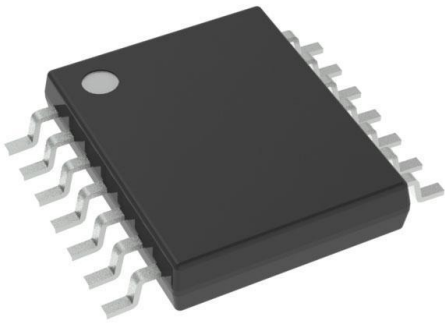


BQ34Z100PWR-G1 Datasheet

www.digi-electronics.com



BQ34Z100PWR-G1

<https://www.DiGi-Electronics.com>

| | |
|------------------------------|---|
| DiGi Electronics Part Number | BQ34Z100PWR-G1-DG |
| Manufacturer | Texas Instruments |
| Manufacturer Product Number | BQ34Z100PWR-G1 |
| Description | IC BATT MON MULTI-CHEM 14TSSOP |
| Detailed Description | Battery Battery Monitor IC Multi-Chemistry 14-TSSOP |



Tel: +00 852-30501935

RFQ Email: Info@DiGi-Electronics.com

DiGi is a global authorized distributor of electronic components.

Purchase and inquiry

Manufacturer Product Number:

BQ34Z100PWR-G1

Series:

Impedance Track™

Function:

Battery Monitor

Number of Cells:

-

Interface:

HDQ, I2C

Mounting Type:

Surface Mount

Supplier Device Package:

14-TSSOP

Manufacturer:

Texas Instruments

Product Status:

Active

Battery Chemistry:

Multi-Chemistry

Fault Protection:

-

Operating Temperature:

-40°C ~ 85°C (TA)

Package / Case:

14-TSSOP (0.173", 4.40mm Width)

Base Product Number:

BQ34Z100

Environmental & Export classification

RoHS Status:

ROHS3 Compliant

REACH Status:

REACH Unaffected

HTSUS:

8542.39.0001

Moisture Sensitivity Level (MSL):

2 (1 Year)

ECCN:

EAR99

BQ34Z100-G1 Wide Range Fuel Gauge with Impedance Track™ Technology

1 Features

- Supports Li-ion, LiFePO₄, PbA, NiMH, and NiCd chemistries
- Capacity estimation using patented Impedance Track™ technology for batteries from 3 V to 65 V
 - Aging compensation
 - Self-discharge compensation
- Supports battery capacities up to 29 Ah with standard configuration options
- Supports charge and discharge currents up to 32 A with standard configuration options
- External NTC thermistor support
- Supports two-wire I²C and HDQ single-wire communication interfaces with host system
- SHA-1/HMAC authentication
- One- or four-LED direct display control
- Five-LED and higher display through port expander
- Reduced power modes (typical battery pack operating range conditions)
 - NORMAL operation: < 145-μA average
 - SLEEP: < 84-μA average
 - FULL SLEEP: < 30-μA average
- Package: 14-pin TSSOP

2 Applications

- [Light electric vehicles](#)
- [Medical instrumentation](#)
- [Mobile radios](#)
- [Power tools](#)
- [Uninterruptible power supplies \(UPS\)](#)

3 Description

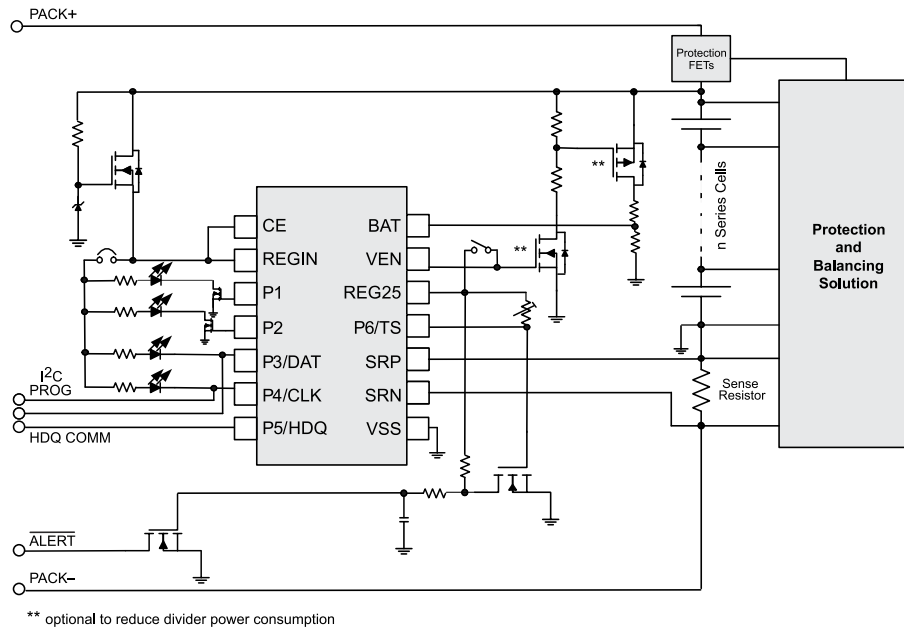
The BQ34Z100-G1 device is an Impedance Track™ fuel gauge for Li-ion, PbA, NiMH, and NiCd batteries, and works independently of battery series-cell configurations. Batteries from 3 V to 65 V can be easily supported through an external voltage translation circuit that is controlled automatically to reduce system power consumption.

The BQ34Z100-G1 device provides several interface options, including an I²C slave, an HDQ slave, one or four direct LEDs, and an $\overline{\text{ALERT}}$ output pin. Additionally, the BQ34Z100-G1 provides support for an external port expander for more than four LEDs.

Device Information

| PART NUMBER (1) | PACKAGE | BODY SIZE (NOM) |
|-----------------|------------|-------------------|
| BQ34Z100-G1 | TSSOP (14) | 5.00 mm × 4.40 mm |

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



Simplified Schematic



BQ34Z100-G1

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4 Revision History

Updated the numbering format for tables, figures, and cross-references throughout the document.

| Changes from Revision C (February 2019) to Revision D (April 2021) | Page |
|--|-------------|
| • Changed Ground System | 54 |
| • Changed Differential Connection Between SRP and SRN Pins with Sense Resistor | 55 |

| Changes from Revision B (July 2016) to Revision C (February 2019) | Page |
|--|-------------|
| • Deleted EV2300 references..... | 42 |

5 Pin Configuration and Functions

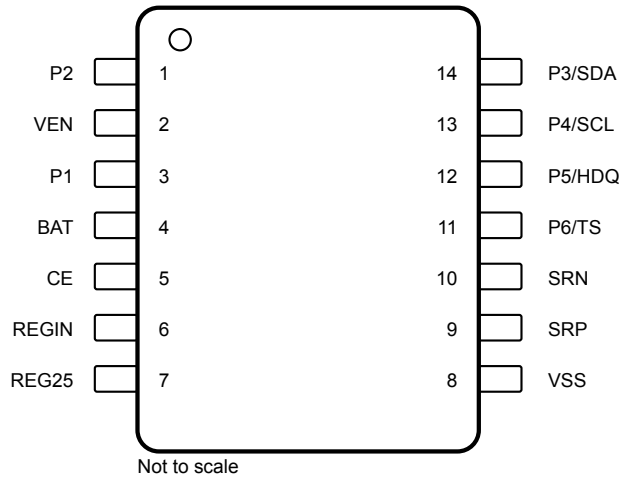


Table 5-1. Pin Functions

| PIN | | I/O | DESCRIPTION |
|--------|--------|-----|--|
| NAME | NUMBER | | |
| P2 | 1 | O | LED 2 or Not Used (connect to Vss) |
| VEN | 2 | O | Active High Voltage Translation Enable. This signal is optionally used to switch the input voltage divider on/off to reduce the power consumption (typ 45 μ A) of the divider network. If not used, then this pin can be left floating or tied to Vss. |
| P1 | 3 | O | LED 1 or Not Used (connect to Vss). This pin is also used to drive an LED for single-LED mode. Use a small signal N-FET (Q1) in series with the LED as shown on Figure 8-4 . |
| BAT | 4 | I | Translated Battery Voltage Input |
| CE | 5 | I | Chip Enable. Internal LDO is disconnected from REGIN when driven low. |
| REGIN | 6 | P | Internal integrated LDO input. Decouple with a 0.1- μ F ceramic capacitor to Vss. |
| REG25 | 7 | P | 2.5-V Output voltage of the internal integrated LDO. Decouple with 1- μ F ceramic capacitor to Vss. |
| VSS | 8 | P | Device ground |
| SRP | 9 | I | Analog input pin connected to the internal coulomb-counter peripheral for integrating a small voltage between SRP and SRN where SRP is nearest the BAT– connection. |
| SRN | 10 | I | Analog input pin connected to the internal coulomb-counter peripheral for integrating a small voltage between SRP and SRN where SRN is nearest the PACK– connection. |
| P6/TS | 11 | I | Pack thermistor voltage sense (use 103AT-type thermistor) |
| P5/HDQ | 12 | I/O | Open drain HDQ Serial communication line (slave). If not used, then this pin can be left floating or tied to Vss. |
| P4/SCL | 13 | I | Slave I ² C serial communication clock input. Use with a 10-K Ω pull-up resistor (typical). This pin is also used for LED 4 in the four-LED mode. If not used, then this pin can be left floating or tied to Vss. |
| P3/SDA | 14 | I/O | Open drain slave I ² C serial communication data line. Use with a 10-k Ω pull-up resistor (typical). This pin is also used for LED 3 in the four-LED mode. If not used, then this pin can be left floating or tied to Vss. |

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6 Specifications**6.1 Absolute Maximum Ratings**Over operating free-air temperature range (unless otherwise noted)⁽¹⁾

| | | MIN | MAX | UNIT |
|--------------------|--|------|-----------------------|------|
| V _{REGIN} | Regulator Input Range | -0.3 | 5.5 | V |
| V _{CC} | Supply Voltage Range | -0.3 | 2.75 | V |
| V _{IOD} | Open-drain I/O pins (SDA, SCL, HDQ, VEN) | -0.3 | 5.5 | V |
| V _{BAT} | Bat Input pin | -0.3 | 5.5 | V |
| V _I | Input Voltage range to all other pins (P1, P2, SRP, SRN) | -0.3 | V _{CC} + 0.3 | V |
| ESD | Human-body model (HBM), BAT pin | | 1.5 | kV |
| | Human-body model (HBM), all other pins | | 2 | kV |
| T _A | Operating free-air temperature range | -40 | 85 | °C |
| T _F | Functional temperature range | -40 | 100 | °C |
| T _{STG} | Storage temperature range | -65 | 150 | °C |
| | Lead temperature (soldering, 10 s) | -40 | 100 | °C |

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

| | | VALUE | UNIT |
|--------------------|-------------------------|--|-------|
| V _(ESD) | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | ±2000 |
| | | Charged device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±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.

6.3 Recommended Operating ConditionsT_A = -40°C to 85°C; Typical Values at T_A = 25°C C_{LDO25} = 1.0 µF, and V_{REGIN} = 3.6 V (unless otherwise noted)

| | | | MIN | NOM | MAX | UNIT |
|---------------------|---|---|-----------------------|-----|-----|------|
| V _{REGIN} | Supply Voltage | No operating restrictions | 2.7 | | 4.5 | V |
| | | No FLASH writes | 2.45 | | 2.7 | V |
| C _{REGIN} | External input capacitor for internal LDO between REGIN and VSS | Nominal capacitor values specified. Recommend a 10% ceramic X5R type capacitor located close to the device. | | 0.1 | | µF |
| C _{LDO25} | External output capacitor for internal LDO between VCC and VSS | | 0.47 | 1 | | µF |
| I _{CC} | NORMAL operating-mode current | Gas Gauge in NORMAL mode, I _{LOAD} > Sleep Current | | 145 | | µA |
| I _{SLP} | SLEEP operating-mode current | Gas Gauge in SLEEP mode, I _{LOAD} < Sleep Current | | 84 | | µA |
| I _{SLP+} | FULLSLEEP operating-mode current | Gas Gauge in FULL SLEEP mode, I _{LOAD} < Sleep Current | | 30 | | µA |
| V _{OL} | Output voltage, low (SCL, SDA, HDQ, VEN) | I _{OL} = 3 mA | | | 0.4 | V |
| V _{OH(PP)} | Output voltage, high | I _{OH} = -1 mA | V _{CC} - 0.5 | | | V |
| V _{OH(OD)} | Output voltage, high (SDA, SCL, HDQ, VEN) | External pull-up resistor connected to V _{CC} | V _{CC} - 0.5 | | | V |
| V _{IL} | Input voltage, low | | -0.3 | | 0.6 | V |

$T_A = -40^\circ\text{C}$ to 85°C ; Typical Values at $T_A = 25^\circ\text{C}$ $C_{LDO25} = 1.0\ \mu\text{F}$, and $V_{\text{REGIN}} = 3.6\ \text{V}$ (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT | |
|---------------------|-------------------------------------|-------------|-----|-----|-------|---------------|
| $V_{\text{IH(OD)}}$ | Input voltage, high (SDA, SCL, HDQ) | 1.2 | | | 6 | V |
| V_{A1} | Input voltage range (TS) | VSS – 0.05 | | | 1 | V |
| V_{A2} | Input voltage range (BAT) | VSS – 0.125 | | | 5 | V |
| V_{A3} | Input voltage range (SRP, SRN) | VSS – 0.125 | | | 0.125 | V |
| I_{LKG} | Input leakage current (I/O pins) | | | | 0.3 | μA |
| t_{PUCD} | Power-up communication delay | | | | 250 | ms |

6.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | BQ34Z100-G1 | | | UNIT |
|-------------------------------|--|-------------|--|--|---------------------------|
| | | TSSOP (PW) | | | |
| | | 14 PINS | | | |
| $R_{\theta\text{JA, High K}}$ | Junction-to-ambient thermal resistance | 103.8 | | | $^\circ\text{C}/\text{W}$ |
| $R_{\theta\text{JC(top)}}$ | Junction-to-case(top) thermal resistance | 31.9 | | | |
| $R_{\theta\text{JB}}$ | Junction-to-board thermal resistance | 46.6 | | | |
| Ψ_{JT} | Junction-to-top characterization parameter | 2.0 | | | |
| Ψ_{JB} | Junction-to-board characterization parameter | 45.9 | | | |
| $R_{\theta\text{JC(bottom)}}$ | Junction-to-case(bottom) thermal resistance | N/A | | | |

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

6.5 Electrical Characteristics: Power-On Reset

$T_A = -40^\circ\text{C}$ to 85°C ; Typical Values at $T_A = 25^\circ\text{C}$ and $V_{\text{REGIN}} = 3.6\ \text{V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|------------------|---|------|------|------|------|
| $V_{\text{IT+}}$ | Positive-going battery voltage input at REG25 | 2.05 | 2.20 | 2.31 | V |
| V_{HYS} | Power-on reset hysteresis | 45 | 115 | 185 | mV |

6.6 Electrical Characteristics: LDO Regulator

$T_A = 25^\circ\text{C}$, $C_{\text{LDO25}} = 1.0\ \mu\text{F}$, $V_{\text{REGIN}} = 3.6\ \text{V}$ (unless otherwise noted)⁽¹⁾

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT | | |
|--------------------------|-----------------------------|---|---|-----|------|-----|----|
| V_{REG25} | Regulator output voltage | $2.7\ \text{V} \leq V_{\text{REGIN}} \leq 4.5\ \text{V}$, $I_{\text{OUT}} \leq 16\ \text{mA}$ | $T_A = -40^\circ\text{C}$ to 85°C | 2.3 | 2.5 | 2.7 | V |
| | | $2.45\ \text{V} \leq V_{\text{REGIN}} < 2.7\ \text{V}$ (low battery), $I_{\text{OUT}} \leq 3\ \text{mA}$ | $T_A = -40^\circ\text{C}$ to 85°C | 2.3 | | | |
| $I_{\text{SHORT}}^{(2)}$ | Short Circuit Current Limit | $V_{\text{REG25}} = 0\ \text{V}$ | $T_A = -40^\circ\text{C}$ to 85°C | | | 250 | mA |

(1) LDO output current, I_{OUT} , is the sum of internal and external load currents.

(2) Specified by design. Not production tested.

6.7 Electrical Characteristics: Internal Temperature Sensor Characteristics

$T_A = -40^\circ\text{C}$ to 85°C , $2.4\ \text{V} < \text{REG25} < 2.6\ \text{V}$; Typical Values at $T_A = 25^\circ\text{C}$ and $\text{REG25} = 2.5\ \text{V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------|---------------------------------|-----|-----|-----|----------------------------|
| G_{TEMP} | Temperature sensor voltage gain | | -2 | | $\text{mV}/^\circ\text{C}$ |

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6.8 Electrical Characteristics: Low-Frequency Oscillator $T_A = -40^\circ\text{C}$ to 85°C , $2.4\text{ V} < \text{REG25} < 2.6\text{ V}$; Typical Values at $T_A = 25^\circ\text{C}$ and $\text{REG25} = 2.5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------|------------------------------------|---|--------|-------|---------------|
| $f_{(\text{LOSC})}$ | Operating frequency | | 32.768 | | kHz |
| $f_{(\text{LEIO})}$ | Frequency error ^{(1) (2)} | $T_A = 0^\circ\text{C}$ to 60°C | -1.5% | 0.25% | 1.5% |
| | | $T_A = -20^\circ\text{C}$ to 70°C | -2.5% | 0.25% | 2.5% |
| | | $T_A = -40^\circ\text{C}$ to 85°C | -4% | 0.25% | 4% |
| $t_{(\text{LSXO})}$ | Start-up time ⁽³⁾ | | 500 | | μs |

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

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

(3) The startup time is defined as the time it takes for the oscillator output frequency to be $\pm 3\%$.**6.9 Electrical Characteristics: High-Frequency Oscillator** $T_A = -40^\circ\text{C}$ to 85°C , $2.4\text{ V} < \text{REG25} < 2.6\text{ V}$; Typical Values at $T_A = 25^\circ\text{C}$ and $\text{REG25} = 2.5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------|------------------------------------|---|-------|-------|------|
| $f_{(\text{OSC})}$ | Operating frequency | | 8.389 | | MHz |
| $f_{(\text{EIO})}$ | Frequency error ^{(1) (2)} | $T_A = 0^\circ\text{C}$ to 60°C | -2% | 0.38% | 2% |
| | | $T_A = -20^\circ\text{C}$ to 70°C | -3% | 0.38% | 3% |
| | | $T_A = -40^\circ\text{C}$ to 85°C | -4.5% | 0.38% | 4.5% |
| $t_{(\text{SXO})}$ | Start-up time ⁽²⁾ | | 2.5 | 5 | ms |

(1) The frequency error is measured from 2.097 MHz.

(2) The startup time is defined as the time it takes for the oscillator output frequency to be $\pm 3\%$.**6.10 Electrical Characteristics: Integrating ADC (Coulomb Counter) Characteristics** $T_A = -40^\circ\text{C}$ to 85°C , $2.4\text{ V} < \text{REG25} < 2.6\text{ V}$; Typical Values at $T_A = 25^\circ\text{C}$ and $\text{REG25} = 2.5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------------|--|---|---------------|---------------|--------------------|
| $V_{(\text{SR})}$ | Input voltage range, $V_{(\text{SRN})}$ and $V_{(\text{SRP})}$ | $V_{(\text{SR})} = V_{(\text{SRN})} - V_{(\text{SRP})}$ | -0.125 | 0.125 | V |
| $t_{\text{SR_CONV}}$ | Conversion time | Single conversion | 1 | | s |
| | Resolution | | 14 | 15 | bits |
| $V_{\text{OS}(\text{SR})}$ | Input offset | | 10 | | μV |
| I_{NL} | Integral nonlinearity error | | $\pm 0.007\%$ | $\pm 0.034\%$ | FSR ⁽²⁾ |
| $Z_{\text{IN}(\text{SR})}$ | Effective input resistance ⁽¹⁾ | | 2.5 | | M Ω |
| $I_{\text{kg}(\text{SR})}$ | Input leakage current ⁽¹⁾ | | | 0.3 | μA |

(1) Specified by design. Not tested in production.

(2) Full-scale reference

6.11 Electrical Characteristics: ADC (Temperature and Cell Measurement) Characteristics $T_A = -40^\circ\text{C}$ to 85°C , $2.4\text{ V} < \text{REG25} < 2.6\text{ V}$; Typical Values at $T_A = 25^\circ\text{C}$ and $\text{REG25} = 2.5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------------|---|--|-----|-----|------------|
| $V_{\text{IN}(\text{ADC})}$ | Input voltage range | 0.05 | | 1 | V |
| $t_{\text{ADC_CONV}}$ | Conversion time | | | 125 | ms |
| | Resolution | 14 | | 15 | bits |
| $V_{\text{OS}(\text{ADC})}$ | Input offset | | 1 | | mV |
| $Z_{\text{ADC}1}$ | Effective input resistance (TS) ⁽¹⁾ | 8 | | | M Ω |
| $Z_{\text{ADC}2}$ | Effective input resistance (BAT) ⁽¹⁾ | BQ34Z100-G1 not measuring cell voltage | 8 | | M Ω |
| | | BQ34Z100-G1 measuring cell voltage | | 100 | K Ω |

$T_A = -40^\circ\text{C}$ to 85°C , $2.4\text{ V} < \text{REG25} < 2.6\text{ V}$; Typical Values at $T_A = 25^\circ\text{C}$ and $\text{REG25} = 2.5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------|--------------------------------------|-----|-----|-----|---------------|
| $I_{\text{kg(ADC)}}$ | Input leakage current ⁽¹⁾ | | | 0.3 | μA |

(1) Specified by design. Not tested in production.

6.12 Electrical Characteristics: Data Flash Memory Characteristics

 $T_A = -40^\circ\text{C}$ to 85°C , $2.4\text{ V} < \text{REG25} < 2.6\text{ V}$; Typical Values at $T_A = 25^\circ\text{C}$ and $\text{REG25} = 2.5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------|---|--------|-----|-----|--------|
| t_{DR} | Data retention ⁽¹⁾ | 10 | | | Years |
| | Flash-programming write cycles ⁽¹⁾ | 20,000 | | | Cycles |
| t_{WORDPROG} | Word programming time ⁽¹⁾ | | | 2 | ms |
| I_{CCPROG} | Flash-write supply current ⁽¹⁾ | | 5 | 10 | mA |

(1) Specified by design. Not tested in production.

6.13 Timing Requirements: HDQ Communication

 $T_A = -40^\circ\text{C}$ to 85°C , $2.45\text{ V} < V_{\text{REGIN}} = V_{\text{BAT}} < 5.5\text{ V}$; typical values at $T_A = 25^\circ\text{C}$ and $V_{\text{REGIN}} = V_{\text{BAT}} = 3.6\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | NOM | MAX | UNIT |
|---------------------|---|-----|-----|-----|---------------|
| $t_{\text{(CYCH)}}$ | Cycle time, host to BQ34Z100-G1 | 190 | | | μs |
| $t_{\text{(CYCD)}}$ | Cycle time, BQ34Z100-G1 to host | 190 | 205 | 250 | μs |
| $t_{\text{(HW1)}}$ | Host sends 1 to BQ34Z100-G1 | 0.5 | | 50 | μs |
| $t_{\text{(DW1)}}$ | BQ34Z100-G1 sends 1 to host | 32 | | 50 | μs |
| $t_{\text{(HW0)}}$ | Host sends 0 to BQ34Z100-G1 | 86 | | 145 | μs |
| $t_{\text{(DW0)}}$ | BQ34Z100-G1 sends 0 to host | 80 | | 145 | μs |
| $t_{\text{(RSPS)}}$ | Response time, BQ34Z100-G1 to host | 190 | | 950 | μs |
| $t_{\text{(B)}}$ | Break time | 190 | | | μs |
| $t_{\text{(BR)}}$ | Break recovery time | 40 | | | μs |
| $t_{\text{(RISE)}}$ | HDQ line rising time to logic 1 (1.2 V) | | | 950 | ns |
| $t_{\text{(RST)}}$ | HDQ Reset | 1.8 | | 2.2 | s |

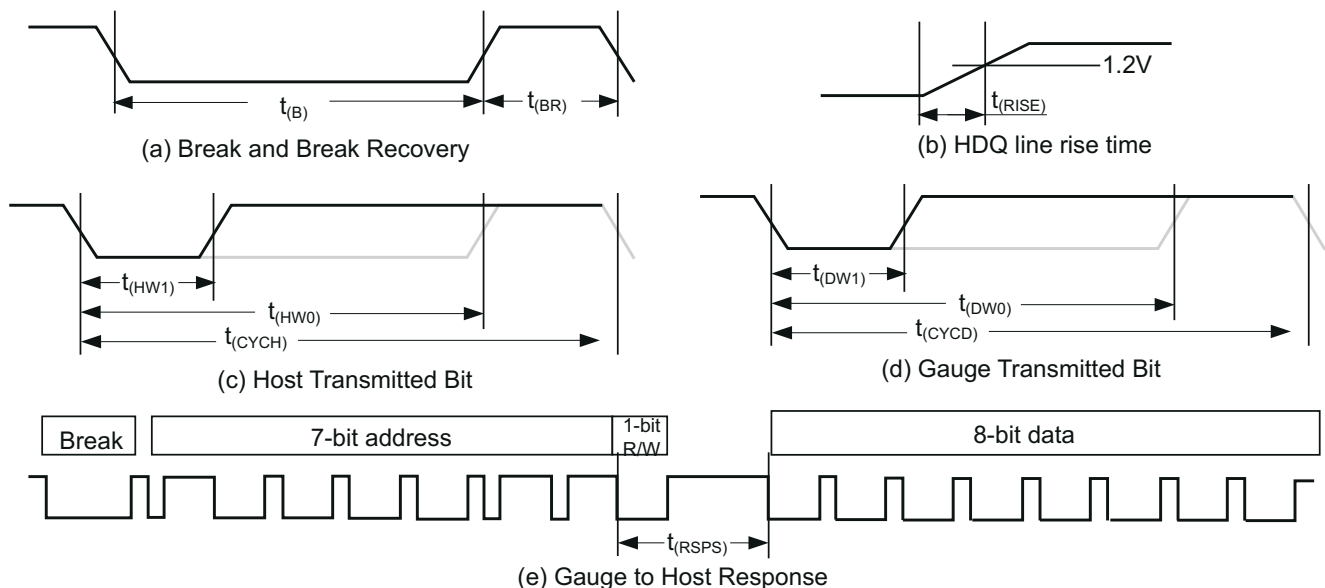


Figure 6-1. Timing Diagrams

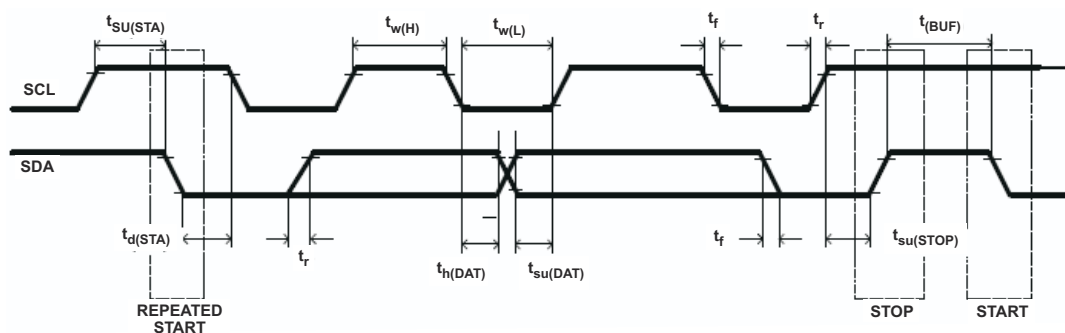
BQ34Z100-G1

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6.14 Timing Requirements: I²C-Compatible Interface

$T_A = -40^\circ\text{C}$ to 85°C , $2.45\text{ V} < V_{\text{REGIN}} = V_{\text{BAT}} < 5.5\text{ V}$; typical values at $T_A = 25^\circ\text{C}$ and $V_{\text{REGIN}} = V_{\text{BAT}} = 3.6\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | NOM | MAX | UNIT |
|-----------------------|--------------------------------------|-----------------|-----|-----|-----|---------------|
| t_r | SCL/SDA rise time | | | | 300 | ns |
| t_f | SCL/SDA fall time | | | | 300 | ns |
| $t_{w(H)}$ | SCL pulse width (high) | | 600 | | | ns |
| $t_{w(L)}$ | SCL pulse width (low) | | 1.3 | | | μs |
| $t_{\text{su(STA)}}$ | Setup for repeated start | | 600 | | | ns |
| $t_{\text{d(STA)}}$ | Start to first falling edge of SCL | | 600 | | | ns |
| $t_{\text{su(DAT)}}$ | Data setup time | | 100 | | | ns |
| $t_{\text{h(DAT)}}$ | Data hold time | | 0 | | | ns |
| $t_{\text{su(STOP)}}$ | Setup time for stop | | 600 | | | ns |
| t_{BUF} | Bus free time between stop and start | | 66 | | | μs |
| f_{SCL} | Clock frequency | | | | 400 | kHz |

**Figure 6-2. I²C-Compatible Interface Timing Diagrams**

6.15 Typical Characteristics

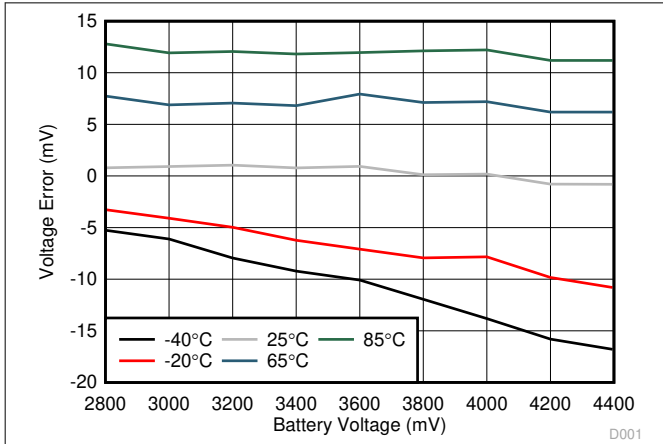


Figure 6-3. $V_{(Err)}$ Across V_{IN} (0 mA)

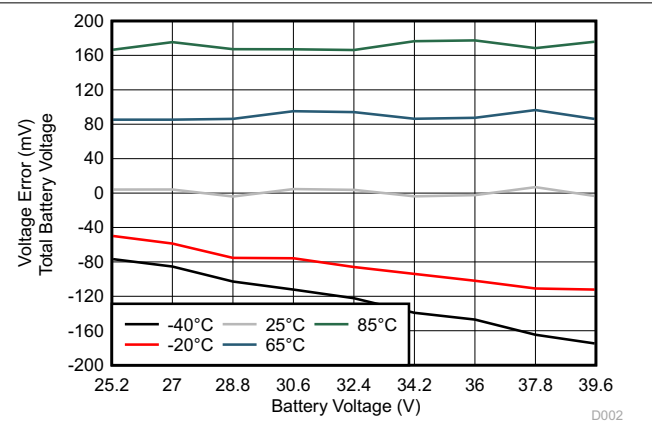


Figure 6-4. $V_{(Err)}$ Across V_{IN} (0 mA) 9 s

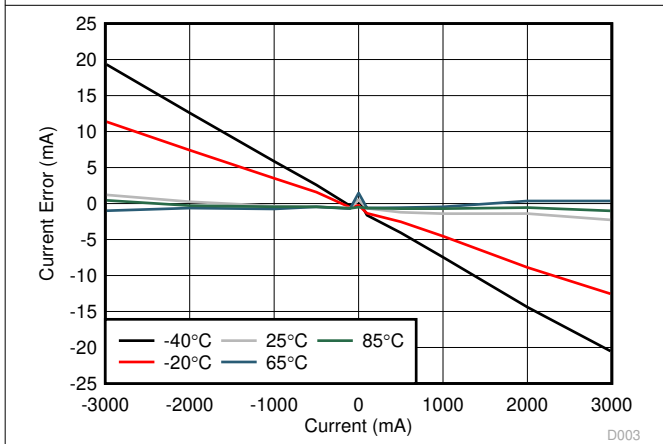


Figure 6-5. $I_{(Err)}$

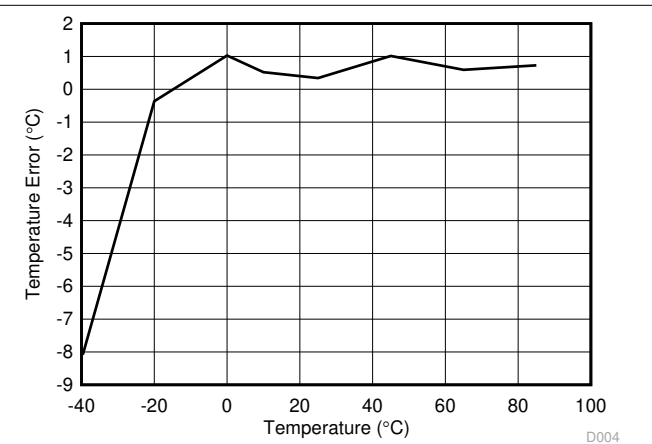


Figure 6-6. $T_{(Err)}$

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7 Detailed Description

7.1 Overview

The BQ34Z100-G1 device accurately predicts the battery capacity and other operational characteristics of a single cell or multiple rechargeable cell blocks, which are voltage balanced when resting. The device supports various Li-ion, Lead Acid (PbA), Nickel Metal Hydride (NiMH), and Nickel Cadmium (NiCd) chemistries, and can be interrogated by a host processor to provide cell information, such as remaining capacity, full charge capacity, and average current.

Information is accessed through a series of commands called Standard Data Commands (see [Section 7.3.1.1](#)). Further capabilities are provided by the additional Extended Data Commands set (see [Section 7.3.2](#)). Both sets of commands, indicated by the general format *Command()*, are used to read and write information contained within the BQ34Z100-G1 device's control and status registers, as well as its data flash locations. Commands are sent from host to gauge using the BQ34Z100-G1 serial communications engines, HDQ and I²C, and can be executed during application development, pack manufacture, or end-equipment operation.

Cell information is stored in the BQ34Z100-G1 in non-volatile flash memory. Many of these data flash locations are accessible during application development and pack manufacture. They cannot, generally, be accessed directly during end-equipment operation. Access to these locations is achieved by using the BQ34Z100-G1 device's companion evaluation software, through individual commands, or through a sequence of data-flash-access commands. To access a desired data flash location, the correct data flash subclass and offset must be known.

The BQ34Z100-G1 provides 32 bytes of user-programmable data flash memory. This data space is accessed through a data flash interface. For specifics on accessing the data flash, refer to [Section 7.3.3](#).

The key to the BQ34Z100-G1 device's high-accuracy gas gauging prediction is Texas Instrument's proprietary Impedance Track algorithm. This algorithm uses voltage measurements, characteristics, and properties to create state-of-charge predictions that can achieve accuracy with as little as 1% error across a wide variety of operating conditions.

The BQ34Z100-G1 measures charge/discharge activity by monitoring the voltage across a small-value series sense resistor connected in the low side of the battery circuit. When an application's load is applied, cell impedance is measured by comparing its Open Circuit Voltage (OCV) with its measured voltage under loading conditions.

The BQ34Z100-G1 can use an NTC thermistor (default is Semitec 103AT or Mitsubishi BN35-3H103FB-50) for temperature measurement, or can also be configured to use its internal temperature sensor. The BQ34Z100-G1 uses temperature to monitor the battery-pack environment, which is used for fuel gauging and cell protection functionality.

To minimize power consumption, the BQ34Z100-G1 has three power modes: NORMAL, SLEEP, and FULL SLEEP. The BQ34Z100-G1 passes automatically between these modes, depending upon the occurrence of specific events.

Multiple modes are available for configuring from one to 16 LEDs as an indicator of remaining state of charge. More than four LEDs require the use of one or two inexpensive SN74HC164 shift register expanders.

A SHA-1/HMAC-based battery pack authentication feature is also implemented on the BQ34Z100-G1. When the IC is in UNSEALED mode, authentication keys can be (re)assigned. A scratch pad area is used to receive challenge information from a host and to export SHA-1/HMAC encrypted responses. See [Section 7.3.15.1](#) for further details.

Note

Formatting conventions in this document:

Commands: *italics* with parentheses and no breaking spaces; for example, *RemainingCapacity()*.

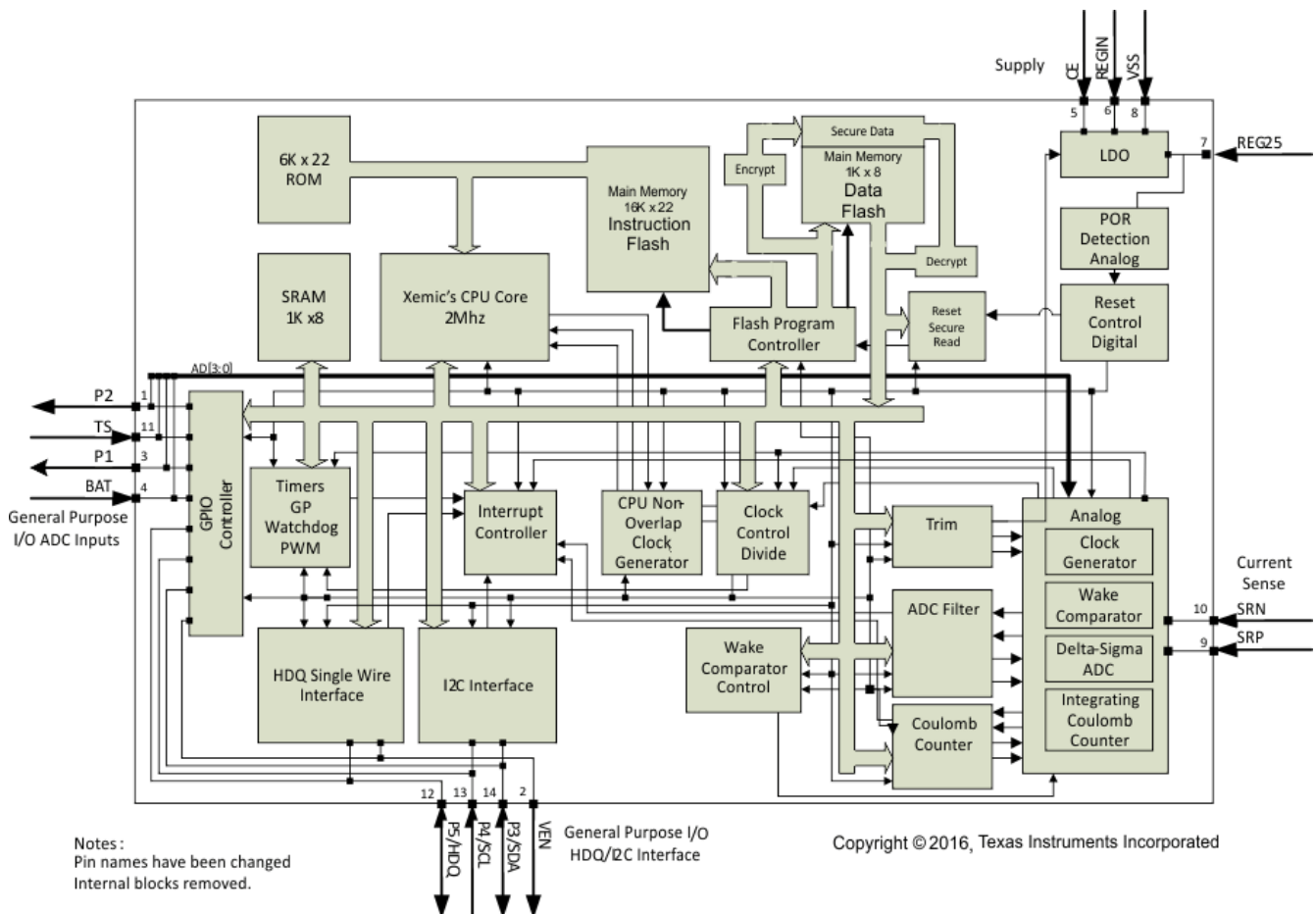
Data Flash: *italics*, **bold**, and breaking spaces; for example, ***Design Capacity***.

Register Bits and Flags: brackets only; for example, [TDA] Data

Flash Bits: *italic* and **bold**; for example, ***[LED1]***

Modes and states: ALL CAPITALS; for example, UNSEALED mode.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Data Commands

7.3.1.1 Standard Data Commands

The BQ34Z100-G1 uses a series of 2-byte standard commands to enable host reading and writing of battery information. Each standard command has an associated command-code pair, as indicated in [Table 7-1](#). Because each command consists of two bytes of data, two consecutive HDQ/I²C transmissions must be executed to initiate the command function and to read or write the corresponding two bytes of data. Standard commands are accessible in NORMAL operation. Also, two block commands are available to read Manufacturer Name and Device Chemistry. Read/Write permissions depend on the active access mode.

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Table 7-1. Commands

| NAME | | COMMAND CODE | UNIT | SEALED ACCESS | UNSEALED ACCESS |
|-----------------------------|--------|--------------|-------|---------------|-----------------|
| <i>Control()</i> | CNTL | 0x00/0x01 | N/A | R/W | R/W |
| <i>StateOfCharge()</i> | SOC | 0x02 | % | R | R |
| <i>MaxError()</i> | ME | 0x03 | % | R | R |
| <i>RemainingCapacity()</i> | RM | 0x04/0x05 | mAh | R | R |
| <i>FullChargeCapacity()</i> | FCC | 0x06/0x07 | mAh | R | R |
| <i>Voltage()</i> | VOLT | 0x08/0x09 | mV | R | R |
| <i>AverageCurrent()</i> | AI | 0x0A/0x0B | mA | R | R |
| <i>Temperature()</i> | TEMP | 0x0C/0x0D | 0.1 K | R | R |
| <i>Flags()</i> | FLAGS | 0x0E/0x0F | N/A | R | R |
| <i>Current()</i> | I | 0x10/0x11 | mA | R | R |
| <i>FlagsB()</i> | FLAGSB | 0x12/0x13 | N/A | R | R |

7.3.1.2 Control(): 0x00/0x01

Issuing a *Control()* command requires a subsequent two-byte subcommand. These additional bytes specify the particular control function desired. The *Control()* command allows the host to control specific features of the BQ34Z100-G1 during normal operation, and additional features when the BQ34Z100-G1 is in different access modes, as described in [Table 7-2](#).

Table 7-2. Control() Subcommands

| CNTL FUNCTION | CNTL DATA | SEALED ACCESS | DESCRIPTION |
|--------------------|-----------|---------------|--|
| CONTROL_STATUS | 0x0000 | Yes | Reports the status of key features. |
| DEVICE_TYPE | 0x0001 | Yes | Reports the device type of 0x100 (indicating BQ34Z100-G1) |
| FW_VERSION | 0x0002 | Yes | Reports the firmware version on the device type |
| HW_VERSION | 0x0003 | Yes | Reports the hardware version of the device type |
| RESET_DATA | 0x0005 | Yes | Returns reset data |
| PREV_MACWRITE | 0x0007 | Yes | Returns previous <i>Control()</i> command code |
| CHEM_ID | 0x0008 | Yes | Reports the chemical identifier of the Impedance Track configuration |
| BOARD_OFFSET | 0x0009 | Yes | Forces the device to measure and store the board offset |
| CC_OFFSET | 0x000A | Yes | Forces the device to measure the internal CC offset |
| CC_OFFSET_SAVE | 0x000B | Yes | Forces the device to store the internal CC offset |
| DF_VERSION | 0x000C | Yes | Reports the data flash version on the device |
| SET_FULLSLEEP | 0x0010 | Yes | Set the [FULLSLEEP] bit in the control register to 1 |
| STATIC_CHEM_CHKSUM | 0x0017 | Yes | Calculates chemistry checksum |
| SEALED | 0x0020 | No | Places the device in SEALED access mode |
| IT_ENABLE | 0x0021 | No | Enables the Impedance Track algorithm |
| CAL_ENABLE | 0x002D | No | Toggle CALIBRATION mode enable |
| RESET | 0x0041 | No | Forces a full reset of the BQ34Z100-G1 |
| EXIT_CAL | 0x0080 | No | Exit CALIBRATION mode |
| ENTER_CAL | 0x0081 | No | Enter CALIBRATION mode |
| OFFSET_CAL | 0x0082 | No | Reports internal CC offset in CALIBRATION mode |

7.3.1.2.1 CONTROL_STATUS: 0x0000

Instructs the fuel gauge to return status information to Control addresses 0x00/0x01. The status word includes the following information.

Table 7-3. CONTROL_STATUS Flags

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-----------|-------|-------|-----------|-------|-------|---------|-------|-------|
| High Byte | RSVD | FAS | SS | CALEN | CCA | BCA | CSV | RSVD |
| Low Byte | RSVD | RSVD | FULLSLEEP | SLEEP | LDMD | RUP_DIS | VOK | QEN |

Legend: **RSVD** = Reserved

FAS: Status bit that indicates the BQ34Z100-G1 is in FULL ACCESS SEALED state. Active when set.

SS: Status bit that indicates the BQ34Z100-G1 is in the SEALED state. Active when set.

CALEN: Status bit that indicates the BQ34Z100-G1 calibration function is active. True when set. Default is 0.

CCA: Status bit that indicates the BQ34Z100-G1 Coulomb Counter Calibration routine is active. Active when set.

BCA: Status bit that indicates the BQ34Z100-G1 Board Calibration routine is active. Active when set.

CSV: Status bit that indicates a valid data flash checksum has been generated. Active when set.

FULLSLEEP: Status bit that indicates the BQ34Z100-G1 is in FULL SLEEP mode. True when set. The state can only be detected by monitoring the power used by the BQ34Z100-G1 because any communication will automatically clear it.

SLEEP: Status bit that indicates the BQ34Z100-G1 is in SLEEP mode. True when set.

LDMD: Status bit that indicates the BQ34Z100-G1 Impedance Track algorithm using constant-power mode. True when set. Default is 0 (CONSTANT CURRENT mode).

RUP_DIS: Status bit that indicates the BQ34Z100-G1 Ra table updates are disabled. True when set.

VOK: Status bit that indicates cell voltages are OK for Qmax updates. True when set.

QEN: Status bit that indicates the BQ34Z100-G1 Qmax updates are enabled. True when set.

7.3.1.2.2 DEVICE TYPE: 0x0001

Instructs the fuel gauge to return the device type to addresses 0x00/0x01.

7.3.1.2.3 FW_VERSION: 0x0002

Instructs the fuel gauge to return the firmware version to addresses 0x00/0x01.

7.3.1.2.4 HW_VERSION: 0x0003

Instructs the fuel gauge to return the hardware version to addresses 0x00/0x01.

7.3.1.2.5 RESET_DATA: 0x0005

Instructs the fuel gauge to return the number of resets performed to addresses 0x00/0x01.

7.3.1.2.6 PREV_MACWRITE: 0x0007

Instructs the fuel gauge to return the previous command written to addresses 0x00/0x01. The value returned is limited to less than 0x0020.

7.3.1.2.7 CHEM ID: 0x0008

Instructs the fuel gauge to return the chemical identifier for the Impedance Track configuration to addresses 0x00/0x01.

7.3.1.2.8 BOARD_OFFSET: 0x0009

Instructs the fuel gauge to calibrate board offset. During board offset calibration the [BCA] bit is set.

7.3.1.2.9 CC_OFFSET: 0x000A

Instructs the fuel gauge to calibrate the coulomb counter offset. During calibration the [CCA] bit is set.

7.3.1.2.10 CC_OFFSET_SAVE: 0x000B

Instructs the fuel gauge to save the coulomb counter offset after calibration.

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7.3.1.2.11 DF_VERSION: 0x000C

Instructs the fuel gauge to return the data flash version to addresses 0x00/0x01.

7.3.1.2.12 SET_FULLSLEEP: 0x0010

Instructs the fuel gauge to set the FULLSLEEP bit in the Control Status register to 1. This allows the gauge to enter the FULL SLEEP power mode after the transition to SLEEP power state is detected. In FULL SLEEP mode, less power is consumed by disabling an oscillator circuit used by the communication engines. For HDQ communication, one host message will be dropped. For I²C communications, the first I²C message will incur a 6-ms–8-ms clock stretch while the oscillator is started and stabilized. A communication to the device in FULL SLEEP will force the part back to the SLEEP mode.

7.3.1.2.13 STATIC_CHEM_DF_CHKSUM: 0x0017

Instructs the fuel gauge to calculate chemistry checksum as a 16-bit unsigned integer sum of all static chemistry data. The most significant bit (MSB) of the checksum is masked yielding a 15-bit checksum. This checksum is compared with the value stored in the data flash Static Chem DF Checksum. If the value matches, the MSB will be cleared to indicate a pass. If it does not match, the MSB will be set to indicate a failure.

7.3.1.2.14 SEALED: 0x0020

Instructs the fuel gauge to transition from UNSEALED state to SEALED state. The fuel gauge should always be set to SEALED state for use in customer's end equipment.

7.3.1.2.15 IT_ENABLE: 0x0021

Forces the fuel gauge to begin the Impedance Track algorithm, sets Bit 2 of **UpdateStatus** and causes the [VOK] and [QEN] flags to be set in the CONTROL STATUS register. [VOK] is cleared if the voltages are not suitable for a Qmax update. Once set, [QEN] cannot be cleared. This command is only available when the fuel gauge is UNSEALED and is typically enabled at the last step of production after the system test is completed.

7.3.1.2.16 CAL_ENABLE: 0x002D

Instructs the fuel gauge to enable entry and exit to CALIBRATION mode.

7.3.1.2.17 RESET: 0x0041

Instructs the fuel gauge to perform a full reset. This command is only available when the fuel gauge is UNSEALED.

7.3.1.2.18 EXIT_CAL: 0x0080

Instructs the fuel gauge to exit CALIBRATION mode.

7.3.1.2.19 ENTER_CAL: 0x0081

Instructs the fuel gauge to enter CALIBRATION mode.

7.3.1.2.20 OFFSET_CAL: 0x0082

Instructs the fuel gauge to perform offset calibration.

7.3.1.3 StateOfCharge(): 0x02

This read-only command returns an unsigned integer value of the predicted remaining battery capacity expressed as a percentage of *FullChargeCapacity()* with a range of 0 to 100%.

7.3.1.4 MaxError(): 0x03

This read-only command returns an unsigned integer value of the expected margin of error, in %, in the state-of-charge calculation, with a range of 1% to 100%. *MaxError()* is incremented internally by 0.05% for every increment of **CycleCount** after the last **QMAX** update. *MaxError()* is incremented in the display by 1% for each increment of **CycleCount**.

Table 7-4. MaxError() Updates

| EVENT | MaxError() SETTING |
|--------------------------|--------------------|
| Full reset | Set to 100% |
| QMAX and Ra table update | Set to 1% |
| QMAX update | Set to 3% |
| Ra table update | Set to 5% |

If *MaxError()* exceeds the value programmed in **Max Error Limit**, then *[CF]* in *ControlStatus()* is set. Only when *MaxError()* returns below this value will *[CF]* be cleared.

7.3.1.5 RemainingCapacity(): 0x04/0x05

This read-only command pair returns the compensated battery capacity remaining. Unit is 1 mAh per bit.

7.3.1.6 FullChargeCapacity(): 0x06/07

This read-only command pair returns the compensated capacity of the battery when fully charged with units of 1 mAh per bit. However, if **PackConfiguration [SCALED]** is set then the units have been scaled through the calibration process. The actual scale is not set in the device and **SCALED** is just an indicator flag. *FullChargeCapacity()* is updated at regular intervals under the control of the Impedance Track algorithm.

7.3.1.7 Voltage(): 0x08/0x09

This read-word command pair returns an unsigned integer value of the measured battery voltage in mV with a range of 0 V to 65535 mV.

7.3.1.8 AverageCurrent(): 0x0A/0x0B

This read-only command pair returns a signed integer value that is the average current flowing through the sense resistor. It is updated every 1 second with units of 1 mA per bit. However, if **PackConfiguration [SCALED]** is set then the units have been scaled through the calibration process. The actual scale is not set in the device and **SCALED** is just an indicator flag.

7.3.1.9 Temperature(): 0x0C/0x0D

This read-only command pair returns an unsigned integer value of the temperature, in units of 0.1 K, measured by the gas gauge and has a range of 0 to 6553.5 K. The source of the measured temperature is configured by the *[TEMPS]* bit in the **Pack Configuration** register .

Table 7-5. Temperature Sensor Selection

| TEMPS | TEMPERATURE() SOURCE |
|-------|-----------------------------|
| 0 | Internal Temperature Sensor |
| 1 | TS Input (default) |

7.3.1.10 Flags(): 0x0E/0x0F

This read-only command pair returns the contents of the Gas Gauge Status register, depicting current operation status.

Table 7-6. Flags Bit Definitions

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-----------|----------|-------|-------|--------|---------|-------|-------|-------|
| High Byte | OTC | OTD | BATHI | BATLOW | CHG_INH | XCHG | FC | CHG |
| Low Byte | OCVTAKEN | RSVD | RSVD | CF | RSVD | SOC1 | SOCF | DSG |

Legend: **RSVD** = Reserved

OTC: Overtemperature in Charge condition is detected. True when set

OTD: Overtemperature in Discharge condition is detected. True when set

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- BATHI:** Battery High bit that indicates a high battery voltage condition. Refer to the data flash **Cell BH** parameters for threshold settings. True when set
- BATLOW:** Battery Low bit that indicates a low battery voltage condition. Refer to the data flash **Cell BL** parameters for threshold settings. True when set
- CHG_INH:** Charge Inhibit: unable to begin charging. Refer to the data flash [**Charge Inhibit Temp Low, Charge Inhibit Temp High**] parameters for threshold settings. True when set
- XCHG:** Charging not allowed
- FC:** Full charge is detected. FC is set when charge termination is reached and **FC Set%** = -1 (see [Section 7.3.11](#) for details) or **StateOfCharge()** is larger than **FC Set%** and **FC Set%** is not -1. True when set
- CHG:** (Fast) charging allowed. True when set
- OCVTAKEN:** Cleared on entry to RELAX mode and set to 1 when OCV measurement is performed in RELAX mode.
- CF:** Condition Flag indicates that the gauge needs to run through an update cycle to optimize accuracy.
- SOC1:** State-of-Charge Threshold 1 reached. True when set
- SOCF:** State-of-Charge Threshold Final reached. True when set
- DSG:** Discharging detected. True when set

7.3.1.11 FlagsB(): 0x12/0x13

This read-word function returns the contents of the gas-gauge status register, depicting current operation status.

Table 7-7. Flags B Bit Definitions

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-----------|-------|-------|----------|-------|-------|--------|-------|-------|
| High Byte | SOH | LIFE | FIRSTDOD | RSVD | RSVD | DODEOC | DTRC | RSVD |
| Low Byte | RSVD | RSVD | RSVD | RSVD | RSVD | RSVD | RSVD | RSVD |

Legend: **RSVD** = Reserved

- SOH:** *StateOfHealth()* calculation is active.
- LIFE:** Indicates that LiFePO₄ RELAX is enabled.
- FIRSTDOD:** Set when RELAX mode is entered and then cleared upon valid DOD measurement for QMAX update or RELAX exit.
- DODEOC:** DOD at End-of-Charge is updated.
- DTRC:** Indicates *RemainingCapacity()* has been changed due to change in temperature.

7.3.1.12 Current(): 0x10/0x11

This read-only command pair returns a signed integer value that is the current flow through the sense resistor. It is updated every 1 s with units of 1 mA; however, if **PackConfiguration [SCALED]** is set, then the units have been scaled through the calibration process. The actual scale is not set in the device and **SCALED** is just an indicator flag.

7.3.2 Extended Data Commands

Extended commands offer additional functionality beyond the standard set of commands. They are used in the same manner; however, unlike standard commands, extended commands are not limited to 2-byte words. The number of command bytes for a given extended command ranges in size from single to multiple bytes, as specified in [Table 7-8](#). For details on the SEALED and UNSEALED states, refer to [Section 7.3.3.3](#).

Table 7-8. Extended Commands

| NAME | COMMAND CODE | UNIT | SEALED ACCESS ^{(1) (2)} | UNSEALED ACCESS ^{(1) (2)} | |
|-----------------------------|--------------|-----------|----------------------------------|------------------------------------|---|
| <i>AverageTimeToEmpty()</i> | ATTE | 0x18/0x19 | Minutes | R | R |
| <i>AverageTimeToFull()</i> | ATTF | 0x1A/0x1B | Minutes | R | R |
| <i>PassedCharge()</i> | PCHG | 0x1C/0x1D | mAh | R | R |
| <i>DoD0Time()</i> | DoD0T | 0x1E/0x1F | Minutes | R | R |
| <i>AvailableEnergy()</i> | AE | 0x24/0x25 | 10 mW/h | R | R |

Table 7-8. Extended Commands (continued)

| NAME | | COMMAND CODE | UNIT | SEALED ACCESS ^{(1) (2)} | UNSEALED ACCESS ^{(1) (2)} |
|---|----------|--------------|--------|----------------------------------|------------------------------------|
| <i>AveragePower()</i> | AP | 0x26/0x27 | 10 mW | R | R |
| <i>Serial Number</i> | SERNUM | 0x28/0x29 | N/A | R | R |
| <i>Internal_Temperature()</i> | INTTEMP | 0x2A/0x2B | 0.1 K | R | R |
| <i>CycleCount()</i> | CC | 0x2C/0x2D | Counts | R | R |
| <i>StateOfHealth()</i> | SOH | 0x2E/0x2F | % | R | R |
| <i>ChargeVoltage()</i> | CHGV | 0x30/0x31 | mV | R | R |
| <i>ChargeCurrent()</i> | CHGI | 0x32/0x33 | mA | R | R |
| <i>PackConfiguration()</i> | PKCFG | 0x3A/0x3B | N/A | R | R |
| <i>DesignCapacity()</i> | DCAP | 0x3C/0x3D | mAh | R | R |
| <i>DataFlashClass()</i> (2) | DFCLS | 0x3E | N/A | N/A | R/W |
| <i>DataFlashBlock()</i> (2) | DFBLK | 0x3F | N/A | R/W | R/W |
| <i>Authenticate()/BlockData()</i> | A/DF | 0x40...0x53 | N/A | R/W | R/W |
| <i>AuthenticateChecksum()/BlockData()</i> | ACKS/DFD | 0x54 | N/A | R/W | R/W |
| <i>BlockData()</i> | DFD | 0x55...0x5F | N/A | R | R/W |
| <i>BlockDataChecksum()</i> | DFDCKS | 0x60 | N/A | R/W | R/W |
| <i>BlockDataControl()</i> | DFDCNTL | 0x61 | N/A | N/A | R/W |
| <i>GridNumber()</i> | GN | 0x62 | N/A | R | R |
| <i>LearnedStatus()</i> | LS | 0x63 | N/A | R | R |
| <i>DoD@EoC()</i> | DEOC | 0x64/0x65 | N/A | R | R |
| <i>QStart()</i> | QS | 0x66/0x67 | mAh | R | R |
| <i>TrueRC()</i> | TRC | 0x68/0x69 | mAh | R | R |
| <i>TrueFCC()</i> | TFCC | 0x6A/0x6B | mAh | R | R |
| <i>StateTime()</i> | ST | 0x6C/0x6D | s | R | R |
| <i>QMaxPassedQ</i> | QPC | 0x6E/0x6F | mAh | R | R |
| <i>DOD0()</i> | DOD0 | 0x70/0x71 | HEX# | R | R |
| <i>QmaxDOD0()</i> | QD0 | 0x72/0x73 | N/A | R | R |
| <i>QmaxTime()</i> | QT | 0x74/0x75 | h/16 | R | R |
| Reserved | RSVD | 0x76...0x7F | N/A | R | R |

(1) SEALED and UNSEALED states are entered via commands to CNTL 0x00/0x01.

(2) In SEALED mode, data flash *cannot* be accessed through commands 0x3E and 0x3F.

7.3.2.1 AverageTimeToEmpty(): 0x18/0x19

This read-only command pair returns an unsigned integer value of the predicted remaining battery life at the present rate of discharge (using *AverageCurrent()*), in minutes. A value of 65535 indicates that the battery is not being discharged.

7.3.2.2 AverageTimeToFull(): 0x1A/0x1B

This read-only command pair returns an unsigned integer value of predicted remaining time until the battery reaches full charge, in minutes, based upon *AverageCurrent()*. The computation should account for the taper current time extension from the linear TTF computation based on a fixed *AverageCurrent()* rate of charge accumulation. A value of 65535 indicates the battery is not being charged.

7.3.2.3 PassedCharge(): 0x1C/0x1D

This read-only command pair returns a signed integer, indicating the amount of charge passed through the sense resistor since the last IT simulation in mAh.

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7.3.2.4 DOD0Time(): 0x1E/0x1F

This read-only command pair returns the time since the last DOD0 update.

7.3.2.5 AvailableEnergy(): 0x24/0x25

This read-only command pair returns an unsigned integer value of the predicted charge or energy remaining in the battery. The value is reported in units of mWh.

7.3.2.6 AveragePower(): 0x26/0x27

This read-word command pair returns an unsigned integer value of the average power of the current discharge. A value of 0 indicates that the battery is not being discharged. The value is reported in units of mW.

7.3.2.7 SerialNumber(): 0x28/0x29

This read-only command pair returns the assigned pack serial number programmed in **Serial Number**.

7.3.2.8 InternalTemperature(): 0x2A/0x2B

This read-only command pair returns an unsigned integer value of the measured internal temperature of the device, in units of 0.1 K, measured by the fuel gauge.

7.3.2.9 CycleCount(): 0x2C/0x2D

This read-only command pair returns an unsigned integer value of the number of cycles the battery has experienced with a range of 0 to 65535. One cycle occurs when accumulated discharge \geq *CC Threshold*.

7.3.2.10 StateOfHealth(): 0x2E/0x2F

This read-only command pair returns an unsigned integer value, expressed as a percentage of the ratio of predicted FCC (25°C, SOH current rate) over the *DesignCapacity()*. The FCC (25°C, SOH current rate) is the calculated full charge capacity at 25°C and the SOH current rate that is specified in the data flash (State of Health Load). The range of the returned SOH percentage is 0x00 to 0x64, indicating 0% to 100%, correspondingly.

7.3.2.11 ChargeVoltage(): 0x30/0x31

This read-only command pair returns the recommended charging voltage output from the JEITA charging profile. It is updated automatically based on the present temperature range.

7.3.2.12 ChargeCurrent(): 0x32/0x33

This read-only command pair returns the recommended charging current output from the JEITA charging profile. It is updated automatically based on the present temperature range.

7.3.2.13 PackConfiguration(): 0x3A/0x3B

This read-only command pair allows the host to read the configuration of selected features of the device pertaining to various features.

7.3.2.14 DesignCapacity(): 0x3C/0x3D

This read-only command pair returns theoretical or nominal capacity of a new pack. The value is stored in **Design Capacity** and is expressed in mAh.

7.3.2.15 DataFlashClass(): 0x3E

UNSEALED Access: This command sets the data flash class to be accessed. The class to be accessed should be entered in hexadecimal.

SEALED Access: This command is not available in SEALED mode.

7.3.2.16 DataFlashBlock(): 0x3F

UNSEALED Access: If **BlockDataControl** has been set to 0x00, this command directs which data flash block will be accessed by the *BlockData()* command. Writing a 0x00 to *DataFlashBlock()* specifies the *BlockData()*

command will transfer authentication data. Issuing a 0x01 instructs the *BlockData()* command to transfer **Manufacturer Data**.

SEALED Access: This command directs which data flash block will be accessed by the *BlockData()* command. Writing a 0x00 to *DataFlashBlock()* specifies that the *BlockData()* command will transfer authentication data. Issuing a 0x01 instructs the *BlockData()* command to transfer **Manufacturer Data**.

7.3.2.17 AuthenticateData/BlockData(): 0x40...0x53

UNSEALED Access: This data block has a dual function: It is used for the authentication challenge and response and is part of the 32-byte data block when accessing data flash.

SEALED Access: This data block has a dual function: It is used for authentication challenge and response, and is part of the 32-byte data block when accessing the **Manufacturer Data**.

7.3.2.18 AuthenticateChecksum/BlockData(): 0x54

UNSEALED Access: This byte holds the authentication checksum when writing the authentication challenge to the device, and is part of the 32-byte data block when accessing data flash.

SEALED Access: This byte holds the authentication checksum when writing the authentication challenge to the device, and is part of the 32-byte data block when accessing **Manufacturer Data**.

7.3.2.19 BlockData(): 0x55...0x5F

UNSEALED Access: This data block is the remainder of the 32-byte data block when accessing data flash.

SEALED Access: This data block is the remainder of the 32-byte data block when accessing **Manufacturer Data**.

7.3.2.20 BlockDataChecksum(): 0x60

UNSEALED Access: This byte contains the checksum on the 32 bytes of block data read or written to data flash.

SEALED Access: This byte contains the checksum for the 32 bytes of block data written to **Manufacturer Data**.

7.3.2.21 BlockDataControl(): 0x61

UNSEALED Access: This command is used to control data flash ACCESS mode. Writing 0x00 to this command enables *BlockData()* to access general data flash. Writing a 0x01 to this command enables the SEALED mode operation of *DataFlashBlock()*.

7.3.2.22 GridNumber(): 0x62

This read-only command returns the active grid point. This data is only valid during DISCHARGE mode when [R_DIS] = 0. If [R_DIS] = 1 or not discharging, this value is not updated.

7.3.2.23 LearnedStatus(): 0x63

This read-only command returns the learned status of the resistance table.

Table 7-9. LearnedStatus(): 0x63

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| RSVD | RSVD | RSVD | RSVD | Qmax | ITEN | CF1 | CF0 |

Legend: **RSVD** = Reserved

QMax (Bit 3): QMax updates in the field.

0 = QMax has not been updated in the field.

1 = QMax updated in the field.

ITEN (Bit 2): IT enable

0 = IT is disabled.

1 = IT is enabled.

CF1, CF0 (Bits 1–0): QMax Status

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0,0 = Battery is OK.

0,1 = QMax is first updated in the learning cycle.

7.3.2.24 Dod@Eoc(): 0x64/0x65

This read-only command pair returns the depth of discharge (DOD) at the end of charge.

7.3.2.25 QStart(): 0x66/0x67

This read-only command pair returns the initial capacity calculated from IT simulation.

7.3.2.26 TrueRC(): 0x68/0x69

This read-only command pair returns the True remaining capacity from IT simulation without the effects of the smoothing function.

7.3.2.27 TrueFCC(): 0x6A/0x6B

This read-only command pair returns the True full charge capacity from IT simulation without the effects of the smoothing function.

7.3.2.28 StateTime(): 0x6C/0x6D

This read-only command pair returns the time past since last state change (DISCHARGE, CHARGE, REST).

7.3.2.29 QmaxPassedQ(): 0x6E/0x6F

This read-only command pair returns the passed capacity since the last Qmax DOD update.

7.3.2.30 DOD0(): 0x70/0x71

This unsigned integer indicates the depth of discharge during the most recent OCV reading.

7.3.2.31 QmaxDod0(): 0x72/0x73

This read-only command pair returns the DOD0 saved to be used for next QMax update of Cell 1. The value is only valid when [VOK] = 1.

7.3.2.32 QmaxTime(): 0x74/0x75

This read-only command pair returns the time since the last Qmax DOD update.

7.3.3 Data Flash Interface**7.3.3.1 Accessing Data Flash**

The BQ34Z100-G1 data flash is a non-volatile memory that contains BQ34Z100-G1 initialization, default, cell status, calibration, configuration, and user information. The data flash can be accessed in several different ways, depending on in what mode the BQ34Z100-G1 is operating and what data is being accessed.

Commonly accessed data flash memory locations, frequently read by a host, are conveniently accessed through specific instructions described in [Section 7.3.1](#). These commands are available when the BQ34Z100-G1 is either in UNSEALED or SEALED modes.

Most data flash locations, however, can only be accessible in UNSEALED mode by use of the BQ34Z100-G1 evaluation software or by data flash block transfers. These locations should be optimized and/or fixed during the development and manufacture processes. They become part of a Golden Image File and can then be written to multiple battery packs. Once established, the values generally remain unchanged during end-equipment operation.

To access data flash locations individually, the block containing the desired data flash location(s) must be transferred to the command register locations where they can be read to the host or changed directly. This is accomplished by sending the set-up command *BlockDataControl()* (code 0x61) with data 0x00. Up to 32 bytes of data can be read directly from the *BlockData()* command locations 0x40...0x5F, externally altered, then re-written to the *BlockData()* command space. Alternatively, specific locations can be read, altered, and re-written if their corresponding offsets are used to index into the *BlockData()* command space. Finally, the data

residing in the command space is transferred to data flash, once the correct checksum for the whole block is written to *BlockDataChecksum()* (command number 0x60).

Occasionally, a data flash class will be larger than the 32-byte block size. In this case, the *DataFlashBlock()* command is used to designate which 32-byte block in which the desired locations reside. The correct command address is then given by $0x40 + \text{offset modulo } 32$. For example, to access **Terminate Voltage** in the Gas Gauging class, *DataFlashClass()* is issued 80 (0x50) to set the class. Because the offset is 48, it must reside in the second 32-byte block. Hence, *DataFlashBlock()* is issued 0x01 to set the block offset, and the offset used to index into the *BlockData()* memory area is $0x40 + 48 \text{ modulo } 32 = 0x40 + 16 = 0x40 + 0x10 = 0x50$; for example, to modify **[VOLTSEL]** in **Pack Configuration** from 0 to 1 to enable the external voltage measurement option.

Note

The subclass ID and Offset values are in decimal format in the documentation and in bqStudio. The example below shows these values converted to hexadecimal. For example, the **Pack Configuration** subclass is $d64 = 0x40$.

1. Unseal the device using the *Control()* (0x00/0x01) command if the device is sealed.
 - a. Write the first 2 bytes of the UNSEAL key using the *Control()*(0x0414) command.
(wr 0x00 0x14 0x04)
 - b. Write the second 2 bytes of the UNSEAL key using the *Control()*(0x3672) command.
(wr 0x00 0x72 0x36)
2. Write 0x00 using *BlockDataControl()* command (0x61) to enable block data flash control.
(wr 0x61 0x00)
3. Write 0x40 (*Pack Configuration* Subclass) using the *DataFlashClass()* command (0x3E) to access the Registers subclass.
(wr 0x3E 0x40)
4. Write the block offset location using *DataFlashBlock()* command (0x3F). To access data located at offset 0 to 31, use offset = 0x00. To access data located at offset 32 to 63, use offset = 0x01, and so on, as necessary.
For example, *Pack Configuration* (offset = 0) is in the first block so use (wr 0x3F 0x00).
5. To read the data of a specific offset, use address $0x40 + \text{mod}(\text{offset}, 32)$. For example, *Pack Configuration* (offset = 0) is located at 0x40 and 0x41; however, **[VOLTSEL]** is in the MSB so only 0x40 needs to be read. Read 1 byte starting at the 0x40 address.
(rd 0x40 old_Pack_Configuration_MSB)
- In this example, assume **[VOLTSEL]** = 0 (default).
6. To read the 1-byte checksum, use the *BlockDataChecksum()* command (0x60).
(rd 0x60 OLD_checksum)
7. In this example, set **[VOLTSEL]** by setting Bit 3 of *old_Pack_Configuration_MSB* to create *new_Pack_Configuration_MSB*.
8. The new value for *new_Pack_Configuration_MSB* can be written by writing to the specific offset location.
For example, to write 1-byte *new_Pack_Configuration_MSB* to **Pack Configuration** (offset=0) located at 0x40, use command (wr 0x4B new_Pack_Configuration_MSB).
9. The data is actually transferred to the data flash when the correct checksum for the whole block (0x40 to 0x5F) is written to *BlockDataChecksum()* (0x60).

(wr 0x60 NEW_checksum)

The checksum is $(255-x)$ where x is the 8-bit summation of the *BlockData()* (0x40 to 0x5F) on a byte-by-byte basis.

A quick way to calculate the new checksum is to make use of the old checksum:

- a. $\text{temp} = \text{mod}(255 - \text{OLD_checksum} - \text{old_Pack_Configuration_MSB}, 256)$
- b. $\text{NEW_checksum} = 255 - \text{mod}(\text{temp} + \text{new_Pack_Configuration_MSB}, 256)$

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10. Reset the gauge to ensure the new data flash parameter goes into effect by using *Control(0x0041)*.

(wr 0x00 0x41 0x00)

If previously sealed, the gauge will automatically become sealed again after RESET.

11. If not previously sealed, then seal the gauge by using *Control(0x0020)*.

(wr 0x00 0x20 0x00)

Reading and writing subclass data are block operations 32 bytes in length. Data can be written in shorter block sizes, however. Blocks can be shorter than 32 bytes in length. Writing these blocks back to data flash will not overwrite data that extend beyond the actual block length.

Note

None of the data written to memory is bounded by the BQ34Z100-G1: The values are not rejected by the gas gauge. 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 resolves the fault.

7.3.3.2 Manufacturer Information Block

The BQ34Z100-G1 contains 32 bytes of user-programmable data flash storage: **Manufacturer Info Block**. The method for accessing these memory locations is slightly different, depending on if the device is in UNSEALED or SEALED modes.

When in UNSEALED mode and when an “0x00” has been written to *BlockDataControl()*, accessing the Manufacturer Info Block is identical to accessing general data flash locations. First, a *DataFlashClass()* command is used to set the subclass, then a *DataFlashBlock()* command sets the offset for the first data flash address within the subclass. The *BlockData()* command codes contain the referenced data flash data. When writing the data flash, a checksum is expected to be received by *BlockDataChecksum()*. Only when the checksum is received and verified is the data actually written to data flash.

As an example, the data flash location for **Manufacturer Info Block** is defined as having a Subclass = 58 and an Offset = 0 through 31 (32 byte block). The specification of Class = System Data is not needed to address **Manufacturer Info Block**, but is used instead for grouping purposes when viewing data flash info in the BQ34Z100-G1 evaluation software.

When in SEALED mode or when “0x01” *BlockDataControl()* does not contain “0x00”, data flash is no longer available in the manner used in UNSEALED mode. Rather than issuing subclass information, a designated **Manufacturer Information Block** is selected with the *DataFlashBlock()* command. Issuing a 0x01, 0x02, or 0x03 with this command causes the corresponding information block (A, B, or C, respectively) to be transferred to the command space 0x40...0x5F for editing or reading by the host. Upon successful writing of checksum information to *BlockDataChecksum()*, the modified block is returned to data flash.

Note

Manufacturer Info Block A is “read only” when in SEALED mode.

7.3.3.3 Access Modes

The BQ34Z100-G1 provides three security modes that control data flash access permissions according to [Table 7-10](#). Public Access refers to those data flash locations specified in [Table 7-11](#) that are accessible to the user. Private Access refers to reserved data flash locations used by the BQ34Z100-G1 system. Care should be taken to avoid writing to Private data flash locations when performing block writes in FULL ACCESS mode by following the procedure outlined in [Section 7.3.3.1](#).

Table 7-10. Data Flash Access

| SECURITY MODE | DF—PUBLIC ACCESS | DF—PRIVATE ACCESS |
|---------------|------------------|-------------------|
| BOOTROM | N/A | N/A |
| FULL ACCESS | R/W | R/W |

Table 7-10. Data Flash Access (continued)

| SECURITY MODE | DF—PUBLIC ACCESS | DF—PRIVATE ACCESS |
|---------------|------------------|-------------------|
| UNSEALED | R/W | R/W |
| SEALED | R | N/A |

Although FULL ACCESS and UNSEALED modes appear identical, FULL ACCESS mode allows the BQ34Z100-G1 to directly transition to BOOTROM mode and also write access keys. UNSEALED mode does not have these abilities.

7.3.3.4 Sealing/Unsealing Data Flash Access

The BQ34Z100-G1 implements a key-access scheme to transition between SEALED, UNSEALED, and FULL ACCESS modes. Each transition requires that a unique set of two keys be sent to the BQ34Z100-G1 via the *Control()* command (these keys are unrelated to the keys used for SHA-1/HMAC authentication). The keys must be sent consecutively, with no other data being written to the *Control()* register in between. Note that to avoid conflict, the keys must be different from the codes presented in the CNTL DATA column of [Table 7-2](#) subcommands.

When in SEALED mode, the [SS] bit of *Control Status()* is set, but when the UNSEAL keys are correctly received by the BQ34Z100-G1, the [SS] bit is cleared. When the full access keys are correctly received, then the *Flags()* [FAS] bit is cleared.

Both sets of keys for each level are 2 bytes each in length and are stored in data flash. The UNSEAL key (stored at **Unseal Key 0** and **Unseal Key 1**) and the FULL ACCESS key (stored at **Full Access Key 0** and **Full Access Key 1**) can only be updated when in FULL ACCESS mode. The order of the bytes entered through the *Control()* command is the reverse of what is read from the part. For example, if the 1st and 2nd word of the `UnSeal Key 0` returns 0x1234 and 0x5678, then *Control()* should supply 0x3412 and 0x7856 to unseal the part.

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7.3.4 Data Flash Summary

Table 7-11 summarizes the data flash locations available to the user, including the default, minimum, and maximum values.

Table 7-11. Data Flash Summary

| CLASS | SUBCLASS | SUBCLASS ID | OFFSET | TYPE | NAME | MIN | MAX | DEFAULT | UNIT |
|---------------|--------------------|-------------|--------|------|-------------------------------|------|----------|------------|-------|
| Configuration | Safety | 2 | 0 | I2 | OT Chg | 0 | 1200 | 550 | 0.1°C |
| Configuration | Safety | 2 | 2 | U1 | OT Chg Time | 0 | 60 | 2 | s |
| Configuration | Safety | 2 | 3 | I2 | OT Chg Recovery | 0 | 1200 | 500 | 0.1°C |
| Configuration | Safety | 2 | 5 | I2 | OT Dsg | 0 | 1200 | 600 | 0.1°C |
| Configuration | Safety | 2 | 7 | U1 | OT Dsg Time | 0 | 60 | 2 | s |
| Configuration | Safety | 2 | 8 | I2 | OT Dsg Recovery | 0 | 1200 | 550 | 0.1°C |
| Configuration | Charge Inhibit Cfg | 32 | 0 | I2 | Chg Inhibit Temp Low | -400 | 1200 | 0 | 0.1°C |
| Configuration | Charge Inhibit Cfg | 32 | 2 | I2 | Chg Inhibit Temp High | -400 | 1200 | 450 | 0.1°C |
| Configuration | Charge Inhibit Cfg | 32 | 4 | I2 | Temp Hys | 0 | 100 | 50 | 0.1°C |
| Configuration | Charge | 34 | 0 | I2 | Suspend Low Temp | -400 | 1200 | -50 | 0.1°C |
| Configuration | Charge | 34 | 2 | I2 | Suspend High Temp | -400 | 1200 | 550 | 0.1°C |
| Configuration | Charge | 34 | 4 | U1 | Pb EFF Efficiency | 0 | 100 | 100 | % |
| Configuration | Charge | 34 | 5 | F4 | Pb Temp Comp | 0 | 0.078125 | 0.01953125 | % |
| Configuration | Charge | 34 | 9 | U1 | Pb Drop Off Percent | 0 | 100 | 96 | % |
| Configuration | Charge | 34 | 10 | F4 | Pb Reduction Rate | 0 | 1.25 | 0.125 | % |
| Configuration | Charge Termination | 36 | 0 | I2 | Taper Current | 0 | 1000 | 100 | mA |
| Configuration | Charge Termination | 36 | 2 | I2 | Min Taper Capacity | 0 | 1000 | 25 | mAh |
| Configuration | Charge Termination | 36 | 4 | I2 | Cell Taper Voltage | 0 | 1000 | 100 | mV |
| Configuration | Charge Termination | 36 | 6 | U1 | Current Taper Window | 0 | 60 | 40 | s |
| Configuration | Charge Termination | 36 | 7 | I1 | TCA Set % | -1 | 100 | 99 | % |
| Configuration | Charge Termination | 36 | 8 | I1 | TCA Clear % | -1 | 100 | 95 | % |
| Configuration | Charge Termination | 36 | 9 | I1 | FC Set % | -1 | 100 | 100 | % |
| Configuration | Charge Termination | 36 | 10 | I1 | FC Clear % | -1 | 100 | 98 | % |
| Configuration | Charge Termination | 36 | 11 | I2 | DODatEOC Delta T | 0 | 1000 | 100 | 0.1°C |
| Configuration | Charge Termination | 36 | 13 | I2 | NiMH Delta Temp | 0 | 255 | 30 | 0.1°C |
| Configuration | Charge Termination | 36 | 15 | U2 | NiMH Delta Temp Time | 0 | 1000 | 180 | s |
| Configuration | Charge Termination | 36 | 17 | U2 | NiMH Hold Off Time | 0 | 1000 | 100 | s |
| Configuration | Charge Termination | 36 | 19 | I2 | NiMH Hold Off Current | 0 | 32000 | 240 | mA |
| Configuration | Charge Termination | 36 | 21 | I2 | NiMH Hold Off Temp | 0 | 1000 | 250 | 0.1°C |
| Configuration | Charge Termination | 36 | 23 | U1 | NiMH Cell Negative Delta Volt | 0 | 100 | 17 | mV |
| Configuration | Charge Termination | 36 | 24 | U1 | NiMH Cell Negative Delta Time | 0 | 255 | 16 | s |

Table 7-11. Data Flash Summary (continued)

| CLASS | SUBCLASS | SUBCLASS ID | OFFSET | TYPE | NAME | MIN | MAX | DEFAULT | UNIT |
|---------------|--------------------|-------------|--------|------|-------------------------------|--------|-------|-------------|------------------------------|
| Configuration | Charge Termination | 36 | 25 | I2 | NIMH Cell Neg Delta Qual Volt | 0 | 32767 | 4200 | mV |
| Configuration | Data | 48 | 2 | U2 | Manufacture Date | 0 | 65535 | 0 | Day + Mo*32 + (Yr -1980)*256 |
| Configuration | Data | 48 | 4 | H2 | Serial Number | 0 | ffff | 1 | hex |
| Configuration | Data | 48 | 6 | U2 | Cycle Count | 0 | 65535 | 0 | Counts |
| Configuration | Data | 48 | 8 | I2 | CC Threshold | 100 | 32767 | 900 | mAh |
| Configuration | Data | 48 | 10 | U1 | Max Error Limit | 0 | 100 | 100 | % |
| Configuration | Data | 48 | 11 | I2 | Design Capacity | 0 | 32767 | 1000 | mAh |
| Configuration | Data | 48 | 13 | I2 | Design Energy | 0 | 32767 | 5400 | mWh |
| Configuration | Data | 48 | 15 | I2 | SOH Load I | -32767 | 0 | -400 | mA |
| Configuration | Data | 48 | 17 | U2 | Cell Charge Voltage T1-T2 | 0 | 4600 | 4200 | mV |
| Configuration | Data | 48 | 19 | U2 | Cell Charge Voltage T2-T3 | 0 | 4600 | 4200 | mV |
| Configuration | Data | 48 | 21 | U2 | Cell Charge Voltage T3-T4 | 0 | 4600 | 4100 | mV |
| Configuration | Data | 48 | 23 | U1 | Charge Current T1-T2 | 0 | 100 | 10 | % |
| Configuration | Data | 48 | 24 | U1 | Charge Current T2-T3 | 0 | 100 | 50 | % |
| Configuration | Data | 48 | 25 | U1 | Charge Current T3-T4 | 0 | 100 | 30 | % |
| Configuration | Data | 48 | 26 | I1 | JEITA T1 | -128 | 127 | -10 | °C |
| Configuration | Data | 48 | 27 | I1 | JEITA T2 | -128 | 127 | 10 | °C |
| Configuration | Data | 48 | 28 | I1 | JEITA T3 | -128 | 127 | 45 | °C |
| Configuration | Data | 48 | 29 | I1 | JEITA T4 | -128 | 127 | 55 | °C |
| Configuration | Data | 48 | 30 | U1 | Design Energy Scale | 0 | 255 | 1 | Num |
| Configuration | Data | 48 | 31 | S12 | Device Name | x | x | BQ34Z100-G1 | — |
| Configuration | Data | 48 | 43 | S12 | Manufacturer Name | x | x | Texas Inst. | — |
| Configuration | Data | 48 | 55 | S5 | Device Chemistry | x | x | LION | — |
| Configuration | Discharge | 49 | 0 | U2 | SOC1 Set Threshold | 0 | 65535 | 150 | mAh |
| Configuration | Discharge | 49 | 2 | U2 | SOC1 Clear Threshold | 0 | 65535 | 175 | mAh |
| Configuration | Discharge | 49 | 4 | U2 | SOCF Set Threshold | 0 | 65535 | 75 | mAh |
| Configuration | Discharge | 49 | 6 | U2 | SOCF Clear Threshold | 0 | 65535 | 100 | mAh |
| Configuration | Discharge | 49 | 8 | I2 | Cell BL Set Volt Threshold | 0 | 5000 | 0 | mV |
| Configuration | Discharge | 49 | 10 | U1 | Cell BL Set Volt Time | 0 | 60 | 0 | s |
| Configuration | Discharge | 49 | 11 | I2 | Cell BL Clear Volt Threshold | 0 | 5000 | 5 | mV |
| Configuration | Discharge | 49 | 13 | I2 | Cell BH Set Volt Threshold | 0 | 5000 | 4300 | mV |
| Configuration | Discharge | 49 | 15 | U1 | Cell BH Volt Time | 0 | 60 | 2 | s |
| Configuration | Discharge | 49 | 16 | I2 | Cell BH Clear Volt Threshold | 0 | 5000 | 5 | mV |
| Configuration | Discharge | 49 | 21 | U1 | Cycle Delta | 0 | 255 | 5 | 0.01% |
| Configuration | Manufacturer Data | 56 | 0 | H2 | Pack Lot Code | 0 | ffff | 0 | hex |
| Configuration | Manufacturer Data | 56 | 2 | H2 | PCB Lot Code | 0 | ffff | 0 | hex |
| Configuration | Manufacturer Data | 56 | 4 | H2 | Firmware Version | 0 | ffff | 0 | hex |
| Configuration | Manufacturer Data | 56 | 6 | H2 | Hardware Revision | 0 | ffff | 0 | hex |
| Configuration | Manufacturer Data | 56 | 8 | H2 | Cell Revision | 0 | ffff | 0 | hex |
| Configuration | Manufacturer Data | 56 | 10 | H2 | DF Config Version | 0 | ffff | 0 | hex |
| Configuration | Lifetime Data | 59 | 0 | I2 | Lifetime Max Temp | 0 | 1400 | 300 | 0.1°C |
| Configuration | Lifetime Data | 59 | 2 | I2 | Lifetime Min Temp | -600 | 1400 | 200 | 0.1°C |

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Table 7-11. Data Flash Summary (continued)

| CLASS | SUBCLASS | SUBCLASS ID | OFFSET | TYPE | NAME | MIN | MAX | DEFAULT | UNIT |
|---------------|-----------------------|-------------|--------|------|---------------------------|--------|-------|---------|--------|
| Configuration | Lifetime Data | 59 | 4 | I2 | Lifetime Max Chg Current | -32767 | 32767 | 0 | mA |
| Configuration | Lifetime Data | 59 | 6 | I2 | Lifetime Max Dsg Current | -32767 | 32767 | 0 | mA |
| Configuration | Lifetime Data | 59 | 8 | U2 | Lifetime Max Pack Voltage | 0 | 65535 | 320 | 20 mV |
| Configuration | Lifetime Data | 59 | 10 | U2 | Lifetime Min Pack Voltage | 0 | 65535 | 350 | 20 mV |
| Configuration | Lifetime Temp Samples | 60 | 0 | U2 | LT Flash Cnt | 0 | 65535 | 0 | Counts |
| Configuration | Registers | 64 | 0 | H2 | Pack Configuration | 0 | ffff | 161 | flags |
| Configuration | Registers | 64 | 2 | H1 | Pack Configuration B | 0 | ff | ff | flags |
| Configuration | Registers | 64 | 3 | H1 | Pack Configuration C | 0 | ff | 30 | flags |
| Configuration | Registers | 64 | 4 | H1 | LED_Comm Configuration | 0 | ff | 0 | flags |
| Configuration | Registers | 64 | 5 | H2 | Alert Configuration | 0 | ffff | 0 | flags |
| Configuration | Registers | 64 | 7 | U1 | Number of series cell | 0 | 100 | 1 | Num |
| Configuration | Lifetime Resolution | 66 | 0 | U1 | LT Temp Res | 0 | 255 | 10 | 0.1°C |
| Configuration | Lifetime Resolution | 66 | 1 | U1 | LT Cur Res | 0 | 255 | 100 | mA |
| Configuration | Lifetime Resolution | 66 | 2 | U1 | LT V Res | 0 | 255 | 1 | 20 mV |
| Configuration | Lifetime Resolution | 66 | 3 | U2 | LT Update Time | 0 | 65535 | 60 | s |
| Configuration | LED Display | 67 | 0 | U1 | LED Hold Time | 0 | 255 | 4 | Num |
| Configuration | Power | 68 | 0 | I2 | Flash Update OK Cell Volt | 0 | 4200 | 2800 | mV |
| Configuration | Power | 68 | 2 | I2 | Sleep Current | 0 | 100 | 10 | mA |
| Configuration | Power | 68 | 11 | U1 | FS Wait | 0 | 255 | 0 | s |
| System Data | Manufacturer Info | 58 | 0 | H1 | Block A 0 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 1 | H1 | Block A 1 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 2 | H1 | Block A 2 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 3 | H1 | Block A 3 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 4 | H1 | Block A 4 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 5 | H1 | Block A 5 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 6 | H1 | Block A 6 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 7 | H1 | Block A 7 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 8 | H1 | Block A 8 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 9 | H1 | Block A 9 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 10 | H1 | Block A 10 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 11 | H1 | Block A 11 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 12 | H1 | Block A 12 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 13 | H1 | Block A 13 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 14 | H1 | Block A 14 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 15 | H1 | Block A 15 | 0 | ff | 0 | hex |

Table 7-11. Data Flash Summary (continued)

| CLASS | SUBCLASS | SUBCLASS ID | OFFSET | TYPE | NAME | MIN | MAX | DEFAULT | UNIT |
|-------------|-------------------|-------------|--------|------|--------------------------------|--------|-------|---------|---------|
| System Data | Manufacturer Info | 58 | 16 | H1 | Block A 16 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 17 | H1 | Block A 17 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 18 | H1 | Block A 18 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 19 | H1 | Block A 19 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 20 | H1 | Block A 20 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 21 | H1 | Block A 21 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 22 | H1 | Block A 22 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 23 | H1 | Block A 23 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 24 | H1 | Block A 24 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 25 | H1 | Block A 25 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 26 | H1 | Block A 26 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 27 | H1 | Block A 27 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 28 | H1 | Block A 28 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 29 | H1 | Block A 29 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 30 | H1 | Block A 30 | 0 | ff | 0 | hex |
| System Data | Manufacturer Info | 58 | 31 | H1 | Block A 31 | 0 | ff | 0 | hex |
| Gas Gauging | IT Cfg | 80 | 0 | U1 | Load Select | 0 | 255 | 1 | Num |
| Gas Gauging | IT Cfg | 80 | 1 | U1 | Load Mode | 0 | 255 | 0 | Num |
| Gas Gauging | IT Cfg | 80 | 10 | I2 | Res Current | 0 | 1000 | 10 | mA |
| Gas Gauging | IT Cfg | 80 | 14 | U1 | Max Res Factor | 0 | 255 | 50 | Num |
| Gas Gauging | IT Cfg | 80 | 15 | U1 | Min Res Factor | 0 | 255 | 1 | Num |
| Gas Gauging | IT Cfg | 80 | 17 | U2 | Ra Filter | 0 | 1000 | 500 | Num |
| Gas Gauging | IT Cfg | 80 | 47 | U1 | Min PassedChg NiMH-LA 1st Qmax | 1 | 100 | 50 | % |
| Gas Gauging | IT Cfg | 80 | 49 | U1 | Maximum Qmax Change | 0 | 255 | 100 | % |
| Gas Gauging | IT Cfg | 80 | 53 | I2 | Cell Terminate Voltage | 1000 | 3700 | 3000 | mV |
| Gas Gauging | IT Cfg | 80 | 55 | I2 | Cell Term V Delta | 0 | 4200 | 200 | mV |
| Gas Gauging | IT Cfg | 80 | 58 | U2 | ResRelax Time | 0 | 65534 | 500 | s |
| Gas Gauging | IT Cfg | 80 | 62 | I2 | User Rate-mA | -32767 | 32767 | 0 | mA |
| Gas Gauging | IT Cfg | 80 | 64 | I2 | User Rate-Pwr | -32767 | 32767 | 0 | mW/cW |
| Gas Gauging | IT Cfg | 80 | 66 | I2 | Reserve Cap-mAh | 0 | 9000 | 0 | mAh |
| Gas Gauging | IT Cfg | 80 | 68 | I2 | Reserve Energy | 0 | 14000 | 0 | mWh/cWh |
| Gas Gauging | IT Cfg | 80 | 72 | U1 | Max Scale Back Grid | 0 | 15 | 4 | Num |
| Gas Gauging | IT Cfg | 80 | 73 | U2 | Cell Min DeltaV | 0 | 65535 | 0 | mV |
| Gas Gauging | IT Cfg | 80 | 75 | U1 | Ra Max Delta | 0 | 255 | 15 | % |
| Gas Gauging | IT Cfg | 80 | 76 | I2 | Design Resistance | 1 | 32767 | 42 | mΩ |
| Gas Gauging | IT Cfg | 80 | 78 | U1 | Reference Grid | 0 | 14 | 4 | — |
| Gas Gauging | IT Cfg | 80 | 79 | U1 | Qmax Max Delta % | 0 | 100 | 10 | mAh |
| Gas Gauging | IT Cfg | 80 | 80 | U2 | Max Res Scale | 0 | 32767 | 32000 | Num |

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Table 7-11. Data Flash Summary (continued)

| CLASS | SUBCLASS | SUBCLASS ID | OFFSET | TYPE | NAME | MIN | MAX | DEFAULT | UNIT |
|-------------|--------------------|-------------|--------|------|-----------------------|--------|-------|---------|------|
| Gas Gauging | IT Cfg | 80 | 82 | U2 | Min Res Scale | 0 | 32767 | 1 | Num |
| Gas Gauging | IT Cfg | 80 | 84 | U1 | Fast Scale Start SOC | 0 | 100 | 10 | % |
| Gas Gauging | IT Cfg | 80 | 89 | I2 | Charge Hys V Shift | 0 | 2000 | 40 | mV |
| Gas Gauging | IT Cfg | 80 | 91 | I2 | Smooth Relax Time | 1 | 32767 | 1000 | s |
| Gas Gauging | Current Thresholds | 81 | 0 | I2 | Dsg Current Threshold | 0 | 2000 | 60 | mA |
| Gas Gauging | Current Thresholds | 81 | 2 | I2 | Chg Current Threshold | 0 | 2000 | 75 | mA |
| Gas Gauging | Current Thresholds | 81 | 4 | I2 | Quit Current | 0 | 1000 | 40 | mA |
| Gas Gauging | Current Thresholds | 81 | 6 | U2 | Dsg Relax Time | 0 | 8191 | 60 | s |
| Gas Gauging | Current Thresholds | 81 | 8 | U1 | Chg Relax Time | 0 | 255 | 60 | s |
| Gas Gauging | Current Thresholds | 81 | 9 | U2 | Cell Max IR Correct | 0 | 1000 | 400 | mV |
| Gas Gauging | State | 82 | 0 | I2 | Qmax Cell 0 | 0 | 32767 | 1000 | mAh |
| Gas Gauging | State | 82 | 2 | U2 | Cycle Count | 0 | 65535 | 0 | Num |
| Gas Gauging | State | 82 | 4 | H1 | Update Status | 0 | 6 | 0 | Num |
| Gas Gauging | State | 82 | 5 | I2 | Cell V at Chg Term | 0 | 5000 | 4200 | mV |
| Gas Gauging | State | 82 | 7 | I2 | Avg I Last Run | -32768 | 32767 | -299 | mA |
| Gas Gauging | State | 82 | 9 | I2 | Avg P Last Run | -32768 | 32767 | -1131 | mWh |
| Gas Gauging | State | 82 | 11 | I2 | Cell Delta Voltage | -32768 | 32767 | 2 | mV |
| Gas Gauging | State | 82 | 13 | I2 | T Rise | 0 | 32767 | 20 | Num |
| Gas Gauging | State | 82 | 15 | I2 | T Time Constant | 0 | 32767 | 1000 | Num |
| Ra Table | R_a0 | 88 | 0 | H2 | R_a0 Flag | 0 | ffff | ff55 | Hex |
| Ra Table | R_a0 | 88 | 2 | I2 | R_a0 0 | 0 | 32767 | 105 | Num |
| Ra Table | R_a0 | 88 | 4 | I2 | R_a0 1 | 0 | 32767 | 100 | Num |
| Ra Table | R_a0 | 88 | 6 | I2 | R_a0 2 | 0 | 32767 | 113 | Num |
| Ra Table | R_a0 | 88 | 8 | I2 | R_a0 3 | 0 | 32767 | 143 | Num |
| Ra Table | R_a0 | 88 | 10 | I2 | R_a0 4 | 0 | 32767 | 98 | Num |
| Ra Table | R_a0 | 88 | 12 | I2 | R_a0 5 | 0 | 32767 | 97 | Num |
| Ra Table | R_a0 | 88 | 14 | I2 | R_a0 6 | 0 | 32767 | 108 | Num |
| Ra Table | R_a0 | 88 | 16 | I2 | R_a0 7 | 0 | 32767 | 89 | Num |
| Ra Table | R_a0 | 88 | 18 | I2 | R_a0 8 | 0 | 32767 | 86 | Num |
| Ra Table | R_a0 | 88 | 20 | I2 | R_a0 9 | 0 | 32767 | 85 | Num |
| Ra Table | R_a0 | 88 | 22 | I2 | R_a0 10 | 0 | 32767 | 87 | Num |
| Ra Table | R_a0 | 88 | 24 | I2 | R_a0 11 | 0 | 32767 | 90 | Num |
| Ra Table | R_a0 | 88 | 26 | I2 | R_a0 12 | 0 | 32767 | 110 | Num |
| Ra Table | R_a0 | 88 | 28 | I2 | R_a0 13 | 0 | 32767 | 647 | Num |
| Ra Table | R_a0 | 88 | 30 | I2 | R_a0 14 | 0 | 32767 | 1500 | Num |
| Ra Table | R_a0x | 89 | 0 | H2 | R_a0x Flag | 0 | ffff | ffff | Hex |
| Ra Table | R_a0x | 89 | 2 | I2 | R_a0x 0 | 0 | 32767 | 105 | Num |
| Ra Table | R_a0x | 89 | 4 | I2 | R_a0x 1 | 0 | 32767 | 100 | Num |
| Ra Table | R_a0x | 89 | 6 | I2 | R_a0x 2 | 0 | 32767 | 113 | Num |
| Ra Table | R_a0x | 89 | 8 | I2 | R_a0x 3 | 0 | 32767 | 143 | Num |
| Ra Table | R_a0x | 89 | 10 | I2 | R_a0x 4 | 0 | 32767 | 98 | Num |
| Ra Table | R_a0x | 89 | 12 | I2 | R_a0x 5 | 0 | 32767 | 97 | Num |
| Ra Table | R_a0x | 89 | 14 | I2 | R_a0x 6 | 0 | 32767 | 108 | Num |
| Ra Table | R_a0x | 89 | 16 | I2 | R_a0x 7 | 0 | 32767 | 89 | Num |
| Ra Table | R_a0x | 89 | 18 | I2 | R_a0x 8 | 0 | 32767 | 86 | Num |

Table 7-11. Data Flash Summary (continued)

| CLASS | SUBCLASS | SUBCLASS ID | OFFSET | TYPE | NAME | MIN | MAX | DEFAULT | UNIT |
|-------------|----------|-------------|--------|------|--------------------|----------|----------|-----------|-------|
| Ra Table | R_a0x | 89 | 20 | I2 | R_a0x 9 | 0 | 32767 | 85 | Num |
| Ra Table | R_a0x | 89 | 22 | I2 | R_a0x 10 | 0 | 32767 | 87 | Num |
| Ra Table | R_a0x | 89 | 24 | I2 | R_a0x 11 | 0 | 32767 | 90 | Num |
| Ra Table | R_a0x | 89 | 26 | I2 | R_a0x 12 | 0 | 32767 | 110 | Num |
| Ra Table | R_a0x | 89 | 28 | I2 | R_a0x 13 | 0 | 32767 | 647 | Num |
| Ra Table | R_a0x | 89 | 30 | I2 | R_a0x 14 | 0 | 32767 | 1500 | Num |
| Calibration | Data | 104 | 0 | F4 | CC Gain | 1.00E-01 | 4.00E+01 | 0.4768 | mΩ |
| Calibration | Data | 104 | 4 | F4 | CC Delta | 2.98E+04 | 1.19E+06 | 567744.56 | mΩ |
| Calibration | Data | 104 | 8 | I2 | CC Offset | -32768 | 32767 | -1200 | Num |
| Calibration | Data | 104 | 10 | I1 | Board Offset | -128 | 127 | 0 | Num |
| Calibration | Data | 104 | 11 | I1 | Int Temp Offset | -128 | 127 | 0 | 0.1°C |
| Calibration | Data | 104 | 12 | I1 | Ext Temp Offset | -128 | 127 | 0 | 0.1°C |
| Calibration | Data | 104 | 14 | U2 | Voltage Divider | 0 | 65535 | 5000 | mV |
| Calibration | Current | 107 | 1 | U1 | Deadband | 0 | 255 | 5 | mA |
| Security | Codes | 112 | 0 | H4 | Sealed to Unsealed | 0 | ffffff | 36720414 | hex |
| Security | Codes | 112 | 4 | H4 | Unsealed to Full | 0 | ffffff | ffffff | hex |
| Security | Codes | 112 | 8 | H4 | Authen Key3 | 0 | ffffff | 1234567 | hex |
| Security | Codes | 112 | 12 | H4 | Authen Key2 | 0 | ffffff | 89abcdef | hex |
| Security | Codes | 112 | 16 | H4 | Authen Key1 | 0 | ffffff | fedcba98 | hex |
| Security | Codes | 112 | 20 | H4 | Authen Key0 | 0 | ffffff | 76543210 | hex |

Table 7-12. Data Flash (DF) to EVSW Conversion

| CLASS | SUBCLASS ID | SUBCLASS | OFFSET | NAME | DATA TYPE | DATA FLASH DEFAULT | DATA FLASH UNIT | EVSW DEFAULT | EVSW UNIT | DF to EVSW CONVERSION |
|-------------|-------------|----------|--------|------------------|-----------|--------------------|-----------------|--------------|-----------|-------------------------|
| Data | 48 | Data | 13 | Manufacture Date | U2 | 0 | code | 1-Jan-1980 | | Day+Mo*32+(Yr-1980)*256 |
| Gas Gauging | 80 | IT Cfg | 59 | User Rate-mW | I2 | 0 | cW | 0 | mW | DF × 10 |
| Gas Gauging | 80 | IT Cfg | 63 | Reserve Cap-mWh | I2 | 0 | cWh | 0 | mWh | DF × 10 |
| Calibration | 104 | Data | 0 | CC Gain | F4 | 0.47095 | Num | 10.124 | mΩ | 4.768/DF |
| Calibration | 104 | Data | 4 | CC Delta | F4 | 5.595E5 | Num | 10.147 | mΩ | 5677445/DF |

7.3.5 Fuel Gauging

The BQ34Z100-G1 measures the cell voltage, temperature, and current to determine the battery SOC based in the Impedance Track algorithm (refer to *Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm Application Report [SLUA450]* for more information). The BQ34Z100-G1 monitors charge and discharge activity by sensing the voltage across a small-value resistor (5 mΩ to 20 mΩ typ.) between the SRP and SRN pins and in-series with the cell. By integrating charge passing through the battery, the cell's SOC is adjusted during battery charge or discharge.

The total battery capacity is found by comparing states of charge before and after applying the load with the amount of charge passed. When an application load is applied, the impedance of the cell is measured by comparing the OCV obtained from a predefined function for the present SOC with the measured voltage under load. Measurements of OCV and charge integration determine chemical state-of-charge and Chemical Capacity (Q_{max}). The initial Q_{max} value is taken from a cell manufacturers' data sheet multiplied by the number of parallel cells. The parallel value is also used for the value programmed in **Design Capacity**. The BQ34Z100-G1 acquires and updates the battery-impedance profile during normal battery usage. It uses this profile, along with SOC and the Q_{max} value, to determine *FullChargeCapacity()* and *StateOfCharge()* specifically for the present load and temperature. *FullChargeCapacity()* is reported as capacity available from a fully charged battery under the present load and temperature until *Voltage()* reaches the **Terminate Voltage**. *NominalAvailableCapacity()*

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and *FullAvailableCapacity()* are the uncompensated (no or light load) versions of *RemainingCapacity()* and *FullChargeCapacity()*, respectively.

During normal battery usage there could be instances where a small rise of SOC for a short period of time could occur at the beginning of discharge. The **[RSOC_HOLD]** option in **Pack Configuration C** prevents SOC rises during discharge. SOC will be held until the calculated value falls below the actual state.

The BQ34Z100-G1 has two flags accessed by the *Flags()* function that warn when the battery's SOC has fallen to critical levels. When *RemainingCapacity()* falls below the first capacity threshold, specified in **SOC1 Set Threshold**, the **[SOC1]** (State of Charge Initial) flag is set. The flag is cleared once *RemainingCapacity()* rises above **SOC1 Clear Threshold**. All units are in mAh.

When *RemainingCapacity()* falls below the second capacity threshold, **SOCF Set Threshold**, the **[SOCF]** (State of Charge Final) flag is set, serving as a final discharge warning. If **SOCF Set Threshold** = -1, the flag is inoperative during discharge. Similarly, when *RemainingCapacity()* rises above **SOCF Clear Threshold** and the **[SOCF]** flag has already been set, the **[SOCF]** flag is cleared. All units are in mAh.

The BQ34Z100-G1 includes charge efficiency compensation that makes use of four *Charge Efficiency* factors to correct for energy lost due to heat. This is commonly used in NiMH and Lead-Acid chemistries and is not always linear with respect to state-of-charge.

7.3.6 Impedance Track Variables

The BQ34Z100-G1 has several data flash variables that permit the user to customize the Impedance Track algorithm for optimized performance. These variables are dependent upon the power characteristics of the application as well as the cell itself.

7.3.6.1 Load Mode

Load Mode is used to select either the constant current or constant power model for the Impedance Track algorithm as used in **Load Select**. See the [Section 7.3.6.2](#) section. When **Load Mode** is 0, the *Constant Current Model* is used (default). When **Load Mode** is 1, the *Constant Power Model* is used. The **[LDMD]** bit of **CONTROL_STATUS** reflects the status of Load Mode.

7.3.6.2 Load Select

Load Select defines the type of power or current model to be used to compute load-compensated capacity in the Impedance Track algorithm. If **Load Mode** = 0 (Constant Current), then the options presented in [Table 7-13](#) are available.

Table 7-13. Current Model Used When Load Mode = 0

| LOAD SELECT VALUE | CURRENT MODEL USED |
|-------------------|---|
| 0 | Average discharge current from previous cycle: There is an internal register that records the average discharge current through each entire discharge cycle. The previous average is stored in this register. However, if this is the first cycle of the gauge, then the present average current is used. |
| 1 (default) | Present average discharge current: This is the average discharge current from the beginning of this discharge cycle until present time. |
| 2 | Average Current: based on the <i>AverageCurrent()</i> |
| 3 | Current: based on a low-pass-filtered version of <i>AverageCurrent()</i> ($\tau=14s$) |
| 4 | Design Capacity/5: C Rate based off of Design Capacity /5 or a C/5 rate in mA. |
| 6 | Use the value in User_Rate-mA : This gives a completely user configurable method. |

If **Load Mode** = 1 (*Constant Power*), then the following options are available:

Table 7-14. Constant-Power Model Used When Load Mode = 1

| LOAD SELECT VALUE | POWER MODEL USED |
|-------------------|---|
| 0 (default) | Average discharge power from previous cycle: There is an internal register that records the average discharge power through each entire discharge cycle. The previous average is stored in this register. |
| 1 | Present average discharge power: This is the average discharge power from the beginning of this discharge cycle until present time. |

Table 7-14. Constant-Power Model Used When Load Mode = 1 (continued)

| LOAD SELECT VALUE | POWER MODEL USED |
|-------------------|--|
| 2 | Average Current × Voltage: based off the <i>AverageCurrent()</i> and <i>Voltage()</i> . |
| 3 | Current × Voltage: based on a low-pass-filtered version of <i>AverageCurrent()</i> ($\tau=14s$) and <i>Voltage()</i> |
| 4 | Design Energy/5: C Rate based off of Design Energy /5 or a C/5 rate in mA. |
| 6 | Use the value in <i>User_Rate-mW/cW</i> . This gives a completely user-configurable method. |

7.3.6.3 Reserve Cap-mAh

Reserve Cap-mAh determines how much actual remaining capacity exists after reaching 0 *RemainingCapacity()* before **Terminate Voltage** is reached. A loaded rate or no-load rate of compensation can be selected for Reserve Cap by setting the [RESCAP] bit in the Pack Configuration register.

7.3.6.4 Reserve Cap-mWh/cWh

Reserve Cap-mWh determines how much actual remaining capacity exists after reaching 0 *AvailableEnergy()* before **Terminate Voltage** is reached. A loaded rate or no-load rate of compensation can be selected for Reserve Cap by setting the [RESCAP] bit in the Pack Configuration register.

7.3.6.5 Design Energy Scale

Design Energy Scale is used to select the scale/unit of a set of data flash parameters. The value of **Design Energy Scale** can be between 1 and 10 only.

When using Design Energy Scale > 1, the value for each of the parameters in [Table 7-15](#) must be adjusted to reflect the new units. See [Section 7.3.12](#).

Table 7-15. Data Flash Parameter Scale/Unit-Based on Design Energy Scale

| DATA FLASH PARAMETER | DESIGN ENERGY SCALE = 1 (default) | DESIGN ENERGY SCALE >1 |
|------------------------|-----------------------------------|--------------------------------------|
| Design Energy | mWh | Scaled by Design Energy Scale |
| Reserve Energy-mWh/cWh | mWh | Scaled by Design Energy Scale |
| Avg Power Last Run | mW | Scaled by Design Energy Scale |
| User Rate-mW/cW | mWh | Scaled by Design Energy Scale |
| T Rise | No Scale | Scaled by Design Energy Scale |

7.3.6.6 Dsg Current Threshold

This register is used as a threshold by many functions in the BQ34Z100-G1 to determine if actual discharge current is flowing into or out of the cell. The default for this register should be sufficient for most applications. This threshold should be set low enough to be below any normal application load current but high enough to prevent noise or drift from affecting the measurement.

7.3.6.7 Chg Current Threshold

This register is used as a threshold by many functions in the BQ34Z100-G1 to determine if actual charge current is flowing into or out of the cell. The default for this register should be sufficient for most applications. This threshold should be set low enough to be below any normal charge current but high enough to prevent noise or drift from affecting the measurement.

7.3.6.8 Quit Current, Dsg Relax Time, Chg Relax Time, and Quit Relax Time

The **Quit Current** is used as part of the Impedance Track algorithm to determine when the BQ34Z100-G1 enters RELAX mode from a current flowing mode in either the charge direction or the discharge direction. The value of **Quit Current** is set to a default value that should be above the standby current of the host system.

Either of the following criteria must be met to enter RELAX mode:

1. $|AverageCurrent()| < |Quit Current|$ for **Dsg Relax Time**
2. $|AverageCurrent()| > |Quit Current|$ for **Chg Relax Time**

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After about 6 minutes in RELAX mode, the device attempts to take accurate OCV readings. An additional requirement of $dV/dt < 4 \mu V/s$ is required for the device to perform Qmax updates. These updates are used in the Impedance Track algorithms. It is critical that the battery voltage be relaxed during OCV readings, and that the current is not higher than C/20 when attempting to go into RELAX mode.

Quit Relax Time specifies the minimum time required for *AverageCurrent()* to remain above the **Quit Current** threshold before exiting RELAX mode.

7.3.6.9 Qmax

Qmax Cell 0 contains the maximum chemical capacity of the cell and is determined by comparing states of charge before and after applying the load with the amount of charge passed. It also corresponds to capacity at low rate of discharge, such as C/20 rate. For high accuracy, this value is periodically updated by the device during operation.

Based on the battery cell capacity information, the initial value of chemical capacity should be entered in the **Qmax Cell 0** data flash parameter. The Impedance Track algorithm will update this value and maintain it internally in the gauge.

7.3.6.10 Update Status

The Update Status register indicates the status of the Impedance Track algorithm.

Table 7-16. Update Status Definitions

| UPDATE STATUS | STATUS |
|---------------|---|
| 0x02 | Qmax and Ra data are learned, but Impedance Track is not enabled. This should be the standard setting for a Golden Image File. |
| 0x04 | Impedance Track is enabled but Qmax and Ra data are not yet learned. |
| 0x05 | Impedance Track is enabled and only Qmax has been updated during a learning cycle. |
| 0x06 | Impedance Track is enabled. Qmax and Ra data are learned after a successful learning cycle. This should be the operation setting for end equipment. |

This register should only be updated by the device during a learning cycle or when the *IT_ENABLE()* subcommand is received. Refer to the *Preparing Optimized Default Flash Constants for Specific Battery Types Application Report (SLUA334B)*.

7.3.6.11 Avg I Last Run

The device logs the current averaged from the beginning to the end of each discharge cycle. It stores this average current from the previous discharge cycle in this register. This register should never be modified. It is only updated by the device when required.

7.3.6.12 Avg P Last Run

The device logs the power averaged from the beginning to the end of each discharge cycle. It stores this average power from the previous discharge cycle in this register. To get a correct average power reading, the device continuously multiplies instantaneous current times *Voltage()* to get power. It then logs this data to derive the average power. This register should never need to be modified. It is only updated by the device when the required.

7.3.6.13 Cell Delta Voltage

The device stores the maximum difference of *Voltage()* during short load spikes and normal load, so the Impedance Track algorithm can calculate remaining capacity for pulsed loads. It is not recommended to change this value, as the device can learn this during operation.

7.3.6.14 Ra Tables

This data is automatically updated during device operation. No user changes should be made except for reading the values from another pre-learned pack for creating Golden Image Files. Profiles have format *Cell0 R_a M*, where M is the number that indicates state-of-charge to which the value corresponds.

7.3.6.15 StateOfCharge() Smoothing

When operating conditions change (such as temperature, discharge current, and resistance, and so on), it can lead to large changes of compensated battery capacity and battery capacity remaining. These changes can result in large changes of *StateOfCharge()*. When **[SmoothEn]** is enabled in **Pack Configuration C**, the smoothing algorithm injects gradual changes of battery capacity when conditions vary. This results in a gradual change of *StateOfCharge()* and can provide a better end-user experience for *StateOfCharge()* reporting.

The *RemainingCapacity()*, *FullChargeCapacity()*, and *StateOfCharge()* are modified depending on **[SmoothEn]**, as below.

| [SmoothEn] | RemainingCapacity() | FullChargeCapacity() | StateOfCharge() |
|-------------------|----------------------------|-----------------------------|-------------------------------------|
| 0 | <i>TrueRC()</i> | <i>TrueFCC()</i> | <i>TrueRC() / TrueFCC()</i> |
| 1 | <i>FilteredRC()</i> | <i>FilteredFCC()</i> | <i>FilteredRC() / FilteredFCC()</i> |

7.3.6.16 Charge Efficiency

Tracking state-of-charge during the charge phase is relatively easy with chemistries such as Li-ion where essentially none of the applied energy from the charger is lost to heat. However, lead-acid and NiMH chemistries may demonstrate significant losses to heat during charging. Therefore, to more accurately track state of charge and Time-to-Full during the charge phase, the BQ34Z100-G1 uses four charge-efficiency factors to compensate for charge acceptance. These factors are **Charge Efficiency**, **Charge Eff Reduction Rate**, **Charge Effi Drop Off**, and **Charge Eff Temperature Compensation**.

The BQ34Z100-G1 applies the **Charge Efficiency** when *RelativeStateOfCharge()* is less than the value stored in **Charge Efficiency Drop Off**. When *RelativeStateOfCharge()* is > or equal to the value coded in **Charge Efficiency Drop Off**, **Charge Efficiency** and **Charge Efficiency Reduction Rate** determine the charge efficiency rate. **Charge Efficiency Reduction Rate** defines the percent efficiency reduction per percentage point of *RelativeStateOfCharge()* over **Charge Efficiency Drop Off**. The **Charge Efficiency Reduction Rate** has units of 0.1%. The BQ34Z100-G1 also adjusts the efficiency factors for temperature. **Charge Efficiency Temperature Compensation** defines the percent efficiency reduction per degree C over 25°C. **Charge Efficiency Temperature Compensation** has units of 0.01%.

Applying the four factors:

Effective Charge Efficiency % = **Charge Efficiency** – **Charge Eff Reduction Rate** [*RSOC()* – **Charge Effi Drop Off**] – **Charge Eff Temperature Compensation** [*Temperature* – 25°C]

Where: *RSOC()* ≥ **Charge Efficiency** and *Temperature* ≥ 25°C

7.3.6.17 Lifetime Data Logging

The Lifetime Data Logging function helps development and diagnosis with the fuel gauge.

Note

IT_ENABLE must be enabled (Command 0x0021) for lifetime data logging functions to be active.

The fuel gauge logs the lifetime data as specified in the **Lifetime Data** and **Lifetime Temp Samples** data flash subclasses. The data log recordings are controlled by the **Lifetime Resolution** data flash subclass.

The Lifetime Data Logging can be started by setting the **IT_ENABLE** bit and setting the **LTUpdate Time** register to a non-zero value.

Once the Lifetime Data Logging function is enabled, the measured values are compared to what is already stored in the data flash. If the measured value is higher than the maximum or lower than the minimum value stored in the data flash by more than the "Resolution" set for at least one parameter, the entire Data Flash Lifetime Registers are updated after at least **LTUpdateTime**.

LTUpdateTime sets the minimum update time between DF writes. When a new maximum or minimum is detected, an LT Update window of [update time] second is enabled and the DF writes occur at the end of this

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window. Any additional max/min value detected within this window will also be updated. The first new max/min value detected after this window will trigger the next LT Update window.

Internal to the fuel gauge, there exists a RAM maximum/minimum table in addition to the DF maximum/minimum table. The RAM table is updated independent of the resolution parameters. The DF table is updated only if at least one of the RAM parameters exceeds the DF value by more than the resolution associated with it. When DF is updated, the entire RAM table is written to DF. Consequently, it is possible to see a new maximum or minimum value for a certain parameter even if the value of this parameter never exceeds the maximum or minimum value stored in the data flash for this parameter value by the resolution amount.

The Life Time Data Logging of one or more parameters can be reset or restarted by writing new default (or starting) values to the corresponding data flash registers through sealed or unsealed access as described below. However, when using unsealed access, new values will only take effect after device reset.

The logged data can be accessed as RW in UNSEALED mode from the Lifetime Data Subclass (Subclass ID = 59) of data flash. Lifetime data may be accessed (RW) when sealed using a process identical **Manufacturer Info Block B**. The *DataFlashBlock* command code is 4. Note only the first 32 bytes of lifetime data (not resolution parameters) can be RW when sealed. See [Section 7.3.3.2](#) for sealed access. The logging settings such as Temperature Resolution, Voltage Resolution, Current Resolution, and Update Time can be configured only in UNSEALED mode by writing to the Lifetime Resolution Subclass (SubclassID = 66) of the data flash.

The Lifetime resolution registers contain the parameters that set the limits related to how much a data parameter must exceed the previously logged maximum/minimum value to be updated in the lifetime log. For example, V must exceed MaxV by more than Voltage Resolution to update MaxV in the data flash.

7.3.7 Device Configuration

The BQ34Z100-G1 has many features that can be enabled, disabled, or modified through settings in the Pack Configuration registers. These registers are programmed/read via the methods described in [Section 7.3.3.1](#).

7.3.7.1 Pack Configuration Register**Table 7-17. Pack Configuration Register Bits**

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-----------|-----------|--------|--------|-------|---------|----------|--------|-------|
| High Byte | RESCAP | CAL_EN | SCALED | RSVD | VOLTSEL | IWAKE | RSNS1 | RSNS0 |
| Low Byte | RFACTSTEP | SLEEP | RMFCC | NI DT | NI DV | QPCCLEAR | GNDSEL | TEMPS |

Legend: **RSVD** = Reserved

RESCAP: No-load rate of compensation is applied to the reserve capacity calculation. True when set. Default is 0.

CAL_EN: When enabled, entering CALIBRATION mode is permitted. For special use only. Default = 0.

SCALED: Scaled Capacity and/or Current bit. The mA, mAh, and cWh settings and reports will take on a value that is artificially scaled. This setting has no actual effect within the gauge. It is the responsibility of the host to reinterpret the reported values. Scaled current measurement is achieved by calibrating the current measurement to a value lower than actual.

VOLTSEL: This bit selects between the use of an internal or external battery voltage divider. The internal divider is for single cell use only. Default is 0.

1 = External

0 = Internal

IWAKE/RSNS1/RSNS0: These bits configure the current wake function (see [Table 7-23](#)). Default is 0/0/1.

RFACTSTEP: Enables Ra step up/down to Max/Min Res Factor before disabling Ra updates. Default is 1.

SLEEP: The fuel gauge can enter sleep, if operating conditions allow. True when set. Default is 1.

RMFCC: RM is updated with the value from FCC on valid charge termination. True when set. Default is 1.

NI DT: Performs primary charge termination using the $\Delta T/\Delta t$ algorithm. See [Section 7.3.11](#). This bit is only acted upon when a NiXX Chem ID is used.

NI DV: Performs primary charge termination using the $-\Delta V$ algorithm. See [Section 7.3.11](#). This bit is only acted upon when a NiXX Chem ID is used.

QPCCLEAR: Upon exit from RELAX where a DOD update occurred, the QMAX Passed Charge is cleared.

- GNDSEL:** The ADC ground select control. The VSS pin is selected as ground reference when the bit is clear. Pin 10 is selected when the bit is set.
- TEMPS:** Selects external thermistor for *Temperature()* measurements. True when set. Uses internal temp when clear. Default is 1.

7.3.7.2 Pack Configuration B Register

Table 7-18. Pack Configuration B Register Bits

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-----------|-------|---------|-------|-------|----------|-------|---------|
| CHGDoDEoC | RSVD | VconsEN | RSVD | JEITA | LFPRelax | DoDWT | FConvEN |

Legend: **RSVD** = Reserved

- CHGDoDEoC:** Enable DoD at EoC during charging only. True when set. Default is 1. Default setting is recommended.
- VconsEN:** Enable voltage measurement consistency check. True when set. Default is 1. Default setting is recommended.
- JEITA:** Enables *ChargingVoltage()* and *ChargingCurrent()* to report data per the JEITA charging algorithm. When disabled, the values programmed in **Cell Charge Voltage** T2–T3 and **Charge Current** T2–T3 are reported.
- LFPRelax:** Enables Lithium Iron Phosphate RELAX mode
- DoDWT:** Enable Dod weighting for LiFePO₄ support when chemical ID 400 series is selected. True when set. Default is 1.
- FConvEN:** Enable fast convergence algorithm. Default is 1. Default setting is recommended.

7.3.7.3 Pack Configuration C Register

Table 7-19. Pack Configuration C Register Bits

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|----------|-----------|-------------|--------------|--------|---------------|-----------------|--------|
| SOH_DISP | RSOC_HOLD | FF_NEAR_EDV | SleepWakeCHG | LOCK_0 | RELAX_JUMP_OK | RELAX_SMOOTH_OK | SMOOTH |

- SOH_DISP:** Enables State-of-Health Display
- RSOC_HOLD:** **RSOC_HOLD** enables RSOC Hold Feature preventing RSOC from increasing during discharge.
NOTE: It is recommended to disable **RSOC_HOLD** when SOC Smoothing is enabled (SMOOTH = 1).
- FF_NEAR_EDV:** Enables Fast Filter Near EDV
- SleepWakeCHG:** Enable for faster sampling in SLEEP mode. Default setting is recommended.
- LOCK_0:** Keep *RemainingCapacity()* and *RelativeStateOfCharge()* jumping back during relaxation after 0 is reached during discharge.
- RELAX_JUMP_OK:** Allows RSOC jump during RELAX mode if [SMOOTH = 1]
- RELAX_SMOOTH_OK:** Smooth RSOC during RELAX mode if [SMOOTH = 1]
- SMOOTH:** Enabled RSOC Smoothing

7.3.8 Voltage Measurement and Calibration

The device is shipped with a factory configuration for the default case of the 1-series Li-ion cell. This can be changed by setting the VOLTSEL bit in the Pack Configuration register and by setting the number of series cells in the data flash configuration section.

Multi-cell applications, with voltages up to 65535 mV, may be gauged by using the appropriate input scaling resistors such that the maximum battery voltage, under all conditions, appears at the BAT input as approximately 900 mV. The actual gain function is determined by a calibration process and the resulting voltage calibration factor is stored in the data flash location **Voltage Divider**.

For single-cell applications, an external divider network is not required. Inside the IC, behind the BAT pin is a nominal 5:1 voltage divider with 88 K Ω in the top leg and 22 K Ω in the bottom leg. This internal divider network is enabled by clearing the VOLTSEL bit in the Pack Configuration register. This ratio is optimum for directly measuring a single Li-ion cell where charge voltage is limited to 4.5 V.

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For higher voltage applications, an external resistor divider network should be implemented as per the reference designs in this document. The quality of the divider resistors is very important to avoid gauging errors over time and temperature. It is recommended to use 0.1% resistors with 25-ppm temperature coefficient. Alternately, a matched network could be used that tracks its dividing ratio with temperature and age due to the similar geometry of each element. Calculation of the series resistor can be made per the equation below.

Note

Exceeding **Vin max mV** results in a measurement with degraded linearity.

The bottom leg of the divider resistor should be in the range of 15 K Ω to 25 K, using 16.5 K Ω :

$$R_{series} = 16500 \Omega (V_{in \max \text{ mV}} - 900 \text{ mV}) / 900 \text{ mV}$$

For all applications, the **Voltage Divider** value in data flash will be used by the firmware to calibrate the total divider ratio. The nominal value for this parameter is the maximum expected value for the stack voltage. The calibration routine adjusts the value to force the reported voltage to equal the actual applied voltage.

7.3.8.1 1S Example

For stack voltages under 4.5 V max, it is not necessary to provide an external voltage divider network. The internal 5:1 divider should be selected by clearing the VOLTSEL bit in the Pack Configuration register. The default value for **Voltage Divider** is 5000 (representing the internal 5000:1000 mV divider) when no external divider resistor is used, and the default number of series cells = 1. In the 1-S case, there is usually no requirement to calibrate the voltage measurement, since the internal divider is calibrated during factory test to within 2 mV.

7.3.8.2 7S Example

In the multi-cell case, the hardware configuration is different. An external voltage divider network is calculated using the Rseries formula above. The bottom leg of the divider should be in the range of 15 K Ω to 25 K Ω . For more details on configuration, see [Section 8.2.2.1](#).

7.3.8.3 Autocalibration

The device provides an autocalibration feature that will measure the voltage offset error across SRP and SRN from time-to-time as operating conditions change. It subtracts the resulting offset error from normal sense resistor voltage, V_{SR} , for maximum measurement accuracy.

The gas gauge performs a single offset calibration when:

1. The interface lines stay low for a minimum of **Bus Low Time** and
2. $V_{SR} > \text{Deadband}$.

The gas gauge also performs a single offset when:

1. The condition of $AverageCurrent() \leq \text{Autocal Min Current}$ and
2. {Voltage change since last offset calibration $\geq \text{Delta Voltage}$ } or {temperature change since last offset calibration is greater than **Delta Temperature** for $\geq \text{Autocal Time}$ }.

Capacity and current measurements should continue at the last measured rate during the offset calibration when these measurements cannot be performed. If the battery voltage drops more than **Cal Abort** during the offset calibration, the load current has likely increased considerably; hence, the offset calibration will be aborted.

7.3.9 Temperature Measurement

The BQ34Z100-G1 can measure temperature via the on-chip temperature sensor or via the TS input, depending on the setting of the [TEMPS] bit *PackConfiguration()*. The bit is set by using the *PackConfiguration()* function, described in [Section 7.3.2](#).

Temperature measurements are made by calling the *Temperature()* function (see [Section 7.3.1.1](#) for specific information).

When an external thermistor is used, REG25 (pin 7) is used to bias the thermistor and TS (pin 11) is used to measure the thermistor voltage (a pull-down circuit is implemented inside the device). The device then correlates the voltage to temperature, assuming the thermistor is a Semitec 103AT or similar device.

7.3.10 Overtemperature Indication

7.3.10.1 Overtemperature: Charge

If during charging, *Temperature()* reaches the threshold of **OT Chg** for a period of **OT Chg Time** and *AverageCurrent()* > **Chg Current Threshold**, then the [OTC] bit of *Flags()* is set. Note: If **OT Chg Time** = 0, then the feature is completely disabled.

When *Temperature()* falls to **OT Chg Recovery**, the [OTC] of *Flags()* is reset.

7.3.10.2 Overtemperature: Discharge

If during discharging *Temperature()* reaches the threshold of **OT Dsg** for a period of **OT Dsg Time**, and *AverageCurrent()* ≤ **-Dsg Current Threshold**, then the [OTD] bit of *Flags()* is set. If **OT Dsg Time** = 0, then the feature is completely disabled.

When *Temperature()* falls to **OT Dsg Recovery**, the [OTD] bit of *Flags()* is reset.

7.3.11 Charging and Charge Termination Indication

For proper BQ34Z100-G1 operation, the battery per cell charging voltage must be specified by the user in **Cell Charging Voltage**. The default value for this variable is **Charging Voltage** = 4200 mV. This parameter should be set to the recommended charging voltage for the entire battery stack divided by the number of series cells.

The device detects valid charge termination in one of three ways:

1. Current Taper method:
 - a. During two consecutive periods of **Current Taper Window**, the *AverageCurrent()* is less than **Taper Current** AND
 - b. During the same periods, the accumulated change in capacity > 0.25 mAh / **Taper Current Window** AND
 - c. *Voltage()* is > **Charging Voltage** – **Charging Taper Voltage**. When this occurs, the [CHG] bit of *Flags()* is cleared. Also, if the [RMFCC] bit of Pack Configuration is set, and *RemainingCapacity()* is set equal to *FullChargeCapacity()*.
2. Delta Temperature ($\Delta T/\Delta t$) method—For $\Delta T/\Delta t$, the BQ34Z100-G1 detects an increase in temperature over many seconds. The $\Delta T/\Delta t$ setting is programmable in the temperature step, **Delta Temp** (0°C – 25.5°C), and the time step, **Delta Temp Time** (0 s–1000 s). Typical settings for 1°C/minute include 2°C/120 s and 3°C/180 s (default). Longer times may be used for increased slope resolution.

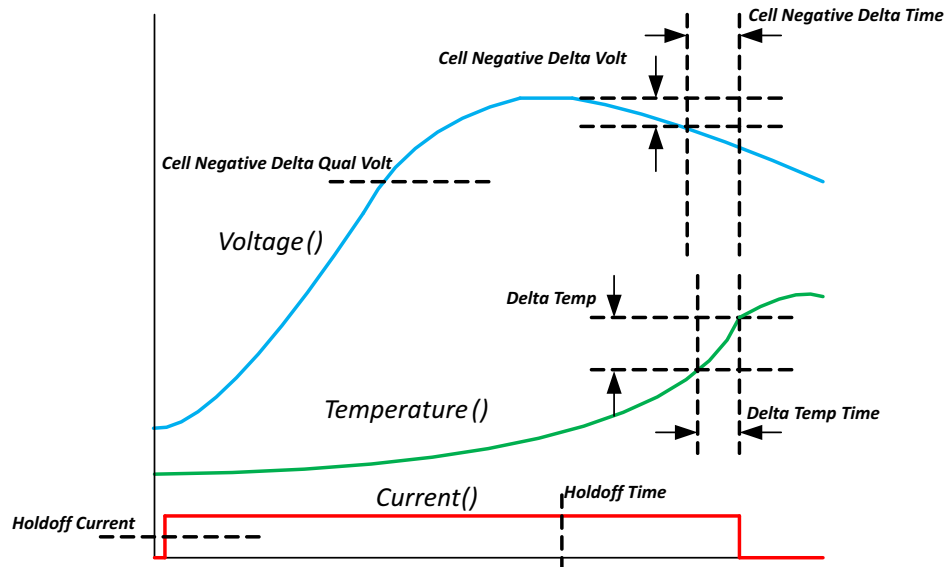
In addition to the $\Delta T/\Delta t$ timer, a holdoff timer starts when the battery is charged at more than **Holdoff Current** (default is 240 mA), and the temperature is above **Holdoff Temp**. Until this timer expires, $\Delta T/\Delta t$ detection is suspended. If *Current()* drops below **Holdoff Current** or *Temperature()* below **Holdoff Temp**, the holdoff timer resets and restarts only when the current and temperature conditions are met again.

3. Negative Delta Voltage ($-\Delta V$) method—For negative delta voltage, the BQ34Z100-G1 detects a charge termination when the pack voltage drops during charging by **Cell Negative Delta Volt** for a period of **Cell Negative Delta Time** during which time *Voltage()* must be greater than **Cell Negative Qual Volt**.

When either condition occurs, the *Flags()*[CHG] bit is cleared. Also, if the [RMFCC] bit of Pack Configuration is set, and *RemainingCapacity()* is set equal to *FullChargeCapacity()*.

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**Figure 7-1. NiXX Termination****7.3.12 SCALED Mode**

The device supports high current and high capacity batteries above 32.76 Amperes and 29 Ampere-Hours indirectly by scaling the actual sense resistor value compared with the calibrated value stored in the device. The need for this is due to the standardization of a 2-byte data command having a maximum representation of ± 32767 . When **[SCALED]** is set in the **Pack Configuration** register, this indicates that the current and capacity data is scaled.

It is important to know that setting the SCALED flag does not actually change anything in the operation of the gauge. It serves as a notice to the host that the various reported values should be reinterpreted based on the scale used. Because the flag has no actual effect, it can be used to represent other scaling values. See [Section 7.3.6.5](#).

Note

It is recommended to only scale by a value between 1 and 10 to optimize resolution and accuracy while still extending the data range.

7.3.13 LED Display

The device supports multiple options for using one to 16 LEDs as an output device to display the remaining state of charge, or, if Pack Configuration C [SOH_DISP] is set, then state-of-health. The LED/COMM Configuration register determines the behavior.

Table 7-20. LED/COMM Configuration Bits

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|----------|----------|----------|----------|--------|-----------|-----------|-----------|
| EXT_LED3 | EXT_LED2 | EXT_LED1 | EXT_LED0 | LED_ON | LED_Mode2 | LED_Mode1 | LED_Mode0 |

Bits 0, 1, 2 are a code for one of five modes. 0 = No LED, 1 = Single LED, 2 = Four LEDs, 3 = External LEDs with I²C comm, 4 = External LEDs with HDQ comm.

Setting Bit 3, LED_ON, will cause the LED display to be always on, except in Single LED mode where it is not applicable. When clear (default), the LED pattern will only be displayed after holding an LED display button for one to two seconds. The button applies 2.5 V from REG25 pin 7 to VEN pin 2 (refer to [Section 8.2](#)). The **LED Hold Time** parameter may be used to configure how long the LED display remains on if LED_ON is clear. **LED Hold Time** configures the update interval for the LED display if LED_ON is set.

Bits 4, 5, 6, and 7 are a binary code for number of external LEDs. Code 0 is reserved. Codes 1 through 15 represents 2~16 external LEDs. So, number of External LEDs is 1 + Value of the 4-bit binary code. Display of Remaining Capacity *RemainingCapacity()* or *StateOfHealth()* will be evenly divided among the selected number of LEDs.

Single LED mode—Upon detecting an A/D value representing 2.5 V on the VEN pin, Single LED mode will toggle the LED as duty cycle on within a period of 1 s where each 1% of RSOC is a 7.8125-ms high time. So, for example, 10% RSOC or SOH will have the LED on for 78.1 ms and off for 921.9 ms. 90% RSOC or SOH will have the LED on for 703.125 ms and off for 296.875 ms. Any value > 90% will display as 90%.

Four-LED mode—Upon detecting an A/D value representing 2.5 V on the VEN pin, Four-LED mode will display the RSOC or SOH by driving pins RC2(LED1), RC0(LED2), RA1(LED3),RA2(LED4) in a proportional manner where each LED represents 25% of the remaining state-of-charge. For example, if RSOC or SOH = 67%, three LEDs will be illuminated.

External LED mode—Upon detecting an A/D value representing 2.5 V on the VEN pin, External LED mode will transmit the RSOC into an SN74HC164 (for 2–8 LEDs) or two SN74HC164 devices (for 9–16 LEDs) using a bit-banged approach with RC2 as Clock and RC0 as Data (see [Figure 8-4](#)). LEDs will be lit for a number of seconds as defined in a data flash parameter. Refer to the *SN54HC164, SN74HC164 8-Bit Parallel-Out Serial Shift Registers Data Sheet (SCLS115E)* for details on these devices.

Extended commands are available to turn the LEDs on and off for test purposes.

7.3.14 Alert Signal

Based on the selected LED mode, various options are available for the hardware implementation of an Alert signal. Software configuration of the Alert Configuration register determines which alert conditions will assert the $\overline{\text{ALERT}}$ pin.

Table 7-21. $\overline{\text{ALERT}}$ Signal Pins

| MODE | DESCRIPTION | ALERT PIN | ALERT PIN NAME | CONFIG REGISTER HEX CODE | COMMENT |
|------|---|-----------|----------------|--------------------------|---|
| 0 | No LED | 1 | P2 | 0 | |
| 1 | Single LED | 1 | P2 | 1 | |
| 2 | 4 LED | 11 | P6 | 2 | Filter and FETs are required to eliminate temperature sense pulses. See Section 8.2 . |
| 3 | 5-LED Expander with I ² C Host Comm | 12 | P5 | 43 | |
| 3 | 10-LED Expander with I ² C Host Comm | 12 | P5 | 93 | |
| 4 | 5-LED Expander with HDQ Host Comm | 13 | P4 | 44 | |
| 4 | 10-LED Expander with HDQ Host Comm | 13 | P4 | 94 | |

The port used for the Alert output will depend on the mode setting in **LED/Comm Configuration** as defined in [Table 7-21](#). The default mode is 0. The $\overline{\text{ALERT}}$ pin will be asserted by driving LOW. However, note that in LED/COM mode 2, pin TS/P6, which has a dual purpose as temperature sense pin, will be driven low except when temperature measurements are made each second. See the reference schematic ([Figure 8-4](#)) for filter implementation details if host alert sensing requires a continuous signal.

The $\overline{\text{ALERT}}$ pin will be a logical OR of the selected bits in the new configuration register when asserted in the Flags register. The default value for Alert Configuration register is 0.

Table 7-22. Alert Configuration Register Bit Definitions

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-----------|-------|-------|----------|--------|---------|-------|-------|-------|
| High Byte | OTC | OTD | BAT_HIGH | BATLOW | CHG_INH | XCHG | FC | CHG |

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Table 7-22. Alert Configuration Register Bit Definitions (continued)

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|----------|----------|-------|-------|-------|-------|-------|-------|-------|
| Low Byte | OCVTAKEN | RSVD | RSVD | CF | RSVD | RCA | EOD | DSG |

Legend: **RSVD** = Reserved

OTC: Over-Temperature in Charge condition is detected. $\overline{\text{ALERT}}$ is enabled when set.

OTD: Over-Temperature in Discharge condition is detected. $\overline{\text{ALERT}}$ is enabled when set.

BAT_HIGH: Battery High bit that indicates a high battery voltage condition. Refer to the data flash **CELL BH** parameters for threshold settings. $\overline{\text{ALERT}}$ is enabled when set.

BATLOW: Battery Low bit that indicates a low battery voltage condition. Refer to the data flash parameters for threshold settings. $\overline{\text{ALERT}}$ is enabled when set.

CHG_INH: Charge Inhibit: unable to begin charging. Refer to the data flash [**Charge Inhibit Temp Low, Charge Inhibit Temp High**] parameters. $\overline{\text{ALERT}}$ is enabled when set.

XCHG: Charging disallowed $\overline{\text{ALERT}}$ is enabled when set.

FC: Full charge is detected. FC is set when charge termination is reached and **FC Set%** = -1 (see [Section 7.3.11](#) for details) or *StateOfCharge()* is larger than **FC Set%** and **FC Set%** is not -1. $\overline{\text{ALERT}}$ is enabled when set.

CHG: (Fast) charging allowed. $\overline{\text{ALERT}}$ is enabled when set.

OCVTAKEN: Cleared on entry to RELAX mode and set to 1 when OCV measurement is performed in RELAX mode. $\overline{\text{ALERT}}$ is enabled when set.

CF: Condition Flag set. $\overline{\text{ALERT}}$ is enabled when set.

RCA: Remaining Capacity Alarm reached. $\overline{\text{ALERT}}$ is enabled when set.

EOD: End-of-Discharge Threshold reached. $\overline{\text{ALERT}}$ is enabled when set.

DSG: Discharging detected. $\overline{\text{ALERT}}$ is enabled when set.

7.3.15 Communications**7.3.15.1 Authentication**

The BQ34Z100-G1 can act as a SHA-1/HMAC authentication slave by using its internal engine. Sending a 160-bit SHA-1 challenge message to the device will cause the IC to return a 160-bit digest, based upon the challenge message and hidden plain-text authentication keys. When this digest matches an identical one generated by a host or dedicated authentication master (operating on the same challenge message and using the same plain text keys), the authentication process is successful.

The device contains a default plain-text authentication key of 0x0123456789ABCDEFEDCBA987654321. If using the device's internal authentication engine, the default key can be used for development purposes, but should be changed to a secret key and the part immediately sealed before putting a pack into operation.

7.3.15.2 Key Programming

When the device's SHA-1/HMAC internal engine is used, authentication keys are stored as plain-text in memory. A plain-text authentication key can only be written to the device while the IC is in UNSEALED mode. Once the IC is UNSEALED, a 0x00 is written to *BlockDataControl()* to enable the authentication data commands. Next, subclass ID and offset are specified by writing 0x70 and 0x00 to *DataFlashClass()* and *DataFlashBlock()*, respectively. The device is now prepared to receive the 16-byte plain-text key, which must begin at command location 0x4C. The key is accepted once a successful checksum has been written to *BlockDataChecksum()* for the entire 32-byte block (0x40 through 0x5F), not just the 16-byte key.

7.3.15.3 Executing an Authentication Query

To execute an authentication query in UNSEALED mode, a host must first write 0x01 to the *BlockDataControl()* command to enable the authentication data commands. If in SEALED mode, 0x00 must be written to *DataFlashBlock()*.

Next, the host writes a 20-byte authentication challenge to the *AuthenticateData()* address locations (0x40 through 0x53). After a valid checksum for the challenge is written to *AuthenticateChecksum()*, the device uses the challenge to perform its own SHA-1/HMAC computation in conjunction with its programmed keys. The

resulting digest is written to *AuthenticateData()*, overwriting the pre-existing challenge. The host may then read this response and compare it against the result created by its own parallel computation.

7.3.15.4 HDQ Single-Pin Serial Interface

The HDQ interface is an asynchronous return-to-one protocol where a processor sends the command code to the device. With HDQ, the least significant bit (LSB) of a data byte (command) or word (data) is transmitted first. Note that the DATA signal on pin 12 is open-drain and requires an external pull-up resistor. The 8-bit command code consists of two fields: the 7-bit HDQ command code (bits 0–6) and the 1-bit R/W field (MSB Bit 7). The R/W field directs the device either to:

- Store the next 8 or 16 bits of data to a specified register or
- Output 8 or 16 bits of data from the specified register.

The HDQ peripheral can transmit and receive data as either an HDQ master or slave.

The return-to-one data bit frame of HDQ consists of three distinct sections. The first section is used to start the transmission by either the host or by the device taking the DATA pin to a logic-low state for a time $t_{STRH,B}$. The next section is for data transmission where the data is valid for a time t_{DSU} after the negative edge used to start communication. The data is held until a time t_{DV} , allowing the host or device time to sample the data bit. The final section is used to stop the transmission by returning the DATA pin to a logic-high state by at least a time t_{SSU} after the negative edge used to start communication. The final logic-high state is held until the end of $t_{CYCH,B}$, allowing time to ensure the transmission was stopped correctly. The timing for data and break communication is shown in [Section 6.13](#).

HDQ serial communication is normally initiated by the host processor sending a break command to the device. A break is detected when the DATA pin is driven to a logic-low state for a time t_B or greater. The DATA pin should then be returned to its normal ready high logic state for a time t_{BR} . The device is now ready to receive information from the host processor.

The device is shipped in the I²C mode. TI provides tools can be used to switch from I²C to HDQ communications.

7.3.15.5 I²C Interface

The gas gauge supports the standard I²C read, incremental read, one-byte write quick read, and functions. The 7-bit device address (ADDR) is the most significant 7 bits of the hex address and is fixed as 1010101. The 8-bit device address is therefore 0xAA or 0xAB for write or read, respectively.

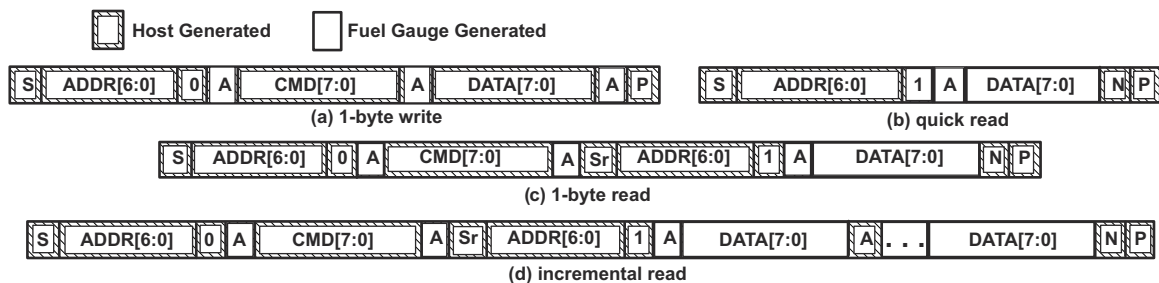


Figure 7-2. Supported I²C formats: (a) 1-byte write, (b) quick read, (c) 1 byte-read, and (d) incremental read (S = Start, Sr = Repeated Start, A = Acknowledge, N = No Acknowledge, and P = Stop).

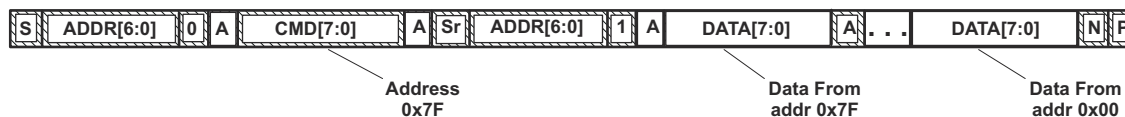
The “quick read” returns data at the address indicated by the address pointer. The address pointer, a register internal to the I²C communication engine, increments whenever data is acknowledged by the device or the I²C master. “Quick writes” function in the same manner and are a convenient means of sending multiple bytes to consecutive command locations (such as 2-byte commands that require two bytes of data).



Figure 7-3. Attempt To Write a Read-Only Address (Nack After Data Sent By Master)

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**Figure 7-4. Attempt To Read An Address Above 0x7F (Nack Command)****Figure 7-5. Attempt At Incremental Writes (nack All Extra Data Bytes Sent)****Figure 7-6. Incremental Read at the Maximum Allowed Read Address**

The I²C engine releases both SDA and SCL if the I²C bus is held low for **Bus Low Time**. If the gas gauge was holding the lines, releasing them frees the master to drive the lines. If an external condition is holding either of the lines low, the I²C engine enters the low-power SLEEP mode.

7.3.15.6 Switching Between I²C and HDQ Modes

Texas Instruments ships the BQ34Z100-G1 device in I²C mode (factory default); however, this mode can be changed to HDQ mode if needed.

Note

To make changes in the data flash, the device must be in I²C mode.

7.3.15.6.1 Converting to HDQ Mode

Using the Battery Management Studio (bqStudio) tool to configure the BQ34Z100-G1 to HDQ mode, a write to the Control command [0x00] of [0x7C40] is required.

To configure HDQ mode with bqStudio:

1. Navigate to the *Registers* screen. HDQ mode is configured by writing data [0x7C40] to Control command [0x00].
2. Click on the **Control value** field.
3. Write 0x7C40 into the text field and click **OK**. Because the change in communication protocol involves writing a flag for the new protocol to data flash, it takes about 200 ms to complete. During this time, communications are disabled. Once the command takes effect, the bqStudio will no longer communicate with the gauge.
4. Close bqStudio. Change communication connections from the gauge to the HDQ port of the EV2400 device (www.ti.com/tool/ev2400 for more information). Run bqStudio. The bqStudio auto-detection only works for devices that operate in I²C mode.

When the BQ34Z100-G1 device is in HDQ mode, it will not be detected.

5. Select BQ34Z100-G1 manually. Click **OK** to all messages that indicate that the device is not detected or not responsive. When the *Registers* screen starts, it will take a period of time from when bqStudio first tries to communicate with the device in I²C before trying HDQ mode.

Once it is complete, the *Registers* screen will display data as it had done initially when it was in I²C mode. The refresh is noticeably slower, due to the slow speed of HDQ.

Use the *Registers* screen only while the BQ34Z100-G1 is in HDQ mode. All other functions will not be supported in Battery Management Studio.

7.3.15.6.2 Converting to I²C Mode

Texas Instruments ships the BQ34Z100-G1 device in I²C mode, which is required when updating data flash. However, this mode can be changed to HDQ mode if needed.

To configure the device to use I²C mode when presently in the HDQ mode, a write to the Control command [0x00] of [0x29E7] is required. Use the Battery Management Studio (bqStudio) tool, as follows:

1. Click on the **Control value** field. Write [0x29E7] in the text field and click **OK**. Once the command takes effect, bqStudio will no longer communicate with the gauge.
2. Close bqStudio. Change communication connections from the gauge to the I²C port of the EV2400 device. Run bqStudio.

7.3.16 Power Control

7.3.16.1 Reset Functions

When the device detects either a hardware or software reset (\overline{MRST} pin is driven low or the [RESET] bit of *Control()* is initiated, respectively), it determines the type of reset and increments the corresponding counter. This information is accessible by issuing the command *Control()* function with the RESET_DATA subcommand.

As shown in Figure 7-7, if a partial reset was detected, a RAM checksum is generated and compared against the previously stored checksum. If the checksum values do not match, the RAM is reinitialized (a "Full Reset"). The stored checksum is updated every time RAM is altered.

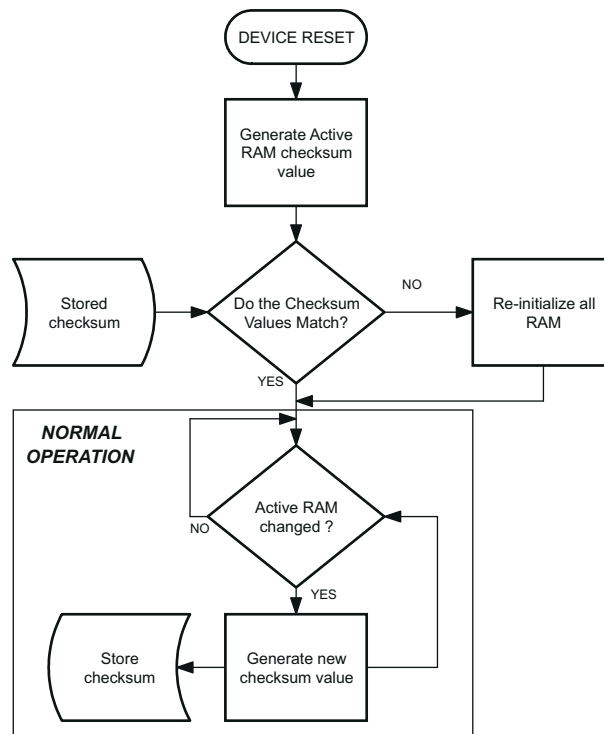


Figure 7-7. Partial Reset Flow Diagram

7.3.16.2 Wake-Up Comparator

The wake up comparator is used to indicate a change in cell current while the device is in SLEEP mode. *PackConfiguration()* uses bits [RSNS1–RSNS0] to set the sense resistor selection. *PackConfiguration()* uses the [IWAKE] bit to select one of two possible voltage threshold ranges for the given sense resistor selection. An internal interrupt is generated when the threshold is breached in either charge or discharge directions. A setting of 0x00 of RSNS1..0 disables this feature.

Table 7-23. I_{WAKE} t=Threshold Settings

| RSNS1 ⁽¹⁾ | RSNS0 | IWAKE | Vth(SRP–SRN) |
|----------------------|-------|-------|----------------------|
| 0 | 0 | 0 | Disabled |
| 0 | 0 | 1 | Disabled |
| 0 | 1 | 0 | +1.25 mV or –1.25 mV |

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Table 7-23. I_{WAKE} t=Threshold Settings (continued)

| RSNS1 ⁽¹⁾ | RSNS0 | IWAKE | V _{th} (SRP–SRN) |
|----------------------|-------|-------|---------------------------|
| 0 | 1 | 1 | +2.5 mV or –2.5 mV |
| 1 | 0 | 0 | +2.5 mV or –2.5 mV |
| 1 | 0 | 1 | +5 mV or –5 mV |
| 1 | 1 | 0 | +5 mV or –5 mV |
| 1 | 1 | 1 | +10 mV or –10 mV |

(1) The actual resistance value vs. the setting of the sense resistor is not important. Only the actual voltage threshold when calculating the configuration is important.

7.3.16.3 Flash Updates

Data flash can only be updated if $Voltage() \geq Flash\ Update\ OK\ Voltage$. Flash programming current can cause an increase in LDO dropout. The value of `Flash Update OK Voltage` should be selected such that the device V_{CC} voltage does not fall below its minimum of 2.4 V during Flash write operations. The default value of 2800 mV is appropriate; however, for more information, refer to [Step 3](#).

7.4 Device Functional Modes

The device has three power modes: NORMAL mode, SLEEP mode, and FULL SLEEP mode.

- In NORMAL mode, the device is fully powered and can execute any allowable task.
- In SLEEP mode, the gas gauge exists in a reduced-power state, periodically taking measurements and performing calculations.
- In FULL SLEEP mode, the high frequency oscillator is turned off, and power consumption is further reduced compared to SLEEP mode.

7.4.1 NORMAL Mode

The gas gauge is in NORMAL mode when not in any other power mode. During this mode, $AverageCurrent()$, $Voltage()$, and $Temperature()$ measurements are taken, and the interface data set is updated. Determinations to change states are also made. This mode is exited by activating a different power mode.

7.4.2 SLEEP Mode

SLEEP mode is entered automatically if the feature is enabled (**Pack Configuration [SLEEP] = 1**) and $Average\ Current()$ is below the programmable level **Sleep Current**. Once entry to sleep has been qualified but prior to entry to SLEEP mode, the device performs an ADC autocalibration to minimize offset. Entry to SLEEP mode can be disabled by the [SLEEP] bit of $Pack\ Configuration()$, where 0 = disabled and 1 = enabled. During SLEEP mode, the device periodically wakes to take data measurements and updates the data set, after which it then returns directly to SLEEP. The device exits SLEEP if any entry condition is broken, a change in protection status occurs, or a current in excess of I_{WAKE} through R_{SENSE} is detected.

7.4.3 FULL SLEEP Mode

FULL SLEEP mode is entered automatically when the device is in SLEEP mode and the timer counts down to 0 ($Full\ Sleep\ Wait\ Time > 0$). FULL SLEEP mode is disabled when $Full\ Sleep\ Wait\ Time$ is set to 0.

During FULL SLEEP mode, the device periodically takes data measurements and updates its data set. However, a majority of its time is spent in an idle condition.

The gauge exits the FULL SLEEP mode when there is any communication activity. Therefore, the execution of `SET_FULLSLEEP` sets [FULLSLEEP] bit, but the EVSW might still display the bit clear. The FULL SLEEP mode can be verified by measuring the current consumption of the gauge. In this mode, the high frequency oscillator is turned off. The power consumption is further reduced compared to the SLEEP mode.

While in FULL SLEEP mode, the fuel gauge can suspend serial communications as much as 4 ms by holding the communication line(s) low. This delay is necessary to correctly process host communication since the fuel gauge processor is mostly halted. For HDQ communication one host message will be dropped.

8 Application and Implementation

Note

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

8.1 Application Information

The BQ34Z100-G1 is a flexible gas gauge device with many options. The major configuration choices comprise the battery chemistry, digital interface, and display.

8.2 Typical Applications

Figure 8-1 is a simplified diagram of the main features of the BQ34Z100-G1. Specific implementations detailing the main configuration options are shown later in this section.

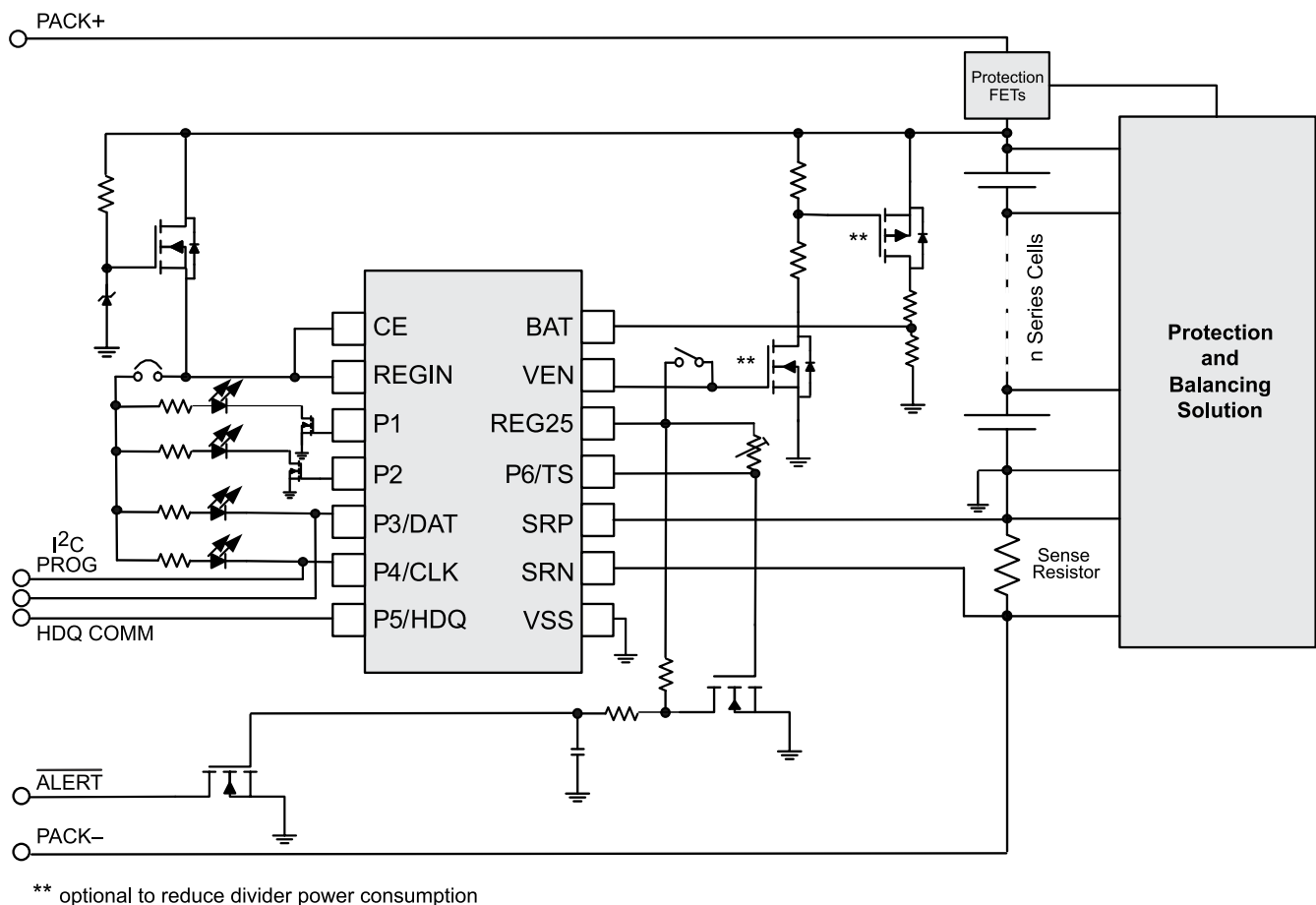


Figure 8-1. BQ34Z100-G1 Simplified Implementation

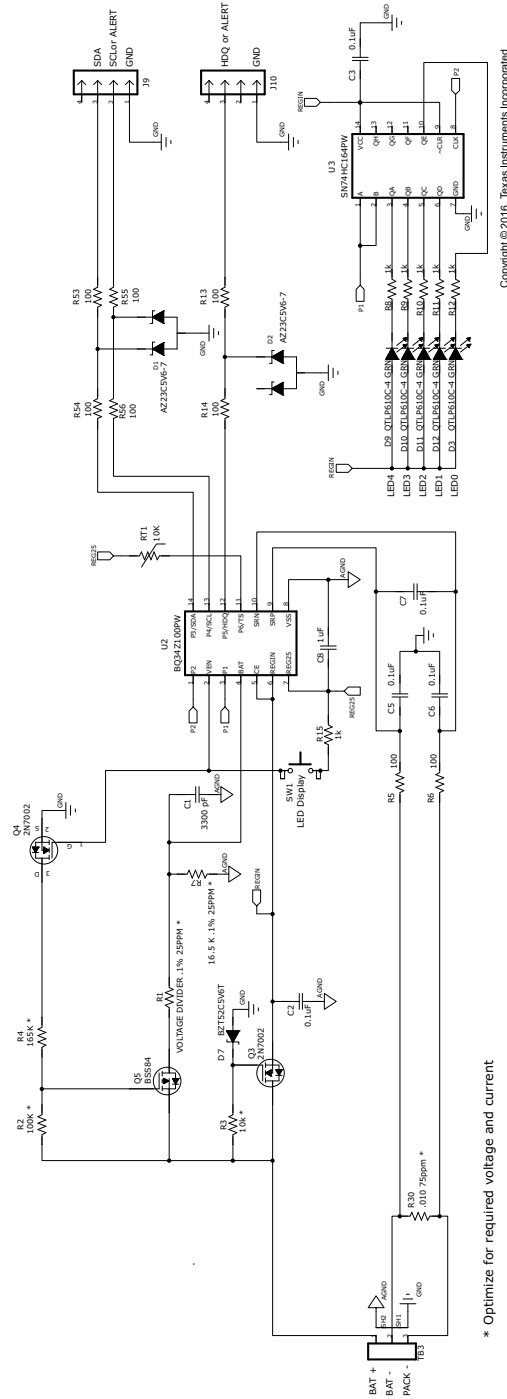


Figure 8-3. Multi-Cell and 5-LED Display

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Figure 8-4 shows the BQ34Z100-G1 full features enabled.

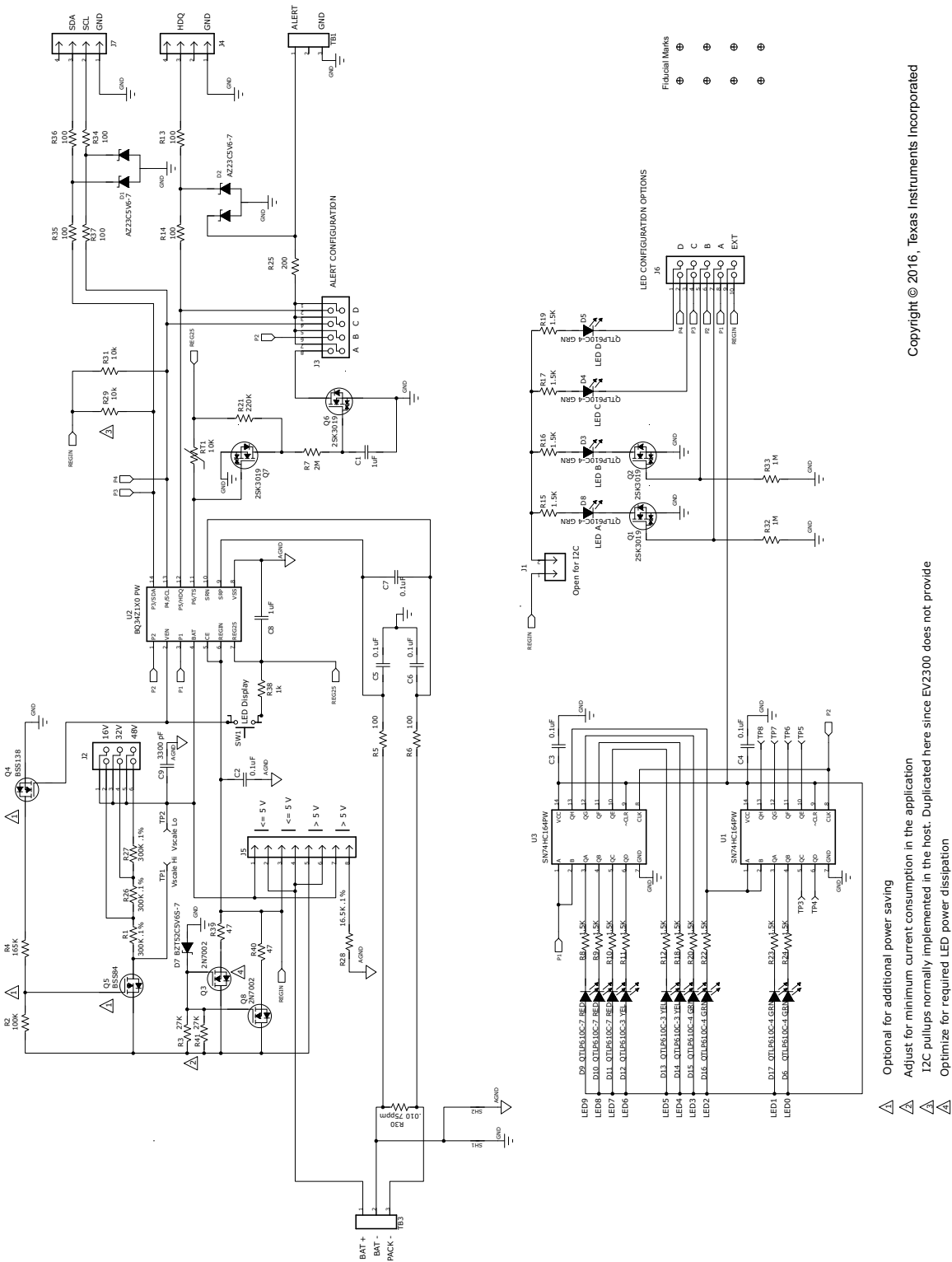


Figure 8-4. Full-Featured Evaluation Module EVM

8.2.1 Design Requirements

For additional design guidelines, refer to the *BQ34Z100 EVM Wide Range Impedance Track Enabled Battery Fuel Gauge User's Guide (SLUU904)*.

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- △ Optional for additional power saving
- △ Adjust for minimum current consumption in the application
- △ I2C pullups normally implemented in the host. Duplicated here since EV2300 does not provide
- △ Optimize for required LED power dissipation

8.2.2 Detailed Design Procedure

8.2.2.1 Step-by-Step Design Procedure

8.2.2.1.1 STEP 1: Review and Modify the Data Flash Configuration Data.

While many of the default parameters in the data flash are suitable for most applications, the following should first be reviewed and modified to match the intended application.

- **Design Capacity:** Enter the value in mAh for the battery, even from the “design energy” point of view.
- **Design Energy:** Enter the value in mWh.
- **Cell Charge Voltage Tx-Ty:** Enter the desired cell charge voltage for each JEITA temperature range.

8.2.2.1.2 STEP 2: Review and Modify the Data Flash Configuration Registers.

- **LED_Comm Configuration:** See [Table 7-20](#) and [Table 7-21](#) to aid in selection of an LED mode. Note that the pin used for the optional Alert signal is dependent upon the LED mode selected.
- **Alert Configuration:** See [Table 7-22](#) to aid in selection of which faults will trigger the $\overline{\text{ALERT}}$ pin.
- **Number of Series Cells**
- **Pack Configuration:** Ensure that the VOLSEL bit is set for multi-cell applications and cleared for single-cell applications.

8.2.2.1.3 STEP 3: Design and Configure the Voltage Divider.

If the battery contains more than 1-s cells, a voltage divider network is required. Design the divider network, based on the formula below. The voltage division required is from the highest expected battery voltage, down to approximately 900 mV. For example, using a lower leg resistor of 16.5 K Ω where the highest expected voltage is 32000 mV:

$$R_{\text{series}} = 16.5 \text{ K}\Omega (32000 \text{ mV} - 900 \text{ mV})/900 \text{ mV} = 570.2 \text{ K}\Omega$$

Based on price and availability, a 600-K resistor or pair of 300-K resistors could be used in the top leg along with a 16.5-K resistor in the bottom leg.

Set the **Voltage Divider** in the Data Flash Calibration section of the Evaluation Software to 32000 mV.

Use the Evaluation Software to calibrate to the applied nominal voltage; for example, 24000 mV. After calibration, a slightly different value will appear in the **Voltage Divider** parameter, which can be used as a default value for the project.

Following the successful voltage calibration, calculate and apply the value to **Flash Update OK Cell Volt** as: **Flash Update OK Cell Volt** = 2800 mV \times **Number Of Series Cells** \times 5000/**Voltage Divider**.

8.2.2.1.4 STEP 4: Determine the Sense Resistor Value.

To ensure accurate current measurement, the input voltage generated across the current sense resistor should not exceed ± 125 mV. For applications with a very high dynamic range, it is allowable to extend this range to absolute maximum of ± 300 mV for overload conditions where a protector device will be taking independent protective action. In such an overloaded state, current reporting and gauging accuracy will not function correctly.

The value of the current sense resistor should be entered into both **CC Gain** and **CC Delta** parameters in the Data Flash Calibration section of the Evaluation Software.

8.2.2.1.5 STEP 5: Review and Modify the Data Flash Gas Gauging Configuration, Data, and State.

- **Load Select:** See [Table 7-13](#) and [Table 7-14](#).
- **Load Mode:** See [Table 7-13](#) and [Table 7-14](#).
- **Cell Terminate Voltage:** This is the theoretical voltage where the system will begin to fail. It is defined as zero state-of-charge. Generally a more conservative level is used in order to have some reserve capacity. Note the value is for a single cell only.
- **Quit Current:** Generally should be set to a value slightly above the expected idle current of the system.
- **Qmax Cell 0:** Start with the C-rate value of your battery.

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8.2.2.1.6 STEP 6: Determine and Program the Chemical ID.

Use the BQChem feature in the Evaluation Software to select and program the chemical ID matching your cell. If no match is found, use the procedure defined in TI's ([Mathcad Chemistry Selection Tool \(SLUC138\)](#)).

8.2.2.1.7 STEP 7: Calibrate.

Follow the steps on the **Calibration** screen in the Evaluation Software. Achieving the best possible calibration is important before moving on to Step 8. For mass production, calibration is not required for single-cell applications. For multi-cell applications, only voltage calibration is required. Current and temperature may be calibrated to improve gauging accuracy if needed.

8.2.2.1.8 STEP 8: Run an Optimization Cycle.

Refer to the [Preparing Optimized Default Flash Constants for Specific Battery Types Application Report \(SLUA334B\)](#).

8.2.3 Battery Chemistry Configuration

When changing the battery chemistry, there are several configurations that need to be considered specific to each chemistry. The CHEM ID drives the majority of the changes but some do remain. These are mostly associated to the charge termination algorithm, but there are some additional registers that should be programmed based on the main chemistry type selected.

8.2.3.1 Battery Chemistry Charge Termination

The default setup of the BQ34Z100-G1 is for Li-ion chemistries.

The charge-termination specific configurations include:

Table 8-1. Charge Termination Configurations

| Class Name | Subclass Name | Parameter Name | Default Value | Units |
|---------------|--------------------|----------------------|---------------|-------|
| Configuration | Charge Termination | Taper Current | 100 | mA |
| Configuration | Charge Termination | Min Taper Capacity | 25 | mAh |
| Configuration | Charge Termination | Cell Taper Voltage | 100 | mV |
| Configuration | Charge Termination | Current Taper Window | 40 | s |

When changing to Lead Acid chemistry there are further configuration options.

Table 8-2. Configuration Options

| Class Name | Subclass Name | Parameter Name | Default Value | Units |
|---------------|---------------|-------------------|---------------|-------|
| Configuration | Charge | Pb Temp Comp | 25% | |
| Configuration | Charge | Pb Reduction Rate | 10% | |

When using Nickel Metal Hydride (NiMH) or Nickel Cadmium (NiCd) batteries, the charge termination criteria change significantly.

Table 8-3. NiMH and NiCd Charge Configuration Options

| Class Name | Subclass Name | Parameter Name | Default Value | Units |
|---------------|--------------------|-------------------------------|---------------|-------|
| Configuration | Charge Termination | NiMH Delta Temp | 3 | 0.1°C |
| Configuration | Charge Termination | NiMH Delta Temp Time | 180 | s |
| Configuration | Charge Termination | NiMH Hold Off Time | 100 | s |
| Configuration | Charge Termination | NiMH Hold Off Current | 240 | mA |
| Configuration | Charge Termination | NiMH Hold Off Temp | 25 | 0.1°C |
| Configuration | Charge Termination | NiMH Cell Negative Delta Volt | 17 | mV |
| Configuration | Charge Termination | NiMH Cell Negative Delta Time | 16 | s |
| Configuration | Charge Termination | NiMH Cell Neg Delta Qual Volt | 4200 | mV |

To switch the charge termination criteria suitable for NiMH/NiCd, set the [NiDT] and/or [NiDV] bits. See [Section 7.3.11](#) for further details.

Where:

NiDT: Performs primary charge termination using the $\Delta T/\Delta t$ algorithm.

NiDV: Performs primary charge termination using the $-\Delta V$ algorithm.

Note

When a Nickel-based chemistry Chem ID is used, then the Li-ion/PbA charge termination method is NOT used regardless of the configuration of the NiDV and NiDT bits.

Table 8-4. Additional Chemistry-Related Configurations

| Parameters | Li-ion | Lead Acid | NiMH/NiCd |
|-------------------------------|--------|-----------|-----------|
| Default Load Select | 1 | 3 | 3 |
| Cell Term V Delta | 200 | 100 | 100 |
| Min % Passed Chg for 1st Qmax | 90 | 50 | 50 |

8.2.4 Replaceable Battery Systems

The BQ34Z100-G1 is also capable of being used as a system-side gauge where the actual battery can be removed and replaced from the system. However, there are limitations to this feature. The replacing battery should be of the same chemistry and close to the original design capacity of the one to be replaced, as this ensures that the other configuration options of the device are still valid.

The BQ34Z100-G1 is enabled to have the option to learn new Impedance Track data in larger steps through the following configuration registers:

Table 8-5. Learning Configuration Registers for Replaceable Battery Packs (Host Side Gauge)

| Class Name | Subclass name | Parameter Name | Default Value | Units |
|-------------|---------------|-----------------|---------------|-------|
| Gas Gauging | IT Cfg | Max Res Factor | 50 | n/a |
| Gas Gauging | IT Cfg | Min Res Factor | 1 | n/a |
| Gas Gauging | IT Cfg | Max Res Scale | 32000 | n/a |
| Gas Gauging | IT Cfg | Min Res Scale | 1 | n/a |
| Gas Gauging | IT Cfg | Max QMAX Change | 100 | n/a |

If the BQ34Z100-G1 and the battery are not designed to be separated, it is recommended to make the following changes. This helps to prevent erroneous measurements from causing the Impedance Track data to be updated to extreme values.

Table 8-6. Learning Configuration Registers for Non-Removable Battery Packs

| Class Name | Subclass name | Parameter Name | Value | Units |
|-------------|---------------|-----------------|-------|-------|
| Gas Gauging | IT Cfg | Max Res Factor | 15 | n/a |
| Gas Gauging | IT Cfg | Min Res Factor | 3 | n/a |
| Gas Gauging | IT Cfg | Max Res Scale | 5000 | n/a |
| Gas Gauging | IT Cfg | Min Res Scale | 200 | n/a |
| Gas Gauging | IT Cfg | Max QMAX Change | 30 | n/a |

8.2.5 Digital Interface Options

The default setup of the BQ34Z100-G1 uses the I²C digital interface with the $\overline{\text{ALERT}}$ pin as an additional digital interrupt output. It is recommended to keep the device in this mode throughout development and battery production even if the single-wire HDQ interface will be used in the field. The I²C is much faster so any modifications to the device configuration and any data logging during battery evaluation or testing would be faster.

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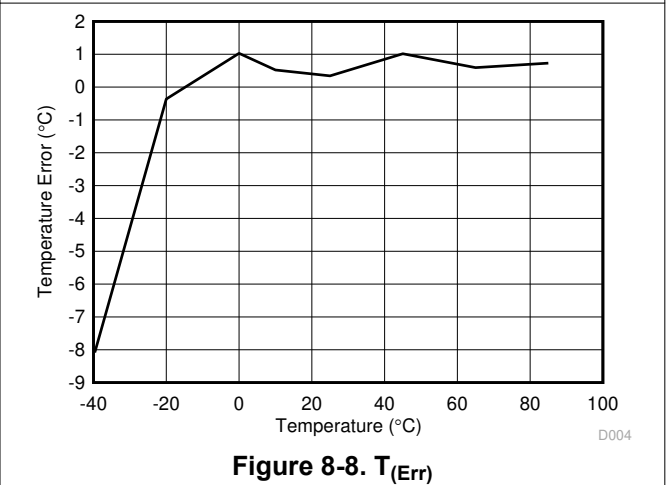
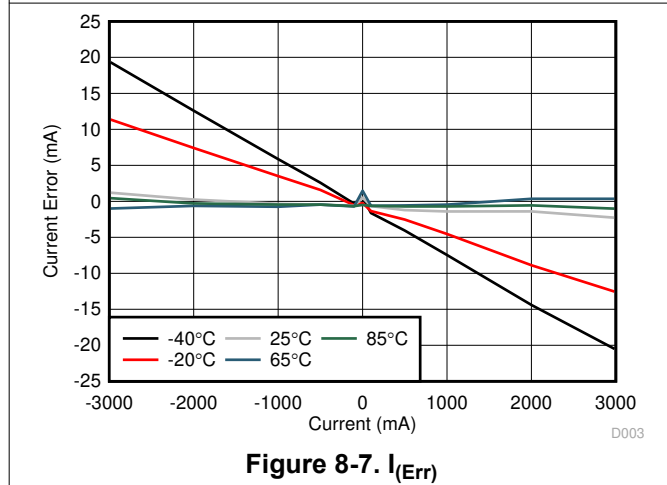
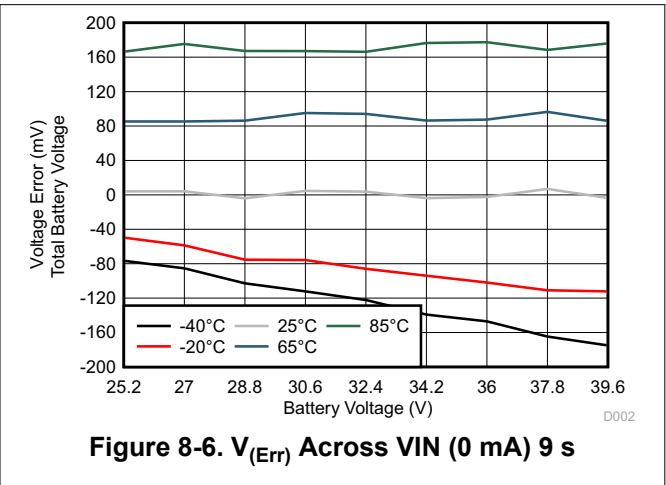
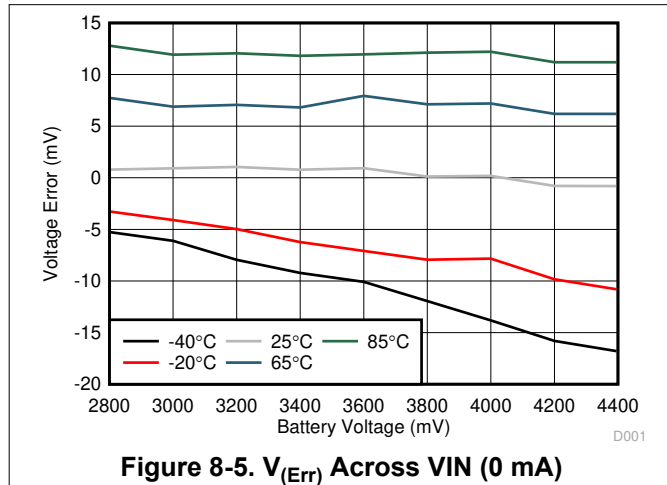
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There are a series of commands required to switch between I²C and HDQ, which are detailed in [Section 7.3.15.6](#).

8.2.6 Display Options

By default, the display is disabled. To setup the appropriate display, the LED/COMM Configuration data flash register needs to be programmed. Care should be taken to ensure the correct digital interface options (Communications and ALERT) are not interfered with when configuring the display. See [Section 7.3.14](#) for further details.

8.2.7 Application Curves



9 Power Supply Recommendations

Power supply requirements for the BQ34Z100-G1 are simplified due to the presence of the internal LDO voltage regulation. The REGIN pin accepts any voltage level between 2.7 V and 4.5 V, which is optimum for a single-cell Li-ion application. For higher battery voltage applications, a simple pre-regulator can be provided to power the bq34Z100-G1 and any optional LEDs. Decoupling the REGIN pin should be done with a 0.1- μ F 10% ceramic X5R capacitor placed close to the device. While the pre-regulator circuit is not critical, special attention should be paid to its quiescent current and power dissipation. The input voltage should handle the maximum battery stack voltage. The output voltage can be centered within the 2.7-V to 4.5-V range as recommended for the REGIN pin.

For high stack count applications, a commercially available LDO is often the best quality solution, but comes with a cost tradeoff. To lower the BOM cost, the following approaches are recommended.

In [Figure 9-1](#), Q1 is used to drop the battery stack voltage to roughly 4 V to power the BQ34Z100-G1 REGIN pin and also to feed the anode of any LEDs used in the application. To avoid unwanted quiescent current consumption, R1 should be set as high as is practical. It is recommended to use a low-current Zener diode.

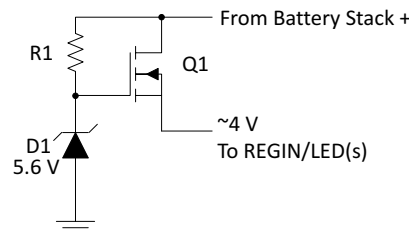


Figure 9-1. Q1 Dropping Battery Stack Voltage to 4 V

Alternatively, if the range of a high-voltage battery stack can be well defined, a simple source follower based on a resistive divider can be used to lower the BOM cost and the quiescent current. For example:

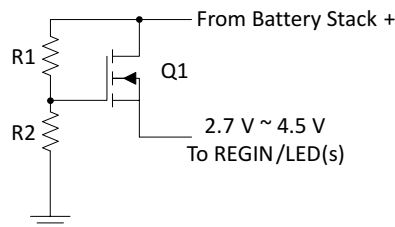


Figure 9-2. Source Follower on a Resistive Divider

Power dissipation of the linear pre-regulator may become an important design decision when multiple LEDs are employed in the application. For example, the BQ34Z100-G1 EVM uses a pair of FETs in parallel to inexpensively dissipate enough power for 10-LED evaluation.

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10 Layout

10.1 Layout Guidelines

10.1.1 Introduction

Attention to layout is critical to the success of any battery management circuit board. The mixture of high-current paths with an ultralow-current microcontroller creates the potential for design issues that are not always trivial to solve. Some of the key areas of concern are described in the following sections, and can help to enable success.

10.1.2 Power Supply Decoupling Capacitor

Power supply decoupling from VCC to ground is important for optimal operation of the gas gauge. To keep the loop area small, place this capacitor next to the IC and use the shortest possible traces. A large loop area renders the capacitor useless and forms a small-loop antenna for noise pickup.

Ideally, the traces on each side of the capacitor should be the same length and run in the same direction to avoid differential noise during ESD. If possible, place a via near the VSS pin to a ground plane layer.

10.1.3 Capacitors

Power supply decoupling for the gas gauges requires a pair of 0.1- μ F ceramic capacitors for (BAT) and (VCC) pins. These should be placed reasonably close to the IC without using long traces back to VSS. The LDO voltage regulator, whether external or internal to the main IC, requires a 0.47- μ F ceramic capacitor to be placed fairly close to the regulation output pin. This capacitor is for amplifier loop stabilization and as an energy well for the 2.5-V supply.

10.1.4 Communication Line Protection Components

The 5.6-V Zener diodes, used to protect the communication pins of the gas gauge from ESD, should be located as close as possible to the pack connector. The grounded end of these Zener diodes should be returned to the Pack(-) node rather than to the low-current digital ground system. This way, ESD is diverted away from the sensitive electronics as much as possible.

In some applications, it is sometimes necessary to cause transitions on the communication lines to trigger events that manage the gas gauge power modes. An example of one of these transitions is detecting a sustained low logic level on the communication lines to detect that a pack has been removed. Given that most of the gas gauges do not have internal pulldown networks, it is necessary to add a weak pulldown resistor to accomplish this when there's an absence of a strong pullup resistor on the system side. If the weak pulldown resistor is used, it may take less board space to use a small capacitor in parallel instead of the Zener diode to absorb any ESD transients that are received through communication lines.

10.2 Layout Example

10.2.1 Ground System

The gas gauge requires a low-current ground system separate from the high-current PACK(-) path. ESD ground is defined along the high-current path from the PACK(-) terminal to low-side protector FETs (if present) or the sense resistor. It is important that the low-current ground systems only connect to the BAT(-) path at the sense resistor Kelvin pick-off point. It is recommended to use an optional inner layer ground plane for the low-current ground system. In [Figure 10-1](#), the green is an example of using the low-current ground as a shield for the gas gauge circuit. Notice how it is kept separate from the high-current ground, which is shown in red. The high-current path is joined with the low-current path only at one point, shown with the small blue connection between the two planes.

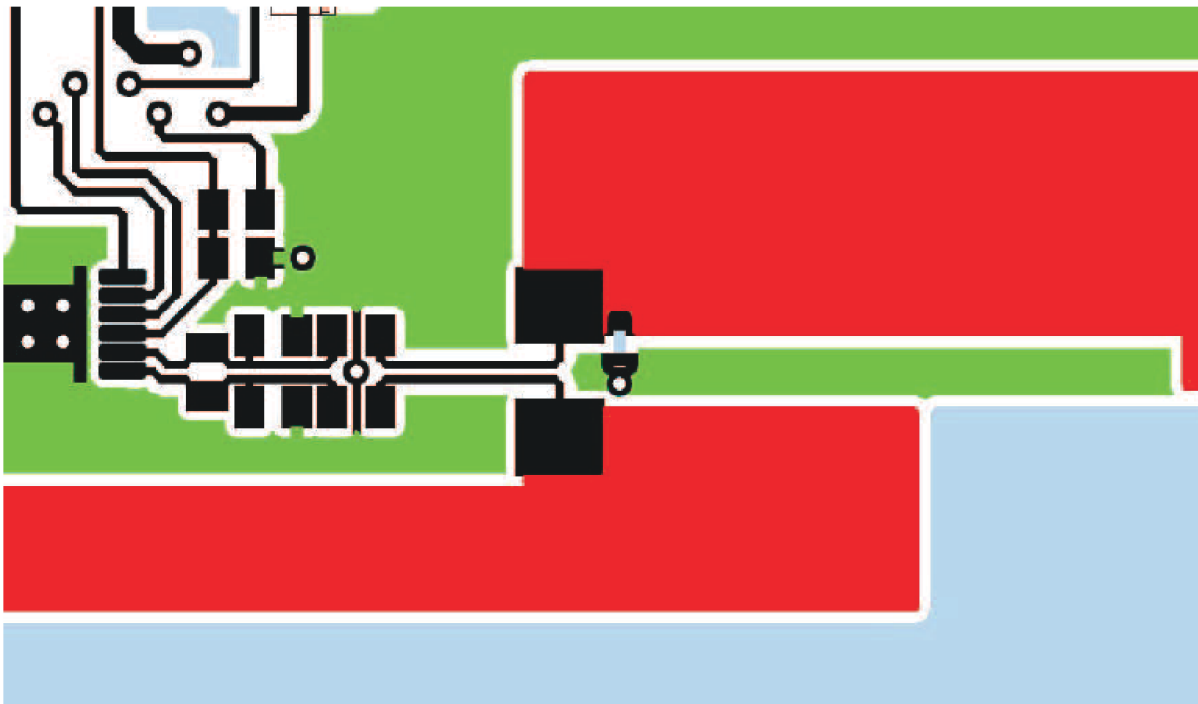


Figure 10-1. Differential Filter Component with Symmetrical Layout

10.2.2 Kelvin Connections

Kelvin voltage sensing is very important to accurately measure current and cell voltage. Notice how the differential connections at the sense resistor do not add any voltage drop across the copper etch that carries the high current path through the sense resistor. See [Figure 10-1](#) and [Figure 10-2](#).

10.2.3 Board Offset Considerations

Although the most important component for board offset reduction is the decoupling capacitor for V_{CC} , additional benefit is possible by using this recommended pattern for the coulomb counter differential low-pass filter network. Maintain the symmetrical placement pattern shown for optimum current offset performance. Use symmetrical shielded differential traces, if possible, from the sense resistor to the 100- Ω resistors, as shown in [Figure 10-2](#).

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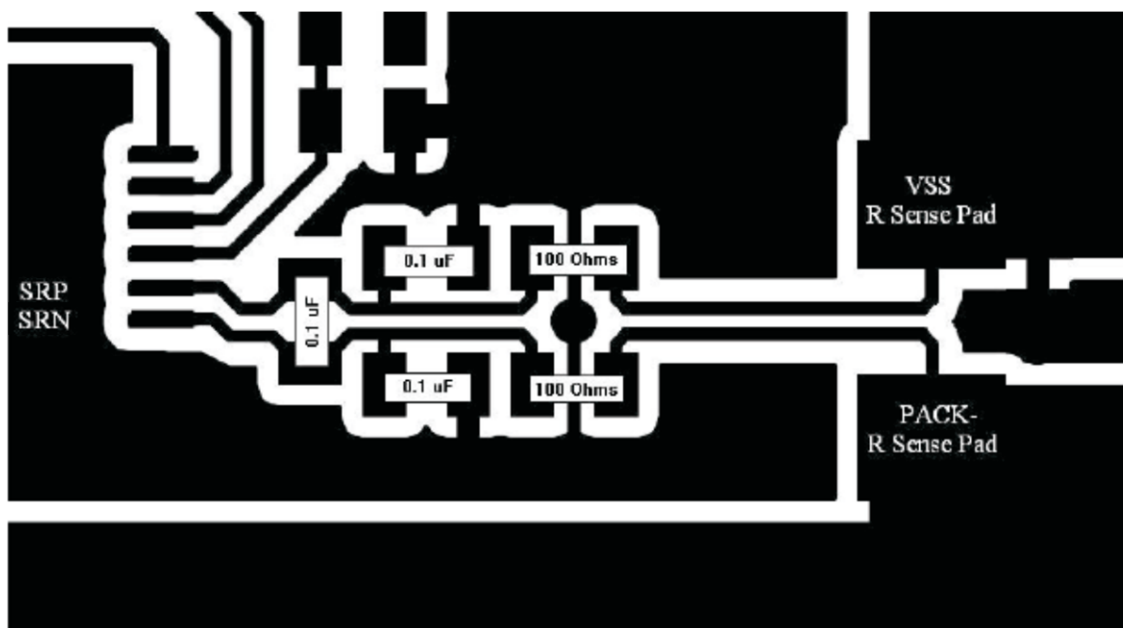


Figure 10-2. Differential Connection Between SRP and SRN Pins with Sense Resistor

10.2.4 ESD Spark Gap

Protect the communication lines from ESD with a spark gap at the connector. [Figure 10-3](#) shows the recommended pattern with its 0.2-mm spacing between the points.

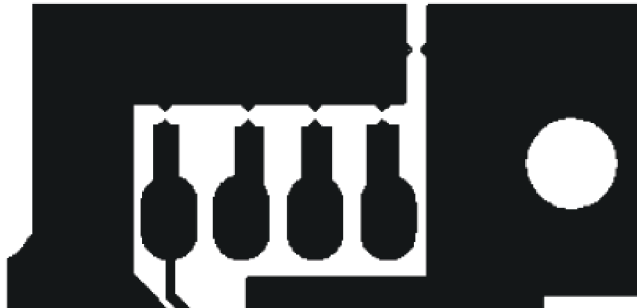


Figure 10-3. Recommended Spark-Gap Pattern Helps Protect Communication Lines from ESD

11 Device and Documentation Support

11.1 Documentation Support

For related documentation, see the application report [BQ34Z100-G1 High Cell Count and High Capacity Applications \(SLUA760\)](#).

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](#). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.3 Support Resources

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

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

11.4 Trademarks

Impedance Track™ is a trademark of Texas Instruments.

TI E2E™ are trademarks of Texas Instruments.

All trademarks are the property of their respective owners.

11.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

12 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 (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|--------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| BQ34Z100PW-G1 | Active | Production | TSSOP (PW) 14 | 90 TUBE | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 34Z100 |
| BQ34Z100PW-G1.B | Active | Production | TSSOP (PW) 14 | 90 TUBE | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 34Z100 |
| BQ34Z100PWR-G1 | Active | Production | TSSOP (PW) 14 | 2000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 34Z100 |
| BQ34Z100PWR-G1.B | Active | Production | TSSOP (PW) 14 | 2000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 34Z100 |
| BQ34Z100PWR-G1G4 | Active | Production | TSSOP (PW) 14 | 2000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 34Z100 |
| BQ34Z100PWR-G1G4.B | Active | Production | TSSOP (PW) 14 | 2000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 34Z100 |

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

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

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

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

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

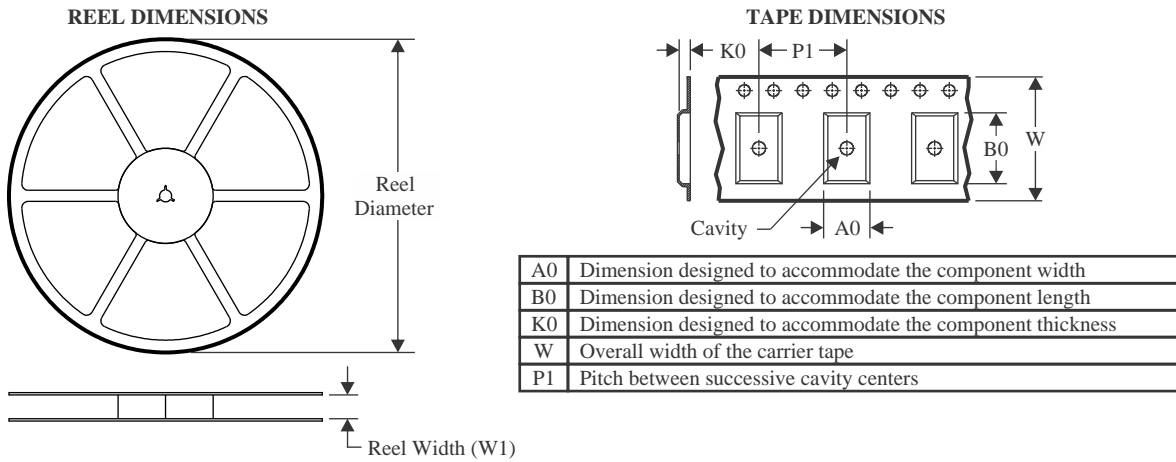
⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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

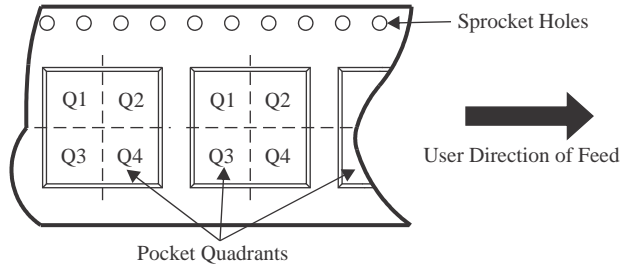
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TAPE AND REEL INFORMATION



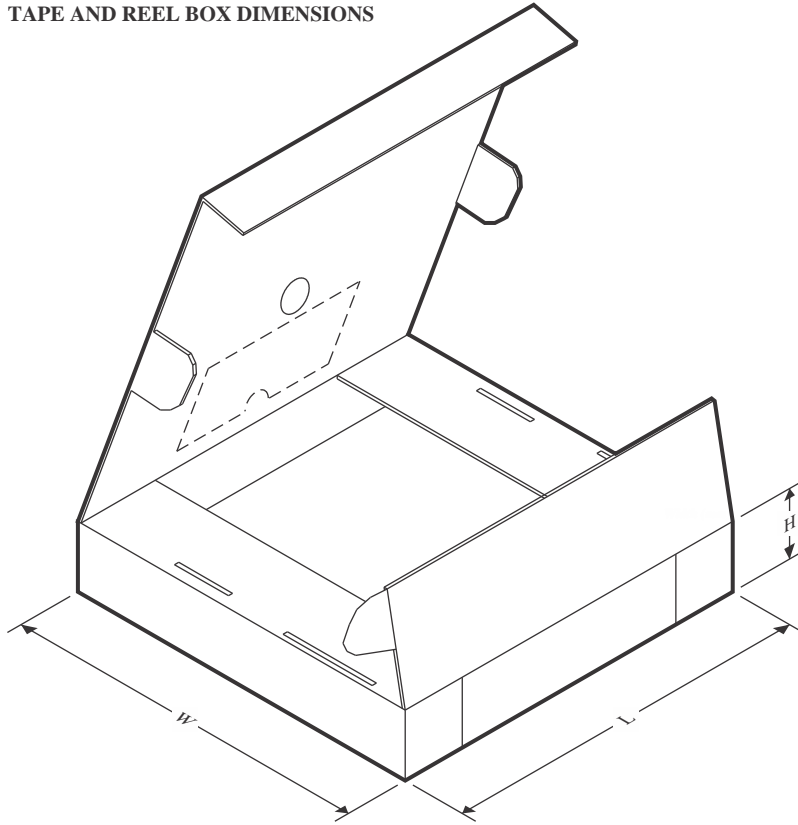
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ34Z100PWR-G1 | TSSOP | PW | 14 | 2000 | 330.0 | 12.4 | 6.9 | 5.6 | 1.6 | 8.0 | 12.0 | Q1 |
| BQ34Z100PWR-G1G4 | TSSOP | PW | 14 | 2000 | 330.0 | 12.4 | 6.9 | 5.6 | 1.6 | 8.0 | 12.0 | Q1 |

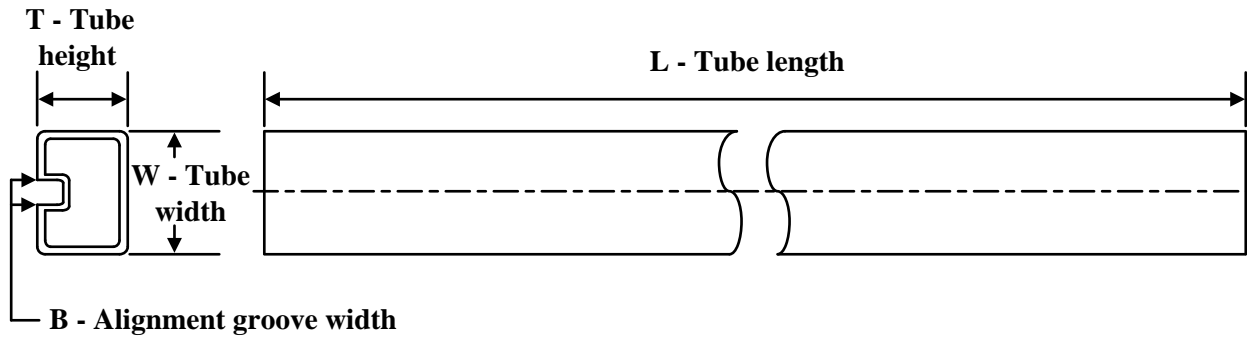
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

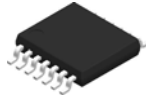
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ34Z100PWR-G1 | TSSOP | PW | 14 | 2000 | 338.1 | 338.1 | 20.6 |
| BQ34Z100PWR-G1G4 | TSSOP | PW | 14 | 2000 | 338.1 | 338.1 | 20.6 |

TUBE



*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-----------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| BQ34Z100PW-G1 | PW | TSSOP | 14 | 90 | 530 | 10.2 | 3600 | 3.5 |
| BQ34Z100PW-G1.B | PW | TSSOP | 14 | 90 | 530 | 10.2 | 3600 | 3.5 |

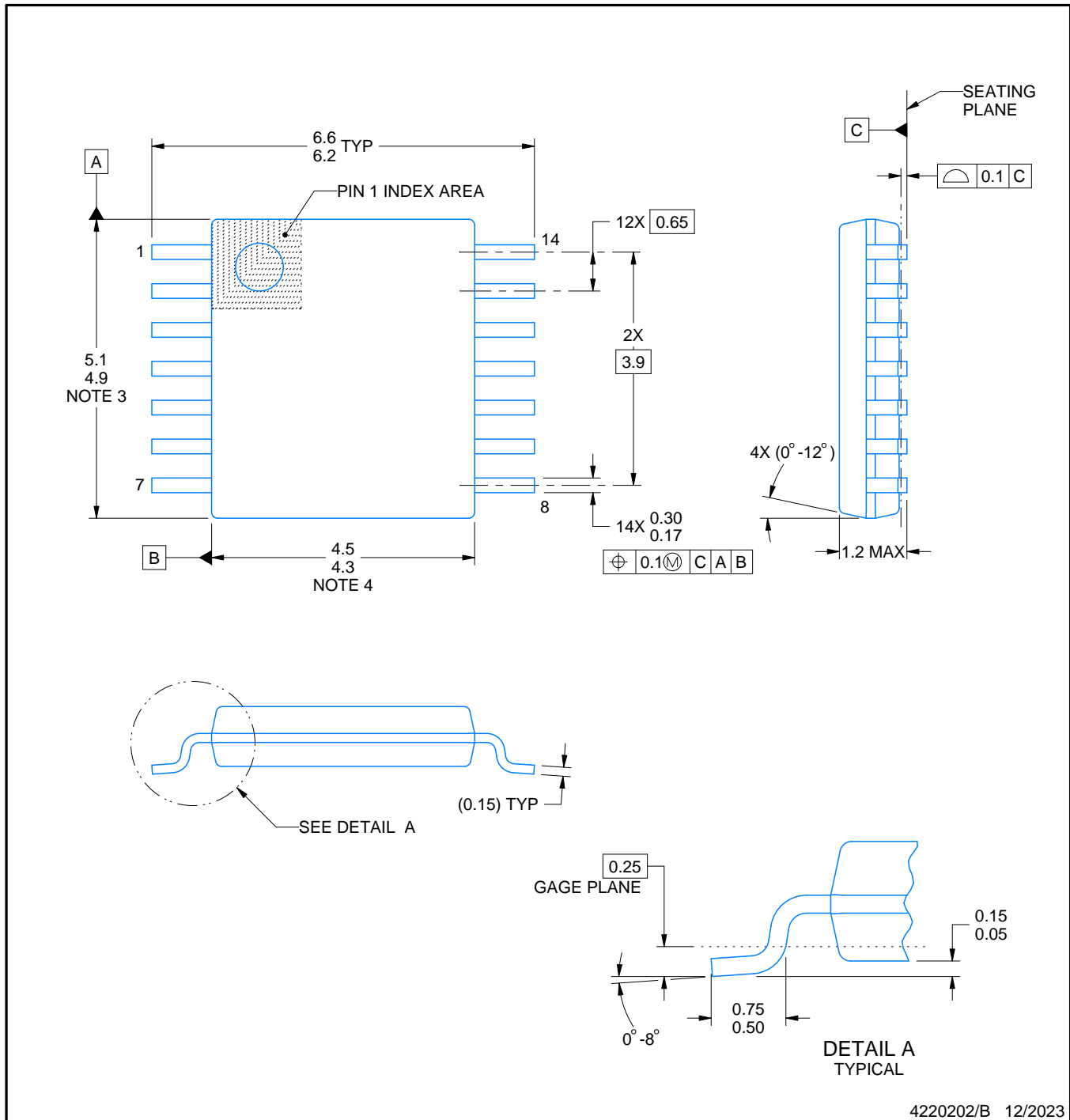


PW0014A

PACKAGE OUTLINE

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



4220202/B 12/2023

NOTES:

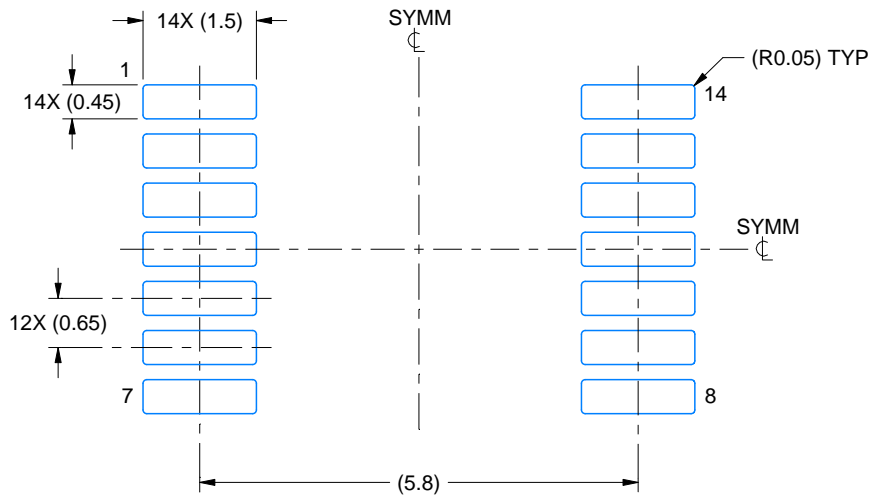
- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- This drawing is subject to change without notice.
- This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate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

EXAMPLE BOARD LAYOUT

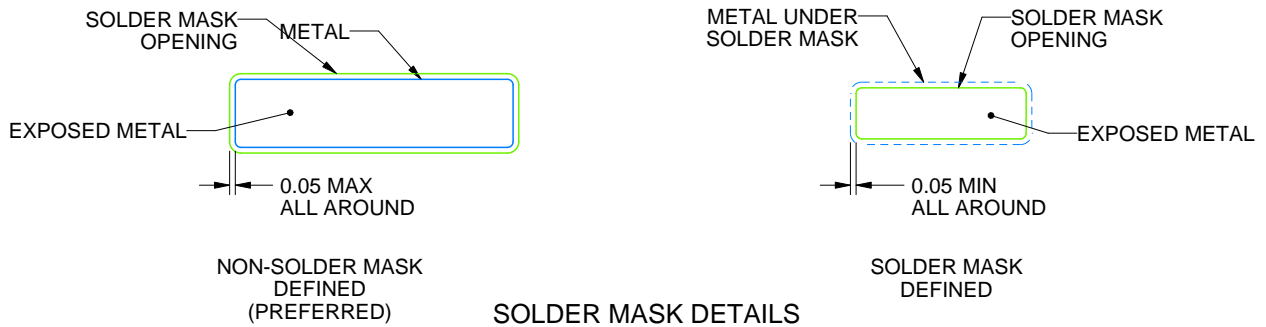
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



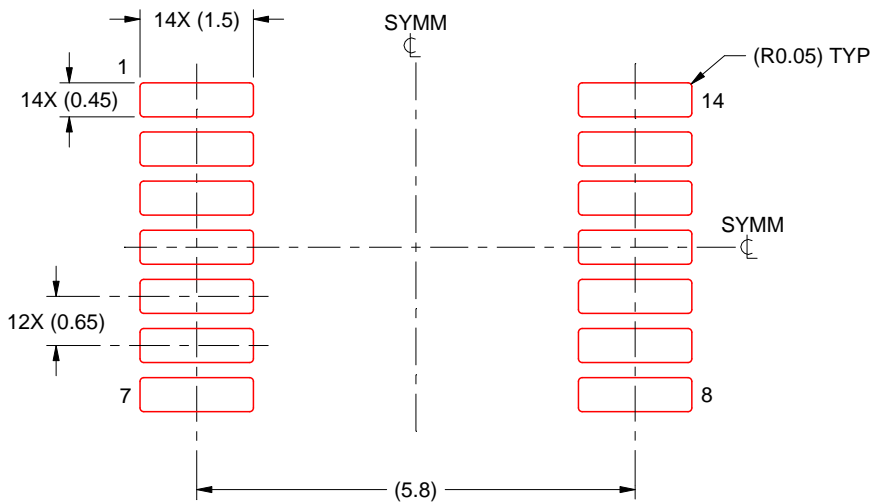
4220202/B 12/2023

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**PW0014A****TSSOP - 1.2 mm max height**

SMALL OUTLINE PACKAGE



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

4220202/B 12/2023

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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