Texas Instruments

Application Report
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How to Configure and Use the bq27410

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ABSTRACT

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

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1 Using Simplified bqEASY™ Software to Configure bq27410 Limited Data Flash Parameters

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

Figure 1. bq27410 Simplified bqEASY™ Tool

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

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

2 bq27410 Data Flash Parameters

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

2.1 Configurations

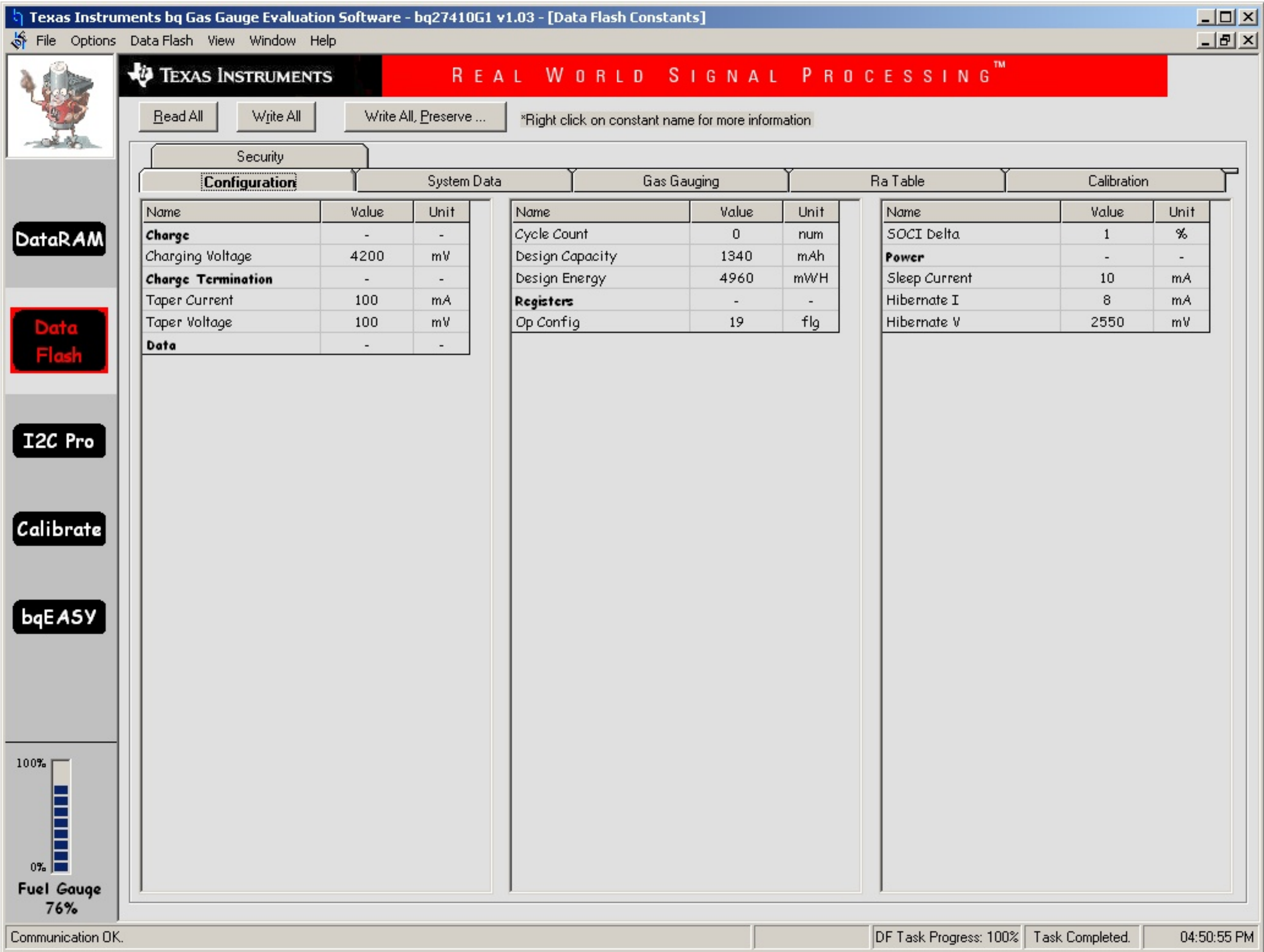

Figure 2. Configuration Screen

2.1.1 Charge

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

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

2.1.2 Charge Termination

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

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

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

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

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

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

2.1.3 Data

Design Capacity
This value is used for initial compensated battery capacity calculations

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

Design Energy
This value is used for initial compensated battery energy calculations

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

2.1.4 Register

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

RESCAP	RSVD	BATLOWEN	SLEEP	RMFCC	BIE	GPIOPOL	WRTEMP

- RESCAP [7]: If set, a no-load rate of compensation is applied to the reserve capacity.
  Normal Setting: True when set. This bit defaults to 0.
- RSVD [6]: Reserved
- BATLOWEN [5]: If set, the BAT_LOW function for GPOUT pin is selected. If cleared, the SOC_INT function is selected for GPOUT.
  Normal Setting: This bit defaults to 0
- SLEEP [4]: If set, the gas gauge can enter sleep if operating conditions allow. The bq27410 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 [3]: If set, on valid charge termination, ***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.
- BIE [2]: Battery Insertion Enable. If set, the battery insertion is detected via BIN pin input (need external pull up on BIN pin). If cleared, the detection relies on the host to issue BAT_INSERT subcommand to indicate battery presence in the system.
  Normal Setting: This bit defaults to a 0.

- GPIOPOL [1]: PGOUT pin polarity control. When set, GPOUT pin is active-high. GPOUT pin is active-low if cleared.
  Normal Setting: This bit defaults to a 0.
- WRTEMP [0]: Enable the host to write *Temperature ( )* to gauge if set. If cleared, the internal temperature sensor is used for *Temperature ( )*.
  Normal Setting: This bit defaults to 1.

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

Normal Setting: The default is 1%

2.1.5 Power

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

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

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

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

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

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

2.2 System Data

2.2.1 Manufacturer Info

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

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

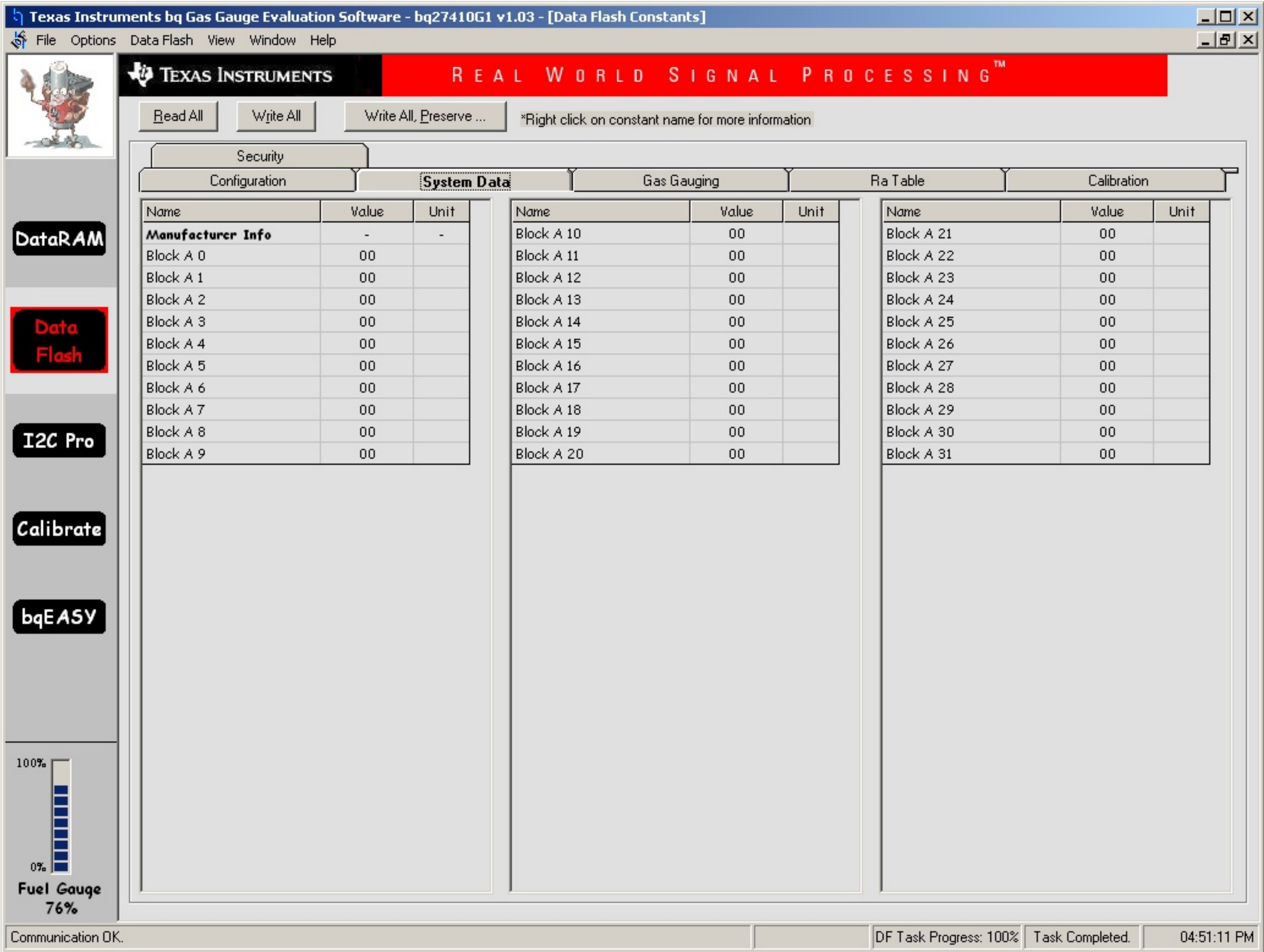

Figure 3. System Data Screen

2.3 Gas Gauging

2.3.1 IT Cfg

Terminate Voltage

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

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

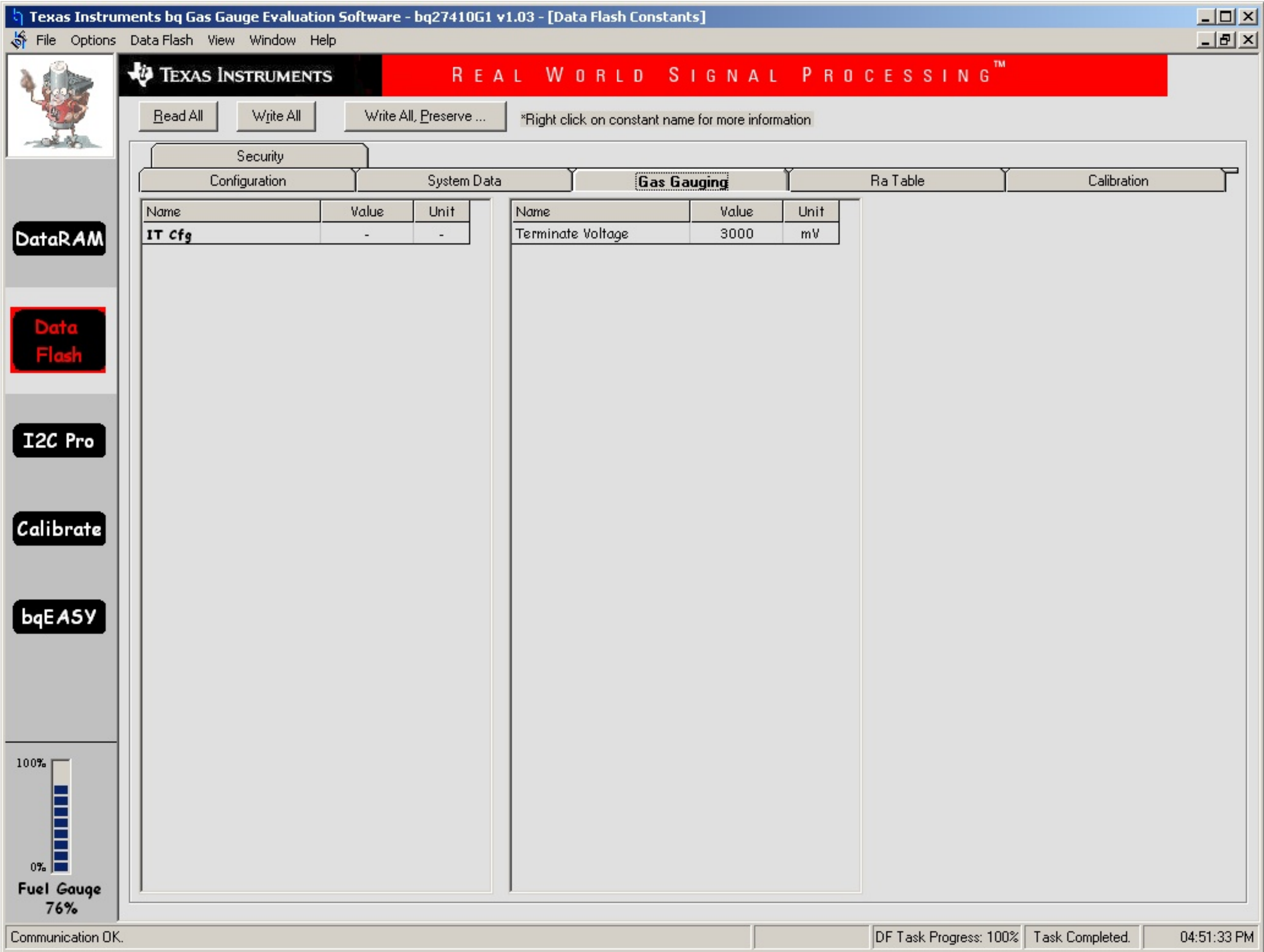

Figure 4. Gas Gauging Screen

2.4 Ra Table

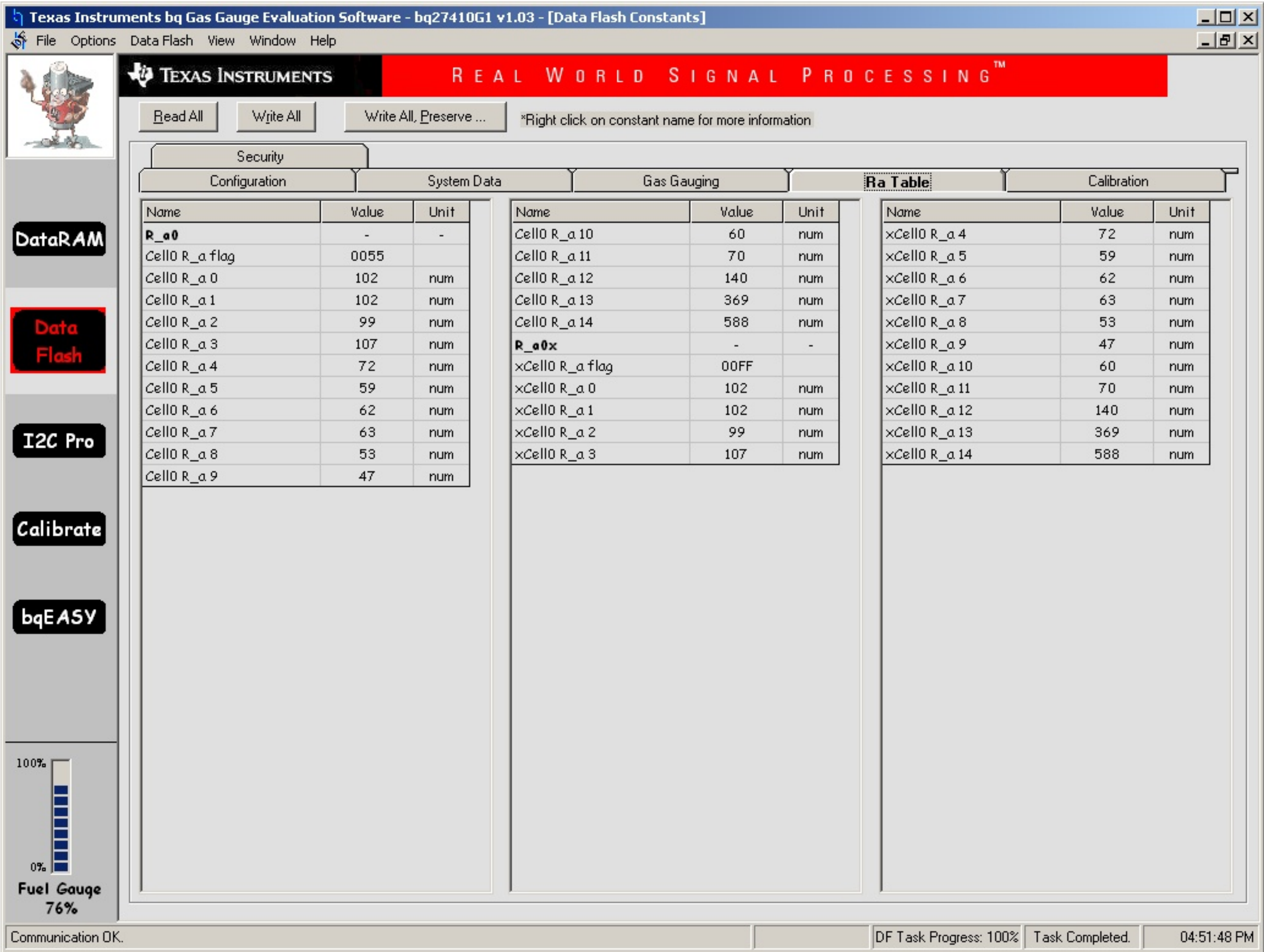

Figure 5. Default Ra Table Screen

This data is automatically updated during device operation. No user changes are necessary. Profiles have the format *Cell0 R_a* M where M is the number indicating the corresponding grid point over the SOC curve.

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

R_a0 or **R_a0x**

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

Cell0 R_a flag and xCell0 R_a flag

Each flag has two bytes:

1. The LSB (least-significant byte) indicates whether the table is currently enabled or disabled. It has the following options:

   (a) 0x00: means the table has had a resistance update in the past; however, it is not the currently

enabled table for the cell. (The alternate table for the cell must be enabled at this time.)
   (b) 0xff: This means that the values in this table are default values. These table resistance values have never been updated, and this table is not the currently enabled table for the cell. (The alternate table for the indicated cell must be enabled at this time.)
   (c) 0x55: This means that this table is enabled for the indicated cell. (The alternate table must be disabled at this time.)
2. The MSB (Most-significant byte) indicates the status of the data in this particular table. The possible values for this byte are:
   (a) 0x00: The data associated with this flag has had a resistance update.
   (b) 0x05: The resistance data associated with this flag has been updated and the pack is no longer discharging.
   (c) 0x55: The resistance data associated with this flag has been updated and the pack is still discharging.

   This data is used by the bq27410 to determine which tables need updating and which tables are being used for the Impedance Track™ algorithm.

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

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

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

For *Cell0 R_aM* where:

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

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

Normal Setting: These resistance profiles are used by the bq27410 for the Impedance Track™ algorithm. This resistance profile description is for information purposes only. It is not intended to give a detailed functional description for the bq27410 resistance algorithms. It is important to note that this data is in mΩ units and is normalized to 25°C. The following are useful observations to note with this data throughout the application development cycle:

1. Watch for negative values in the **Ra Table** class. Negative numbers in profiles do not belong in this class.
2. Watch for smooth consistent transitions from one profile grid point value to the next throughout each profile. As the bq27410 does resistance profile updates, these values are roughly consistent from one learned update to another without huge jumps in consecutive grid points.

2.5 Calibration

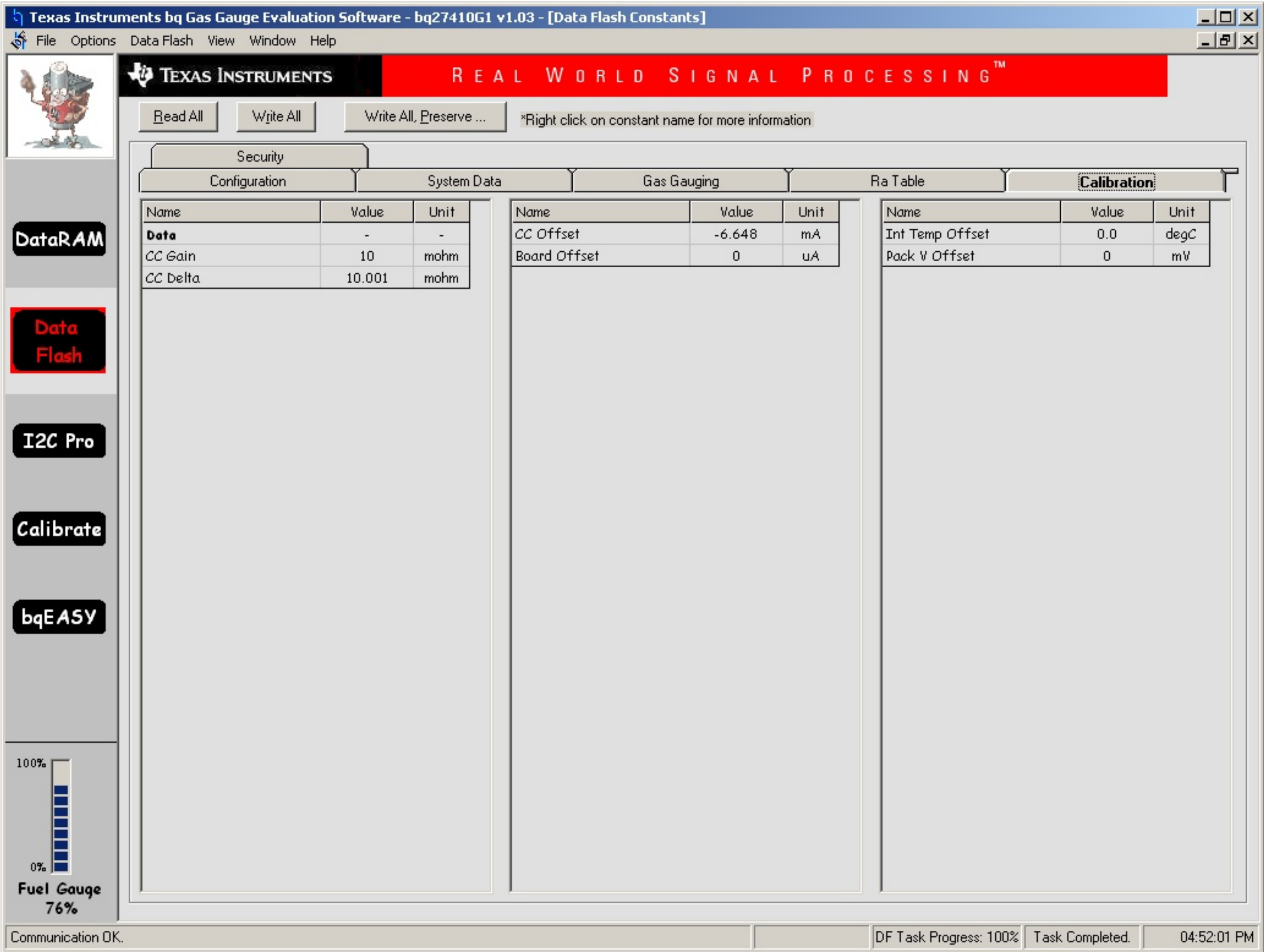

Figure 6. Calibration Screen

2.5.1 Data

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

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

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

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

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

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

1. The first method is to calibrate *CC Offset* by the putting the bq27410 in Calibration mode and initiating the *CC Offset* function as part of the entire bq27410 calibration suite. See the application report *Going to Production With the bq274xx* (SLUA595) for more information on the Calibration mode. This is a short calibration that is not as accurate as the second method, *Board Offset*. Its primary purpose is to calibrate *CC Offset* enough so that it does not affect any other Coulomb Counter calibrations. This is only intended as a temporary calibration because the automatic calibration, *Board Offset*, is done the first time the I2C Data and Clock is low for more than 20 seconds, which is a much more accurate calibration.
2. During normal Gas Gauge Operation when the I2C clock and data lines are low for more than 5 seconds and ***Average Current*** is less than *Sleep Current* in mA, then an automatic *CC Offset* calibration is performed. This takes approximately 16 seconds and is much more accurate than the method in Calibration mode.
   Normal Setting: *CC Offset* never needs to be modified directly by the user. It is modified by the current calibration function from Calibration mode or by Automatic Calibration. See the application report *Going to Production With the bq274xx* (SLUA595) for more information on calibration.

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

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

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

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

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

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

2.6 Security

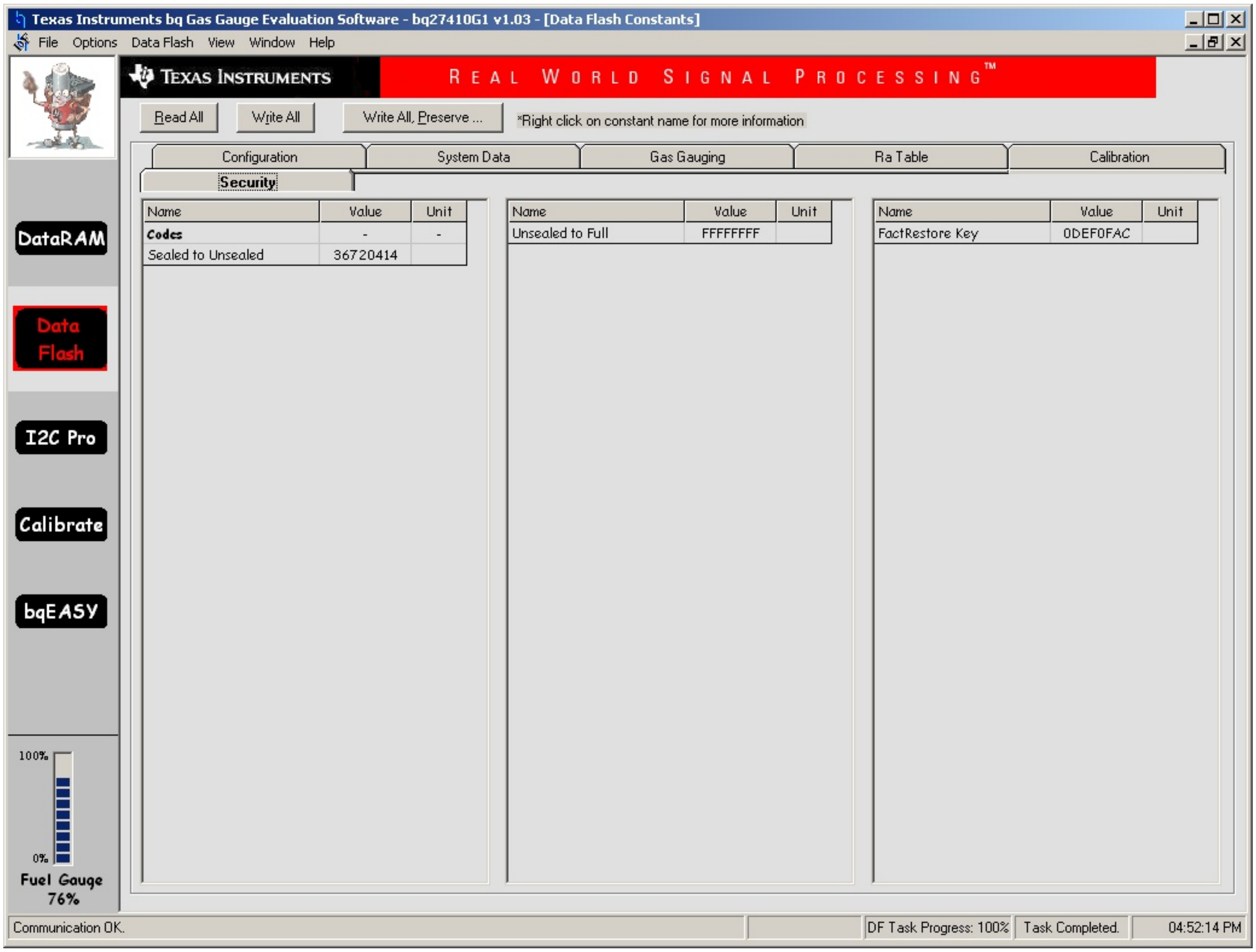

Figure 7. Security Screen

2.6.1 Codes

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

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

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

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

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

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

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