Application Report
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Configuring the bq2754x Data Flash

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ABSTRACT

The bq2754x has many data flash constants that can configure the device with various, different options for most features. The data flash of the bq2754x is divided into sections, which are described in detail in this document.

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1 Glossary

FCC: Full-charge capacity

FET: Field-effect transistor

FET opened/closed: It is common to say that the FET is opened or closed. Used throughout the document, this term means that the FET is turned on or off, respectively.

Flag: This word usually represents a read-only status bit that indicates some action has occurred or is occurring. This bit typically cannot be modified by the user.

RCA: Remaining capacity alarm

RM: Remaining capacity

SOC: This generic acronym means state-of-charge. It can also mean RSOC (Relative SOC) or percentage of actual chemical capacity.

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 that includes the bq2754x.

Italics: All words in this document that are in italics represent names of data flash locations exactly as they are shown in the EV software.

Bold Italics: All words that are bold italic represent SBS-compliant registers exactly as they are shown in the EV software.

[brackets]: All words or letters in brackets represent bit/flag names exactly as they are shown in the SBS and data flash in the EV software.

(–): This is commonly used in this document to represent a minus sign. It is written this way to ensure that the sign is not lost in the translation of formulas in the text of this document.

2 Configuration

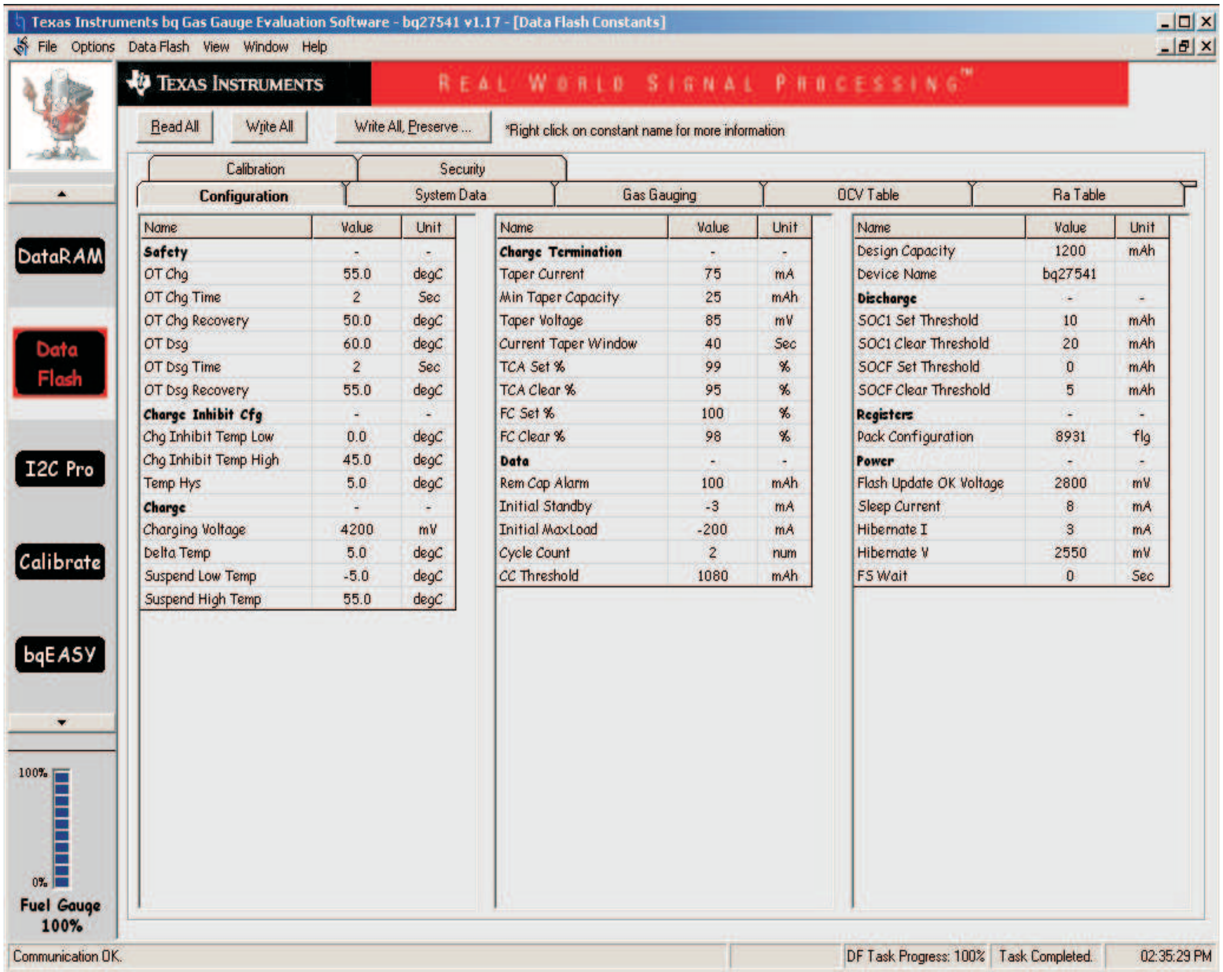

Figure 1. Configuration Screen

2.1 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 no [OTC] is set in ***Flags***. If the condition does not clear, then [OTC] 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 55°C, which is 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*** measured is greater than *OT Chg* and while charging. When the timer expires, the bq2754x forces an [OTC] in ***Flags***. Setting the *OT Chg Time* to 0 disables this function.

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. 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 at which 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 a 5-degree difference from the *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* setting 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* and while discharging. When the timer expires, then the bq2754x forces an [OTD] in ***Flags***. Setting the *OT Dsg Time* to 0 disables this function.

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. It must be set 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 a 5-degree difference from the *OT Dsg*.

2.2 Charge Inhibit Configuration

Chg Inhibit Temp Low

If pack temperature measured by ***Temperature*** falls to or below the charge inhibit temperature low (*Chg Inhibit Temp Low*) threshold while charging (***Current*** > *Chg Current 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***].

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, which is 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 while charging (***Current*** > *Chg Current 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***].

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 settings are sufficient for the application temperature. The default is 45°C, which is sufficient for most Li-ion applications.

Temp Hys

When pack temperature is measured by ***Temperature***, the temperature hysteresis (*Temp Hys*) is defined to prevent false temperature measurement.

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 5°C, which is sufficient for most Li-ion applications.

2.3 Charge

Charging Voltage

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

Normal Setting: This value depends on the charger that is expected to be used for the battery pack containing the bq2754x. The default is 4.2 V.

Delta Temp

If the pack temperature measured by ***Temperature*** is outside the suspend temperature range [***Suspend Low Temp, Suspend High Temp***]) threshold while charging (***Current*** > *Chg Current Threshold*), then the Charge Suspend Alert [XCHG] is set in ***Flags***. The Charge Suspend Alert [XCHG] is reset to "0" once battery temperature returns to the range [***Suspend Low Temp + Delta Temp, Suspend High Temp – Delta Temp***].

Normal Setting: This value depends on the charger that is expected to be used for the battery pack containing the bq2754x. The default is 5°C.

Suspend Low Temp

When the pack temperature measured by ***Temperature*** falls to or below the suspend low temperature (*Suspend Low Temp*) threshold while charging (***Current*** > *Chg Current Threshold*), then the Charge Suspend Alert [XCHG] is set in ***Flags***.

Normal Setting: This value depends on the charger that is expected to be used for the battery pack containing the bq2754x. The default is (–)5°C.

Suspend High Temp

When the pack temperature measured by ***Temperature*** rises to or above the suspend high temperature (*Suspend HighTemp*) threshold while charging (***Current*** > *Chg Current Threshold*), then the Charge Suspend Alert [XCHG] is set in ***Flags.***

Normal Setting: This value depends on the charger that is expected to be used for the battery pack containing the bq2754x. The default is 55°C.

2.4 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 per*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.

Min Taper Capacity

During Primary Charge Termination detection, one of the three requirements is that the accumulated change in capacity > 0.25 mAh per*Current Taper Window* for the bq2754x to start trying to qualify a termination. It must be above this Min Taper Capacity before bq2754x starts trying to detect a primary charge termination.

Normal Setting: If the value selected is too high, then it can cause no termination or late termination detection. An example value is 0.25 mAh.

Taper Voltage

During Primary Charge Termination detection, one of the three requirements is that ***Voltage*** must be above (*Charging Voltage – Taper Voltage*) for the bq2754x to start trying to qualify a termination. It must be above this voltage before bq2754x 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*).

Current Taper Window

During Primary Charge Termination detection, all three requirements as described in *Taper Current* must be valid for two periods of this *Current Taper Window* for the bq2754x to detect a primary charge termination.

Normal Setting: This register does not need to be modified for most applications. 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 the user increases 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 value is 40 seconds.

TCA Set %

This is the Terminate Charge Alarm Set. It determines the SOC % when the Charge (CHG) bit in Flags register is cleared.

Normal Setting: The default value is 99%

TCA Clear %

This is the Terminate Charge Alarm Clear. It is the SOC % at which the CHG bit in Flags register is set when discharging starts.

Normal Setting: The default value is 95%

FC Set %

This is the Full Charge Set. If set to -1, it signals that the FC (Full Charge) bit will not be set until taper termination is detected. Otherwise, FC is set when CC counted charge, SOC, gets to this specified percent.

Normal Setting: The default value is 99%.

FC Clear%

This is the Full Charge Clear. It is the SOC % at which the FC bit is cleared when discharging starts.

Normal Setting: The default value is 98%.

2.5 Data

Rem Cap Alarm

This is the remaining capacity alarm. It provides a user warning when remaining capacity is below the value set.

Normal Setting: The default value is 100 mAh.

Initial Standby

This is the first value that is reported in ***Standby Current***. The ***Standby Current*** value is updated every 1 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 load drawn by the system when in low-power mode. The default value is (–)10 mA.

Initial MaxLoad

This is the first value that is reported in ***MaxLoad Current***. If the measured current is ever greater than *Initial MaxLoad* Current, then ***MaxLoad Current*** updates to the new current. ***MaxLoad Current*** is reduced to the average of the previous value and *Initial MaxLoad Current* 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 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 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 to about 90% of the *Design Capacity*. The default is 900 mAh.

Design Capacity

This value is used for the compensated battery capacity remaining and capacity when fully charged calculations are done by the bq2754x.

Normal Setting: This value is set based on the application battery specification. See the battery manufacturer's data sheet. The default is 1000 mAh.

Device Name

This is string data that can be a maximum of seven characters. This field does not affect the operation, nor is it used by the part in any way. It is returned by reading addresses 0x63 through 0x69. The default is the ASCII values for "bq2754x".

2.6 Discharge

The bq2754x has two flags accessed by the ***Flags*** that warn when the battery's SOC has fallen to critical levels.

SOC1 Set Threshold

When ***Remaining Capacity*** falls below the first capacity threshold, specified in *SOC1 Set Threshold*, the [SOC1] (*State of Charge Initial*) bit is set in ***Flags***. This bit is cleared once ***Remaining Capacity*** rises above *SOC1 Clear Threshold*. The bq2754x's BAT_LOW pin automatically reflects the status of the [SOC1] bit in ***Flags***.

Normal Setting: This is a user preference. It is normally set at approximately 150 mAh.

SOC1 Clear Threshold

When ***Remaining Capacity*** rises to or above this value set by *SOC1 Clear Threshold*, then [SOC1] in ***Flags*** is cleared.

Normal Setting: This is a user preference. If used, it is normally set approximately 10 mAh higher than *SOC1 Set Threshold*. In this case, it is set to 175 mAh.

SOCF Set Threshold

When ***Remaining Capacity*** falls below the first capacity threshold, specified in *SOCF Set Threshold*, the [SOCF] (*State of Charge Final*) bit is set in ***Flags*** serving as a final discharge warning. If *SOCF Set Threshold* = (–)1, the flag is inoperative during discharge. This bit is cleared once ***Remaining Capacity*** rises above *SOCF Clear Threshold*.

Normal Setting: This is a user preference. It is normally set at approximately 75 mAh.

SOCF Clear Threshold

When ***Remaining Capacity*** rises to or above this value set *by SOCF Clear Threshold*, then [SOCF] in ***Flags*** is cleared.

Normal Setting: This is a user preference. If used, it is normally set approximately 30 mAh higher than *SOC1 Set Threshold*. In this case, it is set to 100 mAh.

2.7 Registers

Pack Configurations

This register is used to enable or disable various functions of the bq2754x.

RESCAP	RSVD	RSVD	RSVD	GNDSEL	IWAKE	RSNS1	RSNS0
RSVD	RSVD	SLEEP	RMFCC	SE_PU	SE_POL	RSVD	TEMPS

- RESCAP [15]: If set, a no-load rate of compensation is applied to the reserve capacity.
  Normal Setting: This bit defaults to 0.
- RSVD [14, 13, 12]: These bits are reserved (RSVD).
- GNDSEL [11]: ADC ground selection. If this bit is set to 0, Vss is selected as ADC ground reference. Otherwise, device pin 7 is selected as ADC ground reference.
  Normal Setting: This bit defaults to a 1.
- IWAKE, RSNS1, RSNS0 [10, 9, 8]: The wake-up comparator is used to indicate a change in cell current while the bq2754x is in either Sleep or Hibernate modes. *Op Config* 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 of RSNS1..0 disables this feature. See Table 1 for values.
  Normal Setting: The default setting for these bits is 001.
- RSVD [7, 6]: This bit is reserved.
- SLEEP [5]: If set, the gas gauge can enter sleep if operating conditions allow. The bq2754x enters SLEEP if ***Average Current*** ≤ *Sleep Current*.
  Normal Setting: This bit defaults to a 1, which is used in most applications. Only a few reasons require this bit to be set to 0.
- RMFCC [4]: If set, ***Remaining Capacity*** is updated with the value from ***Full Charge Capacity*** on valid charge termination.
  Normal Setting: The default setting for this bit is 1.
- SE_PU [3]: Pullup enable for SE pin. True when set (push-pull).
  Normal Setting: The default setting is 0.
- SE_POL [2]: Polarity bit for SE pin. SE is active low when clear.
  Normal Setting: The default setting is 1.
- RSVD [1]: This bit is reserved.
- TEMPS [0]: This bit is used to tell the bq2754x the temperature sensor configuration. The bq2754x can use an external sensor, and an internal sensor is also available, if needed. These sensors are able to use two configurations to report temperature in the ***Temperature*** register.
  – 1 = Temperature sensor TS1 is used to generate ***Temperature***.
  – 0 = Internal temperature sensor is used to generate ***Temperature***.

  Normal Setting: The default setting for this bit is 1. The bq2754x requires a Semitec 103AT thermistor. The internal temperature sensor is slightly less accurate than using a Semitec 103AT and is not recommended. It also is not as accurate because it cannot be placed as close to the battery cells in the application as can an external thermistor.

Table 1. IWAKE Threshold Settings[(1)]

RSNS1	RSNS0	IWAKE	Vth(SRP-SRN)
0	0	0	Disabled
0	0	1	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

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

2.8 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, and with a depleted battery, this current can cause the battery voltage to drop dramatically, forcing the bq2754x 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 charger 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

When ***Average Current*** is less than *Sleep Current* or greater than (–)*Sleep Current* in mA, the bq2754x enters SLEEP mode if the feature is enabled (*Op Config* [SLEEP] = 1). The bq2754x 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 bq2754x 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 bq2754x 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.

FS Wait

It is the Full Sleep Wait time and is a delay in seconds that can be set so that after a communication sleep, the gauge has to wait before it turns off the HF oscillator to get into full sleep. For HDQ, if the gauge is in Sleep mode, the first message from the host is always lost because the gauge cannot wake up fast enough to receive the message

Normal Setting: The default is 0 second, which is sufficient for most applications.

3 System Data

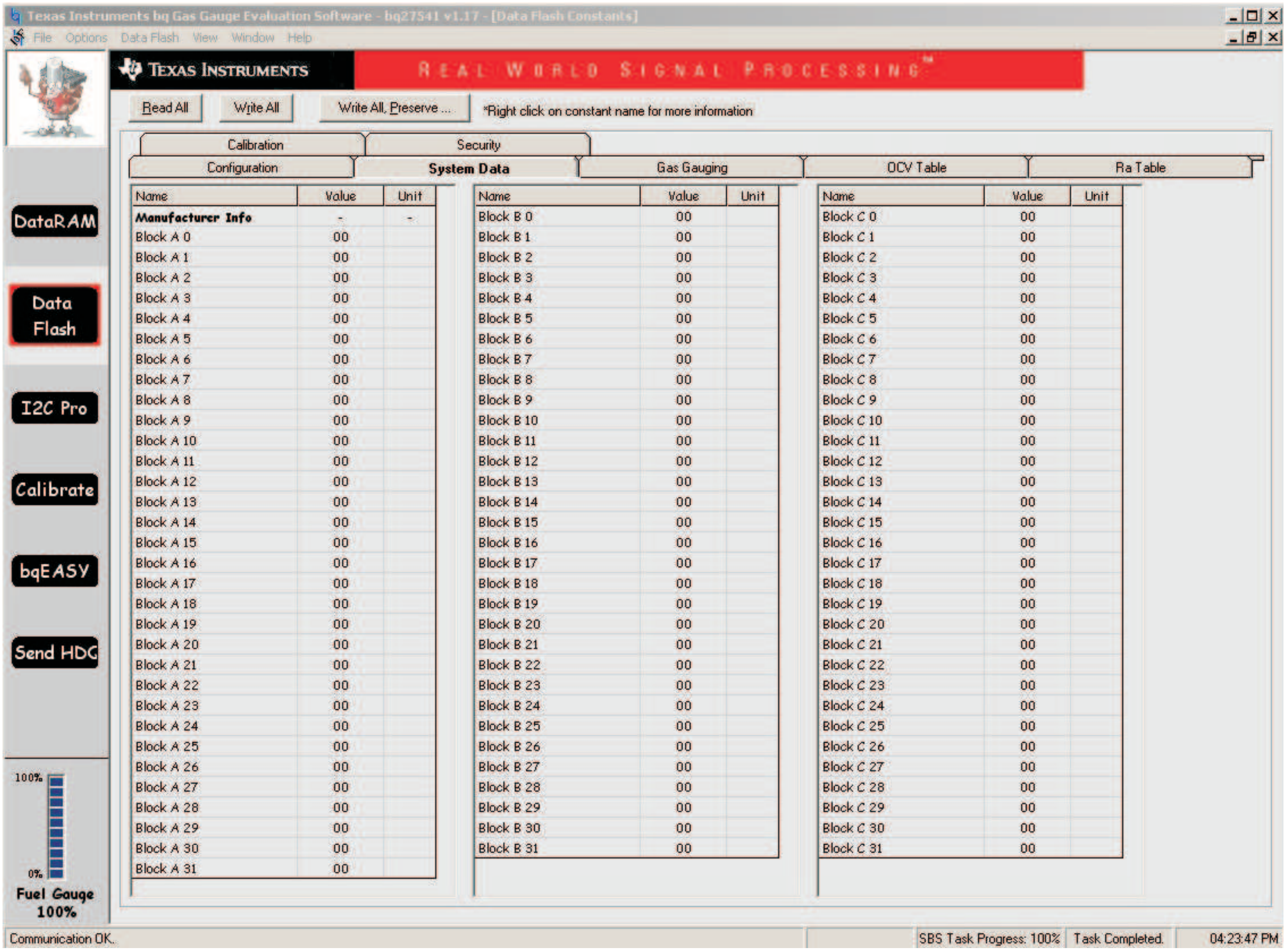

Figure 2. System Data Screen

3.1 Manufacturer Info

Block A

This is string data that can be any user data. It can be a maximum of eight characters.

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

Block B

This is string data that can be any user data. It can be a maximum of eight characters.

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

Block C

This is string data that can be any user data. It can be a maximum of eight characters.

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

4 Gas Gauging

Figure 3. Gas Gauging Screen

4.1 *IT Cfg*

Load Select

Load Select defines the type of power or current model to be used for ***Remaining Capacity*** computation in the Impedance Track™ algorithm.

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

0 = Average discharge current from previous cycle: An internal register records the average discharge current through each entire discharge cycle. The previous average is stored in this register.

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

2 = *Current:* Based off of ***Current***

3 = ***Average Current:*** Based off of ***Average Current***

4 = ***Design Capacity***/5: C Rate based off of ***Design Capacity***/5 or a C/5 rate in mA.

5 = ***At Rate*** (mA): Use whatever current is in ***At Rate*** register.

6 = *User Rate-mA:* Use the value in *User Rate-mA*. This gives a completely user-configurable method.

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

0 = Average discharge power from previous cycle: An internal register records the average discharge power through each entire discharge cycle. The previous average is stored in this register.

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

2 = ***Current*** × ***Voltage:*** Based off of ***Current*** and ***Voltage***

3 = ***Average Current*** × ***Voltage :*** Based off of ***Average Current*** and ***Voltage***

4 = ***Design Energy***/5: C Rate based off of ***Design Energy***/5 or a C/5 rate in mA

5 = ***At Rate*** (10 mW): Use whatever value is in ***At Rate*** register.

6 = *User Rate-mW*: Use the value in *User Rate-mW*. This gives a completely user-configurable method.

Normal Setting: The default for this register is 1. This is application dependent.

Load Mode

Load Mode is used to select either the constant current or constant power model for the Impedance Track™ algorithm as used in *Load Select*. (See *Load Select*.)

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.

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 must be 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 3000 mV.

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 ***Remaining Capacity*** 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-mW

User *Rate-mW* 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 ***Remaining Capacity*** 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 determines how much actual remaining capacity exists after reaching 0 ***RemainingCapacity*** before *Terminate Voltage* is reached. This register is only used if *Load Mode* is set to 0.

Normal Setting: This register defaults to 0, which disables this function. This is the most common setting for this register. This register is application dependent. This is a specialized function for allowing time for a controlled shutdown after 0 ***Remaining Capacity*** is reached.

Reserve Cap-mWh

Reserve Cap-10mWh determines how much actual remaining capacity exists after reaching 0 ***Remaining Capacity*** before *Terminate Voltage* is reached. This register is only used if *Load Mode* is set to 1.

Normal Setting: This register defaults to 0, which basically disables this function. This is the most common setting for this register. This register is application dependent. This is a specialized function for allowing time for a controlled shutdown after 0 ***Remaining Capacity*** is reached.

4.2 Current Thresholds

Dsg Current Threshold

This register is used as a threshold by many functions in the bq2754x to determine if actual discharge current is flowing out of the battery. This is independent from [DSG] in ***Flags***, which indicates whether the bq2754x is in discharge mode or charge mode.

Normal Setting: The [DSG] flag in ***Flags*** is the method for determining charging or discharging. If the bq2754x is charging, then [DSG] is 0 and any other time (***Average Current*** less than or equal to 0) the [DSG] flag is equal to 1. Many algorithms in the bq2754x require more definitive information about whether current is flowing in either the charge or discharge direction. *Dsg Current Threshold* is used for this purpose. The default for this register is 60 mA which is sufficient for most applications. This threshold must be set low enough to be below any normal application load current but high enough to prevent noise or drift from affecting the measurement.

Chg Current Threshold

This register is used as a threshold by many functions in the bq2754x to determine if actual charge current is flowing into the battery. This is independent from [DSG] in Battery Status which indicates whether the bq2754x is in discharge mode or charge mode.

Normal Setting: Many algorithms in the bq2754x require more definitive information about whether current is flowing in either 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 must 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

The *Quit Current* is used as part of the Impedance Track™ algorithm to determine when the bq2754x goes into relaxation mode from a current-flowing mode in either the charge direction or the discharge direction. Either of the following criteria must be met to enter relaxation mode:

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

After 30 minutes in relaxation mode, bq2754x starts checking if the dV/dt < 4 µV/s requirement for OCV readings is satisfied. When the battery relaxes sufficiently to satisfy this criteria, bq2754x takes OCV reading for updating Qmax and for accounting for self-discharge. These updates are used in the Impedance Track™ algorithms.

Normal Setting: It is critical that the battery voltage be relaxed during OCV readings to get the most accurate results. This current must not be higher than C/20 when attempting to go into relaxation mode; however, it must not be so low as to prevent going into relaxation mode due to noise. This must always be less than *Chg Current Threshold* or *Dsg Current Threshold*. Default is 40 mA.

Dsg Relax Time

The *Dsg Relax Time* is used in the function to determine when to go into relaxation mode. When ***Current*** 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 goes into relaxation mode. After 30 minutes in relaxation mode, the bq2754x 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 takes OCV reading for updating Qmax and for accounting for self-discharge. These updates are used in the Impedance Track™ algorithms.

Normal Setting: Care must be taken 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. Default is 1800 seconds.

Chg Relax Time

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

4.3 State

Qmax Cell 0

These are the maximum chemical capacities of the battery cell. The bq2754x 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 during use to keep capacity measuring as accurate as possible.

Normal Setting: Initially must be set to the battery cell data-sheet capacity. Default is 1000 mAh.

Cycle Count

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

Normal Setting: Initially should be set to 0 for fresh battery cell. The default is 0.

Update Status

Two bits in this register are important:

- Bit 1 (0x02) indicates that the bq2754x has learned new Qmax parameters and is accurate.
- Bit 2 (0x04) indicates whether the Impedance Track™ algorithm is enabled.

The remaining bits are reserved.

Normal Setting: Bit 1 and bit 2 are user configurable; however, bit 1 is also a status flag that can be set by the bq2754x. This bit must never be modified except when creating a golden image file. Bit 1 is updated as needed by the bq2754x.

Avg I Last Run

The bq2754x logs the ***Average Current*** averaged from the beginning to the end of each discharge cycle. It stores this average current from the previous discharge cycle in this register.

Normal Setting: This register never needs to be modified. It is only updated by the bq2754x when required.

Avg P Last Run

The bq2754x logs the power averaged from the beginning to the end of each discharge cycle. It stores this average power from the previous discharge cycle in this register. To get a correct average power reading, the bq2754x continuously multiplies instantaneous Current to ***Voltage*** to get power. It then logs this data to derive the average power.

Normal Setting: This register never needs to be modified. It is only updated by the bq2754x when required.

5 Ra Table

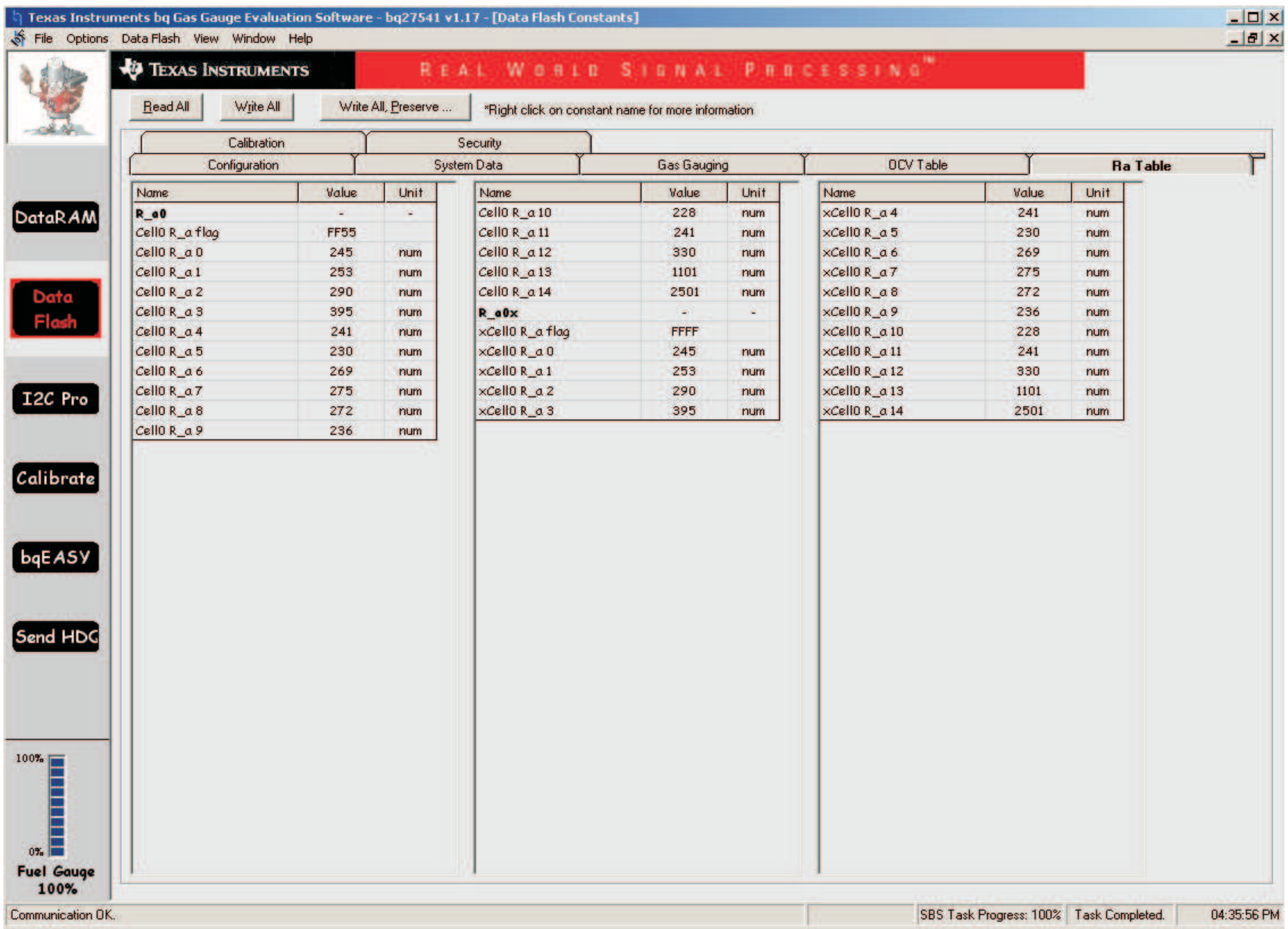

Figure 4. Ra Table Screen

This data is automatically updated during device operation. No user changes need to be made 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* (SLUA504). Profiles have format *Cell0 R_a* M where M is the number indicating state of charge to which the value corresponds.

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**

Cell0 R_a flag, xCell0 R_a flag

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 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, and the *QMax Pack* has been updated.
   B. 0x05: The resistance data associated with this flag has been 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 has been 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 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 Impedance Track™ algorithm. The only reason this data is displayed and accessible is to give the user the ability to update the resistance data on golden image files. This description of the *xCell0 R_a flags* is intended for information purposes only. It is not intended to give a detailed functional description for the bq27350 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 $0 \leq M \leq 8$: The data is the resistance normalized at 0° for: SOC = 100% – (M × 10%)
2. If $9 \leq M \leq 14$: 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: SOC as stated in this description is based on *Qmax Cell0*. It is not derived as a function of SOC. These resistance profiles are used by the bq2754x for the Impedance Track™ algorithm. The only reason this data is displayed and accessible is to give the user the ability to update the resistance data on golden image files. This resistance profile description is for information purposes only. It is not intended to give a detailed functional description for the bq2754x resistance algorithms. It is important to note that this data is in mΩ units and is normalized to 0°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 must never be anywhere in this class.
2. Watch for smooth consistent transitions from one profile grid point value to the next throughout each profile. As the bq2754x does resistance profile updates, these values are roughly consistent from one learned update to another without huge jumps in consecutive grid points.

6 Calibration

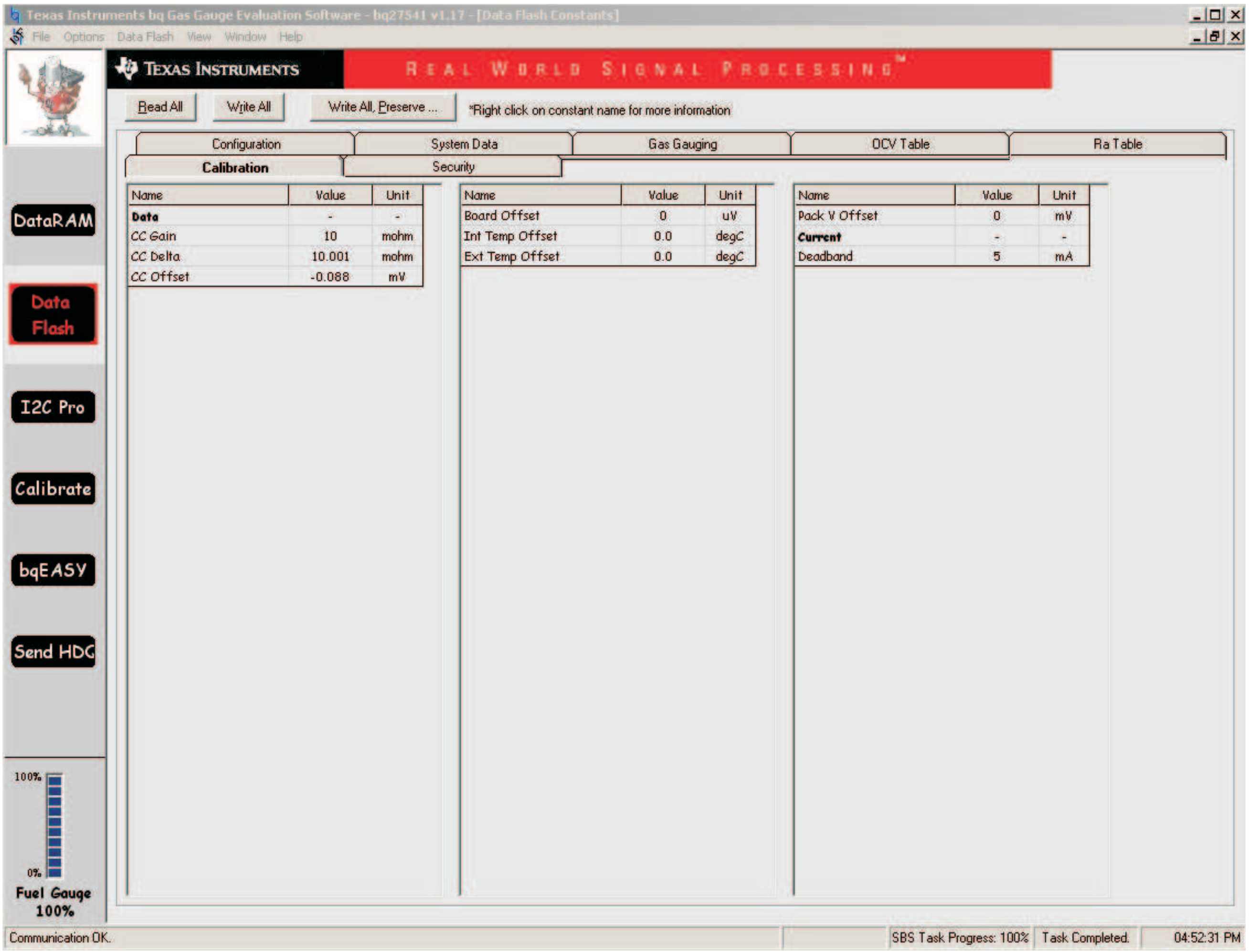

Figure 5. Calibration Screen

6.1 Data

Most of these 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).

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. See the application report *Going to Production with the bq2754x* (SLUA504) for more information.

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 ***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. See the application report *Going to Production with the bq2754x* (SLUA504) for more information.

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 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 bq2754x. *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.

A. The first method is to calibrate *CC Offset* by the putting the bq2754x in Calibration mode and initiating the *CC Offset* function as part of the entire bq2754x calibration suite. See the application report *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 I2C 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 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* must never 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 bq2754x* (SLUA504) 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 bq2754x integrated circuit (IC). The simplified ground circuit design in the bq2754x requires a separate board offset for each tested device.

Normal Setting: This value must only be set one time when all the other data flash constants are modified during the pack production process.

Int Temp Offset

The bq2754x 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* must only be calibrated if the internal temperature sensor is used. See the application report *Going to Production with the bq2754x* (SLUA504) for more information on calibration.

Ext Temp Offset

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

Normal Setting: *Ext Temp Offset* never needs to be modified by the user. It is modified by the external temperature sensor calibration command in Calibration Mode. *Ext Temp Offset* must only be calibrated if a thermistor is connected to the TS pin of the bq2754x. See the application report *Going to Production with the bq2754x* (SLUA504) for more information on calibration.

Pack V Offset

This is the offset to calibrate the bq2754x 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 must only be set one time when all the other data flash constants are modified during the pack production process.

6.2 Current

Deadband

The purpose of the *Deadband* is to create a filter window to the reported ***Average Current*** 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 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.

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