How to Configure and Use the bq27410

Ming Yu

ABSTRACT

TI’s Impedance Track (IT)™ fuel gauge is designed for accurately reporting battery remaining capacity and run time. It is necessary to configure and use the gauge correctly to achieve this. The bq27410 differs from the traditional IT-based gauges which require battery chemistry information and a learning cycle to achieve high accuracy. The bq27410 does not require battery chemistry selection or a learning cycle. It relies on an improved algorithm and far fewer data flash parameters to achieve relatively high accuracy. The bq27410 also greatly reduces the design cycle and provides faster time to market.

Contents

1 Using Simplified bqEASY™ Software to Configure bq27410 Limited Data Flash Parameters .............. 2
2 bq27410 Data Flash Parameters ........................................................................................................ 2
2.1 Configurations ............................................................................................................................... 3
2.2 System Data .................................................................................................................................. 5
2.3 Gas Gauging ..................................................................................................................................... 6
2.4 Ra Table ........................................................................................................................................ 8
2.5 Calibration ...................................................................................................................................... 10
2.6 Security .......................................................................................................................................... 12

List of Figures

1 bq27410 Simplified bqEASY™ Tool .................................................................................................. 2
2 Configuration Screen ......................................................................................................................... 3
3 System Data Screen .......................................................................................................................... 6
4 Gas Gauging Screen ........................................................................................................................... 7
5 Default Ra Table Screen ..................................................................................................................... 8
6 Calibration Screen .............................................................................................................................. 10
7 Security Screen ................................................................................................................................. 12

bqEASY, Impedance Track are trademarks of Texas Instruments.
1 Using Simplified bqEASY™ Software to Configure bq27410 Limited Data Flash Parameters

Unlike traditional IT-based gas gauges, the bq27410 has only a handful of parameters that require input. By following the simplified bqEASY™ steps, these parameters can be set by answering simple questions similar to traditional IT-based gauges. These questions are related to cell characteristics, charge and discharge conditions required by cell manufacturers, and system requirements by design (Figure 1).

In the bqEASY™ process, it is unnecessary to select a chemical ID or run the learning cycle. The calibration process occurs in the calibrate screen. The calibration procedure also is improved. See Section 2.5 for details.

Once these questions are answered, the data is saved into bq27410 data flash and the gauge can be immediately used in a real system without going through the learning cycle.

2 bq27410 Data Flash Parameters

A user needs to configure only 21 data flash parameters, which are far fewer than those found in traditional IT-based gauges.
2.1 Configurations

2.1.1 Charge

**Charging Voltage**
The bq27410 uses this value along with **Taper Voltage** to detect charge termination.

**Normal Setting:** This value depends on the battery and the charger that is expected to be used with the bq27410. The default is 4200 mV.

2.1.2 Charge Termination

**Taper Current**
**Taper Current** is used in the Primary Charge Termination algorithm. **Average Current** is integrated over each of the two **Current Taper Window** periods separately, and then they are averaged separately to give two averages. Both of these averages must be below the **Taper Current** to qualify for a Primary Charge Termination. In total, a primary charge termination has the following requirements:

1. During two consecutive periods of **Current Taper Window**, the **Average Current** is < **Taper Current**.
2. During the same periods, the accumulated change in capacity > 0.25 mAh/Current Taper Window.
3. **Voltage** > **Charging Voltage** - **Taper Voltage**.
When this occurs, the [FC] bit of Flags() is set and [CHG] bit is cleared. Also, if the [RMFCC] bit of Operation Config is set, then Remaining Capacity is set equal to Full Charge Capacity.

**Normal Setting:** This register depends on battery cell characteristics and charger specifications, but typical values are C/10 to C/20. Average Current is not used for this qualification because its time constant is not the same as the Current Taper Window. The reason for making two Current Taper qualifications is to prevent false current taper qualifications. False primary terminations happen with pulse charging and with random starting and stopping of the charge current. This is particularly critical at the beginning or end of the qualification period. It is important to note that as the Current Taper Window value is increased, the current range in the second requirement for primary charge termination is lowered. If you increase the Current Taper Window, then the current used to integrate to the 0.25 mAh is decreased; so, this threshold becomes more sensitive. Therefore, take care when modifying the Current Taper Window. The default is 100 mA.

**Taper Voltage**

During Primary Charge Termination detection, one of the three requirements is that Voltage must be above (Charging Voltage – Taper Voltage) for the bq27410 to start trying to qualify a termination. It must be above this voltage before bq27410 starts trying to detect a primary charge termination.

**Normal Setting:** This value depends on charger characteristics. It needs to be set so that ripple voltage, noise, and charger tolerances are taken into account. A high value selected can cause early termination. If the value selected is too low, then it can cause no termination or late termination detection. An example value is 100 mV (see Taper Current).

### 2.1.3 Data

**Design Capacity**

This value is used for initial compensated battery capacity calculations.

**Normal Setting:** This value is set based on the battery manufacturer's data sheet specification. The default is 1340 mAh.

**Design Energy**

This value is used for initial compensated battery energy calculations.

**Normal Setting:** This value is set based on the battery manufacturer's data sheet specification. The default is 4960 mWh (Default Design Capacity times 3.7V)

### 2.1.4 Register

**Op Config**

This register is used to enable or disable various functions of the bq27410.

<table>
<thead>
<tr>
<th>RESCAP</th>
<th>RSVD</th>
<th>BATLOWEN</th>
<th>SLEEP</th>
<th>RMFCC</th>
<th>BIE</th>
<th>GPIOPOL</th>
<th>WRTTEMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESCAP [7]: If set, a no-load rate of compensation is applied to the reserve capacity. <strong>Normal Setting:</strong> True when set. This bit defaults to 0.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSVD [6]: Reserved</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BATLOWEN [5]: If set, the BAT_LOW function for GPOUT pin is selected. If cleared, the SOC_INT function is selected for GPOUT. <strong>Normal Setting:</strong> This bit defaults to 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLEEP [4]: If set, the gas gauge can enter sleep if operating conditions allow. The bq27410 enters SLEEP if Average Current ≤ Sleep Current <strong>Normal Setting:</strong> This bit defaults to 0, which is used in most applications. Only a few reasons require this bit to be set to 0.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMFCC [3]: If set, on valid charge termination, Remaining Capacity is updated with the value from Full Charge Capacity on valid charge termination. <strong>Normal Setting:</strong> The default setting for this bit is 1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIE [2]: Battery Insertion Enable. If set, the battery insertion is detected via BIN pin input (need external pull up on BIN pin). If cleared, the detection relies on the host to issue BAT_INSERT subcommand to indicate battery presence in the system. <strong>Normal Setting:</strong> This bit defaults to 0.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• GPIOPOL [1]: PGOUT pin polarity control. When set, PGOUT pin is active-high. PGOUT pin is active-low if cleared.
  **Normal Setting:** This bit defaults to a 0.

• WRTEMP [0]: Enable the host to write Temperature ( ) to gauge if set. If cleared, the internal temperature sensor is used for Temperature ( ).
  **Normal Setting:** This bit defaults to 1.

**SOCI_Delta**
This value is used to define the SOC_INT intervals. The intervals are defined as n×SOCI_Delta from 0% to 100% SOC. For example, if SOCI_Delta = 10%, the SOC_INT intervals are 0%, 10%, 20%,......90%, 100%.

  **Normal Setting:** The default is 1%

### 2.1.5 Power

Sleep Current
When **Average Current** is less than Sleep Current or greater than (–) Sleep Current in mA, the bq27410 enters SLEEP mode if the feature is enabled (Op Config [SLEEP] = 1). The bq27410 does an analog-to-digital converter (ADC) calibration and then goes to sleep.

  **Normal Setting:** This setting must be below any normal application currents. The default is 10 mA, which is sufficient for most applications.

Hibernate I
When **Average Current** is less than Hibernate I or greater than (–)Hibernate I in mA, the bq27410 enters Hibernate mode if **Control Status** [HIBERNATE] = 1.

  **Normal Setting:** This setting must be below any normal application currents. The default is 8 mA, which is sufficient for most applications.

Hibernate V
When Voltage is less than Hibernate V or greater than (–)Hibernate V in mV, the bq27410 enters Hibernate mode if **Control Status** [HIBERNATE] = 1.

  **Normal Setting:** This setting must be below any normal application currents. The default is 2550 mV, which is sufficient for most applications.

### 2.2 System Data

### 2.2.1 Manufacturer Info

**Block A**
This is string data that can be any user data. It can be a maximum of 8 characters.

  **Normal Setting:** Can be used for any user data. The default is all data 0.
2.3 Gas Gauging

2.3.1 IT Cfg

Terminate Voltage

Terminate Voltage is used in the Impedance Track™ algorithm to help compute Remaining Capacity. This is the absolute minimum voltage for end of discharge, where the remaining chemical capacity is assumed to be zero.

Normal Setting: This register is application dependent. It is set based on battery cell specifications to prevent damage to the cells or the absolute minimum system input voltage, taking into account impedance drop from the PCB traces, FETs, and wires. The default is 3000mV.
Figure 4. Gas Gauging Screen
2.4 Ra Table

The purpose for two profiles for the cell is to ensure that at any given time at least one profile is enabled and is being used while attempts can be made to update the alternate profile without interference. Having two profiles also helps reduce stress on the flash memory. At the beginning of each of the two subclasses (profiles) is a flag called `Cell0 R_a flag` or `xCell0 R_a flag`. This flag is a status flag that indicates the validity of the table data associated with this flag and whether this particular table is currently in use.

Each subclass (R_a0 and R_a0x) in the Ra Table class is a separate profile of resistance values normalized at 0 degrees for the cell in a design. The cell has two profiles. They are denoted by the x or absence of the x at the end of the subclass title.

### R_a0 or R_a0x

The purpose for two profiles for the cell is to ensure that at any given time at least one profile is enabled and is being used while attempts can be made to update the alternate profile without interference. Having two profiles also helps reduce stress on the flash memory. At the beginning of each of the two subclasses (profiles) is a flag called `Cell0 R_a flag` or `xCell0 R_a flag`. This flag is a status flag that indicates the validity of the table data associated with this flag and whether this particular table is currently in use.

Cell0 R_a flag and xCell0 R_a flag

Each flag has two bytes:

1. The LSB (least-significant byte) indicates whether the table is currently enabled or disabled. It has the following options:
   
   (a) 0x00: means the table has had a resistance update in the past; however, it is not the currently
enabled table for the cell. (The alternate table for the cell must be enabled at this time.)
(b) 0xff: This means that the values in this table are default values. These table resistance values have
never been updated, and this table is not the currently enabled table for the cell. (The alternate
table for the indicated cell must be enabled at this time.)
(c) 0x55: This means that this table is enabled for the indicated cell. (The alternate table must be
disabled at this time.)

2. The MSB (Most-significant byte) indicates the status of the data in this particular table. The possible
values for this byte are:
(a) 0x00: The data associated with this flag has had a resistance update.
(b) 0x05: The resistance data associated with this flag has been updated and the pack is no longer
discharging.
(c) 0x55: The resistance data associated with this flag has been updated and the pack is still
discharging.
This data is used by the bq27410 to determine which tables need updating and which tables are being
used for the Impedance Track™ algorithm.

Normal Setting: This data is used by the bq27410 Impedance Track™ algorithm. This description of
the xCell0 R_a flags are intended for information purposes only. It is not intended to give a detailed
functional description for the bq27410 resistance algorithms. Cell0 R_a flag is set to 0x0055 and xCell0
R_a flag is set to 0x00FF.

Cell0 R_a0 – Cell0 R_a14 and xCell0 R_a0 – xCell0 R_a14,

The Ra Table class has 15 values for each R_a subclass. Each of these values represents a resistance
value normalized at 25°C for the associated Qmax Pack-based SOC grid point as found by the following
rules:

For Cell0 R_aM where:
1. If 0 ≤ M ≤ 8 : The data is the resistance normalized at 0° for: SOC = 100% (M × 10%)
2. If 9 ≤ M ≤ 14 : The data is the resistance normalized at 0° for: SOC = 100% – [80% + (M – 8) × 3.3%]

This gives a profile of resistance throughout the entire SOC profile of the battery cells concentrating more
on the values closer to 0%.

Normal Setting: These resistance profiles are used by the bq27410 for the Impedance Track™ algorithm.
This resistance profile description is for information purposes only. It is not intended to give a detailed
functional description for the bq27410 resistance algorithms. It is important to note that this data is in mΩ
units and is normalized to 25°C. The following are useful observations to note with this data throughout
the application development cycle:
1. Watch for negative values in the Ra Table class. Negative numbers in profiles do not belong in this
class.
2. Watch for smooth consistent transitions from one profile grid point value to the next throughout each
profile. As the bq27410 does resistance profile updates, these values are roughly consistent from one
learned update to another without huge jumps in consecutive grid points.
2.5 Calibration

2.5.1 Data

Most of these values never require modification by the user. They are only modified by the Calibration commands in Calibration mode.

**CC Gain**

This is the gain factor for calibrating Sense Resistor, Trace, and internal Coulomb Counter (integrating ADC delta sigma) errors. It is used in the algorithm that reports Average Current. The difference between CC Gain and CC Delta is that the algorithm that reports Current cancels out the time base because Average Current does not have a time component (it reports in mA) and CC Delta requires a time base for reporting Remaining Capacity (it reports in mAh).

Normal Setting: CC Gain never needs to be modified directly by the user. It is modified by the current calibration function from Calibration mode.

**CC Delta**

This is the delta factor for calibrating Sense Resistor, Trace, and internal Coulomb Counter (integrating ADC delta sigma) errors. It is used in the algorithm that reports charge and discharge in and out of the battery through the Remaining Capacity register. The difference between CC Gain and CC Delta is that the algorithm that reports Average Current cancels out the time base because Average Current does not have a time component (it reports in mA) and CC Delta requires a time base for reporting Remaining Capacity (it reports in mAh).
Normal Setting: CC Delta never needs to be modified directly by the user. It is modified by the current calibration function from Calibration mode.

**CC Offset**

Two offsets are used for calibrating the offset of the internal Coulomb Counter, board layout, sense resistor, copper traces, and other offsets from the Coulomb Counter readings. CC Offset is the calibration value that primarily corrects for the offset error of the bq27410 Coulomb Counter circuitry. The other offset calibration is Board Offset and is described next. To minimize external influences when doing CC Offset calibration either by automatic CC Offset calibration or by the CC Offset calibration function in Calibration Mode, an internal short is placed across the SRP and SRN pins inside the bq27410. CC Offset is a correction for small noise/errors; therefore, to maximize accuracy, it takes about 20 seconds to calibrate the offset. Because it is impractical to do a 20-s offset during production, two different methods for calibrating CC Offset were developed.

1. The first method is to calibrate CC Offset by the putting the bq27410 in Calibration mode and initiating the CC Offset function as part of the entire bq27410 calibration suite. See the application report *Going to Production With the bq274xx* (SLUA595) for more information on the Calibration mode. This is a short calibration that is not as accurate as the second method, Board Offset. Its primary purpose is to calibrate CC Offset enough so that it does not affect any other Coulomb Counter calibrations. This is only intended as a temporary calibration because the automatic calibration, Board Offset, is done the first time the I2C Data and Clock is low for more than 20 seconds, which is a much more accurate calibration.

2. During normal Gas Gauge Operation when the I2C clock and data lines are low for more than 5 seconds and Average Current is less than Sleep Current in mA, then an automatic CC Offset calibration is performed. This takes approximately 16 seconds and is much more accurate than the method in Calibration mode.

Normal Setting: CC Offset never needs to be modified directly by the user. It is modified by the current calibration function from Calibration mode or by Automatic Calibration. See the application report *Going to Production With the bq274xx* (SLUA595) for more information on calibration.

**Board Offset**

Board Offset is the second offset register. Its primary purpose is to calibrate all that the CC Offset does not calibrate out. This includes board layout, sense resistor and copper trace, and other offsets that are external to the bq27410 integrated circuit (IC). The simplified ground circuit design in the bq27410 requires a separate board offset for each tested device.

Normal Setting: This value is set only one time when all the other data flash constants are modified during the pack production process. It defaults to 0 µA.

**Int Temp Offset**

The bq27410 has a temperature sensor built into the IC. The Int Temp Offset is used for calibrating offset errors in the measurement of the reported Temperature if the internal temperature sensor is used. The gain of the internal temperature sensor is accurate enough that a calibration for gain is not required.

Normal Setting: Int Temp Offset never needs to be modified by the user. It is modified by the internal temperature sensor calibration command in Calibration mode. Int Temp Offset is only calibrated if the internal temperature sensor is used. See the application report *Going to Production With the bq274xx* (SLUA595) for more information on calibration. It defaults to 0°C.

**Pack V Offset**

This is the offset to calibrate the bq27510 analog-to-digital converter for cell voltage measurement.

Normal Setting: Pack V Offset never needs to be modified directly by the user. It is modified by the Voltage Calibration function from Calibration mode. This value is only set one time when all the other data flash constants are modified during the pack production process. See the application report *Going to Production With the bq274xx* (SLUA595) for more information on calibration. It defaults to 0 mV.
2.6 Security

2.6.1 Codes

Sealed to Unsealed
This is the register to store the security code to set the device from sealed mode to unsealed mode.

Normal Setting: The default code is set to 0x36720414.

Unsealed to Full
This is the register to store the security code to set the device from unsealed mode to full access mode.

Normal Setting: The default code is set to 0xFFFFFFFF.

FactRestore Key
This is the register to store the factory restore key to allow forcing a factory restore of learned resistance and Qmax to defaults if the device is sealed.

Normal Setting: The default code is set to 0x0DEF0FAC.
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of TI.

Replication of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal and regulatory requirements concerning their products and any use of TI products in such safety-critical applications. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products
Audio www.ti.com/audio
Amplifiers amplifier.ti.com
Data Converters dataconverter.ti.com
DLP® Products www.dlp.com
DSP dsp.ti.com
Clocks and Timers www.ti.com/clocks
Interface interface.ti.com
Logic logic.ti.com
Power Mgmt power.ti.com
Microcontrollers microcontroller.ti.com
RFID www.ti-rfid.com
RF/IF and ZigBee® Solutions www.ti.com/lprf

Applications
Communications and Telecom www.ti.com/communications
Computers and Peripherals www.ti.com/computers
Consumer Electronics www.ti.com/consumer-apps
Energy and Lighting www.ti.com/energy
Industrial www.ti.com/industrial
Medical www.ti.com/medical
Space, Avionics and Defense www.ti.com/space-avionics-defense
Transportation and Automotive www.ti.com/automotive
Video and Imaging www.ti.com/video
Wireless www.ti.com/wireless-apps

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated