TEXAS INSTRUMENTS

Application Report
SLUA419–April 2007

Configuring the bq27350 Data Flash

Battery Management

ABSTRACT

The bq27350 has numerous data flash constants that can be used to configure the device with a variety of different options for most features. The data flash of the bq27350 is split into sections which are described in detail within this document.

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1 Glossary

FCC: Full charge capacity

FET opened/closed: It is common to say FET opened or FET closed. Used throughout the document, this term means that the FET is turned on or the FET is turned 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 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 bq27350.

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

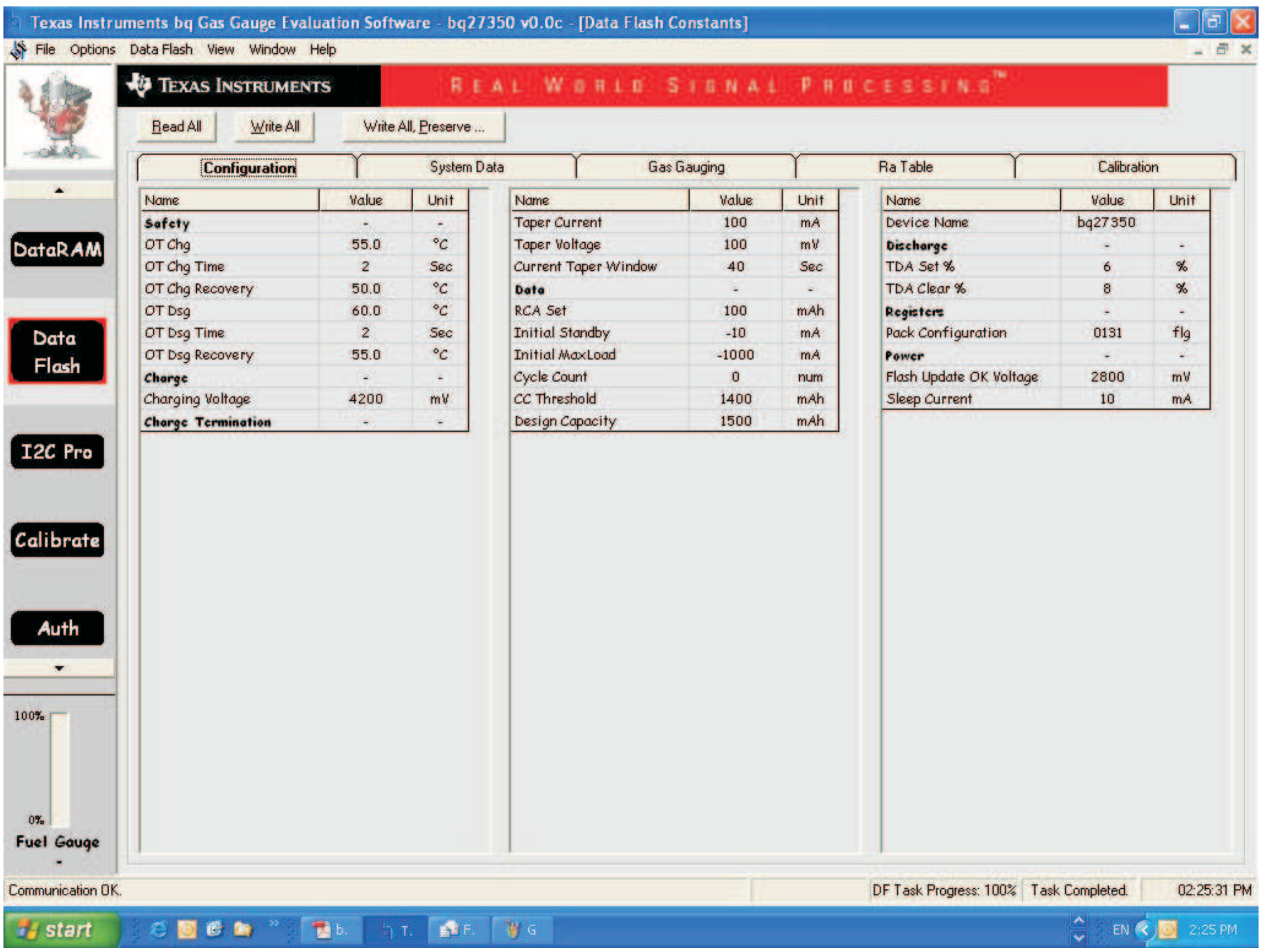

Figure 1. Configuration Screen

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 should be 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 bq27350 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 should be 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 bq27350 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 should 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

Charging Voltage

The bq27350 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 bq27350. The default is 4.2 V.

2.3 Charge Termination

Taper Current

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

1. During two consecutive periods of *Current Taper Window*, the ***Average Current*** is < *Taper Current*.
2. During the same periods, the accumulated change in capacity > 0.25 mAh/*Current Taper Window*.
3. ***Voltage*** > *Charging Voltage* - *Taper Voltage*.

When this occurs, the [FC] bit of Flags( ) is set and [CHG] bit is cleared. Also, if the [RMFCC] bit of *Pack Configuration* is set, then ***RemainingCapacity*** is set equal to ***Full Charge Capacity***

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

Taper Voltage

During Primary Charge Termination detection, one of the three requirements is that ***Voltage*** must be above (*Charging Voltage – Taper Voltage*) for the bq27350 to start trying to qualify a termination. It must be above this voltage before bq27350 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 bq27350 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.

2.4 Data

RCA Set

When the ***Remaining Capacity*** falls below this value, [RCA] is set in ***Flags***.

Normal Setting: The default value is 100 mAh.

Initial Standby Current

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 x *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 Max Load Current

This is the first value that is reported in ***Max Load Current***. If the measured current is ever greater than *Initial Max Load Current*, then ***Max Load Current*** updates to the new current. ***Max Load Current*** is reduced to the average of the previous value and *Initial Max Load 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 (-)1000 mA.

Cycle Count

When the bq27350 accumulates enough discharge capacity equal to the *Cycle Count Threshold*, then it increments *Cycle Count* by 1. This discharge capacity used 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 *Cycle Count Threshold*. Then, *Cycle Count* is incremented.

Normal Setting: This should be set to 0.

Cycle Count Threshold

This value is always used to increment *Cycle Count*. When the bq27350 accumulates enough discharge capacity equal to the *Cycle Count 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 *Cycle Count Threshold*, and increments *Cycle Count*.

Normal Setting: This is normally set to about 90% of the *Design Capacity*. The default is 1400 mAh.

Design Capacity

This value is used for the compensated battery capacity remaining and capacity when fully charged calculations that are done by the bq27350.

Normal Setting: This value should be set based on the application battery specification. See the battery manufacturer's data sheet. The default is 1500 mAh.

Device Name

String data that can be a maximum of 7 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 "bq27350".

2.5 Discharge

TDA Set %

If set to a value between 0 and 100, then when ***SOC*** falls to or below this value, then [TDA] in ***Flags*** is set. If set to (-)1, this function is disabled.

Normal Setting: This is a user preference. This is the threshold that the bq27350 requests that discharge be halted because the battery is nearing depletion. If used, it is normally set around 6%. Ensure that if *TDA Clear %* is used, this should be used as well. They only work together.

TDA Clear %

If set to a value between 0 and 100, then when ***SOC*** rises to or above this value after being set by *TDA Set %*, then [TDA] in ***Flags*** is cleared. This register can only be used to clear [TDA] if it was set by TDA Set %. If set to (-)1, this function is disabled.

Normal Setting: This is a user preference. If used, it is normally set around 8%. Ensure that if *TDA Set %* is used, this should be used as well. They only work together.

2.6 Registers

Pack Configuration

This register is used to enable or disable various functions of the bq27350.

RESCAP	–	BUSLOW	–	–	IWAKE	RSNS1	RSNS0
SHUTDOWN	HIBERNATE	SLEEP	RMFCC	–	–	–	TEMPS

- RESCAP [15]: If set, a no-load rate of compensation is applied to the reserve capacity.
  Normal Setting: This bit defaults to a 0.
- RESERVED [14]: This bit is reserved.
- BUSLOW [13]: If set, the Interface Bus being low becomes a requirement to enter sleep.
  Normal Setting: This bit defaults to a 0.
- RESERVED [12, 11]: These bits are reserved.
- IWAKE, RSNS1, RSNS0 [10, 9, 8]: The wake up comparator is used to indicate a change in cell current while the bq27350 is in either Sleep or Hibernate modes. *PackConfiguration* uses bits [RSNS1-RSNS0] to set the sense resistor selection. *PackConfiguration* uses the [IWAKE] bit to select one of two possible voltage threshold ranges for the given sense resistor selection. An internal interrupt is generated when the threshold is breached in either charge or discharge directions. A setting of 0x00 of RSNS1..0 disables this feature. See Table 1 for values.
  Normal Setting: The default setting for these bits is 001.
- SHUTDOWN [7]: If set, $\overline{\text{SE}}$ is set high before going into HIBERNATE and set low when returning to NORMAL mode.
  Normal Setting: This bit defaults to a 0.
- HIBERNATE [6]: If set and conditions are suitable for sleep, then the gas gauge enters HIBERNATE instead of SLEEP.
  Normal Setting: This bit defaults to a 0.
- SLEEP [5]: If set, the gas gauge can enter sleep if operating conditions allow. The bq27350 enters SLEEP if ***Average Current***≤*Sleep Current*. If [BUS LOW] = 1, then the I2C Data and Clock line must go low for more than 5 seconds to allow sleep.
  Normal Setting: This bit defaults to a 1, which should be used in most applications. Only a few reasons require this bit to be set to 0.
- RMFCC [4]:If set, on valid charge termination, ***Remaining Capacity*** is updated with the value from ***Full Charge Capacity***.
  Normal Setting: The default setting for this bits is 1.
- RESERVED [3, 2, 1]: These bits are reserved.
- TEMPS [0]: This bit is used to tell the bq27350 the temperature sensor configuration. The bq27350 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 bq27350 default configuration is for 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. I_{WAKE} 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 vs. the setting of the sense resistor is not important, just the actual voltage threshold when calculating the configuration.

2.7 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 bq27350, and with a depleted battery, this current can cause the battery voltage to drop dramatically, forcing the bq27350 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 bq27350 enters SLEEP mode.

The bq27350 does an ADC calibration and then goes to sleep.
Normal Setting: This setting should be below any normal application currents. The default is 10 mA, which should be sufficient for most applications.

3 System Data

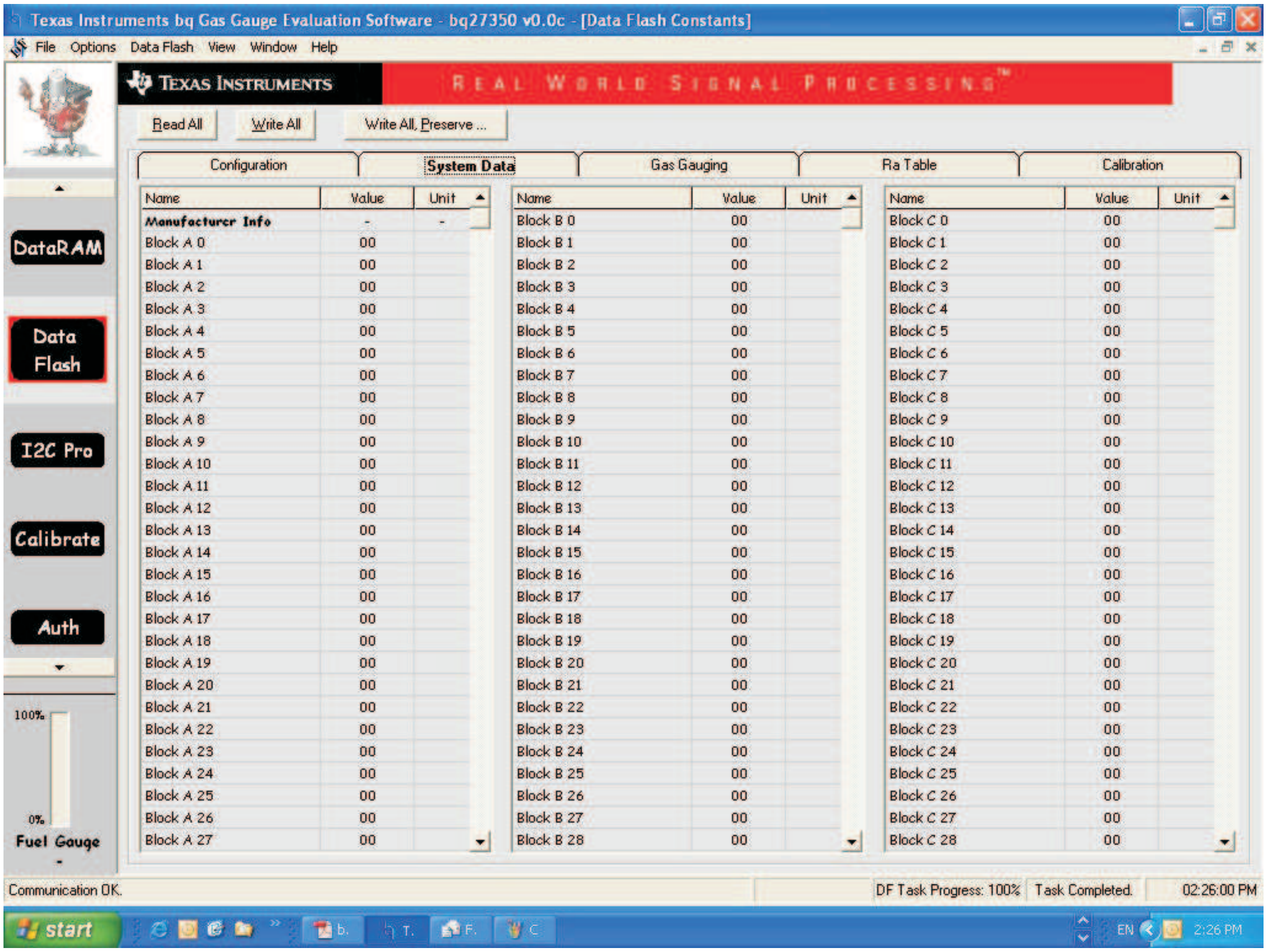

Figure 2. System Data Screen

3.1 Manufacturer Info

Block A

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

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

4 Gas Gauging

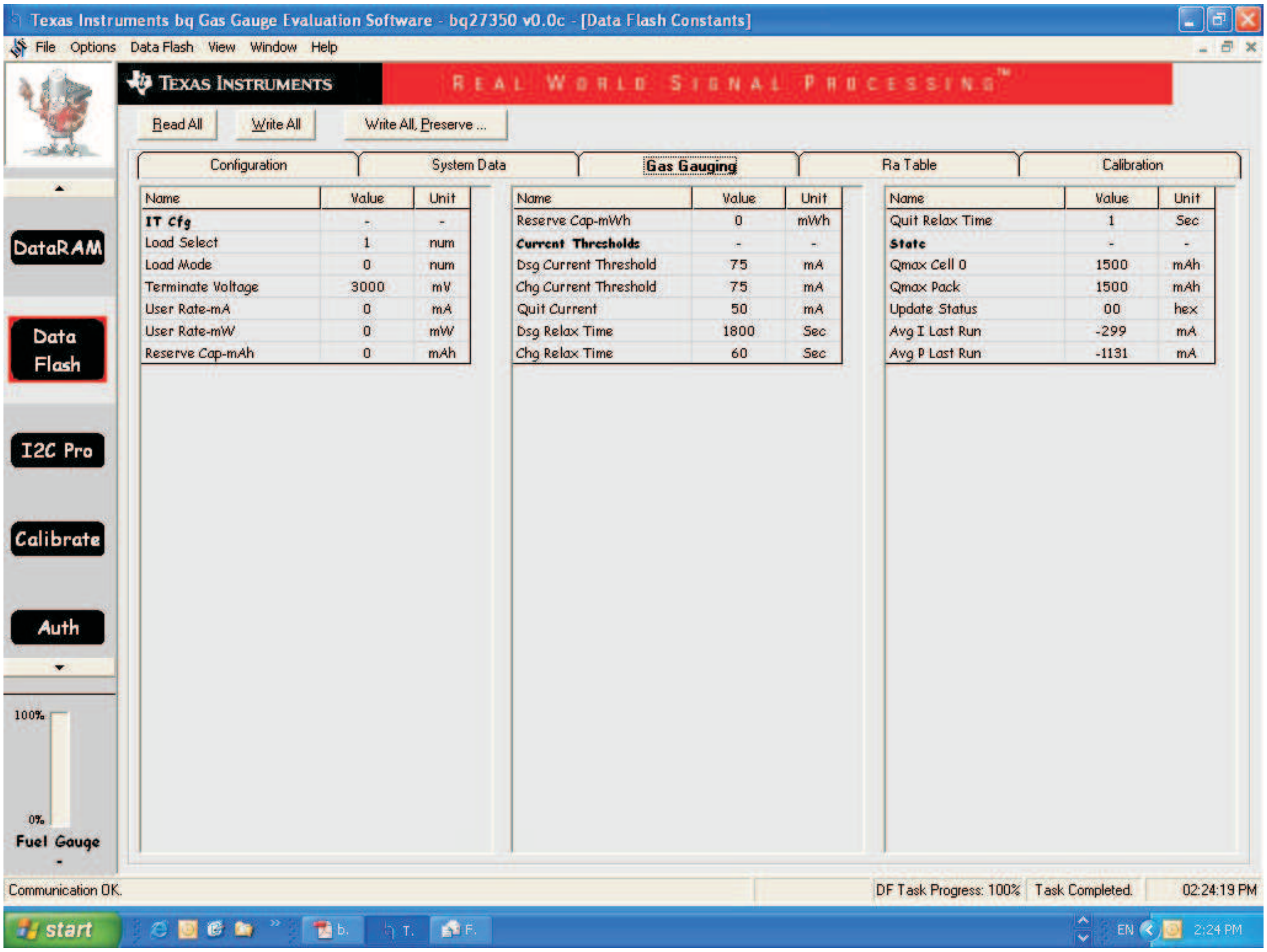

Figure 3. Gas Gauging Screen

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 the ***Average Current***

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

5 = ***AtRate*** (mA): Use whatever current is in ***AtRate***

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 the ***Average Current*** and ***Voltage***

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

5 = ***AtRate*** (10 mW): Use whatever value is in ***AtRate***.

6 = *User_Rate-10mW*: 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 Model
- 1: Constant Power Model

Normal Setting: This is normally set to 0 (Constant Current Model) but it is application specific. If the application load profile more closely matches a constant power model, 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 should 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 would require 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-10mW

User Rate-10mW 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 would require 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 10-mW units.

Reserve Cap-mAh

Reserve Cap-mAh determines how much actual remaining capacity exists after reaching ***SOC*** = 0% before *Terminate Voltage* is reached. This register is only used if *Load Mode* is set to 0. The two ways to interpret this register depending on [RESCAP] in *Pack Configuration* are:

- [RESCAP]=0: If set to 0, then a no-load rate of compensation is applied to this reserve capacity.
- [RESCAP]=1: If set to a 1, then a higher rate of load compensation as defined by *Load Select* is applied to this reserve capacity. (See *Load Select*.)

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% capacity is reached. Another function can serve this purpose, like *RCA Set*.

Reserve Cap-10mWh

Reserve Cap-10mWh determines how much actual remaining capacity exists after reaching SOC = 0% before *Terminate Voltage* is reached. This register is only used if *Load Mode* is set to 1. The two ways to interpret this register depending on [RESCAP] in *Pack Configuration* are:

- 0: If set to 0, then a no-load rate of compensation is applied to this reserve capacity.
- 1: If set to a 1, then a more normal rate of load compensation as defined by *Load Select* is applied to this reserve capacity. (See *Load Select*.)

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% capacity is reached. Another function can serve this purpose, like *RCA Set*.

4.2 Current Thresholds

Dsg Current Threshold

This register is used as a threshold by many functions in the bq27350 to determine if actual discharge current is flowing out of the battery. This is independent from [DSG] in ***Flags***, which indicates whether the bq27350 is in discharge mode or charge mode.
Normal Setting: The [DSG] flag in ***Flags*** is the method for determining charging or discharging. If the bq27350 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 bq27350 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 75 mA which should be sufficient for most applications. This threshold should be set low enough to be below any normal application load current but high enough to prevent noise or drift from affecting the measurement.

Chg Current Threshold

This register is used as a threshold by many functions in the bq27350 to determine if actual charge current is flowing into the battery. This is independent from [DSG] in Battery Status which indicates whether the bq27350 is in discharge mode or charge mode. Normal Setting:
Normal Setting: Many algorithms in the bq27350 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 should be sufficient for most applications. This threshold should be set low enough to be below any normal application load current but high enough to prevent noise or drift from affecting the measurement.

Quit Current

The *Quit Current* is used as part of the Impedance Track™ algorithm to determine when the bq27350 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 **less than** (–)*Quit Current* and then goes within (±)*Quit Current* for *Dsg Relax Time*.
2. ***Average Current*** is **greater than** *Quit Current* and then goes within (±)*Quit Current* for *Chg Relax Time*.

After 30 minutes in relaxation mode, bq27350 starts checking if the dV/dt < 4-µV/s requirement for OCV readings is satisfied. When the battery relaxes sufficiently to satisfy this criteria, bq27350 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 should not be so low as to prevent going into relaxation mode due to noise. This should always be less than *Chg Current Threshold* or *Dsg Current Threshold*. Default is 50 mA.

Dsg Relax Time

The *Dsg Relax Time* is used in the function to determine when to go into relaxation mode. When ***Current*** is **less 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 bq27350 goes into relaxation mode. After 30 minutes in relaxation mode, bq27350 starts checking if the dV/dt < 4-µV/s requirement for OCV readings is satisfied. When the battery relaxes sufficiently to satisfy this criteria, bq27350 takes OCV reading for updating Qmax and for accounting for self-discharge. These updates are used in the Impedance Track™ algorithms.
Normal Setting: Care should 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 s.

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 bq27350 goes into relaxation mode. After approximately 30 minutes in relaxation mode, the bq27350 attempts to take accurate OCV readings. An additional requirement of dV/dt < 4 µV/s (delta voltage over delta time) is required for the bq27350 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 meeting conditions to exit relaxation are 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

This is the maximum chemical capacity of the battery cell. It also corresponds to capacity at a low rate of discharge such as a C/20 rate. This value is updated by the bq27350 continuously during use to keep capacity measuring as accurate as possible.
Normal Setting: Initially should be set to the battery cell data-sheet capacity. Default is 1500 mAh.

Qmax Pack

This is the maximum capacity of the entire battery pack. It also corresponds to capacity at low rate of discharge such as a C/20 rate.
Normal Setting: Initially should be set to the battery cell data-sheet capacity. The default is 1500 mAh.

Update Status

Two bits in this register are important:

- Bit 1 (0x02) indicates that the bq27350 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: These bits are user configurable; however, bit 1 is also a status flag that can be set by the bq27350. These bits should never be modified except when creating a golden image file as explained in the application report “Data Flash Programming and Calibrating the bq27350 Gas Gauge” (SLUA415). Bit 1 is updated as needed by the bq27350 and bit 2 is set with the ***Control*** command 0x0021.

AvgILast Run

The bq27350 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 should never need to be modified. It is only updated by the bq27350 when required.

Avg P Last Run

The bq27350 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 bq27350 continuously multiplies ***Average Current*** times ***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 bq27350 when required.

5 Ra Table

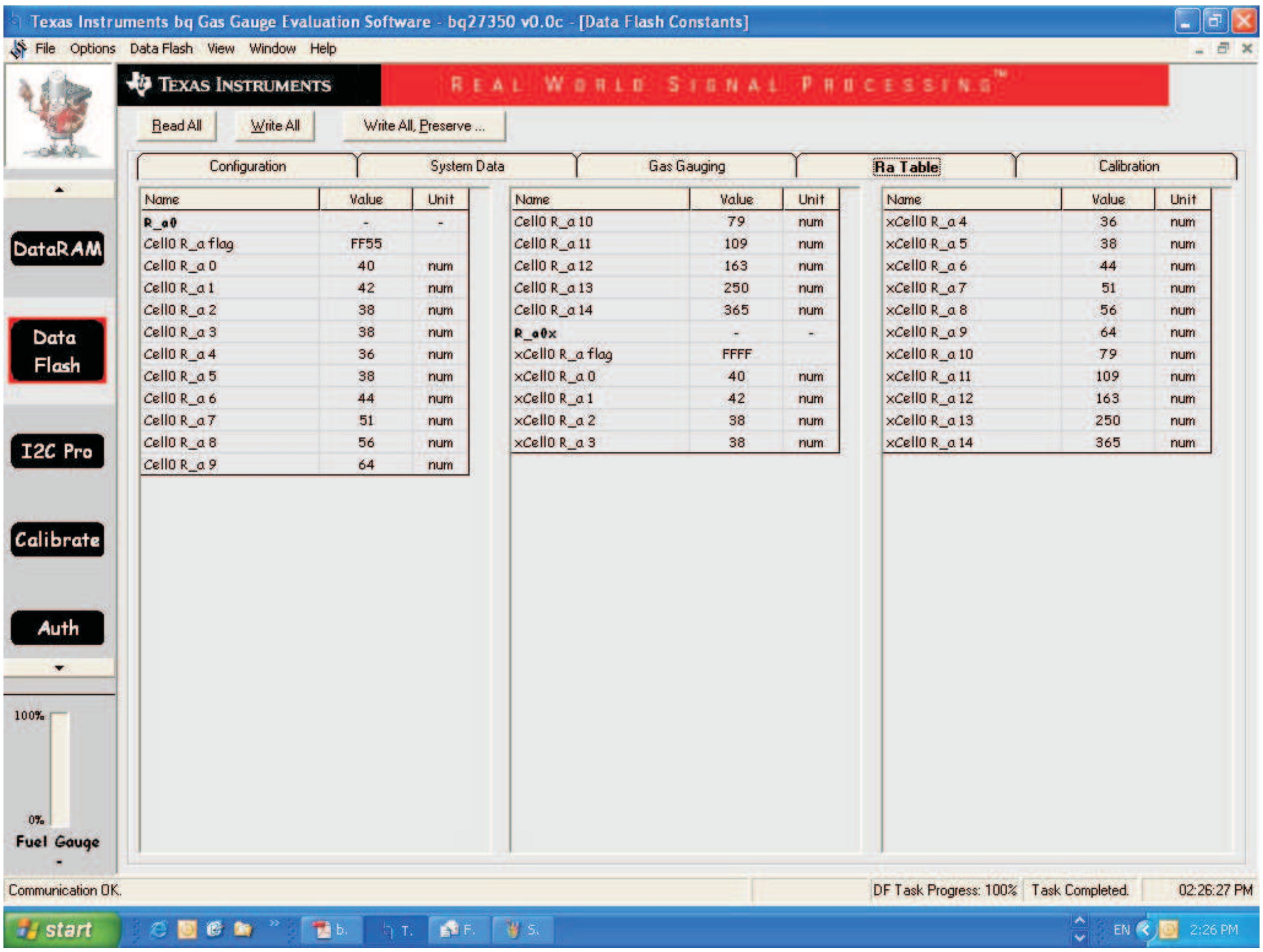

Figure 4. Ra Table Screen

This data is automatically updated during device operation. No user changes should be made except for reading the values from another pre-learned pack for creating “Golden Image Files”. See application report “Data Flash Programming and Calibrating the bq27350 Gas Gauge” (SLUA415). 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/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 bq27350 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 bq27350 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* are 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 gridpoint 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 Pack*. It is not derived as a function of SOC. These resistance profiles are used by the bq27350 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 bq27350 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 should never be anywhere in this class.

2. Watch for smooth consistent transitions from one profile gridpoint value to the next throughout each profile. As the bq27350 does resistance profile updates, these values should be roughly consistent from one learned update to another without huge jumps in consecutive gridpoints.

6 Calibration

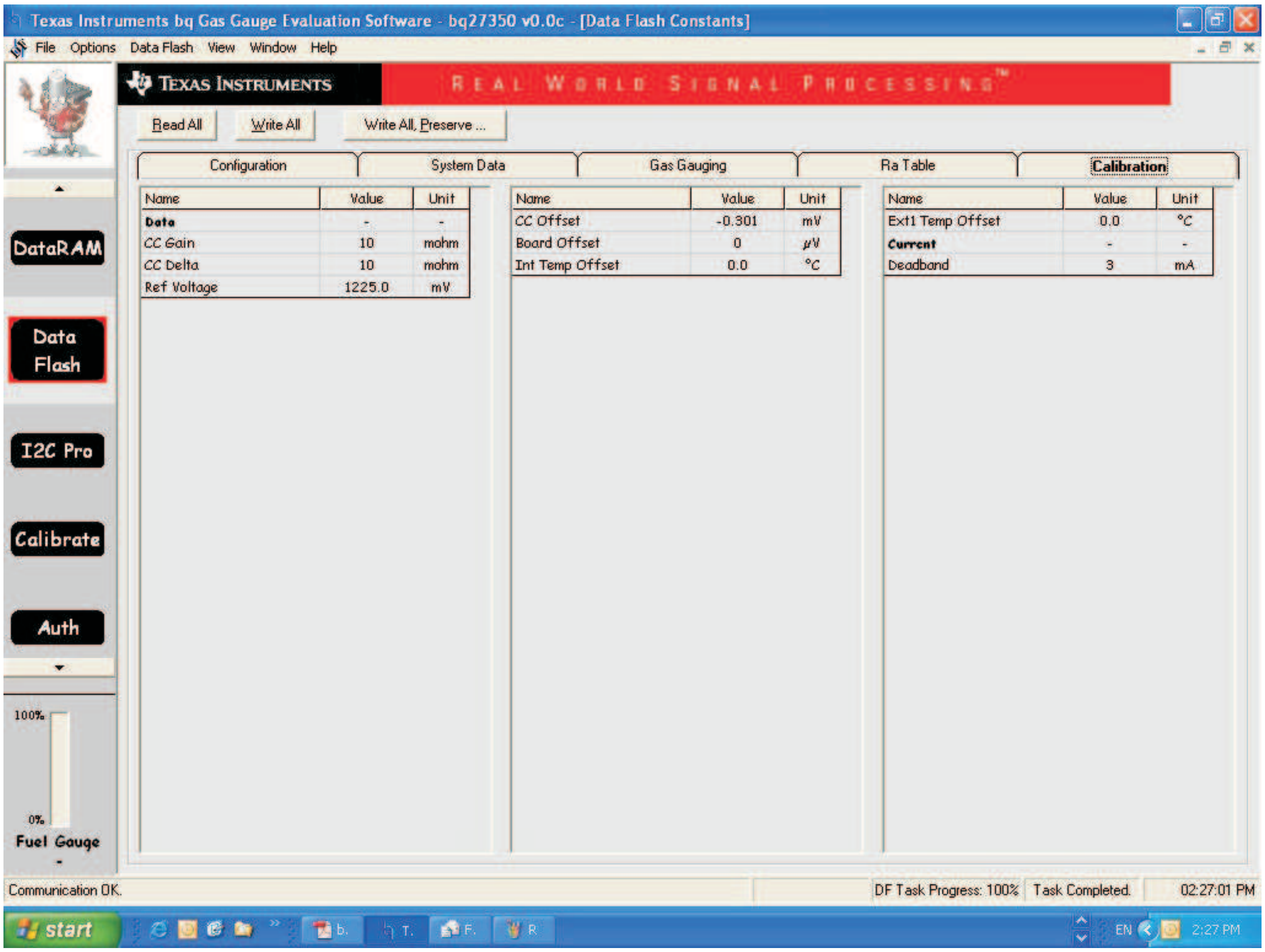

Figure 5. Calibration Screen

6.1 Data

Most of these values should never require modification by the user. They should only be modified by the Calibration commands in Calibration mode as explained in the *Data Flash Programming and Calibrating the bq27350 Gas Gauge* application report (SLUA415).

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* should never need to be modified directly by the user. It is modified by the current calibration function from Calibration mode. See the "Data Flash Programming and Calibrating the bq27350 Gas Gauge" application report (SLUA415) 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* should never need to be modified directly by the user. It is modified by the current calibration function from Calibration mode. See the "Data Flash Programming and Calibrating the bq27350 Gas Gauge" application report (SLUA415) for more information.

Ref Voltage

The *Ref Voltage* is based on the reference voltage for the ADC that measures voltage within the bq27350. Therefore, this is a required constant in all the bq27350 voltage computation formulas for displaying the computed battery voltage (***Voltage***) in millivolts.

Normal Setting:*Ref Voltage* should never need to be modified by the user. It is modified by the voltage calibration command in Calibration mode. See the "Data Flash Programming and Calibrating the bq27350 Gas Gauge" application report (SLUA415) 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 bq27350 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 either 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 bq27350. *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 bq27350 in Calibration mode and initiating the *CC Offset* function as part of the entire bq27350 calibration suite. See the "Data Flash Programming and Calibrating the bq27350 Gas Gauge" application report (SLUA415) 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* should never be modified directly by the user. It is modified by the current calibration function from Calibration mode or by Automatic Calibration. See the "Data Flash Programming and Calibrating the bq27350 Gas Gauge" application report (SLUA415) 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 bq27350 IC. The simplified ground circuit design in the bq27350 requires a separate board offset for each tested device.

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

Int Temp Offset

The bq27350 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* should never need to be modified by the user. It is modified by the internal temperature sensor calibration command in Calibration mode. *Int Temp Offset* should only be calibrated if the internal temperature sensor is used. See the "Data Flash Programming and Calibrating the bq27350 Gas Gauge" application report (SLUA415) for more information on calibration.

Ext1 Temp Offset

Ext1 Temp Offset is for calibrating the offset of the thermistor connected to the TS1 pin of the bq27350 as reported by ***Temperature***. The gain of the thermistor is accurate enough that a calibration for gain is not required.

Normal Setting: *Ext1 Temp Offset* should never need to be modified by the user. It is modified by the external temperature sensor calibration command in Calibration Mode. *Ext1 Temp Offset* should only be calibrated if a thermistor is connected to the TS pin of the bq27350. See the "Data Flash Programming and Calibrating the bq27350 Gas Gauge" application report (SLUA415) for more information on calibration.

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 3 mA. Only a few reasons may require changing this value:

1. If the bq27350 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.