Application Note

BQ34z100 Configuration Guide

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ABSTRACT

This document discusses TI's BQ34z100 hardware and firmware. This gauge is unique in TI's gauging portfolio in that it is a top of stack gauge. This means BQ34z100 measures an entire battery pack and treats the pack as if it were one cell. For BQ34z100 to be able to gauge a multicell pack, the cells need to be balanced and protected by an external battery monitor IC. If the cells are unbalenced, this will introduce error into the SOC and SOH calculations. This document primarily focuses on the BQ34z100-R2 features, outside of a small section discussing BQ34z100-G1 features. Both BQ34z100-G1 and BQ34z100-R2 use the same hardware and any BQ34z100 FW version can be flashed onto either device. Parameters are *italicized*.

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Trademarks

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1 Introduction

Traditionally, multicell battery gauges monitor each cell in a pack, with pins assigned to each cell. As battery pack voltage increases, the number of cells in series within a battery pack continue to increase along with it. Due to this, BQ34z100 was designed with a unique approach to gauging battery packs, where it monitors the voltage of the entire batter stack (pack) to calculate SOC. This document goes over how to configure the BQ34z100-R2.

2 Minimum Parameters

This section contains the minimum parameters recommended to configure on BQ34z100 with a BQ34z100 relevant definition. This section does not discuss calibration parameters; these are discussed in the Calibration section.

2.1 Design Capacity

Design Capacity is the capacity of the entire pack in mAh. This can be calculated by multiplying the capacity of a single cell by the number of cells in parallel for the entire pack. For example, for a 3s2p pack, where the capacity of a single cell is 1000mAh, the *Design Capacity* for this pack is 2000mAh, assuming there is a *Curr Scale* value of 1.

Design Capacity = [(capacity of a single cell) × (number of cells in parallel)]/*Curr Scale*

2.2 Design Voltage

Design Voltage is the voltage for a single cell in the pack in mV. For example, for a 3s2p pack, where the Voltage of a single cell is 1000mV, and the *Design Capacity* for this pack is 2000mAh, assuming you have a *Volt Scale* value of 1, the *Design Voltage* for this pack is 1000mV.

Design Voltage = (Voltage of a single cell)/*Volt scale*

2.3 Design Energy

Design Energy is the energy of a single cell in cWh. This can be calculated by multiplying the *Design Capacity* by *Design Voltage*. For example, for a 3s2p pack, where the Voltage of a single cell is 1000mV, and the *Design Capacity* for this pack is 2000mAh, assuming you have an *Energy Scale* value of 1, the *Design Energy* for this pack is 2000mWh. (200cWh)

Design Energy = [(*Design Capacity*) × (*Design Voltage*)]/*Energy Scale*

Note

Design Energy must be entered in cWh for R2 FW and mWh for G1 FW.

2.4 Load Mode

Load Mode tells the gauge to use either a constant current model or a constant power model for IT simulations. For true constant power loads use constant power mode, for all other applications use constant current mode.

Load mode = 0, Constant Current Model

Load mode = 1, Constant Power Model

2.5 Load Select

Load Select tells the gauge which of the 6 current models to use. Section 3.2.2.1 in the TRM describes Load Mode, Load Select, and the different loads select options. See *BQ34Z100-R2 Technical Reference Manual (Rev. A)* for more information.

For most applications *Load Select* =1 is recommended. For Lead Acid and NiMH/NiCd use *Load Select* = 3. For pulse load applications use *Load Select* = 6 and set U*ser_Rate-mA/mW* equal to the maximum peak pulse. See Impedance Track Gauge Configuration For Dynamic Loads (EPOS) for more information on tuning a gauge for a pulse load.

2.6 Cell Charging Voltage TX-TY

Cell Charging Voltage TX-TY is the batteries voltage level when they are considered fully charged. This parameter is used for Valid Charge Termination (VCT). The voltage used is dependent on the temperature ranges defined with *Jeita TX* and the temperature the gauge is reporting (Temperature() 0x0C/0x0D). Valid Charge Termination Conditions can be found in Section 3.7 in the BQ34Z100-R2 Technical Reference Manual (Rev. A)

Note

These values are automatically scaled by the *Volt Scale* parameter. ChargeVoltage() 0x30/0x31 returns the scaled charge voltage.

ChargeVoltage() = {Cell Charge Voltage TX-TY [Temperature()]* number of series cells }/Volt scale

2.7 Number of Series Cell

Number of Series Cells is the number of cells in series in the pack. For a 2s1p pack this value is two.

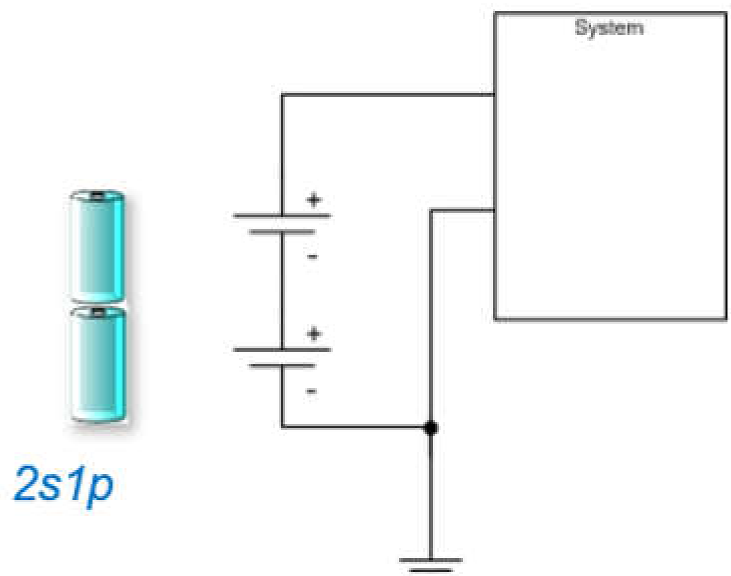

Figure 2-1. Series Batteries Example

2.8 Flash Update OK Cell Voltage

The voltage reported by the gauge (Voltage() 0x8/0x9) must be greater than the *Flash Update OK Cell Voltage* in mV, if it is less than, then writes to data flash fails. This parameter is used to prevent the gauge from dropping below the 2.4V threshold required for flash writes.

2.9 Cell Terminate Voltage

Cell Terminate Voltage must be configured to be the voltage level of a single cell in the battery pack when the battery is empty. Or the single cell voltage when SOC = 0%. This is typically documented in the cell datasheet. For example, for a 2s3p pack with a pack terminate voltage of 2000mV, *Cell Terminate Voltage* is 1000mV.

2.10 Taper Current

The *Taper Current* value is the point where the charger cuts off during the CV phase of charging.

2.11 DSG Current Threshold

DSG Current Threshold is the minimum current threshold for the gauge to be in discharge mode. Enter this as a positive value.

2.12 CHG Current Threshold

CHG Current Threshold is the minimum current threshold for the gauge to be in charge mode.

2.13 Quit Current Threshold

Quit Current Threshold is the current threshold the gauge will recognize the batteries to be in a relaxed state. The current needs to be below this threshold before an OCV measurement will be taken.

Note

The gauge must be configured as such, DSG > Quit, Taper > CHG > Quit.

Note

Current threshold use Current() 0x10/0x11, therefore these thresholds do not need to scaled if the user is using the parameter *Curr Scale* to scale current. If the user scales using the sense resistor then scale these thresholds. See Scaling for more information.

2.14 ChemID

The ChemID contains the gauges OCV table and initial resistance tables. These are created in TI's labs in Dallas in the cell characterization process. Make sure that the cells that are being used are a close match to the ChemID selected. Typically, TI recommends using a ChemID with 3% DoD% error or less. The GPCchem tool can be used to identify the best ChemID matches the database. See GPCCHEM Application software & framework | TI.com for more information.

3 Learning Cycle

The purpose of the learning cycle is to obtain initial Qmax value updates and Ra table updates. Qmax is the theoretical maximum chemical capacity of the cell. The Ra tables are the resistance tables at room temperature. See *Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm* for more information about the Qmax value and Ra tables.

Note

For BQ34z100 *Qmax Cell 0* is the only Qmax value, this value is calculated at the cell level.

Chapter 11 in the *BQ34Z100-R2 Technical Reference Manual* shows how to complete a learning cycle. Both the Qmax value and Ra tables update when a valid OCV readings has occurred. For initial updates a 90% difference in DoD must have occurred. Larger battery packs and LFP cells take longer to relax. OCV measurements are taken once the 1uV/s threshold is satisfied. This typically takes many hours for large packs to achieve.

The popular *Achieving The Successful Learning Cycle* application note has descriptive definitions of the parameters required and clear steps on completing a learning cycle. However, note that the recommended relax times are typically too short for applications with this device.

4 Calibration

For the BQ34z100 to be able to accurately estimate SOC, the gauge requires accurate voltage, temperature, and current readings. Calibration should be done with a power supply rather than with battery cells. Calibrate the voltage before applying a voltage scale factor.

4.1 Current Calibration

This video describes how to calibrate the current using BQstudio.

4.2 Voltage Calibration and Voltage Divider

Getting the correct voltage reading for your gauge is critical for calculating SOC. To get the correct voltage reading on the gauge using an external voltage divider. (PackConfiguration[VoltSel =1]) Configure the number of cells in series to =1. Then configure the parameter Voltage Divider so that the XXXX:1000mV ratio matches the actual voltage divider ratio on the board. For example, if 1M is used as the top leg of the voltage divider and 17.4K as the bottom leg of the voltage divider, then the calculation is as follows.

$V_{out} = V_s \times R2 / (R1 + R2)$

$1V = V_s \times 17.4K/(1M + 17.4K)$

$V_s = 58.471V$

Therefore, the voltage divider is 58.471V to 1V.

Enter 58471mV as the voltage divider parameter.

Then apply a voltage and calibrate the voltage reading using BQstudio. This video discusses the process. The gauge must then read the correct voltage. Then update the number of cells in series to the correct number and divide the voltage divider parameter by the number of cells in series. The gauge should then again read the correct voltage.

4.3 CC Offset Routine

The parameter CC offset cannot be written to. This parameter can only be changed by the gauge using the CC offset routine cmd. (CC_OFFSET 0x000A, CC_OFFSET_SAVE 0x000B) In BQstudio, it can temporarily appear that this parameter has successfully been written to. However, after a read all is performed, see the value return to the previous value.

5 Scaling

Scaling is controlled by three parameters, *Curr Scale*, *Volt Scale*, and *Energy Scale*. These three parameters all are used to enter values for parameter that exceed that parameters limits. For example, the max value for *Design Capacity* is 32767mAh, if the capacity of the cell exceeds this value, use the *Curr Scale* factor. If the actual capacity of the cells is 90000mah, set *Curr Scale* = 3, and then enter 30000 for *Design Capacity*. Then go through the configuration and scale all parameters in mA/mAh/ and so on by the *Curr Scale* factor (3). *Volt Scale* works the same way for all parameters in mV/V/ and so on. *Energy Scale* works the same way for all parameters in mW/mWh and so on.

Note

Curr Scale does not scale the current reading. If the application requires charge and discharge currents greater than 32A, the user must scale using the sense resistor. See G1 in this document for more information on how to scale using the sense resistor. Consider sense resistor size when working with high current applications. See Hardware for more information on selecting a sense resistor.

Note

When using *Curr Scale*, *Quit Current Threshold*, *CHG Current Threshold*, *DSG Current Threshold*, and *Taper Current* are not affected by *Curr scale* and do not need to be divided.

6 Additional Key Parameters and Features

6.1 OCV Wait Time

OCV Wait Time is the amount of time that must elapse before voltage stability measurements occur for OCV updates when the gauge enters a relax state.

6.2 SOH Load I

SOH Load (I) current is the only parameter available that can help tune the SOH% value. This value is the current used in SOH simulations. The greater the SOH Load I the more conservative the SOH % is over time.

6.3 Voltage Divider Parameter

An external voltage divider is not required for all applications, only applications with a pack voltage exceeding 5V. The internal voltage divider uses 5000mV:1000mV voltage divider. The parameter *Voltage Divider* controls this ration and the default value of 5000 corresponds to this internal ratio. The VOLTSEL bit in Pack Configuration (A) switches between the internal and external voltage divider.

VOLTSEL = 0, internal voltage divider

VOLTSEL = 1, external voltage divider

The maximum value for the *Voltage Divider* parameter is 65535mV, therefore the max ratio that can be entered is about a 65:1 voltage divider. For high voltage applications where a larger voltage divider is required please do the following. First, calculate your *Voltage Divider* parameter value with *Volt Scale* = 1. Then divide this by the required *Volt Scale* factor. At this point your voltage reading should be 1/*Volt Scale*. Then configure the *Volt Scale* parameter. The Voltage reading will now read 1/(*Volt Scale* × *Volt Scale*). Next navigate to the calibration tab in BQstudio and multiple the reported voltage by *Volt Scale*. Enter this value into the voltage calibration box in BQstudio and calibrate. Multiply the voltage reading from the gauge by *Volt Scale* to obtain the true applied voltage. See the following example.

Applied Voltage = 10V. Voltage Reading -> 10V

Volt Scale = 1

Top leg resistor = 2 MΩ, Bottom leg resistor = 16.5 kΩ

Divider ratio = 122212:1000 -> 122212 > 65535 (max value for *Voltage Divider*)

122212/2=61106 -> 61106 < 65535

Enter 61106 for the *Voltage Divider* Parameter. Voltage reading will be ½ the applied voltage. ->5V

Set *Volt Scale* = 2. Voltage reading will now equal ¼ the applied voltage. -> 2.5V

Enter 5V in the Voltage calibration box and calibrate.

Voltage reading is now 5V with a *Volt Scale* factor of 2 -> 5V × 2 = 10V

6.4 RA Table Limiters

The below parameters are used to limit or control Ra table updates.

Min Res Factor – The Maximum percentage that an Ra value is allowed to change in the negative direction.

Max Res Factor – The Maximum percentage that an Ra value is allowed to change in the positive direction

Min Res Scale **-** Minimum value an Ra value can update to. (Min Ra clamp)

Max Res Scale **–** Maximum value an Ra value can update to. (Max Ra clamp)

Note

The default value for these parameters must not be edited unless there are issues with resistance updates.

6.5 T Rise and T Time Constant

T Rise and T Time constant compensate for the cells self-heating during charge or discharge. T Rise is the thermal rise factor that is used in the single time constant heating-cooling thermal modeling. A larger T Rise value results in higher temperature rise estimations in IT simulations. T Time Constant is the thermal time constant that is used in single time constant heating-cooling thermal modeling. Temp K is T Rise and Temp A is T Time constant. The GPCRb tool can be used to calculate these coefficients.

6.6 Auto Calibration

The device auto calibrates the occur periodically. Section 3.4.3 in the TRM has more information on autocalibration.

6.7 Smoothing

The Smoothing bit can be found in Pack Configuration C. This bit is useful for smoothing out small SOC calculations errors that are a result of low resolution on the voltage and current measurements. This can be caused by large voltage dividers, or small sense resistors that are required for high current or high voltage applications. TI recommends enabling this bit for smoother SOC performance.

6.8 Sealed SRECs

Default .srecs come unsealed. Once the Seal cmd is sent the first time an internal bit is set in the .srec. Once this bit is set the device automatically seals if a reset cmd is sent or a POR occurs. There is no way to toggle this bit off. If a .srec that has once been sealed is flashed on to any device, this device seals upon POR or reset cmd. To return the device to a state where it will not seal upon POR or reset, use the following steps.

1. Extract the parameters on the device (.gg)
2. Flash the default FW onto the device, then upload the .gg to the default .srec

This new .srec when flashed onto a new device does not seal upon POR or reset cmd.

7 Hardware

7.1 VEN Pin

The VEN pin is unique to BQ34z100. The primary function is to turn on and off the voltage divider when needed. The BQ34z100 periodically drives the FET used to enable and disable the external voltage divider when voltage measurements are needed, through the VEN pin. The secondary function is to detect 2.5V. When 2.5V is detected on the VEN pin, the gauge is notified to switch the external LEDs on or off.

7.2 Thermistor

Only the Semitech 103A-T NTC, or a thermistor with the same Beta values, must be used with this device.

7.3 Sense Resistor

Current is detected by the BQ34z100 by the SRN/SRP pins. The abs. max on these pins is +/-125mV. For large current applications it is important that the abs max is not violated. Sense resistor size can be calculated with Equation 1.

$$Rsense = \frac{125mV}{Imax} \tag{1}$$

Note

When using smaller sense resistor, the accuracy when detecting small currents is reduced. The typical input offset error is 10uV. So, for example with a 1mohm sense resistor the device can detect currents as low as 10mA. 10uV/1mohm = 10mA.

7.4 Voltage Divider Calculation

The voltage on the BAT pin cannot exceed 5V. To compensate for this an external voltage divider is required for pack voltages greater than 5V. For the bottom leg of the voltage divider, the resistor must be between the range of 15KΩ and 25KΩ. The voltage divider can be calculated using Equation 2.

$$Rtopleg = Rbottomleg \times \left[\frac{Max\ pack\ voltage - 900mV}{900\ mV}\right] \tag{2}$$

7.5 LEDs

Section 3.9 in the BQ34Z100-R2 Technical Reference Manual discusses the LED function on BQ34z100.

8 Chemistries

8.1 LFP

For the best performance with LFP cells, a custom chemid must be obtained. For most LFP applications both the DODWT bit and the LFP relax bit must both be set. The LFP relax bit can be helpful for any application where meeting the requirements for a Qmax update are difficult to achieve. The LFP relax allows the gauge to take an OCV measurement when VCT conditions are met without a rest period being required. The DODWT bit helps the gauge in the flat region of the LFP OCV curve. This works by having the gauge considering both the previous and new calculated DOD0, which are weighted according to their respective accuracies.

8.2 NiMH/NiCd

For NiMH or NiCd applications valid charge termination can not be detected using the typical taper current method. For NiMH or NiCd, either the Delta Temperature method, or Negative Delta Voltage method should be used. Section 3.7 in the *BQ34Z100-R2 Technical Reference Manual* describes these methods. To switch to an alternative charge termination detection method, set either the NiMH_PbA VCT_DT or NiMH_PbA VCT_DV bits in Pack Configuration (A).

9 Debugging

- The simplest way to check if the gauge is powered on and in FW mode, is to check the voltage on the TS pin. If the voltage on this pin is pulsing on and off the device is in FW mode.
- The easiest way to verify that VCT conditions have been satisfied is to set FC set % = -1. When this is done the FC flag only sets if VCT conditions are met.
- If the application tends to have the gauge enter and exit sleep mode periodically. Consider disabling the Sleep bit in pack configuration (A). When the gauge enters sleep mode it does not coulomb count for the first 20s, as a result of this, coulomb counter error can accumulate if the gauge is constantly entering and exiting sleep mode.
- During testing if there is a consistent an SOC drop to 0% once a certain grid point is reached at room temperature (25degC). The Ra value associated with that grid point may be incorrect. In this case, you can use GPCRa0 tool to optimize Ra tables.
- When flashing FW is interrupted in BQstudio, it is possible for the device to remain in ROM mode. To check if the device is in ROM mode, connect the I2C port on the EVM to the SMBus port on the EV2400/2500. Then "Read Word" 0x0D, if the result is between 0-100, then the device is in FW mode. If the value is larger than 100, then the device is in ROM mode. To exit ROM mode, connect the I2C port on the EVM to the SMBus port on the EV2400/2500. Then send cmd 0x08 and relaunch BQstudio.

10 G1

- Change list from G1 to R2 can be found at the beginning of the *BQ34Z100-R2 Technical Reference Manual*
- The *Curr Scale* parameter is not available on the G1 FW version. If the application requires support for higher currents (>32A), scale using the sense resistor. The process is described here.
- *Min Taper Capacity* is used in VCT detection. See Section 3.7 in theBQ34Z100-R2 Technical Reference Manual for VCT conditions. In R2 FW min taper capacity is in units of mAh/256, meaning that if the user enters 256, 256/256 = 1mAh. For G1 FW min taper capacity is in units of mAh.

Note

If a user is using R2 FW but application requires currents greater than 32A, then scale using the sense resistor and set Curr Scale = 1.

Note

When scaling with the sense resistor, *Quit Current Threshold*, *CHG Current Threshold*, *DSG Current Threshold*, and *Taper Current* must be scaled by the sense resistor scaling factor.

11 Reference Design

See this reference design using BQ34z100 and BQ76952.

12 Summary

Configuring all critical parameters and understanding the features of BQ34z100-R2 is only one piece of creating the golden image for cells. Once the initial parameters are configured, verification testing must be done that replicates the end application as closely as possible. Finer tuning can be required to reach 1% SOC accuracy.

13 References

Texas Instruments, *Using I2C Communications With the bq34110 bq35100 and bq34z100-G1 Series of Gas*, application note.

Texas Instruments, *(+) [FAQ] BQ34Z100-G1: BQ34Z100-G1 FAQs - Power management forum - Power management - TI E2E support forums*, FAQs

Texas Instruments, *Configuring the bq34z100 Data Flash*, application report.

Texas Instruments, *bq34z100-G1 High Cell Count and High Capacity Applications*, application report.

Texas Instruments, *BQ34Z100 to BQ34Z100-G1 Change List*, application report.

Texas Instruments, *How to Create and Program Authentication Keys into TI Battery Fuel Gauges*, application note.

Texas Instruments, *Quickstart Guide for the bq34z100-G1*, application report.

Texas Instruments, *BQ34Z100-R2 Technical Reference Manual*, technical reference manual.

Texas Instruments, *BQ34Z100-R2 Wide Range Fuel Gauge with Impedance Track™ Technology*, datasheet.