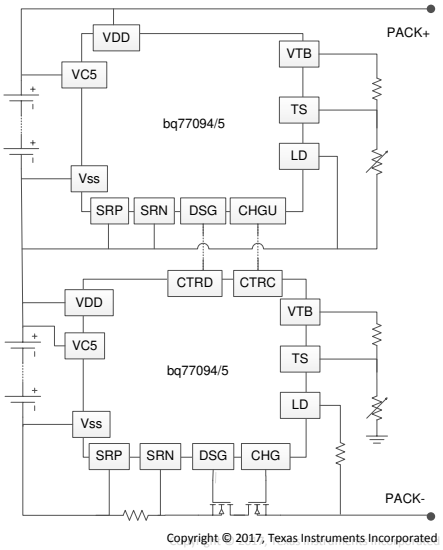
The BQ77904 and BQ77905 devices are low-power battery pack protectors that implement a suite of voltage, current, and temperature protections without microcontroller (MCU) control. The device's stackable interface provides simple scaling to support battery cell applications from 3 series to 20 series or more. Protection thresholds and delays are factory-programmed and available in a variety of configurations. Separate overtemperature and undertemperature thresholds for discharge (OTD and UTD) and charge (OTC and UTC) are provided for added flexibility.

The device achieves pack protection through the integrated independent CHG and DSG low-side NMOS FET drivers, which may be disabled through two control pins. These control pins may also be used to achieve cell protection solutions for higher series (6 series and beyond) in a simple and economical manner. To do this, simply cascade a higher device CHG and DSG outputs to the immediate lower device control pins. For a reduced component count, all protection faults use internal delay timers.

Device Information

PART NUMBER(1)	PACKAGE	BODY SIZE (NOM)
BQ77904	TSSOP (20)	6.50 mm × 4.40 mm
BQ77905		

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



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 J (April 2020) to Revision K (July 2020) — **Page**

- Added the BQ7790521 evice in the *Device Comparison* table....4

Changes from Revision I (December 2019) to Revision J (February 2020) — **Page**

- Changed the BQ7790518 device to a catalog device in the *Device Comparison* table....4

Changes from Revision H (September 2018) to Revision I (December 2019) — **Page**

- Added the BQ7790522 device to the *Device Comparison* table....4

Changes from Revision G (September 2017) to Revision H (September 2018) — **Page**

- Changed some wording throughout the data sheet for clarity and conciseness....1
- Added the BQ7790518 device to the BQ77905 *Device Comparison* table....4

Changes from Revision F (May 2017) to Revision G (September 2017) — **Page**

- Added BQ7790511 and BQ7790512 to the *Device Comparison* table....4

Changes from Revision E (March 2017) to Revision F (May 2017) — **Page**

- Changed the BQ7790400 setting: OV delay from 1 s to 2 s. UV from 2800 mV to 2200 mV, UV delay from 1 s to 2 s, UV Hyst from 200 to 400 mV, UV load recovery from N to Y. OCD2 from 80 mV to 60 mV, OCD2 delay from 700 to 350 ms. SCD from 160 mV to 100 mV....4
- Added BQ7790508 and BQ7790509 to the *Device Comparison* table....4

Changes from Revision D (March 2017) to Revision E (March 2017) — **Page**

- Added BQ7790505 to the *Device Comparison* table....4
- Changed UTC(REC) at 5°C typ from 68.8 to 69.73 %VTB. Changed UTC(REC) at 10°C typ from 64.23 to 65.52 %VTB....7

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Changes from Revision C (February 2017) to Revision D (March 2017) **Page**

- Changed VOTD, VOTD(REC), VOTC, VOTC(REC), VUTD, VUTD(REC), VUTC, VUTC(REC) MIN and MAX specification values....7

Changes from Revision B (November 2016) to Revision C (February 2017) **Page**

- Added values in the *Thermal Information* table to align with JEDEC standards....7

Changes from Revision A (June 2016) to Revision B (November 2016) **Page**

- Changed order of listed items in *Features* 1
- Table 5-1 and Table 5-2, Changed OTC To: UTC in last column under Temperature. Changed BQ7790400 and BQ7790503 to Production Data. Updated the BQ7790503 configuration 4
- Changed pin number from 16-pin to 20-pin 5
- Corrected max value on the UTD at –20°C spec....7
- Changed comparator flowcharts with new flowcharts....14
- Corrected CTRC and CTRD delay time entries....18

Changes from Revision * (June 2016) to Revision A (June 2016) **Page**

- Changed the device From: Product Preview To: Production....1

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5 Device Comparison

DEVICE	NUMBER OF CELLS	PROTECTIONS	TYPICAL NORMAL MODE CURRENT (µA)	PACKAGE
BQ77904	3, 4	OV, UV, OW, OTD, OTC, UTD, UTC, OCD1, OCD2, SCD, CTRC, CTRD	6	20-TSSOP
BQ77905	3, 4, 5			

Unless otherwise specified, the devices in Table 5-1 and Table 5-2 come, by default, with the state comparator enabled with a 2-mV threshold. Filtered fault detection is used by default. Contact Texas Instruments for new configuration options or devices in preview.

Table 5-1. BQ77904 Device Comparison

Part Number	OV			UV				OW	OCD1	
	Threshold (mV)	Delay(s)	Hyst (mV)	Thresh (mV)	Delay(s)	Hyst (mV)	Load Removal Recovery (Y/N)	Current (nA)	Threshold (mV)	Delay (ms)
BQ7790400	4225	2	100	2200	2	400	Y	0 (disable)	40	1420

Part Number (Cont.)	OCD2	SCD	Current Fault Recovery		Temperature (°C)(1)			
	Delay (ms)	Threshold (mV)	Delay (s)	Method	OTD	OTC	UTD	UTC
BQ7790400	350	100	0	Load Removal	70	50	–20	–5

(1) These thresholds are target based on temperature, but they are dependent on external components that could vary based on customer selection. The circuit is based on the 103AT NTC thermistor connected to TS and VSS, and a 10-kΩ resistor connected to VTB and TS. Actual thresholds must be determined in mV. Refers to the overtemperature and undertemperature mV threshold in the Electrical Characteristics table.

Table 5-2. BQ77905 Device Comparison

Part Number	OV			UV				OW	OCD1	
	Threshold (mV)	Delay(s)	Hyst (mV)	Thresh (mV)	Delay(s)	Hyst (mV)	Load Removal Recovery (Y/N)	Current (nA)	Threshold (mV)	Delay (ms)
BQ7790500	4200	0.5	100	2600	1	400	Y	100	30	1420
BQ7790502	4250	1	200	2700	1	200	Y	100	85	700
BQ7790503	4200	1	100	2700	2	400	Y	100	80	1420
BQ7790505	4250	1	200	2700	1	200	N	0	60	10
BQ7790508	3900	1	200	2000	1	400	Y	100	50	700
BQ7790509	4250	1	100	2500	1	400	Y	100	50	700
BQ7790511	4250	1	200	2700	1	200	Y	100	50	350
BQ7790512	4175	1	100	2800	1	400	Y	100	75	1420
BQ7790518	4250	1	100	2750	1	200	Y	100	70	180
BQ7790521	3700	1	200	2500	1	200	Y	100	70	180
BQ7790522	4250	1	100	2800	1	200	Y	100	80	700

Part Number (Cont.)	OCD2		SCD	Current Fault Recovery		Temperature (°C)(1)			
	Threshold (mV)	Delay (ms)	Threshold (mV)	Delay (s)	Method	OTD	OTC	UTD	UTC
BQ7790500	50	700	120	1	Load Removal + Delay	70	50	–20	0
BQ7790502	120	350	240	—	Load Removal	70	50	–20	–5
BQ7790503	160	350	320	—	Load Removal	70	50	–20	–5
BQ7790505	80	5	100	9	Load Removal + Delay	65	45	–20	0
BQ7790508	100	90	200	1	Load Removal + Delay	70	50	–20	–5
BQ7790509	100	90	200	1	Load Removal + Delay	70	50	–20	–5
BQ7790511	120	90	280	—	Load Removal	65	45	–20	0
BQ7790512	150	350	300	1	Load Removal + Delay	65	45	–20	0
BQ7790518	140	20	300	1	Load Removal	70	50	–20	0
BQ7790521	140	20	320	1	Load Removal	70	50	–20	0
BQ7790522	100	350	300	1	Load Removal	70	50	–20	–5

(1) These thresholds are target based on temperature, but they are dependent on external components that could vary based on customer selection. Circuit is based on 103AT NTC thermistor connected to TS and VSS, and a 10-kΩ resistor connected to VTB and TS.

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Actual thresholds must be determined in mV. Refers to the overtemperature and undertemperature mV threshold in the Electrical Characteristics table.

6 Pin Configuration and Functions

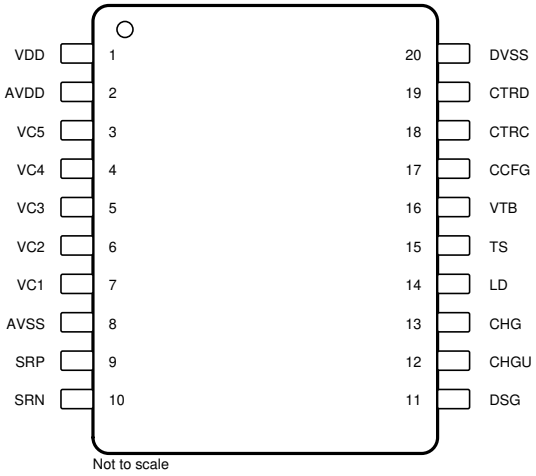


Figure 6-1. PW Package 20-Pin TSSOP Top View

Pin Functions

PIN		I/O[1]	DESCRIPTION
NAME	NO.		
AVDD	2	O	Analog supply (only connect to a capacitor)
AVSS	8	P	Analog ground
CCFG	17	I	Cell in series-configuration input
CHG	13	O	CHG FET driver. Use on a single device or on the bottom device of a stack configuration.
CHGU	12	O	CHG FET signal. Use for the upper device of a stack configuration to feed the CHG signal to the CTRC pin of the lower device.
CTRC	18	I	CHG and DSG override inputs
CTRD	19	I	
DSG	11	O	DSG FET driver
DVSS	20	P	Digital ground
LD	14	I	PACK– load removal detection
SRN	10	I	Current sense input connecting to the PACK– side of sense resistor
SRP	9	I	Current sense input connecting to the battery side of sense resistor
TS	15	I	Thermistor measurement input. Connect a 10-kΩ resistor to AVSS pin if the function is not used.
VC1	7	I	Cell voltage sense inputs
VC2	6	I	
VC3	5	I	
VC4	4	I	
VC5	3	I	Cell voltage sense inputs (Pin 3 must be connected to Pin 4 on the BQ77904 device.)
VDD	1	P	Supply voltage
VTB	16	O	Thermistor bias output

(1) I = Input, O = Output, P = Power

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7 Specifications

7.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted). All values are referenced to VSS unless otherwise noted.(1)

			MIN	MAX	UNIT
V_I	Input voltage	VDD, VC5, VC4, VC3, VC2, VC1, CCFG, CTRD, CTRC	–0.3	36	V
		LD	–30	20	V
		SRN, SRP, TS, AVDD, CCFG	–0.3	3.6	V
V_O	Output voltage range	DSG, CHGU	–0.3	20	V
		CHG	–30	20	V
		VTB	–0.3	3.6	V
I_I	Input current	LD, CHG		500	µA
I_I	Input current	CHGU, DSG		1	mA
I_O	Output current	CHG		1	mA
I_O	Output current	CHGU, DSG		1	mA
Storage temperature, T_{stg}			–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±250	

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

7.3 Recommended Operating Conditions

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

			MIN	MAX	UNIT
V_{BAT}	Supply voltage	VDD	3	25	V
V_I	Input voltage	VC5-VC4, VC4-VC3, VC3-VC2, VC2-VC1, VC1-VSS	0	5	V
		CTRD, CTRC	0	(VDD + 5)	
		CCFG	0	AVDD	
		SRN, SRP	–0.2	0.8	
		LD	0	16	
		TS	0	VTB	
V_O	Output voltage	CHG, CHGU, DSG	0	16	V
		VTB, AVDD	0	3	
T_A	Operating free-range temperature		–40	85	°C

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7.4 Thermal Information

THERMAL METRIC[1]		bq77904 bq77905 PW (TSSOP) 20 PINS	UNITS
$R_{\theta JA}$	Junction-to-ambient thermal resistance	98.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	37	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	49.3	°C/W
ψ_{JT}	Junction-to-top characterization parameter	2.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	48.7	°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

Typical values stated at T_A = 25°C and VDD = 16 V (bq77904) or 20 V (bq77905). MIN and MAX values stated with T_A = –40°C to +85°C and VDD = 3 to 20 V (bq77904) or VDD = 3 to 25 V (bq77905) unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY VOLTAGE						
$V_{(POR)}$	POR threshold	VDD rising, 0 to 6 V			4	V
$V_{(SHUT)}$	Shutdown threshold	VDD falling, 6 to 0 V	2		3.25	V
$V_{(AVDD)}$	AVDD voltage	$C_{(VDD)}$ = 1 µF	2.1	2.5	3.25	V
SUPPLY AND LEAKAGE CURRENT						
I_{CC}	NORMAL mode current (bq77904/bq77905)	Cell1 through Cell5 = 4 V, VDD = 20 V (bq77905)		6	9	µA
$I_{(CFAULT)}$	Fault condition current	State comparator on		8	12	µA
I_{OFF}	SHUTDOWN mode current	VDD < V_{SHUT}			0.5	µA
$I_{LKG(OW_DIS)}$	Input leakage current at VCx pins	All cell voltages = 4 V, Open-wire disable configuration	–100	0	100	nA
$I_{LKG(100nA)}$	Open-wire sink current at VCx pins	All cell voltages = 4 V, 100-nA configuration	30	110	175	nA
$I_{LKG(200nA)}$	Open-wire sink current at VCx pins	All cell voltages = 4 V, 200-nA configuration	95	210	315	nA
$I_{LKG(400nA)}$	Open-wire sink current at VCx pins	All cell voltages = 4 V, 400-nA configuration	220	425	640	nA
PROTECTION ACCURACIES						
V_{OV}	Overvoltage programmable threshold range		3000		4575	mV
V_{UV}	Undervoltage programmable threshold range		1200		3000	mV
$V_{(VA)}$	OV, UV, detection accuracy	T_A = 25°C, OV detection accuracy	–10		10	mV
		T_A = 25°C, UV detection accuracy	–18		18	mV
		T_A = 0 to 60°C	–28		26	mV
		T_A = –40 to 85°C	–40		40	mV
$V_{HYS(OV)}$	OV hysteresis programmable threshold range		0		400	mV
$V_{HYS(UV)}$	UV hysteresis programmable threshold range		200		800	mV
V_{OTD}	Overtemperature in discharge programmable threshold (ratio of V_{TB})	Threshold for 65°C[1]	19.71%	20.56%	21.86%	V
		Threshold for 70°C [1]	17.36%	18.22%	19.51%	VTB

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Typical values stated at T_A = 25°C and VDD = 16 V (bq77904) or 20 V (bq77905). MIN and MAX values stated with T_A = –40°C to +85°C and VDD = 3 to 20 V (bq77904) or VDD = 3 to 25 V (bq77905) unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OTD(REC)}$	Overtemperature in discharge recovery (ratio of V_{TB})	Recovery threshold at 55°C for when V_{OTD} is at 65°C(1)	25.24%	26.12%	27.44%	VTB
		Recovery threshold at 60°C for when V_{OTD} is at 70°C(1)	22.12%	23.2%	24.24%	VTB
V_{OTC}	Overtemperature in charge programmable threshold (ratio of V_{TB})	Threshold for 45°C(1)	32.14%	32.94%	34.54%	VTB
		Threshold for 50°C(1)	29.15%	29.38%	31.45%	VTB
$V_{OTC(REC)}$	Overtemperature in charge recovery (ratio of V_{TB})	Recovery threshold at 35°C when V_{OTD} is at 45°C(1)	38.63%	40.97%	40.99%	VTB
		Recovery threshold at 40°C when V_{OTD} is at 50°C(1)	36.18%	36.82%	38.47%	VTB
V_{UTD}	Undertemperature in discharge programmable threshold (ratio of V_{TB})	Threshold for –20°C(1)	86.41%	87.14%	89.72%	VTB
		Threshold for –10°C(1)	80.04%	80.94%	83.10%	VTB
$V_{UTD(REC)}$	Undertemperature in discharge recovery (ratio of V_{TB})	Recovery threshold at –10°C when V_{UTD} is at –20°C(1)	80.04%	80.94%	83.10%	VTB
		Recovery threshold at 0°C when V_{UTD} is at –10°C(1)	71.70%	73.18%	74.86%	VTB
V_{UTC}	Undertemperature in charge programmable threshold (ratio of V_{TB})	Threshold for –5°C(1)	75.06%	77.22%	78.32%	VTB
		Threshold for 0°C(1)	71.70%	73.18%	74.86%	VTB
$V_{UTC(REC)}$	Undertemperature in Charge Recovery (ratio of V_{TB})	Recovery threshold at 5°C when V_{UTC} is at –5°C(1)	68.80%	69.73%	71.71%	VTB
		Recovery threshold at 10°C when V_{UTC} is at 0°C(1)	64.67%	65.52%	67.46%	VTB
V_{OCD1}	Overcurrent discharge 1 programmable threshold range, ($V_{SRP} – V_{SRN}$)		–85		–10	mV
V_{OCD2}	Overcurrent discharge 2 programmable threshold range, ($V_{SRP} – V_{SRN}$)		–20		–170	mV
V_{SCD}	Short circuit discharge programmable threshold range, ($V_{SRP} – V_{SRN}$)		–40		–340	mV
V_{CCAL}	OCD1 detection accuracy at lower thresholds	V_{OCD1} > –20 mV	–30%		30%	
V_{CCAH}	OCD1, OCD2, SCD detection accuracy	V_{OCD1} ≤ –20 mV; all OCD2 and SCD threshold ranges	–20%		20%	
V_{OW}	Open-wire fault voltage threshold at VCx per cell with respect to VC_{x-1}	Voltage falling on VCx, 3.6 V to 0 V	450	500	550	mV
$V_{OW(HYS)}$	Hysteresis for open wire fault	Voltage rising on VCx, 0 V to 3.6 V		100		mV
CHARGE AND DISCHARGE FET DRIVERS						
$V_{(FETON)}$	CHG/CHGU/DSG on	VDD ≥ 12 V, CL = 10 nF	11	12	14	V
		VDD < 12 V, CL = 10 nF	VDD – 1		VDD	V
$V_{(FETOFF)}$	CHG/CHGU/DSG off	No load when CHG/CHGU/DSG is off.			0.5	V
$R_{(CHGOFF)}$	CHG off resistance	CHG off for > t_{CHGPDN} and pin held at 2 V		0.5		kΩ
$R_{(DSGOFF)}$	CHGU/DSG off resistance	CHGU/DSG off and pin held at 2 V		10	16	Ω
$I_{CHG(CLAMP)}$	CHG clamp current	CHG off and pin held at 18 V			450	µA

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Typical values stated at T_A = 25°C and VDD = 16 V (bq77904) or 20 V (bq77905). MIN and MAX values stated with T_A = –40°C to +85°C and VDD = 3 to 20 V (bq77904) or VDD = 3 to 25 V (bq77905) unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{CHG(CLAMP)}$	CHG clamp voltage	$I_{CHG(CLAMP)}$ = 300 µA	16	18	20.5	V
t_{CHGON}	CHG on rise time	CL = 10 nF, 10% to 90%		50	150	µs
t_{DSGON}	CHGU/DSG on rise time	CL = 10 nF, 10% to 90%		2	75	µs
t_{CHGOFF}	CHG off fall time	CL = 10 nF, 90% to 10%		15	30	µs
t_{DSGOFF}	CHGU/DSG off fall time	CL = 10 nF, 90% to 10%		5	15	µs
CTRC AND CTRD CONTROL						
V_{CTR1}	Enable FET driver (VSS)	With respect to VSS. Enabled < MAX			0.6	V
V_{CTR2}	Enable FET driver (Stacked)	Enabled > MIN	VDD + 2.2			V
$V_{CTR(DIS)}$	Disable FET driver	Disabled between MIN and MAX	2.04		VDD + 0.7	V
$V_{CTR(MAXV)}$	CTRC and CTRD clamp voltage	I_{CTR} = 600 nA	VDD + 2.8	VDD + 4	VDD + 5	V
t_{CTRDEG_ON} (2)	CTRC and CTRD deglitch for ON signal			7		ms
t_{CTRDEG_OFF} (2)	CTRC and CTRD deglitch for OFF signal			7		ms
CURRENT STATE COMPARATOR						
$V_{(STATE_D1)}$	Discharge qualification threshold1	Measured at SRP-SRN	–3	–2	–1	mV
$V_{(STATE_C1)}$	Charge qualification threshold1	Measured at SRP-SRN	1	2	3	mV
t_{STATE} (2)	State detection qualification time				1.2	ms
LOAD REMOVAL DETECTION						
$V_{LD(CLAMP)}$	LD clamp voltage	$I_{(LDCLAMP)}$ = 300 µA	16	18	20.5	V
$I_{LD(CLAMP)}$	LD clamp current	$V_{(LDCLAMP)}$ = 18 V			450	µA
V_{LDT}	LD threshold	Load removed < when V_{LDT}	1.25	1.3	1.35	V
$R_{LD(INT)}$	LD input resistance when enabled	Measured to VSS	160	250	375	kΩ
t_{LD_DEG}	LD detection deglitch		1	1.5	2.3	ms
CCFG PIN						
$V_{(CCFGL)}$	CCFG threshold low (ratio of V_{AVDD})	3-cell configuration			10%	V
$V_{(CCFGH)}$	CCFG threshold high (ratio of V_{AVDD})	4-cell configuration	65%		100%	V
$V_{(CCFGHZ)}$	CFG threshold high-Z (ratio of V_{AVDD})	5-cell configuration, CCFG floating, internally biased	25%	33%	45%	V
t_{CCFG_DEG} (2)	CCFG deglitch			6		ms
CUSTOMER TEST MODE (CTM)						
$V_{(CTM)}$	Customer test mode entry voltage at VDD	VDD > VC5 + $V_{(CTM)}$, T_A = 25°C	8.5		10	V
t_{CTM_ENTRY} (3)	Delay time to enter and exit Customer Test Mode	VDD > VC5 + $V_{(CTM)}$, T_A = 25°C	50			ms
t_{CTM_DELAY} (3)	Delay time of faults while in Customer Test Mode	T_A = 25°C			200	ms
$t_{CTM_OC_REC}$ (3)	Fault recovery time of OCD1, OCD2, and SCD faults while in Customer Test Mode	1 s and 8 s options, T_A = 25°C			100	ms

(1) Based on a 10-KΩ pull-up and 103AT thermistor

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(2) Not production tested parameters. Specified by design
(3) The device is in a no fault state prior to entering Customer Test Mode.

7.6 Timing Requirements

			MIN	TYP	MAX	UNIT
PROTECTION DELAYS (2)						
t_{OVn_DELAY}	Overvoltage detection delay time	0.5-s delay option	0.4	0.5	0.8	s
		1-s delay option	0.8	1	1.4	
		2-s delay option	1.8	2	2.7	
		4.5-s delay option	4	4.5	5.2	
t_{UVn_DELAY}	Undervoltage detection delay time	1-s delay option	0.8	1	1.5	s
		2-s delay option	1.8	2	2.7	
		4.5-s delay option	4	4.5	5.5	
		9-s delay option	8	9	10.2	
t_{OWn_DELAY}	Open-wire detection delay time		3.6	4.5	5.3	s
t_{OTC_DELAY}	Overtemperature charge detection delay time		3.6	4.5	5.3	s
t_{UTC_DELAY}	Undertemperature charge detection delay time		3.6	4.5	5.3	s
t_{OTD_DELAY}	Overtemperature discharge detection delay time		3.6	4.5	5.3	s
t_{UTD_DELAY}	Undertemperature discharge detection delay time		3.6	4.5	5.3	s
t_{OCD1_DELAY}	Overcurrent 1 detection delay time	10-ms delay option	8	10	15	ms
		20-ms delay option	17	20	26	
		45-ms delay option	36	45	52	
		90-ms delay option	78	90	105	
		180-ms delay option	155	180	205	
		350-ms delay option	320	350	405	
		700-ms delay option	640	700	825	
		1420-ms delay option	1290	1420	1620	
t_{OCD2_DELAY}	Overcurrent 2 detection delay time	5-ms delay option	4	5	8	ms
		10-ms delay option	8	10	15	
		20-ms delay option	17	20	26	
		45-ms delay option	36	45	52	
		90-ms delay option	78	90	105	
		180-ms delay option	155	180	205	
		350-ms delay option	320	350	405	
		700-ms delay option	640	700	825	
t_{SCD_RELAY}	Short-circuit detection delay time	360-µs delay option	220	400	610	µs
t_{CD_REC}	Overcurrent 1, Overcurrent 2, and Short-circuit recovery delay time	1-s option	0.8	1	1.4	s
		9-s option	8	9	10.2	

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7.7 Typical Characteristics

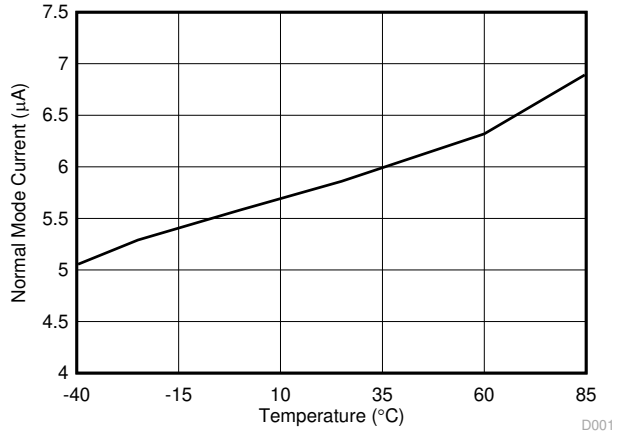


Figure 7-1. NORMAL Mode Current

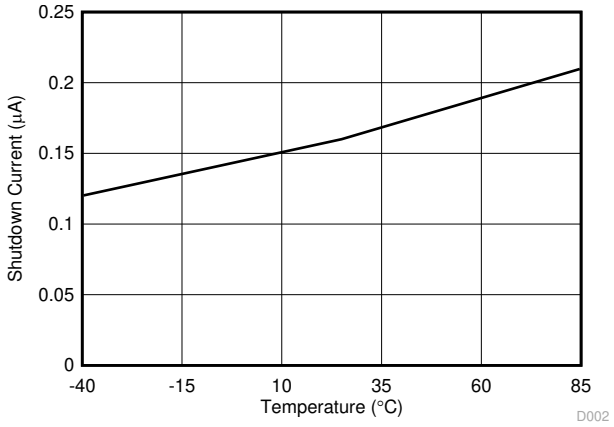


Figure 7-2. Shutdown Current

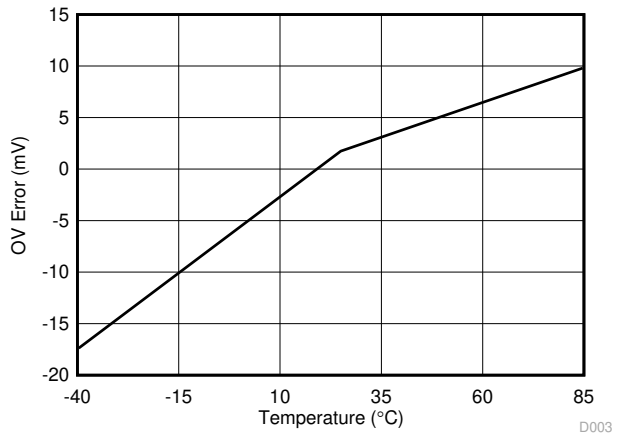


Figure 7-3. OV Error at 4.25-V Threshold

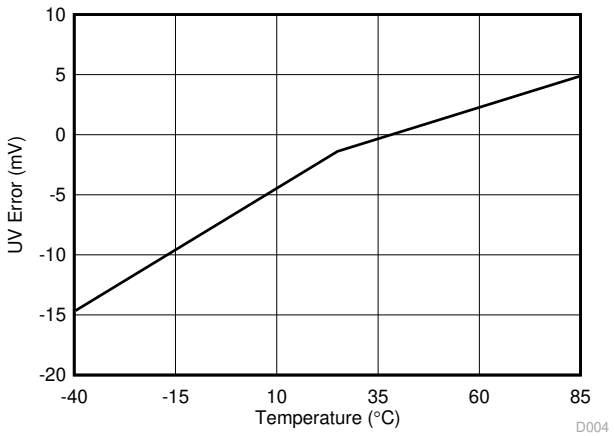


Figure 7-4. UV Error at 2.8-V Threshold

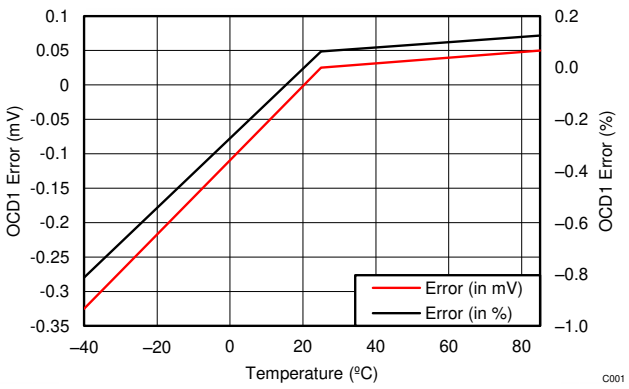


Figure 7-5. OCD1 Error at 40-mV Threshold

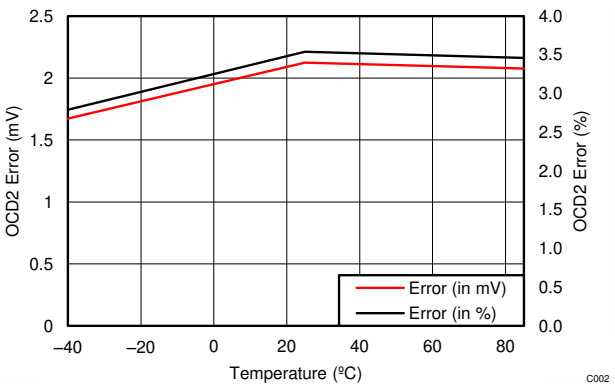


Figure 7-6. OCD2 Error at 60-mV Threshold

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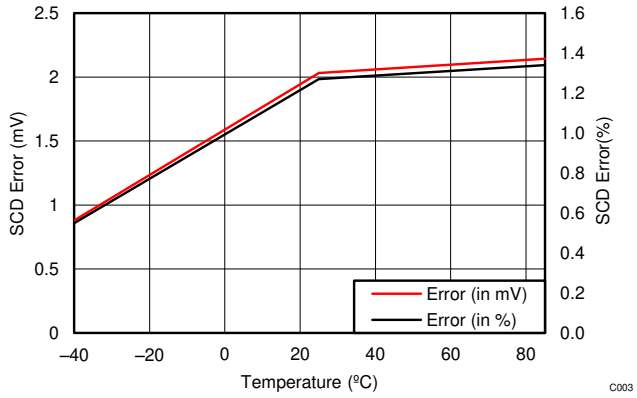


Figure 7-7. SCD Error at 160-mV Threshold

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8 Detailed Description

8.1 Overview

The BQ77904 and BQ77905 families are full-feature stackable primary protectors for Li-ion/Li-Polymer batteries. The devices implement a suite of protections, including:

- Cell voltage: overvoltage, undervoltage
- Current: Overcurrent discharge 1 and 2, short circuit discharge
- Temperature: overtemperature and undertemperature in charge and discharge
- PCB: cell open-wire connection
- FET body diode protection

Protection thresholds and delays are factory-programmed and available in a variety of configurations.

The BQ77904 supports 3-series-to–4-series cell configuration and BQ77905 supports 3-series-to–5-series cell configuration. Up to four devices can be stacked to support ≥6-series cell configurations, providing protections up to 20-series cell configurations.

The device has built-in CHG and DSG drivers for low-side N-channel FET protection, which automatically open up the CHG and/or DSG FETs after protection delay time when a fault is detected. A set of CHG/DSG overrides is provided to allow disabling of CHG and/or DSG driver externally. Although the host system can use this function to disable the FETs' control, the main use of these pins is to channel down the FET control signal from the upper device to the lower device in a cascading configuration in ≥6-series battery packs.

8.1.1 Device Functionality Summary

In this and subsequent sections, a number of abbreviations are used to identify specific fault conditions. The fault descriptor abbreviations and their meanings are defined in Table 8-1.

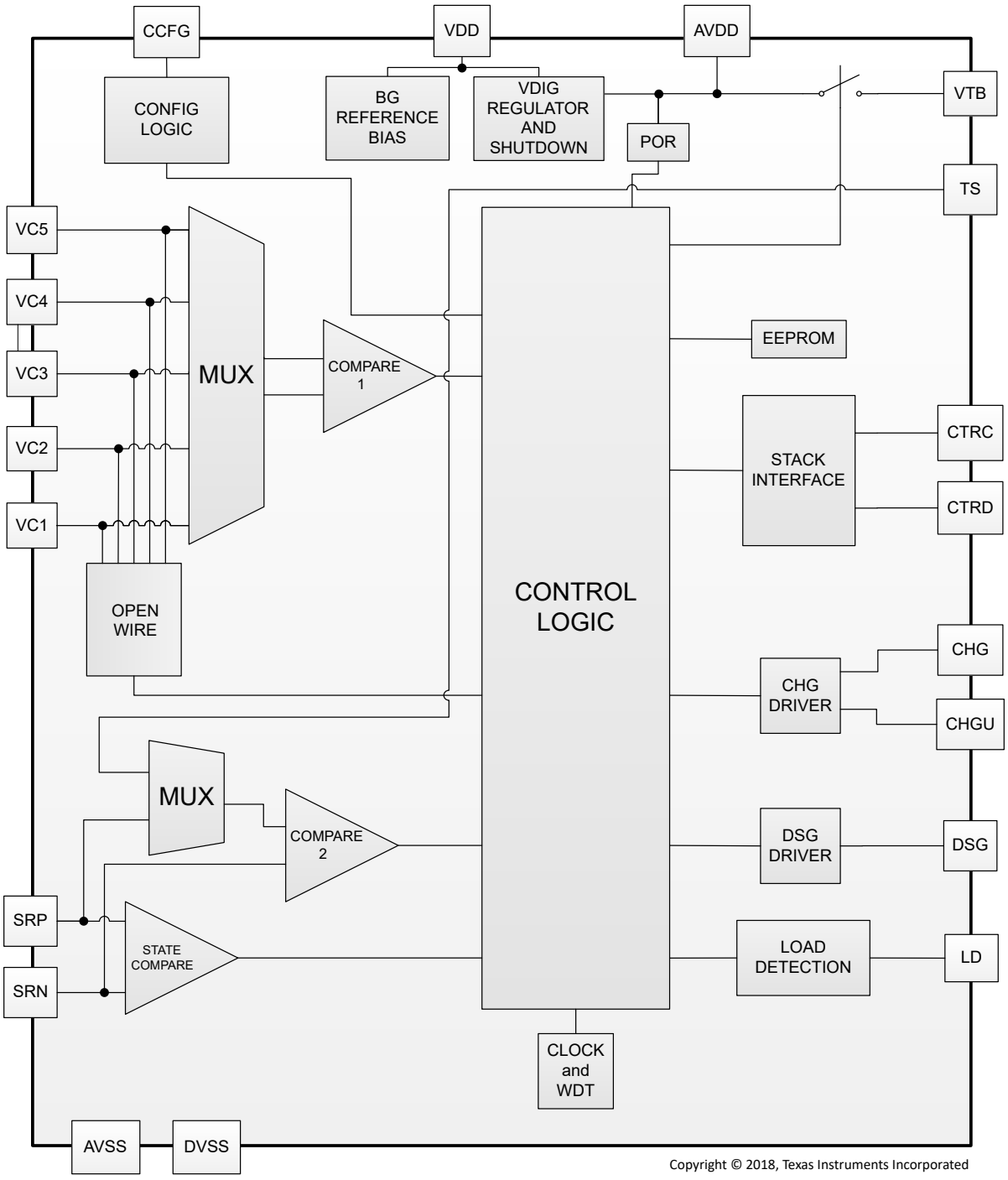
Table 8-1. Device Functionality Summary

FAULT DESCRIPTOR		FAULT DETECTION THRESHOLD and DELAY OPTIONS		FAULT RECOVERY METHOD and SETTING OPTIONS	
OV	Overvoltage	3 V to 4.575 V (25-mV step)	0.5, 1, 2, 4.5 s	Hysteresis	0, 100, 200, 400 mV
UV	Undervoltage	1.2 V to 3 V (100-mV step for < 2.5 V, 50-mV step for ≥ 2.5 V)	1, 2, 4.5, 9 s	Hysteresis OR Hysteresis + Load Removal	200, 400 mV
OW	Open wire (cell to pcb disconnection)	0 (disabled), 100, 200, or 400 nA	4.5 s	Restore bad VCx to pcb connection	VCx > V_{OW}
OTD(1)	Overtemperature during discharge	65°C or 70°C	4.5 s	Hysteresis	10°C
OTC(1)	Overtemperature during charge	45°C or 50°C	4.5 s	Hysteresis	10°C
UTD(1)	Undertemperature during discharge	–20°C or –10°C	4.5 s	Hysteresis	10°C
UTC (1)	Undertemperature during charge	–5°C or 0°C	4.5s	Hysteresis	10°C
OCD1	Overcurrent1 during discharge	10 mV to 85 mV (5-mV step)	10, 20, 45, 90, 180, 350, 700, 1420 ms	Delay OR Delay + Load Removal OR Load Removal	1 s or 9 s
OCD2	Overcurrent1 during discharge	20 mV to 170 mV (10-mV step)	5, 10, 20, 45, 90, 180, 350, 700 ms		
SCD	Short circuit discharge	40 mV to 340 mV (20-mV step)	360 µs		
CTRC	CHG signal override control	Disable via external control or via CHGU signal from the upper device in the stack configuration.	t_{CTRDEG_ON}	Enable via external control or via CHGU signal from the upper device in the stack configuration.	t_{CTRDEG_OFF}
CTRD	DSG signal override control	Disable via external control or via DSG signal from the upper device in the stack configuration.	t_{CTRDEG_ON}	Enable via external control or via DSG signal from the upper device in the stack configuration.	t_{CTRDEG_OFF}

(1) These thresholds are target based on temperature, but they are dependent on external components that could vary based on customer selection. The circuit is based on a 103AT NTC thermistor connected to TS and VSS, and a 10-kΩ resistor connected to VTB and TS. Actual thresholds must be determined in mV. Refers to the overtemperature and undertemperature mV threshold in the Electrical Characteristics table.

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8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Protection Summary

The BQ77904 and BQ77905 have two comparators. Both are time multiplexed to detect all protection fault conditions. Each of the comparators runs on a time-multiplexed schedule and cycles through the assigned

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protection-fault checks. Comparator 1 checks for OV, UV, and OW protection faults. Comparator 2 checks for OCD1, OCD2, SCD, OTC, OTD, UTC, and UTD protection faults. For OV, UV, and OW protection faults, every cell is checked individually in round-robin fashion, starting with cell 1 and ending with the highest-selected cell. The number of the highest cell is configured using the CCFG pin.

Devices can be ordered with various timing and hysteresis settings. See the *Section 5* section for a summary of options available per device type.

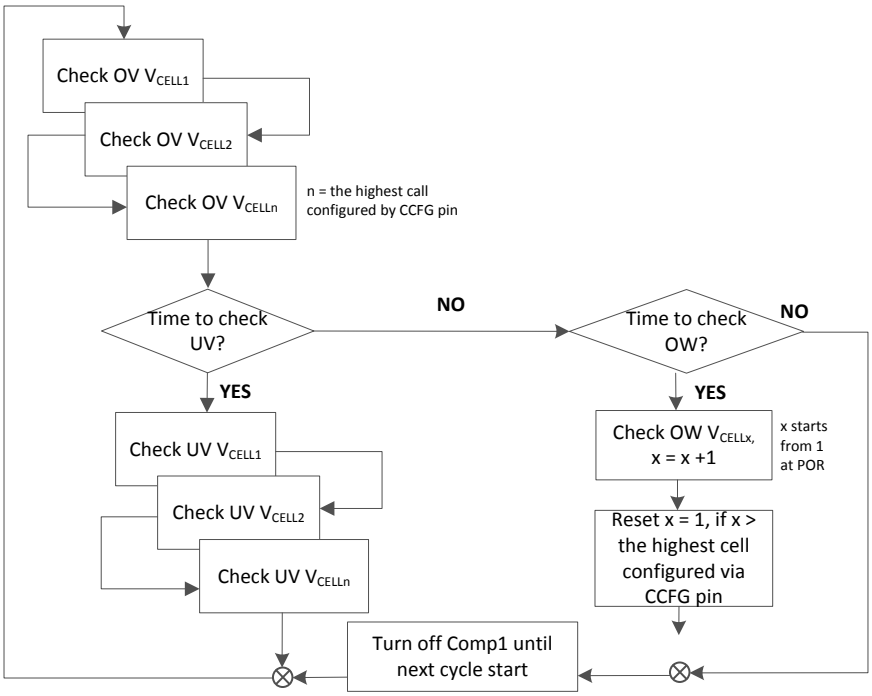


Figure 8-1. Comparator 1 Flowchart

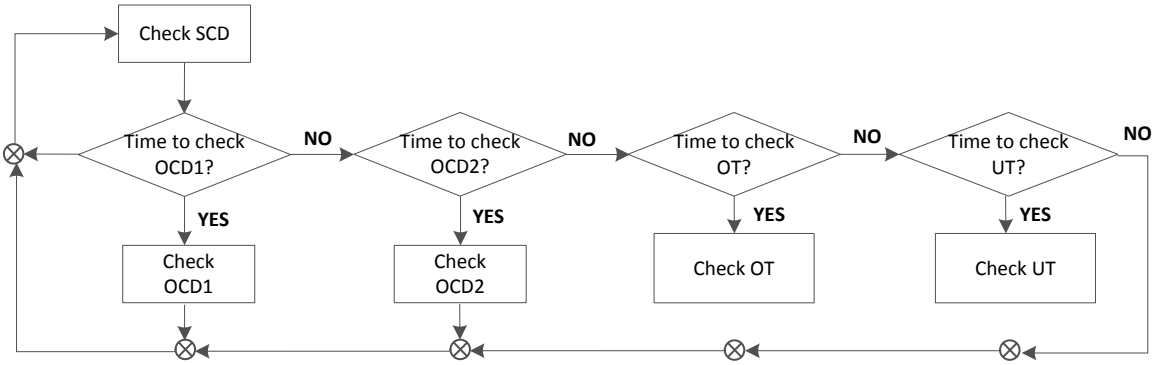


Figure 8-2. Comparator 2 Flowchart

8.3.2 Fault Operation

8.3.2.1 Operation in OV

An OV fault detection is when at least one of the cell voltages is measured above the OV threshold, V_{OV}. The CHG pin is turned off if the fault condition lasts for a duration of OV Delay, t_{OVn_DELAY}. The OV fault recovers when the voltage of the cell in fault is below the (OV threshold – OV hysteresis, V_{HYS_OV}) for a time of OV Delay.

The BQ77904 and BQ77905 assume OV fault after device reset.

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8.3.2.2 Operation in UV

An UV fault detection is when at least one of the cell voltages is measured below the UV threshold, V_{UV}. The DSG is turned off if the fault condition lasts for a duration of UV Delay, t_{UVn_DELAY}. The UV fault recovers when:

- The cell voltage in fault is above the (UV threshold + UV hysteresis, V_{HYS_UV}) for a time of UV Delay only OR
- The cell voltage in fault is above the (UV threshold + UV hysteresis) for a time of UV Delay AND load removal is detected.

If load removal is enabled as part of the UV recovery requirement, the CHG FET R_{GS} value should change to around 3 MΩ. Refer to the *Section 9.1.1.4* section of this document for more detail. This requirement applies to load removal enabled for UV recovery only. Therefore, if load removal is selected for current fault recovery, but not for the UV recovery, a lower CHG FET R_{GS} value (typical of 1MΩ) can be used to reduce the CHG FET turn off time.

To minimize supply current, the device disables all overcurrent detection blocks any time the DSG FET is turned off (due to a fault or CTRD being driven to the DISABLED state). Upon recovery from a fault or when CTRD is no longer externally driven, all overcurrent detection blocks reactivate before the DSG FET turns back on.

8.3.2.3 Operation in OW

An OW fault detection is when at least one of the cell voltages is measured below the OW threshold, V_{OW}. Both CHG and DSG are turned off if the fault condition lasts for a duration of OW Delay, t_{OWn_DELAY}. The OW fault recovers when the cell voltage in fault is above the OW threshold + OW hysteresis, V_{OW_HYS} for a time of OW Delay.

The t_{OWn_DELAY} time starts when voltage at a given cell is detected below the V_{OW} threshold and is not from the time that the actual event of open wire occurs. During an open-wire event, it is common that the device detects an undervoltage and/or overvoltage fault before detecting an open-wire fault. This may happen due to the differences in fault thresholds, fault delays, and the VCx pin filter capacitor values. To ensure both CHG and DSG return to normal operation mode, the OW, OV, and UV faults recovery conditions must be met.

8.3.2.4 Operation in OCD1

An OCD1 fault is when the discharge load is high enough that the voltage across the R_{SNS} resistor, (V_{SRP}-V_{SRN}), is measured below the OCD1 voltage threshold, V_{OCD1}. Both CHG and DSG are turned off if the fault condition lasts for a duration of OCD1 Delay, t_{OCD1_DELAY}.

The OCD1 fault recovers when:

- Load removal is detected only, $V_{LD} < V_{LDT}$ OR
- Overcurrent Recovery Timer, t_{CD_REC}, expiration only OR
- Overcurrent Recovery Timer expiration and load removal are detected.

8.3.2.5 Operation in OCD2

An OCD2 fault is when the discharge load is high enough that the voltage across the R_{SNS} resistor, (V_{SRP}-V_{SRN}), is measured below the OCD2 voltage threshold, V_{OCD2}. Both CHG and DSG are turned off if the fault condition lasts for a duration of OCD2 Delay, t_{OCD2_DELAY}.

The OCD2 fault recovers when:

- Load removal detected only, $V_{LD} < V_{LDT}$ OR
- Overcurrent Recovery Timer, t_{CD_REC}, expiration only OR
- Overcurrent Recovery Timer expiration and load removal are detected.

8.3.2.6 Operation in SCD

An SCD fault is when the discharge load is high enough that the voltage across the R_{SNS} resistor, (V_{SRP}-V_{SRN}), is measured below the SCD voltage threshold, V_{SCD}. Both CHG and DSG are turned off if the fault condition lasts for a duration of SCD Delay, t_{SCD_DELAY}.

The SCD fault recovers when:

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- Load removal detected only, $V_{LD} < V_{LDT}$ OR
- Overcurrent Recovery Timer, t_{CD_REC}, expiration only OR
- Overcurrent Recovery Timer expiration and load removal are detected.

8.3.2.7 Overcurrent Recovery Timer

The timer expiration method activates an internal recovery timer as soon as the initial fault condition exceeds the OCD1/OCD2/SCD time. When the recovery timer reaches its limit, both CHG and DSG drivers are turned back on. If the combination option of timer expiration AND load removal is used, then the load removal condition is only evaluated upon expiration of the recovery timer, which can have an expiration period of t_{CD_REC}.

8.3.2.8 Load Removal Detection

The load removal detection feature is implemented with the LD pin (see Table 8-2). When no undervoltage fault and current fault conditions are present, the LD pin is held in an open-drain state. Once any UV, OCD1, OCD2, or SCD fault occurs and load removal is selected as part of the recovery conditions, a high impedance pull-down path to VSS is enabled on the LD pin. With an external load still present, the LD pin will be externally pulled high: It is internally clamped to $V_{LDCLAMP}$ and should also be resistor-limited through R_{LD} externally to avoid conducting excessive current. If the LD pin exceeds V_{LDT}, this is interpreted as a *load present condition*. When the load is eventually removed, the internal high-impedance path to VSS should be sufficient to pull the LD pin below V_{LDT} for t_{LD_DEG}. This is interpreted as a *load removed condition* and is one of the recovery mechanisms selectable for undervoltage and overcurrent faults.

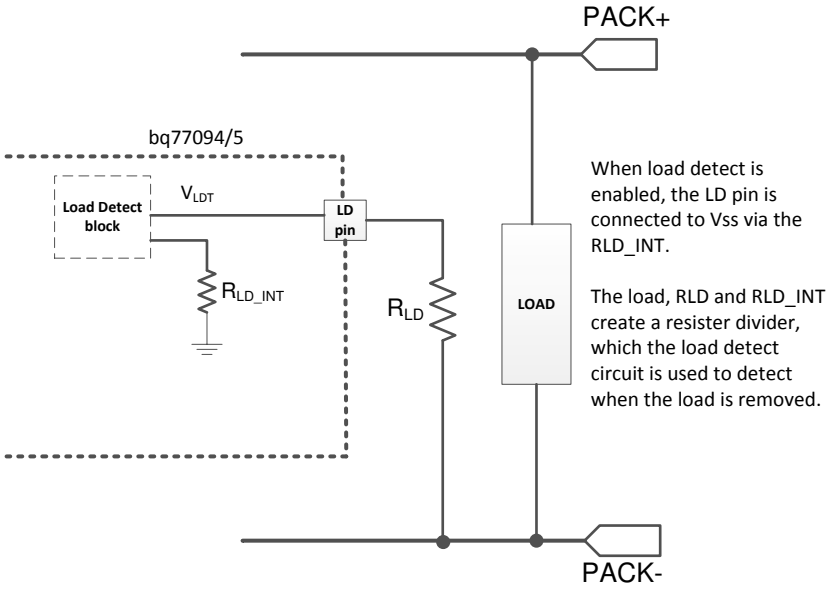


Figure 8-3. Load Detection Circuit for Current Faults Recovery

Table 8-2. Load State

LD PIN	LOAD STATE
≥ V_{LDT}	Load present
< V_{LOT} for t_{LD_DEG}	Load removed

8.3.2.9 Load Removal Detection in UV

During a UV fault, only the DSG FET driver is turned off while the CHG FET driver remains on. When load removal is selected as part of the UV recovery condition, the active CHG FET driver would alter the resistor divider ratio of the load detection circuit. To ensure the load status can still be detected properly, it is required to increase the CHG FET external R_{GS} value to about 3 MΩ. Refer to the *Section 9.1.1.4* section for more detail. Note that if load removal is only selected for the current fault recovery (and is not used for UV recovery), it is not required to use a larger CHG FET R_{GS} value.

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8.3.2.10 Operation in OTC

An OTC Fault occurs when the temperature increases such that the voltage across an NTC thermistor goes below the OTC voltage threshold, V_{OTC}. CHG is turned off if the fault condition lasts for an OTC delay time, t_{OTC_DELAY}. The state comparator is turned on when CHG is turned off. If a discharge current is detected, the device immediately switches the CHG back on. The response time of the state comparator is typically in 700 µs and should not pose any disturbance in the discharge event. The OTC fault recovers when the voltage across thermistor gets above OTC recovery threshold, V_{OTC_REC}, for OTC delay time.

8.3.2.11 Operation in OTD

An OTD fault is when the temperature increases such that the voltage across an NTC thermistor goes below the OTD voltage threshold, V_{OTD}. Both CHG and DSG are turned off if the fault condition lasts for an OTD delay time, t_{OTD_DELAY}. The OTD fault recovers when the voltage across thermistor gets above OTD recovery threshold, V_{OTD_REC}, a time of an OTD delay.

8.3.2.12 Operation in UTC

A UTC fault occurs when the temperature decreases such that the voltage across an NTC thermistor gets above the UTC voltage threshold, V_{UTC}. CHG is turned off if the fault condition lasts for a time of a UTC delay, t_{UTC_DELAY}. The state comparator is turned on when CHG is turned off. If a discharge current is detected, the device will immediately switch CHG back on. The response time of the state comparator is typically in 700 µs and should not pose any disturbance in the discharge event. The UTC fault recovers when the voltage across thermistor gets below UTC recovery threshold, V_{UTC_REC}, a time of a UTC delay.

8.3.2.13 Operation in UTD

A UTD fault occurs when the temperature decreases such that the voltage across an NTC thermistor goes above the UTD voltage threshold, V_{UTD}. Both CHG and DSG are turned off if the fault condition lasts for a UTD delay time. The UTD fault recovers when the voltage across the thermistor gets below the UTD recovery threshold, V_{UTD_REC}, a time of the UTD delay.

8.3.3 Protection Response and Recovery Summary

Table 8-3 summarizes how each fault condition affects the state of the DSG and CHG output signals, as well as the recovery conditions required to resume charging and/or discharging. As a rule, the CHG and DSG output drivers are enabled only when no respective fault conditions are present. When multiple simultaneous faults (such as an OV and OTD) are present, all faults must be cleared before the FET can resume operation.

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Table 8-3. Fault Condition, State, and Recovery Methods

FAULT	FAULT TRIGGER CONDITION	CHG	DSG	RECOVERY METHOD	TRIGGER DELAY	RECOVERY DELAY
CTRC disabled	CTRC disabled for deglitch delay time	OFF	—	CTRC must be enabled for deglitch delay time	t_{CTRDEG_ON}	t_{CTRDEG_OFF}
CTRD disabled	CTRD disabled for deglitch delay time	—	OFF	CTRD must be enabled for deglitch delay time		
OV	V(Cell) rises above V_{OV} for delay time	OFF	—	V(Cell) drops below $V_{OV} – V_{HYS_OV}$ for delay	t_{OVn_DELAY}	
UV	V(Cell) drops below V_{UV} for delay time	—	OFF	V(Cell) rises above $V_{UV} + V_{HYS_UV}$ for delay	t_{UVn_DELAY}	
OW	$VC_X – VC_{X–1} < V_{OW}$ for delay time	OFF	OFF	Bad VC_X recovers such that $VC_X – VC_{X–1} > V_{OW} + V_{OW_HYS}$ for delay	t_{OWn_DELAY}	
OCD1, OCD2, SCD	(VSRP - VSRN) < VOCD1, VOCD2, or VSCD for delay time	OFF	OFF	Recovery delay expires OR LD detects < V_{LDT} OR Recovery delay expires + LD detects < V_{LDT}	t_{OCD1_DELAY}, t_{OCD2_DELAY}, t_{SCD_DELAY},	t_{CD_REC}
OTC(1)	Temperature rises above T_{OTC} for delay time	OFF	—	Temp drops below $T_{OTC} – T_{OTC_REC}$ for delay	t_{OTC_DELAY}	
OTD(1)	Temperature rises above T_{OTD} for delay time	OFF	OFF	Temp drops below $T_{OTD} – T_{OTD_REC}$ for delay	t_{OTD_DELAY}	
UTC(1)	Temperature drops below T_{UTC} for delay time	OFF	—	Temperature rises above $T_{UTC} + T_{UTC_REC}$ for delay	t_{UTC_DELAY}	
UTD(1)	Temp drops below T_{UTD} for delay time	OFF	OFF	Temp rises above $T_{UTD} + T_{UTD_REC}$ for delay	t_{UTD_DELAY}	

(1) T_{UTC}, T_{UTD}, T_{UTC_REC}, and T_{UTD_REC} correspond to the temperature produced by V_{UTC}, V_{UTD}, V_{UTC_REC}, and V_{UTD_REC} of the selected thermistor resistance.

For BQ77904 and BQ77905 devices to prevent CHG FET damage, there are times when the CHG FET may be enabled even though an OV, UTC, OTC, or CTRC low event has occurred. See the *State Comparator* section for details.

8.3.4 Configuration CRC Check and Comparator Built-In-Self-Test

To improve reliability, the device has built in CRC check for all the factory-programmable configurations, such as the thresholds and delay time setting. When the device is set up in the factory, a corresponding CRC value is also programmed to the memory. During normal operation, the device compares the configuration setting against the programmed CRC periodically. A CRC error will reset the digital circuitry and increment the CRC fault counter. The digital reset forces the device to reload the configuration as an attempt to correct the configurations. A correct CRC check reduces the CRC fault counter. Three CRC faults counts will turn off both the CHG and DSG drivers. If FETs are opened due to a CRC error, only a POR can recover the FET state and reset the CRC fault.

In addition to the CRC check, the device also has built-in-self-test (BIST) on the comparators. The BIST runs in a scheduler, and each comparator is checked for a period of time. If a fault is detected for the entire check period, the particular comparator is considered at fault, and both the CHG and DSG FETs is turned off. The BIST continues to run by the scheduler even if a BIST fault is detected. If the next BIST result is good, the FET driver resumes normal operation.

The CRC check and BIST check do not affect the normal operation of the device. However, there is not a specific indication when a CRC or BIST error is detected besides turning off the CHG and DSG drivers. If there is no voltage, current, or temperature fault condition present, but CHG and DSG drivers remain off, it is possible that either a CRC or BIST error is detected. Users can power-on reset (POR) the device.

8.3.5 Fault Detection Method

8.3.5.1 Filtered Fault Detection

The device detects a fault once the applicable fault is triggered after accumulating sufficient trigger sample counts. The filtering scheme is based on a simple add/subtract. Starting with the triggered sample count cleared, the counts go up for a sample that is taken across the tested condition (for example, above the fault threshold when looking for a fault) and the counts go down for a sample that is taken before the tested condition (that is,

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below the fault threshold). Figure 8-4 shows an example of a signal that triggers a fault when accumulating five counts above the fault threshold. Once a fault has been triggered, the triggered sample counts reset, and counts are incremented for every sample that is found to be below the recovery threshold.

Note

With a filtered detection, when the input signal falls below the fault threshold, the sample count does not reset, but only counts down as shown in Figure 8-4. Therefore, it is normal to observe a longer delay time if a signal is right at the detection threshold. The noise can push the delay count to be counting up and down, resulting a longer time for the delay counter to reach its final accumulated trigger target.

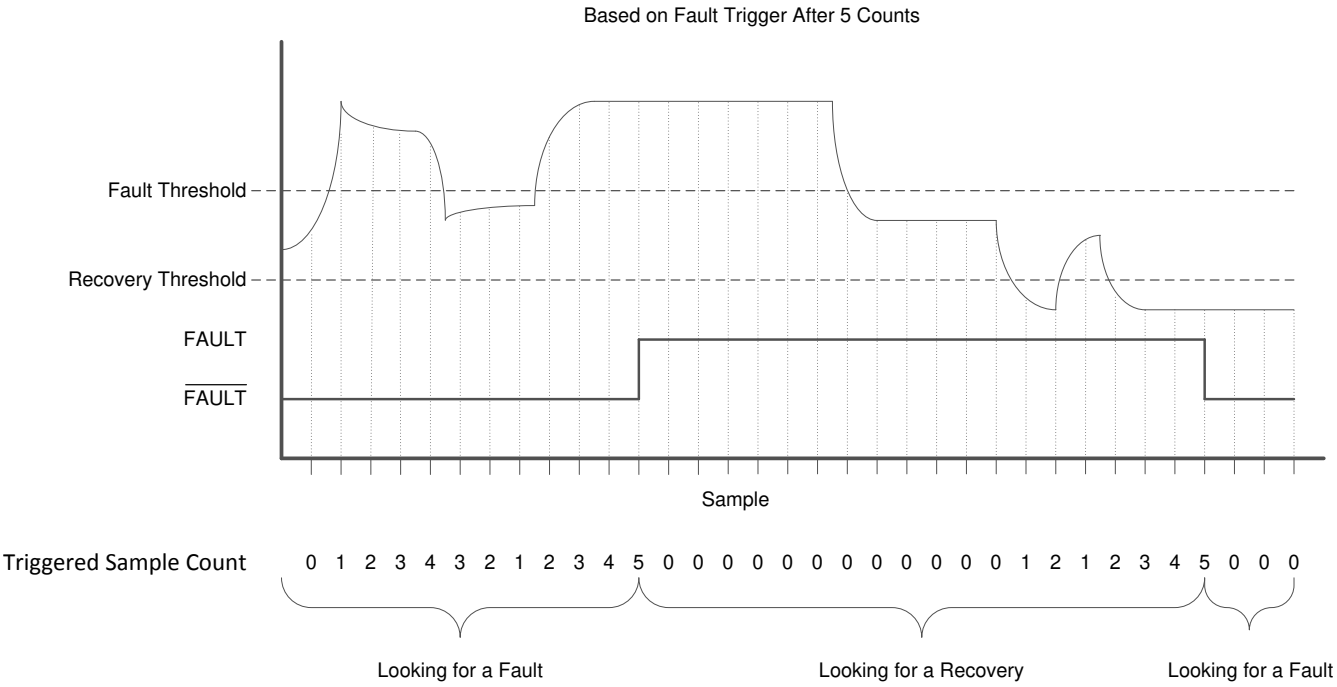


Figure 8-4. Fault Trigger Filtering

8.3.6 State Comparator

A small, low-offset analog state comparator monitors the sense-resistor voltage (SRP-SRN) to determine when the pack is in a DISCHARGE state less than a minimum threshold, V_{STATE_D} or a CHARGE state greater than a maximum threshold, V_{STATE_C}. The state comparator is used to turn the CHG FET on to prevent damage or overheating during discharge in fault states that call for having only the CHG FET off, and vice versa for the DSG FET during charging in fault states that call for having only the DSG FET off.

Table 8-4 summarizes when the state comparator is operational. The state comparator is only on during faults detected that call for only one FET driver to be turned off.

Table 8-4. State Comparator Operation Summary

STATE COMP	CHG	DSG	MODE
OFF	ON	ON	Normal
V_{STATE_C} Detection	ON	OFF	UV, CTRD
V_{STATE_D} Detection	OFF	ON	OV, UTC, OTC, CTRC
OFF	OFF	OFF	OCD1, OCD2, SCD, UTD, OTD, OW

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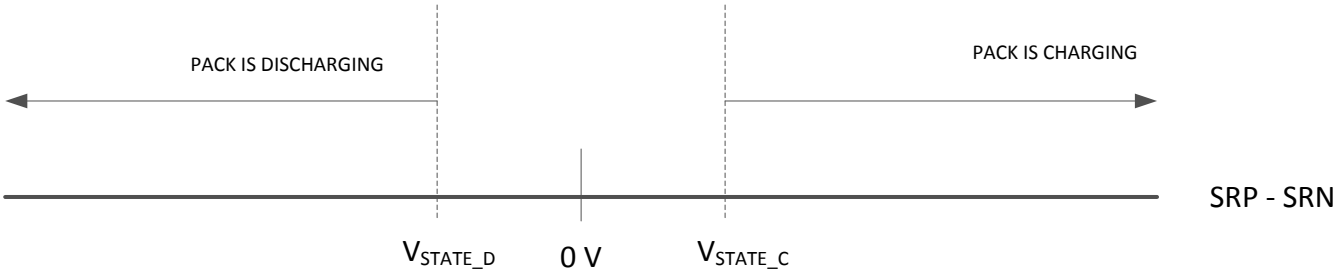


Figure 8-5. State Comparator Thresholds

8.3.7 DSG FET Driver Operation

The DSG pin is driven high only when no related faults (UV, OW, OTD, UTD, OCD1, OCD2, SCD, and CTRD are disabled) are present. It is a fast switching driver with a target on resistance of about 15–20 Ω and an off resistance of R_{DSGOFF}. It is designed to allow users to select the optimized R_{GS} value to archive the desirable FET rise and fall time per the application requirement and the choice of FET characteristics. When the DSG FET is turned off, the DSG pin drives low and all overcurrent protections (OCD1, OCD2, SCD) are disabled to better conserve power. These resume operation when the DSF FET is turned on. The device provides FET body diode protection through the state comparator if one FET driver is on and the other FET driver is off.

The DSG driver may be turned on to prevent FET damage if the battery pack is charging while a discharge inhibit fault condition is present. This is done with the state comparator. The state comparator (with the V_{STATE_C} threshold) remains on for the entire duration of a DSG fault with no CHG fault event.

- If (SRP-SRN) ≤ V_{STATE_C} and no charge event is detected, the DSG FET output will remain OFF due to the present of a DSG fault.
- If (SRP-SRN) > V_{STATE_C} and a charge event is detected, the DSG FET output will turn ON for body diode protection.

See the *Section 8.3.6* section for details.

The presence of any related faults, as shown in Figure 8-6, results in the DSGFET_OFF signal .

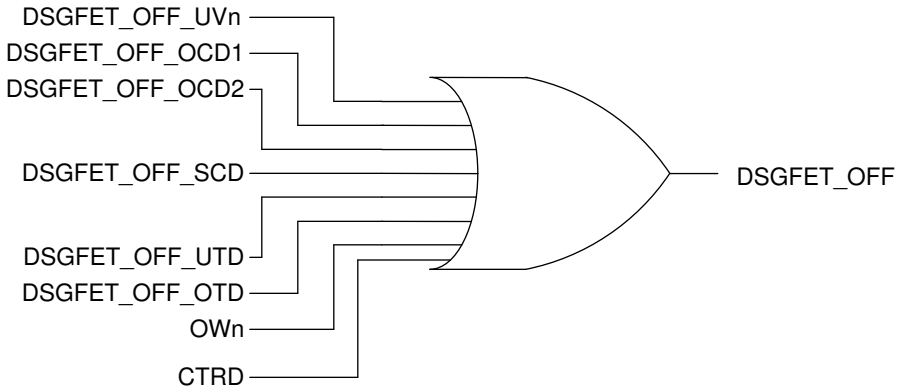


Figure 8-6. Faults that Can Qualify DSGFET_OFF

8.3.8 CHG FET Driver Operation

The CHG and CHGU pins are driven high only when no related faults (OV, OW, OTC, UTC, OTD, UTD, OCD1, OCD2, SCD, and CTRC are disabled) are present or the pack has a discharge current where (SRP-SRN) < V_{STATE_D1} . The CHG pin drives the CHG FET, which is for use on the single device configuration or by the bottom device in a stack configuration. The CHGU pin has the same logic state as the CHG pin and is for use in the upper device (in a multi-stack configuration) to provide the drive signal to the CTRC pin of the lower device. The CHGU pin should never connect to the CHG FET directly.

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Turning off the CHG pin has no influence on the overcurrent protection circuitry. The CHG pin is designed to switch on quickly and the target on resistance is about 2 kΩ. When the pin is turned off, the CHG driver pin is actively driven low and will fall together with PACK–.

The CHG FET may be turned on to protect the FET's body diode if the pack is discharging, even if a charging inhibit fault condition is present. This is done through the state comparator. The state comparator (with the V_{STATE_D} threshold) remains on for the entire duration of a DSG fault with no CHG fault event.

- If (SRP-SRN) > V_{STATE_D} and no discharge event is detected, the CHG FET output will remain OFF due to the present of a CHG fault.
- If (SRP-SRN) ≤ V_{STATE_D} and a charge event is detected, the CHG FET output will turn ON for body diode protection.

The CHGFET_OFF signal is a result of the presence of any related faults, as shown in Figure 8-7.

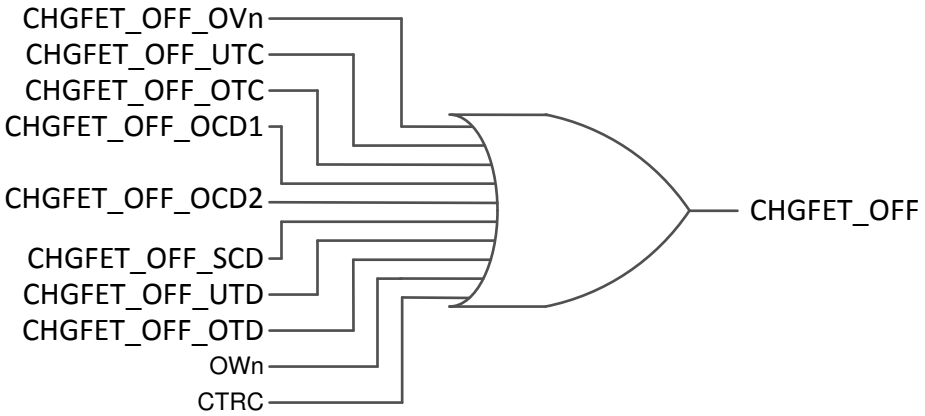


Figure 8-7. Faults That Can Qualify CHGFET OFF

8.3.9 External Override of CHG and DSG Drivers

The device allows direct disabling of the CHG and DSG drivers through the CTRC and CTRD pins, respectively. The operation of the CTRC and CTRD pins is shown in Figure 8-8. To support the simple-stack solution for higher-cell count packs, these pins are designed to operate above the device's VDD level. Simply connect a 10-MΩ resistor between a lower device CTRC and CTRD input pins to an upper device CHGU and DSG output pins (see the schematics in *Section 8.3.11*.

CTRC only enables or disables the CHG pin, while CTRD only enables or disables the DSG pin. When the CTRx pin is in the DISABLED region, the respective FET pin will be off, regardless of the state of the protection circuitry. When the CTRx pin is in either ENABLED region, the protection circuitry determines the state of the FET driver.

Both CTRx pins apply the fault-detection filtered method to improve the robustness of the signal detection: The counter counts up if an ENABLED signal is sampled; the counter counts down if a DISABLED signal is sampled. When the counter counts up from 0% to > 70% of its full range, which takes about 7 ms typical of a solid signal, the CTRx pins take the signal as ENABLED. If the counter counts down from 100% to < 30%, of its full range, which takes about 7 ms typical of a solid signal, the CTRx pins take the signal as DISABLED. From a 0 count counter (solid DISABLE), a solid ENABLE signal takes about t_{CTRDEG_ON} time to deglitch. From a 100% count (solid ENABLE), a solid DISABLE signal takes about t_{CTRDEG_OFF} time to deglitch. Although such a filter scheme provides a certain level of noise tolerance, it is highly recommended to shield the CTRx traces and keep the traces as short as possible in the PCB layout design. The CTRx deglitch time will add onto the FET response timing on the OV, UV, and OW faults in a stack configuration. The t_{CTRDEG_OFF} time adds an additional delay to the fault detection timing and the t_{CTRDEG_ON} time adds an additional delay to the fault recovery timing.

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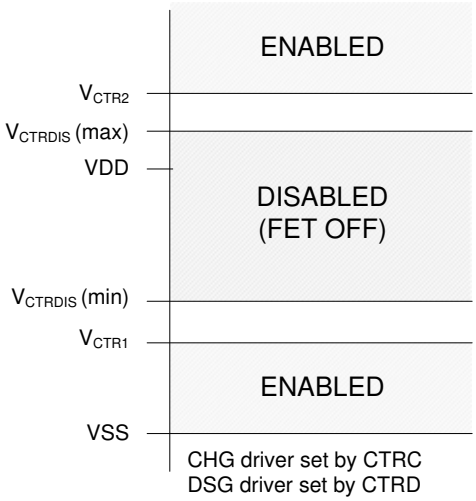


Figure 8-8. External Override of CHG and DSG Drivers

8.3.10 Configuring 3-S, 4-S, or 5-S Mode

The BQ77904 supports 3-S and 4-S packs, while the BQ77905 supports 3-S, 4-S, and 5-S packs. To avoid accidentally detecting a UV fault on unused (shorted) cell inputs, the device must be configured for the specific cell count of the pack. This is set with the configuration pin, CCFG, which is mapped as in Table 8-5. The device periodically checks the CCFG status and takes t_{CCFG_DEG} time to detect the pin status.

Table 8-5. CCFG Configurations

CCFG	CONFIGURATION	CONNECT TO
< V_{CCFGL} for t_{CCFG_DEG}	3 cells	AVSS
Within V_{CCFGM} for t_{CCFG_DEG}	4 cells	AVDD
> V_{CCFGH} for t_{CCFG_DEG}	5 cells	Floating

The CCFG pin should be tied to the recommended net from Table 8-5. The device compares the CCFG input voltage to the AVDD voltage and should never be set above the AVDD voltage. When the device configuration is for 5 S, leave the CCFG pin floating. The internal pin bias is approximately 30% of the AVDD voltage for the 5-S configuration. Note that the BQ77904 should not be configured in 5-S mode, as this results in a permanent UV fault.

8.3.11 Stacking Implementations

Higher than 5-S cell packs may be supported by daisy-chaining multiple devices. Each device ensures OV, UV, OTC, OTD, UTC, and UTD protections of its directly monitored cells, while any fault conditions automatically disable the global CHG and/or DSG FET driver. Note that upper devices do not provide OCD1, OCD2, or SCD protections, as these are based on pack current. For the BQ77904 and BQ77905 devices used on the upper stack, the SRP and SRN pins should be shorted to prevent false detection.

Table 8-6. Stacking Implementation Configurations

CONFIGURATION	CHG PIN	CHGU PIN
Bottom or single device	Connect to CHG FET	Leave unconnected
Upper stack	Leave unconnected	Connect to CTRC of the lower device

To configure higher-cell packs, follow this procedure:

- Each device must have a connection on at least three lowest-cell input pins.
- TI recommends to connect a higher-cell count to the upper devices (for example, for a 7-S configuration, connect four cells on the upper device and three cells on the bottom device). This provides a stronger CRTx signal to the bottom device.

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- Ensure that each device's CCFG pin is configured appropriately for its specific number of cells (three, four, or five cells).
- For the bottom device, the CHG pin should be used to drive the CHG FET and leave the CHGU pin unconnected. For the upper device, the CHGU pin should be used to connect to lower device's CTRC pin with a R_{CTRx} and leave the CHG pin unconnected.
- Connect the upper DSG pins with a R_{CTRx} to the immediate lower device CTRD pin.
- All upper devices should have the SRP and SRN to its AVSS pin.
- If load removal is not used for UV recovery, connect the upper device LD pin to its AVSS pin, as shown in Figure 8-9 and Figure 8-10. Otherwise, refer to Figure 9-7 for proper LD connection.

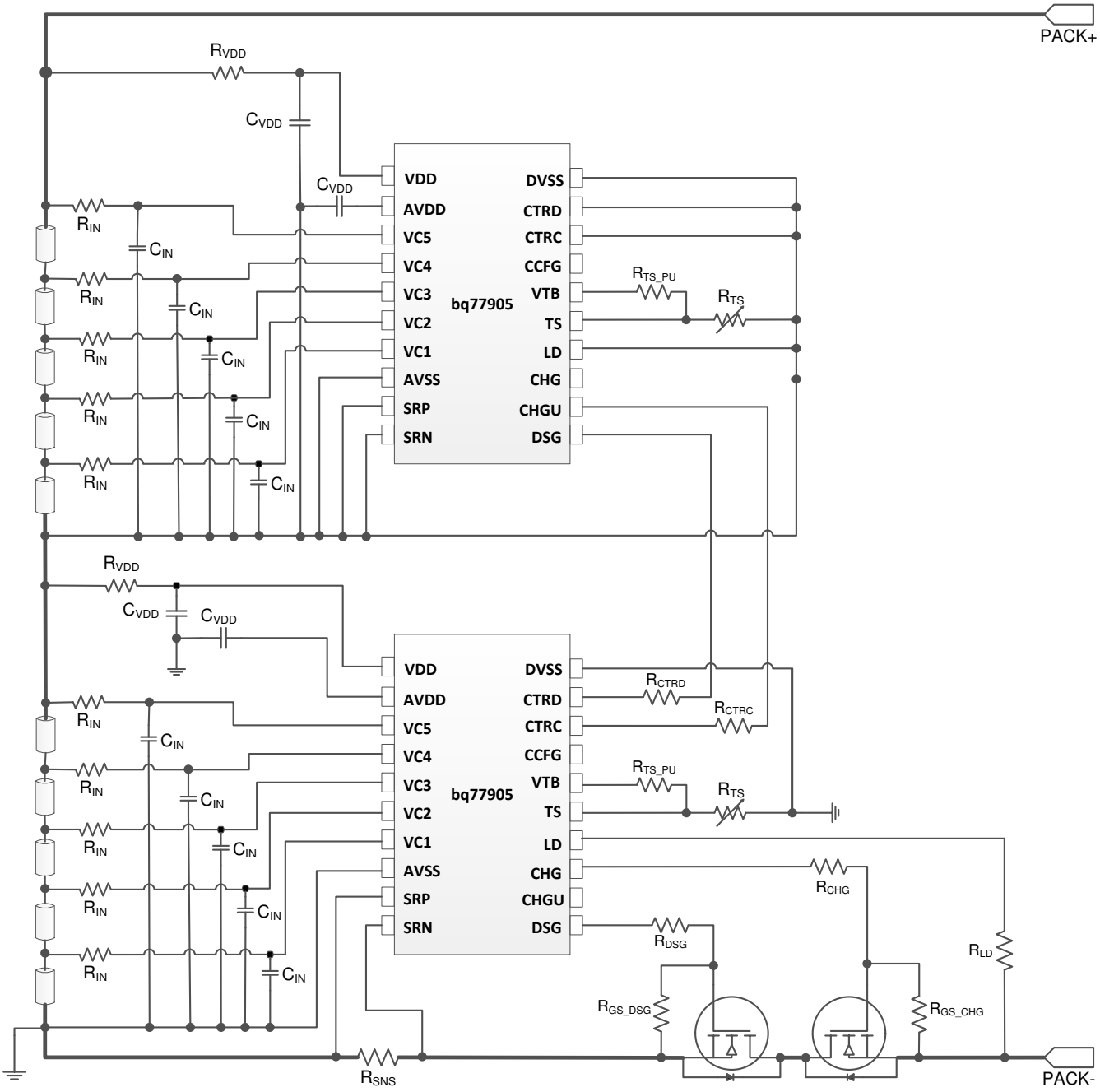


Figure 8-9. 10S Pack Using Two BQ77905 Devices

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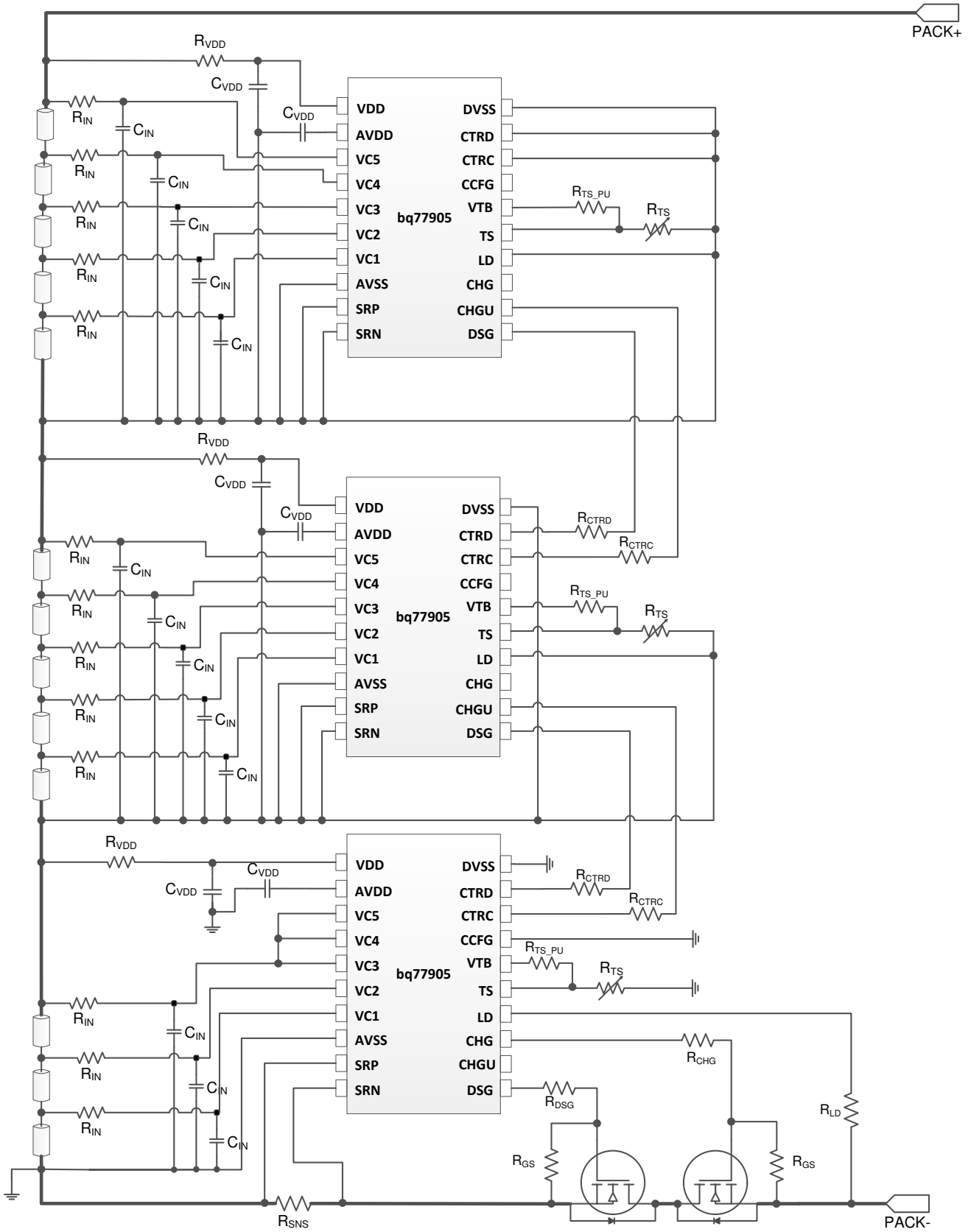


Figure 8-10. 13S Pack Using Three BQ77905 Devices

8.3.12 Zero-Volt Battery Charging Inhibition

Once the device is powered up, it can pull the CHG pin up if the VDD ≥ V_{SHUT}, which varies from about 1 V per cell on a 3-S configuration to about 0.6 V per cell on a 5-S configuration. If the battery stack voltage falls below V_{SHUT}, the device is in SHUTDOWN mode and the CHG driver is no longer active and charging is not allowed unless VDD rises above V_{POR} again.

8.4 Device Functional Modes

8.4.1 Power Modes

8.4.1.1 Power-On Reset (POR)

The device powers up when VDD ≥ V_{POR}. At POR, the following events occur:

- A typical 5-ms hold-off delay applies to both CHG and DSG drivers, keeping both drivers in the OFF state. This provides time for the internal LDO voltage to ramp up.
- CTRC and CTRD deglitch occurs. During the deglitch time, the CHG and DSG driver remains off. Note that deglitch time masks out the 5-ms hold-off delay.
- The device assumes OV fault at POR; thus, the CHG driver is off for OV recovery time if all the cell voltages are < (V_{OV} – V_{HYS_OV}). The OV recovery time starts after the 5-ms hold-off delay. If the device reset occurs when any cell voltage is above the OV hysteresis range, the CHG driver will remain off until an OV recovery condition is met.

8.4.1.2 FAULT Mode

If any configured protection fault is detected, the device enters the FAULT mode. In this mode, the CHG and/or DSG driver can be turned off depending on the fault. Refer to the fault response summary, Section 8.4.1.2, for detail. When one of the FET drivers (either CHG or DSG) is turned off, while the other FET driver is still on, the state comparator is activated for FET body diode protection.

8.4.1.3 SHUTDOWN Mode

This is the lowest power consumption state of the device when VDD falls below V_{SHUT}. In this mode, all fault detections and theCHG and DSG drivers are disabled. The device will wake up and enter NORMAL mode when VDD rises above V_{POR}.

8.4.1.4 Customer Fast Production Test Modes

The BQ7790x device supports the ability to greatly reduce production test time by cutting down on protection fault delay times. To shorten fault times, place the BQ7790x device into Customer Test Mode (CTM). CTM is triggered by raising VDD to V_{CTM} voltage above the highest cell input pin (that is, VC5) for t_{CTM_ENTRY} time.

The CTM is expected to be used in single-chip designs only. CTM is not supported for stacked designs. Once the device is in CTM, all fault delay and non-current fault's recovery delay times reduce to a value of t_{CTM_DELAY}. The fault recovery time for overcurrent faults (OCD1, OCD2, and SCD) is reduced to $t_{CTM_OC_REC}$.

Verification of protection fault functionality can be accomplished in a reduced time frame in CTM. Reducing the VDD voltage to the same voltage applied to the highest-cell input pin for t_{CTM_ENTRY} will exit CTM.

In CTM, with reduced time for all internal delays, qualification of all faults will be reduced to a single instance. Thus in this mode, fault condition qualification is more susceptible to transients, so take care to have fault conditions clearly and cleanly applied during test mode to avoid false triggering of fault conditions during CTM.

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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

The BQ77904 and BQ77905 devices are low-power stackable battery pack protectors with an integrated low-side NMOS FET driver. The BQ77904 and BQ77905 devices provide voltage, current, temperature, and open-wire protections. All the devices protect and recover without MCU control. The following section highlights several recommended implementation when using these devices.

9.1.1 Recommended System Implementation

9.1.1.1 CHG and DSG FET Rise and Fall Time

The CHG and DSG FET drivers are designed to have fast switching time. Users should select a proper gate resistor (R_{CHG} and R_{DSG} in the reference schematic) to set to the desired rise/fall time.

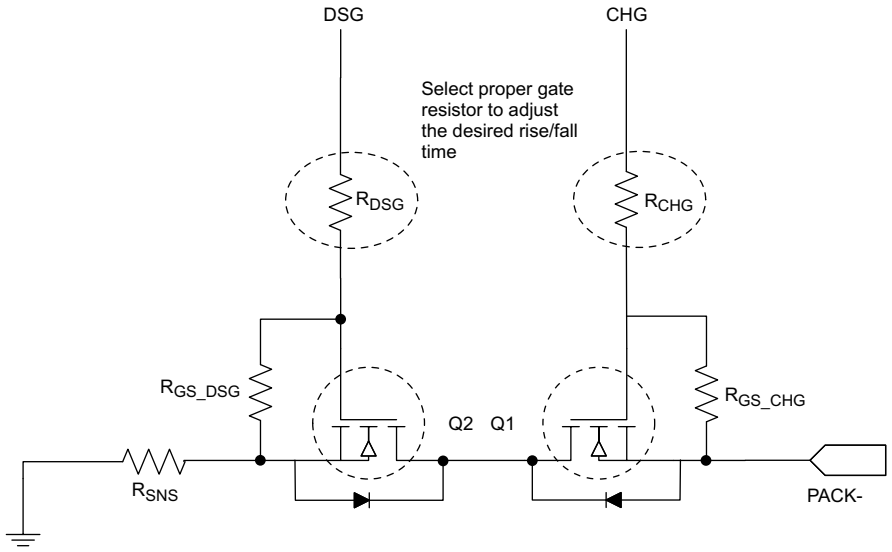


Figure 9-1. Select Proper Gate Resistor for FET Rise and Fall Time

The CHG FET fall time is generally slower, because it is connected to the PACK– terminal. The CHG driver will pull to V_{SS} quickly when the driver is signaled to turn off. Once the gate of the CHG FET reaches ground or Vgsth, the PACK– will start to fall below ground and the CHG signal will follow suit in order to turn off the CHG FET. This portion of the fall time is strongly dependent on the FET characteristic, the number of FETs in parallel, and the value of gate-source resistor (R_{GS_CHG}).

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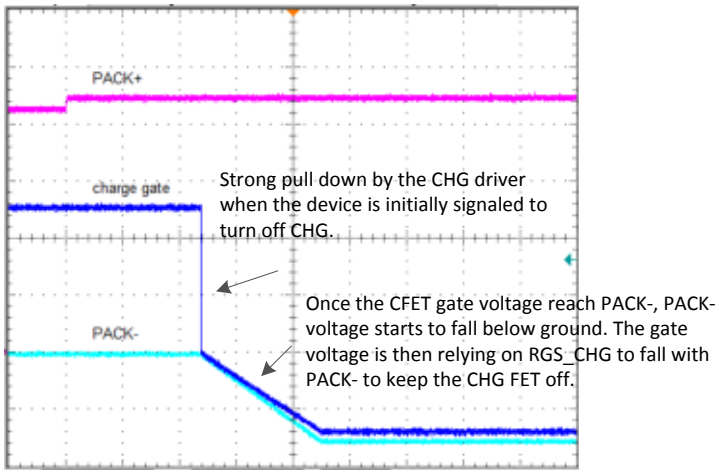


Figure 9-2. CHG FET Fall Time

9.1.1.2 Protecting CHG and LD

Because both CHG and LD are connected to the PACK– terminal, these pins are specially designed to sustain an absolute max of –30 V. However, the device can be used in a wide variety of applications, and it is possible to expose the pins lower than –30 V absolute max rating.

To protect the pins, TI recommends to put a PMOS FET in series of the CHG pin and a diode in series of the LD pin as shown below.

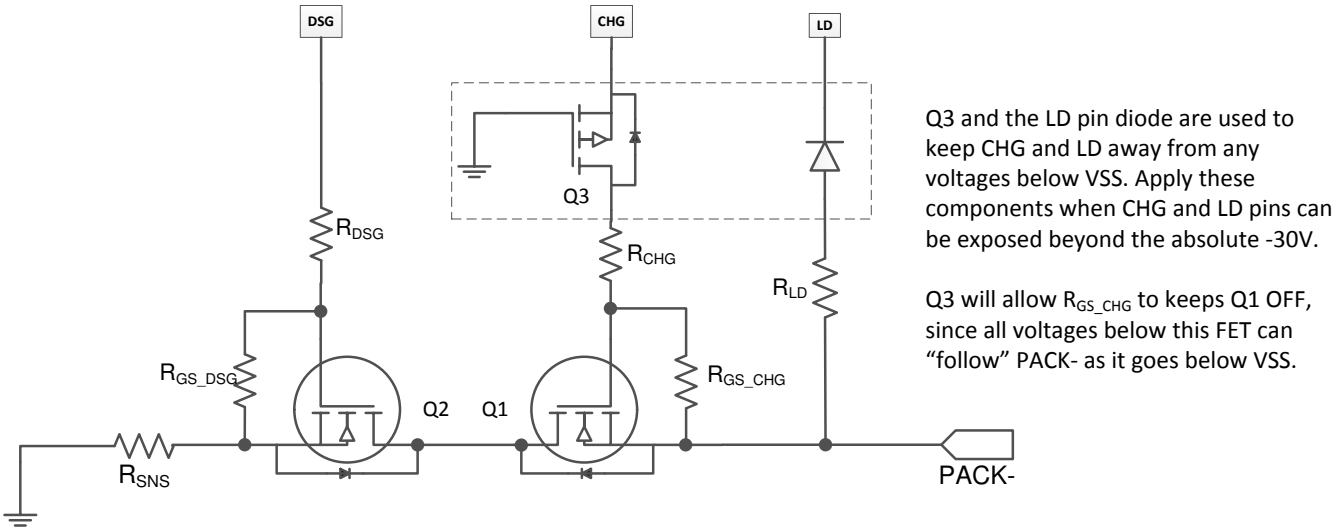


Figure 9-3. Protecting CHG and LD

9.1.1.3 Protecting CHG FET

When the CHG driver is off, CHG is pulled to V_{SS}, the PACK– terminal can be pullup to the PACK+ level when a load is connected. This can put the gate-source voltage above the absolute max of the MOSFET rating. Hence, it is common to place a Zener diode across the CHG FET's gate-source to protect the CHG FET. Additional components are added when a Zener is used to limit current going into the CHG pin, as well as reducing the impact on rise time. See Figure 9-4 for details.

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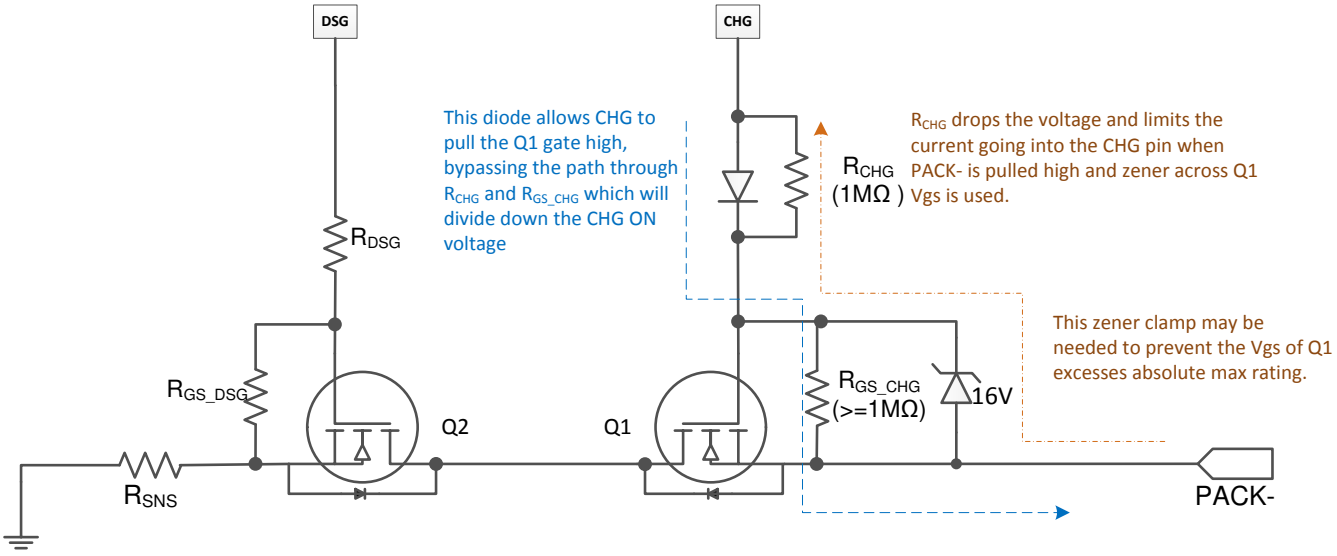


Figure 9-4. Protect CHG FET from a High Voltage on PACK–

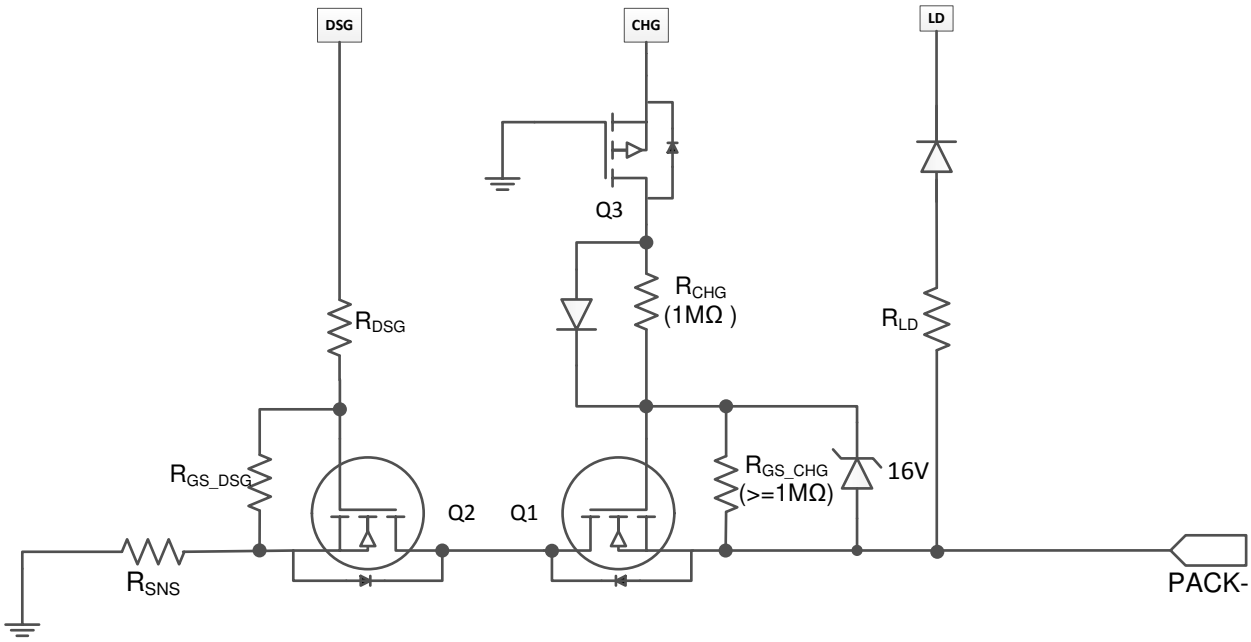


Figure 9-5. Optional Components Combining Protecting CHG and LD and Protecting CHG FET Protections

9.1.1.4 Using Load Detect for UV Fault Recovery

A larger CHG FET gate-source resistor is required if load removal is enabled as part of the UV recovery criteria. When the load removal circuit is enabled, the device is internally connected to Vss. Because in a UV fault the CHG driver remains on, it creates a resistor divider path to the load detect circuit.

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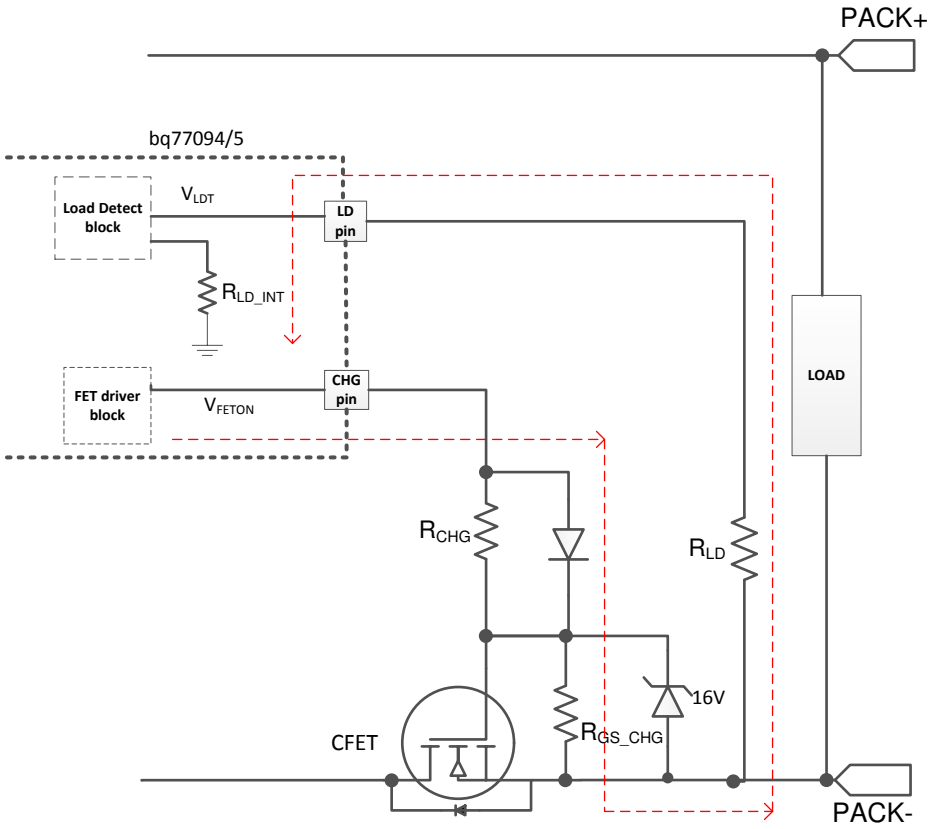


Figure 9-6. Load Detect Circuit During UV Fault

To ensure load removal is detected properly during a UV fault, TI recommends to use 3.3 MΩ for R_{GS_CHG} (instead of a typical of 1 MΩ when load removal is NOT required for UV recovery). R_{CHG} can stay in 1 MΩ as recommended when using CHG FET protection components. The CHG FET rise time impact is minimized as described in the *Protecting CHG FET* section. On a stacked configuration, connect the LD pin, as shown in Figure 9-7 if load removal is used for a UV fault recovery. If load detection is not required for a UV fault recovery, a larger value of R_{GS_CHG} can be used (that is, 10 MΩ) and the LD pin on the upper devices can be left floating.

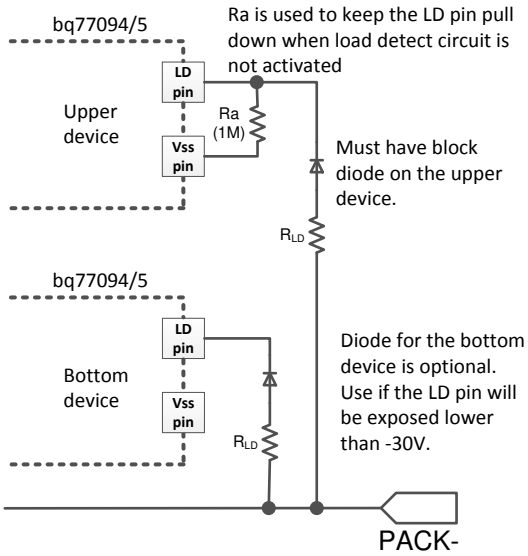


Figure 9-7. Simplified Circuit: LD Connection on Upper Device When Using for UV Fault Recovery

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9.1.1.5 Temperature Protection

The device detects temperature by checking the voltage divided by R_{TS_PU} and R_{TS}, with the assumption of using 10-KΩ R_{TS_PU} and 103AT NTC for R_{TS}. System designers should always check the thermistor resistance characteristics and refer to the temperature protection threshold specifications in the Electrical Characteristics table to determine if a different pullup resistor should be used. If a different temperature trip point is required, it is possible to scale the threshold using this equation: Temperature Protection Threshold = R_{TS} / (R_{TS} + R_{TS_PU}).

Example: Scale OTC trip points from 50°C to 55°C

The OTC protection can be set to 45°C or 50°C. When the device's OTC threshold is set to 50°C, it is referred to configure the V_{OTC} parameter to 29.38% of VTB (typical), with the assumption of R_{TS_PU} = 10 KΩ and R_{TS} = 103AT or similar NTC (which the NTC resistance at 50°C = 4.16 KΩ). The V_{OTC} specification is the resistor divider ratio of R_{TS_PU} and R_{TS}.

The V_{OTC}, V_{OTD}, V_{UTC}, and V_{UTD} configuration options are fixed in the device; thus, the actual temperature trip point can only adjust by using a different B-value NTC and/or using a different R_{TS_PU}.

In this example, the 103AT NTC resistance at 55°C is 3.536 KΩ. By changing the R_{TS_PU} from 10 KΩ to 8.5 KΩ, users can scale the actual OTC temperature trip point from 50°C to 55°C. Because the R_{TS_PU} value is smaller, this change affects all the other temperature trip points and scales OTD, UTC, and UTD to ~5°C higher as well.

9.1.1.6 Adding Filter to Sense Resistor

Current fault is sense through voltage across a sense resistor. Optional RC filters can be added to the sense resistor to improve stability.

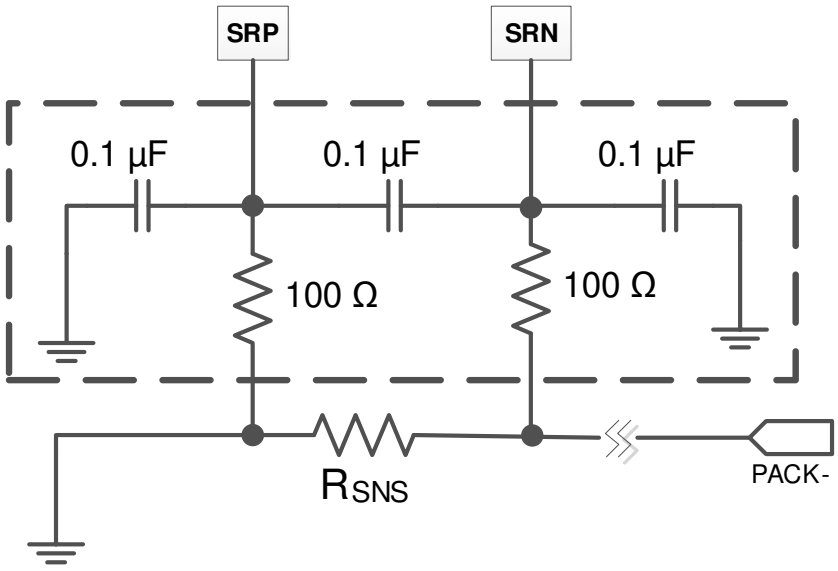


Figure 9-8. Optional Filters Improve Current Measurement

9.1.1.7 Using a State Comparator in an Application

The state comparator does not have built-in hysteresis. It is normal to observe the FET body diode protection toggling on and off with the V_{STATE_C1} or V_{STATE_D1} accuracy range. In a typical application, the sense resistor is selected according to the application current, which usually is not close to the state comparator threshold.

9.1.1.7.1 Examples

As an example, using a 5-Ah battery, with 1C-rate (5 A) charge and 2C-rate (10 A) discharge, the sense resistor is 3 mΩ or less. The typical current to turn on the FET body diode protection is 667 mA using this example. Because there is no built-in hysteresis, noise can reset the state comparator counter and toggle off the FET body diode protection and vice versa; thus, it is normal to observe the device toggles the FET body diode protection on or off within a 1-mV to 3-mV range. With a 3-mΩ sense resistor, it is about 330 mA to 1 A. As this

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behavior is due to noise from the system, the FET toggling behavior usually occurs right at the typical 2-mV state comparator threshold. As current increases or decreases from the typical value, the detection is more solid and has less frequent FET toggling. Using this example, either charge or discharge should provide a solid FET body diode protection detection.

Look at the device behavior during an OV event (and no other fault is detected). In an OV event, CHG FET is off and DSG FET is on. If a discharge of > –1 A occurs, the device would turn on the CHG FET immediately to allow the full discharge current to pass through. Once the overcharged cell is discharged to the OV recovery level, the OV fault is recovered and the CHG driver turns on (or remains on in this scenario) and the state comparator is turned off.

If the discharge current is < 1 A when the device is still in an OV fault, the CHG FET may toggle on and off until the overcharged cell voltage is reduced down to the OV recovery level. When the OV fault recovers, the CHG FET is solidly turned on and the state comparator is off.

Without the FET body diode protection, if a discharge occurs during an OV fault state, the discharge current can only pass through the CHG FET body diode until the OV fault is recovered. This increases the risk of damaging the CHG FET if the MOSFET is not rated to sustain this amount of current through its body diode. It also increases the FET temperature as current is now carried through the body diode.

9.2 Typical Application

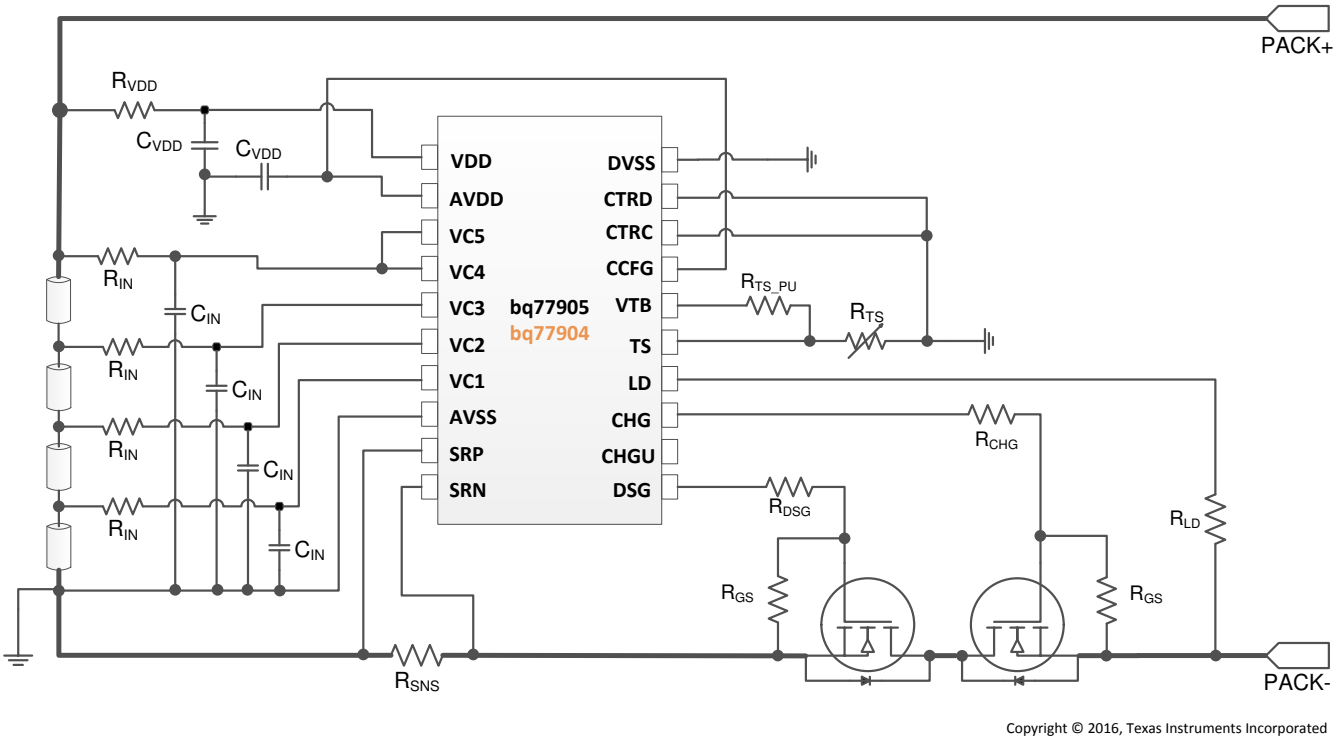


Figure 9-9. BQ77904 and BQ77905 with Four Cells

9.2.1 Design Requirements

For this design example, use the parameters shown in Table 9-1.

Table 9-1. Design Parameters

PARAMETER	DESCRIPTION	VALUES
R_{IN}	Cell voltage sensing (VCx pins) filter resistor	1 kΩ ±5%
C_{IN}	Cell voltage sensing (VCx pins) filter capacitor	0.1 µF ±10%
R_{VDD}	Supply voltage filter resistor	1 kΩ ±5%
C_{VDD}	Supply voltage filter capacitor	1 µF ±20%

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Table 9-1. Design Parameters (continued)

PARAMETER	DESCRIPTION		VALUES
R_{TS}	NTC thermistor		103AT, 10 kΩ ±3%
R_{TS_PU}	Thermistor pullup resistor to VTB pin, assuming using 103AT NTC or NTC with similar resistance-temperature characteristics		10 kΩ ±1%
R_{GS_CHG}	CHG FET gate-source resistor	Load removal is enabled for UV recovery.	3.3 MΩ ±5%
		Load removal is disabled for UV recovery.	1 MΩ ±5%
R_{GS_DSG}	DSG FET gate-source resistor		1 MΩ ±5%
R_{CHG}	CHG gate resistor	System designers should adjust this parameter to meet the desired FET rise/fall time.	1 kΩ ±5%
		If additional components are used to protect the CHG FET and/or to enable load removal detection for UV recovery.	1 MΩ ±5%
R_{DSG}	DSG gate resistor, system designers should adjust this parameter to meet the desired FET rise/fall time.		4.5 kΩ ±5%
R_{CRTC} and R_{CTRD}	CTRC and CTRD current limit resistor		10 MΩ ±5%
R_{LD}	LD resistor for load removal detection		450 KΩ ±5%
R_{SNS}	Current sense resistor for current protection. System designers should change this parameter according to the application current protection requirements.		1 mΩ ±1%

9.2.2 Detailed Design Procedure

The following is the detailed design procedure.

1. Based on the application current, select the proper sense resistor value. The sense resistor should allow detection of the highest current protection, short circuit current.
2. Temperature protection is set with the assumption of using a 103AT NTC (or NTC with similar specification). If a different type of NTC is used, a different R_{TS_PU} may be used for the application. Refer to the actual temperature detection threshold voltage to determine the R_{TS_PU} value.
3. Connect the CCFG pin correctly based on the number of cells in series.
4. Review the Recommended Application Implementation to determine if optional components should be added to the schematic.

9.2.2.1 Design Example

To design the protection for a 36-V Li-ion battery pack using 4.2-V LiCoO2 cells with the following protection requirements:

Voltage Protection
- OV at 4.3 V, recover at 4.1 V
- UV at 2.6 V, recover at 3 V and when load is removed.

Current Protection
- OCD1 at 40 A with 300-ms–400-ms delay
- OCD2 at 80 A with the shortest delay option
- SCD at 100 A with < 500-µs delay
- Requires load removal for recovery

Temperature Protection
- Charge – OTC at 50°C, UTC at –5°C
- Discharge – OTD at 70°C, UTD at –10°C

To start the design:
1. Start the schematic.
   - A 36-V pack using $LiCoO_2$ cells requires 10-S configuration; thus, two BQ77905 devices in a stackable configuration is needed.
   - Follow the 10-S reference schematic in this document. Follow the recommended design parameters listed in the *Section 9.2.1* section of this document.

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- The power FET used in this type of application usually has an absolute of 20 V Vgs. For a 36-V pack design, TI recommends to use the additional components to protect the CHG FET Vgs. See the *Section 9.1.1.4* section for details.
- Because load removal for UV recovery is required, a 3-MΩ R_{GS_CHG} should be used for the schematic.

2. Decide the value of the sense resistor, R_{SNS}.
   - When selecting the value of R_{SNS}, ensure the voltage drop across SRP and SRN is within the available current protection threshold range.
   - In this example, select R_{SNS} = 1 mΩ (any value ≤ 2 mΩ will work in this example).
3. Determine all of the BQ77905 protection configurations (see Table 9-2).
4. Review the available released or preview devices in the *Section 5* section to determine if a suitable option is available. If not, contact TI representative for further assistance.

Table 9-2. Design Example Configuration

Protection	Threshold	Hysteresis	Delay	Recovery Method
OV	4.3 V	200 mV	1 s (default setting)	Hysteresis
UV	2.6 V	400 mV	1 s (default setting)	Hysteresis + load removal
OW	100 nA (default setting)	—	—	(VC_x – VC_{x-1}) > 600 mV (typical)
OCD1	40 mV	—	350 ms	Load removal only
OCD2	80 mV	—	5 ms	Load removal only
SCD	100 mV	—	Fixed at 360 µs	Load removal only
OTC	50°C	10°C	4.5 s	Hysteresis
OTD	70°C	10°C	4.5 s	Hysteresis
UTC	–5°C	10°C	4.5 s	Hysteresis
UTD	–10°C	10°C	4.5 s	Hysteresis

9.2.3 Application Curves

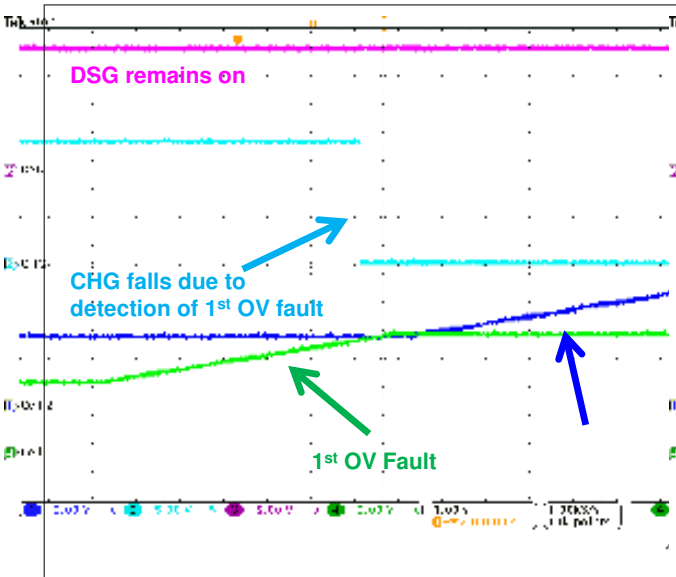


Figure 9-10. OV Fault Protection

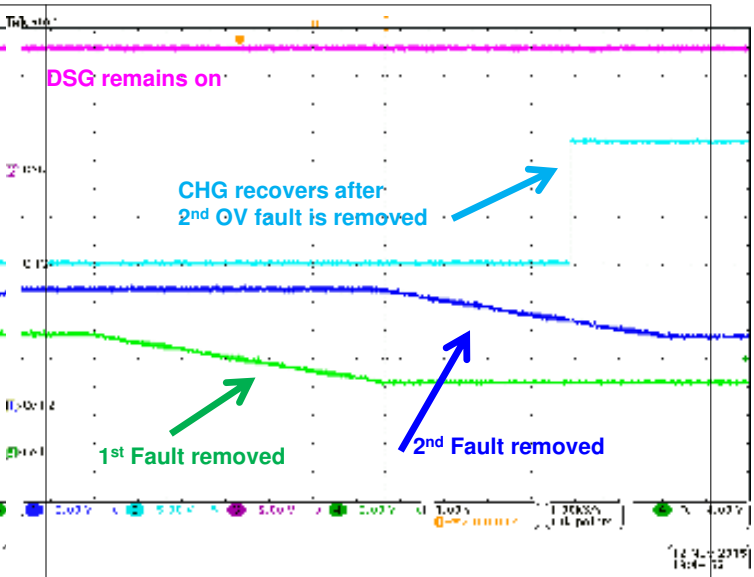


Figure 9-11. OV Fault Recovery

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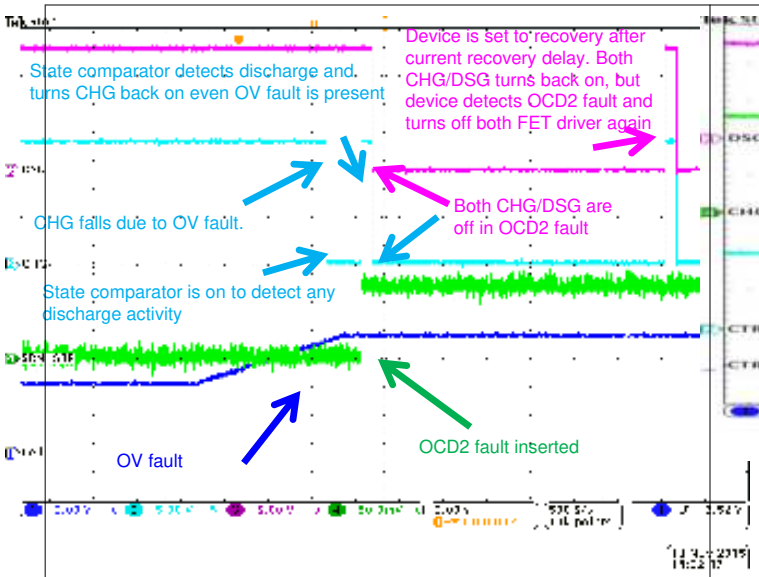


Figure 9-12. OV and OCD2 Faults Protection

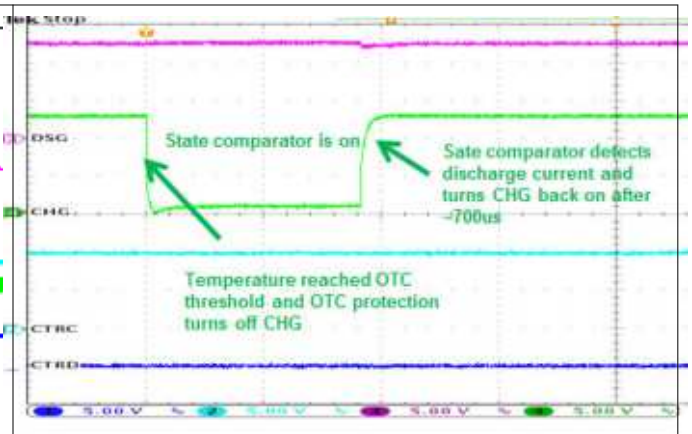


Figure 9-13. Detect OTC Fault While in 30-A Discharge

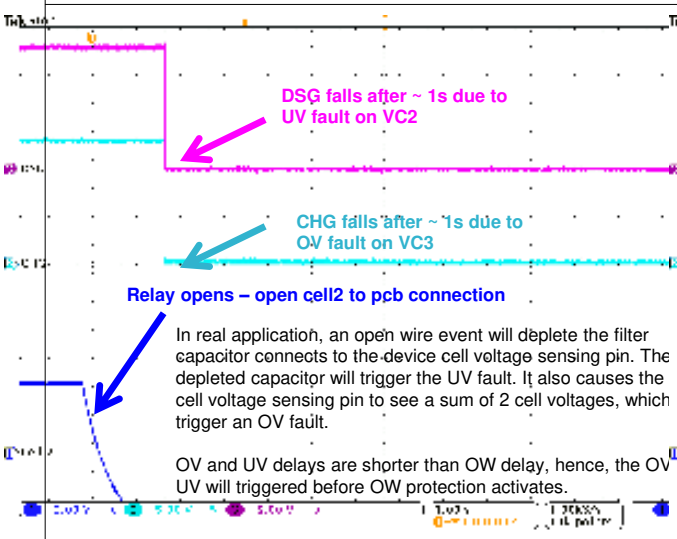


Figure 9-14. OW Fault Protection—Open Cell2 To PCB Connection

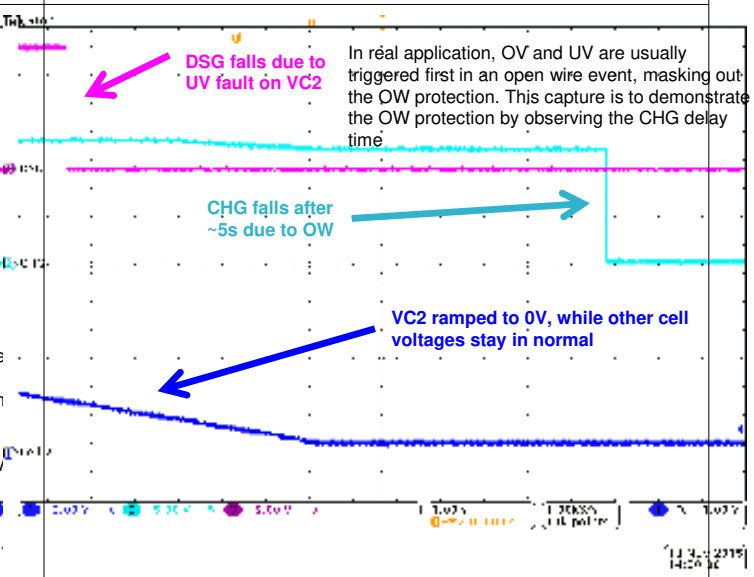


Figure 9-15. OW Fault Protection—Ramping Down Cell2 Voltage

9.3 System Examples

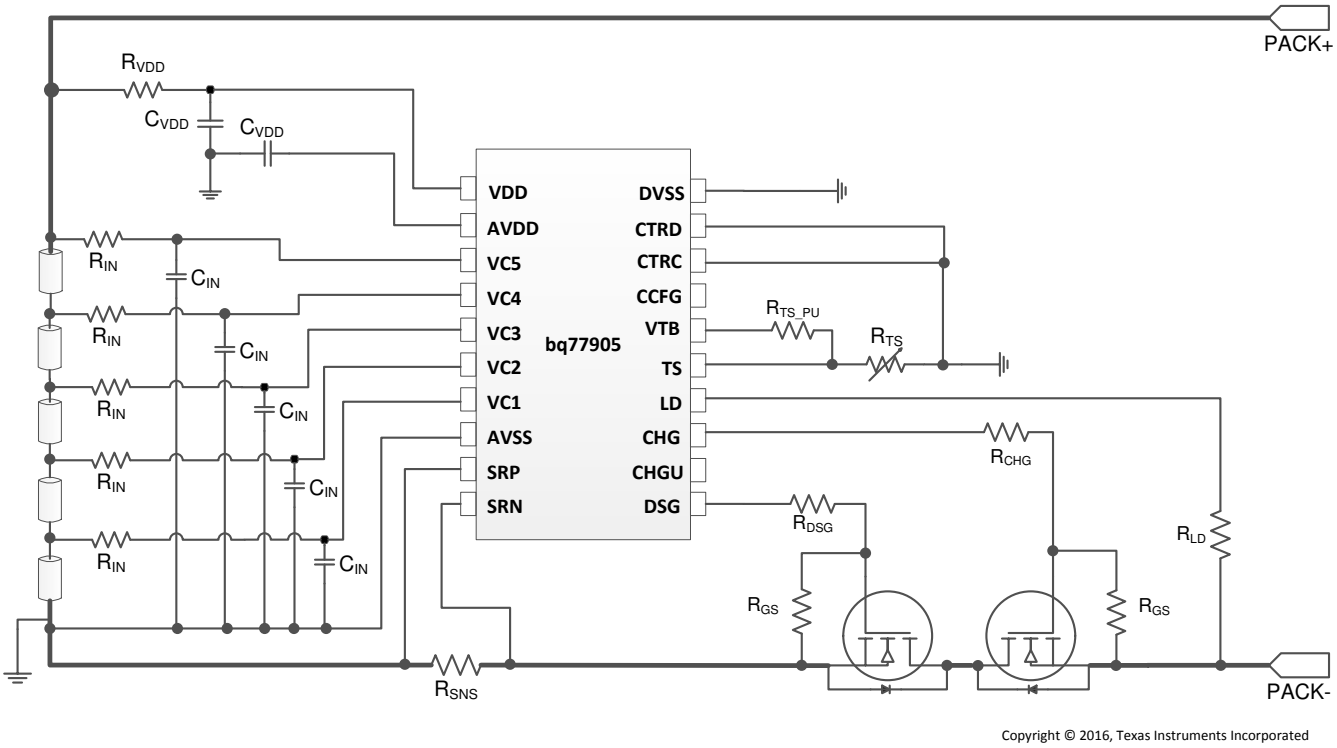


Figure 9-16. BQ77905 with Five Cells

10 Power Supply Recommendations

The recommended cell voltage range is up to 5 V. If three cells in series are connecting to BQ77905, the unused VCx pins should be shorted to the highest unused VCx pin. The recommended VDD range is from 3 V–25 V. This implies the device is still operational when cell voltage is depleted down to approximately 1.5-V range.

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11 Layout

11.1 Layout Guidelines

1. Match SRN and SRP traces.
2. R_{IN} filters, VDD, AVDD filters, and the C_{VDD} capacitor should be placed close to the device pins.
3. Separate the device ground plane (low current ground) from the high current path. Filter capacitors should reference to the low current ground path or device Vss.
4. In a stack configuration, the R_{CTRD} and R_{CTRC} should be placed closer to the lower device CTRD and CTRC pins.
5. R_{GS} should be placed near the FETs.

11.2 Layout Example

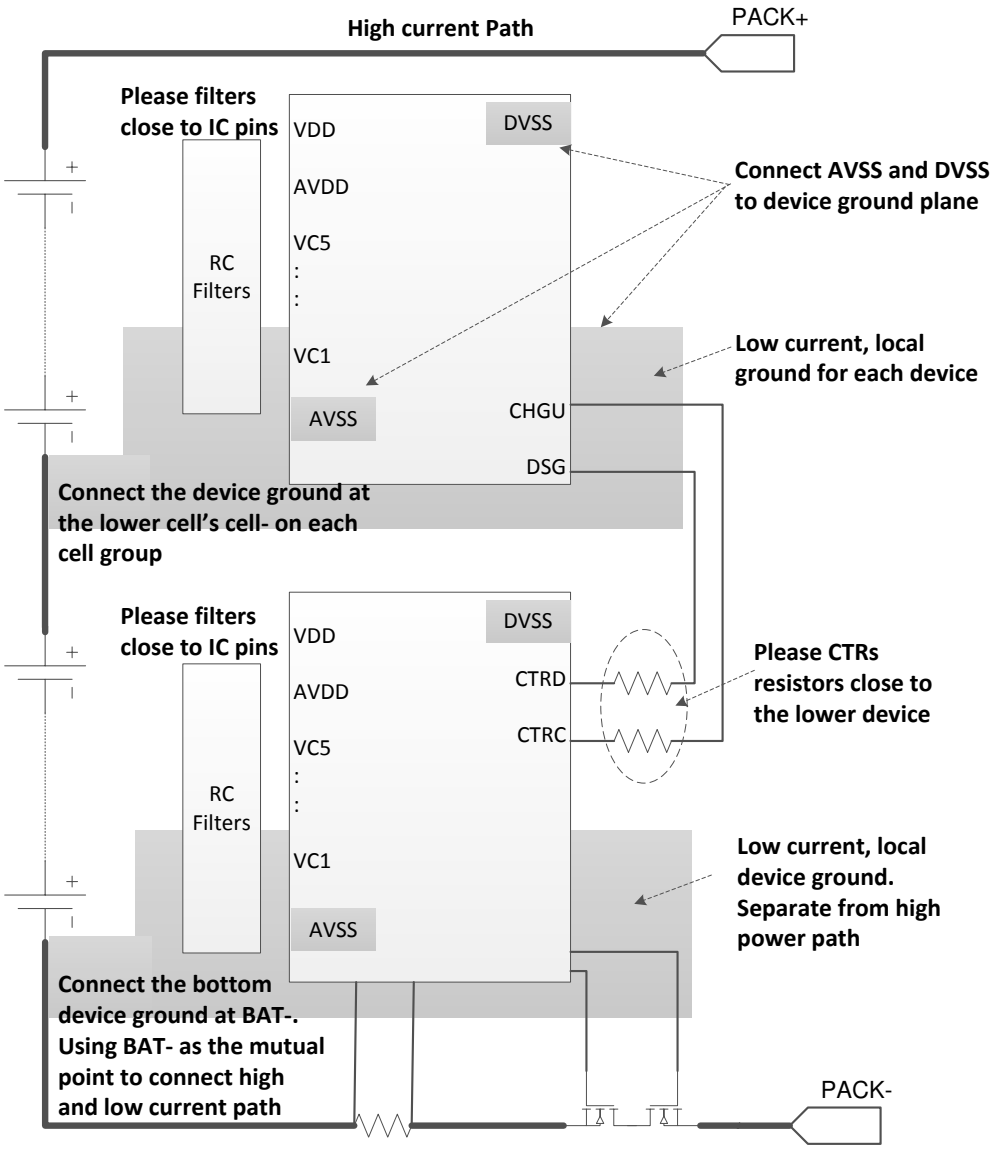


Figure 11-1. Layout Example

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12 Device and Documentation Support

12.1 Documentation Support

12.1.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

Table 12-1. Related Links

PARTS	PRODUCT FOLDER	ORDER NOW	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
BQ77904	Click here	Click here	Click here	Click here	Click here
BQ77905	Click here	Click here	Click here	Click here	Click here

12.2 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.

12.3 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.

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.

12.4 Trademarks

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

12.5 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.

12.6 Glossary

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.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
BQ7790400PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790400
BQ7790400PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790400
BQ7790400PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790400
BQ7790400PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790400
BQ7790500PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790500
BQ7790500PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790500
BQ7790500PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790500
BQ7790500PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790500
BQ7790502PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790502
BQ7790502PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790502
BQ7790502PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790502
BQ7790502PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790502
BQ7790503PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790503
BQ7790503PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790503
BQ7790503PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790503
BQ7790503PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790503
BQ7790505PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790505
BQ7790505PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790505
BQ7790505PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790505
BQ7790505PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790505
BQ7790508PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790508
BQ7790508PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790508
BQ7790508PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790508
BQ7790508PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790508
BQ7790509PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790509
BQ7790509PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790509
BQ7790509PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790509
BQ7790509PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790509
BQ7790511PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790511

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
BQ7790511PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790511
BQ7790511PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790511
BQ7790511PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790511
BQ7790512PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790512
BQ7790512PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790512
BQ7790512PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790512
BQ7790512PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790512
BQ7790518PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790518
BQ7790518PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790518
BQ7790518PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790518
BQ7790518PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790518
BQ7790521PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790521
BQ7790521PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790521
BQ7790521PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790521
BQ7790521PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790521
BQ7790522PW	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790522
BQ7790522PW.A	Active	Production	TSSOP (PW) | 20	70 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790522
BQ7790522PWR	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790522
BQ7790522PWR.A	Active	Production	TSSOP (PW) | 20	2000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B7790522

(1) **Status:** For more details on status, see our product life cycle.

(2) **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.

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

(4) **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.

(5) **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.

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

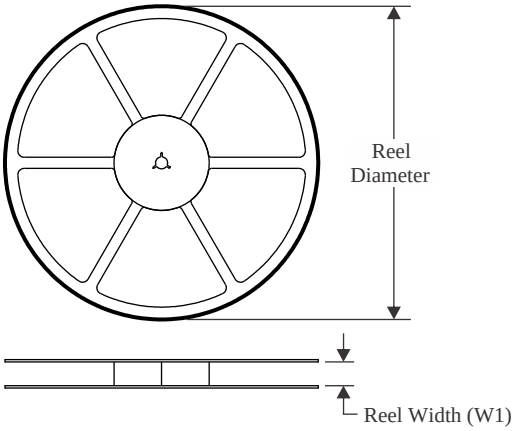
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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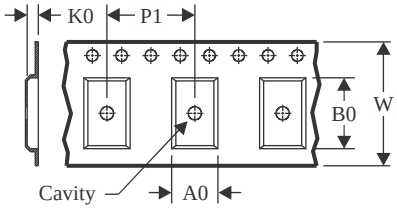
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

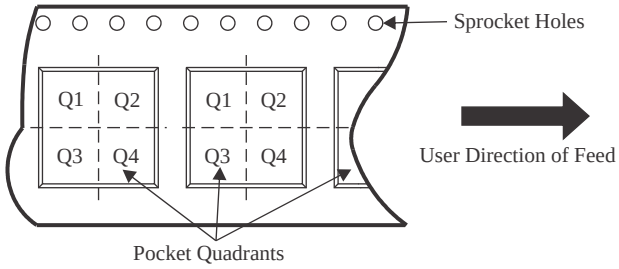


TAPE DIMENSIONS



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

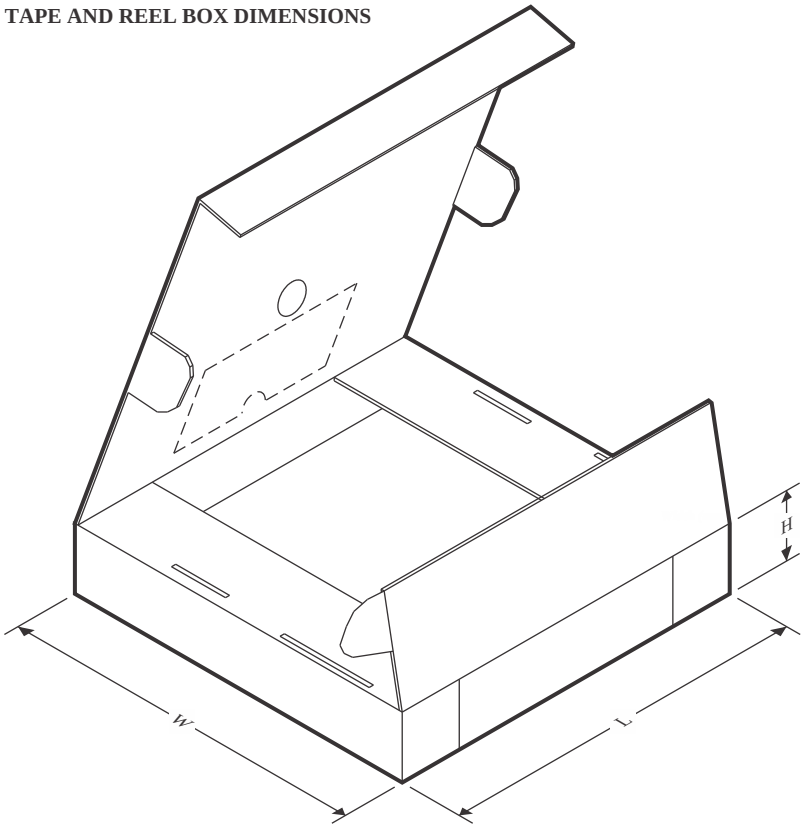
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
BQ7790400PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790500PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790502PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790503PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790505PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790508PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790509PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790511PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790512PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ7790518PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.0	1.4	8.0	16.0	Q1
BQ7790521PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.0	1.4	8.0	16.0	Q1
BQ7790522PWR	TSSOP	PW	20	2000	330.0	16.4	6.95	7.0	1.4	8.0	16.0	Q1

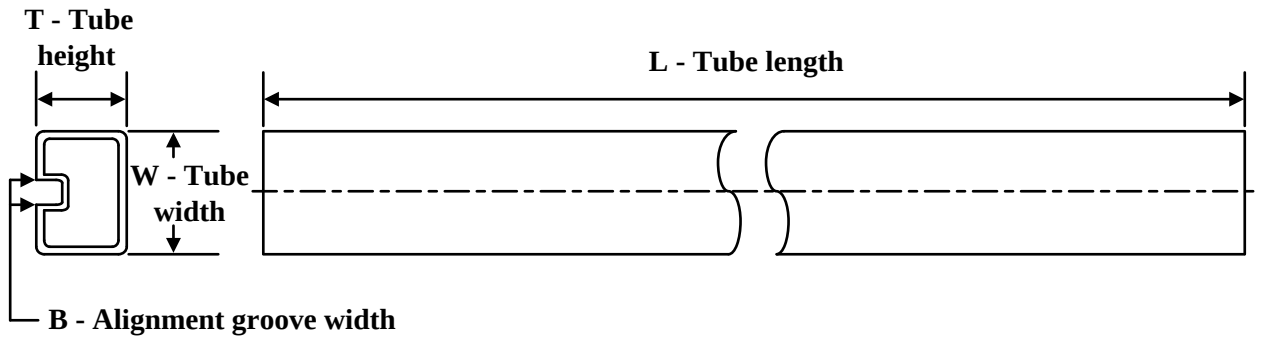
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ7790400PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790500PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790502PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790503PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790505PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790508PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790509PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790511PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790512PWR	TSSOP	PW	20	2000	350.0	350.0	43.0
BQ7790518PWR	TSSOP	PW	20	2000	353.0	353.0	32.0
BQ7790521PWR	TSSOP	PW	20	2000	353.0	353.0	32.0
BQ7790522PWR	TSSOP	PW	20	2000	353.0	353.0	32.0

TUBE



*All dimensions are nominal

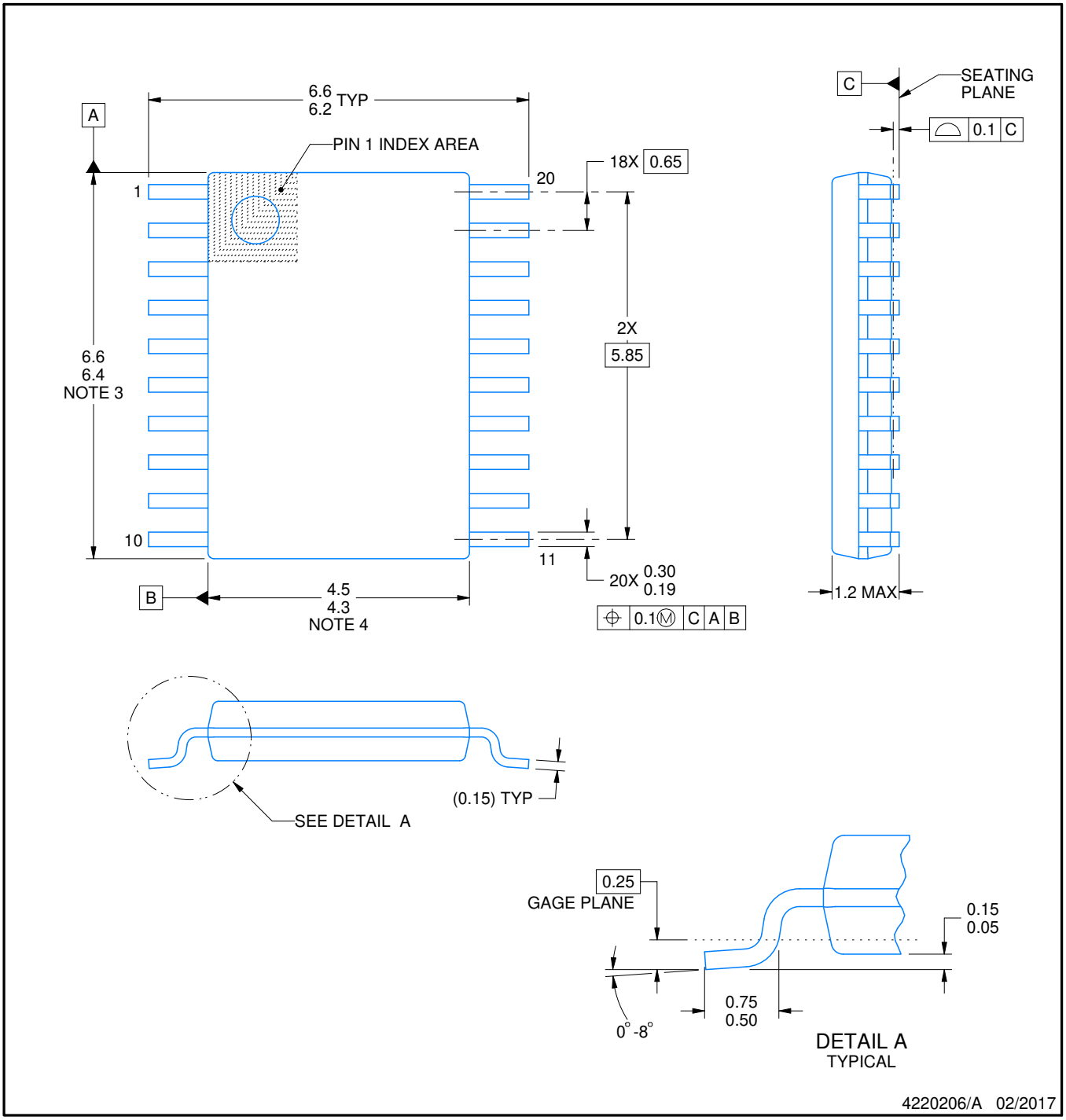
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
BQ7790400PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790400PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790500PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790500PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790502PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790502PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790503PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790503PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790505PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790505PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790508PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790508PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790509PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790509PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790511PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790511PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790512PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790512PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790518PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790518PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790521PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790521PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790522PW	PW	TSSOP	20	70	530	10.2	3600	3.5
BQ7790522PW.A	PW	TSSOP	20	70	530	10.2	3600	3.5

PACKAGE OUTLINE

PW0020A

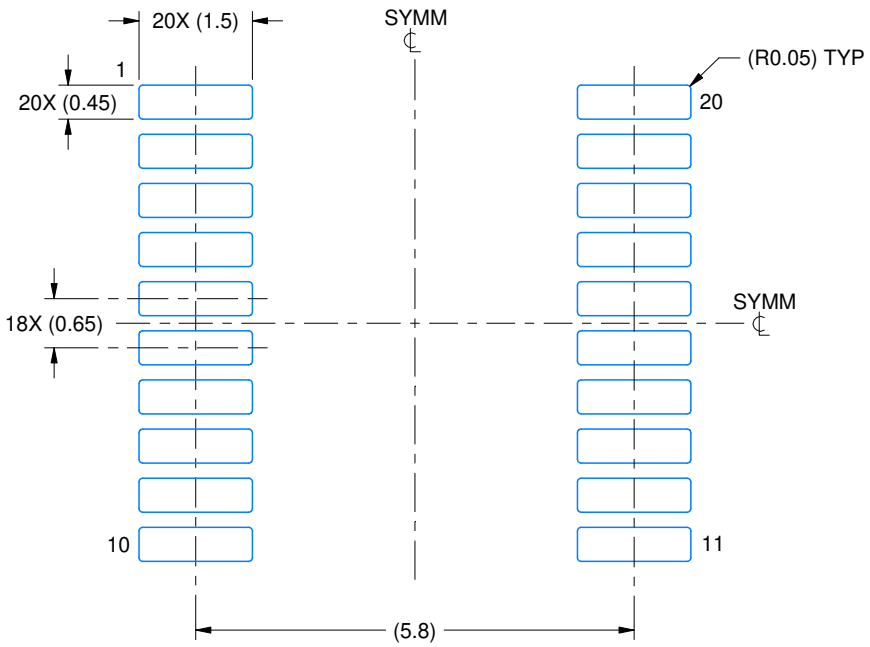
TSSOP - 1.2 mm max height

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

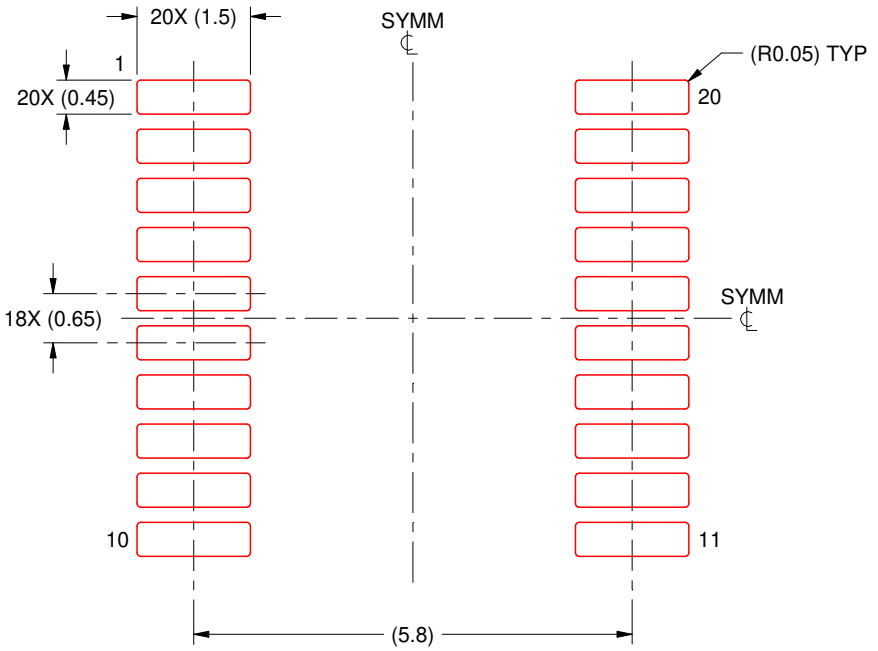


SOLDER MASK DETAILS

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NOTES: (continued)

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



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

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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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