Application Report
SLUA656–December 2012

Configuring the bq2754x-G1 Data Flash

Kang Kang, Jared Casey, David Maxwell *PMP-BMS-Handheld*

ABSTRACT

The bq2754x-G1 pack-side Impedance Track™ fuel gauges are extremely flexible and have many data flash parameters that can be used to configure the device. The configuration options include settings for operation, gauging, and I/O. Some default values are usually used as-is, but many settings should be tailored to match your system characteristics and battery profile. Software tools are available on ti.com to assist in the configuration, but this application note describes each parameter in detail. The data flash of the bq2754x-G1 is split into sections, which are described in detail in this document.

Contents

List of Figures

Impedance Track is a trademark of Texas Instruments, Inc..

List of Tables

1 Introduction

The document describes the different user-configurable data flash (DF) parameters that are utilized by the bq2754x-G1 v2.24 algorithm. The screen shots used in this document are from bq27541-G1, but also apply to the bq27545-G1.

2 Glossary

FCC: Full Charge Capacity, typically referred to in context with the bq2754x-G1's Standard Command *FullChargeCapacity( )*

Flag: This word usually represents a read-only status bit that indicates some action occurred or is occurring. This bit typically cannot be modified. The bq2754x-G1 flags are set and cleared automatically by the gauge.

RM: Remaining Capacity, typically referred to in context with the bq2754x-G1's standard command *RemainingCapacity( )*

SOC: State of Charge, typically referred to in context with the bq2754x-G1's standard command *StateOfCharge( )*

Relaxation Mode: Refers to a mode to where the gauge read *AverageCurrent( )* < ***Quit Current*** for at least 60 seconds.

Discharge Mode: Refers to a mode where the gauge read *AverageCurrent( )* < (***(–)Dsg Current Threshold*** for at least 1 second.

Charge Mode: Refers to a mode to where the gauge read *AverageCurrent( )* > ***Chg Current Threshold*** for at least 1 second.

Set: Refers to a bit in a register becoming a logic HIGH or 1. The bqEvaluation software (EVSW) represents a set bit with the color red.

Clear: Refers to a bit in a register becoming a logic LOW or 0. The bqEvaluation software (EVSW) represents a clear bit with the color green.

System: The word system is sometimes used in this document. When used, it always means a host system that is consuming current from the battery pack.

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: *italics* with brackets[ ], for example, *[TDA]*

Data flash bits: *italics*, **bold**, and brackets [ ], for example, ***[LED1]***

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

3 Configuration

Sections Section 3.1 through Section 3.13 give details for configuration of the bq27754x-G1 including safety, charge inhibit configuration, charge, charge termination, data, discharge, manufacturer data, integrity data, lifetime data, lifetime temp samples, and registers.

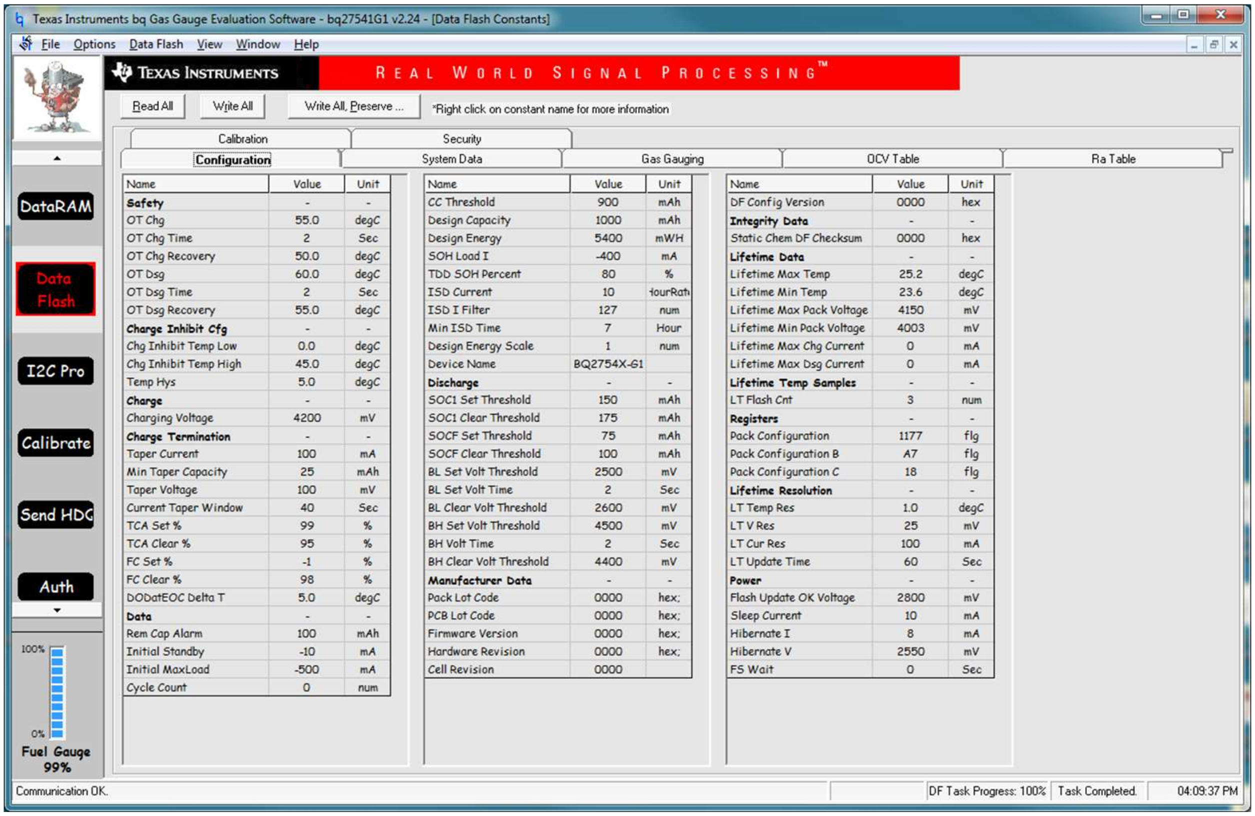

Figure 1. Configuration Screen

3.1 Safety

OT Chg

When the pack temperature measured by *Temperature( )* rises to or above the Over Temperature Charge (***OT Chg***) threshold while charging (***Current*** > ***Chg Current Threshold***), then the Over Temperature in charge direction *[OTC]* is set in *Flags( )* after ***OT Chg Time***. If the OTC condition clears prior to the expiration of the ***OT Chg Time*** timer, then *[OTC]* is not set in *Flags( )*.

Normal Setting: This setting depends on the environment temperature and the battery specification. Verify battery specification allows temperatures up to this setting during a charge and that this setting is sufficient for the application. The default is 55°C, sufficient for most Li-ion applications.

OT Chg Time

See ***OT Chg***. This is a buffer time allotted for Over Temperature in the charge direction condition. The timer starts every time that *Temperature( )* is greater than ***OT Chg*** and during a charge. When the timer expires, the bq2754x-G1 forces an *[OTC]* in *Flags( )*. Setting the ***OT Chg Time*** to 0 disables this function.

Normal Setting: Default is set to 2 seconds, sufficient for most applications. Temperature is normally a slow-varying condition that does not need high-speed triggering. It must be set long enough to prevent false triggering of the *[OTC]* in *Flags( )*, but short enough to prevent damage to the battery pack.

OT Chg Recovery

OT Chg Recovery is the temperature when the battery recovers from an ***OT Chg*** fault. This is the only recovery method for an ***OT Chg*** fault.

Normal Setting: The default is 50°C which is 5°C lower than ***OT Chg***.

OT Dsg

When the pack temperature measured by *Temperature( )* rises to or above this threshold while discharging (***Current*** < (–)***Dsg Current Threshold***), then the Over Temperature in discharge direction *[OTD]* is set in *Flags( )* after ***OT Dsg Time***. If the OTD condition clears prior to the expiration of the ***OT Dsg Time*** timer, then no *[OTD]* is set in *Flags( )*. If the condition does not clear, then *[OTD]* is set in *Flags( )*.

Normal Setting: This setting depends on the environment temperature and the battery specification. Verify that the battery specification allows temperatures up to this setting while charging, and verify that these setting are sufficient for the application temperature. The default is 60°C which is sufficient for most Li-ion applications. The default ***OT Dsg*** is higher than the default ***OT Chg*** because Li-ion can handle a higher temperature in the discharge direction than in the charge direction.

OT Dsg Time

See ***OT Dsg***. This is a buffer time allotted for Over Temperature in the discharge direction condition. The timer starts every time that *Temperature( )* measured is greater than ***OT Dsg*** during a discharge. When the timer expires, then the bq2754x-G1 forces the *[OTD]* bit to set in *Flags( )*. Setting the ***OT Dsg Time*** to 0 disables this feature.

Normal Setting: This is normally set to 2 seconds which is sufficient for most applications. Temperature is normally a slow-acting condition that does not need high-speed triggering. Set ***OT Dsg Time*** long enough to prevent false triggering of the *[OTD]* in *Flags( )*, but short enough to prevent damage to the battery pack.

OT Dsg Recovery

OT Dsg Recovery is the temperature at which the battery recovers from an ***OT Dsg*** fault. This is the only recovery method for an ***OT Dsg*** fault.

Normal Setting: The default is 55°C which is 5°C lower than ***OT Dsg***

3.2 Charge Inhibit Configuration (Charge Inhibit Cfg)

Chg Inhibit Temp Low

If pack temperature measured by *Temperature( )* falls to or below the charge inhibit temperature low (***Chg Inhibit Temp Low***) threshold, then the Charge Inhibit *[CHG_INH]* is set in *Flags( )*. The *[CHG_INH]* is reset to 0 once battery temperature returns to the range ***[Chg Inhibit Temp Low + Temp Hys, Chg Inhibit Temp High – Temp Hys]***. Charging should not start when the *[CHG_INH]* bit is set. Though charging can continue if the charging starts inside the window ***[Chg Inhibit Temp Low, Chg Inhibit Temp High]*** until the temperature is either below ***[Suspend Temperature Low, Suspend Temperature High]***. Therefore, the window ***[Chg Inhibit Temp Low, Chg Inhibit Temp High]*** must be inside the window of ***[Suspend Temperature Low, Suspend Temperature High]***.

Normal Setting: This setting depends on the environment temperature and the battery specification. Verify that the battery specification allows temperatures up to this setting while charging, and verify that these setting are sufficient for the application temperature. The default is 0°C, sufficient for most Li-ion applications.

Chg Inhibit Temp High

If the pack temperature measured by *Temperature( )* rises to or above the charge inhibit temperature high (***Chg Inhibit Temp High***) threshold, the Charge Inhibit *[CHG_INH]* is set in *Flags( )*. The *[CHG_INH]* is reset to 0, once battery temperature returns to the range ***[Chg Inhibit Temp Low + Temp Hys, Chg Inhibit Temp High – Temp Hys]***. Charging should not start when the *[CHG_INH]* bit is set. Though charging can continue if the charging starts inside the window ***[Chg Inhibit Temp Low, Chg Inhibit Temp High]*** until the temperature is either below ***[Suspend Temperature Low, Suspend Temperature High]***. Therefore, the window ***[Chg Inhibit Temp Low, Chg Inhibit Temp High]*** must be inside the window of ***[Suspend Temperature Low, Suspend Temperature High]***.

Normal Setting: This setting depends on the environment temperature and the battery specification. Verify that the battery specification allows temperatures up to this setting while charging, and verify that these setting are sufficient for the application temperature. The default is 45°C, sufficient for most Li-ion applications.

Temp Hys

This parameter is defined to provide hysteresis to recover from a ***Chg Inhibit Temp Low*** or ***Chg Inhibit Temp High*** condition. The hysteresis prevents the flags ***Chg Inhibit Temp Low/High*** from triggering repeatedly when the temperature is close to the thresholds defined above.

Normal Setting: This setting depends on the volatility of the environmental temperature and the battery specifications. The default is 5°C, which is sufficient for most Li-ion applications.

3.3 Charge

Charging Voltage

The bq2754x-G1 uses this value along with ***Taper Voltage*** to detect charge termination.

Normal Setting: The value selected depends on the system, battery, and charger specifications. The default is 4.2 V.

3.4 Charge Termination

Taper Current

Taper Current sets a current threshold that is used as one of the three requirements to detect charge termination. The gauge must detect *AverageCurrent( )* that is below the ***Taper Current*** threshold during two consecutive periods specified by the ***Current Taper Window*** parameter.

Normal Setting: Set ***Taper Current*** based on battery cell characteristics and charger specifications, typical values fall within (***Design Capacity*** / 10) to (***Design Capacity*** / 20). The default value is set to 100 mA.

Min Taper Capacity

Min Taper Capacity sets an accumulated capacity threshold that is used as one of the three requirements to detect charge termination. The minimum taper capacity requirement for charge termination detection is that the gauge must detect an accumulated charge that is greater than the ***Min Taper Capacity*** threshold during two consecutive periods of the ***Current Taper Window***.

Normal Setting: Do not modify ***Min Taper Capacity***. The default value is set to 25 mAh.

Taper Voltage

Taper Voltage

Voltage threshold is one of three requirements for charge termination detection. The gauge must detect *Voltage( )* above the (***Charging Voltage*** – ***Taper Voltage***) threshold during two consecutive periods of the ***Current Taper Window***.

Normal Setting: Set ***Taper Voltage*** based on battery cell characteristics and charger specifications. Typical values are set 100 mV below the maximum battery cell charging voltage. The default value is 4100 mV for a 4.2-V battery.

Current Taper Window

Current Taper Window sets a length of time that is used to determine if all three requirements for charge termination detection are satisfied. Refer to ***Min Taper Capacity***, ***Taper Current***, and ***Taper Voltage*** for more information on charge termination detection. In closing, for the bq2754x-G1 to detect charge termination, during two consecutive periods of ***Current Taper Window***, the following requirements must be satisfied:

1. *AverageCurrent( )* < ***Taper Current***
2. Accumulated capacity is > ***Min Taper Capacity***
3. *Voltage( )* > ***Taper Voltage***

Normal Setting: Do not modify ***Current Taper Window***. The default value is set to 40 seconds.

TCA Set %

TCA Set % is the Terminate Charge Alarm Set Percentage threshold. ***TCA Set %*** sets a *StateOfCharge( )* percentage threshold at which the (Fast) Charge Allowed *[CHG]* bit in the*Flags( )* register is cleared. When ***TCA Set %*** is set to (–)1, it disables the use of the Charge Alarm threshold. When ***TCA Set %*** is set to (–)1, the (Fast) Charge Allowed *[CHG]* bit in the *Flags( )* register is cleared when the taper condition is detected.

Normal Setting: ***TCA Set %*** only affects the (Fast) Charge Allowed *[CHG]* bit in the *Flags( )* register but does not affect the charge termination process or the gauging function. The default value is set to 99%.

TCA Clear %

TCA Clear % is the Terminate Charge Alarm Clear Percentage threshold. ***TCA Clear %*** sets a *StateOfCharge( )* percentage level at which the (Fast) Charge Allowed *[CHG]* bit in the *Flags( )* register is set.

Normal Setting: ***TCA Clear %*** only affects the (Fast) Charge Allowed *[CHG]* bit in the *Flags( )* register but does not affect the charge termination process or the gauging function. The default value is set to 95%.

FC Set %

FC Set % is the Full Charge Set Percentage threshold. ***FC Set %*** sets a *StateOfCharge( )* percentage threshold at which the Full Charge *[FC]* bit in the *Flags( )* register is set. When ***FC Set %*** is a value other than (–)1, the Full Charge *[FC]* bit is set based on the amount of passed charge detected by the gauge and not charge termination detection. If ***FC Set %*** is set to (–)1, the Full Charge *[FC]* bit is set based on charge termination detection (refer to ***Min Taper Capacity***, ***Taper Current*** and ***Taper Voltage*** in Section 3.4).

Normal Setting:***FC Set %*** only affects the Full Charge *[FC]* bit in the *Flags( )* register which does not affect the charge termination process. The default value is set to 100%.

FC Clear %

FC Clear % is the Full Charge Clear Percentage threshold.***FC Clear %*** sets a *StateOfCharge( )* percentage threshold at which the Full Charge *[FC]* bit in the *Flags( )* register is cleared.

Normal Setting: ***FC Clear %*** only affects the Full Charge *[FC]* bit in the *Flags( )* register which does not affect the charge termination process. The default value is set to 98%.

DODatEOC Delta T

This represents the temperature change threshold to update Q_{start} and *RemainingCapacity( )* due to temperature changes. During relaxation and at the start of charging, the remaining capacity is calculated as *RemainingCapacity( )* = *FullChargeCapacity( )* – Q_{start}. As temperature decreases, Q_{start} can become much smaller than that of the old *FullChargeCapacity( )* value, resulting in overestimation of *RemainingCapacity( )*. To improve accuracy, *FullChargeCapacity( )* is updated whenever the temperature change since the last *FullChargeCapacity( )* update is greater than ***DODatEOC Delta T*** × 0.1ºC.

Normal Setting: The default value is 50. Note that the units are a tenth of a degree Celsius which means a value of 50 corresponds to 5 ºC.

3.5 Data

Rem Cap Alarm

This value is not utilized and does not affect gauging performance.

Normal Setting: The default value is 100 mAh.

Initial Standby

This is the first value that is reported in *StandbyCurrent( )*. The *StandbyCurrent( )* value is updated every second when the measured current is above the ***Deadband*** and is less than or equal to 2 × ***Initial Standby*** current.

Normal Setting: This value depends on the system. The initial standby current is the current drawn by the system in low-power mode. The default value is (–)10 mA.

Initial MaxLoad

This is the first value that is reported in *MaxLoadCurrent( )*. If the measured current is ever greater than ***Initial MaxLoad***, then *MaxLoadCurrent( )* updates to the new current. *MaxLoadCurrent( )* is reduced to the average of the previous value and ***Initial MaxLoad*** whenever the battery is charged to full after a previous discharge to an SOC less than 50%. This prevents the reported value from maintaining an unusually high value.

Normal Setting: This value depends on the system. The default value is (–)500 mA.

Cycle Count

When the bq2754x-G1 accumulates enough discharge capacity equal to the ***CC Threshold***, then it increments ***Cycle Count*** by 1. This discharge capacity does not have to be consecutive. The internal register that accumulates the discharge is not cleared at any time except when the internal accumulating register equals the ***CC Threshold***, and increments ***Cycle Count***.

Normal Setting: The default is 0.

CC Threshold

This value is always used to increment ***Cycle Count***. When the bq2754x-G1 accumulates enough discharge capacity equal to the ***CC Threshold***, then it increments ***Cycle Count*** by 1. This discharge capacity does not have to be consecutive. The internal register that accumulates the discharge is not cleared at any time except when the internal accumulating register equals the ***CC Threshold***, and increments ***Cycle Count***.

Normal Setting: This is normally set around 90% of the ***Design Capacity***. The default is 900 mAh.

Design Capacity

Design Capacity stores the typical capacity, in mAh, of the cell being used in the system. ***Design Capacity*** calculates the current thresholds in which the gauge will enter charge mode, discharge mode and relaxation mode. ***Design Capacity*** is also used by the gauge in *RemainingCapacity( )*, *FullChargeCapacity( )* and *StateOfHealth( )* calculations.

Normal Setting: Set ***Design Capacity*** based on the application battery specification. See the battery manufacturer's data sheet. The default value is set to 1000 mAh.

Design Energy

Design Energy is used to store the typical capacity, in mWh or cWh, of the cell being used in the system. The units depends on the value of ***Design Energy Scale***. (See ***Design Energy Scale***).

Normal Setting: Set ***Design Energy*** based on the application battery specification. See the battery manufacturer's data sheet. The default value is set to 5400 mWh (***Design Capacity*** × 3.7).

SOH Load I

State of Health is calculated using the ratio of *FullChargeCapacity( )* (FCC) and *DesignCapacity( )*. The FCC used in the SOH calculation is simulated using a fixed temperature (25ºC) and load (defined by ***SOH Load I***). The FCC value used is not necessarily the same as the *FullChargeCapacity( )* data RAM register since the value reported in data RAM register changes based on current system load and temperature.

Normal Setting: The default is (–)400 mA. It is recommended to set this value to a typical system current.

TDD SOH Percent

The bq2754x-G1 can indicate tab disconnection by detecting change of *StateOfHealth( )*. This feature is enabled by setting ***[SE_TDD]*** bit in ***Pack Configuration B***. The *[TDD]* of *Flags( )* is set when the ratio of current *StateOfHealth( )* divided by the previous *StateOfHealth( )* reported is less than ***TDD SOH Percent***. The *[TDD]* of *Flags( )* can be configured to control an interrupt pin (SE or HDQ) by enabling interrupt mode.

Normal Setting: The default is 80%.

ISD Current

The bq2754x-G1 can indicate detection of an internal battery short if the ***[SE_ISD]*** bit in ***Pack Configuration B*** is set. The gauge compares the self-discharge current calculated based on relaxation mode to the *AverageCurrent( )* measured in the system. The self-discharge rate is measured at 1 hour intervals. When battery *SelfDischargeCurrent( )* is less than the predefined (–)***Design Capacity*** / ***ISD Current*** threshold, the *[ISD]* of *Flags( )* is set high. The *[ISD]* of *Flags( )* can be configured to control interrupt pin (SE or HDQ) by enabling interrupt mode.

Normal Setting: The default is 10 HourRate. The HourRate unit is defined as *DesignCapacity( )* / [HourRate]. It is recommended to test this feature and tune this parameter to obtain the optimal value in order to avoid both false positives and false negatives.

ISD I Filter

The ISD I Filter filters the amount of change allowed in the *SelfDischargeCurrent( )* register. A large value of ***ISD I Filter*** restricts large fluctuations in the value of *SelfDischargeCurrent( )* if the most recent current value read by the gauge is significantly different from the previous readings. A small value of ***ISD I Filter*** allows the value of *SelfDischargeCurrent( )* to update to a value that is closer to the most recent value read by the gauge.

Normal Setting: The default is 127.

Min ISD Time

This parameter defines the amount of time the gauge needs to wait after the initial DOD measurement is made in relaxation mode before an attempt is made to detect an internal short in the battery pack.

Normal Setting: The default is 7 hours.

Design Energy Scale

Design Energy Scale selects the scale or unit of a set of data flash parameters listed in the table below along with *AveragePower( )* [mW for 1, cW for 10]. Please note that ***Design Energy Scale*** can only be 1 or 10, no other values are supported.

Table 1. Data Flash Parameter Scale / Unit Based on Design Energy Scale

Data Flash	Design Energy Scale = 1	Design Energy Scale = 10
Design Energy	mWh	cWh
Reserve Energy		
Average Power Last Run	mW	cW
User Rate-Pwr	mWh	cWh
T Rise	No scale	Scaled by × 10

Normal Setting: The default value is 1. For battery capacities larger than 6 AHr, a value of 10 is recommended.

Device Name

This is string data that can be a maximum of 7 characters. This field does not affect the operation, nor is it used by the gauge in any way. It is returned by reading addresses 0x63 through 0x69. The default is ASCII characters for BQ2754X-G1.

3.6 Discharge

SOC1 Set Threshold

SOC1 Set Threshold sets a *StateOfCharge( )* percentage threshold used to indicate when *StateOfCharge( )* falls to or below a defined *StateOfCharge( )*. The ***SOC1 Set Threshold*** is typically used as an initial low *StateOfCharge( )* warning. When *StateOfCharge( )* falls below the***SOC1 Set Threshold***, the State of Charge Initial *[SOC1]* bit in the *Flags( )* register is set. The State of Charge Initial *[SOC1]* bit is cleared once *StateOfCharge( )* rises above the ***SOC1 Clear Threshold***. If ***SOC1 Set Threshold*** is set to (–)1, then the State of Charge Initial *[SOC1]* bit becomes inoperative.

Normal Setting: The default value is set to 10%.

SOC1 Clear Threshold

SOC1 Clear Threshold sets a *StateOfCharge( )* percentage threshold used to indicate when *StateOfCharge( )* rises above a defined *StateOfCharge( )*. When *StateOfCharge( )* rises above the ***SOC1 Clear Threshold***, the State of Charge Initial *[SOC1]* bit in the *Flags( )* register is cleared.

Normal Setting: ***SOC1 Clear Threshold*** is normally set to 5% above the ***SOC1 Set Threshold***. The default value is set to 15%.

SOCF Set Threshold

The ***SOCF Set Threshold*** is the *StateOfCharge( )* percentage threshold used to indicate when *StateOfCharge( )* falls to or below a defined *StateOfCharge( )*. The ***SOCF Set Threshold*** is typically used as a final low *StateOfCharge( )* warning. When *StateOfCharge( )* falls below the ***SOCF Set Threshold***, the State of Charge Final *[SOCF]* bit in the *Flags( )* register is set. The State of Charge Final *[SOCF]* bit is cleared once *StateOfCharge( )* rises above the ***SOCF Clear Threshold***. If SOCF Set Threshold is set to (–)1, then the State of Charge Final *[SOCF]* bit becomes inoperative.

Normal Setting: The default value is set to 2%.

SOCF Clear Threshold

The ***SOCF Clear Threshold*** is the *StateOfCharge( )* percentage threshold used to indicate when *StateOfCharge( )* rises above a defined *StateOfCharge( )*. When *StateOfCharge( )* rises above the ***SOCF Clear Threshold***, the State of Charge Final *[SOCF]* bit in the *Flags( )* register is cleared.

Normal Setting: ***SOCF Clear Threshold*** is normally set to 3% above the***SOC1 Set Threshold***. The default value is set to 5%.

BL Set Volt Threshold

BL Set Volt Threshold provides a threshold for the *Voltage( )* register. Once the *Voltage( )* register falls below this value for a specific time defined by ***BL Set Volt Time***, the Battery Low *[BATLOW]* bit is set. Fuel gauge must not be in SLEEP mode.

Normal Setting: The default value is set to 2500 mV.

BL Set Volt Time

When *Voltage( )* < ***BL Set Volt Threshold*** is true, ***BL Set Volt Time*** provides the time to wait before the Battery Low *[BATLOW]* bit gets set. Fuel gauge must not be in SLEEP mode.

Normal Setting: The default value is set to 2 seconds.

BL Clear Volt Threshold

BL Clear Volt Threshold provides a threshold for the *Voltage( )* register. Once the *Voltage( )* register rises above this value, the Battery Low *[BATLOW]* bit is cleared immediately. The fuel gauge must not be in SLEEP mode.

Normal Setting: The default value is set to 2600 mV.

BH Set Volt Threshold

BH Set Volt Threshold provides a threshold for the *Voltage( )* register. Once the *Voltage( )* register rises above this value for a specific time defined by ***BH Volt Time***, the Battery High *[BATHI]* bit is set. The fuel gauge must not be in SLEEP mode.

Normal Setting: The default value is set to 4500 mV.

BH Volt Time

When *Voltage( )* < ***BH Set Volt Threshold*** is true, ***BH Volt Time*** provides the time to wait before the Battery High *[BATHI]* bit gets set. Fuel gauge must not be in SLEEP mode.

Normal Setting: The default value is set to 2 seconds.

BH Clear Volt Threshold

BH Clear Volt Threshold provides a threshold for the *Voltage( )* register. Once the *Voltage( )* register falls above this value, the Battery High *[BATHI]* bit is cleared immediately. Fuel gauge must not be in SLEEP mode.

Normal Setting: The default value is set to 4400 mV.

3.7 Manufacturer Data

Pack Lot Code

The pack manufacturer can use this location to store the pack lot code.

PCB Lot Code

The pack manufacturer can use this location to store the PCB lot code.

Firmware Version

The pack manufacturer can use this location to store a firmware version number for their system or pack. This value is user-defined and is not related to the gauge’s *Control(FW_VERSION)*.

Hardware Revision

The pack manufacturer can use this location to store a hardware version number for their system or pack. This value is user-defined and is not related to the gauge’s *Control(HW_VERSION)*.

Cell Revision

The pack manufacturer can use this location to store the version of their cell.

DF Config Version

The pack manufacturer can use this location to store the data flash configuration version. Version control of DFI files used in production is recommended.

3.8 Integrity Data

Static Chem DF Checksum

This value should be programmed by TI’s software tools at the time a specific chemistry ID is programmed. A chemistry ID contains both static private data and dynamic public data. Executing the STATIC_CHEM_DF_CHKSUM sub-command causes the gauge to calculate a checksum on the static data and compare the results to this dataflash parameter. If the calculated checksum matches the checksum stored in ***Static Chem DF Checksum*** then the checksum can be read back from the *Control( )* register and the most significant bit (MSB) will be clear. If they do not match then the calculated checksum will be returned in the *Control( )* register and the MSB will be set to indicate they don’t match. In this way the static private chemistry data integrity can be verified. Use of this feature is optional and any value can be stored in this parameter. It has no effect on the gauge operation and is for information only. See the datasheet description for the STATIC_CHEM_DF_CHKSUM sub-command.

3.9 Lifetime Data

Lifetime data logging provides a way to diagnose the history and condition of a battery pack containing a bq2754x-G1. For this logging function to be active, the Impedance Track algorithm must be enabled. This can be done by sending command (0x0021) through the *Control( )* register and setting ***LT Update Time*** to a non-zero value. Once the lifetime data logging function is enabled, the measured values are compared to what is already in the data flash. If the measured value is higher than the maximum or lower than the minimum by more than the resolution parameters (see Section 3.12) set for at least one parameter, all of the values are updated after ***LT Update Time*** counter is reset. If none of the values go above or below the maximum or minimum ranges defined by the resolution parameters, then no update takes place.

Lifetime Max Temp

Maximum temperature observed by the gauge. It is initialized to 300. The unit is 0.1ºC.

Lifetime Min Temp

Minimum temperature observed by the gauge. It is initialized to 200. The unit is 0.1ºC.

Lifetime Max Pack Voltage

Maximum battery voltage observed by the gauge. It is initialized to 3200. The unit is mV.

Lifetime Min Pack Voltage

Minimum battery voltage observed by the gauge. It is initialized to 4200. The unit is mV.

Lifetime Max Chg Current

Maximum charge current observed by the gauge. It is initialized to 0. The unit is mA.

Lifetime Max Dsg Current

Maximum discharge current observed by the gauge. It is initialized to 0. The unit is mA.

3.10 Lifetime Temp Samples

LT Flash Cnt

Lifetime flash page update counter to keep track of total number of updates. It is initialized to 0. The unit is counts.

3.11 Registers

Pack Configuration

This register enables or disables various functions of the bq2754x-G1. Default bit settings are shown in Table 2

Table 2. Pack Configuration Bit Definition

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
High Byte	RESCAP	RSVD	RSVD	RSVD	GNDSEL	IWAKE	RSNS1	RSNS0
Default =	0	0	0	1	0	0	0	1
	0x11							
Low Byte	RSVD	RSVD	SLEEP	RMFCC	SE_PU	SE_POL	RSVD	TEMPS
Default =	0	1	1	1	0	1	1	1
	0x77							

- RESCAP [15]: If set, a no-load rate of compensation is applied to the reserve capacity calculation.
- RSVD [14, 13, 12]: These bits are reserved and should not be changed from the default values.
- GNDSEL [11]: ADC ground selection. If this bit is set to 0, Vss pin(s) is selected as the ADC ground reference. Otherwise, the SRP pin is selected as the ADC ground reference.
- IWAKE, RSNS1, RSNS0 [10, 9, 8]: The wake-up comparator indicates a change in cell current while the bq2754x-G1 is in either SLEEP or HIBERNATE modes. ***Pack Configuration*** uses bits [RSNS1-RSNS0] to set the sense resistor selection. ***Pack Configuration*** 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 for RSNS1/0 disables this feature. See Table 3 for values.
- RSVD [7, 6]: These bits are reserved and should not be changed from the default values.
- SLEEP [5]: If set, the gas gauge can enter sleep if operating conditions allow. The bq2754x-G1 enters SLEEP if *AverageCurrent( )* ≤ ***Sleep Current***.
- RMFCC [4]: If set, *RemainingCapacity( )* is updated with the value from *FullChargeCapacity( )* on valid charge termination.
- SE_PU [3]: Pull-up enable for SE pin. True when set (push-pull).
- SE_POL [2]: Polarity bit for SE pin. SE is active low when clear.
- RSVD [1]: This bit is reserved.
- TEMPS [0]: This bit tells the bq2754x-G1 the temperature sensor configuration. The bq2754x-G1 can use an external thermistor or its internal sensor. The setting of this bit determines which sensor reports temperature in the *Temperature( )* register.
  - 1 = The external thermistor TS1 generates *Temperature( )*.
  - 0 = Internal temperature sensor generates *Temperature( )*.

  Normal Setting: The default setting for this bit is 1. The bq2754x-G1 requires a Semitec 103AT thermistor or equivalent. Use of the external thermistor is recommended for highest accuracy as it can be placed directly in contact with the battery cell.

Table 3. IWAKE Threshold Settings

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

Pack Configuration B

Some bq2754x-G1 pins are configured via the ***Pack Configuration B*** data flash register. This register is described below.

Table 4. Pack Configuration B Bit Definition

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	ChgDoDEoC	SE_TDD	VconsEN	SE_ISD	RSVD	LFPRelax	DoDWT	FConvEn
Default =	1	0	1	0	0	1	1	1
	0x67							

- ChgDoDEoC = Enable DoD at EoC recalculation during charging only. True when set. Default setting is recommended to prevent DoDatEoC from being recalculated due to temperature changes.
- SE_TDD = Enable Tab Disconnection Detection. True when set.
- VconsEN = Enable voltage consistency check. True when set.
- SE_ISD = Enable Internal Short Detection. True when set.
- RSVD = Reserved. Must be 0
- LFPRelax = Enable LiFePO4 long relaxation mode when chemical ID 400 series is selected. True when set.
- DoDWT = Enable DoD weighting feature of gauging algorithm. This feature can improve accuracy during relaxation in a flat portion of the voltage profile, especially when using LiFePO4 chemistry. True when set.
- FConvEn = Enable fast convergence algorithm. Default setting is recommended.

Pack Configuration C

Some bq2754x-G1 pins are configured via the ***Pack Configuration C*** data flash register. This register is described below.

Table 5. Pack Configuration C Bit Definition

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	RSVD	RSVD	RelaxRCJumpOK	SmoothEn	SleepWkChg	RSVD	RSVD	RSVD
Default =	0	0	0	1	1	0	0	0
	0x18							

- RSVD = These bits are reserved and should not be changed from the default values.
- RelaxRCJumpOK = Allow SOC to change due to temperature change during relaxation when SOC smoothing algorithm is enabled. True when set.
- SmoothEn = Enable SOC smoothing algorithm. True when set.
- SleepWkChg = Enables compensation for the past charge missed when waking up from SLEEP mode.

3.12 Lifetime Resolution

LT Temp Res

This parameter sets the minimum temperature change that forces an update to the Lifetime Dataflash parameters.

Normal Setting: The default for this register is 1.

LT V Res

This parameter sets the minimum voltage change that forces an update to the Lifetime Dataflash parameters.

Normal Setting: The default for this register is 25

LT Cur Res

This parameter sets the minimum current change that forces an update to the Lifetime Dataflash parameters.

Normal Setting: The default for this register is 100

LT Update Time

This parameter sets the minimum time between data flash writes to update the Lifetime Parameters.

Normal Setting: The default for this register is 60

3.13 Power

Flash Update OK Voltage

This register controls one of several data flash protection features. It is critical that data flash is not updated when the battery voltage is too low. Data flash programming takes much more current than normal operation of the bq2754x-G1. With a depleted battery a sudden spike in system current or gauge operation current could cause the battery voltage to drop dramatically, forcing the bq2754x-G1 into reset before completing a data flash write. The effects of an incomplete data flash write can corrupt the memory, resulting in unpredictable and extremely undesirable results. The voltage setting in ***Flash Update OK Voltage*** is used to prevent any writes to the data flash below this value. If a charging condition is detected, then this register is ignored.

Normal Setting: The default for this register is 2800 mV. Ensure that this register is set to a voltage where the battery has plenty of capacity to support data flash writes but below any normal battery operation conditions.

Sleep Current

Sleep Current sets a current threshold that determines if the bq2754x-G1 can enter SLEEP mode. When *AverageCurrent( )* is less than ***Sleep Current*** or greater than (–)***Sleep Current*** the bq2754x-G1 enters SLEEP mode if the feature is enabled (*Op Config* [SLEEP] = 1).

Normal Setting: ***Sleep Current*** should be below any normal application currents. The default value is set to 10 mA.

Hibernate I

Hibernate I is used to set the current threshold the bq2754x-G1 will use as a possible condition to enter HIBERNATE mode. If the *[HIBERNATE]* bit in the *Control_Status( )* register is set, the gauge is allowed to enter HIBERNATE mode if the |*AverageCurrent( )*| is below ***Hibernate I*** and the cell is relaxed (an OCV measurement has been taken).

Normal Setting: ***Hibernate I*** should be below any normal application currents. The default value is set to 8 mA. Please refer to the bq2754x-G1 datasheet for more details on HIBERNATE mode.

Hibernate V

Hibernate V sets the voltage threshold the bq2754x-G1 uses, as a possible condition to enter HIBERNATE mode. If the gauge has taken a valid OCV measurement (cell is relaxed) and *Voltage( )* is less than ***Hibernate V***, the gauge enters HIBERNATE mode. Setting ***Hibernate V*** to 0, disables this method of entry into HIBERNATE mode.

Normal Setting: ***Hibernate V*** should be below any normal application voltages. The default value is set to 2550 mV. Please refer to the bq2754x-G1 datasheet for more details on HIBERNATE mode.

FS Wait

FS Wait provides the time to wait for the fuel gauge to go from SLEEP mode to FULL SLEEP mode. When the ***FS Wait*** value is 0, the gauge waits for the SET_FULLSLEEP command, once the gauge receives this command while in SLEEP mode, it immediately goes to FULL SLEEP mode. If ***FS Wait*** is non-zero, the gauge switches to FULL SLEEP from SLEEP, once the timer expires. During the wait time, SET_FULLSLEEP command is ignored. Please note that when the gauge is in FULL SLEEP mode, any communication with the gauge triggers it to get out of FULL SLEEP mode. The best way to check the mode of the gauge is to monitor the drawn current out of the gauge.

Normal Setting: Default value is 0 seconds.

4 System Data

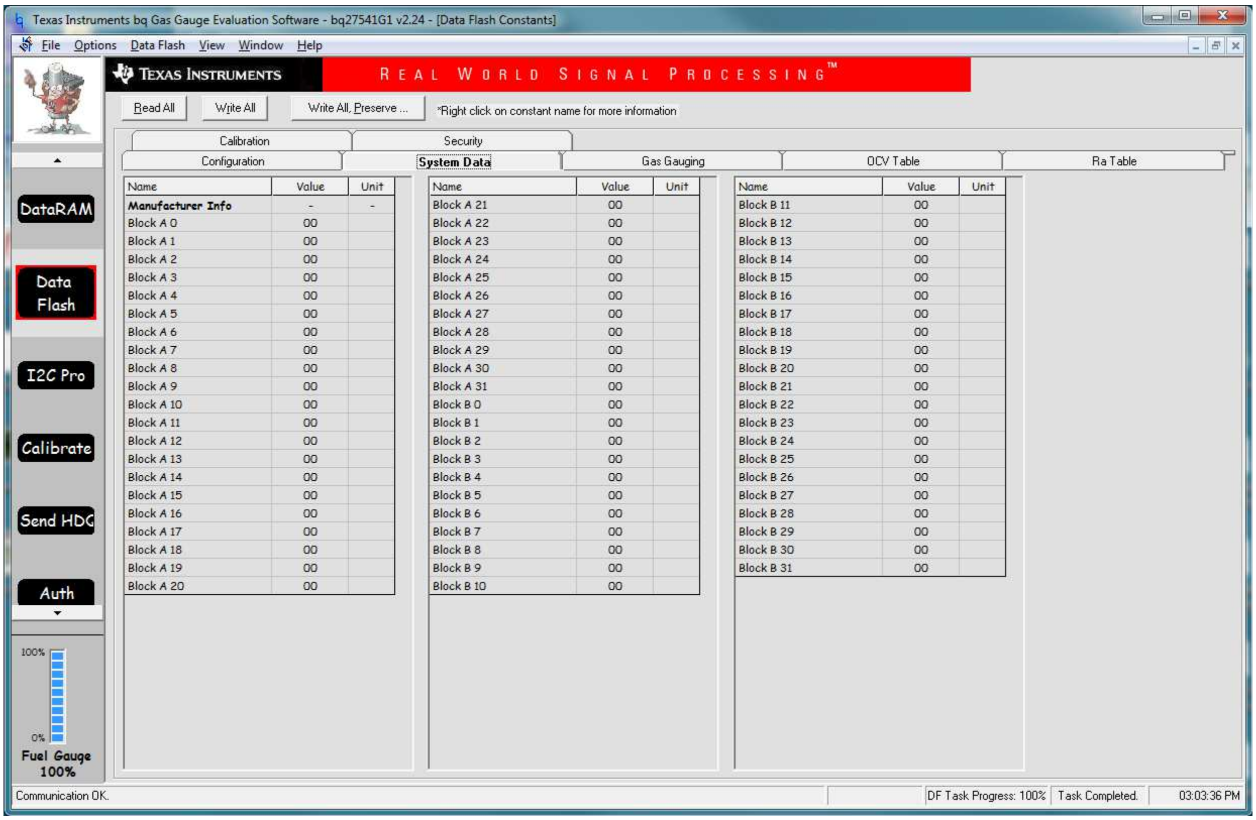

Figure 2. System Data

4.1 Manufacturer Info

Block A

This is string data that can hold any user data. It can be a maximum of 8 characters or 32 bytes.

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

Block B

This is string data that can hold any user data. It can be a maximum of 8 characters or 32 bytes.

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

5 Gas Gauging

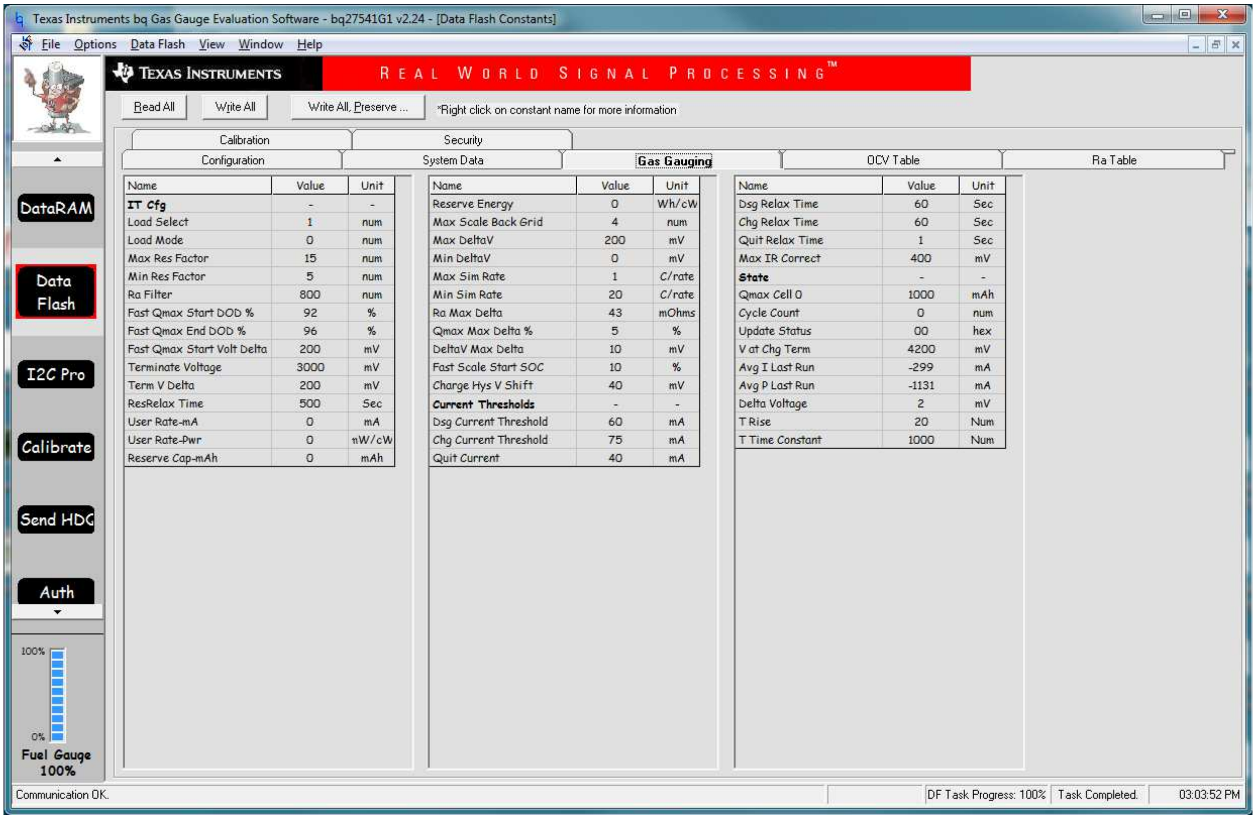

Figure 3. Gas Gauging

5.1 *IT Cfg*

Load Select

Load Select defines the type of power or current model to be used for *RemainingCapacity( )* computation in the Impedance Track algorithm.

If ***Load Mode*** = Constant Current, then the following options are available:

0 = Simulate using average discharge current from previous discharge period: See ***Avg I Last Run***.

1 = Simulate using average discharge current (default): This is the average discharge power from the beginning of this discharge cycle until present time.

2 = Simulate using the value in the *AverageCurrent( )* register.

3 = Simulate using low-pass filtered version of the *AverageCurrent( )* register (τ = 14)

4 = Simulate using the C-rate calculated as *DesignCapacity* / 5 in mA.

5 = Simulate using the value in the *AtRate( )* register. This RAM register can be updated by the host at any time.

6 = Simulate using the value of ***User Rate-mA*** stored in data flash. This is completely customizable by the user and is typically fixed in the golden data flash settings.

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

0 = Simulate using average discharge power from previous discharge period: See ***Avg P Last Run***.

1 = Simulate using average discharge power (default): This is the average discharge power from the beginning of this discharge cycle until present time.

2 = Simulate using ***Current*** × ***Voltage***: Based off of ***Current*** and *Voltage( )*.

3 = Simulate using *AverageCurrent( )* × *Voltage( )*: Based off of ***AverageCurrent*** and *Voltage( )*.

4 = Simulate using ***Design Energy*** / 5 in mA.

5 = Simulate using the value in the *AtRate( )* register. This RAM register can be updated by the host at any time.

6 = Simulate using the value of ***User Rate-Pwr*** stored in the data flash. This is completely customizable by the user and is typically fixed in the golden data flash settings.
Normal Setting: The default for this ***Load Select*** is 1.

Load Mode

Load Mode selects either the constant current or constant power model for the Impedance Track algorithm as used in ***Load Select***, see the ***Load Select*** section for details.

0: Constant Current Mode

1: Constant Power Mode

Normal Setting: This is normally set to 0 (Constant Current Mode) but it is application specific. If the application load profile more closely matches a constant power mode, then set to 1. This provides a better estimation of remaining run time, especially close to the end of discharge where current increases to compensate for decreasing battery voltage.

Max Res Factor

Max percentage (ratio) that an impedance value stored in the Ra table is allowed to change in a single update in the positive direction.

Normal Setting: The default setting is 15. The algorithm divides the value of this parameter by 10. The upper bound is determined by multiplying (***Max Res Factor*** / 10) by the impedance value stored in the Ra table. Therefore a value of 15 indicates resistance can only change by 50% from the current resistance value in the positive direction.

Min Res Factor

Max percentage (ratio) that an impedance value stored in the Ra table is allowed to change in a single update in the negative direction.

Normal Setting: The default setting is 5. The algorithm divides the value of this parameter by 10. The lower bound is determined by multiplying (***Min Res Factor*** / 10) by the impedance value stored in the Ra table. Therefore a value of 5 indicates resistance can only change by 50% from the current resistance value in the negative direction.

Ra Filter

Ra table updates are filtered. This is a weighting factor which takes a certain percentage of the previous Ra table value and the remaining percentage comes from the newest calculated Ra value. This is to prevent resistances in the Ra table from changing quickly. After this filter has been applied, there is a final check to make sure that the new resistances satisfy both ***Max Res Factor*** and ***Min Res Factor***.

Normal Setting: It is normally set to 800 (80% previous Ra value plus 20% learned Ra value to form new Ra value).

Terminate Voltage

Terminate Voltage stores the voltage for the end of discharge where *RemainingCapacity( )* is set to 0 mAh. ***Terminate Voltage*** is used in the Impedance Track algorithm to help compute *RemainingCapacity( )*.

Normal Setting: Set ***Terminate Voltage*** based on battery cell specifications to prevent damage to the cell or set to the absolute minimum system voltage, taking into account impedance drop from the PCB traces, FETs, and wires. The default value is set to 3000 mV.

Term V Delta

Term V Delta stores the offset to add to ***Terminate Voltage*** in order to create a voltage threshold for the *Voltage( )* register for triggering fast resistance scaling provided that *[FConvEn]* bit is set in ***Pack Configuration B***. The fast resistance scaling algorithm is meant to improve accuracy at the end of discharge. This is one of the triggering conditions for fast resistance scaling; the other condition is when *StateOfCharge( )* goes below ***Fast Scale Start SOC***. If SOC goes below ***Fast Scale Start SOC*** before *Voltage( )* goes below ***Terminate Voltage*** + ***Term V Delta***, fast resistance scaling is already enabled.

Normal Setting: The default value for ***Term V Delta*** is 200 mV. For most battery applications, it is recommended to keep (***Terminate Voltage*** + ***Term V Delta***) below 3.4 volts.

ResRelax Time

ResRelax Time or resistance relaxation time is used for transient modeling. It represents the time it takes for the internal resistance to be fully saturated. This way the gauge will not simulate immediate large IR drops when it calculates the instantaneous voltage from the battery under load.

Normal Setting: The default value is 500 seconds, which is sufficient for most applications.

User Rate-mA

User Rate-mA is only used if ***Load Select*** is set to 6 and ***Load Mode*** = 0. If these criteria are met, then the current stored in this register is used for the *RemainingCapacity( )* computation in the Impedance Track algorithm. This is the only function that uses this register.

Normal Setting: It is unlikely that this register is used. An example application that requires this register is one that has increased predefined current at the end of discharge. With this type of discharge, it is logical to adjust the rate compensation to this period because the IR drop during this end period is affected the moment ***Terminate Voltage*** is reached. The default is 0 mA.

User Rate-Pwr

User Rate-Pwr is only used if Load Select is set to 6 and ***Load Mode*** = 1. If these criteria are met, then the power stored in this register is used for the *RemainingCapacity( )* computation in the Impedance Track algorithm. This is the only function that uses this register.

Normal Setting: It is unlikely that this register is used. An example application that requires this register is one that has increased predefined power at the end of discharge. With this application, it is logical to adjust the rate compensation to this period because the IR drop during this end period is affected the moment ***Terminate Voltage*** is reached. The default is 0 to 10-mW units.

Reserve Cap-mAh

Reserve Cap-mAh is used to determine the amount of capacity, in mAh, that will be left in the battery when the bq2754x-G1 reports *RemainingCapacity( )* = 0 mAh when ***Load Mode*** = 0 (Constant Current Mode). The ***Reserve Cap-mAh*** parameter allows for a controlled shutdown after the gauge reports *RemainingCapacity( )* = 0 mAh. ***Reserve Energy*** is calculated by multiplying ***Reserve Cap-mAh*** by 3.6 V.

Normal Setting: Carefully select ***Reserve Cap-mAh*** based upon the system requirements. The default value is set to 0 mAh.

Reserve Energy

Reserve Energy determines how much actual remaining capacity exists after reaching 0 *RemainingCapacity( )* or equivalently 0 remaining power before ***Terminate Voltage*** is reached when ***Load Mode*** = 1 (Constant Power Mode). A loaded rate or no-load rate of compensation can be selected for *Reserve Cap* by setting the ***[RESCAP]*** bit in ***Pack Configuration Register***.

Normal Setting: The default is 0 mAh or 0 Wh/cWh.

Max Scale Back Grid

During the Ra table updates, the Ra value that is learned through previous grid points is scaled up or down depending on the new Ra learned at current grid point. This is the maximum grid point that allows scaling back when doing Ra updates.

Normal Setting: This defaults to grid point 4.

Max DeltaV

This is the maximum ***Delta Voltage*** that is saved during discharge cycles.

Normal Setting: The default is 200 mV.

Min DeltaV

This is the minimum ***Delta Voltage*** that is saved during discharge cycles.

Normal Setting: The default is 0 mV.

Max Sim Rate

Maximum IT simulation rate (reversed). 2 implies C / 2.

Normal Setting: This register defaults to 1.

Min Sim Rate

Minimum IT simulation rate (reversed). 20 implies C / 20.

Normal Setting: This register defaults to 20.

Ra Max Delta

The maximum jump allowed during updates of a Ra table grid point. Manually change *Ra Max Delta* to 15% of the grid 4 Ra value after an optimization cycle is completed.

Normal Setting: Calculate and modify *Ra Max Delta* when creating the golden file, the default is 43.

Qmax Max Delta %

This is the percent of *DesignCapacity( )* to limit how much Qmax may grow or shrink during any one Qmax update

Normal Setting: The default is 5%.

DeltaV Max Delta

Limits on how far ***Delta Voltage*** grows or shrinks on one grid update (in mV).

Normal Setting: This register defaults to 10.

Fast Scale Start SOC

Fast Scale Start SOC is the threshold on *StateOfCharge( )*. When SOC falls below this threshold, fast resistance scaling is enabled provided that ***[FConvEn]*** bit in ***Pack Configuration B*** is set. This is the other condition which might trigger fast resistance scaling, the first condition which is defined in the ***Term V Delta*** flash parameter. If the ***Term V Delta*** flash parameter is reached before SOC falls below ***Fast Scale Start SOC***, fast resistance scaling is already enabled.

Normal Setting: The default value is 10%.

Charge Hys V Shift

Charge Hys V Shift is a flash parameter that helps the gauge track the flat region of operation for the battery. It is recommended to keep this value at the default setting.

Normal Setting: The default value is 40 mV.

5.2 Current Thresholds

Please refer to *Theory and Implementation of Impedance Track™ Battery Fuel-Gauging Algorithm in bq2750x Family* (SLUA450), Figure 1, for the parameters listed in this section.

Dsg Current Threshold

This register is used as a threshold by many functions in the bq2754x-G1 to determine if actual discharge current is flowing out of the battery.

Normal Setting: The *[DSG]* flag in *Flags( )* is the method for determining charging or discharging. If the bq2754x-G1 detects charging or relaxation, then *[DSG]* is 0 and any other time (*AverageCurrent( )* less than or equal to ***Dsg Current Threshold***), the *[DSG]* flag is set equal to 1.

Chg Current Threshold

This register is used as a threshold by many functions in the bq2754x-G1 to determine if actual charge current is flowing out of the battery. It is independent from the *[CHG]* bit which is used to determine charge termination. This threshold also has no effect on the *[DSG]* bit in the *Flags( )* register.

Normal Setting: Many algorithms in the bq2754x-G1 require more definitive information about whether current is flowing in the charge or discharge direction. This is what ***Chg Current Threshold*** is used for. The default for this register is 75 mA which is 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.

Quit Current

Quit Current sets a current threshold to determine when the bq2754x-G1 goes into relaxation mode from charge or discharge mode. The ***Quit Current*** parameter has units of mA. Either of the following criteria must be met to enter relaxation mode:

1. *AverageCurrent( )* is **greater than** (–)***Quit Current*** and then goes within (±)***Quit Current*** for ***Dsg Relax Time***.
2. *AverageCurrent( )* is **less than** ***Quit Current*** and then goes within (±)***Quit Current*** for ***Dsg Relax Time***.

After 30 minutes in relaxation mode, the bq2754x-G1 starts checking if the dV / dt < 1 µV/s requirement for OCV readings is satisfied. When the battery relaxes sufficiently to satisfy this criterion, the bq2754x-G1 takes an OCV reading for updating Q_{max}. These updates are used by the Impedance Track algorithm.

Normal Setting: It is critical that the battery voltage be relaxed during OCV readings to get the most accurate results. The quit current threshold must not be higher than ***Design Capacity*** / 20 when attempting to go into relaxation mode; however, it should not be so low as to prevent going into relaxation mode due to noise. The current threshold that the ***Quit Current*** parameter sets should always be less than the magnitude of the current threshold the ***Chg Current Threshold*** sets and less than the magnitude of the current threshold the ***Dsg Current Threshold*** sets. The default value is set to 40 mA.

Dsg Relax Time

The ***Dsg Relax Time*** is used in the function to determine when to go into relaxation mode after discharge current ceases. When *AverageCurrent( )* is greater than (–)***Quit Current*** and then goes within (±)***Quit Current*** the ***Dsg Relax Time***, the timer is initiated. If the current stays within (±)***Quit Current*** until the ***Dsg Relax Time*** timer expires, then the bq2754x-G1 goes into relaxation mode. After 30 minutes in relaxation mode, the bq2754x-G1 starts checking if the dV / dt < 4 µV/s requirement for OCV readings is satisfied. When the battery relaxes sufficiently to satisfy these criteria, the bq2754x-G1 takes OCV reading for updating Qmax and for accounting for self-discharge. These updates are used in the Impedance Track algorithms.

Normal Setting: Be careful when interpreting discharge descriptions in this document while determining the direction and magnitude of the currents, because they are in the negative direction. This is application specific, the default is 60 seconds.

Chg Relax Time

The ***Chg Relax Time*** is used in the function to determine when to go into relaxation mode after charge current ceases. When *AverageCurrent( )* is greater than ***Quit Current*** and then goes within (±)*Quit Current* the ***Chg Relax Time***, timer is initiated. If the current stays within (±)***Quit Current*** until the ***Chg Relax Time*** timer expires, then the bq2754x-G1 goes into relaxation mode. After approximately 30 minutes in relaxation mode, the bq2754x-G1 attempts to take accurate OCV readings. An additional requirement of dV / dt < 4µV/s (delta voltage over delta time) is required for the bq2754x-G1 to perform Qmax updates. These updates are used in the Impedance Track algorithms.

Normal Setting: This is application specific. Default is 60 seconds.

Quit Relax Time

The ***Quit Relax Time*** is a delay time to exit relaxation. If current is greater than ***Chg Current Threshold*** or less than ***Dsg Current Threshold*** and this condition is maintained during ***Quit Relax Time***, then exiting relaxation is permitted.

Normal Setting: This is particular to handheld applications in which low duty cycle dynamic loads are possible. Default is 1 second. For very short duration loads, it is permissible to consider the battery to have remained in relaxation mode if the loads were not extreme.

Max IR Correct

If current is flowing during a voltage measurement that is used for finding initial DOD, IR correction eliminates the effect of the IR drop across the cell impedance and obtain true OCV. ***Max IR Correct*** is the maximal value of IR correction that is used. It is to avoid artifacts due to very high resistance at low DOD values during charge.

Normal Setting: This is particular to handheld applications. Default is 400 mV.

5.3 State

Qmax Cell 0

This is the maximum chemical capacity of the battery cell. The bq2754x-G1 has only one cell profile stored. It also corresponds to capacity at a low rate of discharge such as a C / 20 rate. This value is updated continuously by the bq2754x-G1 during use to keep capacity measuring as accurate as possible.

Normal Setting: Before an optimization cycle is run, set this value to the battery cell datasheet capacity. After the optimization cycle is run and for creation of the golden settings, set it to the learned value. The default is 1000 mAh.

Cycle Count

These are the numbers of Qmax updates the battery has experienced.

Normal Setting: Initially set *Cycle Count* to 0 for fresh battery cell. The default is 0.

Update Status

Since this is a pack-side gauge, the Update Status register can be represented by the bits below:

x	x	x	x	x	Bit 2	Bit 1	Bit 0

Three bits in this register are important:

- Bit 2 (0x04) indicates whether the Impedance Track algorithm is enabled.
- Bit 1 (0x02) indicates that the bq2754x-G1 learned optimized values for Qmax and the Ra tables during a learning cycle.
- Bit 0 (0x01) indicates that the bq2754x-G1 learned an initial value for Qmax after the charging portion of a learning cycle.

At the beginning of a learning cycle when creating a golden file, Update Status starts at 0x00. When IT is enabled with the IT_ENABLE subcommand being sent to *Control( )*, Update Status automatically changes to 0x04. After the charge and relaxation portion of the learning cycle are complete, Update Status should have become 0x05. Finally, after the discharge and relaxation portion of the learning cycle, Update Status becomes 0x06 if the learning cycle was successfully completed. A golden file can then be generated if Update Status was successfully set to 0x06 by the gauge. When the golden file is created, bit 2 is cleared, leaving Update Status = 0x02.

Do not change any of these bits manually. IT must be enabled only by sending the IT_ENABLE subcommand to the *Control( )* register.

Normal Setting: Bit 1 is a status flag that can be set by the bq2754x-G1 as needed. This bit should never be modified except when creating a golden file.

V at Chg Term

This is the gauge recorded voltage at charge termination. It is used by the gauge to learn the depth of discharge (DoD) of a full battery for a given system. This is updated by the gauge after every charge termination to account for variations between systems and different temperatures.

Normal Setting: ***V at Chg Term*** defaults to 4200 mV but can be initialized to the nominal charging voltage of the system.

Avg I Last Run

The bq2754x-G1 logs the *AverageCurrent( )* averaged from the beginning to the end of each discharge. It stores this average current from the previous discharge period in this register provided that the previous discharge lasted at least 500 seconds.

Normal Setting: This register should never need to be modified, it is only updated by the bq2754x-G1 when the gauge exits discharge mode.

Avg P Last Run

The bq2754x-G1 logs the power averaged from the beginning to the end of each discharge. It stores this average power from the previous discharge period in this register provided the previous discharge lasted at least 500 seconds. To get a correct average power reading, the bq2754x-G1 continuously multiplies instantaneous Current with *Voltage( )* to get power. It then logs this data to derive the average power.

Normal Setting: This register should never need to be modified. It is only updated by the bq2754x-G1 when the gauge exits discharge mode.

Delta Voltage

The maximum difference of *Voltage( )* during short load spikes and normal load, so the Impedance Track algorithm can calculate remaining capacity for pulse loads. The ***Delta Voltage*** value is automatically updated by the gauge during operation as voltage spikes are detected. It can be initialized to a higher value if large spikes are typical for the system. Allowable values are limited by *Max Delta V* and *Min Delta V*. During the IT simulations, the target voltage of the empty battery is ***(Terminate Voltage*** + ***Delta Voltage***). This feature allows ***Terminate Voltage*** to be set at the minimum operating voltage of the system with confidence that the 0% point will be reached at a sufficiently high voltage to prevent voltage spikes from crashing the system while still extracting maximum run time from the battery when spikes are small.

Normal Setting: ***Delta Voltage*** defaults to 2 mV.

T Rise

This is the thermal rise factor that is used in the single time constant heating-cooling thermal modeling. If set to 0, this feature is disabled and simulations in the IT algorithm will not account for self-heating of the battery cell. Larger values of ***T Rise*** lead to higher temperature rise estimates for the IT simulation.

Normal Setting: ***T Rise*** defaults to 20.

T Time Constant

This is the thermal time constant that is used in single time constant heating-cooling thermal modeling. The default setting can be used, or it can be modified to improve low-temperature accuracy if testing shows the model does not match the actual performance.

Normal Setting: ***T Time Constant*** defaults to 1000. This is sufficient for many applications. However, it can be modified if better predictive accuracy at low temperatures is desired.

6 OCV Table

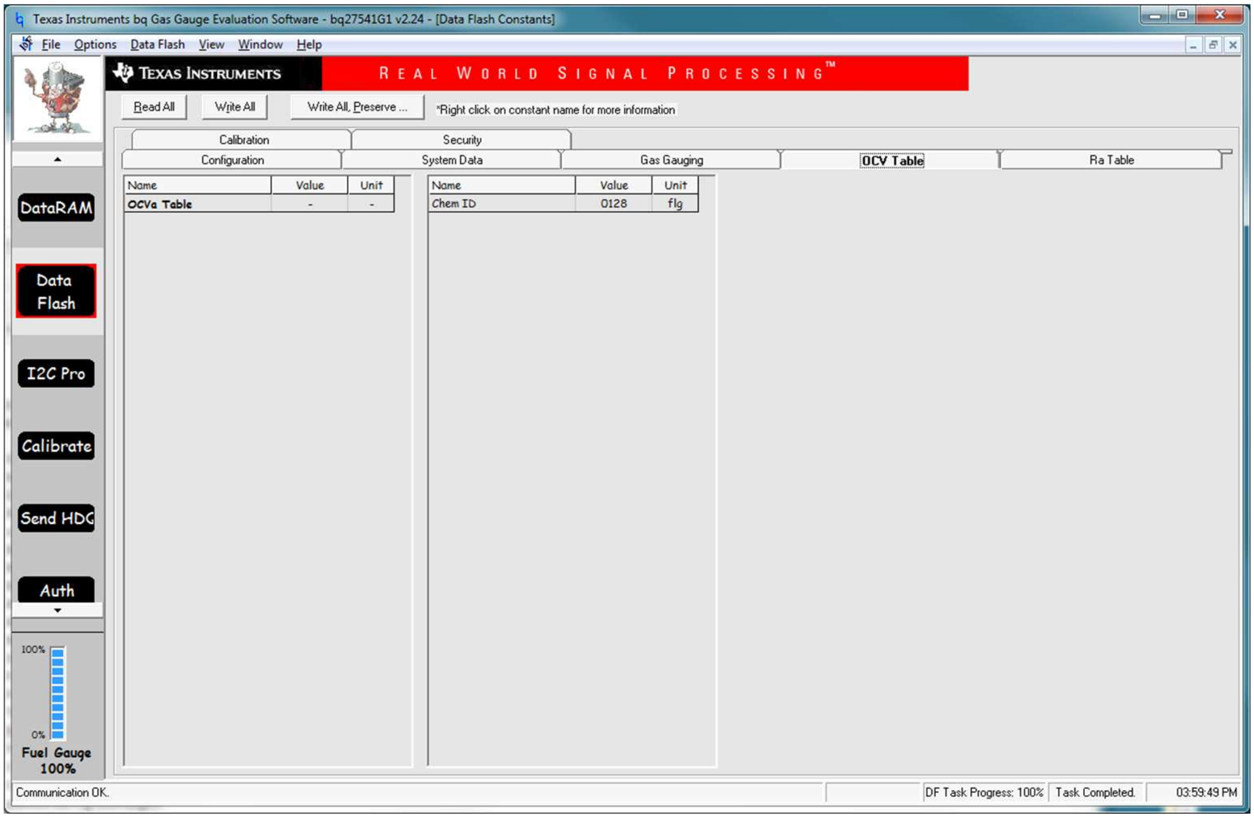

Figure 4. OCV Table

Chem ID

The ***Chem ID*** determines the type of chemistry which is programmed on the gauge. Changing this value by replacing it in data flash has no effect on what is programmed on to the gauge. In order to obtain a new chemistry you must go through an actual chemistry tool. For the bq2754x-G1, this can be done using the bqCONFIG tool.

Normal Setting: It defaults to 0128 when you program the default flash image which can be obtained from the Texas Instruments website.

7 Ra Table

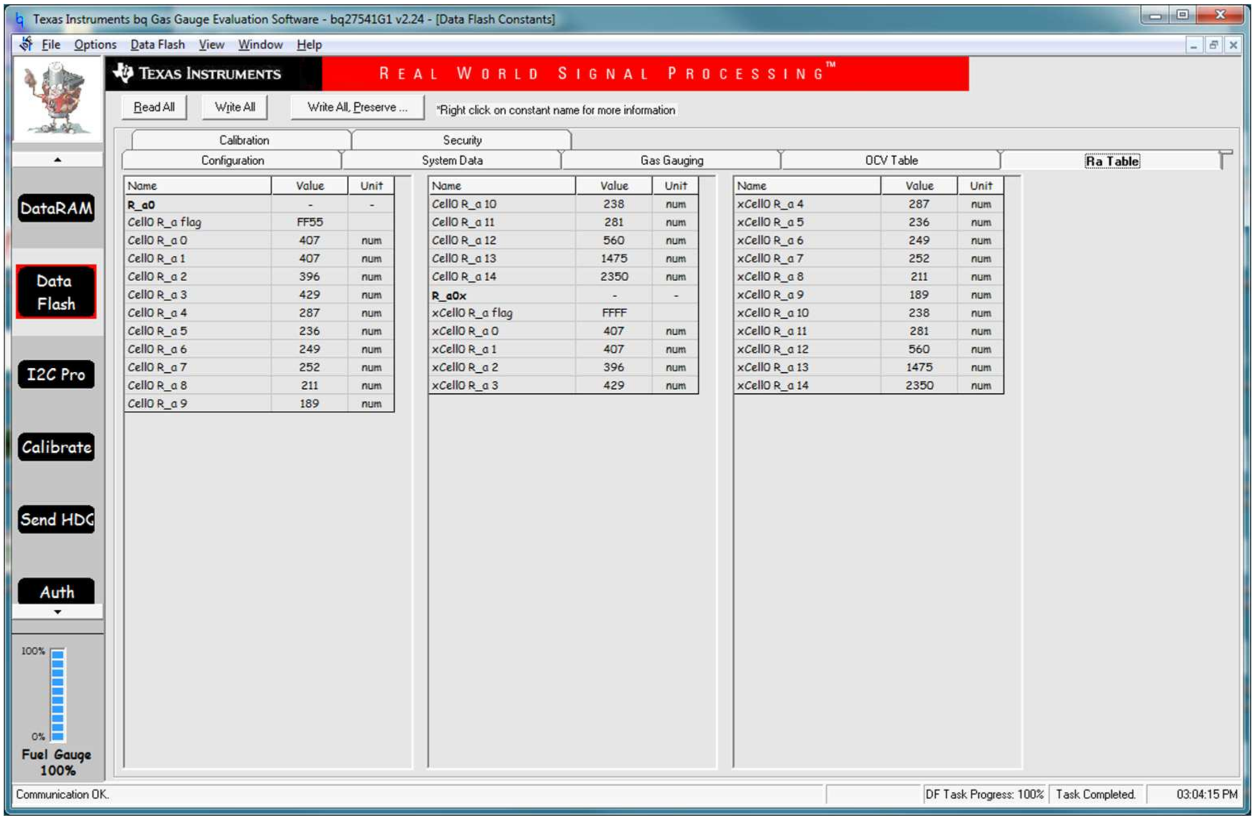

Figure 5. Ra Table Screen

This data is automatically updated during device operation. Do not make changes except for reading the values from another pre-learned pack for creating *Golden Image Files*. See the application report *Going to Production With the bq2754x-G1* (SLUA504). Profiles have format *Cell0 R_a* M where M is the number indicating state of charge to which the value corresponds.

Cell0 R_a flag.

xCell0 R_a flag

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 enabled or disabled.

Each flag has two bytes:

1. The least-significant byte (LSB) indicates whether the table is currently enabled or disabled. It has the following options:
   (a) 0x00: means the table 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 most-significant byte (MSB) 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 a resistance update and the *Qmax Pack* is updated.
   (b) 0x05: The resistance data associated with this flag is updated and the pack is no longer discharging (this is prior to a *Qmax Pack* update).
   (c) 0x55: The resistance data associated with this flag is updated and the pack is still discharging. (Qmax update attempt not possible until discharging stops.)
   (d) 0xff: The resistance data associated with this flag is all default data.

This data is used by the bq2754x-G1 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 bq2754x-G1 Impedance Track algorithm. The only reason this data is displayed and accessible is to allow the resistance data on golden image files to be updated. 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 bq2754x-G1 resistance algorithms.

Cell0 R_a0 – Cell0 R_a14,

xCell0 R_a0 – xCell0 R_a14,

The ***Ra Table*** class has 15 values for each R_a subclass. Each of these values represent a resistance value normalized at 0°C for the associated *Qmax Pack*-based SOC grid point as found by the following rules:

For ***Cell0 R_aM*** where:

1. If $0 \le M \le 7$: The data is the resistance normalized at 0° for: SOC = 100% – (M × 11.1%)
2. If $8 \le M \le 14$: The data is the resistance normalized at 0° for: SOC = 100% – [77.7% + (M – 7)× 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% where resistance quickly increases.

Normal Setting: SOC, as stated in this description is based on *Qmax Pack*. It is not derived as a function of SOC. These resistance profiles are used by the bq2754x-G1 for the Impedance Track algorithm. The only reason this data is displayed and accessible is to allow the resistance data on golden image files to be updated. This resistance profile description is for information purposes only. It is not intended to give a detailed functional description for the bq2754x-G1 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:

- Watch for negative values in the **Ra Table** class. Negative numbers in profiles should never be anywhere in this class.

Watch for smooth consistent transitions from one profile grid point value to the next throughout each profile. As the bq2754x-G1 does resistance profile updates, these values should be roughly consistent from one learned update to another without huge jumps in consecutive grid points.

8 Calibration

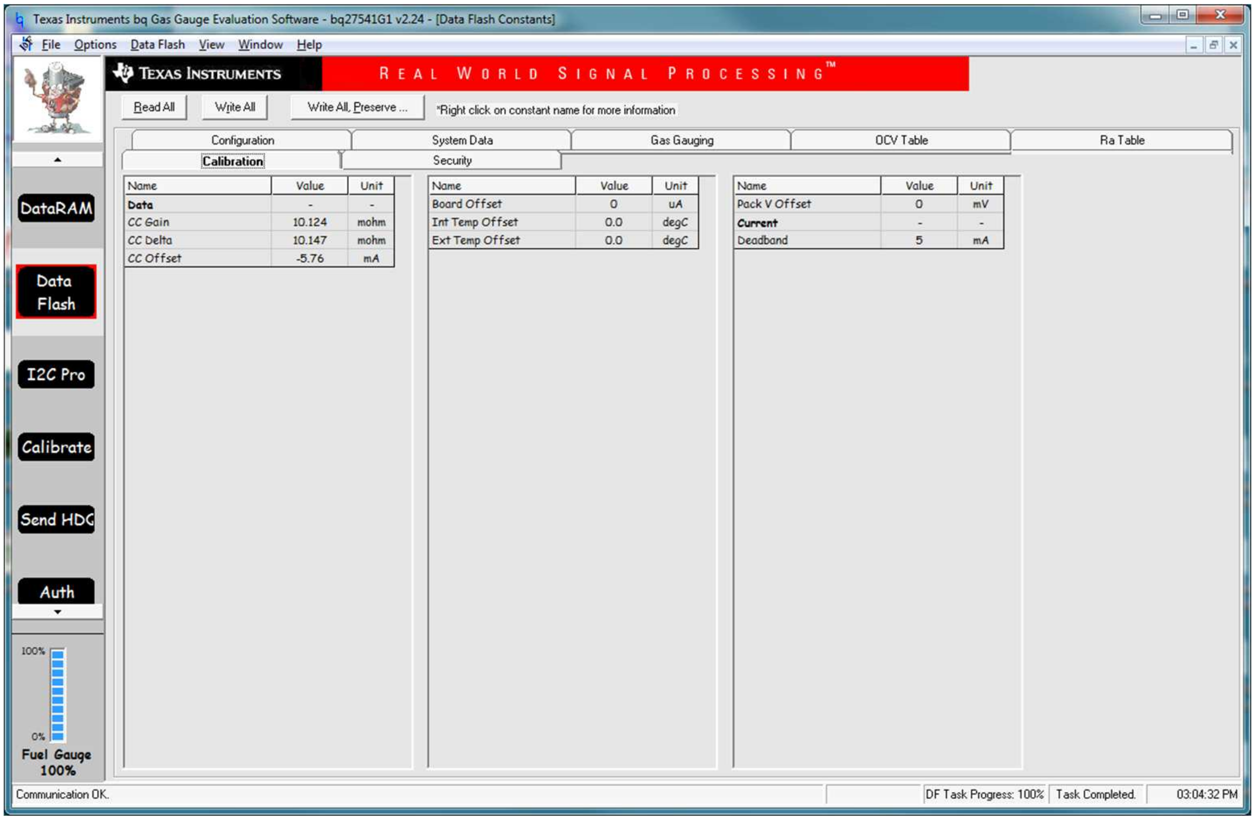

Figure 6. Calibration Screen

8.1 Data

Most of the following values never require modification by the user. They are only modified by the Calibration commands in Calibration mode as explained in the application report *Going to Production with the bq2754x* (SLUA504). For calibration using a host system, refer to *Host System Calibration Method* (SLUA640).

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 charge and discharge in and out of the battery through the *RemainingCapacity( )* register. The difference between ***CC Gain*** and ***CC Delta*** is that the algorithm that reports *AverageCurrent( )* cancels out the time base because *AverageCurrent( )* does not have a time component (it reports in mA) and ***CC Delta*** requires a time base for reporting *RemainingCapacity( )* (it reports in mAh).

CC Delta

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 charge and discharge in and out of the battery through the *RemainingCapacity( )* register. The difference between ***CC Gain*** and ***CC Delta*** is that the algorithm that reports *AverageCurrent( )* cancels out the time base because *AverageCurrent( )* does not have a time component (it reports in mA) and ***CC Delta*** requires a time base for reporting *RemainingCapacity( )* (it reports in mAh).

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 bq2754x-G1 Coulomb Counter circuitry. The other offset calibration is ***Board Offset*** and is described next. To minimize external influences when doing ***CC Offset*** calibration by automatic ***CC Offset*** calibration or ***CC Offset*** calibration function in Calibration Mode, an internal short is placed across the SRP and SRN pins inside the bq2754x-G1. ***CC Offset*** is a correction for small noise and errors; therefore, to maximize accuracy, it takes about 20 seconds to calibrate the offset. Since it is impractical to do a 20-s offset during production, two different methods have been selected for calibrating ***CC Offset***.

(A) The first method is to calibrate ***CC Offset*** by putting the bq2754x-G1 in Calibration mode and initiating the ***CC Offset*** function as part of the entire bq2754x-G1 calibration suite. See the application note *Going to Production with the bq2754x* (SLUA504) 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 I^2C Data and Clock is low for more than 20 seconds, which is a much more accurate calibration.

(B) During normal Gas Gauge Operation when the I^2C clock and data lines are low for more than 5 seconds and *AverageCurrent( )* 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.

Board Offset

Board Offset is the second offset register. Its primary purpose is to calibrate everything the ***CC Offset*** does not calibrate. This includes board layout, sense resistor, copper trace, and other offsets which are external to the bq2754x-G1 chip. The simplified ground circuit design in the bq2754x-G1 requires a separate board offset for each tested device.

Int Temp Offset

The bq2754x-G1 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.

Ext Temp Offset

Ext Temp Offset is for calibrating the offset of the thermistor connected to the TS1 pin of the bq2754x-G1 as reported by *Temperature( )*. The gain of the thermistor is accurate enough that a calibration for gain is not required.

Pack V Offset

Pack V Offset is a calibration value that is used to correct for any offset relating to the bq2754x-G1 analog-to-digital converter's (ADC) cell voltage measurement.

8.2 Current

Deadband

Deadband creates a filter window to the reported *AverageCurrent( )* register where the current is reported as 0. Any negative current above this value or any positive current below this value is displayed as 0.

Normal Setting: This defaults to 5 mA. Only a few reasons may require changing this value:

1. If the bq2754x-G1 is not calibrated.
2. ***Board Offset*** has not been characterized.
3. If the PCB layout has issues that cause inconsistent board offsets from board to board.
4. An extra noisy environment along with reason 3.

9 Security

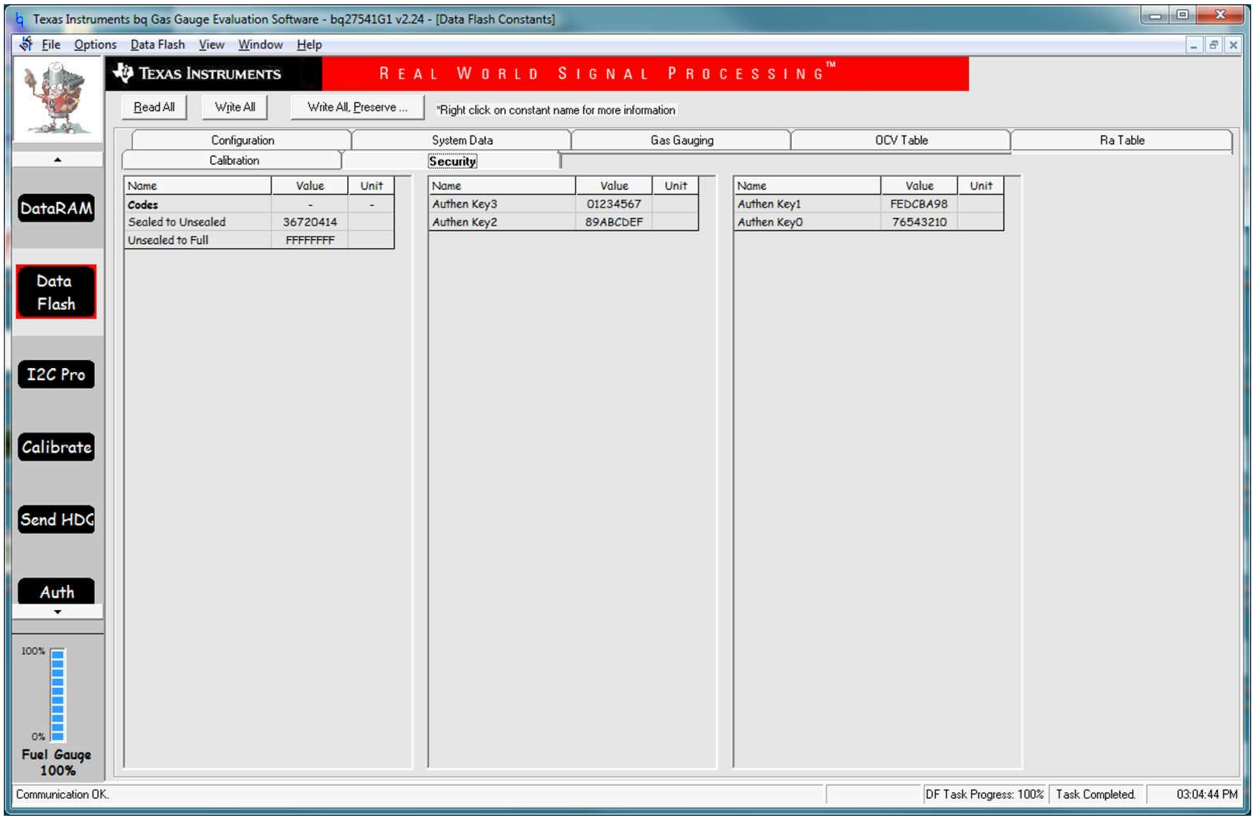

Figure 7. Security Screen

9.1 Codes

Sealed to Unsealed

This register contains the security code to transition the device from SEALED mode to UNSEALED mode.

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

Unsealed to Full

This register contains the security code to transition the device from UNSEALED mode to FULL ACCESS mode.

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

Authen Key0 – Key3

This is the register to store the SHA-1 authentication key to allow a system to authenticate the battery pack. See the datasheet for more details.

Normal Setting: The default key is set to 0x0123456789ABCDEFFEDCBA9876543210.