

# bq3050适用于 2、3 和 4 节串联锂离子电池的 CEDV 电量监测计和电池组管理器

## 1 特性

- 完全集成的 2 节、3 节和 4 节串联的锂离子或者锂聚合物电池组管理器和保护
- 高级补偿放电终点电压 (CEDV) 测量
- 高侧 N 沟道保护场效应晶体管 (FET) 驱动器
- 集成的预充电 FET
- 集成的电池均衡管理
- 低功耗模式
  - 低功率: < 180μA
  - 睡眠模式 < 76μA
- 全面的可编程保护 功能
  - 电压
  - 电流
  - 温度
- 精密的充电算法
  - 日本电子与信息技术工业协会 (JEITA)
  - 增强型充电
  - 自适应充电
- 支持 2 线制系统管理总线 (SMBus) v1.1 接口
- 安全散列算法 (SHA-1) 认证
- 紧凑封装: 38 引线薄型小尺寸封装 (TSSOP)

## 2 应用

- 笔记本电脑和上网本
- 医疗与测试设备
- 便携式仪表

## 4 简化电路原理图

## 3 说明

德州仪器 (TI) bq3050 补偿放电终点电压 (CEDV) 电量监测计和电池组管理器是一款单芯片解决方案, 针对 2、3 和 4 节串联锂离子和锂聚合物电池组提供保护、认证和数据采集等一系列丰富的功能。

通过使用其集成的高性能模拟外设, bq3050 器件测量并保存锂离子或者锂聚合物电池的可用容量、电压、电流、温度、和其它关键参数, 并通过 SMBus v1.1 兼容接口将这些信息报告给系统主机控制器。

bq3050 在过压、欠压、过热、和过度充电情况下提供基于软件的第一级和第二级安全保护, 以及对放电过流, 充放电短路情况下基于硬件的保护。

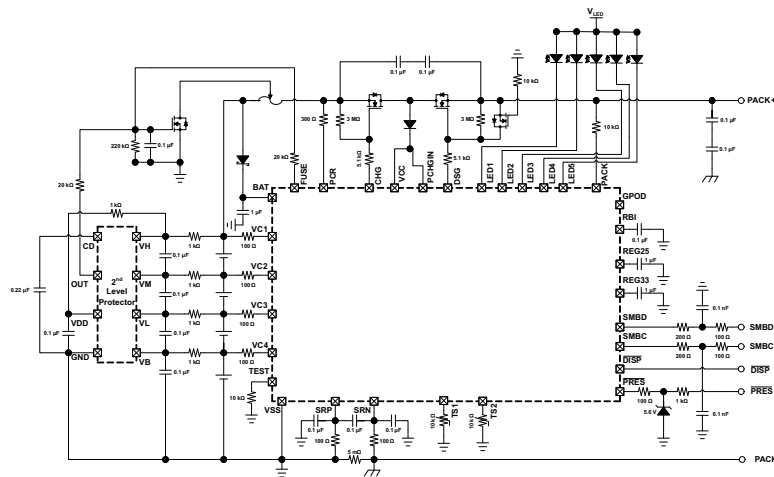
具有用于认证码存储的安全内存的 SHA-1 认证能够毫无疑问地识别真正的电池组。

紧凑的 38 引脚 TSSOP 封装在大大降低解决方案成本并减小解决方案尺寸的同时, 最大限度地地为电池监测应用提供了功能性与 安全性。

器件信息<sup>(1)</sup>

| 器件型号   | 封装         | 封装尺寸 (标称值)      |
|--------|------------|-----------------|
| bq3050 | TSSOP (38) | 9.70mm x 4.40mm |

(1) 要了解所有可用封装, 请见数据表末尾的可订购产品附录。



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## 5 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

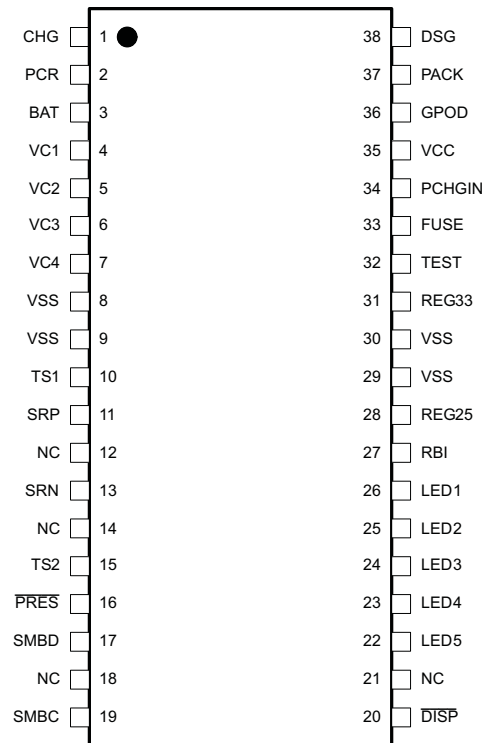
| Changes from Revision C (December 2014) to Revision D | Page |
|-------------------------------------------------------|------|
| • 已添加 社区资源部分                                          | 1    |
| • Changed SRP, SRN absolute maximum values            | 6    |
| • Changed all occurrences of "bq29412" to "bq294705"  | 25   |

| Changes from Revision B (October 2013) to Revision C                                 | Page |
|--------------------------------------------------------------------------------------|------|
| • 已添加 ESD 额定值表, 特性 描述部分, 器件功能模式, 应用和实施部分, 电源相关建议部分, 布局部分, 器件和文档支持部分, 以及机械、封装和可订购信息部分 | 1    |
| • Deleted range from Storage temperature description                                 | 6    |

| Changes from Revision A (June 2011) to Revision B | Page |
|---------------------------------------------------|------|
| • Changed TEST pin resistor value                 | 5    |

| <b>Changes from Original (January 2011) to Revision A</b> | <b>Page</b>        |
|-----------------------------------------------------------|--------------------|
| • Changed TS2 pin number .....                            | <a href="#">4</a>  |
| • Changed schematic .....                                 | <a href="#">23</a> |
| • Changed Block Diagram.....                              | <a href="#">34</a> |

## 6 Pin Configuration and Functions



**Pin Functions**

| PIN NAME | PIN NUMBER | TYPE <sup>(1)</sup> | DESCRIPTION                                                                                                              |
|----------|------------|---------------------|--------------------------------------------------------------------------------------------------------------------------|
| CHG      | 1          | O                   | Charge N-FET gate drive                                                                                                  |
| PCR      | 2          | O                   | Internal Precharge FET output                                                                                            |
| BAT      | 3          | P                   | Alternate power source                                                                                                   |
| VC1      | 4          | I                   | Sense input for positive voltage of top most cell in stack and cell balancing input for top most cell in stack           |
| VC2      | 5          | I                   | Sense input for positive voltage of third lowest cell in stack and cell balancing input for third lowest cell in stack   |
| VC3      | 6          | I                   | Sense input for positive voltage of second lowest cell in stack and cell balancing input for second lowest cell in stack |
| VC4      | 7          | I                   | Sense input for positive voltage of lowest cell in stack and cell balancing input for lowest cell in stack               |
| VSS      | 8          | P                   | Device ground                                                                                                            |
| VSS      | 9          | P                   | Device ground                                                                                                            |
| TS1      | 10         | AI                  | Temperature sensor 1 thermistor input                                                                                    |
| SRP      | 11         | AI                  | Differential Coulomb Counter input                                                                                       |
| NC       | 12         | —                   | Not internally connected. Connect to VSS.                                                                                |
| SRN      | 13         | AI                  | Differential Coulomb Counter input                                                                                       |
| NC       | 14         | —                   | Not internally connected. Connect to VSS.                                                                                |
| TS2      | 15         | AI                  | Temperature sensor 2 thermistor input                                                                                    |
| PRES     | 16         | I                   | Host system present input                                                                                                |
| SMBD     | 17         | I/OD                | SMBus v1.1 data line                                                                                                     |
| NC       | 18         | —                   | Not internally connected. Connect to VSS.                                                                                |
| SMBC     | 19         | I/OD                | SMBus v1.1 clock line                                                                                                    |
| DISP     | 20         | I                   | Display active input                                                                                                     |

(1) P = Power Connection, O = Digital Output, AI = Analog Input, I = Digital Input, I/OD = Digital Input/Output

**Pin Functions (continued)**

| PIN NAME | PIN NUMBER | TYPE <sup>(1)</sup> | DESCRIPTION                                     |
|----------|------------|---------------------|-------------------------------------------------|
| NC       | 21         | —                   | Not internally connected. Connect to VSS.       |
| LED5     | 22         | O                   | LED display constant current sink               |
| LED4     | 23         | O                   | LED display constant current sink               |
| LED3     | 24         | O                   | LED display constant current sink               |
| LED2     | 25         | O                   | LED display constant current sink               |
| LED1     | 26         | O                   | LED display constant current sink               |
| RBI      | 27         | P                   | RAM backup                                      |
| REG25    | 28         | P                   | 2.5-V regulator output                          |
| VSS      | 29         | P                   | Device ground                                   |
| VSS      | 30         | P                   | Device ground                                   |
| REG33    | 31         | P                   | 3.3-V regulator output                          |
| TEST     | 32         | —                   | Test pin, connect to VSS through 10-kΩ resistor |
| FUSE     | 33         | O                   | Fuse drive                                      |
| PCHGIN   | 34         | I                   | Internal Precharge FET input                    |
| VCC      | 35         | P                   | Power supply voltage                            |
| GPOD     | 36         | I/OD                | High voltage general purpose I/O                |
| PACK     | 37         | P                   | Alternate power source                          |
| DSG      | 38         | O                   | Discharge N-FET gate drive                      |

## 7 Specifications

### 7.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                                                  |                                              | MIN             | MAX                                                                           | UNIT |
|--------------------------------------------------|----------------------------------------------|-----------------|-------------------------------------------------------------------------------|------|
| Supply voltage, $V_{MAX}$                        | VCC, PCHGIN, PCR, TEST, PACK w.r.t. $V_{SS}$ | −0.3            | 34                                                                            | V    |
| Input voltage, $V_{IN}$                          | VC1, BAT                                     | $V_{VC2} - 0.3$ | $V_{VC2} + 8.5\text{ V}$<br>or 34 V,<br>whichever is lower                    | V    |
|                                                  | VC2                                          | $V_{VC3} - 0.3$ | $V_{VC3} + 8.5\text{ V}$                                                      |      |
|                                                  | VC3                                          | $V_{VC4} - 0.3$ | $V_{VC4} + 8.5\text{ V}$                                                      |      |
|                                                  | VC4                                          | $V_{SRP} - 0.3$ | $V_{SRP} + 8.5\text{ V}$                                                      |      |
|                                                  | SRP, SRN                                     | −0.5            | 0.5                                                                           |      |
|                                                  | LED1, LED2, LED3, LED4, LED5, SMBC, SMBD     | $V_{SS} - 0.3$  | 6.0                                                                           |      |
|                                                  | DISP, TS1, TS2, PRES                         | −0.3 V          | $V_{REG25} + 0.3\text{ V}$                                                    |      |
| Output voltage, $V_O$                            | DSG                                          | −0.3            | $V_{PACK} + 20\text{ V}$ or<br>$V_{SS} + 34\text{ V}$ ,<br>whichever is lower | V    |
|                                                  | CHG                                          | −0.3            | $V_{BAT} + 20\text{ V}$ or<br>$V_{SS} + 34\text{ V}$ ,<br>whichever is lower  |      |
|                                                  | GPOD, FUSE                                   | −0.3            | 34                                                                            |      |
|                                                  | RBI, REG25                                   | −0.3            | 2.75                                                                          |      |
|                                                  | REG33                                        | −0.3            | 5.0                                                                           |      |
| Maximum VSS current, $I_{SS}$                    |                                              | 50              |                                                                               | mA   |
| Current for cell balancing, $I_{CB}$             |                                              |                 | 10                                                                            |      |
| Functional Temperature, $T_{FUNC}$               |                                              | −40             | 110                                                                           | °C   |
| Lead temperature (soldering, 10 s), $T_{SOLDER}$ |                                              |                 | 300                                                                           | °C   |
| Storage temperature, $T_{stg}$                   |                                              | −65             | 150                                                                           | °C   |

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

### 7.2 ESD Ratings

|                                     |                                                                                |                             | VALUE | UNIT |
|-------------------------------------|--------------------------------------------------------------------------------|-----------------------------|-------|------|
| $V_{(ESD)}$ Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | All pins except pins 3 to 6 | ±2000 | V    |
|                                     |                                                                                | Pins 3 to 6                 | ±1000 |      |
|                                     | Charged device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> |                             | ±500  |      |

- (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

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

|                |                          | MIN | NOM | MAX           | UNIT |
|----------------|--------------------------|-----|-----|---------------|------|
| Supply voltage | VCC, PACK, PCHGIN, PCR   |     |     | 25            | V    |
|                | BAT                      | 3.8 |     | $V_{VC2} + 5$ |      |
| $V_{STARTUP}$  | Start up voltage at PACK | 3   |     | 5.5           | V    |

## Recommended Operating Conditions (continued)

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

|             |                              |                                  | MIN       | NOM | MAX           | UNIT             |
|-------------|------------------------------|----------------------------------|-----------|-----|---------------|------------------|
| $V_{IN}$    | Input voltage range          | VC1, BAT                         | $V_{VC2}$ |     | $V_{VC2} + 5$ | V                |
|             |                              | VC2                              | $V_{VC3}$ |     | $V_{VC3} + 5$ |                  |
|             |                              | VC3                              | $V_{VC4}$ |     | $V_{VC4} + 5$ |                  |
|             |                              | VC4                              | $V_{SRP}$ |     | $V_{SRP} + 5$ |                  |
|             |                              | $VCn - VC(n+1)$ , (n=1, 2, 3, 4) | 0         |     | 5             |                  |
|             |                              | PACK                             |           |     | 25            |                  |
|             |                              | SRP to SRN                       | -0.2      |     | 0.2           |                  |
| $C_{REG33}$ | External 3.3-V REG capacitor |                                  | 1         |     |               | $\mu\text{F}$    |
| $C_{REG25}$ | External 2.5-V REG capacitor |                                  | 1         |     |               | $\mu\text{F}$    |
| $T_{OPR}$   | Operating temperature        |                                  | -40       |     | 85            | $^\circ\text{C}$ |

## 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | bq3050      | UNIT |
|-------------------------------|----------------------------------------------|-------------|------|
|                               |                                              | TSSOP (DBT) |      |
|                               |                                              | 38 PINS     |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 64.2        | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case(top) thermal resistance     | 16.5        | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 31.2        | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 0.3         | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 26.9        | °C/W |
| R <sub>θJC(bot)</sub>         | Junction-to-case(bottom) thermal resistance  | n/a         | °C/W |

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

## 7.5 Electrical Characteristics: Supply Current

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER |          | TEST CONDITIONS                        | MIN | TYP | MAX | UNIT          |
|-----------|----------|----------------------------------------|-----|-----|-----|---------------|
| $I_{CC}$  | Normal   | CHG on, DSG on, no Flash write         |     | 410 |     | $\mu\text{A}$ |
|           | Sleep    | CHG on, DSG on, no SBS communication   |     | 160 |     |               |
|           |          | CHG off, DSG off, no SBS communication |     | 80  |     |               |
|           | Shutdown |                                        |     |     | 3.7 |               |

## 7.6 Power-On Reset (POR)

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER |                              | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------|------------------------------|-----------------|-----|-----|-----|------|
| $V_{IT-}$ | Negative-going voltage input | At REG25        | 1.9 | 2   | 2.1 | V    |
| $V_{HYS}$ | POR Hysteresis               | At REG25        | 65  | 125 | 165 | mV   |

## 7.7 Wake From Sleep

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                                      | TEST CONDITIONS | MIN | TYP  | MAX | UNIT             |
|----------------------------------------------------------------|-----------------|-----|------|-----|------------------|
| $V_{WAKE}$ $V_{WAKE}$ Threshold                                | $V_{WAKE}$      | 0.2 | 1.2  | 2   | mV               |
|                                                                | $V_{WAKE}$      | 0.4 | 2.4  | 3.6 |                  |
|                                                                | $V_{WAKE}$      | 2   | 5    | 6.8 |                  |
|                                                                | $V_{WAKE}$      | 5.3 | 10   | 13  |                  |
| $V_{WAKE\_TCO}$ Temperature drift of $V_{WAKE}$ accuracy       |                 |     | 0.5% |     | $^\circ\text{C}$ |
| $t_{WAKE}$ Time from application of current and wake of bq3050 |                 |     | 0.2  | 1   | ms               |

## 7.8 RBI RAM Backup

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                    | TEST CONDITIONS                                                                           | MIN | TYP | MAX  | UNIT |
|----------------------------------------------|-------------------------------------------------------------------------------------------|-----|-----|------|------|
| $I_{(RBI)}$ RBI data-retention input current | $VRBI > V_{(RBI)MIN}$ , $V_{CC} < V_{IT}$                                                 |     | 20  | 1100 | nA   |
|                                              | $VRBI > V_{(RBI)MIN}$ , $V_{CC} < V_{IT}$ , $T_A = 0^\circ\text{C}$ to $70^\circ\text{C}$ |     |     | 500  |      |
| $V_{(RBI)}$ RBI data-retention voltage       |                                                                                           | 1   |     |      | V    |

## 7.9 3.3-V Regulator

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                                       | TEST CONDITIONS                                                                | MIN | TYP  | MAX | UNIT |
|-----------------------------------------------------------------|--------------------------------------------------------------------------------|-----|------|-----|------|
| $V_{REG33}$ Regulator output voltage                            | $3.8\text{ V} < V_{CC}$ or $BAT \leq 5\text{ V}$ , $I_{CC} \leq 4\text{ mA}$   | 2.4 |      | 3.5 | V    |
|                                                                 | $5\text{ V} < V_{CC}$ or $BAT \leq 6.8\text{ V}$ , $I_{CC} \leq 13\text{ mA}$  | 3.1 | 3.3  | 3.5 |      |
|                                                                 | $6.8\text{ V} < V_{CC}$ or $BAT \leq 20\text{ V}$ , $I_{CC} \leq 30\text{ mA}$ | 3.1 | 3.3  | 3.5 |      |
| $I_{REG33}$ Regulator output current                            |                                                                                | 2   |      |     | mA   |
| $\Delta V_{(VDDTEMP)}$ Regulator output change with temperature | $V_{CC}$ or $BAT = 14.4\text{ V}$ , $I_{REG33} = 2\text{ mA}$                  |     | 0.2% |     |      |
| $\Delta V_{(VDDLIN)}$ Line regulation                           | $V_{CC}$ or $BAT = 14.4\text{ V}$ , $I_{REG33} = 2\text{ mA}$                  |     | 1    | 13  | mV   |
| $\Delta V_{(VDDLLOAD)}$ Load regulation                         | $V_{CC}$ or $BAT = 14.4\text{ V}$ , $I_{REG33} = 2\text{ mA}$                  |     | 5    | 18  | mV   |
| $I_{(REG33MAX)}$ Current limit                                  | $V_{CC}$ or $BAT = 14.4\text{ V}$ , $V_{REG33} = 3\text{ V}$                   |     |      | 70  | mA   |
|                                                                 | $V_{CC}$ or $BAT = 14.4\text{ V}$ , $V_{REG33} = 0\text{ V}$                   |     |      | 33  |      |

## 7.10 2.5-V Regulator

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                |                                          | TEST CONDITIONS                                 | MIN   | TYP | MAX  | UNIT  |    |
|--------------------------|------------------------------------------|-------------------------------------------------|-------|-----|------|-------|----|
| V <sub>REG25</sub>       | Regulator output voltage                 | I <sub>REG25</sub> = 10 mA                      | 2.35  | 2.5 | 2.55 | V     |    |
| I <sub>REG25</sub>       | Regulator output current                 |                                                 | 3     |     |      | mA    |    |
| ΔV <sub>(VDDTEMP)</sub>  | Regulator output change with temperature | VCC or BAT = 14.4 V, I <sub>REG25</sub> = 2 mA  | 0.25% |     |      |       |    |
| ΔV <sub>(VDDLIN)</sub>   | Line regulation                          | VCC or BAT = 14.4 V, I <sub>REG25</sub> = 2 mA  | 1     |     |      | 4 mV  |    |
| ΔV <sub>(VDDLLOAD)</sub> | Load regulation                          | VCC or BAT = 14.4 V, I <sub>REG25</sub> = 2 mA  | 20    |     |      | 40 mV |    |
| I <sub>(REG33MAX)</sub>  | Current limit                            | VCC or BAT = 14.4 V, V <sub>REG25</sub> = 2.3 V |       |     |      | 65    | mA |
|                          |                                          | VCC or BAT = 14.4 V, V <sub>REG25</sub> = 0 V   |       |     |      | 23    |    |

## 7.11 $\overline{\text{DISP}}$ , $\overline{\text{PRES}}$ , $\overline{\text{SMBD}}$ , $\overline{\text{SMBC}}$

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                             |                                          | TEST CONDITIONS                                                                        | MIN   | TYP | MAX  | UNIT |
|-------------------------------------------------------|------------------------------------------|----------------------------------------------------------------------------------------|-------|-----|------|------|
| V <sub>IH</sub>                                       | High-level input                         | $\overline{\text{DISP}}$ , $\overline{\text{PRES}}$ , SMBD, SMBC                       | 2.0   |     |      | V    |
| V <sub>IL</sub>                                       | Low-level input                          | $\overline{\text{DISP}}$ , $\overline{\text{PRES}}$ , SMBD, SMBC                       |       |     | 0.8  | V    |
| V <sub>OL</sub>                                       | Low-level output voltage                 | SMBD, SMBC                                                                             |       |     | 0.4  | V    |
| C <sub>IN</sub>                                       | Input capacitance                        | $\overline{\text{DISP}}$ , $\overline{\text{PRES}}$ , SMBD, SMBC                       |       | 5   |      | pF   |
| I <sub>LKG</sub>                                      | Input leakage current                    | $\overline{\text{DISP}}$ , $\overline{\text{PRES}}$ , SMBD, SMBC                       |       |     | 1    | μA   |
| I <sub>WPU</sub>                                      | Weak Pull Up Current                     | $\overline{\text{PRES}}$ , V <sub>OH</sub> = V <sub>REG25</sub> − 0.5 V                | 60    |     | 120  | μA   |
| I <sub>(<math>\overline{\text{DISP}}</math>)</sub>    | $\overline{\text{DISP}}$ source currents | $\overline{\text{DISP}}$ active, $\overline{\text{DISP}}$ = V <sub>REG25</sub> − 0.6 V | −3    |     |      | mA   |
| I <sub>LKG(<math>\overline{\text{DISP}}</math>)</sub> | $\overline{\text{DISP}}$ leakage current | $\overline{\text{DISP}}$ inactive                                                      | −0.22 |     | 0.22 | μA   |
| R <sub>PD(SMBx)</sub>                                 | SMBC, SMBD Pull-Down                     | T <sub>A</sub> = −40 to 100°C                                                          | 550   | 775 | 1000 | kΩ   |

## 7.12 CHG, DSG FET Drive

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER             | TEST CONDITIONS                                                                                                                                                                                                    | MIN  | TYP | MAX  | UNIT          |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|------|---------------|
| $V_{(\text{FETON})}$  | $V_{\text{O}(\text{FETONDSG})} = V_{(\text{DSG})} - V_{\text{PACK}}$ , $V_{\text{GS}}$ connect $10\text{ M}\Omega$ , $V_{CC} 3.8\text{ V}$ to $8.4\text{ V}$                                                       | 8    | 9.7 | 12   | V             |
|                       | $V_{\text{O}(\text{FETONDSG})} = V_{(\text{DSG})} - V_{\text{PACK}}$ , $V_{\text{GS}}$ connect $10\text{ M}\Omega$ , $V_{CC} > 8.4\text{ V}$                                                                       | 9    | 11  | 12   |               |
|                       | $V_{\text{O}(\text{FETONCHG})} = V_{(\text{CHG})} - V_{\text{BAT}}$ , $V_{\text{GS}}$ connect $10\text{ M}\Omega$ , $V_{CC} 3.8\text{ V}$ to $8.4\text{ V}$                                                        | 8    | 9.7 | 12   |               |
|                       | $V_{\text{O}(\text{FETONCHG})} = V_{(\text{CHG})} - V_{\text{BAT}}$ , $V_{\text{GS}}$ connect $10\text{ M}\Omega$ , $V_{CC} > 8.4\text{ V}$                                                                        | 9    | 11  | 12   |               |
| $V_{(\text{FETOFF})}$ | $V_{\text{O}(\text{FETOFFDSG})} = V_{(\text{DSG})} - V_{\text{PACK}}$                                                                                                                                              | -0.4 |     | 0.4  | V             |
|                       | $V_{\text{O}(\text{FETOFFCHG})} = V_{(\text{CHG})} - V_{\text{BAT}}$                                                                                                                                               | -0.4 |     | 0.4  |               |
| $t_r$                 | $C_L = 4700\text{ pF}$<br>$R_G = 5.1\text{ k}\Omega$<br>$V_{CC} < 8.4$<br>$V_{\text{DSG}}: V_{\text{BAT}}$ to $V_{\text{BAT}} + 4\text{ V}$<br>$V_{\text{CHG}}: V_{\text{PACK}}$ to $V_{\text{PACK}} + 4\text{ V}$ |      | 800 | 1400 | $\mu\text{s}$ |
|                       | $C_L = 4700\text{ pF}$<br>$R_G = 5.1\text{ k}\Omega$<br>$V_{CC} > 8.4$<br>$V_{\text{DSG}}: V_{\text{BAT}}$ to $V_{\text{BAT}} + 4\text{ V}$<br>$V_{\text{CHG}}: V_{\text{PACK}}$ to $V_{\text{PACK}} + 4\text{ V}$ |      | 200 | 500  |               |

## CHG, DSG FET Drive (continued)

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER       | TEST CONDITIONS                                                                                                                                                                                          | MIN | TYP | MAX | UNIT          |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|---------------|
| $t_f$ Fall time | $C_L = 4700\text{ pF}$<br>$R_G = 5.1\text{ k}\Omega$<br>$V_{DSG}: V_{BAT} + V_{O(FETONDSG)} \text{ to } V_{BAT} + 1\text{ V}$<br>$V_{CHG}: V_{PACK} + V_{O(FETONCHG)} \text{ to } V_{PACK} + 1\text{ V}$ |     | 80  | 200 | $\mu\text{s}$ |

## 7.13 Internal Precharge Limiting

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                      | TEST CONDITIONS                                               | MIN | TYP | MAX | UNIT     |
|------------------------------------------------|---------------------------------------------------------------|-----|-----|-----|----------|
| $I_{PCHGMAX}$ Maximum Precharge current        | 3-cell and 4-cell configuration                               |     |     | 100 | mA       |
| $R_{PCHG\_RDSON}$ Internal Precharge FET RDSON | $V_{DS(PRECHG)} \geq 1\text{ V}$ , $V_{CC} < 8.4\text{ V}$    | 30  | 55  | 85  | $\Omega$ |
|                                                | $V_{DS(PRECHG)} \geq 1\text{ V}$ , $V_{CC} \geq 8.4\text{ V}$ | 15  | 30  | 55  |          |

## 7.14 GPOD

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                              | TEST CONDITIONS        | MIN | TYP | MAX      | UNIT |
|----------------------------------------|------------------------|-----|-----|----------|------|
| $V_{PU\_GPOD}$ GPOD Pull-Up Voltage    |                        |     |     | $V_{CC}$ | V    |
| $V_{OL\_GPOD}$ GPOD Output Voltage Low | $I_{OL} = 1\text{ mA}$ | 0.3 |     |          | V    |

## 7.15 FUSE

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                                      | TEST CONDITIONS                                                                                               | MIN | TYP | MAX | UNIT          |
|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----|-----|-----|---------------|
| $V_{OH(FUSE)}$ High-level FUSE output                          | $V_{CC} = 3.8\text{ V}$ to $9\text{ V}$                                                                       | 2.4 |     | 8.5 | V             |
|                                                                | $V_{CC} = 9\text{ V}$ to $25\text{ V}$                                                                        | 7   | 8   | 9   |               |
| $V_{IH(FUSE)}$ Weak pullup current in off state <sup>(1)</sup> |                                                                                                               | 2.8 |     |     | V             |
|                                                                |                                                                                                               |     | 100 |     | nA            |
| $t_{R(FUSE)}$ FUSE output rise time                            | $C_L = 1\text{ nF}$ , $V_{CC} = 9\text{ V}$ to $25\text{ V}$ ,<br>$V_{OH(FUSE)} = 0\text{ V}$ to $5\text{ V}$ |     | 5   | 20  | $\mu\text{s}$ |
| $Z_{O(FUSE)}$ FUSE output impedance                            |                                                                                                               |     | 2   | 5   | k $\Omega$    |

(1) Verified by design. Not production tested.

## 7.16 LED5, LED4, LED3, LED2, LED1

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                | TEST CONDITIONS                           | MIN | TYP | MAX | UNIT          |
|------------------------------------------|-------------------------------------------|-----|-----|-----|---------------|
| $C_{IN}$ Input capacitance               |                                           |     | 5   |     | pF            |
| $I_{LKG}$ Input leakage current          |                                           |     |     | 1   | $\mu\text{A}$ |
| $I_{OL}$ Low-level output current        | $V_{OL} = 0.4\text{ V}$ ,<br>3 mA setting | 2.5 | 3.5 | 4.5 | mA            |
|                                          | $V_{OL} = 0.4\text{ V}$ ,<br>4 mA setting | 3.0 | 4.5 | 6.0 |               |
|                                          | $V_{OL} = 0.4\text{ V}$ ,<br>5 mA setting | 3.5 | 5.5 | 7.5 |               |
| $I_{LEDX}$ Current matching between LEDx |                                           |     | 0.1 |     | mA            |

## 7.17 Coulomb Counter

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                     | TEST CONDITIONS           | MIN   | TYP  | MAX  | UNIT                         |
|-------------------------------|---------------------------|-------|------|------|------------------------------|
| Input voltage range           | SRP – SRN                 | –0.20 |      | 0.25 | V                            |
| Conversion time               | Single conversion         |       | 250  |      | ms                           |
| Resolution (no missing codes) |                           | 16    |      |      | Bits                         |
| Effective resolution          | Single conversion, signed | 15    |      |      | Bits                         |
| Offset error                  | Post calibrated           |       | 10   |      | $\mu\text{V}$                |
| Offset error drift            |                           |       | 0.3  | 0.5  | $\mu\text{V}/^\circ\text{C}$ |
| Full-scale error              |                           | –0.8% | 0.2% | 0.8% |                              |
| Full-scale error drift        |                           |       |      | 150  | PPM/ $^\circ\text{C}$        |
| Effective input resistance    |                           | 2.5   |      |      | $\text{m}\Omega$             |

## 7.18 VC1, VC2, VC3, VC4

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER   | TEST CONDITIONS                                        | MIN   | TYP | MAX | UNIT     |
|-------------|--------------------------------------------------------|-------|-----|-----|----------|
| $V_{IN}$    | Input voltage range                                    | –0.20 |     | 8   | V        |
|             | Conversion time                                        |       | 32  |     | ms       |
|             | Resolution (no missing codes)                          | 16    |     |     | Bits     |
|             | Effective resolution                                   | 15    |     |     | Bits     |
| $R_{(BAL)}$ | $R_{DS(ON)}$ for internal FET at $V_{DS} > 2\text{ V}$ | 200   | 310 | 430 | $\Omega$ |
|             | $R_{DS(ON)}$ for internal FET at $V_{DS} > 4\text{ V}$ | 60    | 125 | 230 |          |

## 7.19 TS1, TS2

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                                          | TEST CONDITIONS               | MIN   | TYP  | MAX                    | UNIT                  |
|--------------------------------------------------------------------|-------------------------------|-------|------|------------------------|-----------------------|
| R Internal pullup resistor                                         |                               | 16.5  | 17.5 | 19                     | $\text{K}\Omega$      |
| $R_{DRIFT}$ Internal pullup resistor drift from $25^\circ\text{C}$ |                               |       |      | 200                    | PPM/ $^\circ\text{C}$ |
| $R_{PAD}$ Internal pin pad resistance                              |                               |       | 84   |                        | $\Omega$              |
| $V_{IN}$                                                           | Input voltage range           | –0.20 |      | $0.8 \times V_{REG25}$ | V                     |
|                                                                    | Conversion time               |       | 16   |                        | ms                    |
|                                                                    | Resolution (no missing codes) | 16    |      |                        | Bits                  |
|                                                                    | Effective resolution          | 11    | 12   |                        | Bits                  |

## 7.20 Internal Temperature Sensor

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER    | TEST CONDITIONS               | MIN  | TYP | MAX  | UNIT                       |
|--------------|-------------------------------|------|-----|------|----------------------------|
| $V_{(TEMP)}$ | Temperature sensor voltage    | –1.9 | –2  | –2.1 | $\text{mV}/^\circ\text{C}$ |
|              | Conversion time               |      | 16  |      | ms                         |
|              | Resolution (no missing codes) | 16   |     |      | Bits                       |
|              | Effective resolution          | 11   | 12  |      | Bits                       |

## 7.21 Internal Thermal Shutdown

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER     |                                 | TEST CONDITIONS | MIN | TYP | MAX | UNIT             |
|---------------|---------------------------------|-----------------|-----|-----|-----|------------------|
| $T_{MAX1}$    | Maximum PCHG temperature        |                 | 110 |     | 150 | $^\circ\text{C}$ |
| $T_{MAX2}$    | Maximum REG33 temperature       |                 | 125 |     | 175 | $^\circ\text{C}$ |
| $T_{RECOVER}$ | Recovery hysteresis temperature |                 |     | 10  |     | $^\circ\text{C}$ |
| $t_{PROTECT}$ | Protection time                 |                 |     | 5   |     | $\mu\text{s}$    |

## 7.22 High-Frequency Oscillator

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER   |                                   | TEST CONDITIONS                                 | MIN | TYP          | MAX | UNIT |
|-------------|-----------------------------------|-------------------------------------------------|-----|--------------|-----|------|
| $f_{(OSC)}$ | Operating frequency of CPU Clock  |                                                 |     | 4.194        |     | MHz  |
| $f_{(EIO)}$ | Frequency error <sup>(1)(2)</sup> | $T_A = -20^\circ\text{C}$ to $70^\circ\text{C}$ | -2% | $\pm 0.25\%$ | 2%  |      |
|             |                                   | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ | -3% | $\pm 0.25\%$ | 3%  |      |
| $t_{(SXO)}$ | Start-up time <sup>(3)</sup>      | $T_A = -25^\circ\text{C}$ to $85^\circ\text{C}$ |     | 3            | 6   | ms   |

(1) The frequency error is measured from 4.194 MHz.

(2) The frequency drift is included and measured from the trimmed frequency at  $V_{REG25} = 2.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

(3) The start-up time is defined as the time it takes for the oscillator output frequency to be  $\pm 3\%$  when the device is already powered.

## 7.23 Low-Frequency Oscillator

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                      | TEST CONDITIONS                                 | MIN   | TYP          | MAX  | UNIT          |
|------------------------------------------------|-------------------------------------------------|-------|--------------|------|---------------|
| $f_{(LOSC)}$ Operating frequency               |                                                 |       | 32.768       |      | kHz           |
| $f_{(LEIO)}$ Frequency error <sup>(1)(2)</sup> | $T_A = -20^\circ\text{C}$ to $70^\circ\text{C}$ | -1.5% | $\pm 0.25\%$ | 1.5% |               |
|                                                | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ | -2.5% | $\pm 0.25\%$ | 2.5% |               |
| $t_{(LSXO)}$ Start-up time <sup>(3)</sup>      | $T_A = -25^\circ\text{C}$ to $85^\circ\text{C}$ |       |              | 100  | $\mu\text{s}$ |

(1) The frequency drift is included and measured from the trimmed frequency at  $V_{CC} = 2.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

(2) The frequency error is measured from 32.768 kHz.

(3) The start-up time is defined as the time it takes for the oscillator output frequency to be  $\pm 3\%$ .

## 7.24 Internal Voltage Reference

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                         | TEST CONDITIONS                                 | MIN   | TYP      | MAX   | UNIT                  |
|---------------------------------------------------|-------------------------------------------------|-------|----------|-------|-----------------------|
| $V_{REF}$ Internal reference voltage              |                                                 | 1.215 | 1.225    | 1.230 | V                     |
| $V_{REF\_DRIFT}$ Internal reference voltage drift | $T_A = -25^\circ\text{C}$ to $85^\circ\text{C}$ |       | $\pm 80$ |       | PPM/ $^\circ\text{C}$ |
|                                                   | $T_A = 0^\circ\text{C}$ to $60^\circ\text{C}$   |       | $\pm 50$ |       |                       |

## 7.25 Flash

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER <sup>(1)</sup>                            | TEST CONDITIONS                                 | MIN | TYP | MAX | UNIT  |
|-----------------------------------------------------|-------------------------------------------------|-----|-----|-----|-------|
| Data retention                                      |                                                 | 10  |     |     | Year  |
| Flash programming write-cycles                      | Data Flash                                      | 20k |     |     | Cycle |
|                                                     | Instruction Flash                               | 1k  |     |     |       |
| $I_{CC(PROG\_DF)}$ Data Flash-write supply current  | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ |     | 3   | 4   | mA    |
| $I_{CC(ERASE\_DF)}$ Data Flash-erase supply current | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ |     | 3   | 18  | mA    |

(1) Verified by design. Not production tested.

## 7.26 OCD Current Protection

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER                                                        | TEST CONDITIONS                         | MIN  | TYP | MAX | UNIT          |
|------------------------------------------------------------------|-----------------------------------------|------|-----|-----|---------------|
| $V_{(OCD)}$ OCD detection threshold voltage range, typical       | $RSNS = 0$                              | 50   |     | 200 | mV            |
|                                                                  | $RSNS = 1$                              | 25   |     | 100 |               |
| $\Delta V_{(OCDT)}$ OCD detection threshold voltage program step | $RSNS = 0$                              |      | 10  |     | mV            |
|                                                                  | $RSNS = 1$                              |      | 5   |     |               |
| $V_{(OFFSET)}$ OCD offset                                        |                                         | -10  |     | 10  | mV            |
| $V_{(Scale\_Err)}$ OCD scale error                               |                                         | -10% |     | 10% |               |
| $t_{(OCDD)}$ Overcurrent in discharge delay                      |                                         | 1    |     | 31  | ms            |
| $t_{(OCDD\_STEP)}$ OCDD step options                             |                                         |      | 2   |     | ms            |
| $t_{(DETECT)}$ Current fault detect time                         | $VSRP - SRN = VTHRESH + 12.5\text{ mV}$ |      |     | 160 | $\mu\text{s}$ |
| $t_{ACC}$ Overcurrent and short-circuit delay time accuracy      | Accuracy of typical delay time          | -20% |     | 20% |               |

## 7.27 SCD1 Current Protection

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER            | TEST CONDITIONS                                   | MIN                            | TYP  | MAX  | UNIT          |
|----------------------|---------------------------------------------------|--------------------------------|------|------|---------------|
| $V_{(SDC1)}$         | SCD1 detection threshold voltage range, typical   | RSNS = 0                       |      | 450  | mV            |
|                      |                                                   | RSNS = 1                       |      | 225  |               |
| $\Delta V_{(SCD1T)}$ | SCD1 detection threshold voltage program step     | RSNS = 0                       | 50   |      | mV            |
|                      |                                                   | RSNS = 1                       | 25   |      |               |
| $V_{(OFFSET)}$       | SCD1 offset                                       |                                | -10  | 10   | mV            |
| $V_{(Scale\_Err)}$   | SCD1 scale error                                  |                                | -10% | 10%  |               |
| $t_{(SCD1D)}$        | Short-circuit in discharge delay                  | AFE.STATE_CNTL[SCDDx2] = 0     | 0    | 915  | $\mu\text{s}$ |
|                      |                                                   | AFE.STATE_CNTL[SCDDx2] = 1     | 0    | 1830 |               |
| $t_{(SCD1D\_STEP)}$  | SCD1D step options                                | AFE.STATE_CNTL[SCDDx2] = 0     | 61   |      | $\mu\text{s}$ |
|                      |                                                   | AFE.STATE_CNTL[SCDDx2] = 1     | 122  |      |               |
| $t_{(DETECT)}$       | Current fault detect time                         | VSRP – SRN = VTHRESH + 12.5 mV |      | 160  | $\mu\text{s}$ |
| $t_{ACC}$            | Overcurrent and short-circuit delay time accuracy | Accuracy of typical delay time |      | -20% | 20%           |

## 7.28 SCD2 Current Protection

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER            | TEST CONDITIONS                                   | MIN                            | TYP  | MAX  | UNIT          |
|----------------------|---------------------------------------------------|--------------------------------|------|------|---------------|
| $V_{(SDC2)}$         | SCD2 detection threshold voltage range, typical   | RSNS = 0                       |      | 450  | mV            |
|                      |                                                   | RSNS = 1                       |      | 225  |               |
| $\Delta V_{(SCD2T)}$ | SCD2 detection threshold voltage program step     | RSNS = 0                       | 50   |      | mV            |
|                      |                                                   | RSNS = 1                       | 25   |      |               |
| $V_{(OFFSET)}$       | SCD2 offset                                       |                                | -10  | 10   | mV            |
| $V_{(Scale\_Err)}$   | SCD2 scale error                                  |                                | -10% | 10%  |               |
| $t_{(SCD1D)}$        | Short-circuit in discharge delay                  | AFE.STATE_CNTL[SCDDx2] = 0     | 0    | 458  | $\mu\text{s}$ |
|                      |                                                   | AFE.STATE_CNTL[SCDDx2] = 1     | 0    | 915  |               |
| $t_{(SCD2D\_STEP)}$  | SCD2D step options                                | AFE.STATE_CNTL[SCDDx2] = 0     | 30.5 |      | $\mu\text{s}$ |
|                      |                                                   | AFE.STATE_CNTL[SCDDx2] = 1     | 61   |      |               |
| $t_{(DETECT)}$       | Current fault detect time                         | VSRP – SRN = VTHRESH + 12.5 mV |      | 160  | $\mu\text{s}$ |
| $t_{ACC}$            | Overcurrent and short-circuit delay time accuracy | Accuracy of typical delay time |      | -20% | 20%           |

## 7.29 SCC Current Protection

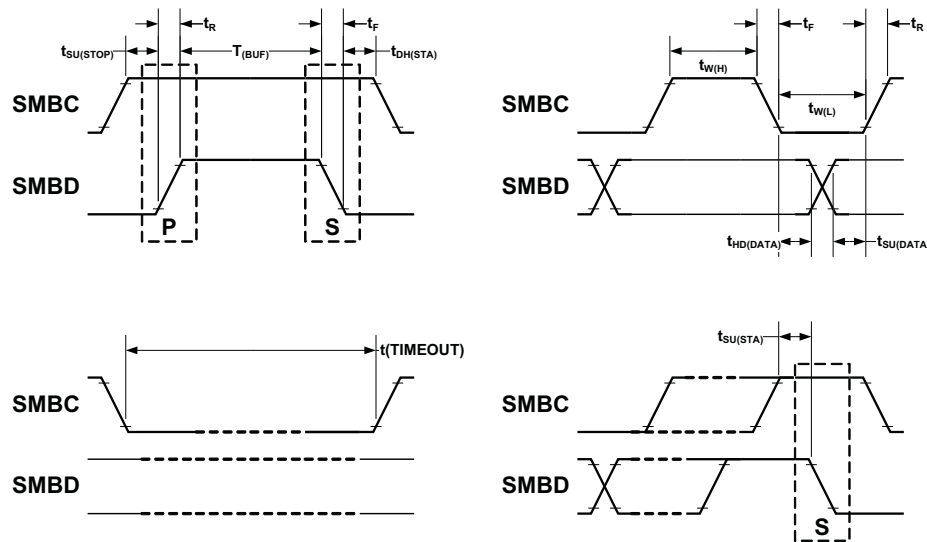
Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 14.4\text{ V}$ , Min/Max values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = 3.8\text{ V}$  to  $25\text{ V}$  (unless otherwise noted)

| PARAMETER            | TEST CONDITIONS                                   | MIN                            | TYP  | MAX  | UNIT          |
|----------------------|---------------------------------------------------|--------------------------------|------|------|---------------|
| $V_{(SCCT)}$         | SCC detection threshold voltage range, typical    | RSNS = 0                       |      | -300 | mV            |
|                      |                                                   | RSNS = 1                       |      | -225 |               |
| $\Delta V_{(SCCDT)}$ | SCC detection threshold voltage program step      | RSNS = 0                       | -50  |      | mV            |
|                      |                                                   | RSNS = 1                       | -25  |      |               |
| $V_{(OFFSET)}$       | SCC offset                                        |                                | -10  | 10   | mV            |
| $V_{(Scale\_Err)}$   | SCC scale error                                   |                                | -10% | 10%  |               |
| $t_{(SCCD)}$         | Short-circuit in charge delay                     |                                | 0    | 915  | ms            |
| $t_{(SCCD\_STEP)}$   | SCCD step options                                 |                                | 61   |      | ms            |
| $t_{(DETECT)}$       | Current fault detect time                         | VSRP – SRN = VTHRESH + 12.5 mV |      | 160  | $\mu\text{s}$ |
| $t_{ACC}$            | Overcurrent and short-circuit delay time accuracy | Accuracy of typical delay time |      | -20% | 20%           |

### 7.30 SBS Timing Requirements

|                |                                         |                                        | MIN | TYP  | MAX      | UNIT    |
|----------------|-----------------------------------------|----------------------------------------|-----|------|----------|---------|
| $f_{SMB}$      | SMBus operating frequency               | Slave mode, SMBC 50% duty cycle        | 10  |      | 100      | kHz     |
| $f_{MAS}$      | SMBus master clock frequency            | Master mode, no clock low slave extend |     | 51.2 |          | kHz     |
| $t_{BUF}$      | Bus free time between start and stop    |                                        | 4.7 |      |          | $\mu$ s |
| $t_{HD:STA}$   | Hold time after (repeated) start        |                                        | 4.0 |      |          | $\mu$ s |
| $t_{SU:STA}$   | Repeated start setup time               |                                        | 4.7 |      |          | $\mu$ s |
| $t_{SU:STO}$   | Stop setup time                         |                                        | 4.0 |      |          | $\mu$ s |
| $t_{HD:DAT}$   | Data hold time                          |                                        | 300 |      |          | ns      |
| $t_{SU:DAT}$   | Data setup time                         |                                        | 250 |      |          | ns      |
| $t_{TIMEOUT}$  | Error signal/detect                     | See <sup>(1)</sup>                     | 25  |      | 35       | ms      |
| $t_{LOW}$      | Clock low period                        |                                        | 4.7 |      |          | $\mu$ s |
| $t_{HIGH}$     | Clock high period                       | See <sup>(2)</sup>                     |     |      | Disabled |         |
| $t_{HIGH}$     | Clock high period                       | See <sup>(2)</sup>                     | 4.0 |      | 50       | $\mu$ s |
| $t_{LOW:SEXT}$ | Cumulative clock low slave extend time  | See <sup>(3)</sup>                     |     |      | 25       | ms      |
| $t_{LOW:MEXT}$ | Cumulative clock low master extend time | See <sup>(4)</sup>                     |     |      | 10       | ms      |
| $t_F$          | Clock/data fall time                    | See <sup>(5)</sup>                     |     |      | 300      | ns      |
| $t_R$          | Clock/data rise time                    | See <sup>(6)</sup>                     |     |      | 1000     | ns      |

- (1) The bq3050 times out when any clock low exceeds  $t_{TIMEOUT}$ .
- (2)  $t_{HIGH}$ , Max, is the minimum bus idle time. SMBC = 1 for  $t > 50 \mu$ s causes reset of any transaction involving bq3050 that is in progress. This specification is valid when the THIGH\_VAL=0. If THIGH\_VAL = 1, then the value of THIGH is set by THIGH\_1,2 and the time-out is not SMBus standard.
- (3)  $t_{LOW:SEXT}$  is the cumulative time a slave device is allowed to extend the clock cycles in one message from initial start to the stop.
- (4)  $t_{LOW:MEXT}$  is the cumulative time a master device is allowed to extend the clock cycles in one message from initial start to the stop.
- (5) Rise time  $t_R = V_{ILMAX} - 0.15$  to  $(V_{IHMIN} + 0.15)$
- (6) Fall time  $t_F = 0.9 V_{DD}$  to  $(V_{ILMAX} - 0.15)$



**Figure 1. SMBus Timing Diagram**

## 7.31 Typical Characteristics

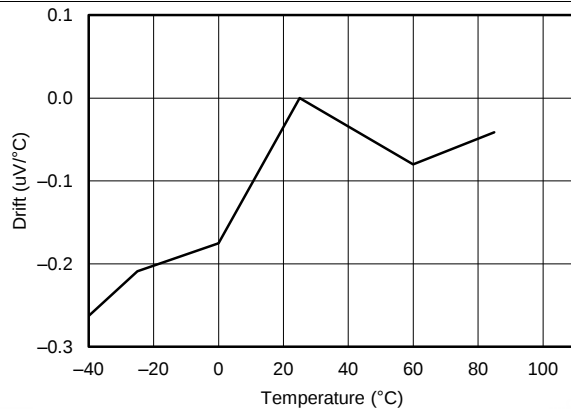


Figure 2. CC Input Offset Drift Overtemperature

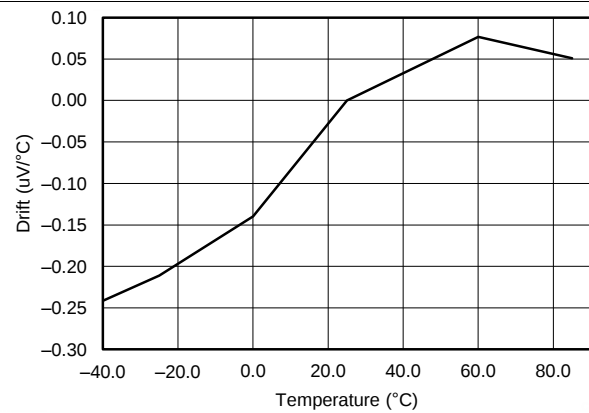


Figure 3. ADC Input Offset Drift Overtemperature

## 8 Parameter Measurement Information

### 8.1 Battery Parameter Measurements

#### 8.1.1 Charge and Discharge Counting

The bq3050 uses an integrating delta-sigma analog-to-digital converter (ADC) for current measurement, and a second delta-sigma ADC for individual cell and battery voltage and temperature measurement.

The integrating delta-sigma ADC measures the charge/discharge flow of the battery by measuring the voltage drop across a small-value sense resistor between the SR1 and SR2 pins. The integrating ADC measures bipolar signals from  $-0.25\text{ V}$  to  $0.25\text{ V}$ . The bq3050 detects charge activity when  $V_{SR} = V_{(SRP)} - V_{(SRN)}$  is positive, and discharge activity when  $V_{SR} = V_{(SRP)} - V_{(SRN)}$  is negative. The bq3050 continuously integrates the signal over time, using an internal counter. The fundamental rate of the counter is  $0.65\text{ nVh}$ .

#### 8.1.2 Voltage

The bq3050 updates the individual series cell voltages at 0.25-second intervals. The internal ADC of the bq3050 measures the voltage, and scales and calibrates it appropriately. This data is also used to calculate the impedance of the cell for the CEDV gas-gauging.

#### 8.1.3 Current

The bq3050 uses the SRP and SRN inputs to measure and calculate the battery charge and discharge current using a  $5\text{-m}\Omega$  to  $20\text{-m}\Omega$  typ. sense resistor.

#### 8.1.4 Auto Calibration

The bq3050 provides an auto-calibration feature to cancel the voltage offset error across SRN and SRP for maximum charge measurement accuracy. The bq3050 performs auto-calibration when the SMBus lines stay low continuously for a minimum of 5 s.

#### 8.1.5 Temperature

The bq3050 has an internal temperature sensor and inputs for two external temperature sensors. All three temperature sensor options are individually enabled and configured for cell or FET temperature. Two configurable thermistor models are provided to allow the monitoring of cell temperature in addition to FET temperature, which may be of a higher temperature type.

#### 8.1.6 Communications

The bq3050 uses SMBus v1.1 with Master Mode and packet error checking (PEC) options per the SBS specification.

##### 8.1.6.1 SMBus On and Off State

The bq3050 detects an SMBus off state when SMBC and SMBD are low for two or more seconds. Clearing this state requires that either SMBC or SMBD transition high. The communication bus will resume activity within 1 ms.

##### 8.1.6.2 SBS Commands

See the *bq3050 Technical Reference Manual* ([SLUU485](#)) for further details.

## 9 Detailed Description

### 9.1 Overview

The bq3050 device measures the voltage, temperature, and current to determine battery capacity and state-of-charge (SOC). The bq3050 monitors charge and discharge activity by sensing the voltage across a small value resistor (5 mΩ to 20 mΩ, typical) between the SRP and SRN pins and in series with the battery. By integrating charge passing through the battery, the battery's SOC is adjusted during battery charge or discharge. Measurements of OCV and charge integration determine chemical SOC.

The Qmax values are taken from a cell manufacturers' data sheet multiplied by the number of parallel cells, and is also used for the value in **Design Capacity**. It uses the OCV and Qmax value to determine *StateOfCharge()* on battery insertion, device reset, or on command. The *FullChargeCapacity()* is reported as the learned capacity available from full charge until *Voltage()* reaches the EDV0 threshold. As *Voltage()* falls below the **Shutdown Voltage** for **Shutdown Time** and has been out of SHUTDOWN mode for at least **Shutdown Time**, the *PF Flags1 ()* [VSHUT] bit is set. For additional details, see *bq3050 Technical Reference Manual* ([SLUU485](#)).

Fuel gauging is derived from the Compensated End of Discharge Voltage (CEDV) method, which uses a mathematical model to correlate remaining state of charge (RSOC) and voltage near to the end of discharge state. This requires a full-discharge cycle for a single-point FCC update. The implementation models cell voltage (OCV) as a function of battery SOC, temperature, and current. The impedance is also a function of SOC and temperature, which can be satisfied by using seven parameters: EMF, C0, R0, T0, R1, TC, and C1.

#### 9.1.1 Configuration

##### 9.1.1.1 Oscillator Function

The bq3050 fully integrates the system oscillators and does not require any external components to support this feature.

##### 9.1.1.2 System Present Operation

The bq3050 checks the  $\overline{\text{PRES}}$  pin periodically (1 s). If  $\overline{\text{PRES}}$  input is pulled to ground by the external system, the bq3050 detects this as system present.

##### 9.1.1.3 2-, 3-, or 4-Cell Configuration

In a 2-cell configuration, VC1 is shorted to VC2 and VC3. In a 3-cell configuration, VC1 is shorted to VC2.

##### 9.1.1.4 Cell Balancing

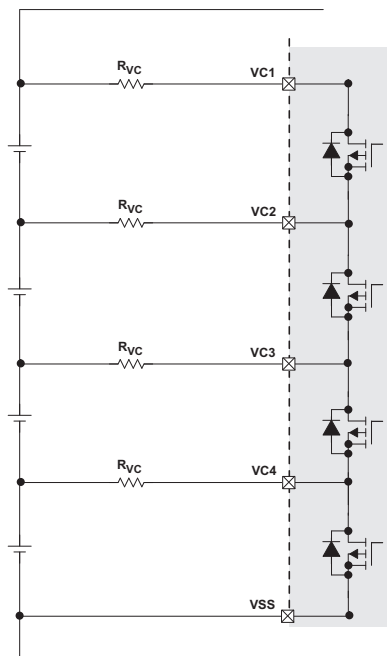
The device supports cell balancing by bypassing the current of each cell during charging or at rest. If the device's internal bypass is used, up to 10 mA can be bypassed and multiple cells can be bypassed at the same time. Higher cell balance current can be achieved by using an external cell balancing circuit. In external cell balancing mode, only one cell at a time can be balanced.

The cell balancing algorithm determines the amount of charge needed to be bypassed to balance the capacity of all cells.

###### 9.1.1.4.1 Internal Cell Balancing

When internal cell balancing is configured, the cell balance current is defined by the external resistor  $R_{VC}$  at the VCx input. See [Figure 4](#).

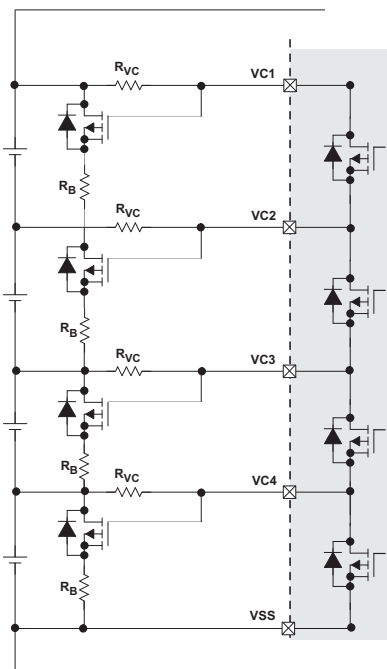
## Overview (continued)



**Figure 4. Internal Cell Balancing with  $R_{Vc}$**

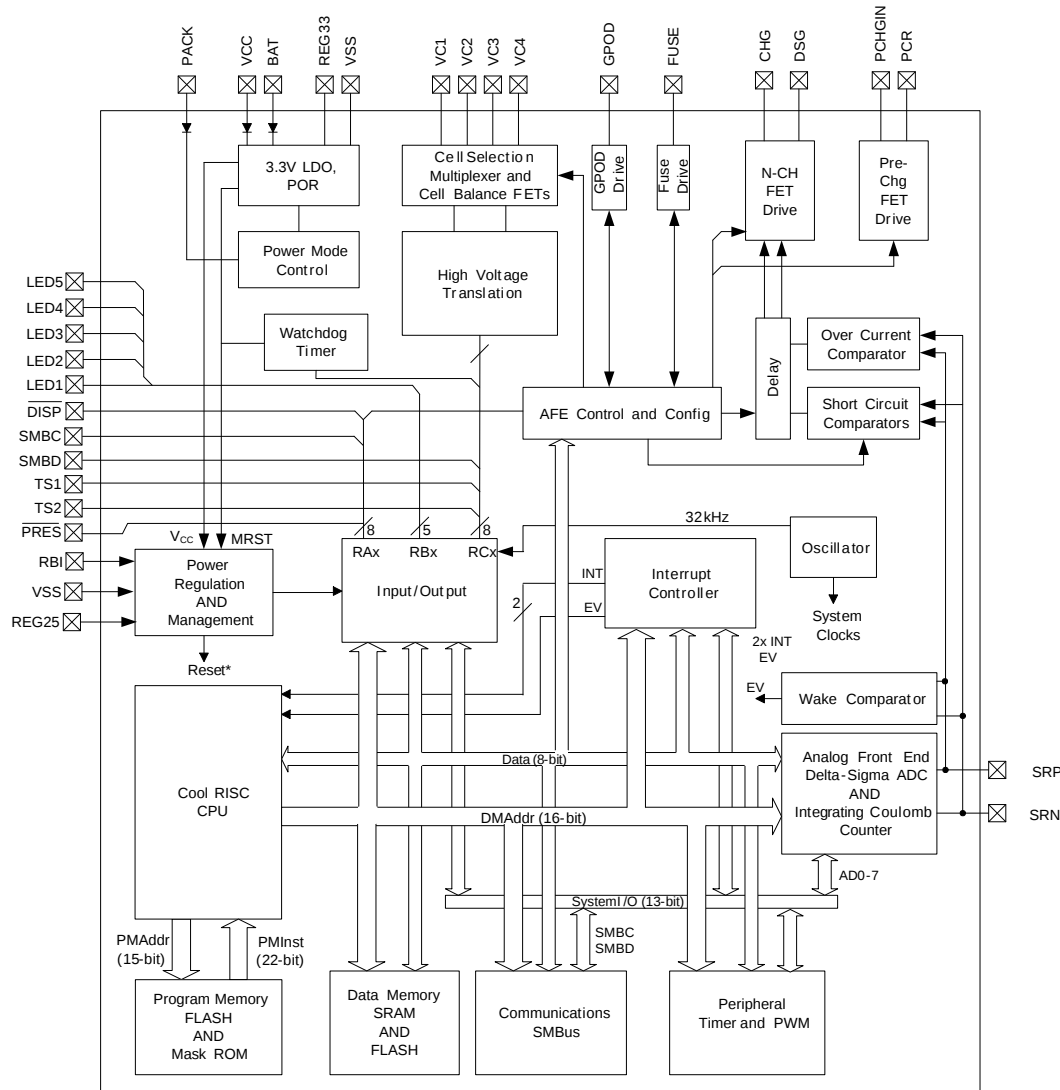
### 9.1.1.4.2 External Cell Balancing

When external cell balancing is configured, the cell balance current is defined by  $R_B$ . See [Figure 5](#). Only one cell at a time can be balanced.



**Figure 5. External Cell Balancing with  $R_B$**

## 9.2 Functional Block Diagram



## 9.3 Feature Description

### 9.3.1 Primary (1st Level) Safety Features

The bq3050 supports a wide range of battery and system protection features that can easily be configured. The primary safety features include:

- Cell Overvoltage and Undervoltage Protection
- Charge and Discharge Overcurrent
- Short-Circuit
- Charge and Discharge Overtemperature
- AFE Watchdog

### 9.3.2 Secondary (2nd Level) Safety Features

The secondary safety features of the bq3050 can be used to indicate more serious faults through the FUSE pin. This pin can be used to blow an in-line fuse to permanently disable the battery pack from charging or discharging. The secondary safety protection features include:

- Safety Overvoltage

## Feature Description (continued)

- Safety Overcurrent in Charge and Discharge
- Safety Overtemperature in Charge and Discharge
- Charge FET, Discharge FET, and Precharge FET Faults
- Cell Imbalance Detection
- Fuse Blow by Secondary Voltage Protection IC
- AFE Register Integrity Fault (AFE\_P)
- AFE Communication Fault (AFE\_C)

### 9.3.3 Charge Control Features

The bq3050 charge control features include:

- Supports JEITA temperature ranges. Reports charging voltage and charging current according to the active temperature range
- Handles more complex charging profiles. Allows for splitting the standard temperature range into two sub-ranges and allows for varying the charging current according to the cell voltage
- Reports the appropriate charging current needed for constant current charging and the appropriate charging voltage needed for constant voltage charging to a smart charger using SMBus broadcasts
- Reduce the charge difference of the battery cells in fully charged state of the battery pack gradually using a voltage-based cell balancing algorithm during charging. A voltage threshold can be set up for cell balancing to be active. This prevents fully charged cells from overcharging and causing excessive degradation and also increases the usable pack energy by preventing premature charge termination.
- Supports precharging and zero-volt charging
- Supports charge inhibit and charge suspend if battery pack temperature is out of temperature range
- Reports charging fault and also indicate charge status through charge and discharge alarms

### 9.3.4 Gas Gauging

The bq3050 uses the CEDV algorithm to measure and calculate the available capacity in battery cells. The bq3050 accumulates a measure of charge and discharge currents and compensates the charge current measurement for the temperature and state-of-charge of the battery. The bq3050 estimates self-discharge of the battery and also adjusts the self-discharge estimation based on temperature. See the *bq3050 Technical Reference Manual* (SLUU485) for further details.

### 9.3.5 Lifetime Data Logging Features

The bq3050 offers limited lifetime data logging for the following critical battery parameters:

- Lifetime Maximum Temperature
- Lifetime Minimum Temperature
- Lifetime Maximum Battery Cell Voltage
- Lifetime Minimum Battery Cell Voltage

### 9.3.6 Authentication

- The bq3050 supports authentication by the host using SHA-1.
- SHA-1 authentication by the gas gauge is required for unsealing and full access.

## 9.4 Device Functional Modes

The bq3050 supports three power modes to reduce power consumption:

- In NORMAL Mode, the bq3050 performs measurements, calculations, protection decisions, and data updates in 0.25-s intervals. Between these intervals, the bq3050 is in a reduced power stage.
- In SLEEP Mode, the bq3050 performs measurements, calculations, protection decisions, and data updates in adjustable time intervals. Between these intervals, the bq3050 is in a reduced power stage. The bq3050 has a wake function that enables exit from Sleep mode when current flow or failure is detected.
- In SHUTDOWN Mode, the bq3050 is completely disabled.

## 10 Application and Implementation

### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 10.1 Application Information

The bq3050 gas gauge is a primary protection device that can be used with a 2-series, 3-series, or 4-series Li-Ion or Li-Polymer battery pack. To implement and design a comprehensive set of parameters for a specific battery pack, the user needs the bqEVSU tool, which is a graphical user-interface tool installed on a PC during development. The firmware installed in the product has default values, which are summarized in the *bq3050 Technical Reference Manual* ([SLUU485](#)). Using the bqEVSU tool, these default values can be changed to cater to specific application requirements during development once the system parameters are known, such as fault-trigger thresholds for protection, enable or disable certain features for operation, configuration of cells, and more.

### 10.2 Typical Application

In a typical application, the bq3050 is typically paired with a 2<sup>nd</sup>-level overvoltage protection device to provide an independent level of voltage protection.

The bq3050 is often used to provide a visual display using the LED Display feature, but this is optional.

# Typical Application (continued)

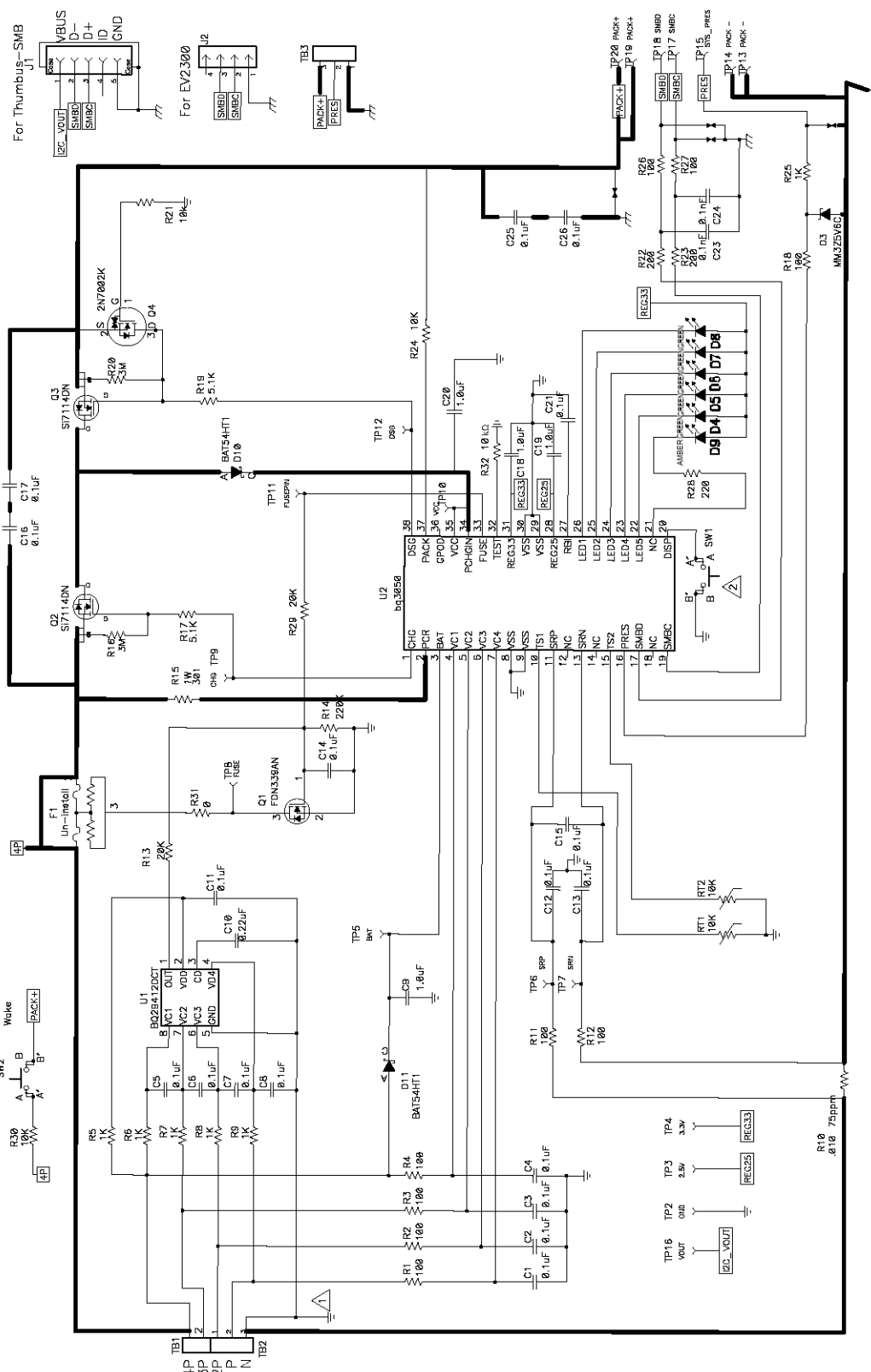


Figure 6. Application Schematic

## Typical Application (continued)

### 10.2.1 Design Requirements

For the bq3050 design example, use the parameters in [Table 1](#) as input parameters.

**Table 1. Requirements**

| DESIGN PARAMETER                        | VALUE OR STATE                          |
|-----------------------------------------|-----------------------------------------|
| Cell Configuration                      | 3s2p (4-series with 1 Parallel)         |
| Design Capacity                         | 4400 mAh                                |
| Device Chemistry                        | Chem ID 100 (LiCoO2/graphitized carbon) |
| Cell Overvoltage (per cell)             | 4500 mV                                 |
| Cell Undervoltage (per cell)            | 2200 mV                                 |
| 1st Tier Overcurrent in CHARGE Mode     | 6000 mA                                 |
| 1st Tier Overcurrent in DISCHARGE Mode  | –6000 mA                                |
| AFE Overcurrent in CHARGE Mode          | 0.120 V/Rsense across SRP, SRN          |
| AFE Short-Circuit in DISCHARGE Mode     | 0.450 V/Rsense across SRP, SRN          |
| AFE Short-Circuit in CHARGE Mode        | 0.250V/Rsense across SRP, SRN           |
| Overtemperature in CHARGE Mode          | 55°C                                    |
| Overtemperature in DISCHARGE Mode       | 60°C                                    |
| SAFE Pin Activation Enabled             | No                                      |
| Safety Overvoltage (per cell)           | 4600 mV                                 |
| Shutdown Voltage                        | 5250 mV                                 |
| Cell Balancing Enabled                  | Yes                                     |
| Internal or External Temperature Sensor | External Enabled                        |
| SMB BROADCAST Mode                      | Disabled                                |
| Display Mode (Number of LEDs)           | 5-bar                                   |
| PRES Feature Enabled                    | No                                      |

### 10.2.2 Detailed Design Procedure

#### 10.2.2.1 High-Current Path

The high-current path begins at the PACK+ terminal of the battery pack. As charge current travels through the pack, it finds its way through protection FETs, a chemical fuse, the lithium-ion cells and cell connections, and the sense resistor, and then returns to the PACK– terminal. In addition, some components are placed across the PACK+ and PACK– terminals to reduce effects from electrostatic discharge.

##### 10.2.2.1.1 Protection FETs

The N-channel charge and discharge FETs must be selected for a given application ([Figure 7](#)). Most portable battery applications are a good match for the CSD17308Q3. The TI CSD17308Q3 is an 47A-A, 30-V device with Rds(on) of 8.2 mΩ when the gate drive voltage is 10 V.

If a precharge FET is used, R15 is calculated to limit the precharge current to the desired rate. Be sure to account for the power dissipation of the series resistor. The precharge current is limited to  $(V_{\text{charger}} - V_{\text{bat}})/R15$  and maximum power dissipation is  $(V_{\text{charger}} - V_{\text{bat}})^2/R15$ .

The gates of all protection FETs are pulled to the source with a high-value resistor between the gate and source to ensure they are turned off if the gate drive is open.

Capacitors C16 and C17 help protect the FETs during an ESD event. The use of two devices ensures normal operation if one of them becomes shorted. To have good ESD protection, the copper trace inductance of the capacitor leads must be designed to be as short and wide as possible. Ensure that the voltage rating of both C16 and C17 are adequate to hold off the applied voltage if one of the capacitors becomes shorted.

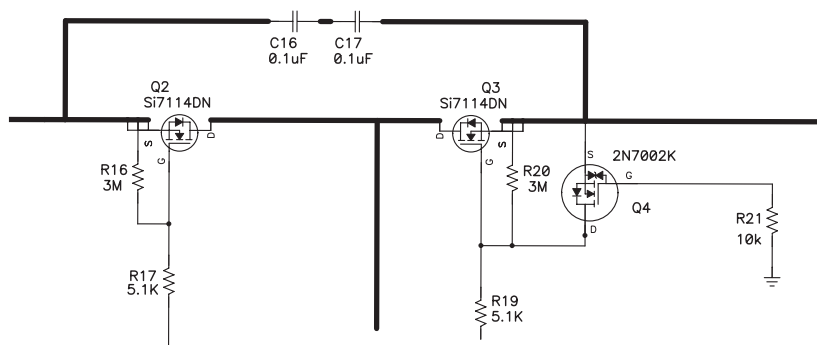


Figure 7. bq3050 Protection FETs

#### 10.2.2.1.2 Chemical Fuse

The chemical fuse (Sony Chemical, Uchihashi, and so forth) is ignited under command from either the bq294705 secondary voltage protection IC or from the FUSE pin of the gas gauge. Either event applies a positive voltage to the gate of Q1, shown in [Figure 8](#), which then sinks current from the third terminal of the fuse, causing it to ignite and open permanently.

It is important to carefully review the fuse specifications and match the required ignition current to that available from the N-channel FET. Ensure that the proper voltage, current, and  $R_{ds(on)}$  ratings are used for this device. The fuse control circuit is discussed in detail in [FUSE Circuitry](#).

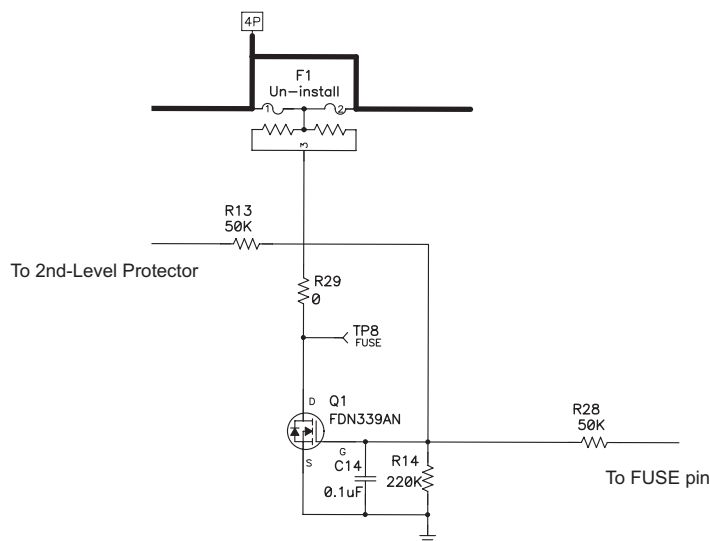
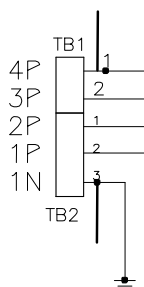


Figure 8. FUSE Circuit

#### 10.2.2.1.3 Lithium-Ion Cell Connections

The important thing to remember about the cell connections is that high current flows through the top and bottom connections; therefore, the voltage sense leads at these points must be made with a Kelvin connection to avoid any errors due to a drop in the high-current copper trace. The location marked 4P in [Figure 9](#) indicates the Kelvin connection of the most positive battery node. The connection marked 1N is equally important. The VC5 pin (a ground reference for cell voltage measurement), which is in the older generation devices, is not in the bq3050 device. Hence, the single-point connection at 1N to the low-current ground is needed to avoid an undesired voltage drop through long traces while the gas gauge is measuring the bottom cell voltage.

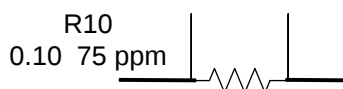


**Figure 9. Lithium-Ion Cell Connections**

#### 10.2.2.1.4 Sense Resistor

As with the cell connections, the quality of the Kelvin connections at the sense resistor is critical. The sense resistor must have a temperature coefficient no greater than 75 ppm to minimize current measurement drift with temperature (Figure 10). Choose the value of the sense resistor to correspond to the available overcurrent and short-circuit ranges of the bq3050. Select the smallest value possible to minimize the negative voltage generated on the bq3050  $V_{SS}$  nodes during a short-circuit. This pin has an absolute minimum of  $-0.3$  V. For a pack with two parallel cylindrical cells, 10 m $\Omega$  is generally ideal. Parallel resistors can be used as long as good Kelvin sensing is ensured.

The ground scheme of bq3050 is different from the older generation devices. In previous devices, the device ground (or low-current ground) is connected to the SRN side of the Rsense resistor pad. The bq3050, however, connects the low-current ground on the SRP side of the Rsense resistor pad, close to the battery 1N terminal (see [Lithium-Ion Cell Connections](#)). This is because the bq3050 has one less VC pin (a ground reference pin VC5) compared to the previous devices. The pin was removed and was internally combined to SRP.



**Figure 10. Sense Resistor**

#### 10.2.2.1.5 ESD Mitigation

A pair of series 0.1- $\mu$ F ceramic capacitors is placed across the PACK+ and PACK– terminals to help in the mitigation of external electrostatic discharges. The two devices in series ensure continued operation of the pack if one of the capacitors becomes shorted.

Optionally, a tranzorb, such as the SMBJ2A, can be placed across the terminals to further improve ESD immunity.

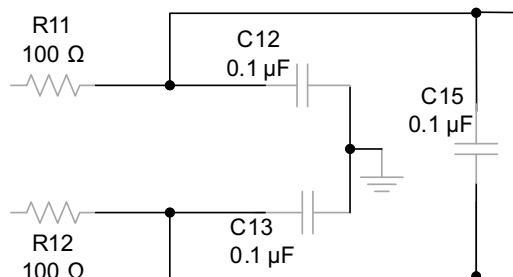
#### 10.2.2.2 Gas Gauge Circuit

The Gas Gauge Circuit includes the bq3050 and its peripheral components. These components are divided into the following groups: Differential Low-Pass Filter, Power Supply Decoupling/RBI, System Present, SMBus Communication, FUSE circuit, and LED.

##### 10.2.2.2.1 Differential Low-Pass Filter

As shown in Figure 11, a differential filter must precede the current sense inputs of the gas gauge. This filter eliminates the effect of unwanted digital noise, which can cause offset in the measured current. Even the best differential amplifier has less common-mode rejection at high frequencies. Without a filter, the amplifier input stage may rectify a strong RF signal, which then may appear as a DC offset error.

Five percent tolerance of the components is adequate because capacitor C15 shunts C12/C13, and reduces AC common mode arising from component mismatch. It is also proven to reduce offset and noise error by maintaining  $\mu$ a symmetrical placement pattern and adding ground shielding for the differential filter network.

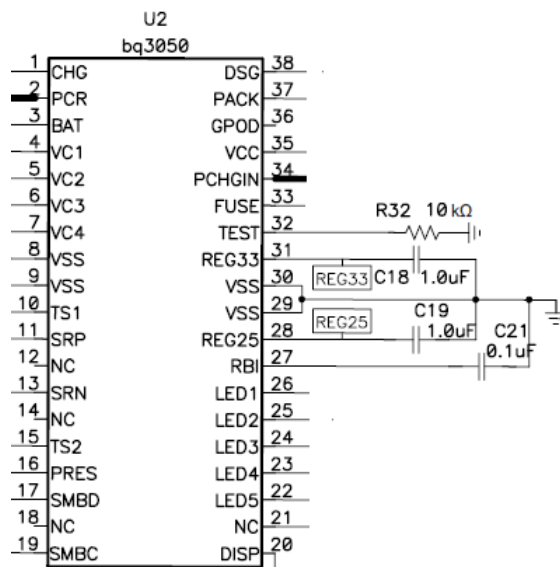


**Figure 11. Differential Low-Pass Filter**

#### 10.2.2.2.2 Power Supply Decoupling and RBI

Power supply decoupling is important for optimal operation of the bq3050 advanced gas gauges. As shown in , a single 1-μF ceramic decoupling capacitor from REG33 to V<sub>SS</sub> and REG25 to V<sub>SS</sub> must be placed adjacent to the IC pins.

The RBI pin is used to supply backup RAM voltage during brief transient power outages. The partial reset mechanism makes use of the RAM to restore the critical CPU registers following a temporary loss of power. A standard 0.1-μF ceramic capacitor is connected from the RBI pin to ground, as shown in [Figure 12](#).

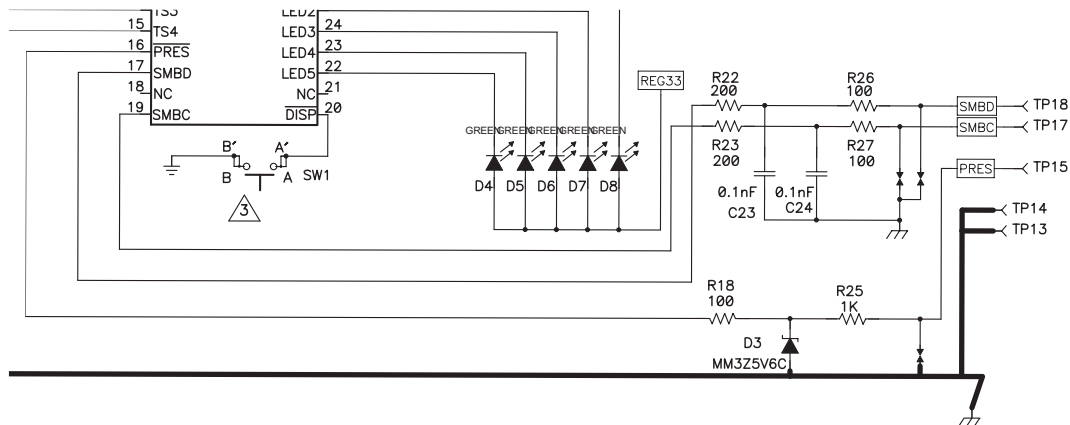


**Figure 12. Power Supply Decoupling**

### 10.2.2.2.3 System Present

The System Present signal is used to inform the gas gauge whether the pack is installed into or removed from the system. In the host system, this pin is grounded. The PRES pin of the bq3050 is occasionally sampled to test for system present. To save power, an internal pullup resistor is provided by the gas gauge during a brief 4- $\mu$ s sampling pulse once per second.

Because the System Present signal is part of the pack connector interface to the outside world, it must be protected from external electrostatic discharge events. An integrated ESD protection on the PRES device pin reduces the external protection requirement to just R25 for an 8-kV ESD contact rating (Figure 13). However, if it is possible that the System Present signal may short to PACK+, then R18 and D3 must be included for high-voltage protection.

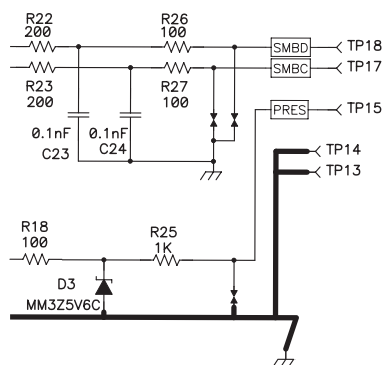


**Figure 13. System Present ESD and Short Protection**

### 10.2.2.2.4 SMBus Communication

Similar to the System Present pin, the SMBus clock and data pins have integrated high-voltage ESD protection circuits that reduce the need for external Zener diode protection. When using the circuit shown in Figure 14, the communication lines can withstand an 8-kV (contact) ESD strike. C23 and C24 are selected with a 100-pF value to meet the SMBus specifications. If it is desirable to provide increased protection with a larger input resistor and/or Zener diode, carefully investigate the signal quality of the SMBus signals under worst-case communication conditions.

The SMBus clock and data lines have internal pulldowns. When the gas gauge senses that both lines are low (such as during removal of the pack), the device performs auto-offset calibration and then goes into sleep mode to conserve power.



**Figure 14. ESD Protection for SMB Communication**

#### 10.2.2.2.5 FUSE Circuitry

The FUSE pin of the bq3050 is designed to ignite the chemical fuse if one of the various safety criteria is violated (Figure 15). The FUSE pin also monitors the state of the secondary-voltage protection IC. Q3 ignites the chemical fuse when its gate is high. The 7-V output of the bq29705 is divided by R13 and R14, which provides adequate gate drive for Q1 while guarding against excessive back current into the bq29705 if the FUSE signal is high.

Using C14 is generally a good practice, especially for RFI immunity. C14 may be removed, if desired, because the chemical fuse is a comparatively slow device and is not affected by any sub-microsecond glitches that may come from the SAFE output during the cell connection process.

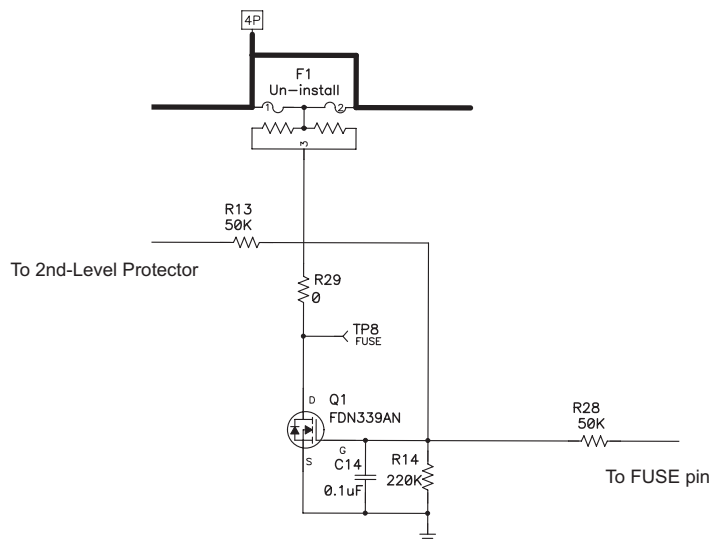


Figure 15. FUSE Circuit

When the bq3050 is commanded to ignite the chemical fuse, the FUSE pin activates to give a typical 8-V output. The new design makes it possible to use a higher  $V_{gs}$  FET for Q1. This improves the robustness of the system, as well as widens the choices for Q1.

#### 10.2.2.2.6 PFIN Detection

As previously mentioned, the FUSE pin has a dual role on this device. When bq3050 is not commanded to ignite the chemical fuse, the FUSE pin defaults to sense the OUT pin status of the secondary voltage protector. When the secondary voltage protector ignites the chemical fuse, the high voltage is sensed by the FUSE pin, and the bq3050 sets the PFIN flag accordingly.

#### 10.2.2.3 Secondary-Current Protection

The bq3050 provides secondary overcurrent and short-circuit protection, cell balancing, cell voltage multiplexing, and voltage translation. The following sections examine Cell and Battery Inputs, Pack and FET Control, Regulator Output, Temperature Output, and Cell Balancing.

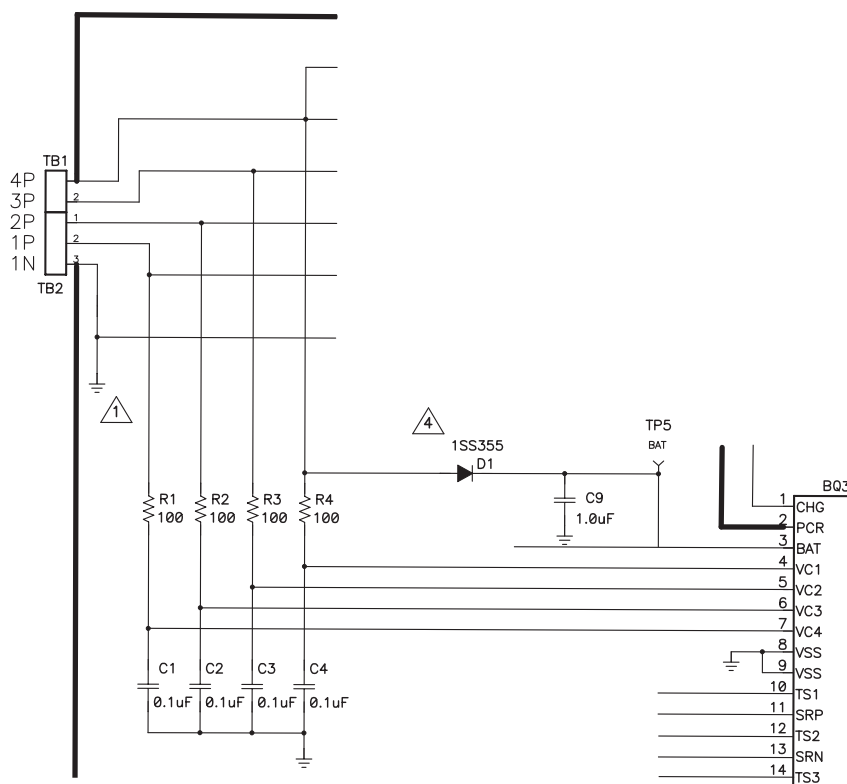
##### 10.2.2.3.1 Cell and Battery Inputs

Each cell input is conditioned with a simple RC filter, which provides ESD protection during cell connect and acts to filter unwanted voltage transients. The resistor value allows some trade-off for cell balancing versus safety protection.

The internal cell balancing FETs in bq3050 provide about typically  $310\ \Omega$  ( $310\ \Omega$  with cell voltage  $\geq 2\text{ V}$ . The cell balancing FETs  $R_{ds-on}$  reduced to typically  $125\ \Omega$  with cell voltage  $\geq 4\text{ V}$ ), which can be used to bypass charge current in individual cells that may be overcharged with respect to the others (Figure 16). The purpose of this bypass path is to reduce the current into any one cell during charging to bring the series elements to the same voltage. Series resistors placed between the input pins and the positive series element nodes control the bypass current value. The bq3050 device is designed to take up to 10-mA cell balancing current. Series input resistors between  $100\ \Omega$  and  $1\text{ k}\Omega$  are recommended for effective cell balancing.

The BAT input uses a diode (D1) and 1- $\mu\text{F}$  ceramic capacitor (C9) to isolate and decouple it from the cells in the event of a transient dip in voltage caused by a short-circuit event.

Also, as described previously in [High-Current Path](#), the top and bottom nodes of the cells must be sensed at the battery connections with a Kelvin connection to prevent voltage sensing errors caused by a drop in the high-current PCB copper.



**Figure 16. Cell and BAT Inputs**

#### 10.2.2.3.2 External Cell Balancing

Internal cell balancing can only support up to 10 mA. External cell balancing provides another option for faster cell balancing. For details, refer to the application note, *Fast Cell Balancing Using External MOSFET* (SLUA420).

#### 10.2.2.3.3 PACK and FET Control

The PACK and  $V_{CC}$  inputs provide power to the bq305x from the charger. The PACK input also provides a method to measure and detect the presence of a charger. The PACK input uses a 10-K $\Omega$  resistor, whereas the  $V_{CC}$  input uses a diode to guard against input transients and prevents malfunction of the data driver during short-circuit events (Figure 17).

The N-channel charge and discharge FETs are controlled with 5.1-K $\Omega$  series gate resistors, which provide a switching time constant of a few microseconds. The 3.01-M $\Omega$  resistors ensure that the FETs are off in the event of an open connection to the FET drivers. Q4 is provided to protect the discharge FET (Q3) in the event of a reverse-connected charger. Without Q4, Q3 can be driven into its linear region and suffer severe damage if the PACK+ input becomes slightly negative.

Q4 turns on in that case to protect Q3 by shorting its gate to source. To use the simple ground gate circuit, the FET must have a low gate turnon threshold. If it is desired to use a more standard device, such as the 2N7000 as the reference schematic, the gate should be biased up to 3.3 V with a high-value resistor. The bq3050 device has the capability to provide a current-limited charging path typically used for low battery voltage or low temperature charging. The pre-charge FET is integrated into the bq3050 device, allowing users to only connect an external pre-charge load resistor via the PCR pin through the PCHGIN input. The bq3050 device supports up to 100-mA of pre-charge current. When selecting the external load resistor, user should take into account the max charger voltage and the  $R_{ds(on)}$  of the internal precharge FET.

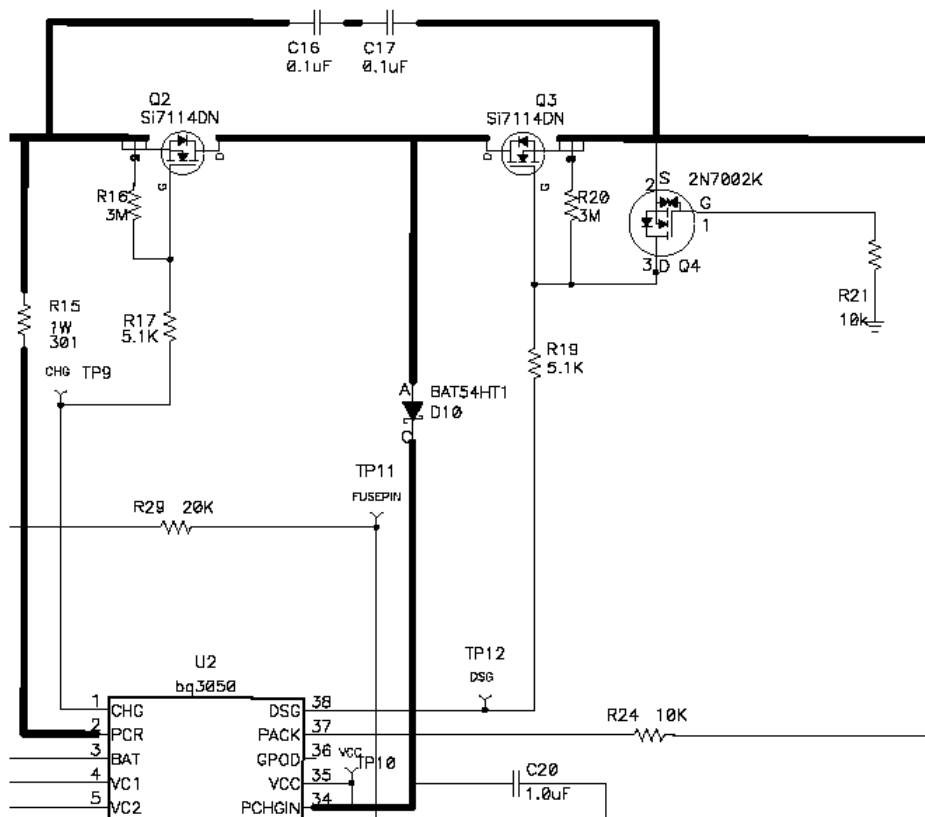


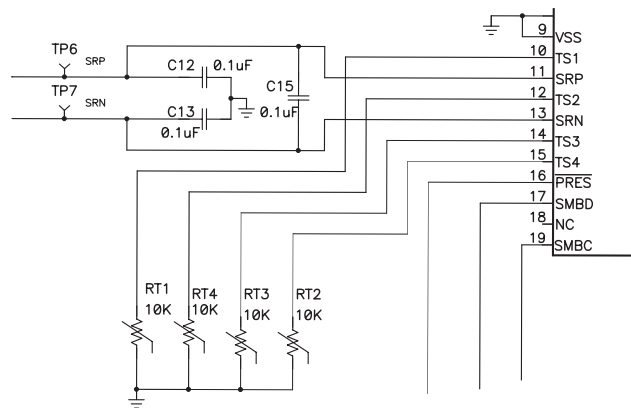
Figure 17. bq3050 PACK and FET Control

#### 10.2.2.3.4 Regulator Output

As mentioned in [Power Supply Decoupling and RBI](#), the two low-dropout regulators in the bq3050 require capacitive compensation on the output. The outputs must have a 1- $\mu$ F ceramic capacitor placed close to the IC terminal pins.

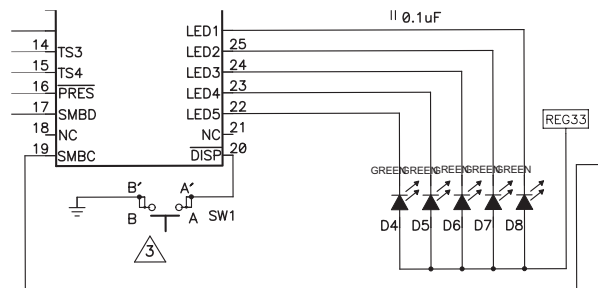
#### 10.2.2.3.5 Temperature Output

For the bq3050 device, TS1 and TS2 provide thermistor drive-under program control ([Figure 18](#)). Each pin can be enabled with an integrated 18-k $\Omega$  (typical) linearization pullup resistor to support the use of a 10-k $\Omega$  at 25°C (103) NTC external thermistor, such as a Mitsubishi BN35-3H103. The reference design includes two 10-k $\Omega$  thermistors: RT1 and RT2.


**Figure 18. Thermistor Drive**

#### 10.2.2.3.6 LEDs

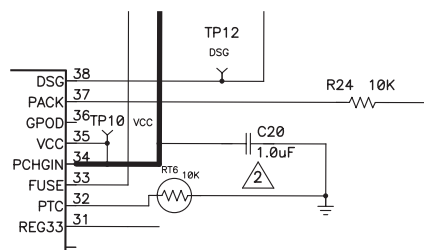
The LEDs do not need current-limiting resistors, because the bq3050 LED pins have a programmable current sink to simplify the design (Figure 19). The display switch pulls the bq3050 pin 20 to ground to generate an interrupt. The REG33 output powers the LEDs.


**Figure 19. LEDs**

#### 10.2.2.3.7 Safety PTC Thermistor

The bq3050 device provides support for a safety PTC thermistor (Figure 20). The PTC thermistor is connected between the PTC pin and V<sub>SS</sub>. It can be placed close to the CHG/DSG FETs to monitor the temperature. The PTC pin outputs a very small current, typical approximate 370 nA, and the PTC fault will be triggered at approximately 0.7 V typical. A PTC fault is one of the permanent failure modes. It can only be cleared by a POR.

To disable this feature, connect a 10-KΩ resistor between PTC and V<sub>SS</sub>.


**Figure 20. PTC Thermistor**

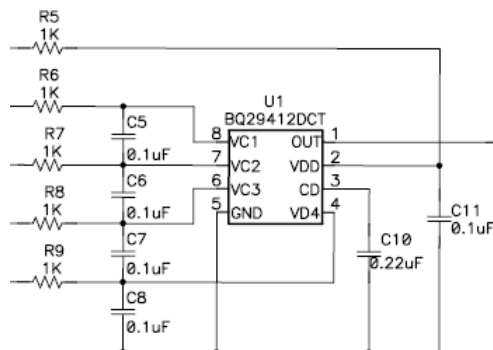
#### 10.2.2.4 Secondary-Overvoltage Protection

The bq29705 provides secondary-overvoltage protection and commands the chemical fuse to ignite if any cell exceeds the internally referenced threshold. The peripheral components are Cell Inputs and Time Delay Capacitor.

#### 10.2.2.4.1 Cell Inputs

An input filter is provided for each cell input. This comprises the resistors R5, R6, R7, and R9 along with capacitors C5, C6, C7, and C8 (Figure 21). This input network is completely independent of the filter network used as input to the bq3050. To ensure independent safety functionality, the two devices must have separate input filters.

Because the filter capacitors are implemented differentially, a low-voltage device can be used in each case.

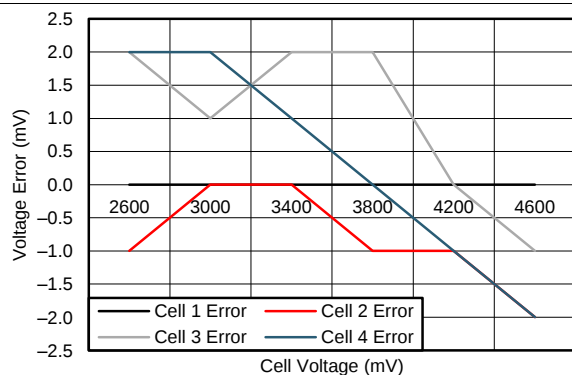


**Figure 21. bq29705 Cell Inputs and Time-Delay Capacitor**

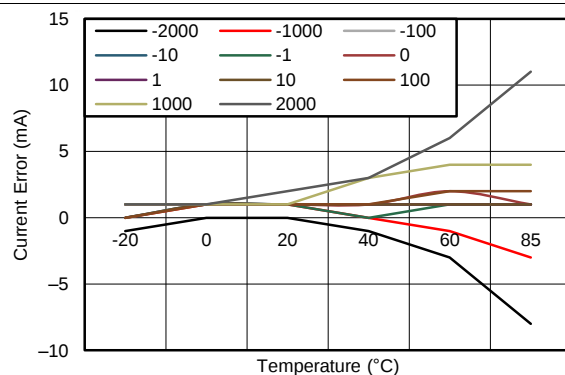
#### 10.2.2.4.2 Time-Delay Capacitor

C10 sets the time delay for activation of the output after any cell exceeds the threshold voltage. The time delay is calculated as  $t_d = 1.2 \text{ V} \times \text{DelayCap} (\mu\text{F}) / 0.18 \mu\text{A}$ .

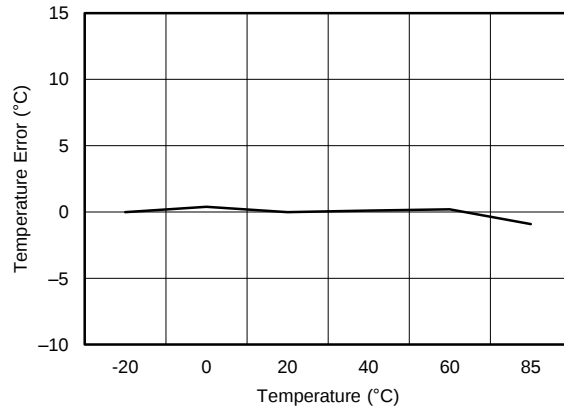
### 10.2.3 Application Curves



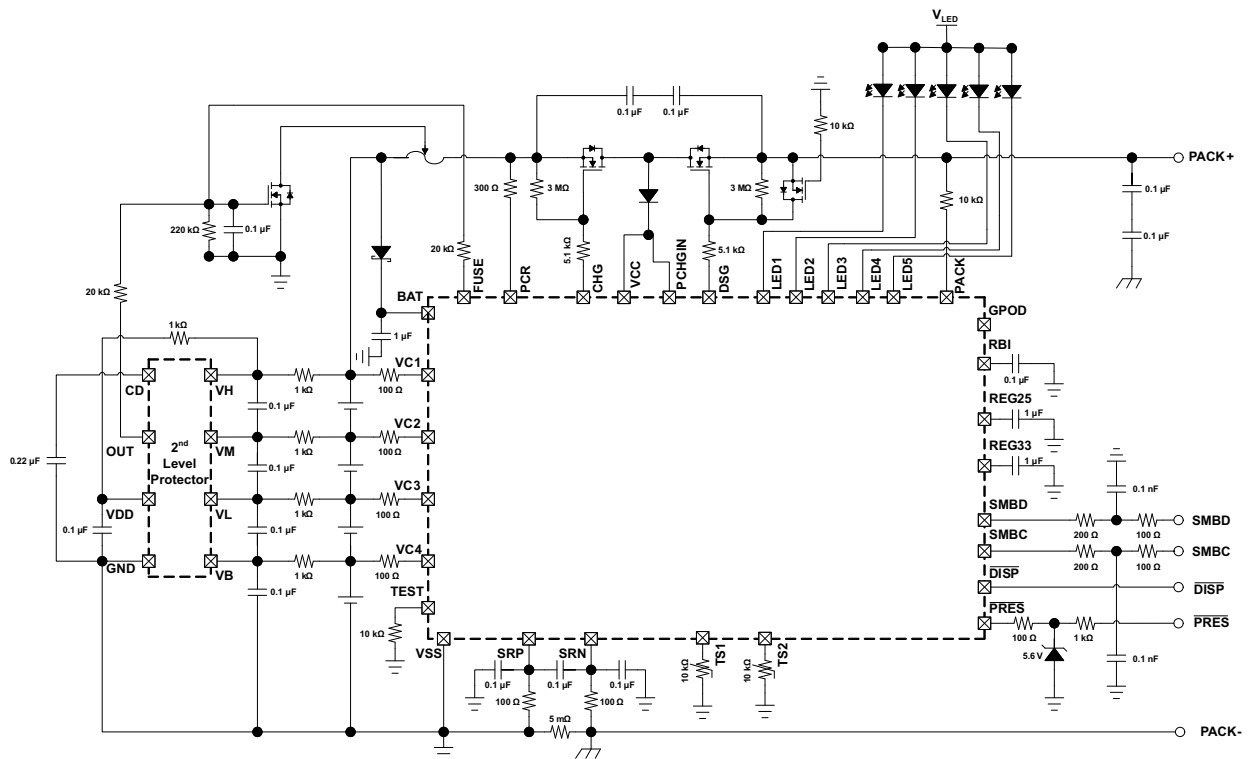
**Figure 22. Cell Voltage Error Across Input Range at 25°C**



**Figure 23. Current Error vs Temperature**


**Figure 24. TSx Error vs Temperature**

### 10.3 System Example


**Figure 25. bq3050 Implementation**

## 11 Power Supply Recommendations

Power supply decoupling is important for optimal operation of the bq3050 Gas Gauge. A single 1.0- $\mu$ F ceramic decoupling capacitor from REG33 to VSS and REG25 to VSS must be placed adjacent to the integrated circuit (IC) pins.

The RBI pin is used to supply backup RAM voltage during brief transient-power outages. The partial reset mechanism makes use of RAM to restore the critical CPU registers following a temporary loss of power. A standard 0.1- $\mu$ F ceramic capacitor is connected from the RBI pin to ground.

## 12 Layout

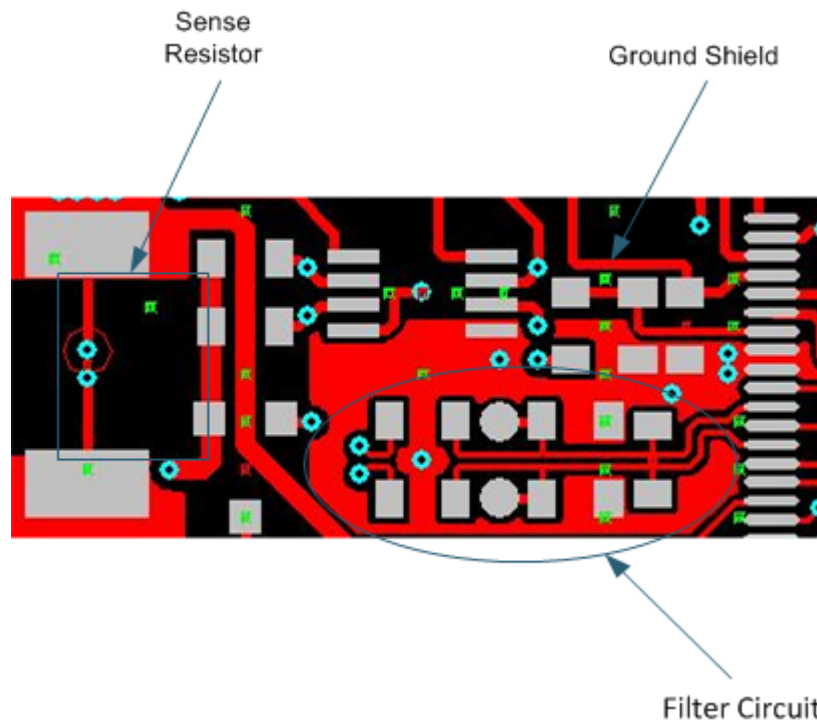
### 12.1 Layout Guidelines

The predominant layout concern for the bq3050 is related to the coulomb counter measurement. The external components and PCB layout surrounding the SRP and SRN pins should be carefully considered.

### 12.2 Layout Example

As shown in [Figure 26](#), a differential filter must precede the current sense inputs of the gas gauge. This filter eliminates the effect of unwanted digital noise, which can cause offset in the measured current. Even the best differential amplifier has less common-mode rejection at high frequencies. Without a filter, the amplifier input stage may rectify a strong RF signal, which then may appear as a DC-offset error.

Five percent tolerance of the components is adequate, because capacitor C15 shunts C12 and C13 and reduces AC common mode arising from a component mismatch. It is important to locate C15 as close as possible to the gas gauge pins. The other components also must be relatively close to the IC. The ground connection of C12 and C13 must be close to the IC. It is also proven to reduce offset and noise error by maintaining a symmetrical placement pattern and adding ground shielding for the differential filter network.



**Figure 26. PCB Layout Example**

## 13 器件和文档支持

### 13.1 文档支持

#### 13.1.1 相关文档

相关文档如下：

- 《bq3050 技术参考》手册（文献编号：[SLUU485](#)）
- 《采用外部 MOSFET 快速实现电池均衡》（文献编号：[SLUA420](#)）

### 13.2 社区资源

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**TI E2E™ Online Community** *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](#), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

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### 13.4 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 14 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

## 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="#">BQ3050DBT</a>  | Active        | Production           | TSSOP (DBT)   38 | 50   BULK             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | BQ3050              |
| BQ3050DBT.A                | Active        | Production           | TSSOP (DBT)   38 | 50   BULK             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | BQ3050              |
| <a href="#">BQ3050DBTR</a> | Active        | Production           | TSSOP (DBT)   38 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | BQ3050              |
| BQ3050DBTR.A               | Active        | Production           | TSSOP (DBT)   38 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | BQ3050              |

<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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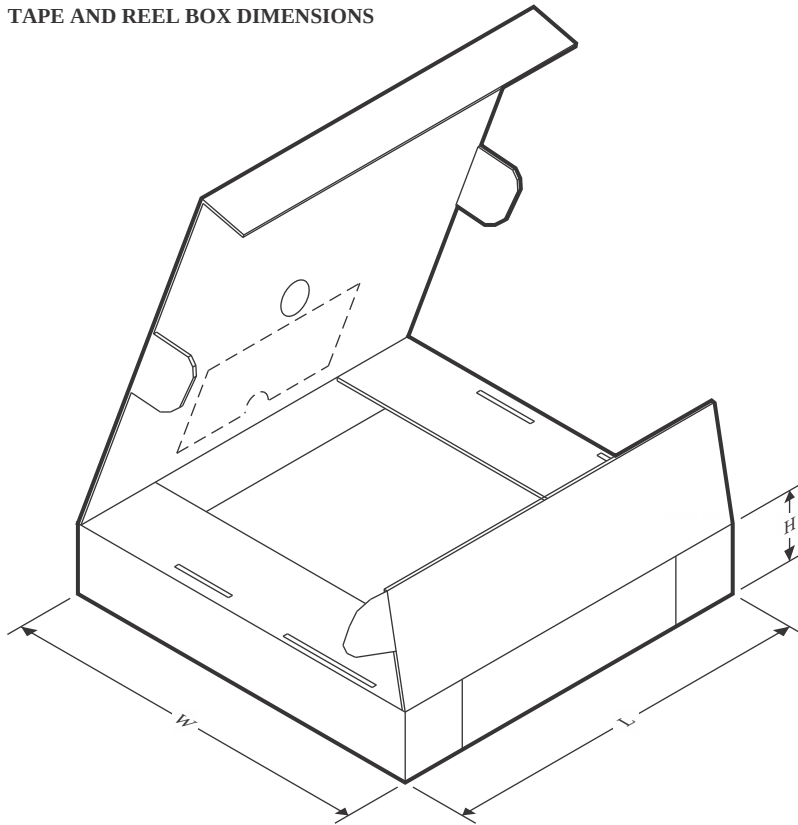
## TAPE AND REEL INFORMATION



\*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 |
|------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ3050DBTR | TSSOP        | DBT             | 38   | 2000 | 330.0              | 16.4               | 6.9     | 10.2    | 1.8     | 12.0    | 16.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

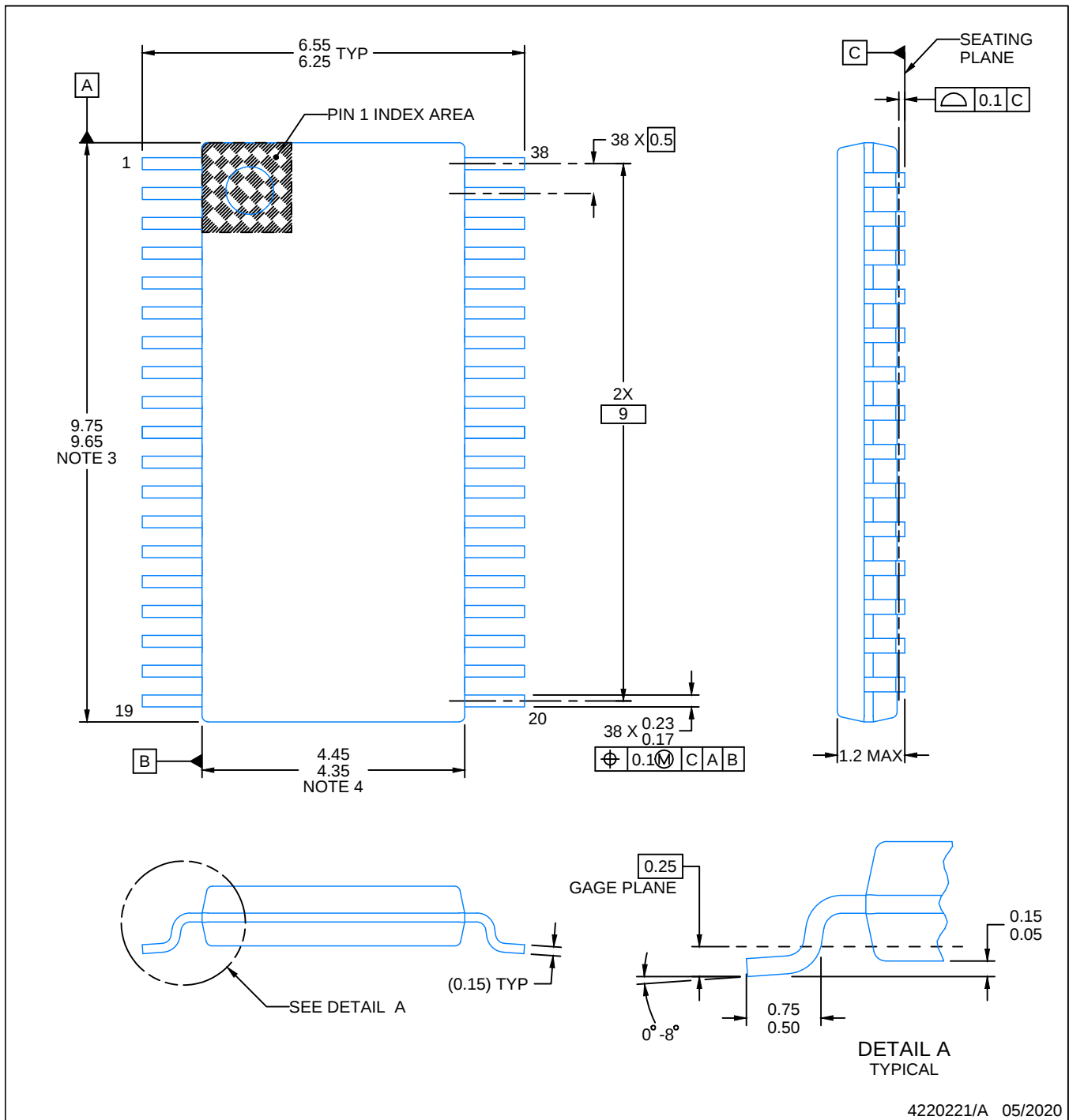
| Device     | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ3050DBTR | TSSOP        | DBT             | 38   | 2000 | 350.0       | 350.0      | 43.0        |

## TUBE



\*All dimensions are nominal

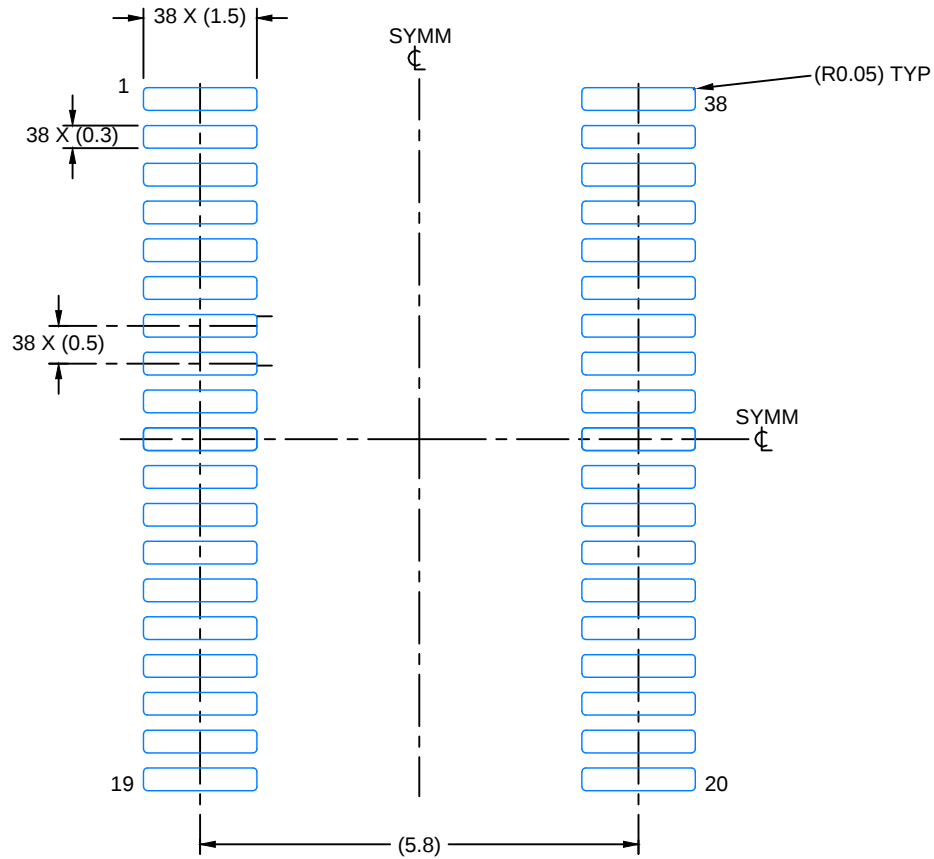
| Device      | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| BQ3050DBT   | DBT          | TSSOP        | 38   | 50  | 530    | 10.2   | 3600   | 3.5    |
| BQ3050DBT.A | DBT          | TSSOP        | 38   | 50  | 530    | 10.2   | 3600   | 3.5    |



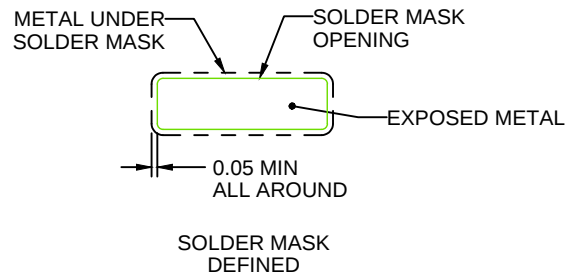
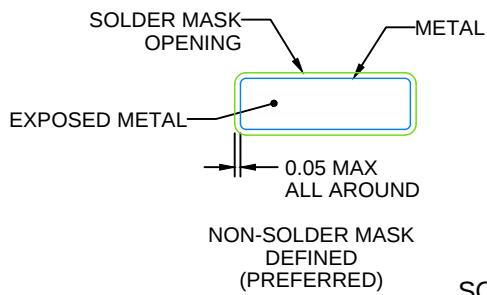
4220221/A 05/2020

#### NOTES:

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



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



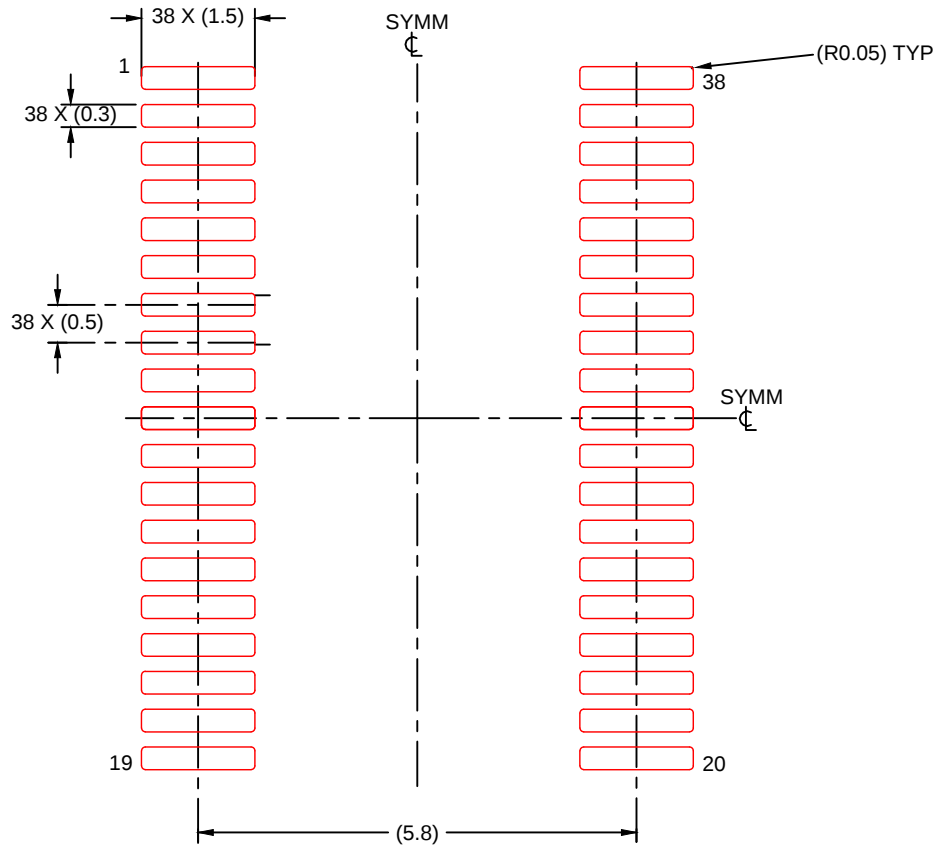
SOLDER MASK DETAILS

4220221/A 05/2020

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



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

4220221/A 05/2020

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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