

# BQ77904、BQ77905 3-20 节串联超低功耗电压、电流、温度和断线可堆叠锂离子电池保护器

## 1 特性

- 正常模式：6 $\mu$ A ( bQ77904 和 bQ77905 )
- 整套电压、电流和温度保护功能
- 电池节数可扩展，支持从 3 节串联到 20 节或更多节数串联
- 电压保护 ( 精度为  $\pm 10$ mV )
  - 过压：3V 至 4.575V
  - 欠压：1.2V 至 3V
- 开路电池和断线检测 (OW)
- 电流保护
  - 过流放电 1：-10mV 至 -85mV
  - 过流放电 2：-20mV 至 +170mV
  - 短路放电：-40mV 至 +340mV
  - 整个温度范围内，电压  $\leq 20$ mV 时的精度为  $\pm 20\%$ ，电压  $> 20$ mV 时的精度为  $\pm 30\%$
- 温度保护
  - 过热充电：45°C 至 50°C
  - 过热放电：65°C 至 70°C
  - 欠温充电：-5°C 至 0°C
  - 低温放电：-20°C 或 -10°C
- 附加特性
  - 独立充电 (CHG) 和放电 (DSG) FET 驱动器
  - 每节电池输入的绝对最大额定电压为 36V
  - 内置自检功能，实现高可靠性
- 关断模式：0.5 $\mu$ A ( 最大值 )
- 提供功能安全
  - 可帮助进行功能安全系统设计的文档

## 2 应用

- 电动工具、园艺工具
- 启停电池组
- 铅酸 (PbA) 备用电池
- 轻型电动车辆
- 储能系统、不间断电源 (UPS)
- 10.8V 至 72V 电池组

## 3 说明

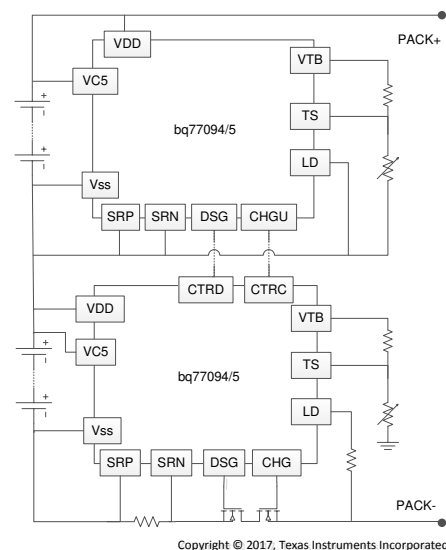
BQ77904 和 BQ77905 器件为低功耗电池组保护器，无需微控制器 (MCU) 控制即可实现一系列电压、电流和温度保护。该器件的可堆叠接口可进行简单扩展，支持从 3 节串联到 20 节或更多节数串联的电池应用。保护阈值和延迟均为出厂编程设定，有多种配置可供选用。为提升灵活性，还提供了单独的过热和欠温放电阈值 ( OTD 和 UTD ) 以及过热和欠温充电阈值 ( OTC 和 UTC ) 。

此器件可通过集成的独立 CHG 和 DSG 低侧 NMOS FET 驱动器实现电池组保护，这些驱动器可通过两个控制引脚禁用。这些控制引脚还能够以简单经济的方式为更多节串联电池 ( 6 节以上 ) 提供电池保护解决方案。为此，只需将上级器件的 CHG 和 DSG 输出级联到下级器件控制引脚。为减少元件数量，所有保护故障均使用内部延迟计时器。

### 器件信息

| 器件型号 <sup>(1)</sup> | 封装         | 封装尺寸 ( 标称值 )           |
|---------------------|------------|------------------------|
| BQ77904             | TSSOP (20) | 6.50mm $\times$ 4.40mm |
| BQ77905             |            |                        |

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。



简化版原理图



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## 4 Revision History

注：以前版本的页码可能与当前版本的页码不同

|                                                                                                                                                                                                                                                                    |             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| <b>Changes from Revision J (April 2020) to Revision K (July 2020)</b> .....                                                                                                                                                                                        | <b>Page</b> |
| • Add the BQ7790521 device in the <i>Device Comparison</i> table.....                                                                                                                                                                                              | 4           |
| <b>Changes from Revision I (December 2019) to Revision J (February 2020)</b> .....                                                                                                                                                                                 | <b>Page</b> |
| • Changed the BQ7790518 device to a catalog device in the <i>Device Comparison</i> table.....                                                                                                                                                                      | 4           |
| <b>Changes from Revision H (September 2018) to Revision I (December 2019)</b> .....                                                                                                                                                                                | <b>Page</b> |
| • Added the BQ7790522 device to the <i>Device Comparison</i> table.....                                                                                                                                                                                            | 4           |
| <b>Changes from Revision G (September 2017) to Revision H (September 2018)</b> .....                                                                                                                                                                               | <b>Page</b> |
| • 为简洁明了，更改了整个数据表中的一些措辞.....                                                                                                                                                                                                                                        | 1           |
| • Added the BQ7790518 device to the BQ77905 <i>Device Comparison</i> table.....                                                                                                                                                                                    | 4           |
| <b>Changes from Revision F (May 2017) to Revision G (September 2017)</b> .....                                                                                                                                                                                     | <b>Page</b> |
| • Added BQ7790511 and BQ7790512 to the <i>Device Comparison</i> table.....                                                                                                                                                                                         | 4           |
| <b>Changes from Revision E (March 2017) to Revision F (May 2017)</b> .....                                                                                                                                                                                         | <b>Page</b> |
| • 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 <i>Device Comparison</i> table.....                                                                                                                                                                                         | 4           |
| <b>Changes from Revision D (March 2017) to Revision E (March 2017)</b> .....                                                                                                                                                                                       | <b>Page</b> |
| • Added BQ7790505 to the <i>Device Comparison</i> 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

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**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

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

- 更改了特性中所列项的顺序.....1
- 表 5-1 and 表 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

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

- 将器件从“产品预发布”更改为“量产” ..... 1
-

## 5 Device Comparison

| DEVICE  | NUMBER OF CELLS | PROTECTIONS                                                 | TYPICAL NORMAL MODE CURRENT ( $\mu$ A) | 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 表 5-1 and 表 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.

**表 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 | OCD2       | SCD            | Current Fault Recovery |              | Temperature ( $^{\circ}$ C) <sup>(1)</sup> |     |      |     |
|-------------|------------|----------------|------------------------|--------------|--------------------------------------------|-----|------|-----|
|             | 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-k $\Omega$  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.

**表 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 | OCD2           |            | SCD            | Current Fault Recovery |                      | Temperature ( $^{\circ}$ C) <sup>(1)</sup> |     |      |     |
|-------------|----------------|------------|----------------|------------------------|----------------------|--------------------------------------------|-----|------|-----|
|             | 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-k $\Omega$  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.

## 6 Pin Configuration and Functions

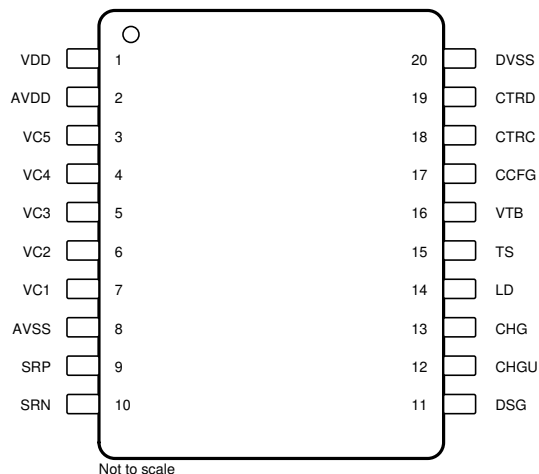


图 6-1. PW Package 20-Pin TSSOP Top View

### Pin Functions

| PIN  |     | I/O <sup>(1)</sup> | 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-k $\Omega$ 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

## 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.<sup>(1)</sup>

|                                       |                      | MIN                                            | MAX   | UNIT |    |
|---------------------------------------|----------------------|------------------------------------------------|-------|------|----|
| V <sub>I</sub>                        | 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 <sub>O</sub>                        | Output voltage range | DSG, CHGU                                      | – 0.3 | 20   | V  |
|                                       |                      | CHG                                            | – 30  | 20   | V  |
|                                       |                      | VTB                                            | – 0.3 | 3.6  | V  |
| I <sub>I</sub>                        | Input current        | LD, CHG                                        |       | 500  | μA |
| I <sub>I</sub>                        | Input current        | CHGU, DSG                                      |       | 1    | mA |
| I <sub>O</sub>                        | Output current       | CHG                                            |       | 1    | mA |
| I <sub>O</sub>                        | Output current       | CHGU, DSG                                      |       | 1    | mA |
| Storage temperature, T <sub>stg</sub> |                      | – 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 <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±1000 | V    |
|                    |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±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 <sub>BAT</sub> | Supply voltage                   | VDD                                         | 3     | 25        | V    |
| V <sub>I</sub>   | 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 <sub>O</sub>   | Output voltage                   | CHG, CHGU, DSG                              | 0     | 16        | V    |
|                  |                                  | VTB, AVDD                                   | 0     | 3         |      |
| T <sub>A</sub>   | Operating free-range temperature |                                             | – 40  | 85        | °C   |

## 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | bq77904<br>bq77905 | UNITS |
|-------------------------------|----------------------------------------------|--------------------|-------|
|                               |                                              | PW (TSSOP)         |       |
|                               |                                              | 20 PINS            |       |
| $R_{\theta JA}$               | 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  |
| $\psi_{JT}$                   | Junction-to-top characterization parameter   | 2.9                | °C/W  |
| $\psi_{JB}$                   | 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  $T_A = 25^\circ\text{C}$  and  $V_{DD} = 16\text{ V}$  (bq77904) or  $20\text{ V}$  (bq77905). MIN and MAX values stated with  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$  and  $V_{DD} = 3$  to  $20\text{ V}$  (bq77904) or  $V_{DD} = 3$  to  $25\text{ V}$  (bq77905) unless otherwise noted.

| PARAMETER                         |                                                                          | TEST CONDITIONS                                             | MIN    | TYP    | MAX    | UNIT          |
|-----------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------|--------|--------|--------|---------------|
| <b>SUPPLY VOLTAGE</b>             |                                                                          |                                                             |        |        |        |               |
| $V_{(POR)}$                       | POR threshold                                                            | $V_{DD}$ rising, 0 to 6 V                                   |        |        | 4      | V             |
| $V_{(SHUT)}$                      | Shutdown threshold                                                       | $V_{DD}$ falling, 6 to 0 V                                  | 2      |        | 3.25   | V             |
| $V_{(AVDD)}$                      | AVDD voltage                                                             | $C_{(VDD)} = 1\text{ }\mu\text{F}$                          | 2.1    | 2.5    | 3.25   | V             |
| <b>SUPPLY AND LEAKAGE CURRENT</b> |                                                                          |                                                             |        |        |        |               |
| $I_{CC}$                          | NORMAL mode current (bq77904/bq77905)                                    | Cell1 through Cell5 = 4 V, $V_{DD} = 20\text{ V}$ (bq77905) |        | 6      | 9      | $\mu\text{A}$ |
| $I_{(CFAULT)}$                    | Fault condition current                                                  | State comparator on                                         |        | 8      | 12     | $\mu\text{A}$ |
| $I_{OFF}$                         | SHUTDOWN mode current                                                    | $V_{DD} < V_{SHUT}$                                         |        |        | 0.5    | $\mu\text{A}$ |
| $I_{LKG(OW\_DIS)}$                | 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            |
| <b>PROTECTION ACCURACIES</b>      |                                                                          |                                                             |        |        |        |               |
| $V_{OV}$                          | Overvoltage programmable threshold range                                 |                                                             | 3000   |        | 4575   | mV            |
| $V_{UV}$                          | Undervoltage programmable threshold range                                |                                                             | 1200   |        | 3000   | mV            |
| $V_{(VA)}$                        | OV, UV, detection accuracy                                               | $T_A = 25^\circ\text{C}$ , OV detection accuracy            | - 10   |        | 10     | mV            |
|                                   |                                                                          | $T_A = 25^\circ\text{C}$ , UV detection accuracy            | - 18   |        | 18     | mV            |
|                                   |                                                                          | $T_A = 0$ to $60^\circ\text{C}$                             | - 28   |        | 26     | mV            |
|                                   |                                                                          | $T_A = -40$ to $85^\circ\text{C}$                           | - 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 $65^\circ\text{C}$ <sup>(1)</sup>             | 19.71% | 20.56% | 21.86% | V             |
|                                   |                                                                          | Threshold for $70^\circ\text{C}$ <sup>(1)</sup>             | 17.36% | 18.22% | 19.51% | VTB           |

Typical values stated at  $T_A = 25^\circ\text{C}$  and  $V_{DD} = 16\text{ V}$  (bq77904) or  $20\text{ V}$  (bq77905). MIN and MAX values stated with  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$  and  $V_{DD} = 3$  to  $20\text{ V}$  (bq77904) or  $V_{DD} = 3$  to  $25\text{ V}$  (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 $55^\circ\text{C}$ for when $V_{OTD}$ is at $65^\circ\text{C}^{(1)}$ | 25.24%       | 26.12% | 27.44%   | VTB           |
|                                         |                                                                                 | Recovery threshold at $60^\circ\text{C}$ for when $V_{OTD}$ is at $70^\circ\text{C}^{(1)}$ | 22.12%       | 23.2%  | 24.24%   | VTB           |
| $V_{OTC}$                               | Overtemperature in charge programmable threshold (ratio of $V_{TB}$ )           | Threshold for $45^\circ\text{C}^{(1)}$                                                     | 32.14%       | 32.94% | 34.54%   | VTB           |
|                                         |                                                                                 | Threshold for $50^\circ\text{C}^{(1)}$                                                     | 29.15%       | 29.38% | 31.45%   | VTB           |
| $V_{OTC(REC)}$                          | Overtemperature in charge recovery (ratio of $V_{TB}$ )                         | Recovery threshold at $35^\circ\text{C}$ when $V_{OTD}$ is at $45^\circ\text{C}^{(1)}$     | 38.63%       | 40.97% | 40.99%   | VTB           |
|                                         |                                                                                 | Recovery threshold at $40^\circ\text{C}$ when $V_{OTD}$ is at $50^\circ\text{C}^{(1)}$     | 36.18%       | 36.82% | 38.47%   | VTB           |
| $V_{UTD}$                               | Undertemperature in discharge programmable threshold (ratio of $V_{TB}$ )       | Threshold for $-20^\circ\text{C}^{(1)}$                                                    | 86.41%       | 87.14% | 89.72%   | VTB           |
|                                         |                                                                                 | Threshold for $-10^\circ\text{C}^{(1)}$                                                    | 80.04%       | 80.94% | 83.10%   | VTB           |
| $V_{UTD(REC)}$                          | Undertemperature in discharge recovery (ratio of $V_{TB}$ )                     | Recovery threshold at $-10^\circ\text{C}$ when $V_{UTD}$ is at $-20^\circ\text{C}^{(1)}$   | 80.04%       | 80.94% | 83.10%   | VTB           |
|                                         |                                                                                 | Recovery threshold at $0^\circ\text{C}$ when $V_{UTD}$ is at $-10^\circ\text{C}^{(1)}$     | 71.70%       | 73.18% | 74.86%   | VTB           |
| $V_{UTC}$                               | Undertemperature in charge programmable threshold (ratio of $V_{TB}$ )          | Threshold for $-5^\circ\text{C}^{(1)}$                                                     | 75.06%       | 77.22% | 78.32%   | VTB           |
|                                         |                                                                                 | Threshold for $0^\circ\text{C}^{(1)}$                                                      | 71.70%       | 73.18% | 74.86%   | VTB           |
| $V_{UTC(REC)}$                          | Undertemperature in Charge Recovery (ratio of $V_{TB}$ )                        | Recovery threshold at $5^\circ\text{C}$ when $V_{UTC}$ is at $-5^\circ\text{C}^{(1)}$      | 68.80%       | 69.73% | 71.71%   | VTB           |
|                                         |                                                                                 | Recovery threshold at $10^\circ\text{C}$ when $V_{UTC}$ is at $0^\circ\text{C}^{(1)}$      | 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                                     | $V_{OCD1} > -20\text{ mV}$                                                                 | - 30%        |        | 30%      |               |
| $V_{CCAH}$                              | OCD1, OCD2, SCD detection accuracy                                              | $V_{OCD1} \leq -20\text{ mV}$ ; all OCD2 and SCD threshold ranges                          | - 20%        |        | 20%      |               |
| $V_{OW}$                                | Open-wire fault voltage threshold at $VC_x$ per cell with respect to $VC_{x-1}$ | Voltage falling on $VC_x$ , 3.6 V to 0 V                                                   | 450          | 500    | 550      | mV            |
| $V_{OW(HYS)}$                           | Hysteresis for open wire fault                                                  | Voltage rising on $VC_x$ , 0 V to 3.6 V                                                    |              | 100    |          | mV            |
| <b>CHARGE AND DISCHARGE FET DRIVERS</b> |                                                                                 |                                                                                            |              |        |          |               |
| $V_{(FETON)}$                           | CHG/CHGU/DSG on                                                                 | $V_{DD} \geq 12\text{ V}$ , $CL = 10\text{ nF}$                                            | 11           | 12     | 14       | V             |
|                                         |                                                                                 | $V_{DD} < 12\text{ V}$ , $CL = 10\text{ nF}$                                               | $V_{DD} - 1$ |        | $V_{DD}$ | 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    |          | k $\Omega$    |
| $R_{(DSGOFF)}$                          | CHGU/DSG off resistance                                                         | CHGU/DSG off and pin held at 2 V                                                           |              | 10     | 16       | $\Omega$      |
| $I_{CHG(CLAMP)}$                        | CHG clamp current                                                               | CHG off and pin held at 18 V                                                               |              |        | 450      | $\mu\text{A}$ |



Typical values stated at  $T_A = 25^\circ\text{C}$  and  $V_{DD} = 16\text{ V}$  (bq77904) or  $20\text{ V}$  (bq77905). MIN and MAX values stated with  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$  and  $V_{DD} = 3$  to  $20\text{ V}$  (bq77904) or  $V_{DD} = 3$  to  $25\text{ V}$  (bq77905) unless otherwise noted.

| PARAMETER                       |                                                                               | TEST CONDITIONS                                                 | MIN            | TYP            | MAX          | UNIT          |
|---------------------------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------|----------------|--------------|---------------|
| $V_{\text{CHG}(\text{CLAMP})}$  | CHG clamp voltage                                                             | $I_{\text{CHG}(\text{CLAMP})} = 300\text{ }\mu\text{A}$         | 16             | 18             | 20.5         | V             |
| $t_{\text{CHGON}}$              | CHG on rise time                                                              | $CL = 10\text{ nF}$ , 10% to 90%                                |                | 50             | 150          | $\mu\text{s}$ |
| $t_{\text{DSGON}}$              | CHGU/DSG on rise time                                                         | $CL = 10\text{ nF}$ , 10% to 90%                                |                | 2              | 75           | $\mu\text{s}$ |
| $t_{\text{CHGOFF}}$             | CHG off fall time                                                             | $CL = 10\text{ nF}$ , 90% to 10%                                |                | 15             | 30           | $\mu\text{s}$ |
| $t_{\text{DSGOFF}}$             | CHGU/DSG off fall time                                                        | $CL = 10\text{ nF}$ , 90% to 10%                                |                | 5              | 15           | $\mu\text{s}$ |
| <b>CTRC AND CTRD CONTROL</b>    |                                                                               |                                                                 |                |                |              |               |
| $V_{\text{CTR1}}$               | Enable FET driver (VSS)                                                       | With respect to VSS. Enabled < MAX                              |                |                | 0.6          | V             |
| $V_{\text{CTR2}}$               | Enable FET driver (Stacked)                                                   | Enabled > MIN                                                   | $V_{DD} + 2.2$ |                |              | V             |
| $V_{\text{CTR}(\text{DIS})}$    | Disable FET driver                                                            | Disabled between MIN and MAX                                    | 2.04           | $V_{DD} + 0.7$ |              | V             |
| $V_{\text{CTR}(\text{MAXV})}$   | CTRC and CTRD clamp voltage                                                   | $I_{\text{CTR}} = 600\text{ nA}$                                | $V_{DD} + 2.8$ | $V_{DD} + 4$   | $V_{DD} + 5$ | V             |
| $t_{\text{CTRDEG\_ON}}^{(2)}$   | CTRC and CTRD deglitch for ON signal                                          |                                                                 |                | 7              |              | ms            |
| $t_{\text{CTRDEG\_OFF}}^{(2)}$  | CTRC and CTRD deglitch for OFF signal                                         |                                                                 |                | 7              |              | ms            |
| <b>CURRENT STATE COMPARATOR</b> |                                                                               |                                                                 |                |                |              |               |
| $V_{(\text{STATE\_D1})}$        | Discharge qualification threshold1                                            | Measured at SRP-SRN                                             | - 3            | - 2            | - 1          | mV            |
| $V_{(\text{STATE\_C1})}$        | Charge qualification threshold1                                               | Measured at SRP-SRN                                             | 1              | 2              | 3            | mV            |
| $t_{\text{STATE}}^{(2)}$        | State detection qualification time                                            |                                                                 |                |                | 1.2          | ms            |
| <b>LOAD REMOVAL DETECTION</b>   |                                                                               |                                                                 |                |                |              |               |
| $V_{\text{LD}(\text{CLAMP})}$   | LD clamp voltage                                                              | $I_{(\text{LDCLAMP})} = 300\text{ }\mu\text{A}$                 | 16             | 18             | 20.5         | V             |
| $I_{\text{LD}(\text{CLAMP})}$   | LD clamp current                                                              | $V_{(\text{LDCLAMP})} = 18\text{ V}$                            |                |                | 450          | $\mu\text{A}$ |
| $V_{\text{LDT}}$                | LD threshold                                                                  | Load removed < when $V_{\text{LDT}}$                            | 1.25           | 1.3            | 1.35         | V             |
| $R_{\text{LD}(\text{INT})}$     | LD input resistance when enabled                                              | Measured to VSS                                                 | 160            | 250            | 375          | k $\Omega$    |
| $t_{\text{LD\_DEG}}$            | LD detection deglitch                                                         |                                                                 | 1              | 1.5            | 2.3          | ms            |
| <b>CCFG PIN</b>                 |                                                                               |                                                                 |                |                |              |               |
| $V_{(\text{CCFGL})}$            | CCFG threshold low (ratio of $V_{\text{AVDD}}$ )                              | 3-cell configuration                                            |                |                | 10%          | V             |
| $V_{(\text{CCFGH})}$            | CCFG threshold high (ratio of $V_{\text{AVDD}}$ )                             | 4-cell configuration                                            | 65%            |                | 100%         | V             |
| $V_{(\text{CCFGHZ})}$           | CFG threshold high-Z (ratio of $V_{\text{AVDD}}$ )                            | 5-cell configuration, CCFG floating, internally biased          | 25%            | 33%            | 45%          | V             |
| $t_{\text{CCFG\_DEG}}^{(2)}$    | CCFG deglitch                                                                 |                                                                 |                | 6              |              | ms            |
| <b>CUSTOMER TEST MODE (CTM)</b> |                                                                               |                                                                 |                |                |              |               |
| $V_{(\text{CTM})}$              | Customer test mode entry voltage at $V_{DD}$                                  | $V_{DD} > V_{C5} + V_{(\text{CTM})}$ , $T_A = 25^\circ\text{C}$ | 8.5            |                | 10           | V             |
| $t_{\text{CTM\_ENTRY}}^{(3)}$   | Delay time to enter and exit Customer Test Mode                               | $V_{DD} > V_{C5} + V_{(\text{CTM})}$ , $T_A = 25^\circ\text{C}$ | 50             |                |              | ms            |
| $t_{\text{CTM\_DELAY}}^{(3)}$   | Delay time of faults while in Customer Test Mode                              | $T_A = 25^\circ\text{C}$                                        |                |                | 200          | ms            |
| $t_{\text{CTM\_OC\_REC}}^{(3)}$ | Fault recovery time of OCD1, OCD2, and SCD faults while in Customer Test Mode | 1 s and 8 s options, $T_A = 25^\circ\text{C}$                   |                |                | 100          | ms            |

(1) Based on a 10-K $\Omega$  pull-up and 103AT thermistor

- (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 <sup>(2)</sup> |                                                                     |                      |      |      |      |      |
| t <sub>OVn_DELAY</sub>           | 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 <sub>UVn_DELAY</sub>           | 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 <sub>OWn_DELAY</sub>           | Open-wire detection delay time                                      |                      | 3.6  | 4.5  | 5.3  | s    |
| t <sub>OTC_DELAY</sub>           | Overtemperature charge detection delay time                         |                      | 3.6  | 4.5  | 5.3  | s    |
| t <sub>UTC_DELAY</sub>           | Undertemperature charge detection delay time                        |                      | 3.6  | 4.5  | 5.3  | s    |
| t <sub>OTD_DELAY</sub>           | Overtemperature discharge detection delay time                      |                      | 3.6  | 4.5  | 5.3  | s    |
| t <sub>UTD_DELAY</sub>           | Undertemperature discharge detection delay time                     |                      | 3.6  | 4.5  | 5.3  | s    |
| t <sub>OCD1_DELAY</sub>          | 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 <sub>OCD2_DELAY</sub>          | 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 <sub>SCD_RELAY</sub>           | Short-circuit detection delay time                                  | 360-μs delay option  | 220  | 400  | 610  | μs   |
| t <sub>CD_REC</sub>              | 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 |      |

## 7.7 Typical Characteristics

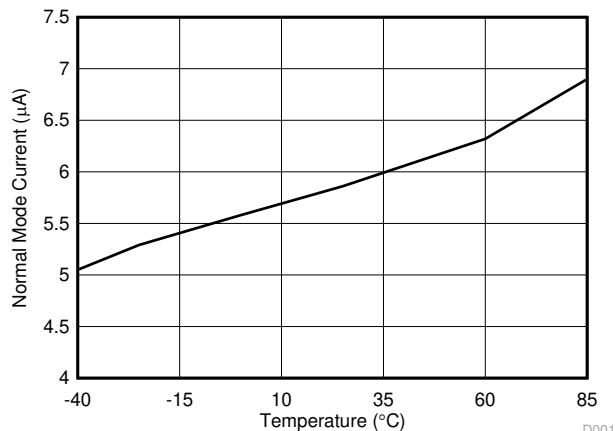


图 7-1. NORMAL Mode Current

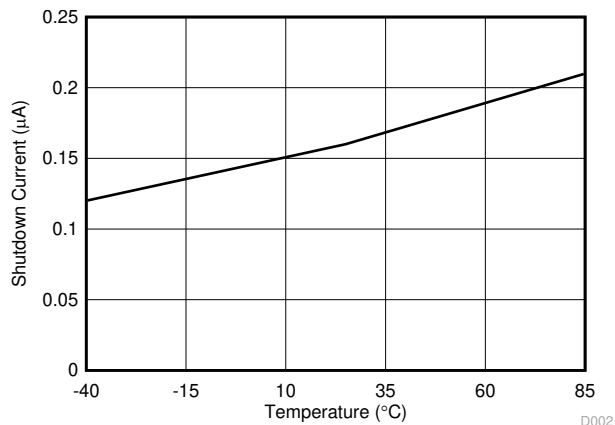


图 7-2. Shutdown Current

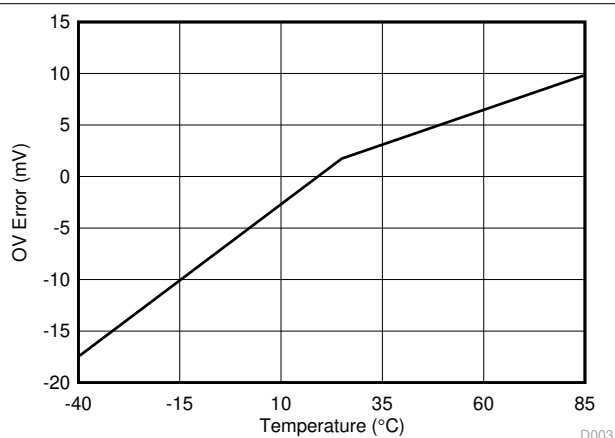


图 7-3. OV Error at 4.25-V Threshold

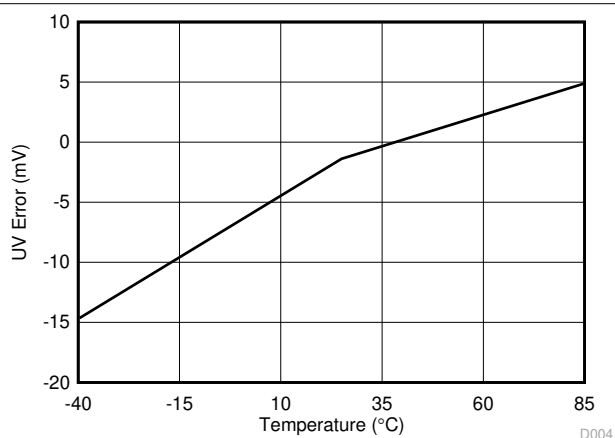


图 7-4. UV Error at 2.8-V Threshold

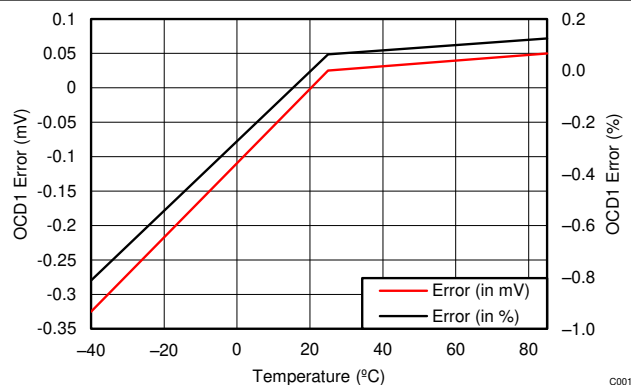


图 7-5. OCD1 Error at 40-mV Threshold

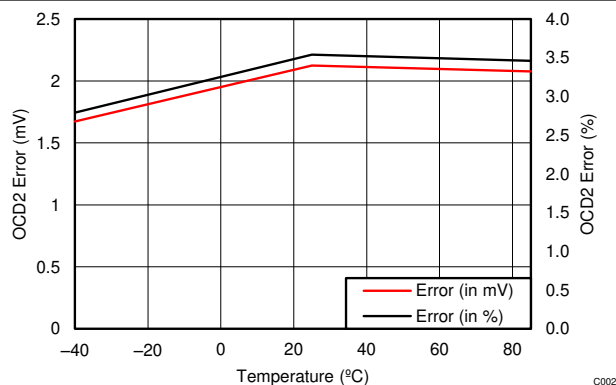


图 7-6. OCD2 Error at 60-mV Threshold

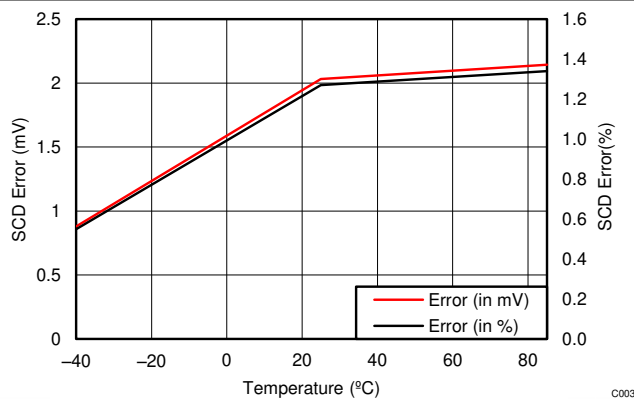


图 7-7. SCD Error at 160-mV Threshold

## 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  $\geq 6$ -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  $\geq 6$ -series battery packs.

#### 8.1.1 Device Functionality Summary

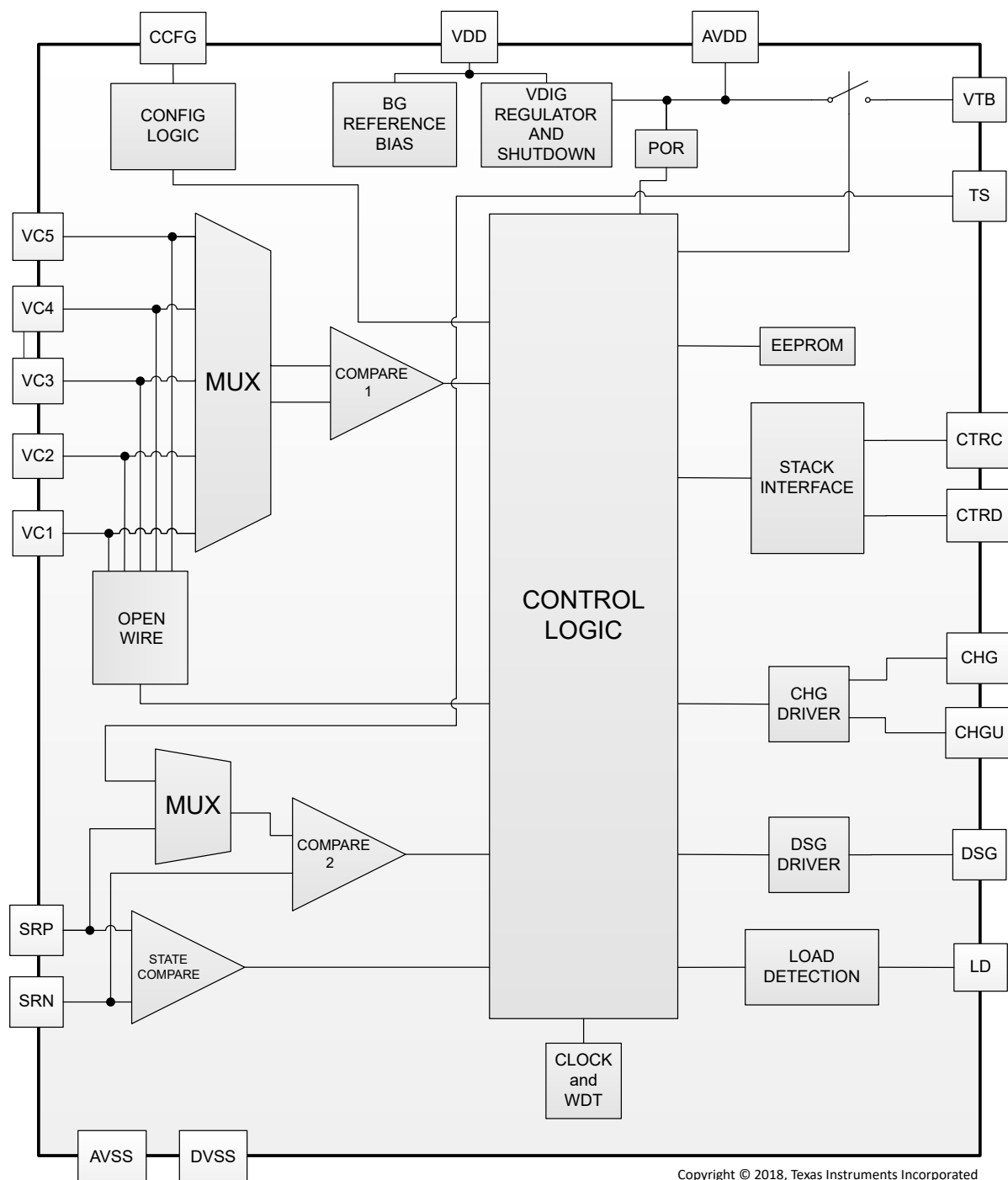
In this and subsequent sections, a number of abbreviations are used to identify specific fault conditions. The fault descriptor abbreviations and their meanings are defined in [表 8-1](#).

**表 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<br>(100-mV step for $< 2.5$ V,<br>50-mV step for $\geq 2.5$ V)                       | 1, 2, 4.5, 9 s                         | Hysteresis OR<br>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 <sup>(1)</sup> | Overtemperature during discharge      | 65°C or 70°C                                                                                      | 4.5 s                                  | Hysteresis                                                                                       | 10°C                |
| OTC <sup>(1)</sup> | Overtemperature during charge         | 45°C or 50°C                                                                                      | 4.5 s                                  | Hysteresis                                                                                       | 10°C                |
| UTD <sup>(1)</sup> | Undertemperature during discharge     | - 20°C or - 10°C                                                                                  | 4.5 s                                  | Hysteresis                                                                                       | 10°C                |
| UTC <sup>(1)</sup> | 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<br>Delay + Load Removal OR<br>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 $\mu$ s                            |                                                                                                  |                     |
| 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-k  $\Omega$  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.

## 8.2 Functional Block Diagram



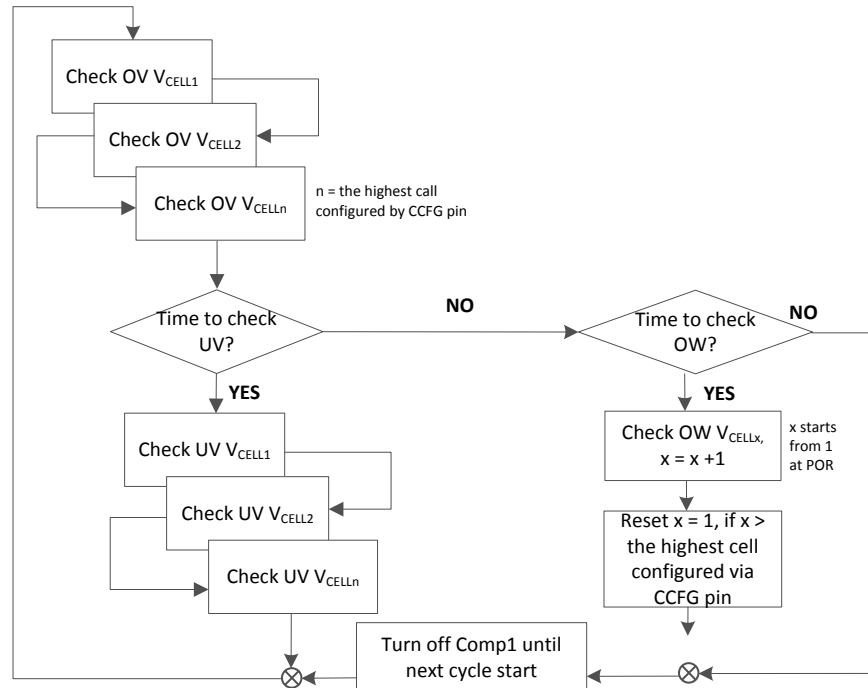
## 8.3 Feature Description

### 8.3.1 Protection Summary

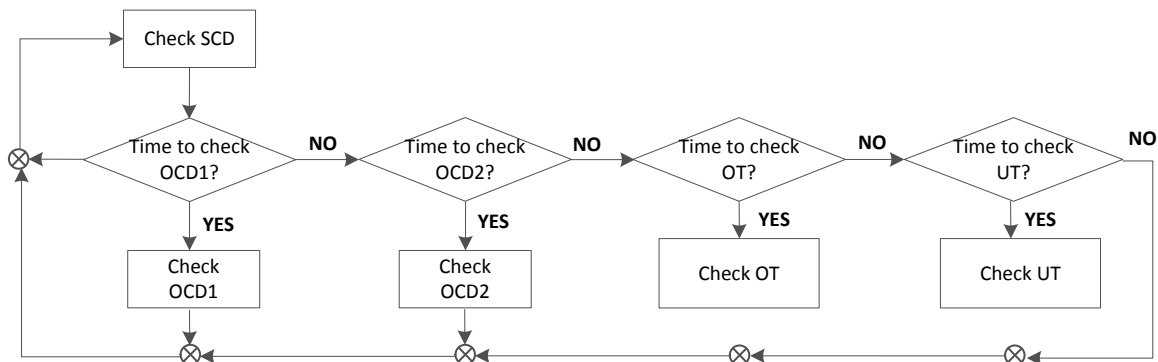
The BQ77904 and BQ77905 have two comparators. Both are time multiplexed to detect all protection fault conditions. Each of the comparators runs on a time-multiplexed schedule and cycles through the assigned

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 [节 5](#) section for a summary of options available per device type.



**图 8-1. Comparator 1 Flowchart**



**图 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.

### 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  $3\text{ M}\Omega$ . Refer to the § 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  $1\text{ M}\Omega$ ) 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:



- 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 表 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.

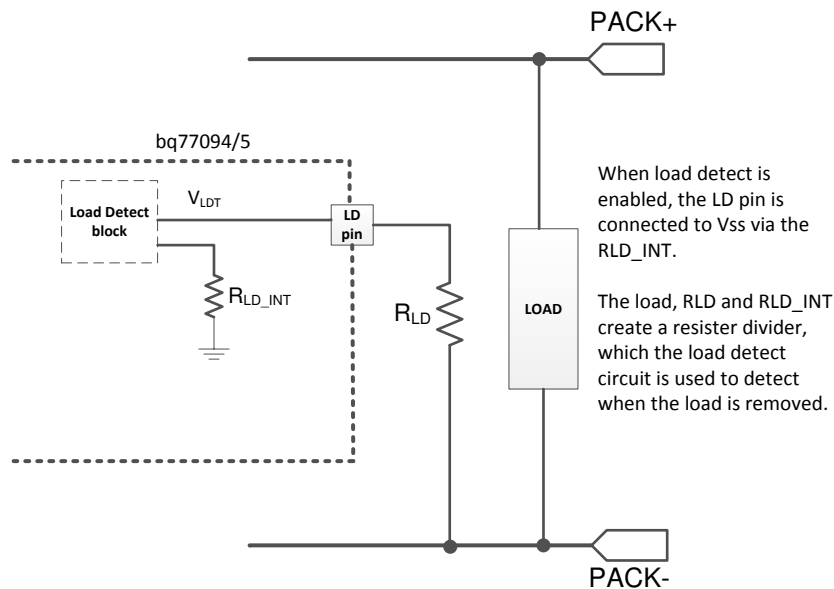


图 8-3. Load Detection Circuit for Current Faults Recovery

表 8-2. Load State

| LD PIN                        | LOAD STATE   |
|-------------------------------|--------------|
| $\geq V_{LDT}$                | Load present |
| $< V_{LDT}$ 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  $3\text{ M}\Omega$ . Refer to the 节 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.

### 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  $\mu$ s 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  $\mu$ s 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

表 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.

**表 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 <sub>CTRDEG_ON</sub>                                                       | t <sub>CTRDEG_OFF</sub> |
| CTRD disabled      | CTRD disabled for deglitch delay time                                  | —   | OFF | CTRD must be enabled for deglitch delay time                                                                                   |                                                                              |                         |
| OV                 | V(Cell) rises above V <sub>OV</sub> for delay time                     | OFF | —   | V(Cell) drops below V <sub>OV</sub> - V <sub>HYS_OV</sub> for delay                                                            | t <sub>OVn_DELAY</sub>                                                       |                         |
| UV                 | V(Cell) drops below V <sub>UV</sub> for delay time                     | —   | OFF | V(Cell) rises above V <sub>UV</sub> + V <sub>HYS_UV</sub> for delay                                                            | t <sub>UVn_DELAY</sub>                                                       |                         |
| OW                 | VC <sub>X</sub> - VC <sub>X - 1</sub> < V <sub>OW</sub> for delay time | OFF | OFF | Bad VC <sub>X</sub> recovers such that VC <sub>X</sub> - VC <sub>X - 1</sub> > V <sub>OW</sub> + V <sub>OW_HYS</sub> for delay | t <sub>OWn_DELAY</sub>                                                       |                         |
| OCD1, OCD2, SCD    | (VSRP - VSRN) < VOCD1, VOCD2, or VSCD for delay time                   | OFF | OFF | Recovery delay expires OR LD detects < V <sub>LDT</sub> OR Recovery delay expires + LD detects < V <sub>LDT</sub>              | t <sub>OCD1_DELAY</sub> , t <sub>OCD2_DELAY</sub> , t <sub>SCD_DELAY</sub> , | t <sub>CD_REC</sub>     |
| OTC <sup>(1)</sup> | Temperature rises above T <sub>OTC</sub> for delay time                | OFF | —   | Temp drops below T <sub>OTC</sub> - T <sub>OTC_REC</sub> for delay                                                             | t <sub>OTC_DELAY</sub>                                                       |                         |
| OTD <sup>(1)</sup> | Temperature rises above T <sub>OTD</sub> for delay time                | OFF | OFF | Temp drops below T <sub>OTD</sub> - T <sub>OTD_REC</sub> for delay                                                             | t <sub>OTD_DELAY</sub>                                                       |                         |
| UTC <sup>(1)</sup> | Temperature drops below T <sub>UTC</sub> for delay time                | OFF | —   | Temperature rises above T <sub>UTC</sub> + T <sub>UTC_REC</sub> for delay                                                      | t <sub>UTC_DELAY</sub>                                                       |                         |
| UTD <sup>(1)</sup> | Temp drops below T <sub>UTD</sub> for delay time                       | OFF | OFF | Temp rises above T <sub>UTD</sub> + T <sub>UTD_REC</sub> for delay                                                             | t <sub>UTD_DELAY</sub>                                                       |                         |

(1) T<sub>UTC</sub>, T<sub>UTD</sub>, T<sub>UTC\_REC</sub>, and T<sub>UTD\_REC</sub> correspond to the temperature produced by V<sub>UTC</sub>, V<sub>UTD</sub>, V<sub>UTC\_REC</sub>, and V<sub>UTD\_REC</sub> 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

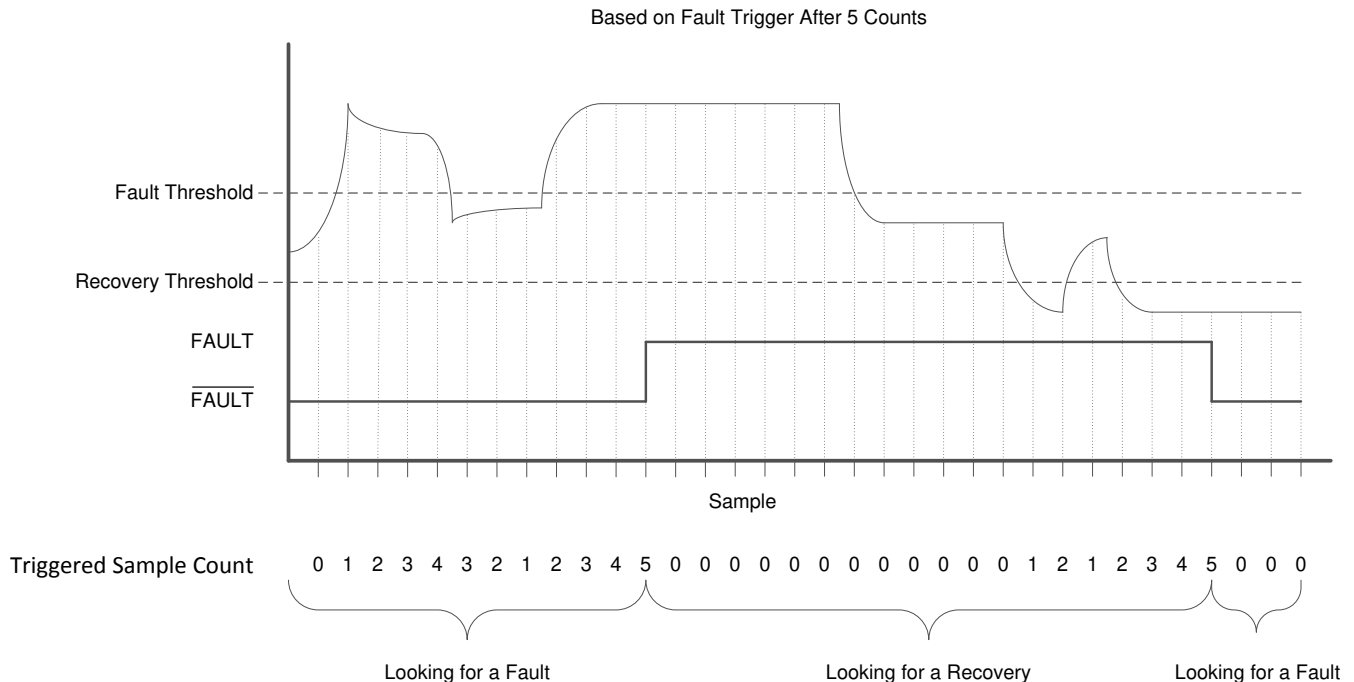
#### 8.3.5.1 Filtered Fault Detection

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,

below the fault threshold). 图 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 图 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.



**图 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,  $V_{\text{STATE\_D}}$  or a CHARGE state greater than a maximum threshold,  $V_{\text{STATE\_C}}$ . 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.

### 表 8-4. State Comparator Operation Summary

| STATE COMP                     | CHG | DSG | MODE                          |
|--------------------------------|-----|-----|-------------------------------|
| OFF                            | ON  | ON  | Normal                        |
| V <sub>STATE_C</sub> Detection | ON  | OFF | UV, CTRD                      |
| V <sub>STATE_D</sub> Detection | OFF | ON  | OV, UTC, OTC, CTRC            |
| OFF                            | OFF | OFF | OCD1, OCD2, SCD, UTD, OTD, OW |

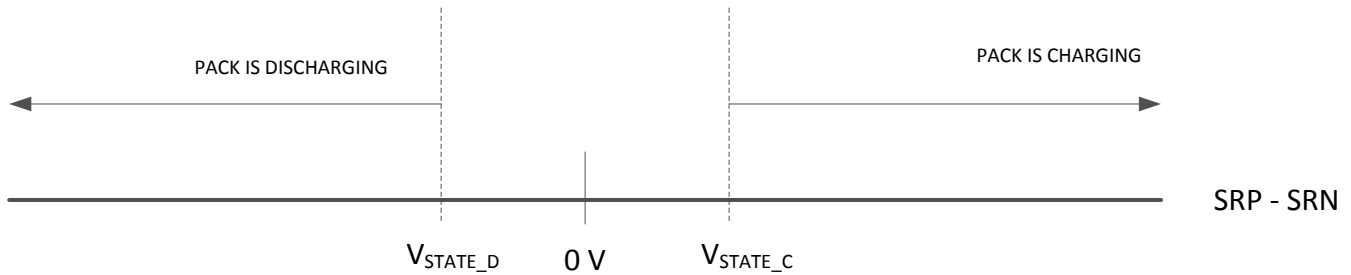


图 8-5. State Comparator Thresholds

### 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  $\Omega$  and an off resistance of  $R_{DSG\text{OFF}}$ . 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 DSG 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  $V_{\text{STATE\_C}}$  threshold) remains on for the entire duration of a DSG fault with no CHG fault event.

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

See the 节 8.3.6 section for details.

The presence of any related faults, as shown in 图 8-6, results in the DSGFET\_OFF signal .

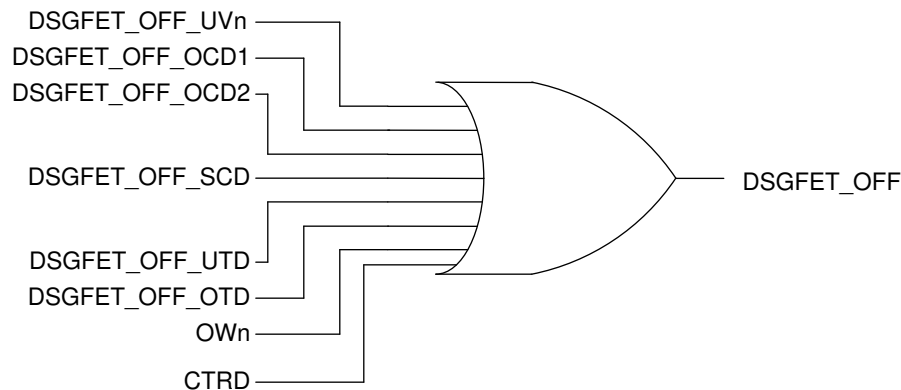


图 8-6. Faults that Can Qualify DSGFET\_OFF

### 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  $(\text{SRP-SRN}) < V_{\text{STATE\_D1}}$ . 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.

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  $2\text{ k}\Omega$ . 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  $V_{\text{STATE\_D}}$  threshold) remains on for the entire duration of a DSG fault with no CHG fault event.

- If  $(\text{SRP-SRN}) > V_{\text{STATE\_D}}$  and no discharge event is detected, the CHG FET output will remain OFF due to the present of a CHG fault.
- If  $(\text{SRP-SRN}) \leq V_{\text{STATE\_D}}$  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 图 8-7.

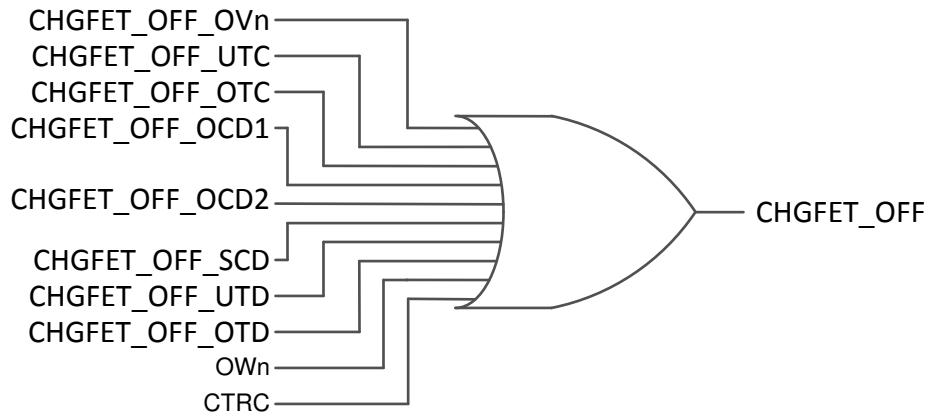


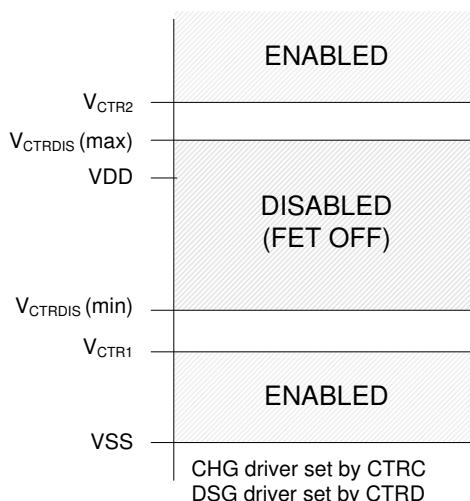
图 8-7. Faults That Can Qualify CHGFET OFF

### 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 图 8-8. To support the simple-stack solution for higher-cell count packs, these pins are designed to operate above the device's  $V_{\text{DD}}$  level. Simply connect a  $10\text{-M}\Omega$  resistor between a lower device CTRC and CTRD input pins to an upper device CHGU and DSG output pins (see the schematics in 节 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  $t_{\text{CTRDEG\_ON}}$  time to deglitch. From a 100% count (solid ENABLE), a solid DISABLE signal takes about  $t_{\text{CTRDEG\_OFF}}$  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  $t_{\text{CTRDEG\_OFF}}$  time adds an additional delay to the fault detection timing and the  $t_{\text{CTRDEG\_ON}}$  time adds an additional delay to the fault recovery timing.



**图 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 表 8-5. The device periodically checks the CCFG status and takes  $t_{CCFG\_DEG}$  time to detect the pin status.

**表 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 表 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.

**表 8-6. Stacking Implementation Configurations**

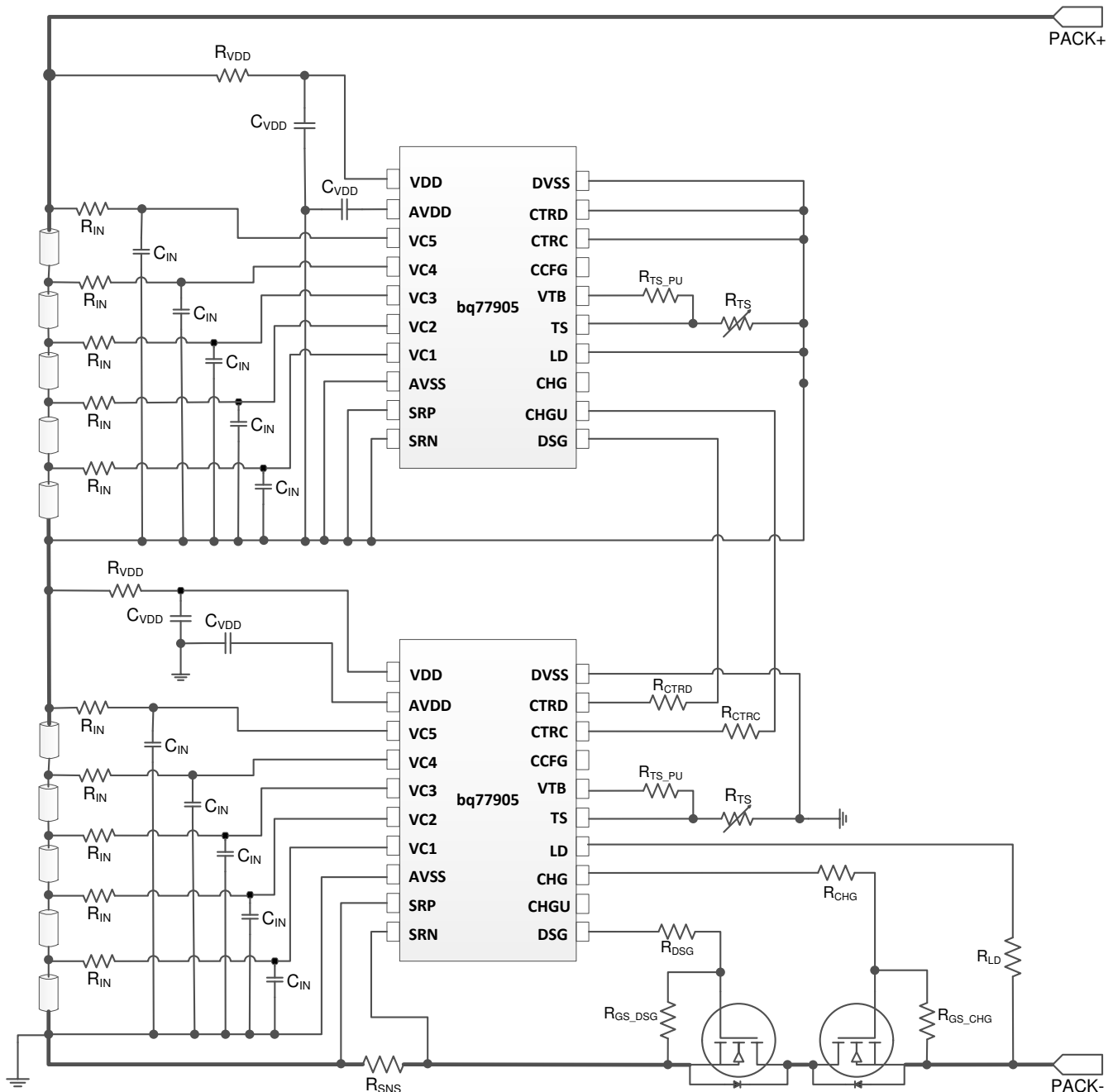
| CONFIGURATION           | CHG PIN            | CHGU PIN                            |
|-------------------------|--------------------|-------------------------------------|
| Bottom or single device | Connect to CHG FET | Leave unconnected                   |
| Upper stack             | Leave unconnected  | 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.



- 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.



**图 8-9. 10S Pack Using Two BQ77905 Devices**



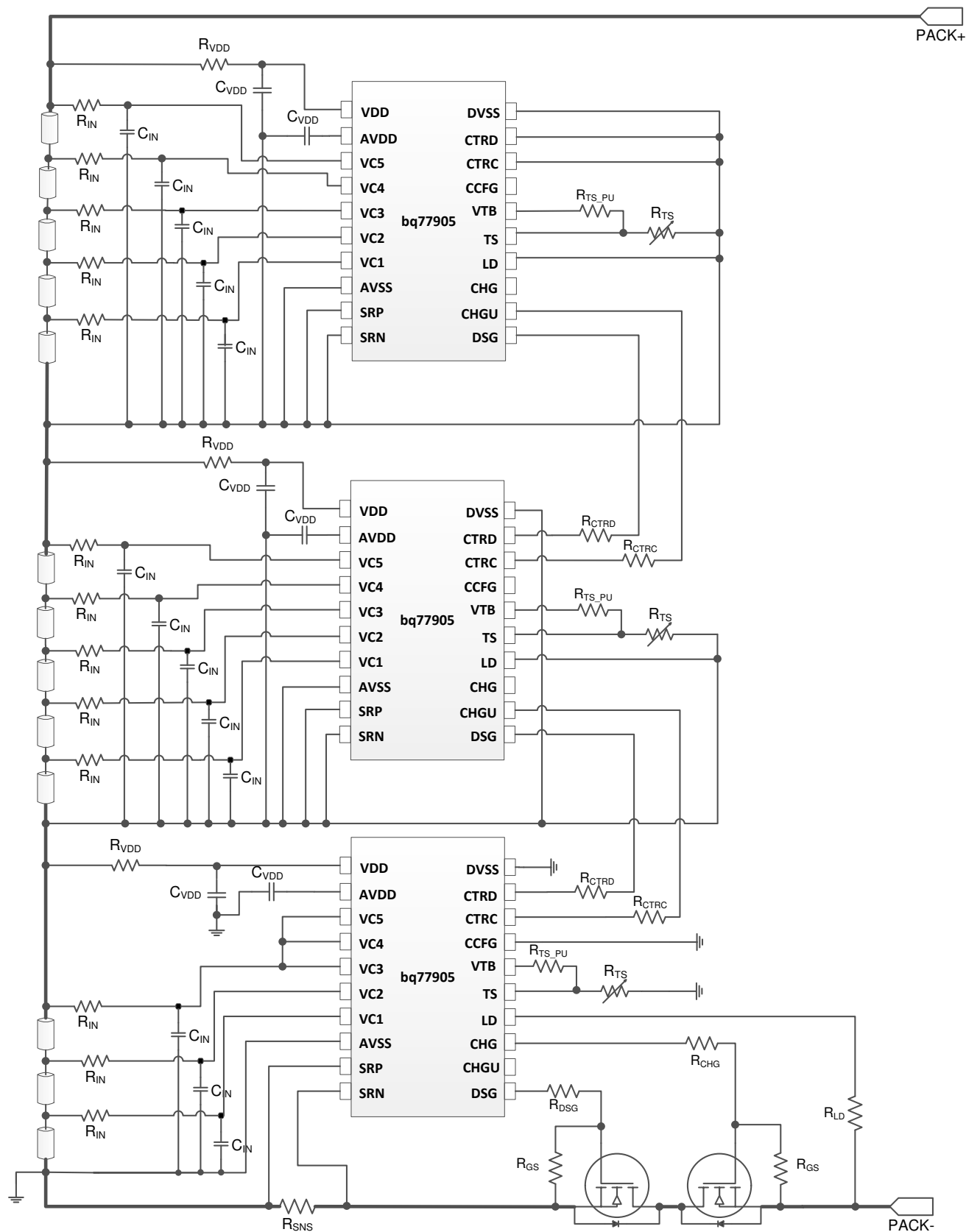


图 8-10. 13S Pack Using Three BQ77905 Devices

### 8.3.12 Zero-Volt Battery Charging Inhibition

Once the device is powered up, it can pull the CHG pin up if the  $V_{DD} \geq V_{SHUT}$ , 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  $V_{DD}$  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  $V_{DD} \geq V_{POR}$ . 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, 节 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  $V_{DD}$  falls below  $V_{SHUT}$ . In this mode, all fault detections and the CHG and DSG drivers are disabled. The device will wake up and enter NORMAL mode when  $V_{DD}$  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  $V_{DD}$  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  $V_{DD}$  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.

## 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.

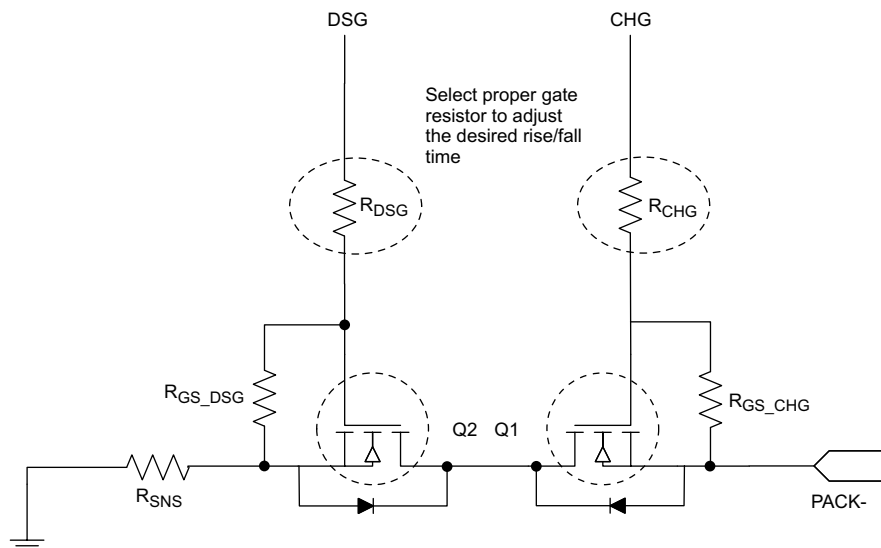


图 9-1. Select Proper Gate Resistor for FET Rise and Fall Time

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  $V_{gsth}$ , 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 ( $R_{GS\_CHG}$ ).

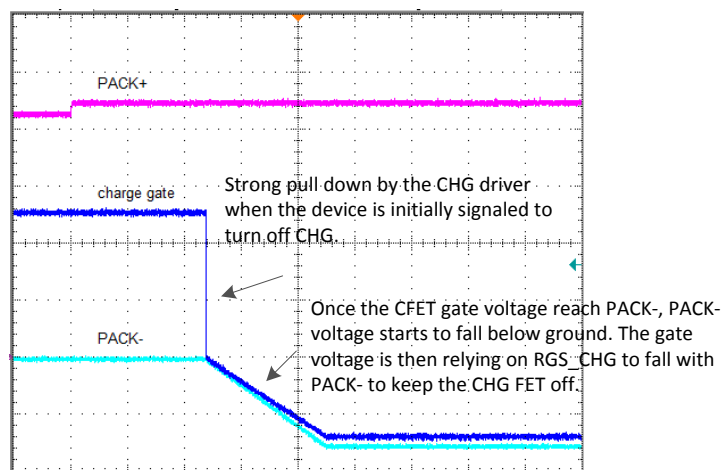


图 9-2. CHG FET Fall Time

### 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.

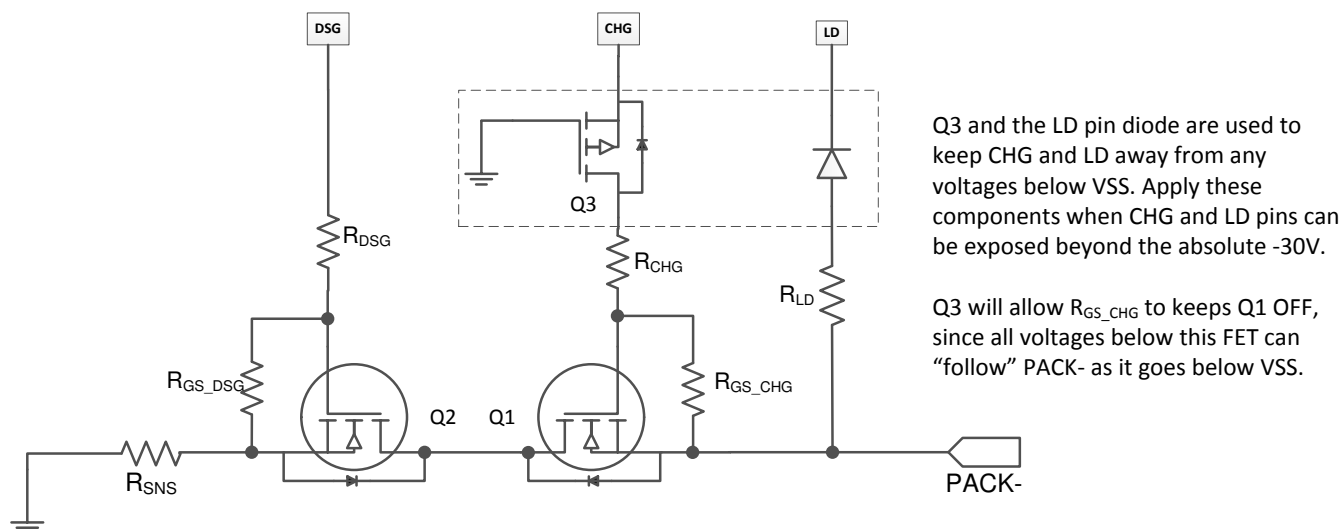


图 9-3. Protecting CHG and LD

### 9.1.1.3 Protecting CHG FET

When the CHG driver is off, CHG is pulled to VSS, the PACK – terminal can be pulled up 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 图 9-4 for details.

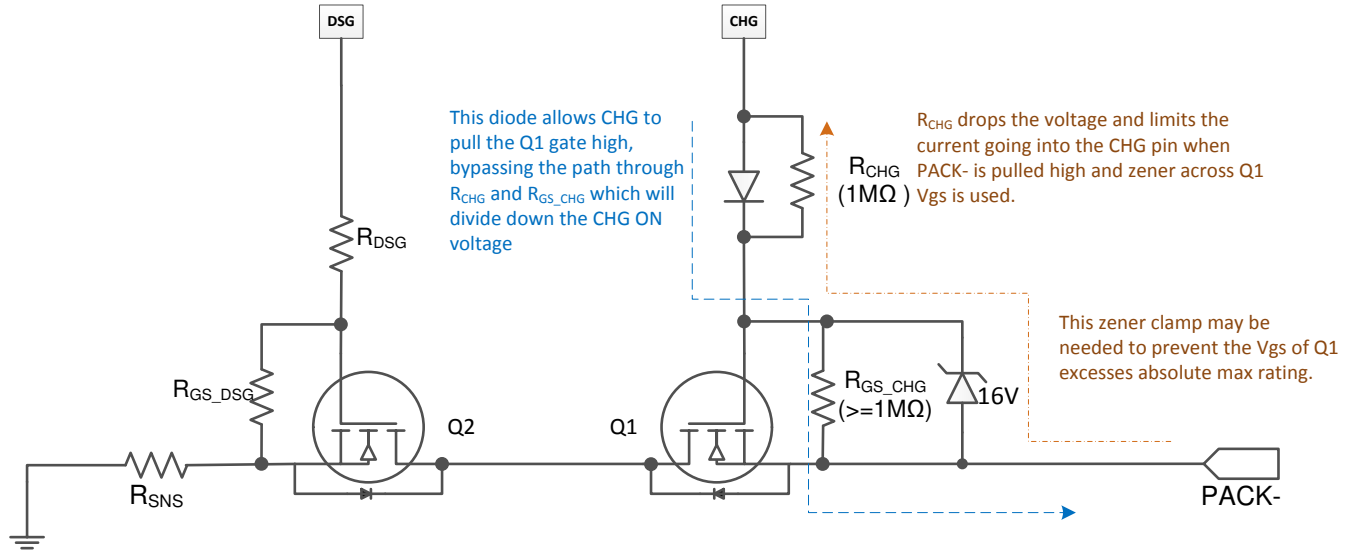


图 9-4. Protect CHG FET from a High Voltage on PACK -

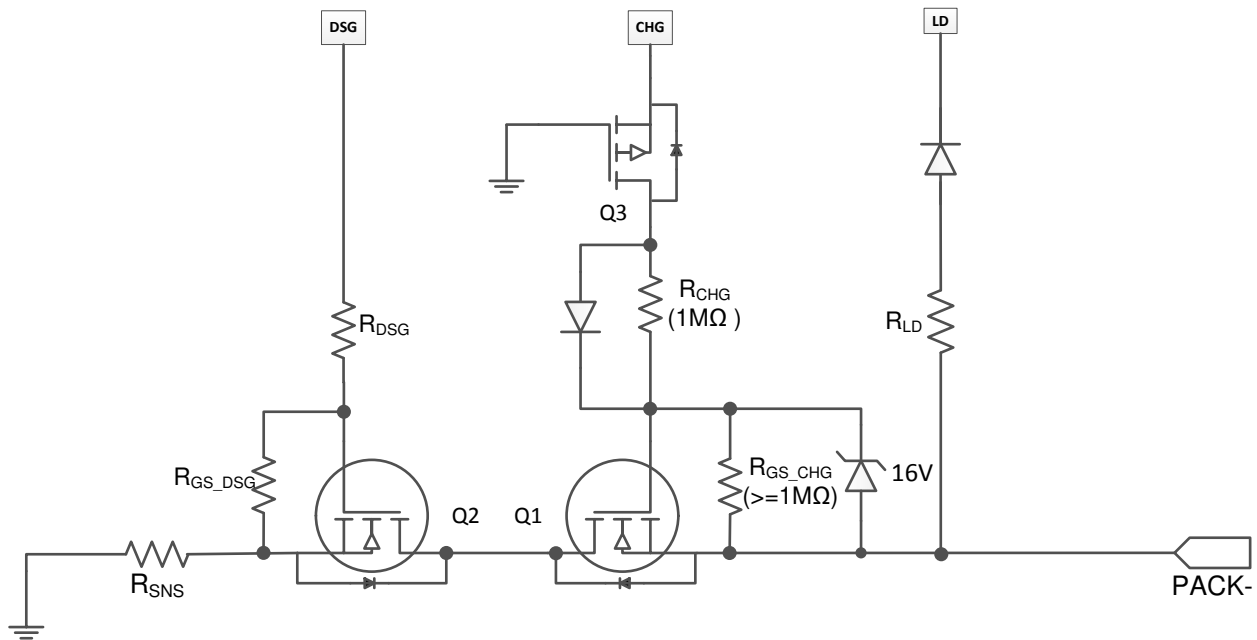


图 9-5. Optional Components Combining Protecting CHG and LD and Protecting CHG FET Protections

#### 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.

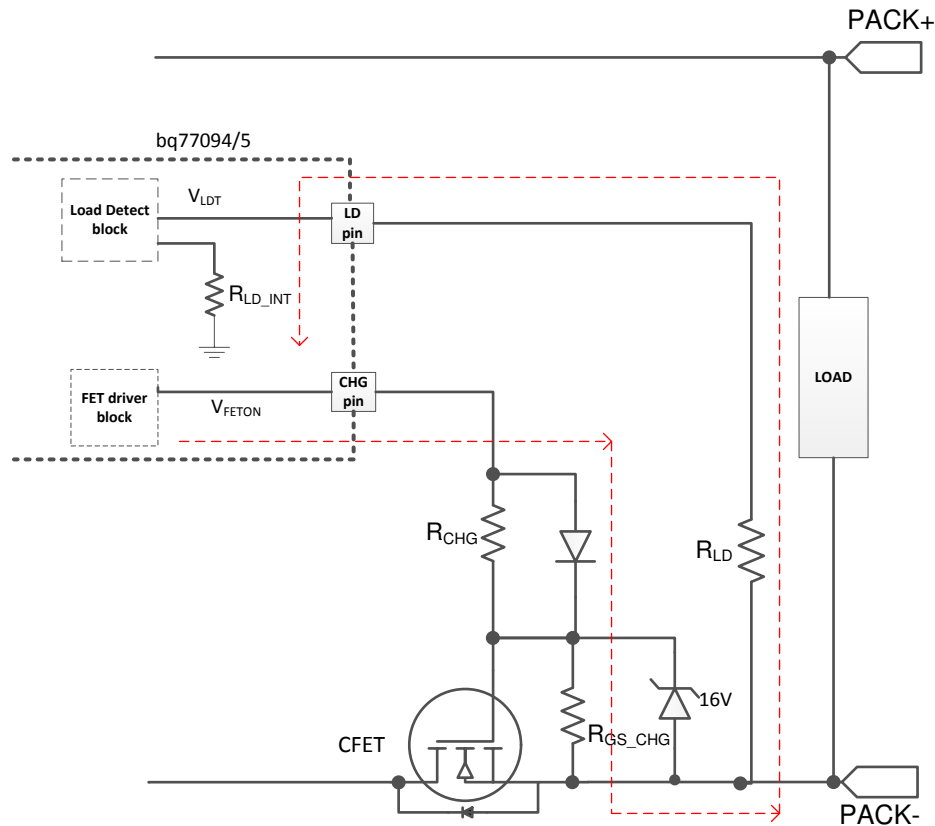


图 9-6. Load Detect Circuit During UV Fault

To ensure load removal is detected properly during a UV fault, TI recommends to use  $3.3\text{ M}\Omega$  for  $R_{GS\_CHG}$  (instead of a typical of  $1\text{ M}\Omega$  when load removal is NOT required for UV recovery).  $R_{CHG}$  can stay in  $1\text{ M}\Omega$  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 [图 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,  $10\text{ M}\Omega$ ) and the LD pin on the upper devices can be left floating.

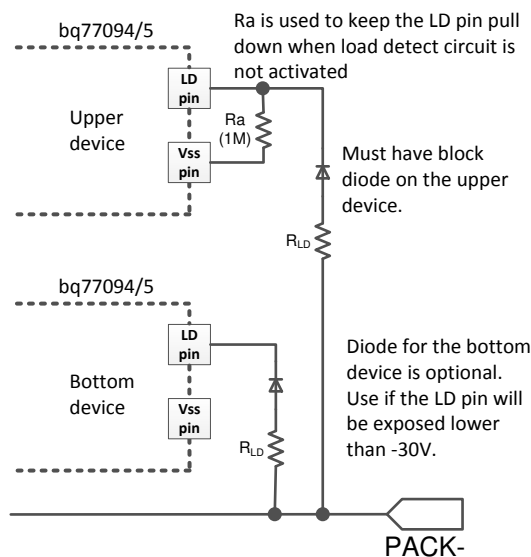


图 9-7. Simplified Circuit: LD Connection on Upper Device When Using for UV Fault Recovery

### 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  $10\text{-K}\Omega$   $R_{TS\_PU}$  and  $103\text{AT}$  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  $50^\circ\text{C}$  to  $55^\circ\text{C}$

The OTC protection can be set to  $45^\circ\text{C}$  or  $50^\circ\text{C}$ . When the device's OTC threshold is set to  $50^\circ\text{C}$ , it is referred to configure the  $V_{OTC}$  parameter to 29.38% of  $V_{TB}$  (typical), with the assumption of  $R_{TS\_PU} = 10\text{ K}\Omega$  and  $R_{TS} = 103\text{AT}$  or similar NTC (which the NTC resistance at  $50^\circ\text{C} = 4.16\text{ K}\Omega$ ). 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  $103\text{AT}$  NTC resistance at  $55^\circ\text{C}$  is  $3.536\text{ K}\Omega$ . By changing the  $R_{TS\_PU}$  from  $10\text{ K}\Omega$  to  $8.5\text{ K}\Omega$ , users can scale the actual OTC temperature trip point from  $50^\circ\text{C}$  to  $55^\circ\text{C}$ . Because the  $R_{TS\_PU}$  value is smaller, this change affects all the other temperature trip points and scales OTD, UTC, and UTD to  $\sim 5^\circ\text{C}$  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.

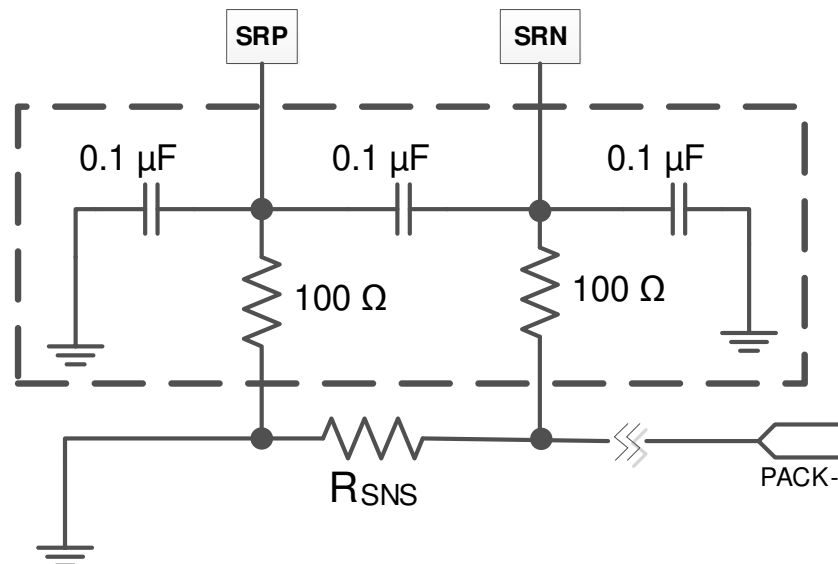


图 9-8. Optional Filters Improve Current Measurement

### 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  $3\text{ m}\Omega$  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

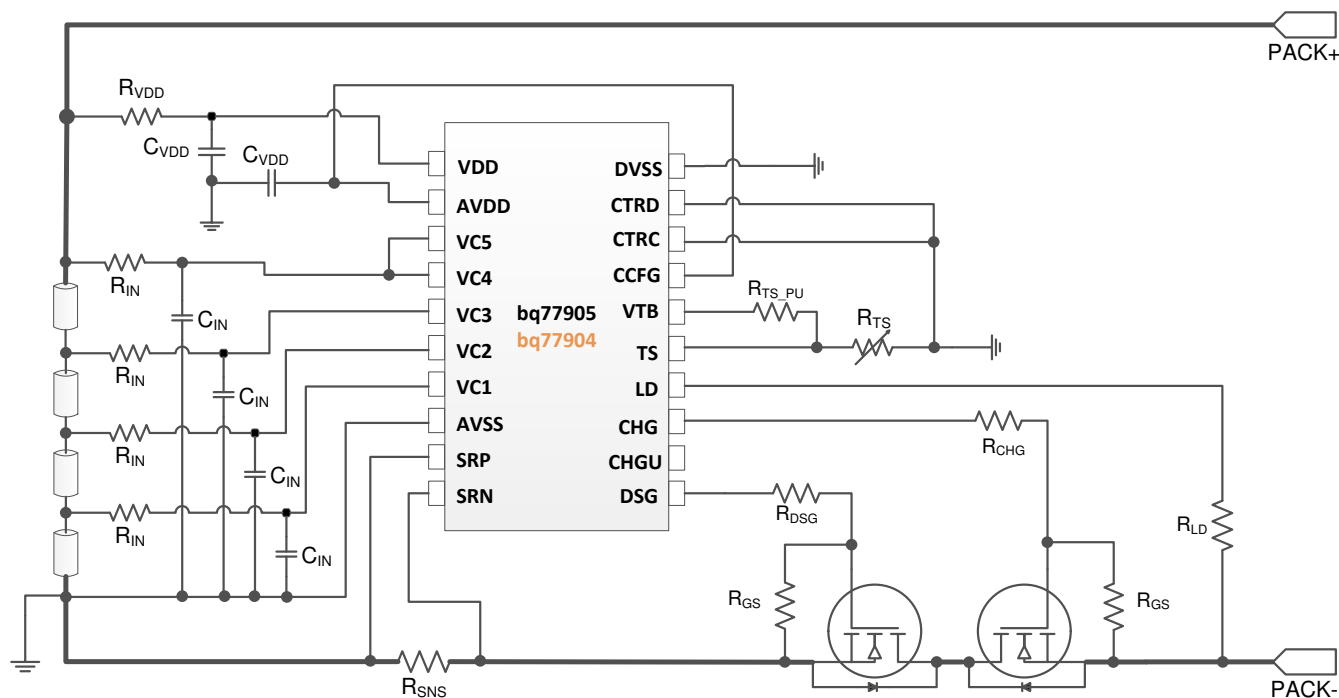
on or off within a 1-mV to 3-mV range. With a 3-m $\Omega$  sense resistor, it is about 330 mA to 1 A. As this behavior is due to noise from the system, the FET toggling behavior usually occurs right at the typical 2-mV state comparator threshold. As current increases or decreases from the typical value, 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



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图 9-9. BQ77904 and BQ77905 with Four Cells

### 9.2.1 Design Requirements

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

表 9-1. Design Parameters

| PARAMETER | DESCRIPTION                                      | VALUES                |
|-----------|--------------------------------------------------|-----------------------|
| $R_{IN}$  | Cell voltage sensing (VCx pins) filter resistor  | 1 k $\Omega$ $\pm$ 5% |
| $C_{IN}$  | Cell voltage sensing (VCx pins) filter capacitor | 0.1 $\mu$ F $\pm$ 10% |
| $R_{VDD}$ | Supply voltage filter resistor                   | 1 k $\Omega$ $\pm$ 5% |



**表 9-1. Design Parameters (continued)**

| PARAMETER                               | DESCRIPTION                                                                                                                                                |                                                                                                                   | VALUES                        |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|-------------------------------|
| C <sub>VDD</sub>                        | Supply voltage filter capacitor                                                                                                                            |                                                                                                                   | 1 $\mu$ F $\pm$ 20%           |
| R <sub>TS</sub>                         | NTC thermistor                                                                                                                                             |                                                                                                                   | 103AT, 10 k $\Omega$ $\pm$ 3% |
| R <sub>TS_PU</sub>                      | Thermistor pullup resistor to VTB pin, assuming using 103AT NTC or NTC with similar resistance-temperature characteristics                                 |                                                                                                                   | 10 k $\Omega$ $\pm$ 1%        |
| R <sub>GS_CHG</sub>                     | CHG FET gate-source resistor                                                                                                                               | Load removal is enabled for UV recovery.                                                                          | 3.3 M $\Omega$ $\pm$ 5%       |
|                                         |                                                                                                                                                            | Load removal is disabled for UV recovery.                                                                         | 1 M $\Omega$ $\pm$ 5%         |
| R <sub>GS_DSG</sub>                     | DSG FET gate-source resistor                                                                                                                               |                                                                                                                   | 1 M $\Omega$ $\pm$ 5%         |
| R <sub>CHG</sub>                        | CHG gate resistor                                                                                                                                          | System designers should adjust this parameter to meet the desired FET rise/fall time.                             | 1 k $\Omega$ $\pm$ 5%         |
|                                         |                                                                                                                                                            | If additional components are used to protect the CHG FET and/or to enable load removal detection for UV recovery. | 1 M $\Omega$ $\pm$ 5%         |
| R <sub>DSG</sub>                        | DSG gate resistor, system designers should adjust this parameter to meet the desired FET rise/fall time.                                                   |                                                                                                                   | 4.5 k $\Omega$ $\pm$ 5%       |
| R <sub>CTRC</sub> and R <sub>CTRD</sub> | CTRC and CTRD current limit resistor                                                                                                                       |                                                                                                                   | 10 M $\Omega$ $\pm$ 5%        |
| R <sub>LD</sub>                         | LD resistor for load removal detection                                                                                                                     |                                                                                                                   | 450 K $\Omega$ $\pm$ 5%       |
| R <sub>SNS</sub>                        | Current sense resistor for current protection. System designers should change this parameter according to the application current protection requirements. |                                                                                                                   | 1 m $\Omega$ $\pm$ 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<sub>TS\_PU</sub> may be used for the application. Refer to the actual temperature detection threshold voltage to determine the R<sub>TS\_PU</sub> 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 LiCoO<sub>2</sub> 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- $\mu$ s 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:

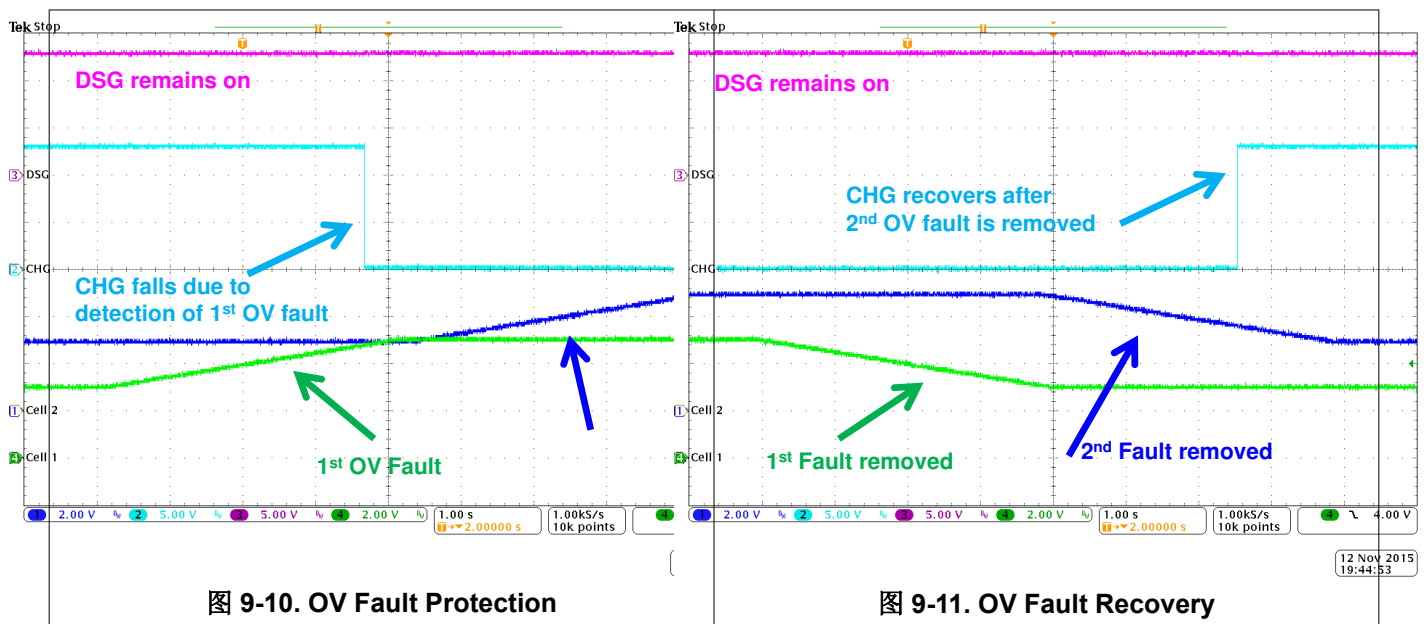
1. Start the schematic.
  - A 36-V pack using LiCoO<sub>2</sub> cells requires 10-S configuration; thus, two BQ77905 devices in a stackable configuration is needed.

- Follow the 10-S reference schematic in this document. Follow the recommended design parameters listed in the [§ 9.2.1](#) section of this document.
  - The power FET used in this type of application usually has an absolute of 20 V V<sub>GS</sub>. For a 36-V pack design, TI recommends to use the additional components to protect the CHG FET V<sub>GS</sub>. See the [§ 9.1.1.4](#) section for details.
  - Because load removal for UV recovery is required, a 3-M $\Omega$  R<sub>GS\_CHG</sub> should be used for the schematic.
- Decide the value of the sense resistor, R<sub>SNS</sub>.
    - When selecting the value of R<sub>SNS</sub>, ensure the voltage drop across SRP and SRN is within the available current protection threshold range.
    - In this example, select R<sub>SNS</sub> = 1 m $\Omega$  (any value  $\leq$  2 m $\Omega$  will work in this example).
  - Determine all of the BQ77905 protection configurations (see [表 9-2](#)).
  - Review the available released or preview devices in the [§ 5](#) section to determine if a suitable option is available. If not, contact TI representative for further assistance.

**表 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) | —          | —                     | (V <sub>Cx</sub> - V <sub>Cx-1</sub> ) > 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 $\mu$ s  | 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



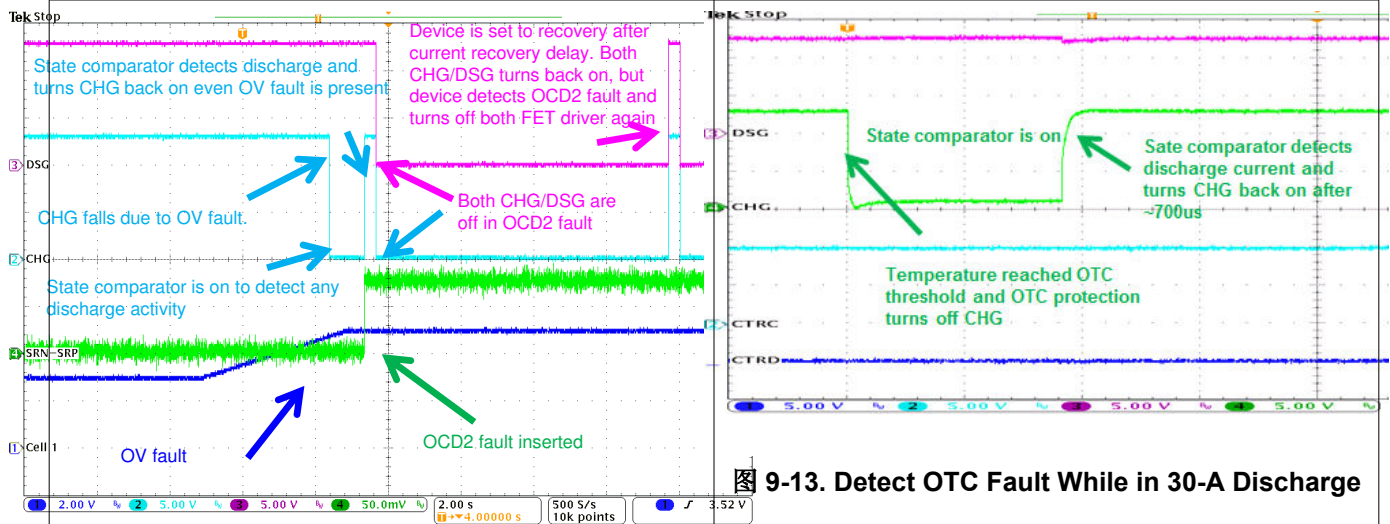


图 9-12. OV and OCD2 Faults Protection

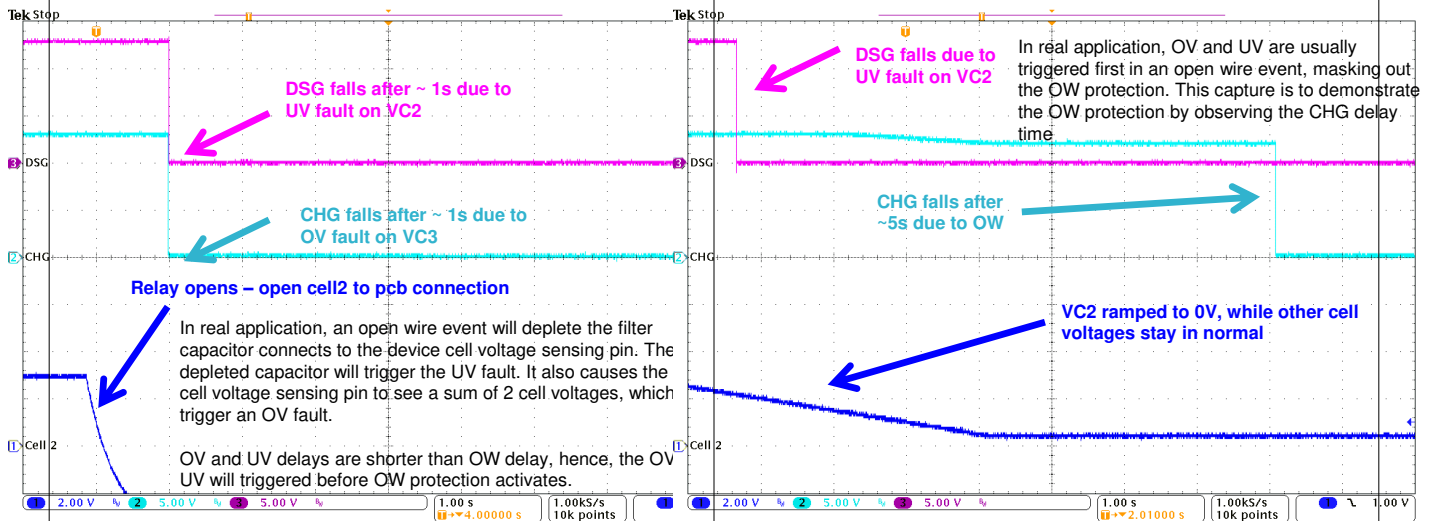


图 9-14. OW Fault Protection—Open Cell2 To PCB Connection

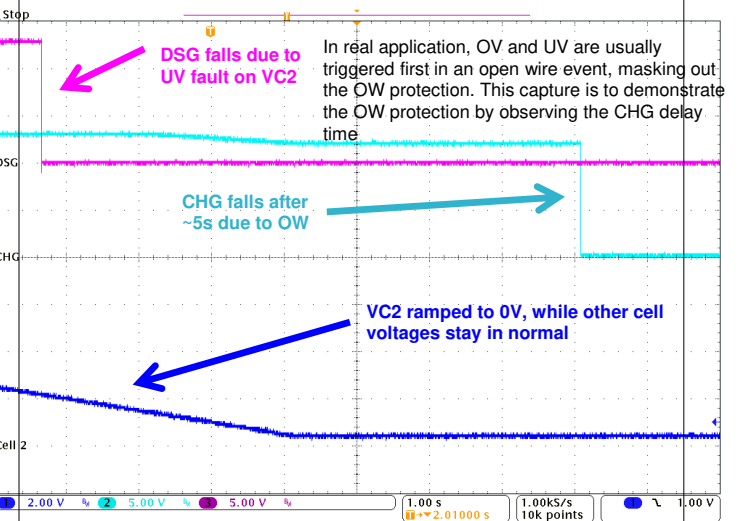


图 9-15. OW Fault Protection—Ramping Down Cell2 Voltage

### 9.3 System Examples

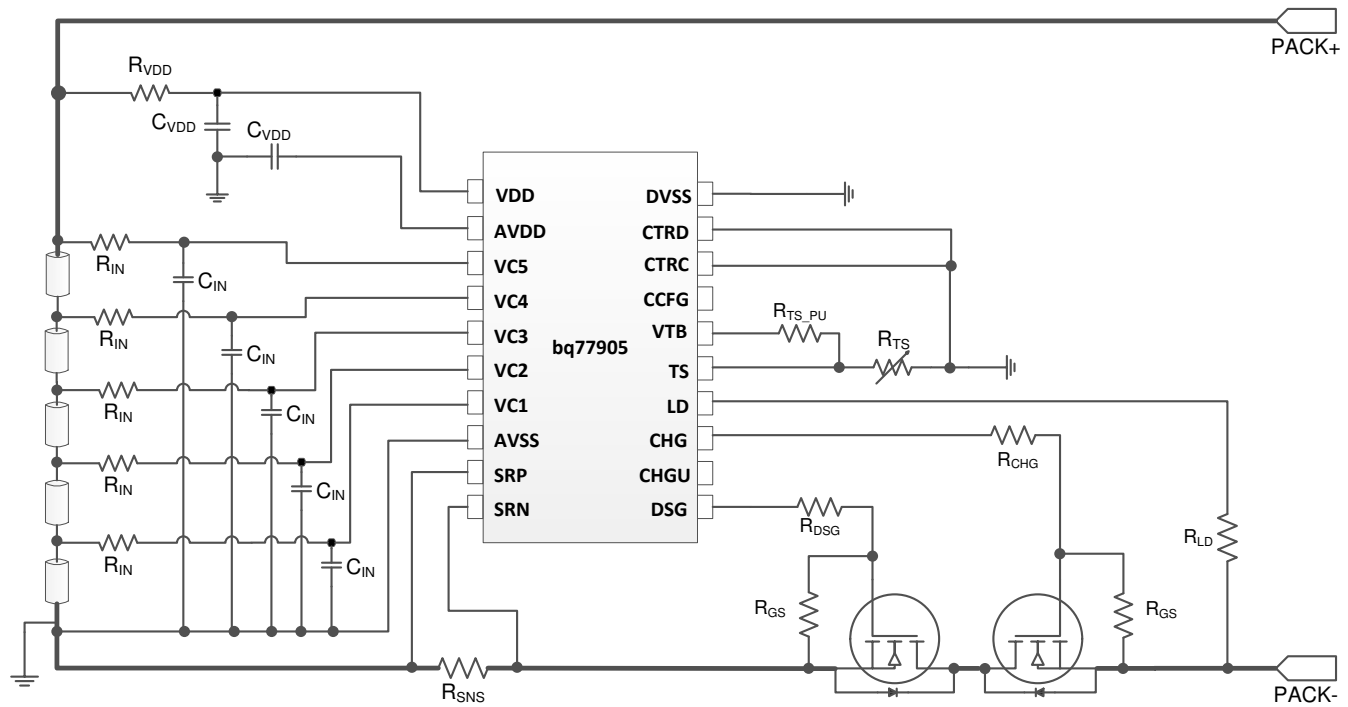


图 9-16. BQ77905 with Five Cells

## 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.

## 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

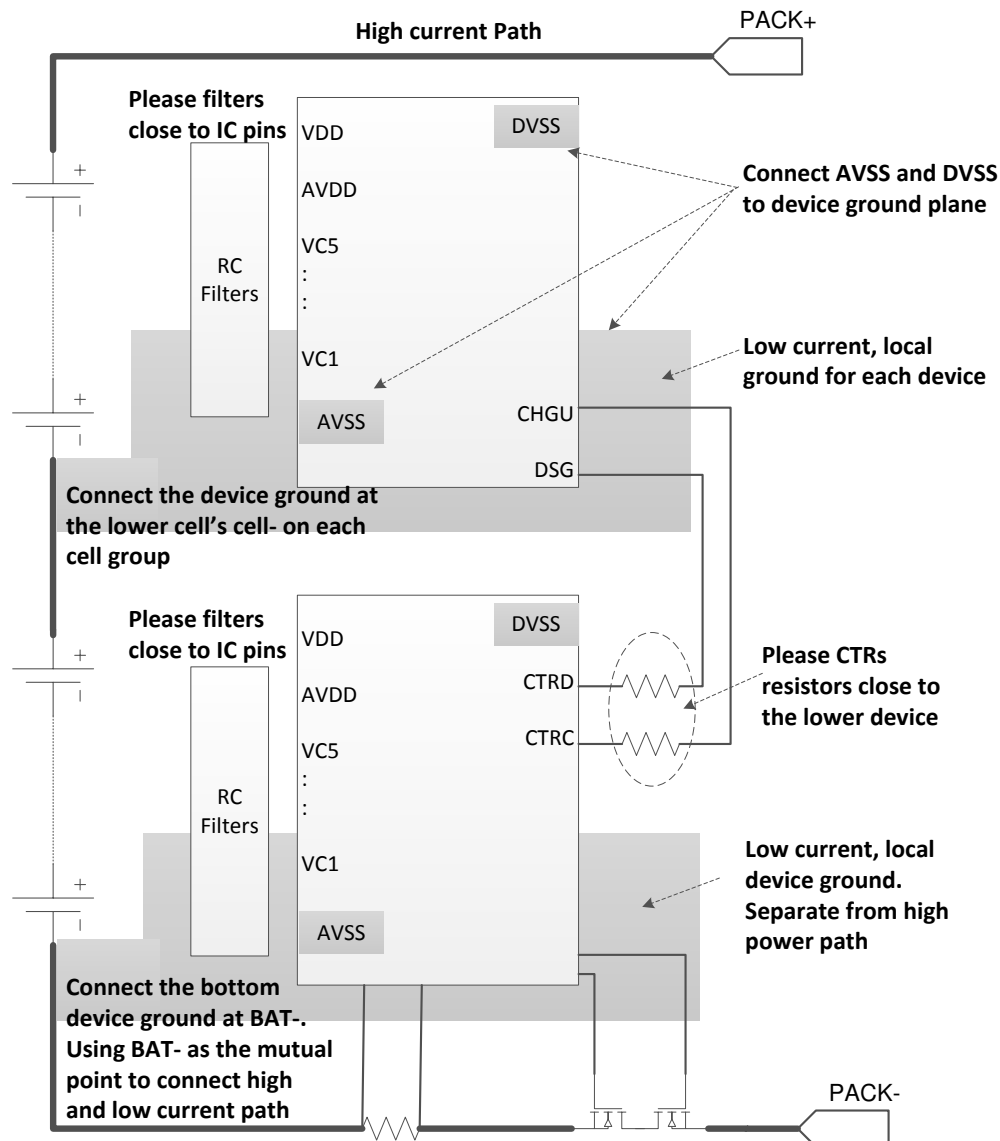


图 11-1. Layout Example

## 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.

表 12-1. Related Links

| PARTS   | PRODUCT FOLDER             | ORDER NOW                  | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|---------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| BQ77904 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| BQ77905 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

### 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.

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### 12.4 Trademarks

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### 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.

**PACKAGING INFORMATION**

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">BQ7790400PW</a>  | 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            |
| <a href="#">BQ7790400PWR</a> | 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            |
| <a href="#">BQ7790500PW</a>  | 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            |
| <a href="#">BQ7790500PWR</a> | 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            |
| <a href="#">BQ7790502PW</a>  | 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            |
| <a href="#">BQ7790502PWR</a> | 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            |
| <a href="#">BQ7790503PW</a>  | 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            |
| <a href="#">BQ7790503PWR</a> | 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            |
| <a href="#">BQ7790505PW</a>  | 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            |
| <a href="#">BQ7790505PWR</a> | 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            |
| <a href="#">BQ7790508PW</a>  | 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            |
| <a href="#">BQ7790508PWR</a> | 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            |
| <a href="#">BQ7790509PW</a>  | 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            |
| <a href="#">BQ7790509PWR</a> | 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            |
| <a href="#">BQ7790511PW</a>  | Active        | Production           | TSSOP (PW)   20 | 70   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | B7790511            |



| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| BQ7790511PW.A                | Active        | Production           | TSSOP (PW)   20 | 70   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | B7790511            |
| <a href="#">BQ7790511PWR</a> | 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            |
| <a href="#">BQ7790512PW</a>  | 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            |
| <a href="#">BQ7790512PWR</a> | 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            |
| <a href="#">BQ7790518PW</a>  | 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            |
| <a href="#">BQ7790518PWR</a> | 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            |
| <a href="#">BQ7790521PW</a>  | 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            |
| <a href="#">BQ7790521PWR</a> | 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            |
| <a href="#">BQ7790522PW</a>  | 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            |
| <a href="#">BQ7790522PWR</a> | 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            |

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

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

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

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



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

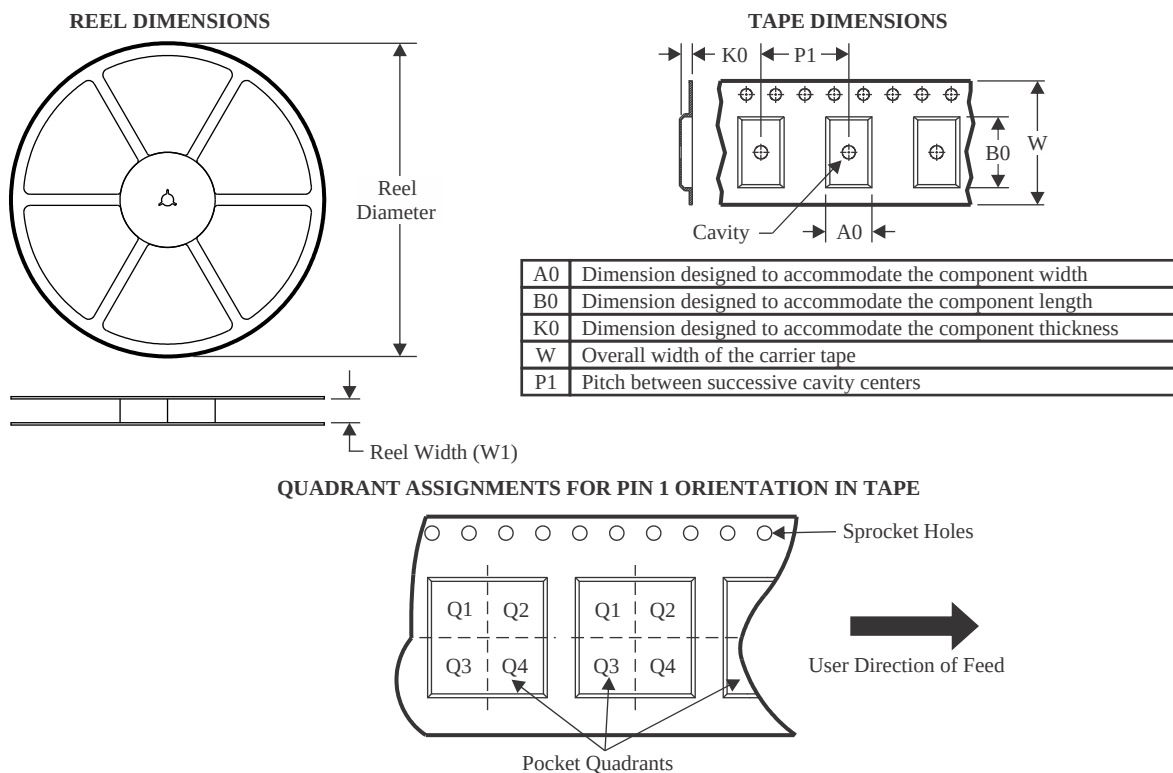
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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.

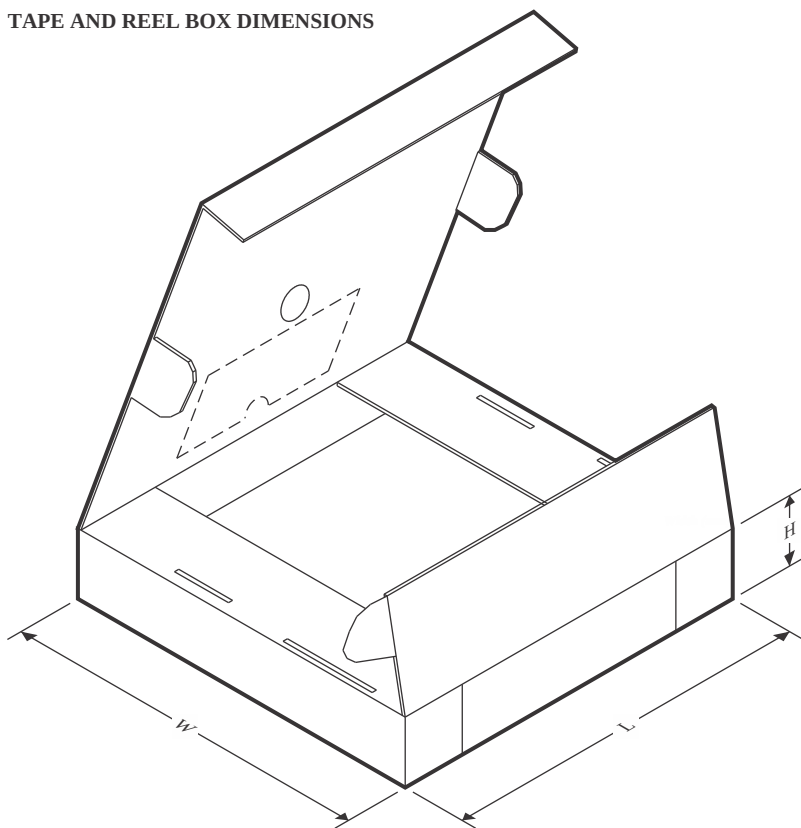
## TAPE AND REEL INFORMATION



\*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            |

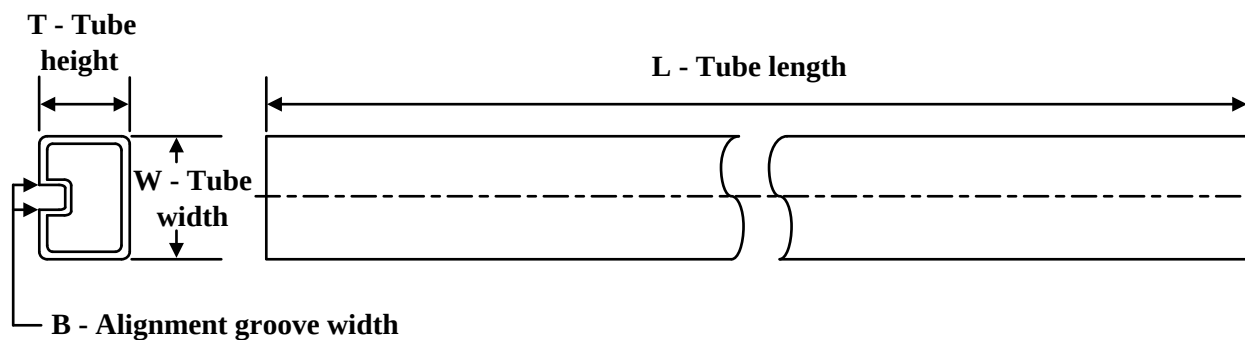
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

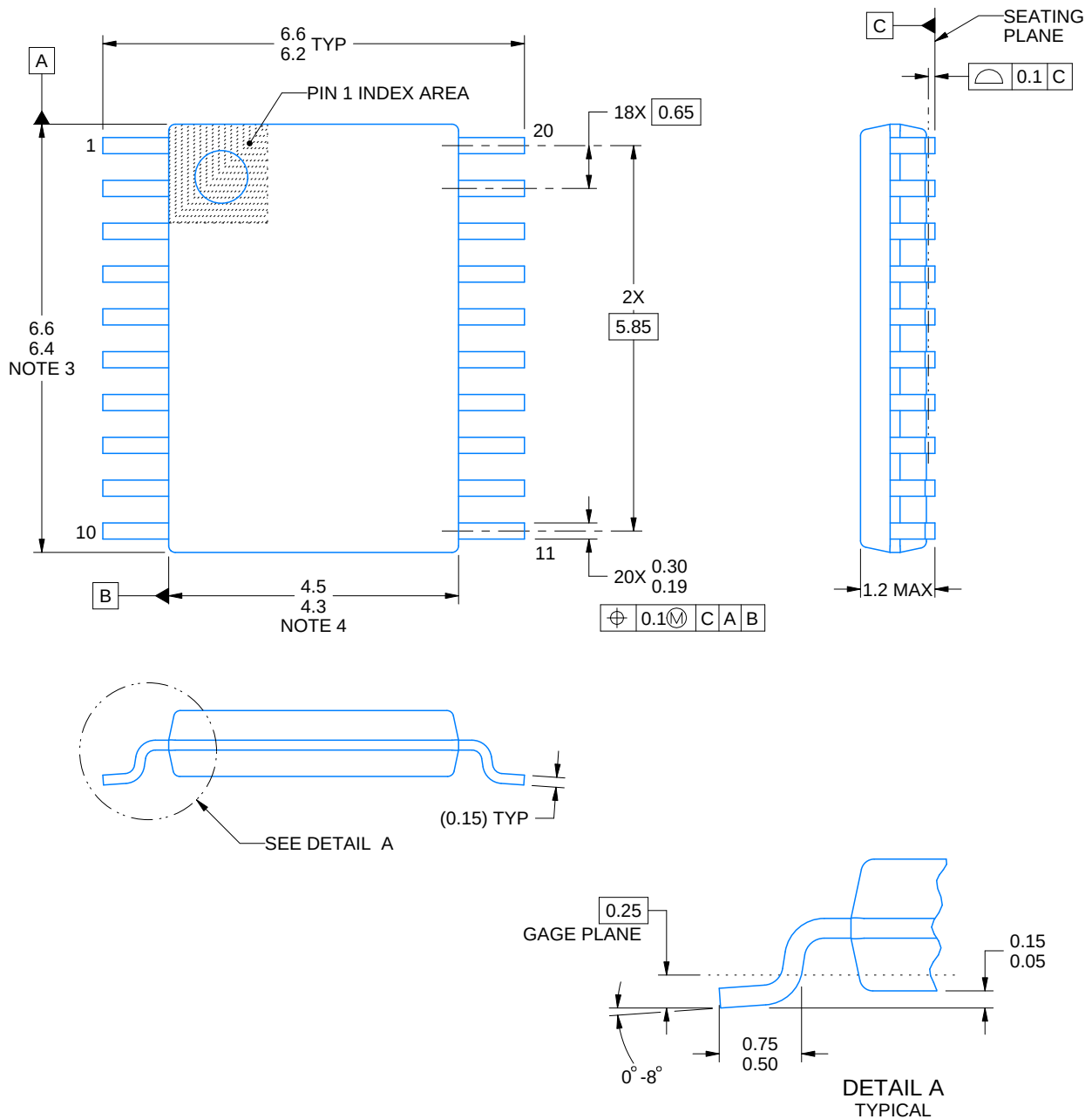
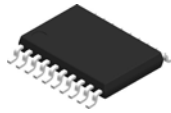
| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ7790400PWR | TSSOP        | PW              | 20   | 2000 | 350.0       | 350.0      | 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    |



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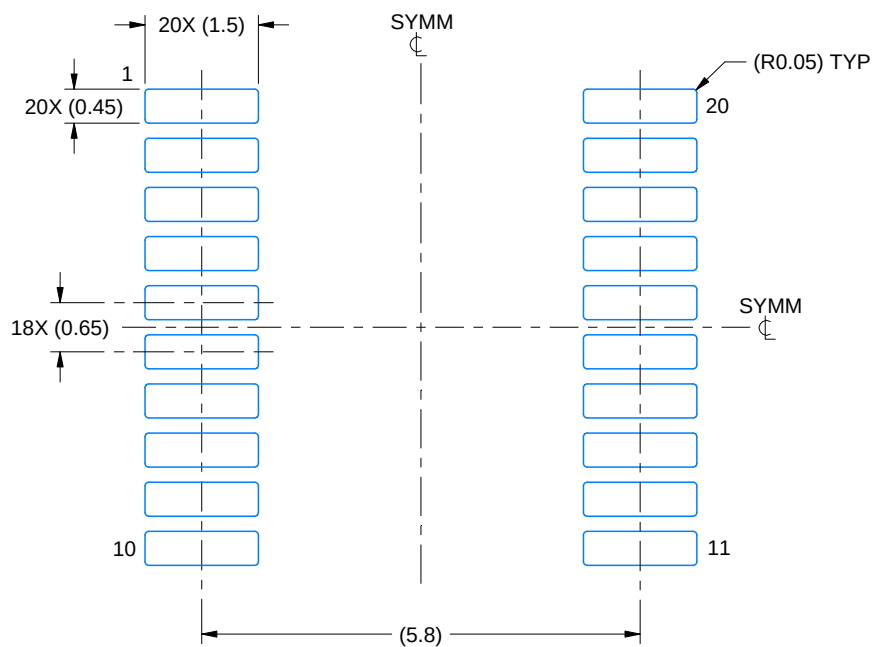
## NOTES:

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.

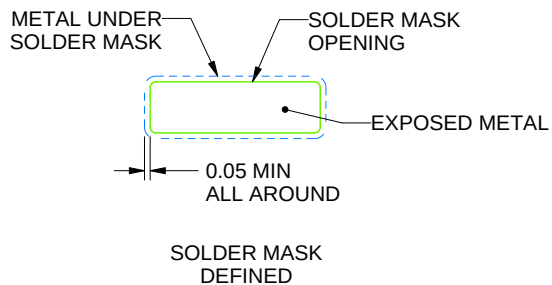
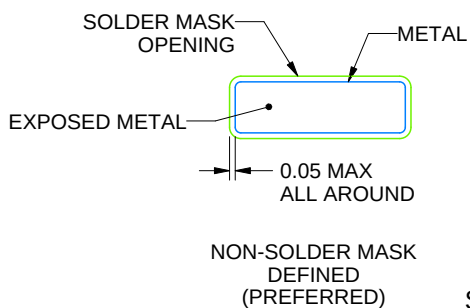
**PW0020A**

**TSSOP - 1.2 mm max height**

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



## SOLDER MASK DETAILS

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NOTES: (continued)

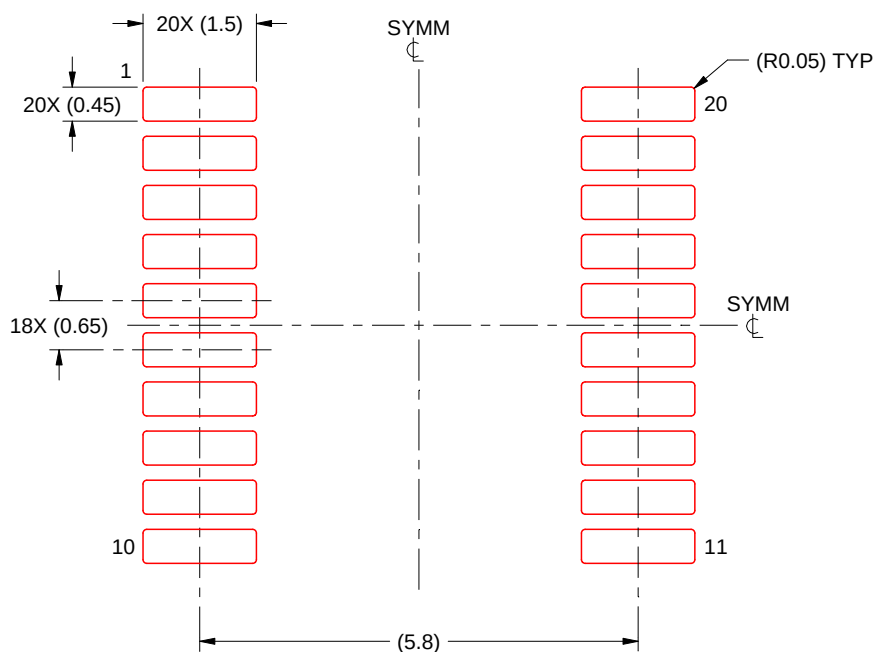
6. Publication IPC-7351 may have alternate designs.  
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

PW0020A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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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最后更新日期：2025 年 10 月