

# BQ33100 Super Capacitor Manager

## 1 Features

- Fully integrated 2-, 3-, 4-, and 5-series Super Capacitor Manager
- Can be used with up to 9-series capacitors without individual integrated capacitor monitoring and balancing
- Active capacitor voltage balancing
  - Prevents super capacitor overvoltage during charging
- Capacitor health monitoring
  - Capacitance learning
  - ESR measurement
  - Operation status
  - State-of-charge
  - State-of-health
  - Charging voltage and current reports
  - Safety alerts with optional pin indication
- Integrated protection monitoring and control
  - Overvoltage
  - Short circuit
  - Excessive temperature
  - Excessive capacitor leakage
- 2-wire SMBus serial communications
- High-accuracy 16-bit delta-sigma ADC with a 16-channel multiplexer for measurement
  - Used for voltage, current, and temperature
- Low power consumption
  - < 660  $\mu$ A in NORMAL operating mode
  - < 1  $\mu$ A in SHUTDOWN mode
- Wide operating temperature:  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$

## 2 Applications

- RAID systems
- Server blade cards
- UPS
- Medical and test equipment
- Portable instruments

## 3 Description

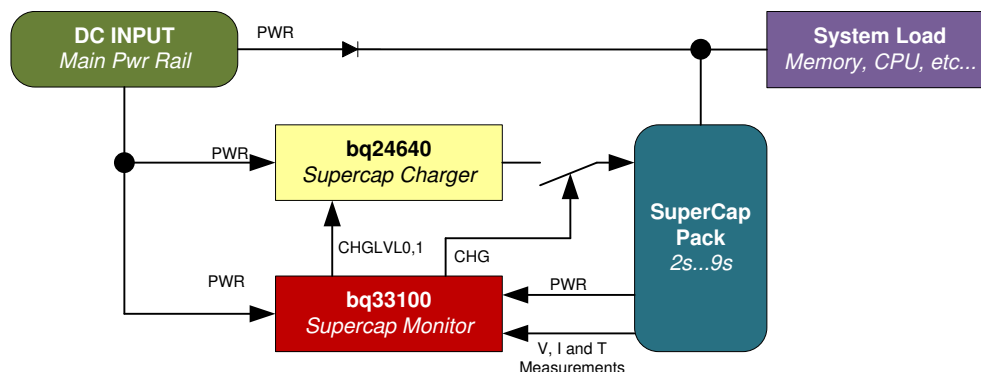
The Texas Instruments BQ33100 Super Capacitor Manager is a fully integrated, single-chip solution that provides a rich array of features for charge control, monitoring, and protection for either 2-, 3-, 4-, or 5-series super capacitors with individual capacitor monitoring and balancing or up to 9-series capacitors with only the stack voltage being measured. With a small footprint of 7.8 mm  $\times$  6.4 mm in a compact 24-pin TSSOP package, the BQ33100 maximizes functionality and safety while dramatically increasing ease of use and cutting the solution cost and size for super capacitor applications.

### Device Information<sup>(1)</sup>

| PART NUMBER | PACKAGE    | BODY SIZE (NOM)          |
|-------------|------------|--------------------------|
| BQ33100     | TSSOP (24) | 7.80 mm $\times$ 4.40 mm |

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

### Simplified Schematic



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## 4 Revision History

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

| Changes from Revision B (December 2015) to Revision C | Page |
|-------------------------------------------------------|------|
| • Changed <i>Recommended Operating Conditions</i>     | 6    |
| • Changed <i>OC Dsg</i>                               | 43   |
| • Changed <i>OC Dsg Time</i>                          | 44   |
| • Changed <i>SC Dsg Cfg</i>                           | 45   |
| • Changed <i>SC Chg Cfg</i>                           | 46   |
| • Changed <i>Initial 1st Capacitance</i>              | 47   |
| • Changed <i>Capacitance</i>                          | 47   |
| • Changed <i>Measurement Margin %</i>                 | 50   |
| • Changed <i>Max Dsg Time</i>                         | 51   |
| • Changed <i>V Chg Nominal</i>                        | 51   |
| • Changed <i>V Chg A</i>                              | 51   |
| • Changed <i>V Chg B</i>                              | 51   |
| • Changed <i>V Chg Max</i>                            | 51   |
| • Changed <i>Min Voltage</i>                          | 51   |
| • Changed <i>Learning Frequency</i>                   | 52   |

**Changes from Revision A (March 2011) to Revision B**
**Page**

|                                                                                                                                                                                                                                                                                                                                                      |                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| • Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section ..... | <a href="#">1</a>  |
| • OperationStatus() register bit 9 change from RSVD to CHGOR.....                                                                                                                                                                                                                                                                                    | <a href="#">38</a> |

**Changes from Original (January 2011) to Revision A**
**Page**

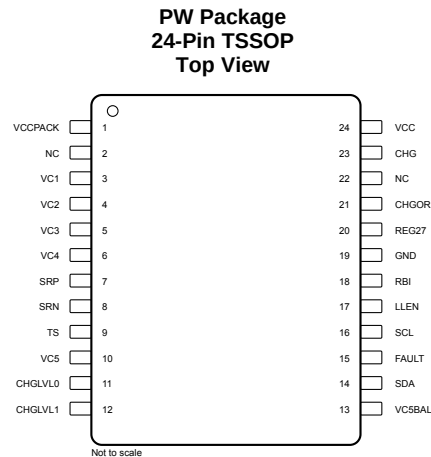
|                                                                          |                    |
|--------------------------------------------------------------------------|--------------------|
| • Changed SYSTEM PARTITIONING DIAGRAM.....                               | <a href="#">14</a> |
| • Changed Voltage as Current During Learning graphic. ....               | <a href="#">15</a> |
| • Changed equation 1 denominator from (V[D] - [C]) to (V[C] - V[D])..... | <a href="#">15</a> |
| • Changed Application Reference Schematic. ....                          | <a href="#">53</a> |

## 5 Description (Continued)

Using its integrated high-performance analog peripherals, the BQ33100 battery manager measures and maintains an accurate record of available capacitance, state-of-health, voltage, current, temperature, and other critical parameters in super capacitors, and reports the information to the system host controller over a 2-wire SMBus 1.1 compatible interface.

The BQ33100 provides firmware-controlled protection on overvoltage, overtemperature, and overcharge, along with hardware-controlled protection for overcurrent in discharge and short circuit protection during charge and discharge.

## 6 Pin Configuration and Functions



**Pin Functions**

| PIN     |     | TYPE <sup>(1)</sup> | DESCRIPTION                                                                                                                                                                                                                           |
|---------|-----|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME    | NO. |                     |                                                                                                                                                                                                                                       |
| CHG     | 23  | O                   | P-Channel FET drive for controlling charge                                                                                                                                                                                            |
| CHGLVL0 | 11  | O                   | Charge Control Output 0                                                                                                                                                                                                               |
| CHGLVL1 | 12  | O                   | Charge Control Output 1                                                                                                                                                                                                               |
| CHGOR   | 21  | I                   | CHG override input. If not used, connect to VSS.                                                                                                                                                                                      |
| FAULT   | 15  | O                   | Active high output to indicate fault condition                                                                                                                                                                                        |
| GND     | 19  | P                   | Ground                                                                                                                                                                                                                                |
| LLEN    | 17  | O                   | Learn Load Enable Output                                                                                                                                                                                                              |
| NC      | 2   | O                   | Not used and must be connected to VCC                                                                                                                                                                                                 |
| NC      | 22  | —                   | No connect. Leave the NC pin floating.                                                                                                                                                                                                |
| RBI     | 18  | P                   | RAM backup pin to provide backup potential to the internal DATA RAM if power is momentarily lost by using a capacitor attached between RBI and GND.                                                                                   |
| REG27   | 20  | P                   | Internal power supply 2.7-V bias output                                                                                                                                                                                               |
| SCL     | 16  | I/OD                | Serial clock input: Clocks data on SDA                                                                                                                                                                                                |
| SDA     | 14  | I/OD                | Serial data: transmits and receives data                                                                                                                                                                                              |
| SRN     | 8   | IA                  | Analog input pin connected to the internal ADC peripheral for measuring a small voltage between SRP and SRN where SRN is the bottom of the sense resistor.                                                                            |
| SRP     | 7   | IA                  | Analog input pin connected to the internal ADC peripheral for measuring a small voltage between SRP and SRN where SRP is the top of the sense resistor.                                                                               |
| TS      | 9   | IA                  | Thermistor input                                                                                                                                                                                                                      |
| VC1     | 3   | IA                  | Sense voltage input terminal and external capacitor voltage balancing drive output for the 5th-series capacitor, and stack measurement input. See <a href="#">Series Capacitor Configuration</a> for systems with less than 5 series. |

(1) I = Input, O = Output, P = Power, IA = Analog Input, OD = Open Drain

## Pin Functions (continued)

| PIN     |     | TYPE <sup>(1)</sup> | DESCRIPTION                                                                                                                                                                                              |
|---------|-----|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME    | NO. |                     |                                                                                                                                                                                                          |
| VC2     | 4   | IA                  | Sense voltage input terminal and external capacitor voltage balancing drive output for the 4th-series capacitor. See <a href="#">Series Capacitor Configuration</a> for systems with less than 5 series. |
| VC3     | 5   | IA                  | Sense voltage input terminal and external capacitor voltage balancing drive output for the 3rd-series capacitor. See <a href="#">Series Capacitor Configuration</a> for systems with less than 5 series. |
| VC4     | 6   | IA                  | Sense voltage input terminal and external capacitor voltage balancing drive output for the 2nd-series capacitor. See <a href="#">Series Capacitor Configuration</a> for systems with less than 5 series. |
| VC5     | 10  | IA                  | Sense voltage input terminal and external capacitor voltage balancing drive output for the 1st capacitor. See <a href="#">Series Capacitor Configuration</a> for systems with less than 5 series.        |
| VC5BAL  | 13  | O                   | Cell balance control output for the least positive capacitor (only used in a 5-series capacitor configuration)                                                                                           |
| VCCPACK | 1   | P                   | Power supply from the super capacitors. The top of the super capacitor stack must be connected to this pin.                                                                                              |
| VCC     | 24  | P                   | Positive input from power supply                                                                                                                                                                         |

## 7 Specifications

### 7.1 Absolute Maximum Ratings

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

|                   |                                              |                                  | MIN                    | MAX                                              | UNIT |
|-------------------|----------------------------------------------|----------------------------------|------------------------|--------------------------------------------------|------|
| V <sub>MAX</sub>  | Supply voltage                               | VCC w.r.t. GND                   | −0.3                   | 34                                               | V    |
| V <sub>IN</sub>   | Input voltage                                | VC1, VCC                         | V <sub>VC2</sub> − 0.3 | V <sub>VC2</sub> + 8.5 or 34, whichever is lower | V    |
|                   |                                              | VC2                              | V <sub>VC3</sub> − 0.3 | V <sub>VC3</sub> + 8.5                           | V    |
|                   |                                              | VC3                              | V <sub>VC4</sub> − 0.3 | V <sub>VC4</sub> + 8.5                           | V    |
|                   |                                              | VC4                              | V <sub>SRP</sub> − 0.3 | V <sub>SRP</sub> + 8.5                           | V    |
|                   |                                              | SRP, SRN                         | −0.3                   | V <sub>REG27</sub>                               | V    |
|                   |                                              | SDA, SCL                         | −0.3                   | 6.0                                              | V    |
|                   |                                              | CHGOR                            | −0.3                   | VCC                                              | V    |
|                   |                                              | TS, VC5, CHGLVL0, CHGLVL1, FAULT | −0.3                   | V <sub>REG27</sub> + 0.3                         | V    |
| V <sub>O</sub>    | Output voltage                               | CHG                              | −0.3                   | VCC                                              | V    |
|                   |                                              | VC5BAL                           | −0.3                   | V <sub>REG27</sub> + 0.3                         | V    |
|                   |                                              | RBI, REG27                       | −0.3                   | 2.75                                             | V    |
| I <sub>SS</sub>   | Maximum combined sink current for input pins |                                  |                        | 50                                               | mA   |
| T <sub>FUNC</sub> | Functional temperature                       |                                  | −40                    | 110                                              | °C   |
| T <sub>stg</sub>  | Storage temperature                          |                                  | −65                    | 150                                              | °C   |

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

### 7.2 ESD Ratings

|                    |                         | VALUE                                                                          | UNIT  |
|--------------------|-------------------------|--------------------------------------------------------------------------------|-------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±2000 |
|                    |                         | 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

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

|                        |                                     | MIN       | NOM | MAX           | UNIT        |
|------------------------|-------------------------------------|-----------|-----|---------------|-------------|
| Supply voltage         | VCC                                 |           |     | 25            | V           |
|                        | VCC                                 | 3.8       |     | $V_{VC2} + 5$ |             |
| $V_{STARTUP}$          | Start up voltage at VCC             |           | 5.2 | 5.5           | V           |
| $V_{SHUTDOWN}$         | VCC or VCCPACK, whichever is higher | 3         | 3.2 | 3.3           | V           |
| $V_{IN}$ Input voltage | VC1, VCC                            | $V_{VC2}$ |     | $V_{VC2} + 5$ | 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             |             |
|                        | VC5                                 | 0         |     | 1             |             |
|                        | VCC                                 |           |     | 25            |             |
|                        | CHGOR                               | 0         |     | $VCC - 0.3$   | V           |
|                        | SRP to SRN                          | -0.3      |     | 1             | V           |
| $C_{REG27}$            | External 2.7-V REG capacitor        | 1         |     |               | $\mu F$     |
| $T_{OPR}$              | Operating temperature               | -40       |     | 85            | $^{\circ}C$ |

## 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | BQ33100    | UNIT          |
|-------------------------------|----------------------------------------------|------------|---------------|
|                               |                                              | PW (TSSOP) |               |
|                               |                                              | 24 PINS    |               |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 83.6       | $^{\circ}C/W$ |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 16.5       | $^{\circ}C/W$ |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 39.4       | $^{\circ}C/W$ |
| $\psi_{JT}$                   | Junction-to-top characterization parameter   | 0.4        | $^{\circ}C/W$ |
| $\psi_{JB}$                   | Junction-to-board characterization parameter | 38.8       | $^{\circ}C/W$ |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | —          | $^{\circ}C/W$ |

(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: General Purpose I/O

Typical values stated where  $T_A = 25^{\circ}C$  and  $VCC = VCC = 14.4 V$ , minimum and maximum values stated where  $T_A = -40^{\circ}C$  to  $85^{\circ}C$  and  $VCC = VCC = 3.8 V$  to  $25 V$  (unless otherwise noted)

| PARAMETER      | TEST CONDITIONS                                                                                            | MIN               | TYP | MAX  | UNIT       |
|----------------|------------------------------------------------------------------------------------------------------------|-------------------|-----|------|------------|
| $V_{IH}$       | High-level input voltage<br>SDA, SCL, TS, VC5                                                              | 2                 |     |      | V          |
| $V_{IL}$       | Low-level input voltage<br>SDA, SCL, TS, VC5                                                               |                   |     | 0.8  | V          |
| $V_{OH}$       | Output voltage high<br>SDA, SCL, VC5BAL, CHGLVL0, CHGLVL1, LLEN, FAULT, $I_L = -0.5 mA$                    | $V_{REG27} - 0.5$ |     |      | V          |
| $V_{OL}$       | Low-level output voltage<br>SDA, SCL, VC5BAL, CHGLVL0, CHGLVL1, LLEN, FAULT, $I_L = 7 mA$                  |                   |     | 0.4  | V          |
| $C_{IN}$       | Input capacitance                                                                                          |                   | 5   |      | pF         |
| $I_{lkg}$      | Input leakage current<br>SDA, SCL, TS, VC5, CHGLVL0, CHGLVL1, LLEN, FAULT<br>SDA and SCL pulldown disabled |                   |     | 1    | $\mu A$    |
| $V_{CHGOR}$    | CHG override active high                                                                                   | 0.8               | 2   | 3.2  | V          |
| $R_{PD(SMBx)}$ | SDA and SCL pulldown<br>$T_A = -40^{\circ}C$ to $100^{\circ}C$                                             | 600               | 950 | 1300 | k $\Omega$ |
| $R_{PAD}$      | Pad resistance<br>TS                                                                                       |                   | 87  | 110  | $\Omega$   |

## 7.6 Supply Current

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

| PARAMETER      | TEST CONDITIONS                                                   | MIN | TYP | MAX | UNIT          |
|----------------|-------------------------------------------------------------------|-----|-----|-----|---------------|
| $I_{CC}$       | NORMAL mode<br>Firmware running, no flash writes                  |     | 660 |     | $\mu\text{A}$ |
| $I_{SHUTDOWN}$ | SHUTDOWN mode<br>$T_A = -40^\circ\text{C}$ to $110^\circ\text{C}$ |     | 0.5 | 1   | $\mu\text{A}$ |

## 7.7 REG27 LDO

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

| PARAMETER              | TEST CONDITIONS                                                                                                         | MIN  | TYP         | MAX      | UNIT |
|------------------------|-------------------------------------------------------------------------------------------------------------------------|------|-------------|----------|------|
| $V_{REG-}$             | Regulator output voltage<br>$I_{REG27} = 10\text{ mA}$<br>$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$               | 2.5  | 2.7         | 2.75     | V    |
| $V_{REG27IT-}$         | Negative-going POR voltage<br>At REG27                                                                                  | 2.22 | 2.35        | 2.34     | V    |
| $V_{REG27IT+}$         | Positive-going POR voltage<br>At REG27                                                                                  | 2.25 | 2.5         | 2.6      | V    |
| $\Delta V_{(REGTEMP)}$ | Regulator output change with temperature<br>$I_{REG} = 10\text{ mA}$<br>$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ |      | $\pm 0.5\%$ |          |      |
| $\Delta V_{(REGLINE)}$ | Line regulation<br>$I_{REG} = 10\text{ mA}$                                                                             |      | $\pm 2$     | $\pm 4$  | mV   |
| $\Delta V_{(REGLOAD)}$ | Load regulation<br>$I_{REG} = 0.2$ to $10\text{ mA}$                                                                    |      | $\pm 20$    | $\pm 40$ | mV   |
| $I_{(REGMAX)}$         | Current limit                                                                                                           | 25   |             | 50       | mA   |

## 7.8 Coulomb Counter

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

| PARAMETER                       | TEST CONDITIONS                                 | MIN   | TYP           | MAX           | UNIT                         |
|---------------------------------|-------------------------------------------------|-------|---------------|---------------|------------------------------|
| Input voltage range             |                                                 | -0.2  |               | 0.25          | V                            |
| Conversion time                 | Single conversion                               |       | 250           |               | ms                           |
| Effective resolution            | Single conversion                               | 15    |               |               | Bits                         |
| Integral nonlinearity           | $T_A = -25^\circ\text{C}$ to $85^\circ\text{C}$ |       | $\pm 0.007\%$ | $\pm 0.034\%$ | FSR                          |
| Offset error <sup>(1)</sup>     | $T_A = -25^\circ\text{C}$ to $85^\circ\text{C}$ |       | 10            |               | $\mu\text{V}$                |
| Offset error drift              |                                                 |       | 0.3           | 0.5           | $\mu\text{V}/^\circ\text{C}$ |
| Full-scale error <sup>(2)</sup> |                                                 | -0.8% | 0.2%          | 0.8%          |                              |
| Full-scale error drift          |                                                 |       |               | 150           | PPM/ $^\circ\text{C}$        |
| Effective input resistance      |                                                 | 2.5   |               |               | M $\Omega$                   |

(1) Post calibration performance

(2) Uncalibrated performance. This gain error can be eliminated with external calibration.

## 7.9 ADC

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

| PARAMETER                     | TEST CONDITION        | MIN   | TYP         | MAX                    | UNIT                         |
|-------------------------------|-----------------------|-------|-------------|------------------------|------------------------------|
| Input voltage range           | TS, VC5               | -0.2  |             | $0.8 \times V_{REG27}$ | V                            |
| Conversion time               |                       |       | 31.5        |                        | ms                           |
| Resolution (no missing codes) |                       | 16    |             |                        | Bits                         |
| Effective resolution          |                       | 14    | 15          |                        | Bits                         |
| Integral nonlinearity         |                       |       |             | $\pm 0.02\%$           | FSR                          |
| Offset error <sup>(1)</sup>   |                       |       | 70          | 160                    | $\mu\text{V}$                |
| Offset error drift            |                       |       | 1           |                        | $\mu\text{V}/^\circ\text{C}$ |
| Full-scale error              | $V_{IN} = 1\text{ V}$ | -0.8% | $\pm 0.2\%$ | 0.4%                   |                              |
| Full-scale error drift        |                       |       |             | 150                    | PPM/ $^\circ\text{C}$        |
| Effective input resistance    |                       | 8     |             |                        | M $\Omega$                   |

(1) Channel to channel offset

## 7.10 External Capacitor Voltage Balance Drive

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

| PARAMETER                                                                                   | TEST CONDITIONS                                                                                             | MIN | TYP  | MAX | UNIT       |
|---------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-----|------|-----|------------|
| $R_{\text{BAL\_drive}}$ Internal pulldown resistance for external capacitor voltage balance | Capacitor voltage balance ON for VC1, $V_{Ci} - V_{Ci} + 1 = 4\text{ V}$ , where $i = 1$ to approximately 4 |     | 5.7  |     | k $\Omega$ |
|                                                                                             | Capacitor voltage balance ON for VC2, $V_{Ci} - V_{Ci} + 1 = 4\text{ V}$ , where $i = 1$ to approximately 4 |     | 3.7  |     |            |
|                                                                                             | Capacitor voltage balance ON for VC3, $V_{Ci} - V_{Ci} + 1 = 4\text{ V}$ , where $i = 1$ to approximately 4 |     | 1.75 |     |            |
|                                                                                             | Capacitor voltage balance ON for VC4, $V_{Ci} - V_{Ci} + 1 = 4\text{ V}$ , where $i = 1$ to approximately 4 |     | 0.85 |     |            |

## 7.11 Capacitor Voltage Monitor

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

| PARAMETER                              | TEST CONDITIONS                                 | MIN | TYP      | MAX      | UNIT |
|----------------------------------------|-------------------------------------------------|-----|----------|----------|------|
| CAPACITOR Voltage Measurement Accuracy | $T_A = -10^\circ\text{C}$ to $60^\circ\text{C}$ |     | $\pm 10$ | $\pm 20$ | mV   |
|                                        | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ |     | $\pm 10$ | $\pm 35$ |      |

## 7.12 Internal Temperature Sensor

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

| PARAMETER                                       | TEST CONDITIONS | MIN | TYP       | MAX | UNIT             |
|-------------------------------------------------|-----------------|-----|-----------|-----|------------------|
| $T_{\text{(TEMP)}}$ Temperature sensor accuracy |                 |     | $\pm 3\%$ |     | $^\circ\text{C}$ |

## 7.13 Thermistor Measurement Support

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

| PARAMETER                                | TEST CONDITIONS | MIN | TYP  | MAX | UNIT                  |
|------------------------------------------|-----------------|-----|------|-----|-----------------------|
| $R_{\text{ERR}}$ Internal resistor drift |                 |     | -230 |     | ppm/ $^\circ\text{C}$ |
| $R$ Internal resistor                    | TS              |     | 17   | 20  | k $\Omega$            |

## 7.14 Internal Thermal Shutdown

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

| PARAMETER <sup>(1)</sup>                             | TEST CONDITIONS | MIN | TYP | MAX | UNIT             |
|------------------------------------------------------|-----------------|-----|-----|-----|------------------|
| $T_{\text{MAX}}$ Maximum REG27 temperature           |                 | 125 |     | 175 | $^\circ\text{C}$ |
| $T_{\text{RECOVER}}$ Recovery hysteresis temperature |                 |     | 10  |     | $^\circ\text{C}$ |

(1) Parameters assured by design. Not production tested

## 7.15 High-Frequency Oscillator

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

| PARAMETER                                           | TEST CONDITIONS                                 | MIN | TYP          | MAX | UNIT |
|-----------------------------------------------------|-------------------------------------------------|-----|--------------|-----|------|
| $f_{\text{(OSC)}}$ Operating frequency of CPU clock |                                                 |     | 2.097        |     | MHz  |
| $f_{\text{(EIO)}}$ Frequency error <sup>(1)</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%  |      |
| $t_{\text{(SXO)}}$ Start-up time <sup>(2)</sup>     | $T_A = -25^\circ\text{C}$ to $85^\circ\text{C}$ |     | 3            | 6   | ms   |

(1) The frequency drift is included and measured from the trimmed frequency at  $V_{CC} = V_{CC} = 14.4\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

(2) 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.

## 7.16 Low-Frequency Oscillator

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

| PARAMETER                                          | TEST CONDITIONS                                 | MIN   | TYP          | MAX  | UNIT |
|----------------------------------------------------|-------------------------------------------------|-------|--------------|------|------|
| $f_{(\text{LOSC})}$ Operating frequency            |                                                 |       | 32.768       |      | MHz  |
| $f_{(\text{LEIO})}$ Frequency error <sup>(1)</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% |      |
| $t_{(\text{LSXO})}$ Start-up time <sup>(2)</sup>   | $T_A = -25^\circ\text{C}$ to $85^\circ\text{C}$ |       |              | 100  | ms   |

(1) The frequency drift is included and measured from the trimmed frequency at  $V_{CC} = V_{CC} = 14.4\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

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

## 7.17 RAM Backup

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

| PARAMETER                                                    | TEST CONDITIONS                                                                                                                              | MIN | TYP | MAX  | UNIT |
|--------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|------|------|
| $I_{(\text{RBI})}$ RBI data-retention input current          | $V_{\text{RBI}} > V_{(\text{RBI})\text{MIN}}$ , $V_{\text{REG27}} < V_{\text{REG27IT-1}}$<br>$T_A = 70^\circ\text{C}$ to $110^\circ\text{C}$ |     | 20  | 1500 | nA   |
|                                                              | $V_{\text{RBI}} > V_{(\text{RBI})\text{MIN}}$ , $V_{\text{REG27}} < V_{\text{REG27IT-1}}$<br>$T_A = -40^\circ\text{C}$ to $70^\circ\text{C}$ |     |     | 500  |      |
| $V_{(\text{RBI})}$ RBI data-retention voltage <sup>(1)</sup> |                                                                                                                                              | 1   |     |      | V    |

(1) Specified by design. Not production tested

## 7.18 Flash

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

| PARAMETER <sup>(1)</sup>                                 | TEST CONDITIONS                                | MIN | TYP | MAX | UNIT   |
|----------------------------------------------------------|------------------------------------------------|-----|-----|-----|--------|
| Data retention                                           |                                                | 10  |     |     | Years  |
| Flash programming write-cycles                           |                                                | 20k |     |     | Cycles |
| $t_{(\text{ROWPROG})}$ Row programming time              |                                                |     |     | 2   | ms     |
| $t_{(\text{MASSERASE})}$ Mass-erase time                 |                                                |     |     | 250 | ms     |
| $t_{(\text{PAGEERASE})}$ Page-erase time                 |                                                |     |     | 25  | ms     |
| $I_{\text{CC}(\text{PROG})}$ Flash-write supply current  |                                                |     | 4   | 6   | mA     |
| $I_{\text{CC}(\text{ERASE})}$ Flash-erase supply current | $T_A = -40^\circ\text{C}$ to $0^\circ\text{C}$ |     | 8   | 22  | mA     |
|                                                          | $T_A = 0^\circ\text{C}$ to $85^\circ\text{C}$  |     | 3   | 15  |        |

(1) Specified by design. Not production tested

## 7.19 Current Protection Thresholds

Typical values stated where  $T_A = 25^\circ\text{C}$  and  $V_{CC} = V_{CC} = 14.4\text{ V}$ , minimum and maximum values stated where  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  and  $V_{CC} = V_{CC} = 3.8\text{ V}$  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   |      |      |
| $V_{(SCCT)}$        | SCC detection threshold voltage range, typical | RSNS = 0        | -100 |     | -300 | mV   |
|                     |                                                | RSNS = 1        | -50  |     | -225 |      |
| $\Delta V_{(SCCT)}$ | SCC detection threshold voltage program step   | RSNS = 0        |      | -50 |      | mV   |
|                     |                                                | RSNS = 1        |      | -25 |      |      |
| $V_{(SCDT)}$        | SCD detection threshold voltage range, typical | RSNS = 0        | 100  |     | 450  | mV   |
|                     |                                                | RSNS = 1        | 50   |     | 225  |      |
| $\Delta V_{(SCDT)}$ | SCD detection threshold voltage program step   | RSNS = 0        |      | 50  |      | mV   |
|                     |                                                | RSNS = 1        |      | 25  |      |      |
| $V_{(OFFSET)}$      | SCD, SCC and OCD offset                        |                 | -10  |     | 10   | mV   |
| $V_{(Scale\_Err)}$  | SCD, SCC and OCD scale error                   |                 | -10% |     | 10%  |      |

## 7.20 Current Protection Timing

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

|                          |                                                   |                                                                                         | MIN  | NOM | MAX  | UNIT |
|--------------------------|---------------------------------------------------|-----------------------------------------------------------------------------------------|------|-----|------|------|
| t <sub>(OCDD)</sub>      | Overcurrent in discharge delay                    |                                                                                         | 1    |     | 31   | ms   |
| t <sub>(OCDD_STEP)</sub> | OCDD step options                                 |                                                                                         |      | 2   |      | ms   |
| t <sub>(SCDD)</sub>      | Short circuit in discharge delay                  | AFE.STATE_CNTL[SCDDx2] = 0                                                              | 0    |     | 915  | μs   |
|                          |                                                   | AFE.STATE_CNTL[SCDDx2] = 1                                                              | 0    |     | 1830 |      |
| t <sub>(SCDD_STEP)</sub> | SCDD step options                                 | AFE.STATE_CNTL[SCDDx2] = 0                                                              |      | 61  |      | μs   |
|                          |                                                   | AFE.STATE_CNTL[SCDDx2] = 1                                                              |      | 122 |      |      |
| t <sub>(SCCD)</sub>      | Short circuit in charge delay                     |                                                                                         | 0    |     | 915  | μs   |
| t <sub>(SCCD_STEP)</sub> | SCCD step options                                 |                                                                                         |      | 61  |      | μs   |
| t <sub>(DETECT)</sub>    | Current fault detect time                         | V <sub>SRP-SRN</sub> = V <sub>THRESH</sub> + 12.5 mV,<br>T <sub>A</sub> = −40°C to 85°C |      | 35  | 160  | μs   |
| t <sub>ACC</sub>         | Overcurrent and short circuit delay time accuracy | Accuracy of typical delay time with WDI active                                          | −20% |     | 20%  |      |
|                          |                                                   | Accuracy of typical delay time with no WDI input                                        | −50% |     | 50%  |      |

## 7.21 Timing Requirements: SMBus

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

|                       |                                         |                                        | MIN | NOM  | MAX  | UNIT          |
|-----------------------|-----------------------------------------|----------------------------------------|-----|------|------|---------------|
| $f_{\text{SMB}}$      | SMBus operating frequency               | Slave mode, SCL 50% duty cycle         | 10  |      | 100  | kHz           |
| $f_{\text{MAS}}$      | SMBus master clock frequency            | Master mode, no clock low slave extend |     | 51.2 |      | kHz           |
| $t_{\text{BUF}}$      | Bus free time between start and stop    |                                        | 4.7 |      |      | $\mu\text{s}$ |
| $t_{\text{HD:STA}}$   | Hold time after (repeated) start        |                                        | 4   |      |      | $\mu\text{s}$ |
| $t_{\text{SU:STA}}$   | Repeated start setup time               |                                        | 4.7 |      |      | $\mu\text{s}$ |
| $t_{\text{SU:STO}}$   | Stop setup time                         |                                        | 4   |      |      | $\mu\text{s}$ |
| $t_{\text{HD:DAT}}$   | Data hold time                          | Receive mode                           | 0   |      |      | ns            |
|                       |                                         | Transmit mode                          | 300 |      |      |               |
| $t_{\text{SU:DAT}}$   | Data setup time                         |                                        | 250 |      |      | ns            |
| $t_{\text{TIMEOUT}}$  | Error signal and detect                 | See <sup>(1)</sup>                     | 25  |      | 35   | ms            |
| $t_{\text{LOW}}$      | Clock low period                        |                                        | 4.7 |      |      | $\mu\text{s}$ |
| $t_{\text{HIGH}}$     | Clock high period                       | See <sup>(2)</sup>                     | 4   |      | 50   | $\mu\text{s}$ |
| $t_{\text{LOW:SEXT}}$ | Cumulative clock low slave extend time  | See <sup>(3)</sup>                     |     |      | 25   | ms            |
| $t_{\text{LOW:MEXT}}$ | Cumulative clock low master extend time | See <sup>(4)</sup>                     |     |      | 10   | ms            |
| $t_{\text{F}}$        | Clock and data fall time                | See <sup>(5)</sup>                     |     |      | 300  | ns            |
| $t_{\text{R}}$        | Clock and data rise time                | See <sup>(6)</sup>                     |     |      | 1000 | ns            |

(1) The BQ33100 times out when any clock low exceeds  $t_{\text{TIMEOUT}}$ .

(2)  $t_{\text{HIGH}}$  maximum is the minimum bus idle time. SCL = SDA = 1 for  $t > 50\text{ }\mu\text{s}$  causes reset of any transaction involving BQ33100 that is in progress.

(3)  $t_{\text{LOW:SEXT}}$  is the cumulative time a slave device is allowed to extend the clock cycles in one message from initial start to the stop.

(4)  $t_{\text{LOW:MEXT}}$  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  $t_{\text{R}} = V_{\text{ILMAX}} - 0.15$  to  $(V_{\text{IHMIN}} + 0.15)$

(6) Fall time  $t_{\text{F}} = 0.9 V_{\text{DD}}$  to  $(V_{\text{ILMAX}} - 0.15)$

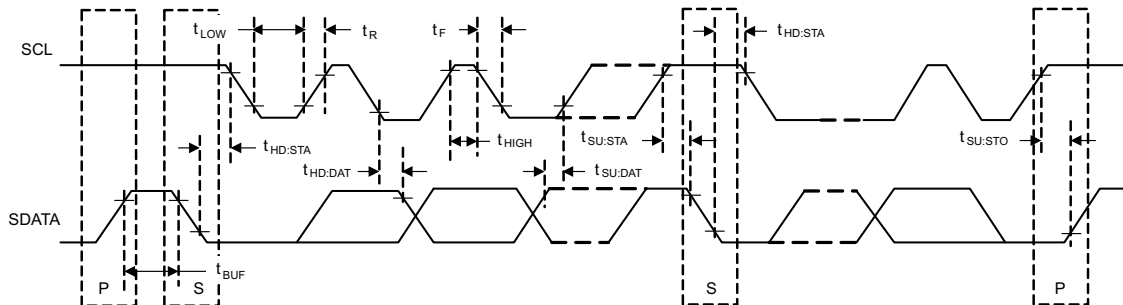


**Figure 1. SMBus Timing**

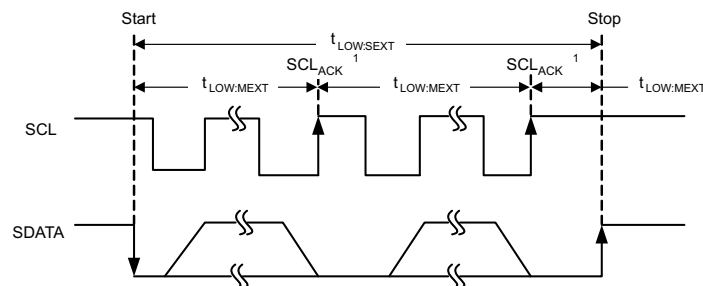


**Figure 2. SMBus  $t_{\text{TIMEOUT}}$**

## 7.22 Typical Characteristics

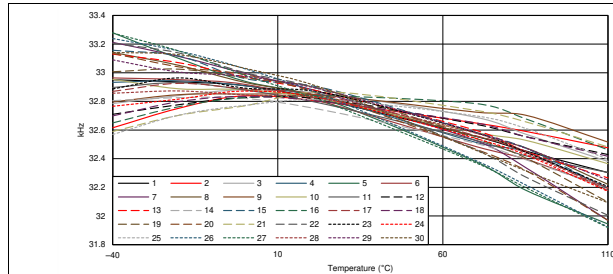


Figure 3. Low Frequency Oscillator (LFO) Value Across Temperature With REG27 = 2.5 V

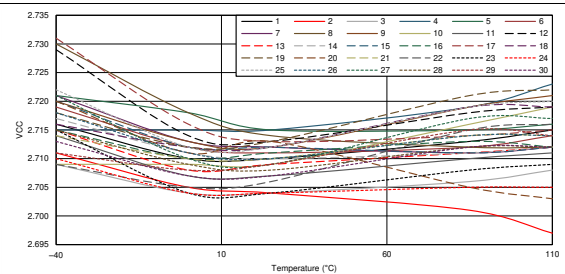


Figure 4. REG27 Output Voltage Variation Across Temperature With a Nominal Load of 2 mA

## 8 Detailed Description

### 8.1 Overview

The BQ33100 is a super capacitor monitor, balancing controller, and overall system manager. The device can individually monitor up to five series capacitors and up to nine when monitoring the total stack.

The device can also interact with an external charging solution to provide capacitance and effective series resistance (ESR) data on the stack.

#### NOTE

The following notation is used in this document if SBS commands and data flash values are mentioned within a text block:

- SBS commands are set in *italic*, for example: *Voltage*
- SBS bits and flags are capitalized, set in *italic* and enclosed with square brackets, for example: *[SS]*
- Data flash values are set in ***italic***, for example: ***OV Threshold***
- All data flash bits and flags are capitalized, set in ***italic***, and enclosed with square brackets, for example: ***[OV]***

All SBS commands, data flash values and flags mentioned in a chapter are listed at the beginning of each chapter for reference.

The reference format for SBS commands is:

SBS:Command Name(Command No.):Manufacturer Access(MA No.)[Flag], for example:

SBS:Voltage(0x09), or SBS:ManufacturerAccess(0x00):Seal Device(0x0020)

#### 8.1.1 Super Capacitor Measurements

The BQ33100 measures the series capacitor voltages or stack voltage, current, and temperature using a delta-sigma analog-to-digital converter (ADC). The BQ33100 uses this measured data and advanced algorithms to determine the state-of-health (SOH) and available capacitance of the super capacitor.

##### 8.1.1.1 Voltage

The BQ33100 has two separate modes, NORMAL mode and STACK mode, where measurements are taken and managed differently. Setting ***Operation Cfg [STACK]*** to 1 enables STACK mode; otherwise, the BQ33100 operates in NORMAL mode.

## Overview (continued)

The BQ33100 updates the individual series capacitor voltages and stack voltage at one (1) second intervals when in NORMAL mode and measures the stack voltage at one (1) second intervals when in STACK mode. The internal ADC of the BQ33100 measures the voltage, scales, and offsets, and calibrates it appropriately. To ensure an accurate differential voltage sensing, the IC ground must be connected directly to the most negative terminal of the super capacitor stack, not to the positive side of the sense resistor. This minimizes the voltage drop across the PCB trace.

### 8.1.1.2 Current, Charge, and Discharge Counting

The delta-sigma ADC measures the system current of the super capacitor by measuring the voltage drop across a small-value sense resistor (typically 5 mΩ to 20 mΩ typical) between the SRP and SRN pins. The ADC measures bipolar signals from –0.20 V to 0.25 V.

### 8.1.1.3 Device Calibration

The BQ33100 requires voltage calibration to maximize accuracy of the monitoring system, and the BQ33100 evaluation software can perform this calibration. The external filter resistors, connected from each capacitor to the VCx input of the BQ33100, are required to be 1 kΩ.

For maximum capacitor voltage measurement accuracy, the BQ33100 can automatically calibrate its offset between the A-to-D converter and the input of the high-voltage translation circuit during normal operation.

### 8.1.1.4 Temperature

The BQ33100 has an internal temperature sensor and input for an external temperature sensor input, TS. The external input is used in conjunction with an NTC thermistor (default is Semitec 103AT) to sense the super capacitor temperature. The BQ33100 can be configured to use internal or external temperature sensors.

### 8.1.1.5 Series Capacitor Configuration

The BQ33100 can monitor two, three, four, or five capacitors in series. [Table 1](#) shows the appropriate connectivity for the different options.

**Table 1. Series Capacitor Connectivity**

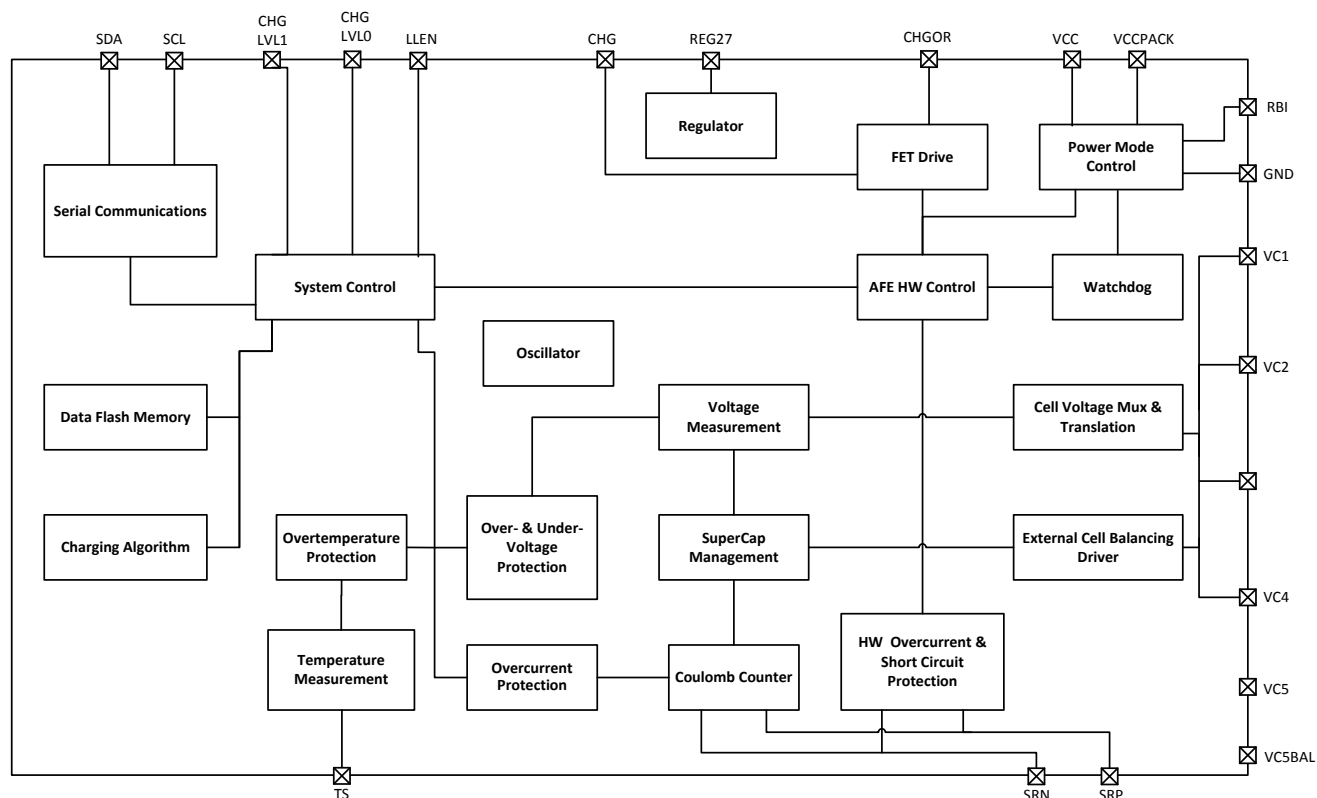
| BQ33100 PIN | 5-SERIES                            | 4-SERIES                            | 3-SERIES                            | 2-SERIES                            |
|-------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| VC1         | P of Top (5th) Cap                  | P of 4th Cap                        | Short to VC2                        | Short to VC2                        |
| VC2         | P of 4th Cap, N of 5th Cap          | P of 3rd Cap, N of 4th Cap          | P of 3rd Cap                        | Short to VC3                        |
| VC3         | P of 3rd Cap, N of 4th Cap          | P of 2nd Cap, N of 3rd Cap          | P of 2nd Cap, N of 3rd Cap          | P of 2nd Cap                        |
| VC4         | P of 2nd Cap, N of 3rd Cap          | P of Bottom (1st) Cap, N of 2nd Cap | P of Bottom (1st) Cap, N of 2nd Cap | P of Bottom (1st) Cap, N of 2nd Cap |
| VC5         | P of Bottom (1st) Cap, N of 2nd Cap | N of Bottom Cap (1st)               | N of Bottom Cap (1st)               | N of Bottom Cap (1st)               |
| VSS         | N of Bottom Cap (1st)               | Short to VC5                        | Short to VC5                        | Short to VC5                        |

#### NOTE

The CC0...CC2 bits in **Operation Cfg** must be programmed to match the corresponding configuration.

When in STACK mode (**Operation Cfg [STACK] = 1**), VC1 must be connected to VC2 and VC3 connected to VC4. Additionally, a *divide-by-2* resistor divider must connect between the top and bottom of the capacitor array with VC1,2 being the top, VC3,4 being the middle, and VSS being the bottom. In this configuration, pins VC5 and VC5BAL are not used and must be connected to VSS.

## 8.2 Functional Block Diagram



### 8.3 Feature Description

### 8.3.1 Capacitance Monitoring and Learning

#### 8.3.1.1 Monitoring and Control Operational Overview

The BQ33100 periodically determines the capacitance and equivalent series resistance (ESR) of the super capacitor array during normal operation. The *Learning Frequency* is a register that sets the time between automatic learning cycles of the super capacitor, which can also be manually executed by issuing a *Learn* command. The BQ33100 uses the learning cycles to update the *Capacitance* and *ESR* registers accordingly, and both are accessible through the SMBus interface.

The learning process is a multi-step procedure fully controlled by the BQ33100 that will perform the following sequence to learn capacitance and ESR:

1. Charge to **V Learn Max**.
2. Discharge using constant current load to a minimum voltage of the present charging voltage and internally record voltage and time.
3. Charge to **V Learn Max**.
4. Discharge using constant current load and internally record current and time.
5. Calculate capacitance and ESR based on recorded voltage and current.
6. Determine the new charging voltage.

## Feature Description (continued)

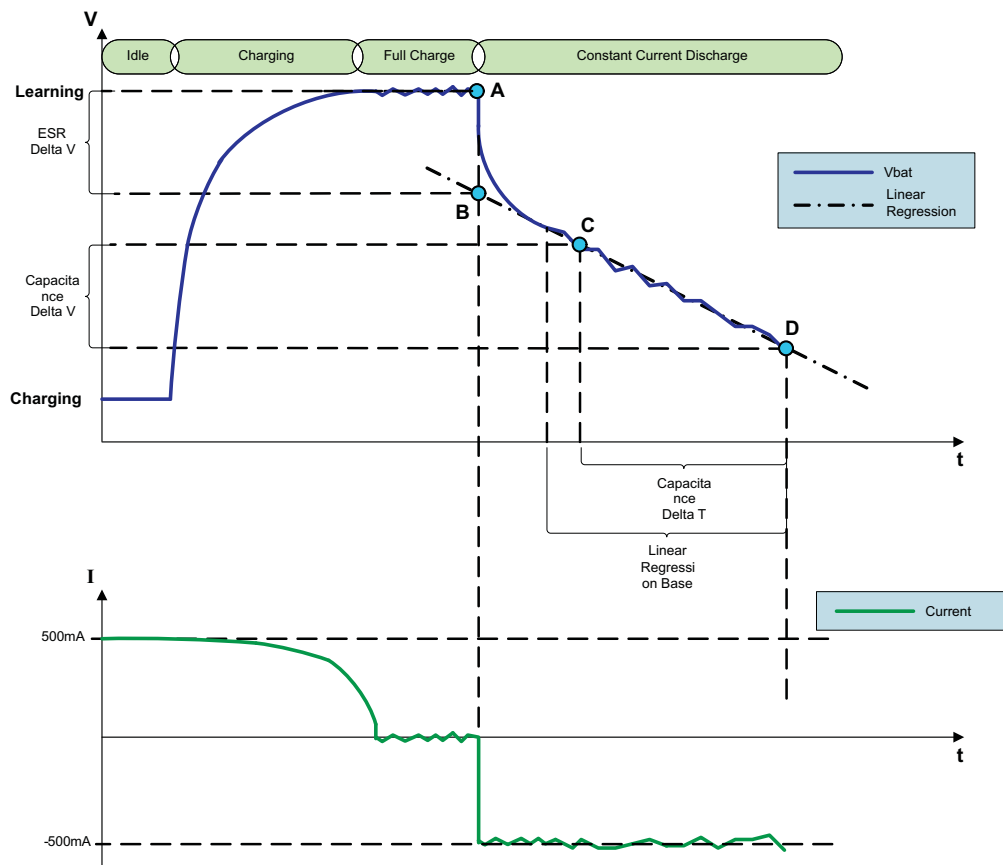


Figure 5. Voltage as Current During Learning

where:

$$C = I \times (t[D] - t[C]) / (V[C] - V[D]) \quad (1)$$

and

$$ESR = (V[A] - V[B]) / I \quad (2)$$

### 8.3.1.2 Main Monitoring Registers

**Capacitance** represents the total capacitance in the capacitor array and presents the value in units of F (Farads) to 1 decimal place.

On initialization, the BQ33100 sets **Capacitance** to the data flash value stored in **Initial Capacitance**. During subsequent learning cycles, the BQ33100 updates **Capacitance** with the last measured capacitance of the capacitor array. Once updated, the BQ33100 writes the new **Capacitance** value to data flash to **Capacitance**. **Capacitance** represents the full super capacitor reference for relative state-of-charge calculations.

**InitialCapacitance**—This is the first updated value of super capacitor capacitance and represented in units of F.

**RelativeStateOfCharge (RSOC)**—This represents the % of available energy. Use Equation 3 to calculate the RSOC.

$$(\text{Voltage} - \text{Min voltage}) / (\text{Charging Voltage} - \text{Min voltage}) \quad (3)$$

**Learning Frequency**—The **Learning Frequency** register sets the time between automatic learning cycles of the super capacitor, which can also be manually executed by issuing a **ManufacturerAccess Learn** command. The BQ33100 uses the learning cycles to measure the super capacitor capacitance and update the **Capacitance** register accordingly. When the BQ33100 is in UNSEALED mode then a value of 250 is used to set the learning Frequency to 10 minutes for test purposes.

## Feature Description (continued)

### 8.3.1.3 Initial Capacitance at Device Reset

The BQ33100 estimates the initial capacitance of a device reset, which is the case when the capacitors are first attached to the application circuit. This gives a reasonably accurate capacitance and RSOC value; however, super capacitor capacitance learning is required to improve the accuracy of capacitance and RSOC.

### 8.3.1.4 Qualified Capacitance Learning

The BQ33100 updates capacitance with an amount based on the value learned during a qualified learning cycle. Once updated, the BQ33100 writes the new *Capacitance* value to data flash to **Capacitance**.

The BQ33100 sets  $[CL] = 1$  and clears  $[LPASS]$  in *OperationStatus()* when a qualified capacitance learning cycle begins. The period of time that the learning takes is set by **CL Time**, although the first learning cycle after a device reset will not occur until after an elapsed time of **Learning Frequency**. When a qualified learn has occurred,  $[LPASS]$  in *OperationStatus()* is set.

During the learning process, there are specific timeouts to protect from overcharge or overdischarge of the super capacitor array. At the beginning of each phase of charge and discharge, a timer is started. If the timer exceeds **Max Discharge Time** during the discharging phase, then *OperationStatus()*  $[LDT0]$  is set. If the timer exceeds **Max Charge Time** for the charging phase, then *OperationStatus()*  $[LCT0]$  is set. The flags are cleared upon the beginning of the next learning cycle.

### 8.3.1.5 Health Determination

The BQ33100 uses [Equation 4](#) to determine the relative health of the capacitor:

$$\text{Health} = (\text{Capacitance} / \text{InitialCapacitance}) \quad (4)$$

The BQ33100 will determine a new *ChargingVoltage()* at end of the learning cycle based on the newly learned *Capacitance*. The following warnings will be set based on the changes in *ChargingVoltage()* and the capacitor's ability to provide the minimum power needs.

*ChargingVoltage()* = **V Chg Nominal**, then *SafetyStatus* $[HLOW]$ ,  $[HWARN]$  and  $[HFAIL]$  are cleared.

If *ChargingVoltage()* is set to **V Chg A** or **V Chg B**, then *SafetyStatus* $[HLOW]$  is set.

If *ChargingVoltage()* is set to **V Chg Max** then *SafetyStatus*  $[HWARN]$  is set.

If *ChargingVoltage()* is set to **V Chg Max** and the BQ33100 determines that the newly learned *Capacitance* cannot provide the minimum power requirements then *SafetyStatus*  $[HFAIL]$  is set.

The minimum power requirements is determined by the **Min Power**, **Required Time** and **Min Voltage** data flash values.

If the corresponding  $[HLOW]$ ,  $[HWARN]$  or  $[HFAIL]$  bits are set in **FAULT** when the *SafetyStatus* $[HLOW]$  or  $[HWARN]$  bit is set then the FAULT pin is set.

### 8.3.1.6 ESR Measurement

The BQ33100 measures the voltage on the capacitor stack when the LLEN pin (pin 17) is high with the initial learned value stored in **Initial ESR**, which is only updated once. The LLEN pin is controlled by firmware to enable a circuit that presents a constant current load to the full capacitor stack. With the known voltage and known current the ESR of the capacitor array can be determined. The final reported value of ESR is also adjusted by the data flash value of **ESR Offset**. The original value of the capacitor array ESR is stored in **Design ESR** but is not used by the BQ33100.

The final value of ESR can be read from the BQ33100 through *ESR*, which is in mΩ.

### 8.3.1.7 Monitor Operating Modes

Entry and exit of each mode is controlled by data flash parameters. In DISCHARGE mode, the  $[DSG]$  flag in *OperationStatus()* is set. DISCHARGE mode is entered when *Current* goes below (–)**Dsg Current Threshold**. DISCHARGE mode is exited when *Current* goes above **Chg Current Threshold** threshold for more than 1 second.

## Feature Description (continued)

CHARGE mode is entered when *Current* goes above **Chg Current Threshold**. CHARGE mode is exited when *Current* goes below **Dsg Current Threshold** for more than 1 second.

### 8.3.2 Capacitor Voltage Balancing

Capacitor voltage balancing in the BQ33100 is accomplished by connecting an external parallel bypass load to each capacitor, and enabling the bypass load depending on each individual capacitors voltage level. The bypass load is typically formed by a P-CH MOSFET and a resistor connected in series across each capacitor. The filter resistors that connect the capacitor tabs to VC1 to approximately VC4 pins of the BQ33100 are required to be 1 k ohms to support this function on all capacitors other than the lowest. The lowest capacitor bypass is enabled through the VC5BAL pin. Capacitor Voltage Balancing is only operational after the *ManufacturerAccess* Lifetime and Capacitor Balancing Enable (0x21) command is sent to the BQ33100.

Using this circuit, the BQ33100 balances the capacitors during charge and after charge termination by discharging those capacitors with voltage above the threshold set in **CB Threshold** and if the  $\Delta V$  in capacitor voltages exceeds the value programmed in **CB Min**. During capacitor voltage balancing, the BQ33100 measures the capacitor voltages periodically (during which time the voltage balancing circuit is turned off) and based on the capacitor voltages, the BQ33100 selects the appropriate capacitor to discharge. When  $\Delta V$  of *CapacitorVoltage5...1* < **CB Min** then capacitor voltage balancing stops. Capacitor voltage balancing restarts when  $\Delta V$  of *CapacitorVoltage5...1*  $\geq$  **CB Restart** to avoid balancing start-stop oscillations.

Capacitor voltage balancing only occurs when:

- Charging current is detected (*Current* > **Chg Current Threshold** OR
- The [FC] flag in *OperationStatus* has been set AND
- $\Delta \text{CapacitorVoltage5...1} \geq \text{CB Restart}$ .

Capacitor voltage balancing stops when:

- $\Delta \text{CapacitorVoltage5...1} < \text{CB Min}$
- Discharging current detected (*Current* > **Dsg Current Threshold**)

This feature is disabled when in STACK mode, when **Operation Cfg [STACK]** = 1.

### 8.3.3 Charge Control

The BQ33100 supports two main charge control architectures: discrete control and smart control. In a discrete charge control implementation, the CHGLVL0 and CHGLVL1 pins can be used to adjust the charging voltage of an external supply (see the reference schematic).

As the super capacitors age a higher charging voltage can be configured to offset the deteriorating super capacitor ESR and Capacitance due to aging. With the discrete control method there are 4 levels of charging voltages that can be chosen, **V Chg Nominal**, **V Chg A**, **V Chg B** and **V Chg Max**. The setting of the charging voltage is determined by the value of the latest determined required *Charging Voltage*.

The CHGLVL0 and CHGLVL1 pin states are defined by the V Chg X parameters selected per [Table 2](#):

**Table 2. ChargingVoltage() Parameters**

| CHARGINGVOLTAGE      | CHGLVL1 (PIN 12) | CHGLVL0 (PIN11) |
|----------------------|------------------|-----------------|
| <b>V Chg Nominal</b> | 0                | 0               |
| <b>V Chg A</b>       | 0                | 1               |
| <b>V Chg B</b>       | 1                | 0               |
| <b>V Chg Max</b>     | 1                | 1               |

In a smart control architecture the BQ33100 makes the appropriate maximum charging current and charging voltage per the charging algorithm available through the *ChargingCurrent* and *ChargingVoltage()* SMBus commands respectively. This enables either an SMBus master or smart charger to manage the charging of the super capacitor pack.

### 8.3.3.1 Charge Termination

The BQ33100 determines charge termination if:

- The average charge current < **Taper Current** during 2 consecutive **Current Taper Window** time periods, AND
- $Voltage + Taper\ Voltage \geq ChargingVoltage()$

#### NOTE

To make sure that the charge terminates properly, TI recommends that **Taper Current** be set to a value greater than the maximum charger voltage inaccuracy. In other words, the charger taper current must be set to a lower value than the taper current programmed in the dataflash to ensure proper charge termination and the FC bit gets set.

The BQ33100 sets the [FC] flag in *OperationStatus()* when a valid charge termination occurs and cleared when *RelativeStateOfCharge* is less than **FC Clear %**.

The **taper voltage** must be set to a value less than the **OV threshold**. This prevents an over voltage condition from occurring after the CL bit clears upon learning completion.

The BQ33100 can also determine charge termination if the RSOC is at a value equal to or greater than **FC set %**. If this is not the desired means of charge termination, **FC set %** must be set to -1%.

### 8.3.3.2 CHG Override Control

During the normal operation of the BQ33100 the CHG output of the BQ33100 is typically controlled automatically but can be overridden through the CHGOR pin (pin 21). On a low-to-high transition the CHG output is released turning off the external CHG FET and on a high-to-low transition the CHG output is pulled low after a programmable delay **CHG Enable Delay**. If **CHG Enable Delay** is programmed to 0 the delay is a maximum of 250 ms. If the CHG override function is not needed, then the CHGOR pin must connect to VSS.

### 8.3.4 Lifetime Data Gathering

#### 8.3.4.1 Lifetime Maximum Temperature

During the operation lifetime of the BQ33100 it gathers temperature data. During this time the BQ33100 can be enabled to record the maximum value that the measured temperature reached. If the [LTE] flag is set in *OperationStatus*, **Lifetime Max Temp** value is updated if one of the following conditions are met:

- Internal measurement temperature – **Lifetime Max Temp** > 1°C.
- Internal measurement temperature > **Lifetime Max Temp** for a period > 60 seconds.
- Internal measurement temperature > **Lifetime Max Temp** AND any other lifetime value is updated.

**Table 3. Lifetime Maximum Temperature**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME              | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|-------------|---------------|--------|-------------------|---------|---------------|-----------|-----------|---------------|-------|
| 59          | Lifetime Data | 0      | Lifetime Max Temp | Integer | 2             | 0         | 1400      | 350           | 0.1°C |

#### 8.3.4.2 Lifetime Minimum Temperature

During the operation lifetime of the BQ33100 it gathers temperature data. During this time the BQ33100 can be enabled to record the minimum value that the measured temperature reached. If the [LTE] flag is set, **Lifetime Min Temp** is updated if one of the following conditions are met:

- **Lifetime Min Temp** – internal measurement temperature > 1°C.
- **Lifetime Min Temp** > internal measurement temperature for a period > 60 seconds.
- **Lifetime Min Temp** > internal measurement temperature > AND any other lifetime value is updated.

**Table 4. Lifetime Minimum Temperature**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME              | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|-------------|---------------|--------|-------------------|---------|---------------|-----------|-----------|---------------|-------|
| 59          | Lifetime Data | 2      | Lifetime Min Temp | Integer | 2             | –600      | 1400      | 50            | 0.1°C |

### 8.3.4.3 Lifetime Maximum Capacitor Voltage

During the operation lifetime of the BQ33100, it gathers voltage data . During this time, the BQ33100 can be enabled to record the maximum value that the measured voltage reached. If the [LTE] flag is set, **Lifetime Max Capacitor Voltage** is updated if one of the following conditions are met:

- Any internally measured capacitor voltage – **Lifetime Max Capacitor Voltage** > 25 mV.
- Any internally measured capacitor voltage > **Lifetime Max Capacitor Voltage** for a period > 60 seconds.
- Any internally measured capacitor voltage **Lifetime Max Capacitor Voltage** AND any other lifetime value is updated.

**Table 5. Lifetime Max Capacitor Voltage**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME                           | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|--------------------------------|---------|---------------|-----------|-----------|---------------|------|
| 59          | Lifetime Data | 4      | Lifetime Max Capacitor Voltage | Integer | 2             | 0         | 32767     | 0             | mV   |

### 8.3.5 Safety Detection Features

The BQ33100 supports a wide range of super capacitor and system safety detection and protection features that are easily configured or enabled through the integrated data flash. These features are intended, through various configuration options, to provide a level of safety from external influences causing damage to components with the power path; for example, limiting the period of time the CHG FET is exposed to high current pulse charge conditions.

#### 8.3.5.1 Capacitor Overvoltage (OV)

The BQ33100 can detect capacitor overvoltage condition and protect capacitors from damage. When any *CapacitorVoltage5...1* exceeds (*ChargingVoltage()* / number of capacitors (see **Operation Cfg [CC2,1,0]** ) + **OV Threshold**) the [OV] flag in *SafetyAlert* is set.

When any *CapacitorVoltage5...1* exceeds (*ChargingVoltage()* / number of capacitors (see **Operation Cfg [CC2,1,0]** ) + **OV Threshold**) for a period greater than **OV Time** the [OV] flag in *SafetyStatus* is set.

When the BQ33100 is configured for PACK mode, when **Operation Cfg [STACK]** =1, then a fault is detected when *Voltage* exceeds (*ChargingVoltage()* + **OV Threshold**) the [OV] flag in *SafetyAlert* is set.

When the BQ33100 is configured for PACK mode, when **Operation Cfg [STACK]** =1, then a fault is detected when *Voltage* exceeds (*ChargingVoltage()* + **OV Threshold**) for a period greater than **OV Time** the [OV] flag in *SafetyStatus* is set.

This function is disabled if **OV Time** is set to 0.

In an overvoltage condition charging is disabled and the CHG FET is turned off, *ChargingCurrent* and *ChargingVoltage()* are set to 0.

The BQ33100 recovers from a capacitor overvoltage condition if all *CapacitorVoltages5..1* are equal to or lower than (*ChargingVoltage()* / number of capacitors (see **Operation Cfg [CC2,1,0]** ) + **OV Recovery**. If the BQ33100 is configured for PACK mode, then the recover occurs when *Voltage* is equal to or lower than (*ChargingVoltage()* + **OV Recovery**.

On recovery the [OV] flag is reset, and *ChargingCurrent* and *ChargingVoltage()* are set back to appropriate values per the charging algorithm.

#### NOTE

When *ChargingVoltage()* has been set to 0 due to a detected condition then the capacitor overvoltage function is suspended.

#### 8.3.5.2 Capacitor Voltage Imbalance (CIM)

The BQ33100 starts capacitor voltage imbalance detection when *Current* is less than or equal to **CIM Current** AND ALL *CapacitorVoltage5..1* > **Min CIM Check Voltage**.

When the difference between highest capacitor voltage and lowest capacitor voltage exceeds **CIM Fail Voltage** the [CIM] flag in *SafetyAlert* is set.

When the difference between highest capacitor voltage and lowest capacitor voltage exceeds **CIM Fail Voltage** for a period greater than **CIM Time** the [CIM] flag in *SafetyStatus* is set and *ChargingCurrent* and *ChargingVoltage()* are set to 0 and the CHG FET is turned off. *SafetyStatus()* [CIM] is cleared and CHG FET is allowed to turn ON when the differences between the highest capacitor voltage and lowest capacitor voltage is less than **CIM Recovery**.

This function is disabled if **CIM Time** is set to 0.

The capacitor voltage imbalance detection is cleared when the difference between highest capacitor voltage and lowest capacitor voltage is less than **CIM Fail Voltage**. When this is detected then the CHG FET is allowed to be turned on, if other safety and configuration states permit, *ChargingCurrent* and *ChargingVoltage()* are set to the appropriate value per the charging algorithm, and the [CIM] flag in *SafetyStatus* is reset.

#### 8.3.5.3 Weak Capacitor (CLBAD)

When the capacitor array has been fully charged (indicated by *OperationStatus* [FC] being set) then it is monitored for excessive leakage.

When *Current* exceeds **CLBAD Current** the [CLBAD] flag in *SafetyAlert* is set.

When *Current* exceeds **CLBAD** for a period greater than **CLBAD Time** the [CLBAD] flag in *SafetyStatus* is set.

This function is disabled if **CLBAD Time** is set to 0.

In a weak capacitor condition, charging is disabled and the CHG FET is turned off, *ChargingCurrent* and *ChargingVoltage()* are set to 0.

The weak capacitor fault is cleared when *Current* falls equal to or below the **CLBAD Recovery** limit. When the recovery condition is detected, then the CHG FET is allowed to be turned on, if other safety and configuration states permit, *ChargingCurrent* and *ChargingVoltage()* are set to the appropriate value per the charging algorithm, and the [CLBAD] flag in *SafetyStatus* is reset.

#### 8.3.5.4 Overtemperature (OT)

The BQ33100 has overtemperature protection to prevent charging at excessive temperatures.

When *Temperature* exceeds **OT Chg** the [OT] flag in *SafetyAlert* is set.

When *Temperature* exceeds **OT Chg** for a period greater than **OT Chg Time** the [OT] flag in *SafetyStatus* is set.

This function is disabled if **OT Chg Time** is set to 0.

In an overtemperature condition, charging is disabled and the CHG FET is turned off, *ChargingCurrent* and *ChargingVoltage()* are set to 0.

The overtemperature fault is cleared when *Temperature* falls equal to or below the **OT Chg Recovery** limit. When the recovery condition is detected, then the CHG FET is allowed to be turned on, if other safety and configuration states permit, *ChargingCurrent* and *ChargingVoltage()* are set to the appropriate value per the charging algorithm, and the [OT] flag in *SafetyStatus* is reset.

#### 8.3.5.5 Overcurrent During Charging (OC Chg)

The BQ33100 has an independent level of recoverable overcurrent protection during charging.

When *Current* exceeds **OC Chg** the [OCC] flag in *SafetyAlert* is set.

When *Current* exceeds **OC Chg** for a period greater than **OC Chg Time** the *[OCC]* flag in *SafetyStatus* is set and *ChargingCurrent* and *ChargingVoltage()* are set to 0.

This function is disabled if **OC Chg Time** is set to 0.

The overcurrent fault is cleared when *Current* falls below **OC Chg Recovery**. When a charging-fault recovery condition is detected, then the CHG FET is allowed to be turned on, if other safety and configuration states permit, *ChargingCurrent* and *ChargingVoltage()* are set to the appropriate value per the charging algorithm, and the *[OCC]* flag in *SafetyStatus* is reset.

### 8.3.5.6 Overcurrent During Discharging (OC Dsg)

The BQ33100 overcurrent is discharge detection executed by the integrated AFE is configured by the BQ33100 data flash **OC Dsg** and **OC Dsg Time** registers.

When the integrated AFE detects a overcurrent in discharge condition the charge FET is turned off and the *[OCD]* flag in *SafetyStatus* is set, the internal current recovery timer is reset and *ChargingCurrent* and *ChargingVoltage()* are set to 0.

The recovery is controlled by the BQ33100 and requires that *Current* be  $\leq$  **OC Dsg Recovery** threshold and that the internal AFE current recovery timer  $\geq$  **Current Recovery Time**.

When the recovery condition is detected, *ChargingCurrent* and *ChargingVoltage()* are set to the appropriate value per the charging algorithm, and the *[OCD]* flag in *SafetyStatus* is reset.

### 8.3.5.7 Short-Circuit During Charging (SC Chg)

The BQ33100 short-circuit during charging protection is executed by the integrated AFE is configured by the BQ33100 data flash **SC Chg Cfg** register.

When the integrated AFE detects a short circuit fault the charge FET is turned off and the *[SCC]* flag in *SafetyStatus* is set, the internal current recovery timer is reset and *ChargingCurrent* and *ChargingVoltage()* are set to 0.

The recovery is controlled by the BQ33100 and requires that *AverageCurrent* be  $\leq$  **SC Recovery** threshold and that the internal AFE current recovery timer  $\geq$  **Current Recovery Time**.

When the recovery condition is detected, *ChargingCurrent* and *ChargingVoltage()* are set to the appropriate value per the charging algorithm, and the *[SCC]* flag in *SafetyStatus* is reset.

### 8.3.5.8 Short-Circuit During Discharging (SC Dsg)

The BQ33100 short-circuit during discharging detection is executed by the integrated AFE is configured by the BQ33100 data flash **SC Dsg Cfg** register.

When the integrated AFE detects a short circuit fault the charge FET is turned off and the *[SCD]* flag in *SafetyStatus* is set, the internal current recovery timer is reset and *ChargingCurrent* and *ChargingVoltage()* are set to 0.

The recovery is controlled by the BQ33100 and requires that *Current* be  $\leq$  **SC Recovery** threshold and that the internal AFE current recovery timer  $\geq$  **Current Recovery Time**.

When the recovery condition is detected, *ChargingCurrent* and *ChargingVoltage()* are set to the appropriate value per the charging algorithm, and the *[SCD]* flag in *SafetyStatus* is reset.

### 8.3.5.9 AFE Watchdog (WDF)

The integrated AFE automatically turns off the CHG FET and sets the *[WDF]* flag in *SafetyStatus* if the integrated AFE does not receive the appropriate frequency on the internal watchdog input (WDI) signal.

### 8.3.5.10 Integrated AFE Communication Fault (AFE\_C)

After a full reset the BQ33100 and the AFE offset and gain values are read twice and compared. The **AFE Init Limit** sets the maximum difference in A/D counts of two successful readings of offset and gain, which the device still considers as the same value. If the gain and offset values are still not considered the same after **AFE Init Retry Limit** comparison retries, the device reports a permanent failure error by setting *SafetyStatus()* *[AFE\_C]*.

Additionally, the BQ33100 periodically validates its read and write communications with the integrated AFE. If either a read or write verify fails, an internal AFE\_Fail\_Counter is incremented. If the AFE\_Fail\_Counter reaches AFE Fail Limit, the BQ33100 sets the [AFE\_C] flag in SafetyStatus. An AFE communication fault condition can also be declared if, after a full reset, the initial gain and offset values read from the AFE cannot be verified. These values are A to D readings of the integrated AFE VCx signal. The integrated AFE offset values are verified by reading the values twice and confirming that the readings are within acceptable limits. The maximum number of read retries, if offset and gain value verification fails and [AFE\_C] fault is declared, is set in AFE Fail Limit. If the AFE Fail Limit is set to 0, this feature is disabled.

#### 8.3.5.11 Data Flash Fault (DFF)

The BQ33100 can detect if the data flash is not operating correctly. A permanent failure is reported when either: (i) After a full reset the instruction flash checksum does not verify; (ii) if any data flash write does not verify; or (iii) if any data flash erase does not verify

When a data flash fault is detected then the [DFF] flag in SafetyStatus is set.

#### 8.3.5.12 FAULT Indication (FAULT Pin)

The BQ33100 provides the status of the safety detection through SafetyStatus. To provide an extra indication of a fault state ( SafetyStatus ≠ 0x00) the BQ33100 will set the FAULT pin (pin 15) if the corresponding SafetyStatus bit is set in **Fault**.

### 8.3.6 Communications

The BQ33100 uses SMBus v1.1 for host communications although an SMBus slave can be communicated with through an I<sup>2</sup>C master.

#### 8.3.6.1 SMBus On and Off State

The BQ33100 detects a SMBus off state when SCL and SDA are logic-low for ≥ 2 seconds. Clearing this state requires either SCL or SDA to transition high. Within 1 ms, the communication bus is available.

### 8.3.7 Security (Enables and Disables Features)

There are two levels of secured operation within the BQ33100, Sealed and Unsealed. To switch between the levels, different operations are needed with different codes.

1. Unsealed to Sealed — The use of the *Seal* command instructs the BQ33100 to limit access to the SBS functions and data flash space and sets the [SS] flag. In SEALED mode, available standard SBS functions have access per the Smart Battery Data Specification (SBS). Extended SBS Functions and data flash are not accessible. Once in SEALED mode, the part can never permanently return to UNSEALED mode.

2. Sealed to Unsealed — Instructs the BQ33100 to extend access to the SBS and data flash space and clears the [SS] flag. In UNSEALED mode, all data, SBS, and DF have read and write access. Unsealing is a 2 step command performed by writing the 1st word of the *UnSealKey* to *ManufacturerAccess* followed by the second word of the *UnSealKey* to *ManufacturerAccess*. The unseal key can be read and changed through the extended SBS block command *UnSealKey* when in UNSEALED mode. To return to the SEALED mode, either a hardware reset is needed, or the *ManufacturerAccess Seal* command is needed.

### 8.3.8 Measurement System Calibration

The BQ33100 does not require calibration, but can be calibrated for improved measurement accuracy.

#### 8.3.8.1 Coulomb Counter Deadband

The BQ33100 does not accumulate charge or discharge for monitoring when the current input is below the **Deadband** threshold which must be set sufficiently high to prevent false signal detection with no charge or discharge flowing through the sense resistor.

#### 8.3.8.2 Auto Calibration

The BQ33100 provides an auto-calibration feature to cancel the voltage offset error across SRP and SRN for maximum charge measurement accuracy. The BQ33100 performs auto-calibration when the SMBus lines stay low continuously for a minimum of 5 s and *Temperature* is within bounds of 5°C and 45°C.

### 8.3.8.3 Current Gain

**Current Gain** sets the mA current scale factor for the coulomb counter. Use calibration routines to set this value.

**Table 6. Current Gain**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME         | FORMAT         | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|--------------|----------------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 0      | Current Gain | Floating point | 4             | 1.0E-01   | 4.0E+00   | 0.9419        | mΩ   |

### 8.3.8.4 CC Delta

**CC Delta** sets the mF capacitance scale factor for the coulomb counter. Use calibration routines to set this value.

**Table 7. CC Delta**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME     | FORMAT         | SIZE IN BYTES | MIN VALUE  | MAX VALUE    | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|----------|----------------|---------------|------------|--------------|---------------|------|
| 104         | Data          | 4      | CC Delta | Floating point | 4             | 2.9826E+04 | 1.193046E+06 | 280932.825    | mΩ   |

### 8.3.8.5 Cap1 K-factor

This register value stores the ADC voltage translation factor for the top capacitor (Capacitor 1), which is connected between the VC1 and VC2 pins. By default, this value is not used and the factory calibration are in effect. This value overrides the factory calibration when the K-factor Override Flag is set to 0x9669 by the software calibration process. The calibration routine sets this value, however the value can be manually modified according to [Equation 5](#):

$$\text{New StackVoltageKfactor} = \text{Existing StackVoltageKfactor} \times \text{Actual Applied Voltage} / \text{Reported Voltage} \quad (5)$$

**Table 8. Cap1 K-factor**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME          | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|---------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 8      | Cap1 K-factor | Integer | 2             | 0         | 32767     | 20500         |      |

### 8.3.8.6 Cap2 K-factor

This register value stores the ADC voltage translation factor for Capacitor 2, which is connected between the VC2 and VC3 pins. By default, this value is not used and the factory calibration are in effect. This value overrides the factory calibration when the K-factor Override Flag is set to 0x9669 by the software calibration process. The calibration routine sets this value, however the value can be manually modified according to [Equation 6](#):

$$\text{New StackVoltageKfactor} = \text{Existing StackVoltageKfactor} \times \text{Actual Applied Voltage} / \text{Reported Voltage} \quad (6)$$

**Table 9. Cap2 K-factor**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME          | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|---------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 10     | Cap2 K-factor | Integer | 2             | 0         | 32767     | 20500         |      |

### 8.3.8.7 Cap3 K-factor

This register value stores the ADC voltage translation factor for Capacitor 3, which is connected between the VC3 and VC4 pins. By default, this value is not used and the factory calibration are in effect. This value overrides the factory calibration when the K-factor Override Flag is set to 0x9669 by the software calibration process. The calibration routine sets this value, however the value can be manually modified according to [Equation 7](#):

$$\text{New StackVoltageKfactor} = \text{Existing StackVoltageKfactor} \times \text{Actual Applied Voltage} / \text{Reported Voltage} \quad (7)$$

Table 10. Cap3 K-factor

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME          | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|---------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 12     | Cap3 K-factor | Integer | 2             | 0         | 32767     | 20500         |      |

### 8.3.8.8 Cap4 K-factor

This register value stores the ADC voltage translation factor for Capacitor 4, which is connected between the VC4 and VC5 pins. By default, this value is not used and the factory calibration are in effect. This value overrides the factory calibration when the K-factor Override Flag is set to 0x9669 by the software calibration process. The calibration routine sets this value, however the value can be manually modified according to [Equation 8](#):

$$\text{New StackVoltageKfactor} = \text{Existing StackVoltageKfactor} \times \text{Actual Applied Voltage} / \text{Reported Voltage} \quad (8)$$

Table 11. Cap4 K-factor

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME          | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|---------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 14     | Cap4 K-factor | Integer | 2             | 0         | 32767     | 20500         |      |

### 8.3.8.9 Cap5 K-factor

This register value stores the ADC voltage translation factor for the bottom capacitor (Capacitor 5), which is connected between the VC5 and VSS pins. The calibration routine sets this value, however the value can be manually modified according to [Equation 9](#):

$$\text{New StackVoltageKfactor} = \text{Existing StackVoltageKfactor} \times \text{Actual Applied Voltage} / \text{Reported Voltage} \quad (9)$$

Table 12. Cap5 K-factor

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME          | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|---------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 16     | Cap5 K-factor | Integer | 2             | 0         | 32767     | 20500         |      |

### 8.3.8.10 K-factor Override Flag

This register value is by default 0, indicating that the factory calibrated K-factors are being used. If this register is set to 0x9669, Cap1 to approximately Cap5 K-factors in the data flash are used for voltage translation.

Table 13. K-factor Override Flag

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME                   | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------------------|--------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 18     | K-factor Override Flag | Hex    | 2             | 0x0       | 0xffff    | 0x0           |      |

### 8.3.8.11 System Voltage K-factor

This register value stores the scale factor for the PackVoltage, voltage measured at the VCCPACK pin of the BQ33100. The calibration routine sets this value, however the value can be manually modified according to [Equation 10](#):

$$\text{New StackVoltageKfactor} = \text{Existing StackVoltageKfactor} \times \text{Actual Applied Voltage} / \text{Reported Voltage} \quad (10)$$

Table 14. System Voltage K-factor

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME                    | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-------------------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 20     | System Voltage K-factor | Integer | 2             | 0         | 32767     | 24500         |      |

### 8.3.8.12 Stack Voltage K-factor

This register value stores the scale factor for the Stack Voltage, voltage measured at the VCC pin of the BQ33100. The calibration routine sets this value, however the value can be manually modified according to [Equation 11](#):

$$\text{New StackVoltageKfactor} = \text{Existing StackVoltageKfactor} \times \text{Actual Applied Voltage} / \text{Reported Voltage} \quad (11)$$

**Table 15. Stack Voltage K-factor**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME                   | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 22     | Stack Voltage K-factor | Integer | 2             | 0         | 32767     | 24500         |      |

### 8.3.8.13 K-factor Stack Override Flag

This register value is by default 0, indicating that the factory calibrated stack K-factor is being used. If this register is set to 0x9669, Stack Voltage K-factor in the data flash are used for stack voltage translation.

**Table 16. K-factor Stack Override Flag**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME                         | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------------------------|--------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 24     | K-factor stack Override Flag | Hex    | 2             | 0x0       | 0xffff    | 0x0           |      |

### 8.3.8.14 CC Offset

This register value stores the coulomb counter offset compensation. It is set during CC Offset calibration, or by automatic calibration of the BQ33100 before the gauge enters shutdown. TI does not recommend to manually change this value.

**Table 17. CC Offset**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME      | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-----------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 20     | CC Offset | Integer | 2             | –32768    | 32767     | –7744         | (mV) |

### 8.3.8.15 Board Offset

This register value stores the compensation for the PCB dependant coulomb counter offset. TI recommends to use characterization data of the actual PCB to set this value.

**Table 18. Board Offset**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME         | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|--------------|---------|---------------|-----------|-----------|---------------|------|
| 104         | Data          | 22     | Board Offset | Integer | 2             | –32767    | 32767     | 0             | uV   |

### 8.3.8.16 Int Temp Offset

This register value stores the internal temperature sensor offset compensation. Use calibration routines to set this value

**Table 19. Int Temp Offset**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME            | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|-------------|---------------|--------|-----------------|---------|---------------|-----------|-----------|---------------|-------|
| 104         | Data          | 24     | Int Temp Offset | Integer | 1             | –128      | 127       | 0             | 0.1°C |

### 8.3.8.17 Ext1 Temp Offset

This register value stores the temperature sensor offset compensation for the external temperature sensor 1 connected at the TS pin of the BQ33100. Use calibration routines to set this value

**Table 20. Ext1 Temp Offset**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME             | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|-------------|---------------|--------|------------------|---------|---------------|-----------|-----------|---------------|-------|
| 104         | Data          | 25     | Ext1 Temp Offset | Integer | 1             | –128      | 127       | 0             | 0.1°C |

### 8.3.8.18 CC Current

This value sets the current used for the CC calibration when in CALIBRATION mode.

**Table 21. CC Current**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME       | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------|---------|---------------|-----------|-----------|---------------|------|
| 105         | Config        | 0      | CC Current | Integer | 2             | 0         | 32767     | 3000          | mA   |

### 8.3.8.19 Voltage Signal

This value sets the voltage used for calibration when in CALIBRATION mode.

**Table 22. Voltage Signal**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME           | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|----------------|---------|---------------|-----------|-----------|---------------|------|
| 105         | Config        | 2      | Voltage Signal | Integer | 2             | 0         | 32767     | 12600         | mV   |

### 8.3.8.20 Temp Signal

This value sets the temperature used for the temperature calibration in CALIBRATION mode.

**Table 23. Temp Signal**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME        | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|-------------|---------------|--------|-------------|---------|---------------|-----------|-----------|---------------|-------|
| 105         | Config        | 4      | Temp Signal | Integer | 2             | 0         | 32767     | 298           | 0.1°K |

### 8.3.8.21 CC Offset Time

This value sets the time used for the CC Offset calibration in CALIBRATION mode. More time means more accuracy. The legitimate values for this constant are integer multiples of 250. Numbers less than 250 will cause a CC Offset calibration error. Numbers greater than 250 will be rounded down to the nearest multiple of 250.

**Table 24. CC Offset Time**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME           | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT   |
|-------------|---------------|--------|----------------|------------------|---------------|-----------|-----------|---------------|--------|
| 105         | Config        | 6      | CC Offset Time | Unsigned Integer | 2             | 0         | 65535     | 250           | s (ms) |

### 8.3.8.22 ADC Offset Time

This constant defines the time for the ADC Offset calibration in CALIBRATION mode. More time means more accuracy. The legitimate values for this constant are integer multiples of 32. Numbers less than 32 will cause an ADC offset calibration error. Numbers greater than 32 will be rounded down to the nearest multiple of 32.

**Table 25. ADC Offset Time**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME            | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-----------------|------------------|---------------|-----------|-----------|---------------|------|
| 105         | Config        | 8      | ADC Offset Time | Unsigned Integer | 2             | 0         | 65535     | 32            | ms   |

### 8.3.8.23 Current Gain Time

This constant defines the time for the Current Gain calibration in CALIBRATION mode. More time means more accuracy. The legitimate values for this constant are integer multiples of 250. Numbers less than 250 will cause a Current gain calibration error. Numbers greater than 250 will be rounded down to the nearest multiple of 250.

**Table 26. Current Gain Time**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME              | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-------------------|------------------|---------------|-----------|-----------|---------------|------|
| 105         | Config        | 10     | Current Gain Time | Unsigned Integer | 2             | 0         | 65535     | 250           | ms   |

### 8.3.8.24 Voltage Time

This constant defines the time for the voltage calibration in CALIBRATION mode. More time means more accuracy. The legitimate values for this constant are integer multiples of 1984. Numbers less than 1984 will cause a voltage calibration error. Numbers greater than 1984 will be rounded down to the nearest multiple of 1984.

**Table 27. Voltage Time**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME         | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|--------------|------------------|---------------|-----------|-----------|---------------|------|
| 105         | Config        | 12     | Voltage Time | Unsigned Integer | 2             | 0         | 65535     | 1888          | ms   |

### 8.3.8.25 Temperature Time

This constant defines the time for the temperature calibration in CALIBRATION mode. More time means more accuracy. The legitimate values for this constant are integer multiples of 32. Numbers less than 32 will cause a temperature calibration error. Numbers greater than 32 will be rounded down to the nearest multiple of 32.

**Table 28. Temperature Time**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME             | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------------|------------------|---------------|-----------|-----------|---------------|------|
| 105         | Config        | 14     | Temperature Time | Unsigned Integer | 2             | 0         | 65535     | 32            | ms   |

### 8.3.8.26 Cal Mode Timeout

The BQ33100 will exit CALIBRATION mode automatically after a **Cal Mode Timeout** period.

**Table 29. Cal Mode Timeout**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME             | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT        |
|-------------|---------------|--------|------------------|------------------|---------------|-----------|-----------|---------------|-------------|
| 105         | Config        | 17     | Cal Mode Timeout | Unsigned Integer | 2             | 0         | 65535     | 38400         | 1/128 s (s) |

### 8.3.8.27 Ext Coef a1..a5, b1..b4, Ext rc0, Ext adc0

These values characterize the external thermistor connected to the TS pin of the BQ33100. The default values characterize the Semitec 103AT NTC thermistor. Do not modify these values without consulting TI.

**Table 30. Ext Coef a1..a5, b1..b4, Ext rc0, Ext adc0**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME        | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-------------|---------|---------------|-----------|-----------|---------------|------|
| 106         | Temp Model    | 0      | Ext Coef a1 | Integer | 2             | –32768    | 32767     | –11130        | num  |
|             |               | 2      | Ext Coef a2 |         |               |           |           | 19142         |      |
|             |               | 4      | Ext Coef a3 |         |               |           |           | –19262        |      |
|             |               | 6      | Ext Coef a4 |         |               |           |           | 28203         |      |
|             |               | 8      | Ext Coef a5 |         |               |           |           | 892           |      |
|             |               | 10     | Ext Coef b1 |         |               |           |           | 328           |      |
|             |               | 12     | Ext Coef b2 |         |               |           |           | –605          |      |
|             |               | 14     | Ext Coef b3 |         |               |           |           | –2443         |      |
|             |               | 16     | Ext Coef b4 |         |               |           |           | 4696          |      |
|             |               | 18     | Ext rc0     |         |               |           |           | 11703         |      |
|             |               | 20     | Ext adc0    |         |               |           |           | 11338         |      |

### 8.3.8.28 Rpad

This value characterizes the pad resistance of the BQ33100. Do not modify without consulting TI.

**Table 31. Rpad**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------|---------|---------------|-----------|-----------|---------------|------|
| 106         | Temp Model    | 22     | Rpad | Integer | 2             | –32768    | 32767     | 87            | Ω    |

### 8.3.8.29 Rint

This value characterizes the internal resistance of the BQ33100. Do not modify without consulting TI.

**Table 32. Rint**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------|---------|---------------|-----------|-----------|---------------|------|
| 106         | Temp Model    | 24     | Rint | Integer | 2             | –32768    | 32767     | 17740         | Ω    |

### 8.3.8.30 Int Coef 1..4, Int Min AD, Int Max Temp

These values characterize the internal thermistor of the BQ33100. Do not modify these values without consulting TI.

**Table 33. Int Coef 1..4, Int Min AD, Int Max Temp**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME         | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|-------------|---------------|--------|--------------|---------|---------------|-----------|-----------|---------------|-------|
| 106         | Temp Model    | 26     | Int Coef 1   | Integer | 2             | –32768    | 32767     | 0             | s     |
|             |               | 28     | Int Coef 2   |         |               |           |           | 0             |       |
|             |               | 30     | Int Coef 3   |         |               |           |           | –12263        |       |
|             |               | 32     | Int Coef 4   |         |               |           |           | 6106          |       |
|             |               | 34     | Int Min AD   |         |               |           |           | 0             |       |
|             |               | 36     | Int Max Temp |         |               |           |           | 6106          | 0.1°K |

### 8.3.8.31 Filter

**Filter** defines the filter constant used in the AverageCurrent calculation, [Equation 12](#):

$$\text{AverageCurrent}_{\text{new}} = a \times \text{AverageCurrent}_{\text{old}} + (1 - a) \times \text{Current}$$

where

- $a = \langle \text{Filter} \rangle / 256$ ; the time constant =  $1 \text{ sec} / \ln(1/a)$  (default 14.5 sec) (12)

**Table 34. Filter**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME   | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|--------|------------------|---------------|-----------|-----------|---------------|------|
| 107         | Current       | 0      | Filter | Unsigned Integer | 1             | 0         | 255       | 239           |      |

### 8.3.8.32 Deadband

Any current within  $\pm \text{DeadBand}$  will be reported as 0 mA by the *Current* function.

**Table 35. Deadband**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME     | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|----------|------------------|---------------|-----------|-----------|---------------|------|
| 107         | Current       | 1      | Deadband | Unsigned Integer | 1             | 0         | 255       | 0             | mA   |

### 8.3.8.33 CC Deadband

This constant defines the deadband voltage for the measured voltage between the SR1 and SR2 pins used for capacitance accumulation in units of 294 nV. Any voltages within  $\pm \text{CC Deadband}$  do not contribute to capacitance accumulation.

**Table 36. CC Deadband**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME     | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT   |
|-------------|---------------|--------|----------|------------------|---------------|-----------|-----------|---------------|--------|
| 107         | Current       | 2      | Deadband | Unsigned Integer | 1             | 0         | 255       | 10            | 294 nV |

## 8.4 Device Functional Modes

The BQ33100 supports two power modes:

- In NORMAL mode, the BQ33100 performs measurements, calculations, protection decisions, and data updates in 1 second intervals. Between these intervals, the BQ33100 is in a reduced power mode.
- In SHUTDOWN mode, the BQ33100 is powered down with only a voltage based wake function operating.

### 8.4.1 Operating Power Modes

The BQ33100 has two operating power modes, NORMAL and SHUTDOWN mode.

**NORMAL mode**—During normal operation, the BQ33100 takes *Current*, *Voltage*, and *Temperature* measurements, performs calculations, updates SBS data, and makes protection and status decisions at one-second intervals. Between these periods of activity, the BQ33100 is in a reduced power state.

**SHUTDOWN mode**—The BQ33100 enters SHUTDOWN mode if the following conditions are met:

- $V_{\text{VCC}} \leq \text{Minimum operating voltage}$
- ManufacturerAccess*: *Shutdown* command received AND *Current* = 0 AND *Voltage* < **Shutdown Voltage** threshold.

Upon initial power up or a reset of the BQ33100, application of a voltage  $> V_{\text{STARTUP}}$  must be applied to the VCCPACK pin. The BQ33100 will then power up and enter NORMAL mode.

## 8.5 Programming

### 8.5.1 Communications

The BQ33100 uses SMBus v1.1 with optional packet error checking (PEC) per the SMBus specification.

#### 8.5.1.1 BQ33100 Slave Address

The BQ33100 uses the address 0x16 on SMBus for communication.

#### 8.5.1.2 SMBus On and Off State

The BQ33100 detects an SMBus off state when SCL and SDA are logic-low for  $\geq 2$  seconds. Clearing this state requires either SCL or SDA to transition high. Within 1 ms, the communication bus is available.

#### 8.5.1.3 Packet Error Checking

The BQ33100 can receive data with or without PEC. In the write-word protocol, the BQ33100 receives the PEC after the last byte of data from the host. If the host does not support PEC, the last byte of data is followed by a stop condition. After receipt of the PEC, the BQ33100 compares the value to its calculation. If the PEC is correct, the BQ33100 responds with an ACKNOWLEDGE. If it is not correct, the BQ33100 responds with a NOT ACKNOWLEDGE.

### 8.5.2 SBS Commands

All SBS Values are updated in 1-second intervals. The extended SBS commands are only available when the BQ33100 device is in UNSEALED mode.

#### 8.5.2.1 SBS Command Summary

**Table 37. SBS Commands**

| SBS CMD | MODE | NAME                  | FORMAT       | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|---------|------|-----------------------|--------------|---------------|-----------|-----------|---------------|-------|
| 0x00    | R/W  | ManufacturerAccess    | hex          | 2             | 0x0000    | 0xffff    | —             |       |
| 0x08    | R    | Temperature           | unsigned int | 2             | 0         | 65535     | —             | 0.1°K |
| 0x09    | R    | Voltage               | unsigned int | 2             | 0         | 65535     | —             | mV    |
| 0x0A    | R    | Current               | signed int   | 2             | –32768    | 32767     | —             | mA    |
| 0x0B    | R    | ESR                   | unsigned int | 2             | 0         | 65535     | —             | mΩ    |
| 0x0D    | R    | RelativeStateOfCharge | unsigned int | 1             | 0         | 100       | —             | %     |
| 0x0E    | R    | Health                | unsigned int | 1             | 0         | 100       | —             | %     |
| 0x10    | R    | Capacitance           | unsigned int | 2             | 0         | 65535     | —             | F     |
| 0x14    | R    | ChargingCurrent       | unsigned int | 2             | 0         | 65534     | —             | mA    |
| 0x15    | R    | ChargingVoltage       | unsigned int | 2             | 0         | 65534     | —             | mV    |
| 0x3B    | R    | CapacitorVoltage5     | unsigned int | 2             | 0         | 65534     | —             | mV    |
| 0x3C    | R    | CapacitorVoltage4     | unsigned int | 2             | 0         | 65535     | —             | mV    |
| 0x3D    | R    | CapacitorVoltage3     | unsigned int | 2             | 0         | 65535     | —             | mV    |
| 0x3e    | R    | CapacitorVoltage2     | unsigned int | 2             | 0         | 65535     | —             | mV    |
| 0x3F    | R    | CapacitorVoltage1     | unsigned int | 2             | 0         | 65535     | —             | mV    |

**Table 38. Extended SBS Commands**

| SBS CMD | MOD E | NAME            | FORMAT       | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|-------|-----------------|--------------|---------------|-----------|-----------|---------------|------|
| 0x46    | R/W   | FETControl      | Hex          | 2             | 0x0000    | 0xffff    | —             |      |
| 0x50    | R     | SafetyAlert     | Hex          | 2             | 0x0000    | 0xffff    | —             |      |
| 0x51    | R     | SafetyStatus    | Hex          | 2             | 0x0000    | 0xffff    | —             |      |
| 0x54    | R     | OperationStatus | Hex          | 2             | 0x0000    | 0xf7f7    | —             |      |
| 0x5a    | R     | SystemVoltage   | unsigned int | 2             | 0         | 65535     | —             | mV   |

**Table 38. Extended SBS Commands (continued)**

| SBS CMD | MOD E | NAME             | FORMAT | SIZE IN BYTES | MIN VALUE  | MAX VALUE  | DEFAULT VALUE | UNIT |
|---------|-------|------------------|--------|---------------|------------|------------|---------------|------|
| 0x60    | R/W   | UnSealKey        | Hex    | 4             | 0x00000000 | 0xffffffff | —             |      |
| 0x70    | R/W   | ManufacturerInfo | String | 31+1          | —          | —          | —             |      |

### 8.5.2.2 SBS Command Details

The following provides detailed descriptions of the SBS commands.

#### 8.5.2.2.1 ManufacturerAccess (0x00)

This read- or write-word function provides super capacitor data to system along with access to BQ33100 controls and security features.

**Table 39. ManufacturerAccess**

| SBS CMD | MODE | NAME               | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|--------------------|--------|---------------|-----------|-----------|---------------|------|
| 0x00    | R/W  | ManufacturerAccess | hex    | 2             | 0x0000    | 0xffff    | —             |      |

**Table 40. MAC Command Summary Table**

| SBS CMD      | MODE | NAME                                    | DESCRIPTION                                                                                                                                                                                  |
|--------------|------|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0x0001       | R    | Device Type                             | Returns the IC part number.                                                                                                                                                                  |
| 0x0002       | R    | Firmware Version                        | Returns the firmware version.                                                                                                                                                                |
| 0x0003       | R    | Hardware Version                        | Returns the hardware version                                                                                                                                                                 |
| 0x0004       | R    | DF Checksum                             | Generates a checksum of the full Data Flash (DF) array                                                                                                                                       |
| 0x0020       | W    | Seal                                    | Enters SEALED mode with limited access to the extended SBS functions and data flash space                                                                                                    |
| 0x0021       | R/W  | Lifetime and Capacitor Balancing Enable | 0 = Disables logging of lifetime data to non-volatile memory and disables capacitor balancing<br>1 = Enables logging of lifetime data to non-volatile memory and enables capacitor balancing |
| 0x0022       | R    | IF Checksum                             | Returns the value of the Instruction Flash (IF) checksum                                                                                                                                     |
| 0x0023       | W    | Learn                                   | This write function instructs the BQ33100 to enter a capacitance learning cycle(capacitance update).                                                                                         |
| 0x0024       | W    | Learn Value Reset                       | This write function instructs the BQ33100 to reset the capacitance learned values (capacitance) to initial default values.                                                                   |
| 0x0025       | W    | Learn Initialization                    | This write function instructs the BQ33100 to enter a capacitance learning cycle(capacitance update) and update initial values for capacitance and ESR.                                       |
| 0x0030       | W    | FAULT Activation                        | Drives the FAULT pin high                                                                                                                                                                    |
| 0x0031       | W    | FAULT Clear                             | Sets FAULT pin low                                                                                                                                                                           |
| 0x0032       | W    | Charge Level Nominal                    | Drives the CHGLVL0,1 pins low                                                                                                                                                                |
| 0x0033       | W    | Charge Level A                          | Drives the CHGLVL0,1 pins high, low                                                                                                                                                          |
| 0x0034       | W    | Charge Level B                          | Drives the CHGLVL0,1 pins low, high                                                                                                                                                          |
| 0x0035       | W    | Charge Level Max                        | Drives the CHGLVL0,1 pins high                                                                                                                                                               |
| 0x0036       | R    | Read AD Current                         | Read A-to-D converter current measurement                                                                                                                                                    |
| 0x0037       | W    | Learn Load Activation                   | Drives the LLEN pin high (does not activate actual learning algorithm, see 0x0023)                                                                                                           |
| 0x0038       | W    | Learn Load Clear                        | Sets the LLEN pin low                                                                                                                                                                        |
| 0x0040       | W    | Calibration Mode                        | Places BQ33100 into CALIBRATION mode                                                                                                                                                         |
| 0x0041       | W    | Reset                                   | BQ33100 undergoes complete reset                                                                                                                                                             |
| Unseal Key   | W    | Unseal Device                           | Enables access to SBS and DF space                                                                                                                                                           |
| Extended SBS | R/W  | Extended SBS Commands                   | Access to Extended SBS commands                                                                                                                                                              |

#### 8.5.2.2.1.1 Device Type (0x0001)

Returns the IC part number

**Table 41. Device Type**

| SBS CMD | MODE | NAME        | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-------------|--------|---------------|-----------|-----------|---------------|------|
| 0x0001  | R    | Device Type | Hex    | 2             | —         | —         | —             |      |

#### 8.5.2.2.1.2 Firmware Version (0x0002)

Returns the firmware version. The format is most-significant byte (MSB) = Decimal integer, and the least-significant byte (LSB) = subdecimal integer, for example: 0x0120 = version 01.20.

**Table 42. Firmware Version**

| SBS CMD | MODE | NAME             | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|------------------|--------|---------------|-----------|-----------|---------------|------|
| 0x0002  | R    | Firmware Version | Hex    | 2             | —         | —         | —             |      |

#### 8.5.2.2.1.3 Hardware Version (0x0003)

Returns the hardware version stored in a single byte of reserved data flash, for example: 0x00A7 = Version A7.

**Table 43. Hardware Version**

| SBS CMD | MODE | NAME             | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|------------------|--------|---------------|-----------|-----------|---------------|------|
| 0x00    | R    | Hardware Version | Hex    | 2             | —         | —         | —             |      |

#### 8.5.2.2.1.4 DF Checksum (0x0004)

This function is only available when the BQ33100 is in UNSEALED mode, indicated by the [SS] *OperationStatus* flag. A write to this command forces the BQ33100 to generate a checksum of the full data flash (DF) array. The generated checksum is then returned within 45 ms.

#### NOTE

If another SMBus command is received while the checksum is being generated, the DF checksum is generated but the response may time out.

**Table 44. DF Checksum**

| SBS CMD | MODE | NAME        | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-------------|--------|---------------|-----------|-----------|---------------|------|
| 0x0004  | R    | DF Checksum | Hex    | 2             | —         | —         | —             |      |

#### 8.5.2.2.1.5 Seal Device (0x0020)

Instructs the BQ33100 to limit access to the extended SBS functions and data flash space, sets the [SS] flag. This command is only available when the BQ33100 is in UNSEALED mode. See [Security \(Enables and Disables Features\)](#) for detailed information.

#### 8.5.2.2.1.6 Lifetime and Capacitor Balancing Enable (0x0021)

Enables and Disables the logging of lifetime data to non-volatile memory and capacitor balancing

#### 8.5.2.2.1.7 FAULT Activation (0x0030)

This command drives the FAULT pin high. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.8 FAULT Clear (0x0031)**

This command sets the FAULT pin back to low. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.9 CHGLVL0 Activation (0x0032)**

This command drives the CHGLVL0 pin high. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.10 CHGLVL0 Clear (0x0033)**

This command sets the CHGLVL0 pin back to low. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.11 CHGLVL1 Activation (0x0033)**

This command drives the CHGLVL0 pin high. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.12 CHGLVL1 Clear (0x0034)**

This command sets the CHGLVL0 pin back to low. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.13 Learn Load Activation (0x0037)**

This command drives the LLEN pin high. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.14 Learn Load Clear (0x0038)**

This command sets the LLEN pin back to low. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.15 Calibration Mode (0x0040)**

Places the BQ33100 into CALIBRATION mode. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.16 Reset (0x0041)**

The BQ33100 undergoes a full reset. The BQ33100 holds the clock line down for a few milliseconds to complete the reset. If *ChargingVoltage()* < *Voltage* after a reset, then the pack is discharged using the capacitor voltage balancing circuitry. This command is only available when the BQ33100 is in UNSEALED mode.

**8.5.2.2.1.17 Unseal Device (UnsealKey)**

Instructs the BQ33100 to enable access to the SBS functions and data flash space and clear the [SS] flag. This two-step command needs to be written to *ManufacturerAccess* in the following order: 1st word of the UnSealKey followed by the 2nd word of the UnSealKey. If the command fails 4 seconds must pass before the command can be reissued. This command is only available when the BQ33100 is in SEALED mode. See [Security \(Enables and Disables Features\)](#) for detailed information.

**8.5.2.2.1.18 Extended SBS Commands**

Also available through *ManufacturerAccess* in UNSEALED mode are some of the extended SBS commands. The result of these commands need to be read from *ManufacturerAccess* after a write to *ManufacturerAccess*.

**8.5.2.2.2 Temperature (0x08)**

This read-word function returns an unsigned integer value of the temperature in units of 0.1°K, as measured by the BQ33100. It has a range of 0 to 6553.5°K. The source of the measured temperature is configured by the [TEMP1] and [TEMP0] bits in the *Operation Cfg* register.

**Table 45. Temperature**

| SBS CMD | MODE | NAME        | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT  |
|---------|------|-------------|------------------|---------------|-----------|-----------|---------------|-------|
| 0x08    | R    | Temperature | Unsigned Integer | 2             | 0         | 65535     | —             | 0.1°K |

#### 8.5.2.2.3 Voltage (0x09)

This read-word function returns an unsigned integer value of the capacitor stack array (voltage at the VC1 input) in mV with a range of 0 to 20000 mV.

**Table 46. Voltage**

| SBS CMD | MODE | NAME    | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|---------|------------------|---------------|-----------|-----------|---------------|------|
| 0x09    | R    | Voltage | Unsigned Integer | 2             | 0         | 20000     | —             | mV   |

#### 8.5.2.2.4 Current (0x0A)

This read-word function returns a signed integer value of the measured current being supplied (or accepted) by the super capacitor pack in mA, with a range of –32768 to 32767. A positive value indicates charge current and a negative value indicates discharge.

Any current value within the **Deadband** will be reported as 0 mA by the *Current* function.

**Table 47. Current**

| SBS CMD | MODE | NAME    | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|---------|------------------|---------------|-----------|-----------|---------------|------|
| 0x0A    | R    | Current | Unsigned Integer | 2             | –32768    | 32767     | —             | mA   |

#### 8.5.2.2.5 ESR (0x0B)

This read-word function returns an unsigned integer value of the Super Capacitor array total ESR in mΩ with a range of 0 to 65535 mΩ.

**Table 48. ESR**

| SBS CMD | MODE | NAME | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|------|------------------|---------------|-----------|-----------|---------------|------|
| 0x0B    | R    | ESR  | Unsigned Integer | 2             | 0         | 65535     | —             | mΩ   |

#### 8.5.2.2.6 RelativeStateofCharge (0x0D)

This read-word function returns an unsigned integer value of the predicted remaining super capacitor capacitance expressed as a percentage of *Capacitance* with a range of 0 to 100%, with fractions of % rounded up.

If the **[RSOCL]** bit in **Operation Cfg** is set, then *RelativeStateofCharge* is held at 99% until primary charge termination occurs and only displays 100% upon entering primary charge termination.

If the **[RSOCL]** bit in **Operation Cfg** is cleared, then *RelativeStateofCharge* is not held at 99% until primary charge termination occurs. Fractions of % greater than 99% are rounded up to display 100%.

**Table 49. RelativeStateofCharge**

| SBS CMD | MODE | NAME                  | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-----------------------|------------------|---------------|-----------|-----------|---------------|------|
| 0x0D    | R    | RelativeStateofCharge | Unsigned Integer | 1             | 0         | 100       | —             | %    |

#### 8.5.2.2.7 Health (0x0E)

This read-word function returns an unsigned integer value of the predicted health of the super capacitor pack expressed as a percentage of *Capacitance / InitialCapacitance* with a range of 0 to 100%, with fractions of % rounded up.

**Table 50. Health**

| SBS CMD | MODE | NAME   | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|--------|------------------|---------------|-----------|-----------|---------------|------|
| 0x0E    | R    | Health | Unsigned Integer | 1             | 0         | 100       | —             | %    |

#### 8.5.2.2.8 Capacitance (0x10)

This read- or write-word function returns an unsigned integer value, with a range of 0 to 65535, of the predicted full charge capacitance in the super capacitor pack. This value is expressed in F.

**Table 51. Capacitance**

| SBS CMD | MODE | NAME        | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-------------|------------------|---------------|-----------|-----------|---------------|------|
| 0x10    | R/W  | Capacitance | Unsigned Integer | 2             | 0         | 65534     | —             | F    |

#### 8.5.2.2.9 ChargingCurrent (0x14)

This read-word function returns an unsigned integer value of the desired charging current, in mA, with a range of 0 to 65534.

**Table 52. ChargingCurrent**

| SBS CMD | MODE | NAME            | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-----------------|------------------|---------------|-----------|-----------|---------------|------|
| 0x14    | R    | ChargingCurrent | Unsigned Integer | 2             | 0         | 65534     | —             | mA   |

#### 8.5.2.2.10 ChargingVoltage (0x15)

This read-word function returns an unsigned integer value of the desired charging voltage, in mV, where the range is 0 to 65534.

**Table 53. ChargingVoltage**

| SBS CMD | MODE | NAME            | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-----------------|------------------|---------------|-----------|-----------|---------------|------|
| 0x15    | R    | ChargingVoltage | Unsigned Integer | 2             | 0         | 65534     | —             | mV   |

#### 8.5.2.2.11 CapacitorVoltage5..1 (0x3B..0x3F)

These read-word functions return an unsigned value of the calculated individual capacitor voltages, in mV, with a range of 0 to 65535. *CapacitorVoltage1* corresponds to the bottom most series capacitor element, while *CapacitorVoltage5* corresponds to the top-most series capacitor element.

**Table 54. CapacitorVoltage5..1**

| SBS CMD | MODE | NAME              | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-------------------|------------------|---------------|-----------|-----------|---------------|------|
| 0x3B    | R    | CapacitorVoltage5 | Unsigned Integer | 2             | 0         | 65535     | —             | mV   |
| 0x3C    |      | CapacitorVoltage4 |                  |               |           |           |               |      |
| 0x3D    |      | CapacitorVoltage3 |                  |               |           |           |               |      |
| 0x3E    |      | CapacitorVoltage2 |                  |               |           |           |               |      |
| 0x3F    |      | CapacitorVoltage1 |                  |               |           |           |               |      |

#### 8.5.2.2.12 Extended SBS Commands

Also available through *ManufacturerAccess* in SEALED mode are some of the extended SBS commands. The commands available are listed below. The result of these commands needs to be read from *ManufacturerAccess* after a write to *ManufacturerAccess*.

##### 8.5.2.2.12.1 FETControl(0x46)

This write- and read-word function allows direct control of the CHG FET for test purposes. The BQ33100 overrides this command unless in NORMAL mode.

**Table 55. FETControl**

| SBS CMD | MODE | NAME       | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|------------|--------|---------------|-----------|-----------|---------------|------|
| 0x46    | R    | FETControl | hex    | 2             | 0x0000    | 0xffff    | —             |      |

**Figure 6. FETControl Registers**

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| 15   | 14   | 13   | 12   | 11   | 10   | 9    | 8    |
| RSVD | RSVD | RSVD | RSVD | RSVD | RSVD | RSVD | RSVD |
| 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| RSVD | RSVD | RSVD | RSVD | RSVD | CHG  | RSVD | RSVD |

LEGEND: All values are read-only.

**CHG**—Charge (CHG) FET Control

0 = CHG FET is turned OFF.

1 = CHG FET is turned ON.

##### 8.5.2.2.12.2 SafetyAlert (0x50)

This read-word function returns indications of pending safety issues, such as running safety timers, or fail counters that are non-0, but have not reached the required time or value to trigger a *SafetyStatus* failure. These flags do not cause the FAULT pin to be set.

**Table 56. SafetyAlert**

| SBS CMD | MODE | NAME        | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-------------|--------|---------------|-----------|-----------|---------------|------|
| 0x50    | R    | SafetyAlert | hex    | 2             | 0x0000    | 0xffff    | —             |      |

**Figure 7. SafetyAlert Registers**

|       |      |      |      |      |     |     |     |
|-------|------|------|------|------|-----|-----|-----|
| 15    | 14   | 13   | 12   | 11   | 10  | 9   | 8   |
| CLBAD | RSVD | RSVD | RSVD | RSVD | OTC | CIM | OV  |
| 7     | 6    | 5    | 4    | 3    | 2   | 1   | 0   |
| RSVD  | RSVD | RSVD | RSVD | OCC  | OCD | SCC | SCD |

LEGEND: All values are read-only.

|              |                                                         |
|--------------|---------------------------------------------------------|
| <b>CLBAD</b> | 1 = Excessive capacitor leakage alert                   |
| <b>OTC</b>   | 1 = Charge overtemperature alert                        |
| <b>CIM</b>   | 1 = Capacitor voltage Imbalance permanent failure alert |
| <b>OV</b>    | 1 = Capacitor overvoltage alert                         |
| <b>OCC</b>   | 1 = Overcurrent during charge alert                     |
| <b>OCD</b>   | 1 = AFE overcurrent during discharge alert              |
| <b>SCC</b>   | 1 = AFE short circuit during charge alert               |
| <b>SCD</b>   | 1 = AFE short circuit during discharge alert            |

#### 8.5.2.2.12.3 SafetyStatus (0x51)

This read-word function returns the status of the safety features. These flags do not cause the FAULT pin to be set unless the corresponding bit in **FAULT** is set.

**Table 57. SafetyStatus**

| SBS CMD | MODE | NAME         | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|--------------|--------|---------------|-----------|-----------|---------------|------|
| 0x51    | R    | SafetyStatus | hex    | 2             | 0x0000    | 0xffff    | —             |      |

**Figure 8. SafetyStatus Registers**

|       |       |       |      |      |     |     |     |
|-------|-------|-------|------|------|-----|-----|-----|
| 15    | 14    | 13    | 12   | 11   | 10  | 9   | 8   |
| CLBAD | HFAIL | HWARN | HLOW | RSVD | OT  | CIM | OV  |
| 7     | 6     | 5     | 4    | 3    | 2   | 1   | 0   |
| DFF   | RSVD  | AFE_C | WDF  | OCC  | OCD | SCC | SCD |

LEGEND: All values are read-only.

|              |                                                |
|--------------|------------------------------------------------|
| <b>CLBAD</b> | 1 = Excessive capacitor leakage fault          |
| <b>HWARN</b> | 1 = Health low warning                         |
| <b>HLOW</b>  | 1 = Health low indication                      |
| <b>HFAIL</b> | 1 = Health failure                             |
| <b>OT</b>    | 1 = Charge overtemperature fault               |
| <b>CIM</b>   | 1 = Capacitor voltage Imbalance fault          |
| <b>OV</b>    | 1 = Capacitor overvoltage fault                |
| <b>DFF</b>   | 1 = Data flash fault permanent failure fault   |
| <b>AFE_C</b> | 1 = Permanent AFE Communications failure fault |
| <b>WDF</b>   | 1 = AFE watchdog fault                         |
| <b>OCC</b>   | 1= Overcurrent during charge fault             |
| <b>OCD</b>   | 1= AFE overcurrent during discharge fault      |
| <b>SCC</b>   | 1= AFE short circuit during charge fault       |

**SCD** 1 = AFE short circuit during discharge fault

#### 8.5.2.2.12.4 OperationStatus (0x54)

This read-word function returns the current operation status.

**Table 58. OperationStatus**

| SBS CMD | MODE | NAME            | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-----------------|--------|---------------|-----------|-----------|---------------|------|
| 0x54    | R    | OperationStatus | hex    | 2             | 0x0000    | 0xf7f7    | —             |      |

**Figure 9. OperationStatus Registers**

|      |      |       |    |      |      |       |      |
|------|------|-------|----|------|------|-------|------|
| 15   | 14   | 13    | 12 | 11   | 10   | 9     | 8    |
| RSVD | DSG  | SS    | FC | LTE  | RSVD | CHGOR | CB   |
| 7    | 6    | 5     | 4  | 3    | 2    | 1     | 0    |
| LDTO | LCTO | LPASS | CL | RSVD | CFET | RSVD  | RSVD |

**DSG** Discharging

0 = BQ33100 is in CHARGING mode.

1 = BQ33100 is in DISCHARGING mode, RELAXATION mode, or a valid charge termination has occurred.

**SS** 1 = Sealed security mode

**FC** 1 = Fully charged

**LTE** 1 = Lifetime data and CHG FET operation enabled

**CHGOR** 1 = Charge override enabled

**CB** 1 = Capacitor voltage balancing in progress

**CL** 1 = Capacitance learning in progress

**LPASS** 1 = Learning complete and successful

**LCTO** 1 = Learning charging phase time out

**LDTO** 1 = Learning discharging phase time out

#### 8.5.2.2.12.5 SystemVoltage (0x5a)

This read-word function returns an unsigned integer value of the voltage at VCC (pin 24) in mV with a range of 0 mV to 20000 mV.

**Table 59. SystemVoltage**

| SBS CMD | MODE | NAME          | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|---------------|------------------|---------------|-----------|-----------|---------------|------|
| 0x5a    | R    | SystemVoltage | Unsigned Integer | 2             | 0         | 20000     | —             | mV   |

#### 8.5.2.2.12.6 UnSealKey(0x60)

This read- or write-block command allows the user to change the Unseal key for the Sealed-to-Unsealed security-state transition. This function is only available when the BQ33100 is in the UNSEALED mode, indicated by a cleared [SS] flag.

The order of the bytes, when entered in *ManufacturerAccess*, is the reverse of what is written to or read from the part. For example, if the 1st and 2nd word of the UnSealKey block read returns 0x1234 and 0x5678, then in *ManufacturerAccess*, 0x3412 and 0x7856 must be entered to unseal the part.

**Table 60. UnSealKey**

| SBS CMD | MODE | NAME      | FORMAT | SIZE IN BYTES | MIN VALUE  | MAX VALUE  | DEFAULT VALUE | UNIT |
|---------|------|-----------|--------|---------------|------------|------------|---------------|------|
| 0x60    | R/W  | UnSealKey | Hex    | 4             | 0x00000000 | 0xffffffff | —             |      |

#### 8.5.2.2.12.7 ManufacturerInfo(0x70)

This read and write block function returns the data stored in Manuf. Info where byte 0 is the MSB with a maximum length of 31 data + 1 length byte. When the BQ33100 is in UNSEALED mode, this block is read and write. When the BQ33100 is in SEALED mode, this block is read-only.

**Table 61. ManufacturerInfo**

| SBS CMD | MODE | NAME             | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|------------------|--------|---------------|-----------|-----------|---------------|------|
| 0x70    | R/W  | ManufacturerInfo | String | 31+1          | —         | —         | —             |      |

### 8.5.3 Data Flash

#### NOTE

Take care when mass programming the data flash space using previous versions of data flash memory map files (such as \*.gg files) to make sure that all public locations are updated correctly.

Data flash can only be updated if *Voltage* ≥ **Flash Update OK Voltage**. Data flash reads and writes are verified according to the method detailed in the [Data Flash Fault \(DFF\)](#) section of this data sheet.

#### 8.5.3.1 Accessing Data Flash

In different security modes, the data flash access conditions change. See [Security \(Enables and Disables Features\)](#) and [ManufacturerAccess \(0x00\)](#) sections for further details.

#### 8.5.3.2 Data Flash Interface

The BQ33100 data flash is organized into subclasses where each data flash variable is assigned an offset within its numbered subclass: for example, the OT Time location is defined as:

- Class = Safety
- SubClass = Temperature = 2
- Offset = 2

#### NOTE

Data flash commands are NACKed if the BQ33100 is in SEALED mode ([SS] flag is set).

Each subclass can be addressed individually by using the *DataFlashSubClassID* (0x77) command, and the data within each subclass is accessed by using the *DataFlashSubClassPage1..8* (0x78...0x7f) commands. Reading and writing subclass data are block operations which are each 32 bytes long. However, data can be written in shorter block sizes. The final block in one subclass can be shorter than 32 bytes so take care not to write over the subclass boundary. No values written are bounded by the BQ33100 and the values are not rejected by the BQ33100. Writing an incorrect value may result in hardware failure due to firmware program interpretation of the invalid data. The data written is persistent, so a power on reset does resolve the fault.

#### 8.5.3.3 Data Flash Summary

The following notation is used in [Table 62](#) with regards to the Data Type column:

##### The Alpha Character

- H = Hexadecimal value
- I = Integer value
- S = String

- U = Unsigned Integer value

The **Numeric Value** following the alpha character is the length of the data in bytes: for example, OT Time Data Type = U1 = Unsigned Integer of 1 byte in length.

**Table 62. Data Flash Values**

| CLASS NAME     | SUBCLASS ID | SUBCLASS NAME    | OFFSET | PARAMETER NAME        | DATA TYPE | MIN   | MAX   | DEFAULT | UNITS   |
|----------------|-------------|------------------|--------|-----------------------|-----------|-------|-------|---------|---------|
| Safety         | 0           | Voltage          | 0      | OV Threshold          | I2        | 0     | 1000  | 100     | mV      |
| Safety         | 0           | Voltage          | 2      | OV Recovery           | I2        | –500  | 1000  | 0       | mV      |
| Safety         | 0           | Voltage          | 4      | OV Time               | U1        | 0     | 255   | 2       | s       |
| Safety         | 0           | Voltage          | 5      | CIM Fail Voltage      | I2        | 0     | 5000  | 550     | mV      |
| Safety         | 0           | Voltage          | 7      | CIM Time              | U1        | 0     | 240   | 10      | s       |
| Safety         | 0           | Voltage          | 8      | CIM Recovery          | I2        | 0     | 5000  | 500     | mV      |
| Safety         | 0           | Voltage          | 10     | Min CIM Check Voltage | U2        | 0     | 65535 | 1000    | mV      |
| Safety         | 1           | Current          | 0      | OC Chg                | I2        | 0     | 5000  | 1000    | mA      |
| Safety         | 1           | Current          | 2      | OC Chg Time           | U1        | 0     | 240   | 5       | mA      |
| Safety         | 1           | Current          | 3      | OC Chg Recovery       | I2        | –1000 | 5000  | 900     | mA      |
| Safety         | 1           | Current          | 5      | CLBAD Current         | I2        | 0     | 30000 | 15      | mA      |
| Safety         | 1           | Current          | 7      | CLBAD Time            | U1        | 0     | 240   | 60      | s       |
| Safety         | 1           | Current          | 8      | CLBAD Recovery        | I2        | 0     | 1000  | 10      | mA      |
| Safety         | 1           | Current          | 10     | Current Recovery Time | U1        | 0     | 240   | 5       | s       |
| Safety         | 1           | Current          | 11     | OC Dsg                | H1        | 0     | f     | F       | hex     |
| Safety         | 1           | Current          | 12     | OC Dsg Time           | H1        | 0     | f     | F       | hex     |
| Safety         | 1           | Current          | 13     | OC Dsg Recovery       | I2        | 5     | 1000  | 5       | mA      |
| Safety         | 1           | Current          | 15     | SC Chg Cfg            | H1        | 0     | f7    | f4      | hex     |
| Safety         | 1           | Current          | 16     | SC Dsg Cfg            | H1        | 0     | f7    | f7      | hex     |
| Safety         | 1           | Current          | 17     | SC Recovery           | I2        | 0     | 200   | 1       | mA      |
| Safety         | 2           | Temperature      | 0      | OT Chg                | I2        | 0     | 1200  | 680     | 0.1°C   |
| Safety         | 2           | Temperature      | 2      | OT Chg Time           | U1        | 0     | 240   | 2       | s       |
| Safety         | 2           | Temperature      | 3      | OT Chg Recovery       | I2        | 0     | 1200  | 630     | 0.1°C   |
| Safety         | 3           | AFE Verification | 1      | AFE Fail Limit        | U1        | 0     | 255   | 100     | Counts  |
| Safety         | 3           | AFE Verification | 3      | AFE Init Retry Limit  | U1        | 0     | 255   | 6       | num     |
| Safety         | 3           | AFE Verification | 4      | AFE Init Limit        | U1        | 0     | 255   | 20      | Counts  |
| Charge Control | 34          | Charge Cfg       | 0      | Chg Voltage           | I2        | 0     | 32767 | 8400    | mV      |
| Charge Control | 34          | Charge Cfg       | 2      | Chg Current           | I2        | 0     | 20000 | 500     | mA      |
| Charge Control | 34          | Charge Cfg       | 4      | Chg Enable Delay      | U2        | 0     | 65000 | 0       | ms      |
| Charge Control | 35          | Full Charge Cfg  | 0      | Taper Current         | I2        | 0     | 1000  | 3       | mA      |
| Charge Control | 35          | Full Charge Cfg  | 2      | Taper Voltage         | I2        | 0     | 1000  | 100     | mVolt   |
| Charge Control | 35          | Full Charge Cfg  | 4      | Current Taper Window  | U1        | 0     | 240   | 2       | s       |
| Charge Control | 35          | Full Charge Cfg  | 5      | FC Set %              | I1        | –1    | 100   | –1      | Percent |

**Table 62. Data Flash Values (continued)**

| CLASS NAME     | SUBCLASS ID | SUBCLASS NAME             | OFFSET | PARAMETER NAME                 | DATA TYPE | MIN  | MAX   | DEFAULT                                 | UNITS                             |
|----------------|-------------|---------------------------|--------|--------------------------------|-----------|------|-------|-----------------------------------------|-----------------------------------|
| Charge Control | 35          | Full Charge Cfg           | 6      | FC Clear %                     | I1        | -1   | 100   | 98                                      | Percent                           |
| Charge Control | 36          | Capacitance Balancing Cfg | 0      | CB Threshold                   | I2        | 0    | 5000  | 1500                                    | mVolt                             |
| Charge Control | 36          | Capacitance Balancing Cfg | 2      | CB Min                         | U1        | 0    | 255   | 5                                       | mVolt                             |
| Charge Control | 36          | Capacitance Balancing Cfg | 3      | CB Restart                     | U1        | 0    | 255   | 10                                      | mVolt                             |
| System Data    | 48          | Data                      | 0      | Design Voltage                 | I2        | 0    | 18000 | 8400                                    | mVolt                             |
| System Data    | 48          | Data                      | 2      | Manuf Date                     | U2        | 0    | 65535 | 0                                       | Day + Mo × 32 + (Yr – 1980) × 256 |
| System Data    | 48          | Data                      | 4      | Ser. Num.                      | H2        | 0    | ffff  | 1                                       | hex                               |
| System Data    | 48          | Data                      | 6      | Design Capacitance             | I2        | 0    | 65535 | 250                                     | F                                 |
| System Data    | 48          | Data                      | 8      | Init 1st Capacitance           | I2        | 0    | 65535 | 250                                     | F                                 |
| System Data    | 48          | Data                      | 10     | Capacitance                    | I2        | 0    | 65535 | 250                                     | F                                 |
| System Data    | 48          | Data                      | 12     | Design ESR                     | I2        | 0    | 65535 | 320                                     | mΩ                                |
| System Data    | 48          | Data                      | 14     | Initial ESR                    | I2        | 0    | 65535 | 320                                     | mΩ                                |
| System Data    | 48          | Data                      | 16     | ESR                            | I2        | 0    | 65535 | 320                                     | mΩ                                |
| System Data    | 48          | Data                      | 18     | Manuf Name                     | S12       | x    | x     | Texas Instruments                       | —                                 |
| System Data    | 48          | Data                      | 30     | Device Name                    | S8        | x    | x     | BQ33100                                 | —                                 |
| System Data    | 48          | Data                      | 38     | Init Safety Status             | H2        | 0    | ffff  | 0                                       | hex                               |
| System Data    | 56          | Manufacturer Data         | 0      | Pack Lot Code                  | H2        | 0    | ffff  | 0                                       | —                                 |
| System Data    | 56          | Manufacturer Data         | 2      | PCB Lot Code                   | H2        | 0    | ffff  | 0                                       | —                                 |
| System Data    | 56          | Manufacturer Data         | 4      | Firmware Version               | H2        | 0    | ffff  | 0                                       | —                                 |
| System Data    | 56          | Manufacturer Data         | 6      | HardwareVersion                | H2        | 0    | ffff  | 0                                       | —                                 |
| System Data    | 58          | Manufacturer Info         | 0      | Manuf. Info                    | S32       | x    | x     | 0123456789A<br>BCDEF01234<br>56789ABCDE | —                                 |
| System Data    | 59          | Lifetime Data             | 0      | Lifetime Max Temp              | I2        | 0    | 1400  | 0                                       | 0.1°C                             |
| System Data    | 59          | Lifetime Data             | 2      | Lifetime Min Temp              | I2        | –600 | 1400  | 500                                     | 0.1°C                             |
| System Data    | 59          | Lifetime Data             | 4      | Lifetime Max Capacitor Voltage | I2        | 0    | 32767 | 0                                       | mVolt                             |
| Configuration  | 64          | Registers                 | 0      | Operation Cfg                  | H2        | 0    | FFFF  | 308                                     | flags                             |
| Configuration  | 64          | Registers                 | 4      | FET Action                     | H2        | 0    | FFFF  | 0                                       | flags                             |
| Configuration  | 64          | Registers                 | 8      | Fault                          | H2        | 0    | FFFF  | 0                                       | flags                             |
| Configuration  | 65          | AFE                       | 1      | AFE State_CTL                  | H1        | 0    | ff    | 0                                       | flags                             |
| Configuration  | 67          | Power                     | 0      | Flash Update OK Voltage        | I2        | 0    | 20000 | 4000                                    | mVolt                             |
| Configuration  | 67          | Power                     | 2      | Shutdown Voltage               | I2        | 0    | 5500  | 4000                                    | mVolt                             |
| Monitoring     | 86          | System Requirement        | 0      | Min Power                      | I2        | 0    | 16800 | 10                                      | Watt/100                          |
| Monitoring     | 86          | System Requirement        | 2      | Required Time                  | I2        | 0    | 32767 | 60                                      | s                                 |
| Monitoring     | 86          | System Requirement        | 4      | Min Voltage                    | I2        | 0    | 10000 | 4000                                    | mVolt                             |

**Table 62. Data Flash Values (continued)**

| CLASS NAME  | SUBCLASS ID | SUBCLASS NAME          | OFFSET | PARAMETER NAME               | DATA TYPE | MIN        | MAX        | DEFAULT  | UNITS   |
|-------------|-------------|------------------------|--------|------------------------------|-----------|------------|------------|----------|---------|
| Monitoring  | 87          | Charging Voltage       | 0      | V Chg Nominal                | I2        | 0          | 32767      | 8400     | mVolt   |
| Monitoring  | 87          | Charging Voltage       | 2      | V Chg A                      | I2        | 0          | 32767      | 8900     | mVolt   |
| Monitoring  | 87          | Charging Voltage       | 4      | V Chg B                      | I2        | 0          | 32767      | 9500     | mVolt   |
| Monitoring  | 87          | Charging Voltage       | 6      | V Chg Max                    | I2        | 0          | 32767      | 10000    | mVolt   |
| Monitoring  | 87          | Charging Voltage       | 8      | V Learn Max                  | I2        | 0          | 32767      | 10000    | mVolt   |
| Monitoring  | 88          | Learning Configuration | 0      | Learning Frequency           | U1        | 0          | 255        | 2        | week    |
| Monitoring  | 88          | Learning Configuration | 1      | Measurement Margin %         | U1        | 0          | 100        | 10       | Percent |
| Monitoring  | 88          | Learning Configuration | 2      | Max Chg Time                 | I2        | 0          | 32767      | 300      | s       |
| Monitoring  | 88          | Learning Configuration | 4      | Max Dsg Time                 | I2        | 0          | 32767      | 10       | s       |
| Monitoring  | 88          | Learning Configuration | 6      | Learn Delta Voltage          | I2        | 0          | 2000       | 500      | mVolt   |
| Monitoring  | 88          | Learning Configuration | 8      | Cap Start Time               | U2        | 0          | 65535      | 320      | msec    |
| Monitoring  | 81          | Current Thresholds     | 0      | Dsg Current Threshold        | I2        | 0          | 2000       | 10       | mA      |
| Monitoring  | 81          | Current Thresholds     | 2      | Chg Current Threshold        | I2        | 0          | 2000       | 0        | mA      |
| Calibration | 104         | Data                   | 0      | Current Gain                 | F4        | 1.00E – 01 | 4.00E + 00 | 0.47095  | Number  |
| Calibration | 104         | Data                   | 4      | CC Delta                     | F4        | 2.98E + 04 | 1.19E + 06 | 140466.3 | Number  |
| Calibration | 104         | Data                   | 8      | Cap1 K-factor                | I2        | 0          | 32767      | 20500    | —       |
| Calibration | 104         | Data                   | 10     | Cap2 K-factor                | I2        | 0          | 32767      | 20500    | —       |
| Calibration | 104         | Data                   | 12     | Cap3 K-factor                | I2        | 0          | 32767      | 20500    | —       |
| Calibration | 104         | Data                   | 14     | Cap4 K-factor                | I2        | 0          | 32767      | 20500    | —       |
| Calibration | 104         | Data                   | 16     | Cap5 K-factor                | I2        | 0          | 32767      | 20500    | —       |
| Calibration | 104         | Data                   | 18     | K-factor cap override flag   | H2        | 0          | FFFF       | 0        | num     |
| Calibration | 104         | Data                   | 20     | System Voltage K-factor      | I2        | 0          | 32767      | 24500    | —       |
| Calibration | 104         | Data                   | 22     | Stack Voltage K-factor       | I2        | 0          | 32767      | 24500    | —       |
| Calibration | 104         | Data                   | 24     | K-factor stack override flag | H2        | 0          | FFFF       | 0        | num     |
| Calibration | 104         | Data                   | 26     | CC Offset                    | I2        | –32768     | 32767      | –7744    | num     |
| Calibration | 104         | Data                   | 28     | Board Offset                 | I2        | –32767     | 32767      | 0        | uV      |
| Calibration | 104         | Data                   | 30     | Int Temp Offset              | I1        | –128       | 127        | 0        | 0.1°C   |
| Calibration | 104         | Data                   | 31     | Ext1 Temp Offset             | I1        | –128       | 127        | 0        | 0.1°C   |
| Calibration | 104         | Data                   | 32     | Ext2 Temp Offset             | I1        | –128       | 127        | 0        | 0.1°C   |
| Calibration | 104         | Data                   | 33     | ESR Offset                   | I1        | –128       | 127        | 0        | mΩ      |
| Calibration | 105         | Config                 | 0      | CC Current                   | I2        | 0          | 32767      | 3000     | mA      |
| Calibration | 105         | Config                 | 2      | Voltage Signal               | I2        | 0          | 32767      | 8400     | mVolt   |
| Calibration | 105         | Config                 | 4      | Temp Signal                  | I2        | 0          | 32767      | 2980     | 0.1°K   |
| Calibration | 105         | Config                 | 6      | CC Offset Time               | U2        | 0          | 65535      | 250      | s       |
| Calibration | 105         | Config                 | 8      | ADC Offset Time              | U2        | 0          | 65535      | 32       | s       |

**Table 62. Data Flash Values (continued)**

| CLASS NAME  | SUBCLASS ID | SUBCLASS NAME | OFFSET | PARAMETER NAME   | DATA TYPE | MIN    | MAX   | DEFAULT | UNITS  |
|-------------|-------------|---------------|--------|------------------|-----------|--------|-------|---------|--------|
| Calibration | 105         | Config        | 10     | CC Gain Time     | U2        | 0      | 65535 | 250     | s      |
| Calibration | 105         | Config        | 12     | Voltage Time     | U2        | 0      | 65535 | 1984    | ms     |
| Calibration | 105         | Config        | 14     | Temperature Time | U2        | 0      | 65535 | 32      | s      |
| Calibration | 105         | Config        | 17     | Cal Mode Timeout | U2        | 0      | 65535 | 38400   | s/128  |
| Calibration | 106         | Temp Model    | 0      | Ext Coef a1      | I2        | –32768 | 32767 | –14812  | num    |
| Calibration | 106         | Temp Model    | 2      | Ext Coef a2      | I2        | –32768 | 32767 | 24729   | num    |
| Calibration | 106         | Temp Model    | 4      | Ext Coef a3      | I2        | –32768 | 32767 | –21265  | num    |
| Calibration | 106         | Temp Model    | 6      | Ext Coef a4      | I2        | –32768 | 32767 | 28353   | num    |
| Calibration | 106         | Temp Model    | 8      | Ext Coef a5      | I2        | –32768 | 32767 | 759     | num    |
| Calibration | 106         | Temp Model    | 10     | Ext Coef b1      | I2        | –32768 | 32767 | –399    | num    |
| Calibration | 106         | Temp Model    | 12     | Ext Coef b2      | I2        | –32768 | 32767 | 764     | num    |
| Calibration | 106         | Temp Model    | 14     | Ext Coef b3      | I2        | –32768 | 32767 | –3535   | num    |
| Calibration | 106         | Temp Model    | 16     | Ext Coef b4      | I2        | –32768 | 32767 | 5059    | num    |
| Calibration | 106         | Temp Model    | 18     | Ext rc0          | I2        | –32768 | 32767 | 11703   | num    |
| Calibration | 106         | Temp Model    | 20     | Ext adc0         | I2        | –32768 | 32767 | 11813   | num    |
| Calibration | 106         | Temp Model    | 22     | Rpad             | I2        | –32768 | 32767 | 87      | Ω      |
| Calibration | 106         | Temp Model    | 24     | Rint             | I2        | –32768 | 32767 | 17740   | Ω      |
| Calibration | 106         | Temp Model    | 26     | Int Coef 1       | I2        | –32768 | 32767 | 0       | s      |
| Calibration | 106         | Temp Model    | 28     | Int Coef 2       | I2        | –32768 | 32767 | 0       | s      |
| Calibration | 106         | Temp Model    | 30     | Int Coef 3       | I2        | –32768 | 32767 | –12263  | s      |
| Calibration | 106         | Temp Model    | 32     | Int Coef 4       | I2        | –32768 | 32767 | 6106    | s      |
| Calibration | 106         | Temp Model    | 34     | Int Min AD       | I2        | –32768 | 32767 | 0       | s      |
| Calibration | 106         | Temp Model    | 36     | Int Max Temp     | I2        | –32768 | 32767 | 6106    | 0.1°K  |
| Calibration | 107         | Current       | 0      | Filter           | U1        | 0      | 255   | 239     | Number |
| Calibration | 107         | Current       | 1      | Dead Band        | U1        | 0      | 255   | 5       | mA     |
| Calibration | 107         | Current       | 2      | CC Deadband      | U1        | 0      | 255   | 10      | 294 nV |

### 8.5.3.4 Specific Data Flash Programming Details

In this section, the data flash values that are not detailed elsewhere in this data sheet are shown in detail and others are summarized for easy reference.

#### 8.5.3.4.1 OC Dsg

The **OC Dsg** is programmed into the OCDV register of the integrated AFE device. The **OC Dsg** sets the overcurrent in discharging voltage threshold. Changes to this data flash value require a firmware full reset or a power reset of the BQ33100 to take effect.

**Table 63. OC Dsg**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME   | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|--------|--------|---------------|-----------|-----------|---------------|------|
| 1           | Current       | 11     | OC Dsg | Hex    | 1             | 0x00      | 0x0F      | 0x0F          | —    |

**Figure 10. OCDV Register**

|   |   |   |   |       |       |       |       |
|---|---|---|---|-------|-------|-------|-------|
| 7 | 6 | 5 | 4 | 3     | 2     | 1     | 0     |
| — | — | — | — | OCDV3 | OCDV2 | OCDV1 | OCDV0 |

0000 is the BQ33100 power on reset default.

**OCDV3, OCDV2, OCDV1, OCDV0**—Sets the overcurrent voltage threshold (VSRP-VSRN)) in discharging of the integrated AFE.

0x0 – 0xf = sets the short circuit in discharging delay between 0 ms – 915-ms in 61-ms steps.

**[RSNS] = 0**, 0x0 – 0xf sets the voltage threshold between 50 mV and 200 mV in 10-mV steps.

**[RSNS] = 1**, 0x0 – 0xf sets the voltage threshold between 20 mV and 100 mV in 5-mV steps.

**OCDV (b7...b4)**—Not used

**Table 64. OCDV (b2-b0) Configuration Bits with Corresponding Voltage Threshold When STATE\_CTL[RSNS] = 0**

| SETTING | THRESHOLD | SETTING | THRESHOLD |
|---------|-----------|---------|-----------|
| 0x00    | 0.050 V   | 0x08    | 0.130 V   |
| 0x01    | 0.060 V   | 0x09    | 0.140 V   |
| 0x02    | 0.070 V   | 0x0A    | 0.150 V   |
| 0x03    | 0.080 V   | 0x0B    | 0.160 V   |
| 0x04    | 0.090 V   | 0x0C    | 0.170 V   |
| 0x05    | 0.100 V   | 0x0D    | 0.180 V   |
| 0x06    | 0.110 V   | 0x0E    | 0.190 V   |
| 0x07    | 0.120 V   | 0x0F    | 0.200 V   |

**Table 65. OCDV (b2-b0) Configuration Bits with Corresponding Voltage Threshold When STATE\_CTL[RSNS] = 1**

| SETTING | THRESHOLD | SETTING | THRESHOLD |
|---------|-----------|---------|-----------|
| 0x00    | 0.025 V   | 0x08    | 0.065 V   |
| 0x01    | 0.050 V   | 0x09    | 0.070V    |
| 0x02    | 0.035 V   | 0x0A    | 0.075 V   |
| 0x03    | 0.040 V   | 0x0B    | 0.080 V   |
| 0x04    | 0.045 V   | 0x0C    | 0.085 V   |
| 0x05    | 0.050 V   | 0x0D    | 0.090 V   |
| 0x06    | 0.055 V   | 0x0E    | 0.095V    |
| 0x07    | 0.060 V   | 0x0F    | 0.100 V   |

#### 8.5.3.4.2 OC Dsg Time

The **OC Dsg Time** is programmed into the OCDD register of the integrated AFE device. The **OC Dsg Time** sets the overcurrent in discharging delay. Changes to this data flash value require a firmware full reset or a power reset of the BQ33100 to take effect.

**Table 66. OC Dsg Time**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME        | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-------------|--------|---------------|-----------|-----------|---------------|------|
| 1           | Current       | 12     | OC Dsg Time | Hex    | 1             | 0x00      | 0x0F      | 0x0F          | —    |

**Figure 11. OCDD Register**

|   |   |   |   |       |       |       |       |
|---|---|---|---|-------|-------|-------|-------|
| 7 | 6 | 5 | 4 | 3     | 2     | 1     | 0     |
| — | — | — | — | OCDD3 | OCDD2 | OCDD1 | OCDD0 |

0000 is the BQ33100 power on reset default.

**OCDD3, OCDD2, OCDD1, OCDD0**—Sets the overcurrent in discharging delay of the integrated AFE

0x0 – 0xf = sets the overvoltage trip delay between 1 ms to 31-ms in 2-ms steps

**OCDD (b7...b4)** —Not used

**Table 67. OCDD (b7-b4) Configuration Bits With Corresponding Delay Time**

| SETTING | DELAY | SETTING | DELAY | SETTING | DELAY | SETTING | DELAY |
|---------|-------|---------|-------|---------|-------|---------|-------|
| 0x00    | 1 ms  | 0x04    | 9 ms  | 0x08    | 17 ms | 0x0C    | 25 ms |
| 0x01    | 3 ms  | 0x05    | 11 ms | 0x09    | 19 ms | 0x0D    | 27 ms |
| 0x02    | 5 ms  | 0x06    | 13 ms | 0x0A    | 21 ms | 0x0E    | 29 ms |
| 0x03    | 7 ms  | 0x07    | 15 ms | 0x0B    | 23 ms | 0x0F    | 31 ms |

#### 8.5.3.4.3 SC Dsg Cfg

The **SC Dsg Cfg** is programmed into the SCD register of the integrated AFE device. The **SC Dsg Cfg** sets the short circuit in discharging voltage threshold and the short circuit in discharging delay. Changes to this data flash value require a firmware full reset or a power reset of the BQ33100 to take effect.

**Table 68. SC Dsg Cfg**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME       | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------|--------|---------------|-----------|-----------|---------------|------|
| 1           | Current       | 16     | SC Dsg Cfg | Hex    | 1             | 0x00      | 0x0F      | 0x0F          | —    |

**Figure 12. SCD Register**

|       |       |       |       |   |       |       |       |
|-------|-------|-------|-------|---|-------|-------|-------|
| 7     | 6     | 5     | 4     | 3 | 2     | 1     | 0     |
| SCDD3 | SCDD2 | SCDD1 | SCDD0 | — | SCDV2 | SCDV1 | SCDV0 |

0000 is the BQ33100 power on reset default.

**SCDD3, SCDD2, SCDD1, SCDD0**—Sets the short circuit delay in discharging of the integrated AFE.

0x0 – 0xf = sets the short circuit in discharging delay between 0 ms to 915 ms in 61-ms steps.

If **STATE\_CTL[SCDDx2]** is set, the delay time is double of that programmed in this register.

**SCDV2, SCDV1, SCDV0**—Sets the short circuit voltage threshold (VSRP-VSRN)) in discharging of the integrated AFE

**[RSNS] = 0**, 0x0 – 0x7 sets the short circuit voltage threshold between 100 mV and 450 mV in 50-mV steps.

**[RSNS] = 1**, 0x0 – 0x7 sets the short circuit voltage threshold between 50 mV and 475 mV in 25-mV steps.

**SCD (b3)**—Not used

**Table 69. SCDV (b2-b0) Configuration Bits with Corresponding Voltage Threshold When STATE\_CTL[RSNS] = 0**

| SETTING | THRESHOLD | SETTING | THRESHOLD |
|---------|-----------|---------|-----------|
| 0x00    | 0.100 V   | 0x04    | 0.300 V   |
| 0x01    | 0.150 V   | 0x05    | 0.350 V   |
| 0x02    | 0.200 V   | 0x06    | 0.400 V   |
| 0x03    | 0.250 V   | 0x07    | 0.450 V   |

**Table 70. SCDV (b2-b0) Configuration Bits with Corresponding Voltage Threshold When STATE\_CTL[RSNS] = 1**

| SETTING | THRESHOLD | SETTING | THRESHOLD |
|---------|-----------|---------|-----------|
| 0x00    | 0.050 V   | 0x04    | 0.150 V   |
| 0x01    | 0.075 V   | 0x05    | 0.175 V   |
| 0x02    | 0.100 V   | 0x06    | 0.200 V   |
| 0x03    | 0.125 V   | 0x07    | 0.225 V   |

**Table 71. SCDD (b7-b4) Configuration Bits with Corresponding Delay Time**

| SETTING | DELAY       | SETTING | DELAY       | SETTING | DELAY       | SETTING | DELAY       |
|---------|-------------|---------|-------------|---------|-------------|---------|-------------|
| 0x00    | 0 $\mu$ s   | 0x04    | 244 $\mu$ s | 0x08    | 488 $\mu$ s | 0x0C    | 732 $\mu$ s |
| 0x01    | 61 $\mu$ s  | 0x05    | 305 $\mu$ s | 0x09    | 549 $\mu$ s | 0x0D    | 793 $\mu$ s |
| 0x02    | 112 $\mu$ s | 0x06    | 366 $\mu$ s | 0x0A    | 610 $\mu$ s | 0x0E    | 854 $\mu$ s |
| 0x03    | 183 $\mu$ s | 0x07    | 427 $\mu$ s | 0x0B    | 671 $\mu$ s | 0x0F    | 915 $\mu$ s |

#### 8.5.3.4.4 SC Chg Cfg

**SC Chg Cfg** is programmed into the SCC register of the integrated AFE device. The **SC Chg Cfg** sets the short circuit in charging voltage threshold and the short circuit in charging delay. Changes to this data flash value require a firmware full reset or a power reset of the BQ33100 to take effect.

**Table 72. SC Chg Cfg**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME       | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------|--------|---------------|-----------|-----------|---------------|------|
| 1           | Current       | 15     | SC Chg Cfg | Hex    | 1             | 0x00      | 0xF7      | 0xF7          | —    |

**Figure 13. SCC Register**

| 7     | 6     | 5     | 4     | 3 | 2     | 1     | 0     |
|-------|-------|-------|-------|---|-------|-------|-------|
| SCCD3 | SCCD2 | SCCD1 | SCCD0 | — | SCCV2 | SCCV1 | SCCV0 |

0000 is the BQ33100 power on reset default.

**SCCD3, SCCD2, SCCD1, SCCD0**—Sets the short circuit delay in charging of the integrated AFE

0x0 – 0xf = Sets the short circuit in charging delay between 0 ms to 915 ms in 61-ms steps

If **STATE\_CTL[SCDDx2]** is set, the delay time is double of that programmed in this register.

**SCCV2, SCCV1, SCCV0**—Sets the short circuit voltage threshold (VSRP-VSRN)) in charging of the integrated AFE

**[RSNS] = 0**, 0x0 – 0x7 sets the short circuit voltage threshold between 100 mV and 450 mV in 50-mV steps.

**[RSNS] = 1**, 0x0 – 0x7 sets the short circuit voltage threshold between 50 mV and 475 mV in 25-mV steps.

**SCC (b3)**—Not used

**Table 73. SCCV (b2-b0) Configuration Bits with Corresponding Voltage Threshold When STATE\_CTL[RSNS] = 0**

| SETTING | THRESHOLD | SETTING | THRESHOLD |
|---------|-----------|---------|-----------|
| 0x00    | –0.100 V  | 0x04    | –0.300 V  |
| 0x01    | –0.150 V  | 0x05    | n/a       |
| 0x02    | –0.200 V  | 0x06    | n/a       |
| 0x03    | –0.250 V  | 0x07    | n/a       |

**Table 74. SCCV (b2-b0) Configuration Bits with Corresponding Voltage Threshold When STATE\_CTL[RSNS] = 1**

| SETTING | THRESHOLD | SETTING | THRESHOLD |
|---------|-----------|---------|-----------|
| 0x00    | –0.050 V  | 0x04    | –0.150 V  |
| 0x01    | –0.075 V  | 0x05    | –0.175 V  |
| 0x02    | –0.100 V  | 0x06    | –0.200 V  |
| 0x03    | –0.125 V  | 0x07    | –0.225 V  |

**Table 75. SCCD (b7-b4) Configuration Bits with Corresponding Delay Time**

| SETTING | DELAY  | SETTING | DELAY  | SETTING | DELAY  | SETTING | DELAY  |
|---------|--------|---------|--------|---------|--------|---------|--------|
| 0x00    | 0 μs   | 0x04    | 244 μs | 0x08    | 488 μs | 0x0C    | 732 μs |
| 0x01    | 61 μs  | 0x05    | 305 μs | 0x09    | 549 μs | 0x0D    | 793 μs |
| 0x02    | 112 μs | 0x06    | 366 μs | 0x0A    | 610 μs | 0x0E    | 854 μs |
| 0x03    | 183 μs | 0x07    | 427 μs | 0x0B    | 671 μs | 0x0F    | 915 μs |

#### 8.5.3.4.5 Initial 1st Capacitance

The value of **Initial 1st Capacitance** is used in the health and other calculations.

**Table 76. Initial 1st Capacitance**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME                    | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-------------------------|---------|---------------|-----------|-----------|---------------|------|
| 48          | Data          | 8      | Initial 1st Capacitance | Integer | 2             | 0         | 65535     | 250           | F    |

#### 8.5.3.4.6 Capacitance

This value is used as the **Capacitance** at device reset. This value is updated by the gauging algorithm when a qualified learning cycle has completed.

**Table 77. Capacitance**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME        | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-------------|---------|---------------|-----------|-----------|---------------|------|
| 48          | Data          | 10     | Capacitance | Integer | 2             | 0         | 65535     | 250           | F    |

#### 8.5.3.4.7 Firmware Version

The **ManufacturerAccess** function reports **Firmware Version** as part of its return value.

**Table 78. Firmware Version**

| SUBCLASS ID | SUBCLASS NAME     | OFFSET | NAME             | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|-------------------|--------|------------------|--------|---------------|-----------|-----------|---------------|------|
| 56          | Manufacturer Data | 4      | Firmware Version | Hex    | 2             | 0x0000    | 0xffff    | 0x00000       | —    |

#### 8.5.3.4.8 Hardware Version

The **ManufacturerAccess** function reports **Hardware Version** as part of its return value.

**Table 79. Hardware Version**

| SUBCLASS ID | SUBCLASS NAME     | OFFSET | NAME             | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|-------------------|--------|------------------|--------|---------------|-----------|-----------|---------------|------|
| 56          | Manufacturer Data | 6      | Hardware Version | Hex    | 2             | 0x0000    | 0xffff    | 0x0000        | —    |

#### 8.5.3.4.9 Manuf. Info

The **ManufacturerInfo** function returns the string stored in **Manuf. Info**. The maximum text length is 31 characters.

**Table 80. Manuf. Info**

| SUBCLASS ID | SUBCLASS NAME     | OFFSET | NAME        | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE                               | UNIT |
|-------------|-------------------|--------|-------------|--------|---------------|-----------|-----------|---------------------------------------------|------|
| 58          | Manufacturer Info | 0      | Manuf. Info | String | 32            | —         | —         | 012345678<br>9ABCDEF0<br>123456789<br>ABCDE |      |

#### 8.5.3.4.10 Operation Cfg

This register enables, disables, or configures various features of the BQ33100.

**Table 81. Operation Cfg**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME          | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|---------------|--------|---------------|-----------|-----------|---------------|------|
| 64          | Registers     | 0      | Operation Cfg | Hex    | 2             | 0x0000    | 0xffff    | 0x04a8        |      |

**Figure 14. Operation Cfg Register**

|      |       |      |       |       |      |      |       |
|------|-------|------|-------|-------|------|------|-------|
| 15   | 14    | 13   | 12    | 11    | 10   | 9    | 8     |
| RSVD | RSVD  | RSVD | RSVD  | RSVD  | CC2  | CC1  | CC0   |
| 7    | 6     | 5    | 4     | 3     | 2    | 1    | 0     |
| RSVD | LT_EN | RSVD | TEMP1 | TEMP0 | RSVD | RSVD | STACK |

LEGEND: RSVD = Reserved and must be programmed to 0 unless otherwise specified.

**CC2, CC1, CC0**—These bits configure the BQ33100 for the number of series capacitors in the super capacitor stack.

0,0,0 = Reserved

0,0,1 = 2 capacitors

0,1,0 = 3 capacitors (default)

0,1,1 = 4 capacitors

1,0,0 = 5 capacitors

**LT\_EN**—Lifetime Data logging bit; this bit enables or disables Lifetime Data logging from occurring. This bit can be directly set by the *Lifetime Enable* command.

0 = All Lifetime Data logging is prevented from occurring.

1 = All Lifetime Data logging is allowed.

**TEMP1, TEMP0**—These bits configure the source of the Temperature function.

0,0 = Internal Temperature Sensor

0,1 = TS Input (default)

**STACK**—This bit configure the BQ33100 to measure all series voltages up to 5-series cells or just the stack voltage.

0 = Each series cell is measured and can be balanced up to 5-series capacitors.

1 = The capacitor stack is measured and Capacitor Balancing and Cell Imbalance Detection are disabled.

#### 8.5.3.4.11 FET ACTION

The **FET Action** register enables the charge FET to turn off when a safety condition occurs. The charge FET turns off when the a bit in the **SafetyStatus** register is set that corresponds to a set bit in the **FET Action** register.

**Table 82. FET Action**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME       | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|------------|--------|---------------|-----------|-----------|---------------|------|
| 64          | Registers     | 4      | FET Action | Hex    | 2             | 0x0000    | 0xffff    | 0x0000        |      |

**Figure 15. FET Action Register**

|       |       |       |      |      |     |     |     |
|-------|-------|-------|------|------|-----|-----|-----|
| 15    | 14    | 13    | 12   | 11   | 10  | 9   | 8   |
| CLBAD | HFAIL | HWARN | HLOW | RSVD | OTC | CIM | OV  |
| 7     | 6     | 5     | 4    | 3    | 2   | 1   | 0   |
| DFF   | RSVD  | AFE_C | WDF  | OCC  | OCD | SCC | SCD |

**CLBAD:** Weak capacitor condition

**HFAIL:** Health fault condition

**HWARN:** Health warning condition

**HLOW:** Health low condition

**AFE\_C:** AFE Communications failure condition

**CIM:** Capacitor voltage imbalance condition

**DFF:** Data Flash Fault failure condition

**OTC:** Charge overtemperature condition

**OV:** Capacitor overvoltage condition

**WDF:** AFE Watchdog fault condition

**OCC:** Charge overcurrent condition

**OCD:** AFE overcurrent on discharge condition

**SCC:** AFE short circuit on charge condition

**SCD:** AFE short circuit on discharge condition

**OV:** Capacitor overvoltage condition

#### 8.5.3.4.12 FAULT

The **FAULT** register enables or disables the use of the FAULT pin when the corresponding bit in **SafetyStatus** is set.

**Table 83. FAULT**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME  | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|-------|--------|---------------|-----------|-----------|---------------|------|
| 64          | Registers     | 8      | FAULT | Hex    | 2             | 0x0000    | 0xffff    | 0x0000        |      |

**Figure 16. FAULT Register**

|       |       |       |      |      |     |     |     |
|-------|-------|-------|------|------|-----|-----|-----|
| 15    | 14    | 13    | 12   | 11   | 10  | 9   | 8   |
| CLBAD | HFAIL | HWARN | HLOW | RSVD | OTC | CIM | OV  |
| 7     | 6     | 5     | 4    | 3    | 2   | 1   | 0   |
| DFF   | RSVD  | AFE_C | WDF  | OCC  | OCD | SCC | SCD |

**CLBAD:** Weak capacitor condition

**HFAIL:** Health fault condition

**HWARN:** Health warning condition

**HLOW:** Health low condition

**AFE\_C:** AFE Communications failure condition

**CIM:** Capacitor voltage imbalance condition

**DFF:** Data Flash Fault failure condition

**OTC:** Charge overtemperature condition

**OV:** Capacitor overvoltage condition

**WDF:** AFE Watchdog fault condition

**OCC:** Charge overcurrent condition

**OCD:** AFE overcurrent on discharge condition

**SCC:** AFE short circuit on charge condition

**SCD:** AFE short circuit on discharge condition

#### 8.5.3.4.13 AFE State\_CTL

This register adjusts the AFE hardware overcurrent and short circuit detection thresholds and delay.

**Table 84. AFE State\_CTL**

| SUBCLASS ID | SUBCLASS NAME | OFFSET | NAME          | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|---------------|--------|---------------|--------|---------------|-----------|-----------|---------------|------|
| 65          | AFE           | 1      | AFE State_CTL | Hex    | 1             | 0x00      | 0xff      | 0x00          |      |

**Figure 17. AFE State\_CTL Register**

|      |      |        |      |      |      |      |      |
|------|------|--------|------|------|------|------|------|
| 7    | 6    | 5      | 4    | 3    | 2    | 1    | 0    |
| RSVD | RSVD | SCDDX2 | RSNS | RSVD | RSVD | RSVD | RSVD |

LEGEND: RSVD = Reserved and must be programmed to 0

**SCDDX2**—Set this bit to double the SCD delay periods 0 (default) = Short Circuit current protection delay is as programmed.

1 = Short Circuit current protection delay is twice that programmed.

**RSNS**—This bit, if set, configures the SCD threshold into a range suitable for a low sense resistor value by dividing the SCDV selected voltage threshold by 2 0 (default) = Current protection voltage thresholds as programmed.

1 = Current protection voltage threshold divided by 2 as programmed

#### 8.5.3.4.14 Measurement Margin %

**Measurement Margin %** provides any needed addition margin for measurement error or other error sources.

**Table 85. Measurement Margin %**

| SUBCLASS ID | SUBCLASS NAME          | OFFSET | NAME                 | FORMAT           | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|------------------------|--------|----------------------|------------------|---------------|-----------|-----------|---------------|------|
| 88          | Learning Configuration | 1      | Measurement Margin % | Unsigned Integer | 1             | 0         | 100       | 10            | %    |

#### 8.5.3.4.15 Max Dsg Time

**Max Dsg Time** provides the maximum amount of time for a learning cycle to complete.

**Table 86. Max Dsg Time**

| SUBCLASS ID | SUBCLASS NAME          | OFFSET | NAME         | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|------------------------|--------|--------------|---------|---------------|-----------|-----------|---------------|------|
| 88          | Learning Configuration | 4      | Max Dsg Time | Integer | 2             | 0         | 32767     | 10            | s    |

#### 8.5.3.4.16 V Chg Nominal

Nominal charging voltage(min) representing CHGLVL1 = Low (0) and CHGLVL0 = Low (0)

**Table 87. V Chg Nominal**

| SUBCLASS ID | SUBCLASS NAME    | OFFSET | NAME          | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|------------------|--------|---------------|---------|---------------|-----------|-----------|---------------|------|
| 88          | Charging Voltage | 0      | V Chg Nominal | Integer | 2             | 0         | 25000     | 10400         | mV   |

#### 8.5.3.4.17 V Chg A

Charging voltage representing CHGLVL1 = Low (0) and CHGLVL0 = High (1)

**Table 88. V Chg A**

| SUBCLASS ID | SUBCLASS NAME    | OFFSET | NAME    | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|------------------|--------|---------|---------|---------------|-----------|-----------|---------------|------|
| 88          | Charging Voltage | 2      | V Chg A | Integer | 2             | 0         | 25000     | 11125         | mV   |

#### 8.5.3.4.18 V Chg B

Charging voltage representing CHGLVL1 = High (1) and CHGLVL0 = Low (0)

**Table 89. V Chg B**

| SUBCLASS ID | SUBCLASS NAME    | OFFSET | NAME    | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|------------------|--------|---------|---------|---------------|-----------|-----------|---------------|------|
| 88          | Charging Voltage | 4      | V Chg B | Integer | 2             | 0         | 25000     | 11875         | mV   |

#### 8.5.3.4.19 V Chg Max

Charging voltage(max) representing CHGLVL1 = High (1) and CHGLVL0 = High (1)

**Table 90. V Chg Max**

| SUBCLASS ID | SUBCLASS NAME    | OFFSET | NAME      | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|------------------|--------|-----------|---------|---------------|-----------|-----------|---------------|------|
| 88          | Charging Voltage | 6      | V Chg Max | Integer | 2             | 0         | 25000     | 125000        | mV   |

#### 8.5.3.4.20 Min Voltage

**Min Voltage** is the minimum voltage that the super capacitor must discharge. **Min Voltage** is used in capacitance estimation, which defines the super capacitor usage range.

**Table 91. Min Voltage**

| SUBCLASS ID | SUBCLASS NAME      | OFFSET | NAME        | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|--------------------|--------|-------------|---------|---------------|-----------|-----------|---------------|------|
| 88          | System Requirement | 4      | Min Voltage | Integer | 2             | 0         | 10000     | 4000          | mV   |

#### 8.5.3.4.21 Learning Frequency

**Learning Frequency** is the amount of time elapsed between automatic learning cycles.

#### NOTE

A value of 250 is used to set the **Learning Frequency** to 10 minutes for test purposes.

**Table 92. Learning Frequency**

| Subclass ID | Subclass Name          | Offset | Name               | Format           | Size in Bytes | Min Value | Max Value | Default Value | Unit |
|-------------|------------------------|--------|--------------------|------------------|---------------|-----------|-----------|---------------|------|
| 88          | Learning Configuration | 0      | Learning Frequency | Unsigned Integer | 1             | 0         | 255       | 2             | week |

#### 8.5.3.4.22 Dsg Current Threshold

The BQ33100 enters DISCHARGE mode from CHARGE mode if  $Current < (-)Dsg\ Current\ Threshold$ .

**Table 93. Dsg Current Threshold**

| Subclass ID | Subclass Name      | Offset | Name                  | Format  | Size in Bytes | Min Value | Max Value | Default Value | Unit |
|-------------|--------------------|--------|-----------------------|---------|---------------|-----------|-----------|---------------|------|
| 81          | Current Thresholds | 0      | Dsg Current Threshold | Integer | 2             | 0         | 2000      | 10            | mA   |

#### 8.5.3.4.23 Chg Current Threshold

The BQ33100 enters CHARGE mode from DISCHARGE mode if  $Current > Chg\ Current\ Threshold$ .

**Table 94. Chg Current Threshold**

| SUBCLASS ID | SUBCLASS NAME      | OFFSET | NAME                  | FORMAT  | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|-------------|--------------------|--------|-----------------------|---------|---------------|-----------|-----------|---------------|------|
| 81          | Current Thresholds | 2      | Chg Current Threshold | Integer | 2             | 0         | 2000      | 0             | mA   |

## 9 Application and Implementation

#### NOTE

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

### 9.1 Application Information

The BQ33100 is a super capacitor manager that can provide capacitance and ESR measurements for up to 9-series capacitors and balancing for systems with up to 5-series capacitors. This section of the data sheet provides practical applications information for hardware and systems engineers designing the BQ33100 into their end equipment.

## 9.2 Typical Application

- ⚠ R8–R11: Required to be 1k.
- ⚠ IC ground should be connected to the 1N cell tab.
- ⚠ R14 – R17 and R31: If smaller resistors are used, user should make sure the power rating of the resistor can handle the desired cell balance current
- ⚠ R29 should not be installed.

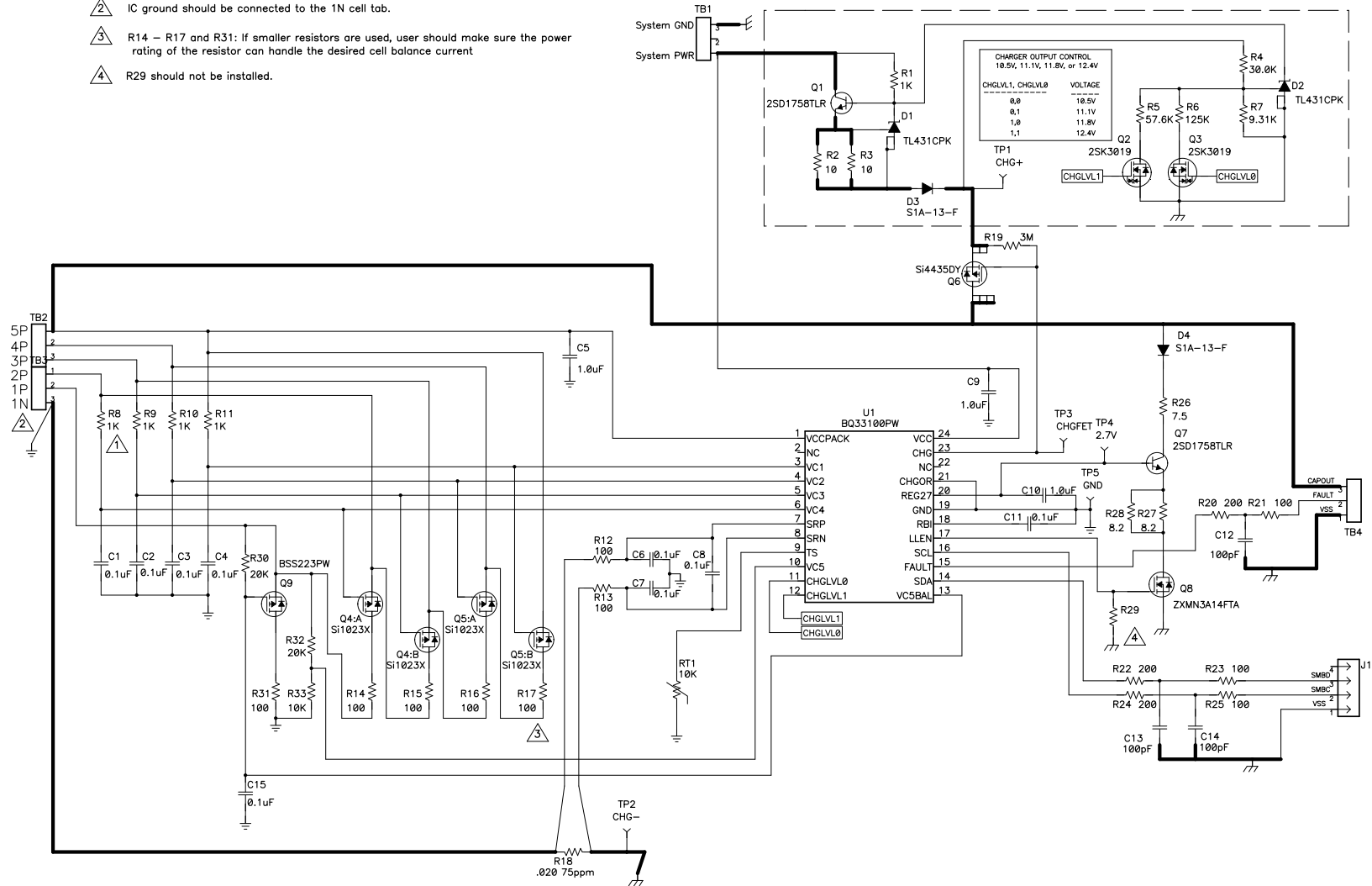


Figure 18. Application Reference Schematic

## 9.2.1 Design Requirements

The BQ33100 comes programmed to support 4-series capacitor systems with cell balancing enabled. [Table 95](#) shows other key configuration defaults.

**Table 95. Design Parameters**

| DESIGN PARAMETER       | EXAMPLE VALUE |
|------------------------|---------------|
| Number of Series Cells | 4             |
| Design Capacitance     | 250 F         |
| Design ESR             | 320 mΩ        |
| Cell Balancing         | Enabled       |
| V Chg Nominal          | 8400 mV       |
| V CHG A                | 8900 mV       |
| V CHG                  | 9500 mV       |
| V CHG MAX              | 10000 mV      |
| Learn Frequency        | 2 weeks       |
| Learn Delta Voltage    | 500 mV        |

Use the BQEVSW tool to update the settings to meet the specific application or pack configuration requirements.

## 9.2.2 Detailed Design Procedure

This section provides information on selecting key device configuration options. More information on these and other configuration options is available in *BQ33100 Super Capacitor Manager - Top 13 Design Considerations* ([SLUA751](#)).

### 9.2.2.1 Selecting Number of Series Capacitor Support

The BQ33100 can support 2- to 5-series capacitors when **Operation Cfg [STACK]** = 0 or 2 to 9 series capacitors when **[STACK]** = 1. The main difference is that when **[STACK]** = 1, the BQ33100 will not perform cell balancing.

### 9.2.2.2 Selecting Charging Voltage Values

The BQ33100 learning algorithm requires that the capacitors not be charged to their maximum charging value: for example, 2.5 V, under normal conditions. This enables the BQ33100 to charge the capacitors a small amount and then enable a discharge as part of the learning process. The value to which the capacitors must charge to is configured in **V Learn Max** and is expected to be the maximum charging voltage as specified by the capacitor manufacturer: for example, 2.5 V. This is typically also the **V Chg MAX** value, although some capacitor manufacturers will allow a higher voltage for the short learning period compared to the DC value it is held at during normal charging.

The nominal charging voltage must be selected to enable the capacitor array to provide the required amount of energy from the capacitance at that voltage. This data is available from the capacitor manufacturer's data sheet. The default value is 2.1 V per capacitor and as the device is configured as a 4-series system, then the programmed value in **V Chg Nominal** is 8400 mV.

**V Chg A** and **V Chg B** must be selected to be evenly spread between **V Chg Nominal** and **V Chg Max**: for example, **V Chg A** = 8900 mV (2.225 V per cap) and **V Chg B** = 9500 (2.375 V per cap).

### 9.2.2.3 Learning Frequency Selection

The default learning frequency of the BQ33100 is set to two weeks. The capacitance and ESR changes relatively slowly over time so selecting a period such as two weeks or longer allows for a change to be detected.

Setting an automatic update to occur on a very slow rate, for two weeks, and then enabling the host system to update at a faster rate—for example, each day, or synchronized to a host system event, and after a host system reboot, is common.

### 9.2.3 Application Curve

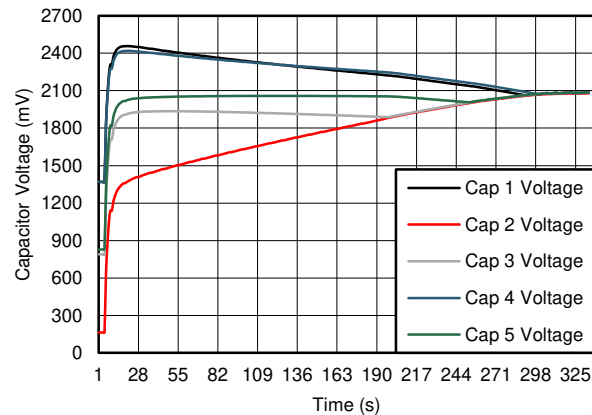


**Figure 19. Voltage Convergence During Capacitor Balancing**

## 10 Power Supply Recommendations

The device manages its supply voltage dynamically according to the operation conditions. Normally, the VCC and PACK input is the primary power source to the device. The VCC and PACK pin must be connected to the positive termination of the capacitor array. The input voltage for the VCC and PACK pin ranges from 3.8 V to 25 V. A 1- $\mu$ F capacitor must be connected to the VCC and PACK as close to the device as possible for supply decoupling.

## 11 Layout

### 11.1 Layout Guidelines

A capacitance monitor circuit board is a challenging environment due to the fundamental incompatibility of high current traces and ultra-low current semiconductor devices. The best way to protect against unwanted trace-to-trace coupling is with a component placement where the high-current section is on the opposite side of the board from the electronic devices. Ensure to route high-current traces away from signal traces, which enter the BQ33100 directly. IC references and registers can be disturbed and in rare cases damaged due to magnetic and capacitive coupling from the high-current path.

#### NOTE

During surge current and ESD events, the high-current traces appear inductive and can couple unwanted noise into sensitive nodes of the gas gauge electronics.

The learning load components can become heated depending on the component values selected. TI recommends that any heat is dissipated away from the BQ33100 to ensure its maximum operating temperature is not exceeded.

## 11.2 Layout Example

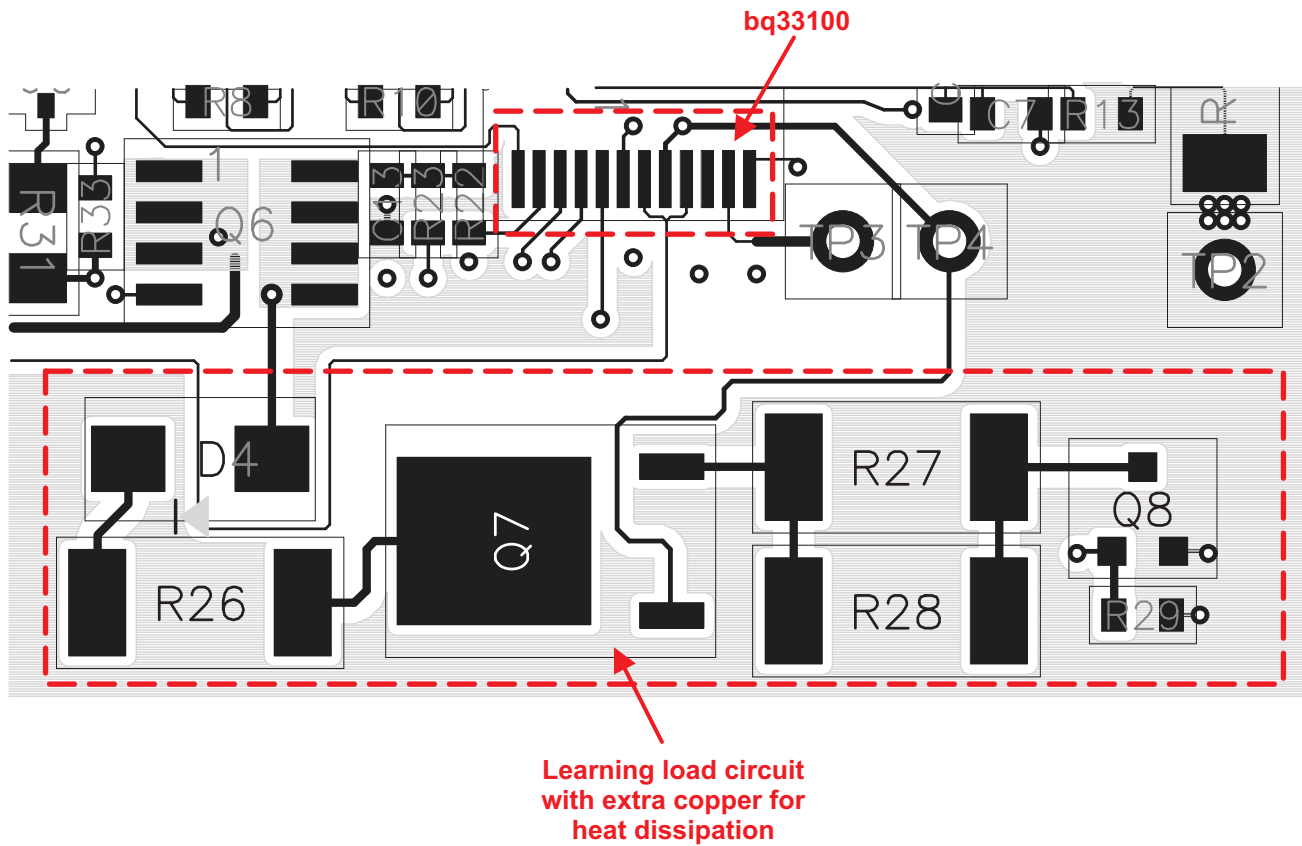


Figure 20. BQ33100 Board Layout

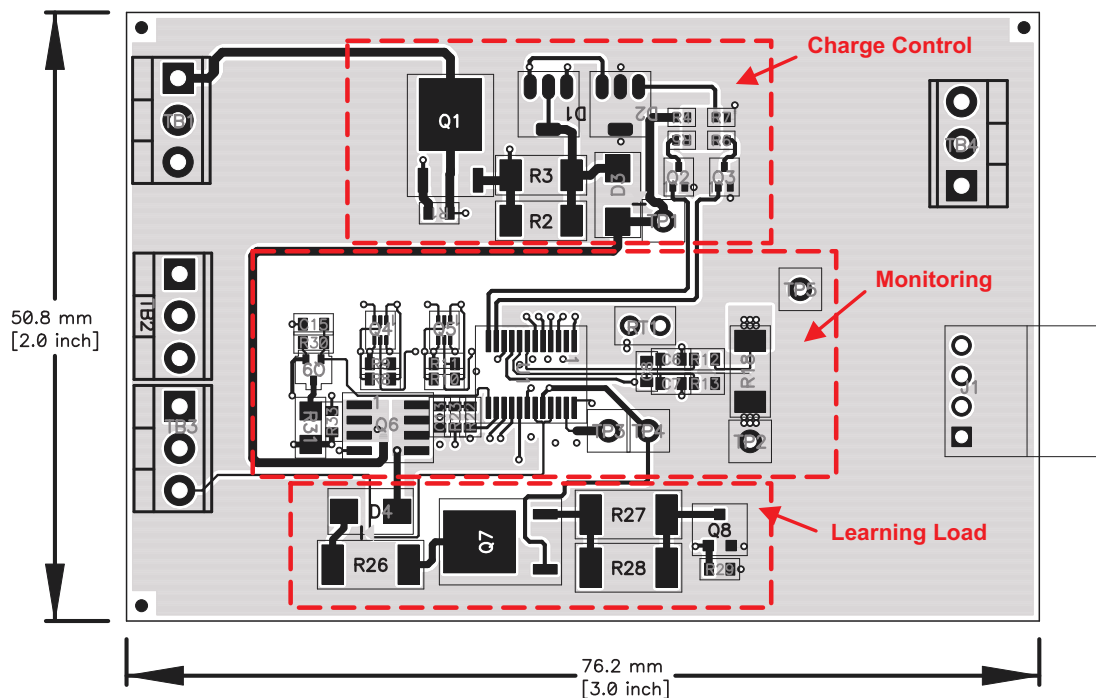


Figure 21. Top Layer

## Layout Example (continued)

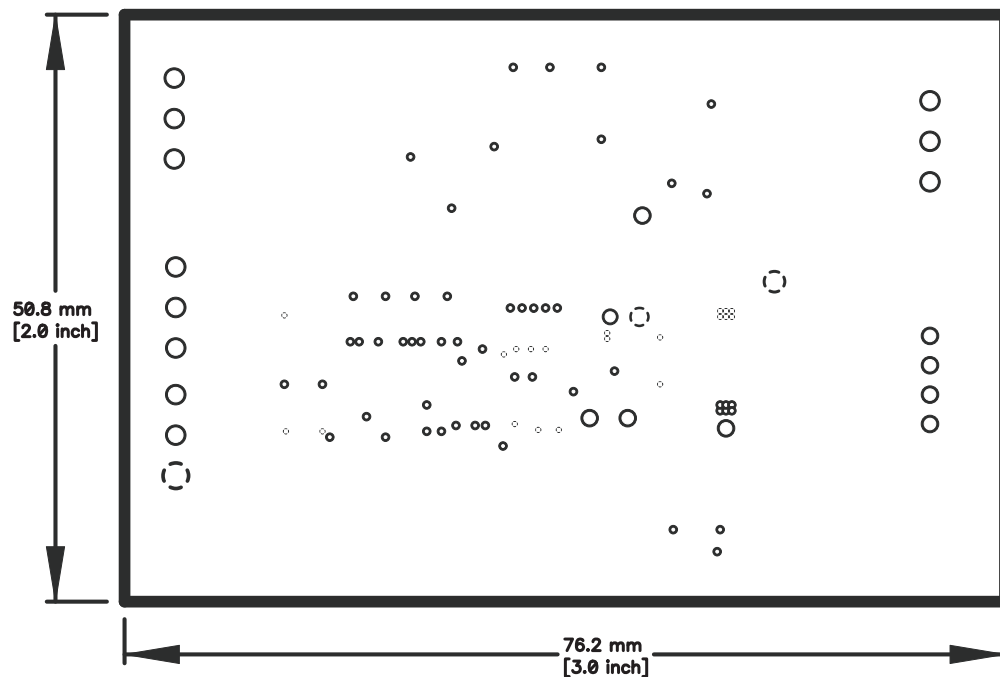


**Figure 22. Internal Layer 1**

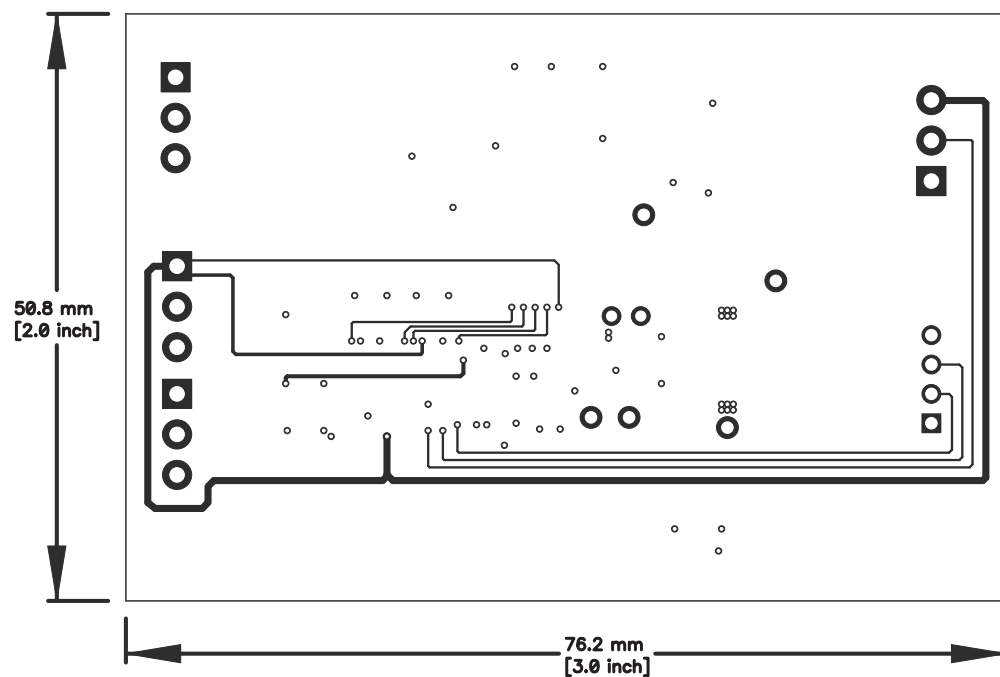


**Figure 23. Internal Layer 2**

## Layout Example (continued)

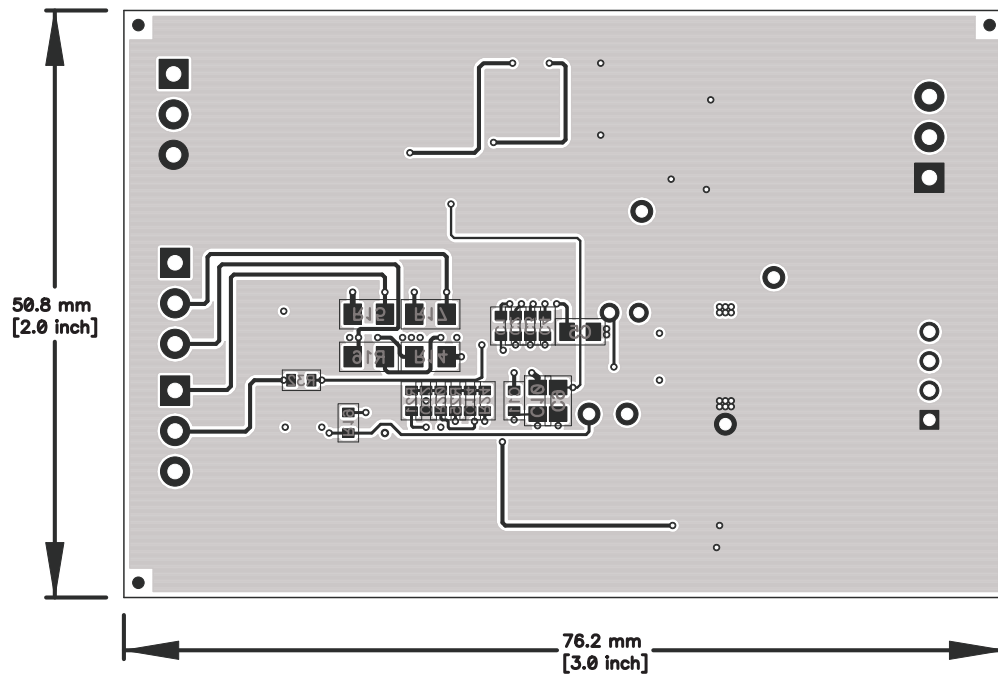


**Figure 24. Bottom Layer**

## 12 Device and Documentation Support

### 12.1 Documentation Support

#### 12.1.1 Related Documentation

For related documentation, see the following:

*BQ33100 Super Capacitor Manager - Top 13 Design Considerations*, [SLUA751](#)

### 12.2 Support Resources

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

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 12.3 Trademarks

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

### 12.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 12.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 13 Mechanical, Packaging, and Orderable Information

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

## PACKAGING INFORMATION

| Orderable part number      | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">BQ33100PW</a>  | Active        | Production           | TSSOP (PW)   24 | 60   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | 33100               |
| BQ33100PW.A                | Active        | Production           | TSSOP (PW)   24 | 60   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | 33100               |
| <a href="#">BQ33100PWR</a> | Active        | Production           | TSSOP (PW)   24 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | 33100               |
| BQ33100PWR.A               | Active        | Production           | TSSOP (PW)   24 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | 33100               |

<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.

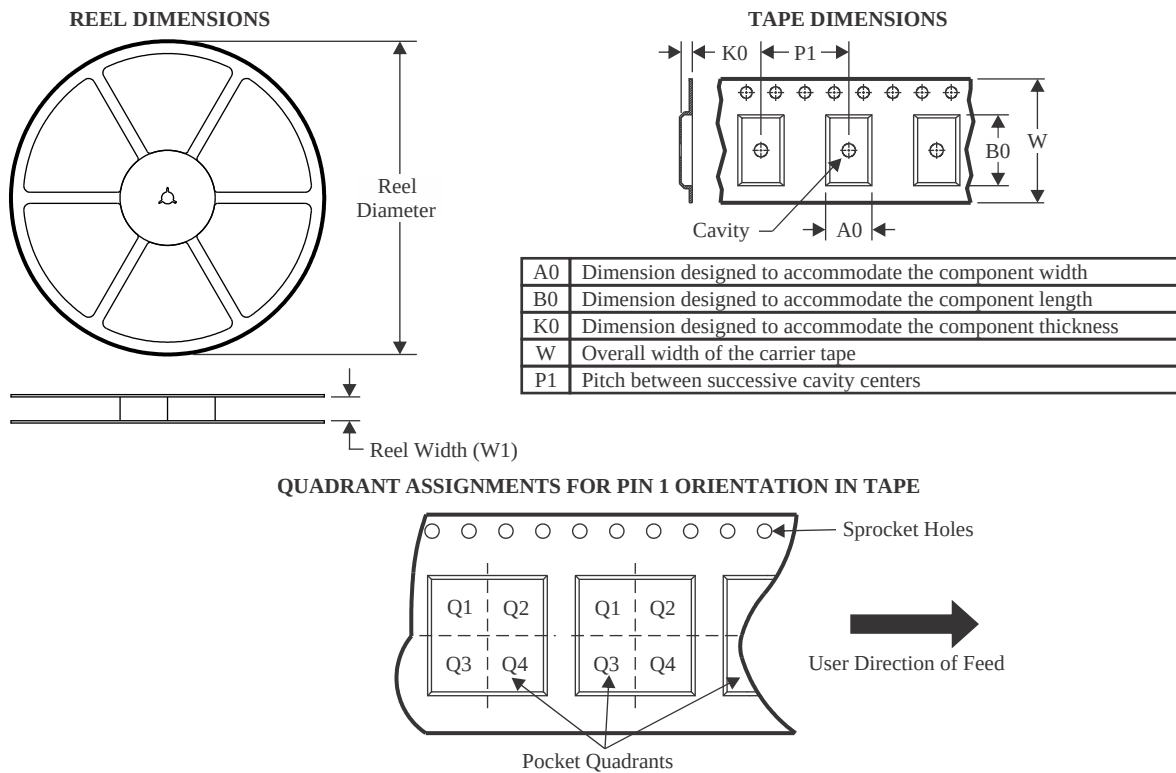
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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

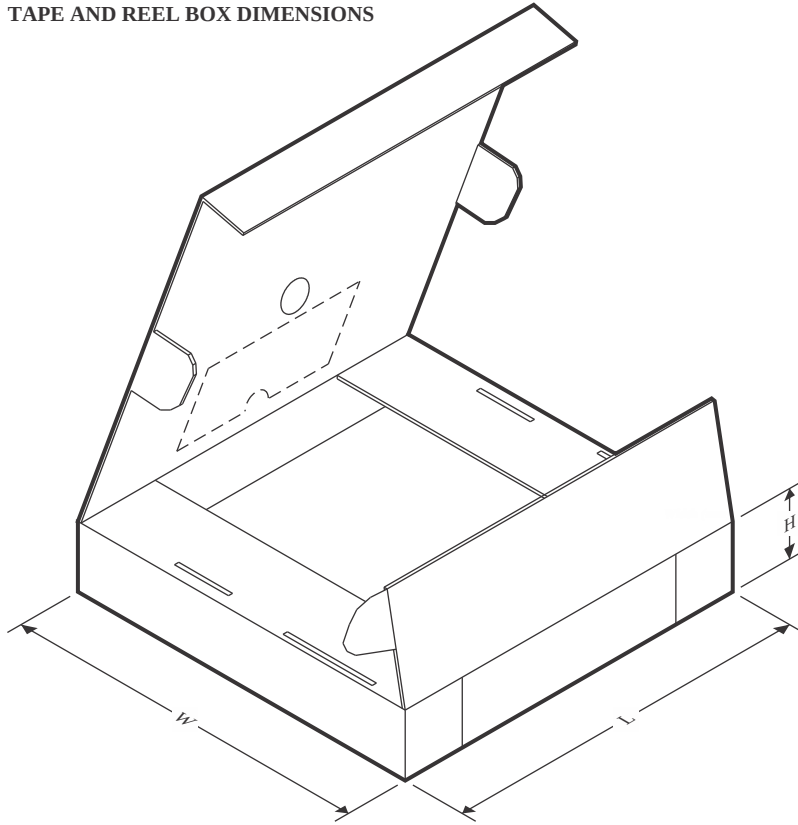
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device     | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ33100PWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |

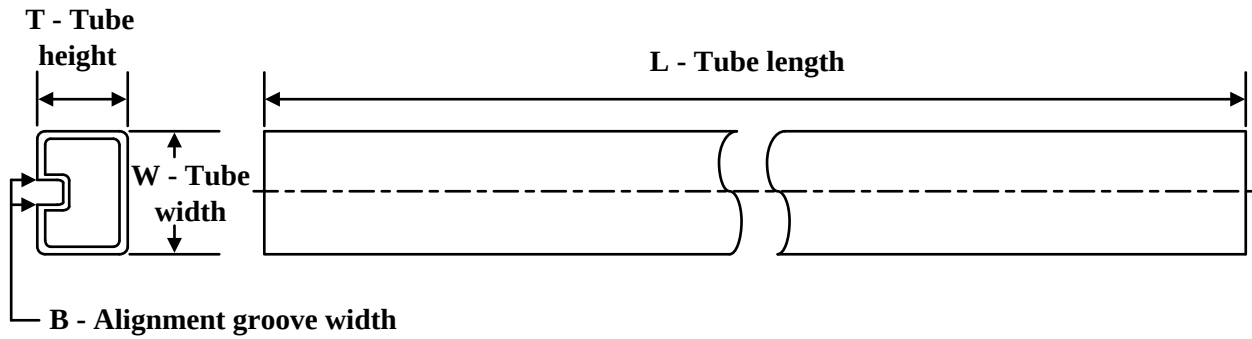
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device     | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ33100PWR | TSSOP        | PW              | 24   | 2000 | 353.0       | 353.0      | 32.0        |

## TUBE



\*All dimensions are nominal

| Device      | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| BQ33100PW   | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| BQ33100PW.A | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |



**TSSOP - 1.2 mm max height**

### SMALL OUTLINE PACKAGE

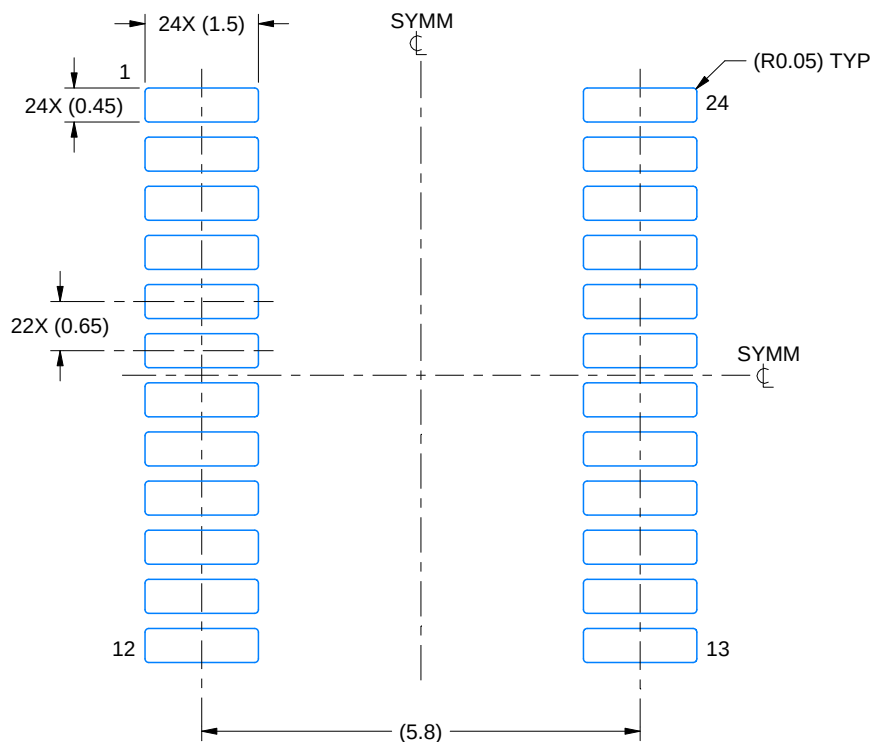


1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or 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.

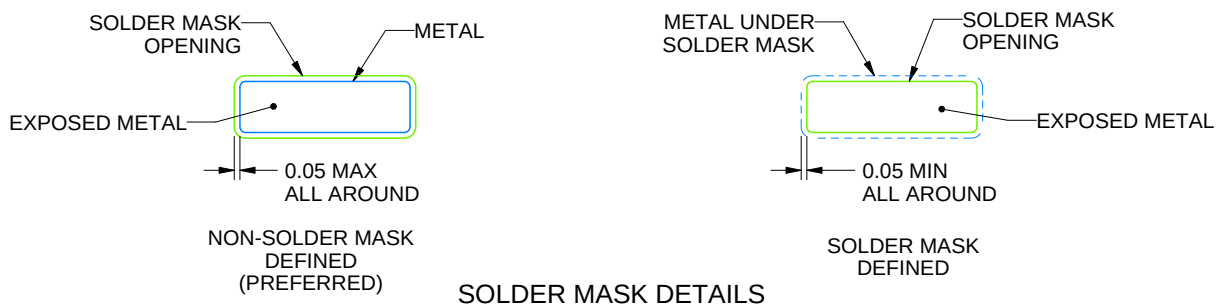
**PW0024A**

**TSSOP - 1.2 mm max height**

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



4220208/A 02/2017

NOTES: (continued)

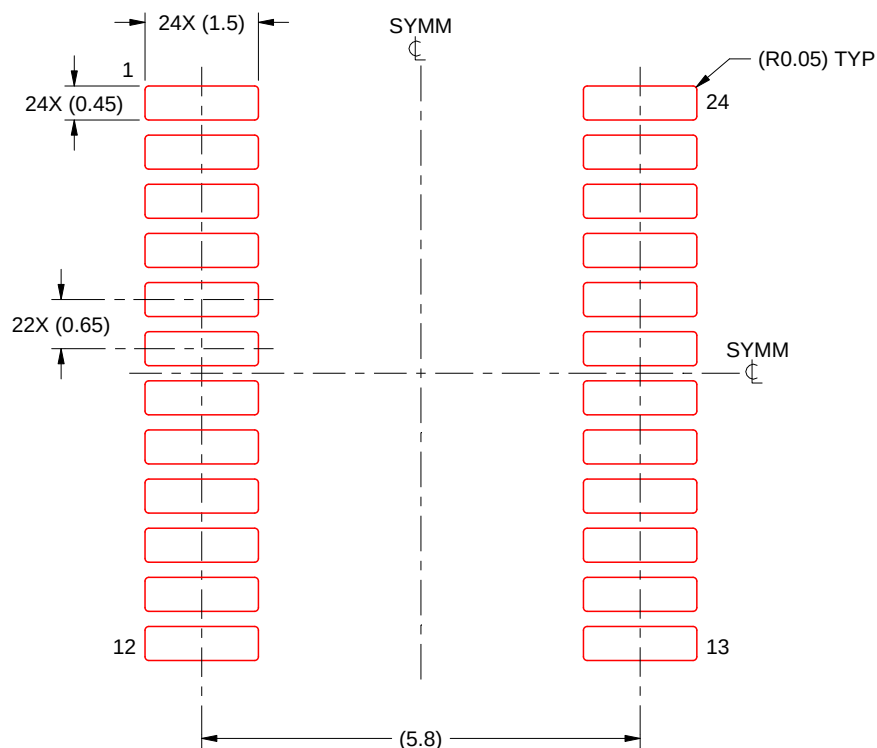
6. Publication IPC-7351 may have alternate designs.  
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

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NOTES: (continued)

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

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