Quick Start Guide for bq2750x Family Gas Gauge

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ABSTRACT

This application report provides you a design process overview, procedures to use the evaluation module and software, and helpful troubleshooting techniques.

Contents

List of Figures

List of Tables

1 Introduction

The Texas Instruments bq27500/01 system-side Li-Ion battery fuel gauge is a microcontroller peripheral that provides fuel gauging for single-cell Li-Ion battery packs. The device requires little system microcontroller firmware development. The bq27500/01 resides on the system main board, and manages an embedded battery (non-removable) or a removable battery pack.

The bq2750x uses a patented Impedance algorithm for fuel gauging, and provides information such as remaining battery capacity (mAh), state-of-charge (%), run-time to empty (min.), battery voltage (mV), and temperature (°C).

Battery fuel gauging with the bq27500 requires only PACK+ (P+), PACK– (P–), and Thermistor (T) connections to a removable battery pack or embedded battery. The bq27501 works with identification resistors in battery packs to gauge batteries of different fundamental chemistries and/or significantly different rated capacities.

1.1 Related Documentation

TI recommends that you familiarize yourself with these documents before working with the Impedance Track™ gas gauge devices.

- *Quick Start Guide for bq27500/1EVM Kit* (SLUU298)
- *Single-Cell Impedance Track™ Gas Gauge Introduction* (SLUA422)
- *Key Design Considerations for the bq27500 and bq27501* (SLUA439)
- *bq2750xEVM System Side Single-Cell Impedance Track™ Technology Evaluation Module* (SLUU287)
- *Host-side gas-gauge-system design considerations for single-cell handheld apps* (SLYT285)
- *Configuring the bq27500 Data Flash* (SLUA432)
- *bq2750x Datasheet* (SLUS785)
- *Using bqTester Single Site Software* (SLUA352)
- *bq27500 Theory and implementation of Impedance Track battery fuel-gauging algorithm* (SLUA450)
- *Data Flash Programming and Calibrating the bq27500 Gas Gauge* (SLUA440)
- *Going to Production with the bq2750x* (SLUA449)

1.2 Terminology

Acronym	Description	Acronym	Description
DF	Data Flash	IT	Impedance Track™
GG	Gas gauge	MAC	Manufacturer Access Command
SENC	Firmware file (encrypted)	DFI	Data Flash Image file (binary) with modified data
bqEASY	bq2750x programming wizard	ENCR	Data Flash file specific to a fresh TI fuel gauge
CHEM	Chemical model files for different LI-ion batteries	EZY	bqEASY project file

1.3 Document Overview

This document covers procedures for evaluation module setup and working with bq Evaluation Software. Additionally, the document highlights multiple approaches to troubleshooting the software connection, graphical user interface navigation, and key elements for the different configuration windows.

Example step-by-step procedures are described in Section 6 for:

- Choosing the correct chemistry
- Resetting the pack
- Logging data during testing
- Sealing and unsealing a pack

2 Getting Started With the bq2750x Evaluation Module

To get started with the bq2750x evaluation module (EVM), you will want to:

1. Gather all needed components
2. Acquaint yourself with the EVM board, pin descriptions, and basic EVM configuration
3. Download the bq Evaluation Software
4. Install the bq Evaluation Software
5. Install two USB drivers to communicate with the EV2300
6. Make the circuit module connections
7. Start the bq Evaluation Software
8. Become familiar with key Li-Ion battery fuel gauge software procedures

2.1 Necessary Components

To perform the bq2750x procedures described in this report, you need:

- bq2750x EVM board (HPA291) - check bq27500 Errata (SLUZ015) and bq27500 EVM (HPA291 Rev. A) Errata (SLUZ016)
- EV2300 USB PC Interface Board
- 4-colored wire set connector (I^2C communication from EVM **J4** to EV2300)
- USB cable (A-B type)
- NTC103AT Thermistor
- bq2750x EVM CD or latest documentation and software from the Texas Instruments Internet site (see Figure 3)
- PC host running the Windows™ 98SE, Windows XP, or Windows 2000 operating system and an available USB port
- Power supply or single-cell in series Li-ion battery (Li-ion battery preferred)
- Electronic load or electronic system (range 3 V to 4.2 V)

- Single-cell Li-ion battery charger (optional)

2.2 bq2750x EVM Board and Pin Description

Use this section to become familiar with the bq2750xEVM module, pin/jumper descriptions, and the basic EVM configuration.

Figure 1. bq2750x Evaluation Module

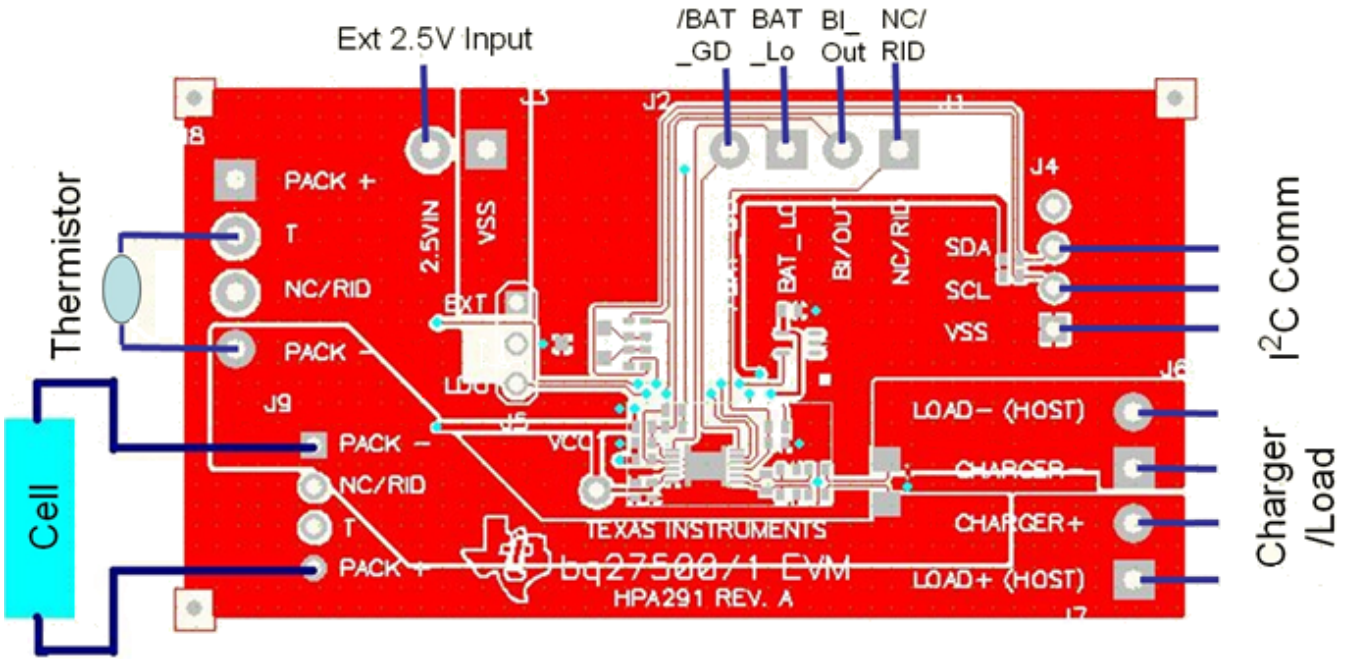
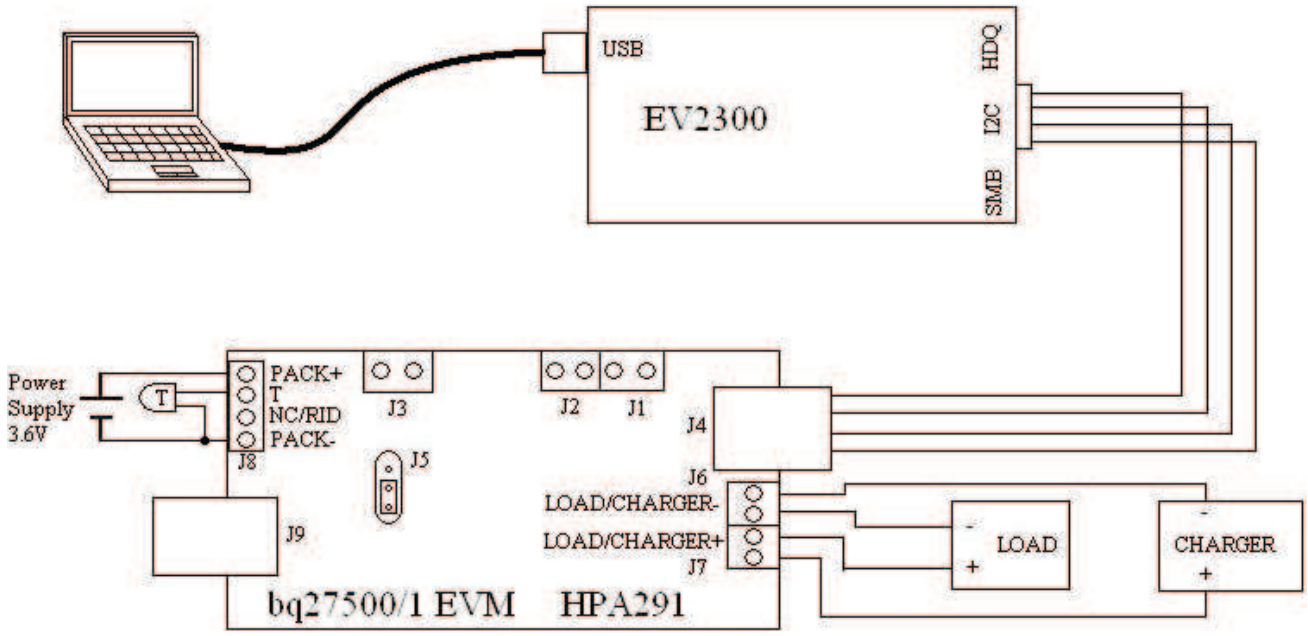


Table 1. bq2750x Pin/Jumper Descriptions

PIN NAME / Jumper	DESCRIPTION
PACK+ (**J8**)	Pack positive terminal
PACK– (**J8**)	Pack negative terminal
T	Pack thermistor input
NC/RID	Pack resistor ID input (only for bq27501)
SDA (**J4**)	I^2C communication data line
SCL (**J4**)	I^2C communication clock line
VSS (**J4**)	Signal return for communication line; shared with charger and ground
CHARGER+/LOAD+ (**J7**)	Power for load or charger connection
CHARGER–/LOAD– (**J6**)	Ground for load or charger connection (system VSS)
BAT_LOW	Access to push-pull output that signals low state-of-charge
$\overline{\text{BAT\_GD}}$	Access to open drain output indicating pack is ready to connect to the EVM
BI_OUT	Battery-Insertion detection input. Power pin for pack thermistor network.

Figure 2. Basic bq2750xEVM Configuration



2.3 Download the bq2750x Evaluation Software

This software is included with the EVM on a CD or can be downloaded from the evaluation module product folder (use the Part Number *bq27500EVM* as the search keyword) from www.TI.com. Figure 3 displays the portion of the Internet page with the EVM software link named: *bq27500 EVSW installation File*.

Figure 3. bq27500EVM Product Folder

System-Side Impedance Track(TM) Fuel Gauge Evaluation Module
BQ27500EVM, Status: ACTIVE

Texas Instruments

Description	Support Software	Technical Documents
Features	Available Updates	Order Options
What's Included	Compatibility Issues	Related Products

Other text about bq27500EVM

What's Included

- SLUU287,bq2750xEVM System Side Single-Cell Impedance Track™

Support Software

bq27500 EVSW Installation File (Rev. A) (sluc082a.zip, 5482 KB)
18 Dec 2007 zip

2.4 Install bq2750x Evaluation Software

Note: Before you install the bq2750xEVM software, make sure the EV2300 communication box is disconnected from the PC Host.

Using the CD included with the bq2750xEVM or the zip file you downloaded from the TI Internet site:

1. {Download only) Unzip the SLUC082.zip file to a temporary directory.
2. In your temporary directory (or the EVM CD), browse for the preliminary software installation file with the generic name: bqEV-EASY-HH SWSetup00.**XX**.**yy**_bq27500v1.00_bqEasyv**z.zz**.exe, where **XX**=major preliminary number, **yy**=minor preliminary number, and **z.zz**= version number.
3. Double-click and follow the standard installation instructions; accept license agreement, choose folder, and display Readme file.

2.5 Install USB Drivers for EV2300 Communication

Note: Before installing the USB drivers, use the supplied USB cable to connect the EV2300 to the computer that has the bq2750x evaluation software installed.

Installing the driver for the EV2300 communication box requires you to install two USB drivers for proper operation. Complete instructions for installing the USB drivers can be found in the *EV2300 Driver to USB Port Association* section of the *Using bqTester Single Site Software* document (SLUA352).

Briefly, the required steps are:

1. When the operating system prompts you with a **Found New Hardware Wizard**, Choose the *No, not at this time* option.
2. On the next screen, select the *Install from a list or specific location* option and use the **Browse** button to navigate to the PC Host folder (XP system): C:\Windows\TI\USB1
3. Respond **Continue Anyway** to the warning that drivers are not certified by Microsoft.
   You have successfully installed the *TI USB Firmware Update*r.
4. Once again, the operating system prompts you with a **Found New Hardware Wizard**, Choose the *No, not at this time* option.
5. On the next screen, select the *Install from a list or specific location* option and use the **Browse** button to navigate to the PC Host folder (XP system): C:\Windows\TI\USB2
6. Respond **Continue Anyway** to the warning that drivers are not certified by Microsoft.
   You have successfully installed the *TI USB bq2750x Driver*.

2.6 EVM Connection Setup

Refer to Figure 2 when performing the EVM setup:

1. Connect one side of the 4-wire-set connector to the EV2300's I2C port (black wire aligned with GND pin) and the other side to the board's **J4** connector (black wire aligned with the VSS pin).
2. Ensure that jumper in **J5** of board is connected at the bottom position as shown Figure 2.
3. Ensure that NTC103AT thermistor is connected to the T and PACK– terminals of the **J8** block of the board.
4. Ensuring proper polarity, connect the 3-V to 4.2-V power supply or single-cell Li-ion battery between the PACK+ and PACK– terminals (**J8**) of the board.
5. To see current measurements, apply a load to **J7** and **J6** board connectors.

Note: **J6** is for host or charger *ground* and **J7** is for host or charger *power*.

6. To properly configure the fuel gauge IC for a given application, proceed to the **bqEASY** area of the evaluation software (Section 4.5) and the bq2750x EVM User's Guide (SLUU287).

For detailed instructions on operating the fuel gauge system, see the *bq2750x Datasheet* (SLUS785) and the *bq2750xEVM System Side Single-Cell Impedance Track™ Technology Evaluation Module* User's Guide (SLUU287).

2.7 Starting the bq2750EVM Software

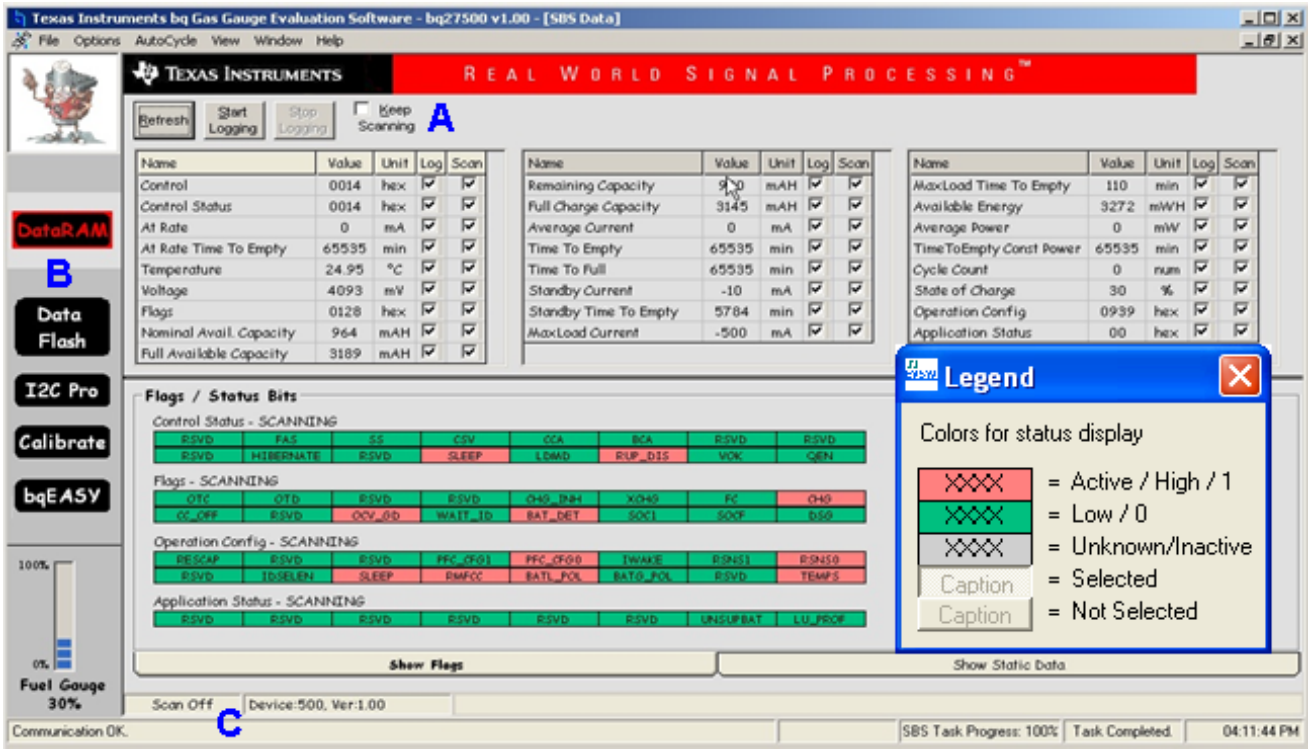
Beginning at the Windows Start menu, start the bq27500x evaluation software by selecting the application from the cascading menus: **start** → **Programs** → **Texas Instruments** → **bq Evaluation Software**. To become familiar with the bq2750x evaluation module (EVM) you can simulate a battery cell with resistors and a power supply. You can vary the voltage across these resistors to simulate different states of charge. This configuration is shown in Figure 2 and described in the *bq2750xEVM System Side Single-Cell Impedance Track ™ Technology Evaluation Module* application note (SLUU287).

2.8 bqEVSW Software Sections

The bq2750x evaluation software uses five major sections (Figure 4):

- **DataRAM**—standard I^2C information you can read from the pack when it is sealed and important IC status registers.
- **Data Flash**—shows all the parameters you can change when designing your system. Because this multiple-dialog window contains so much information, you can right-click the mouse to display a Help pop-up window that describes each value name.
- **I2C Pro**—reads and writes data from any gas gauge, plus can also load a new firmware file.
- **Calibrate**—performs temperature, coulomb counter (CC) input, board current, and pack current calibration tests.
- **bqEASY**—software wizard that acts like a workflow to simplify the configuring, chemistry selection, and performing learning cycles needed to produce the final "golden image" file.

Figure 4. bq2750x EVM Software Organization



A Check box to **Keep Scanning** while you make changes.

B Switches you quickly between major software areas.

C Area provides information on Communication status, device type, and firmware version number.

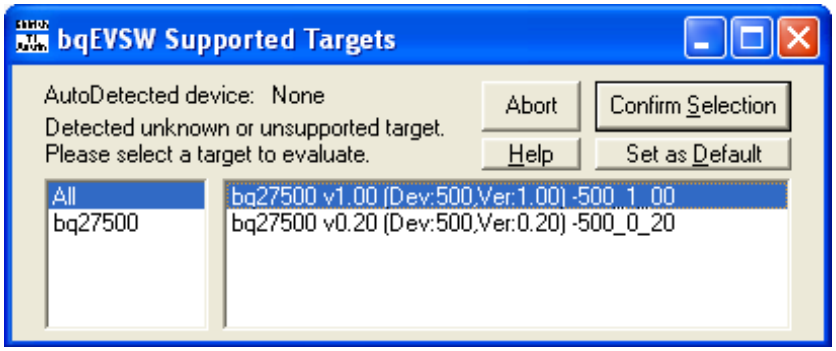
3 Software Communication and Trouble Shooting

When you start the bq2750x EVM software (**bqEVSW**), it should automatically recognize the firmware and hardware version. If there is a EV2300 USB PC Interface board communication problem, the message in Figure 5 displays.

Figure 5. bqEVSW Unable to Communicate With EV2300

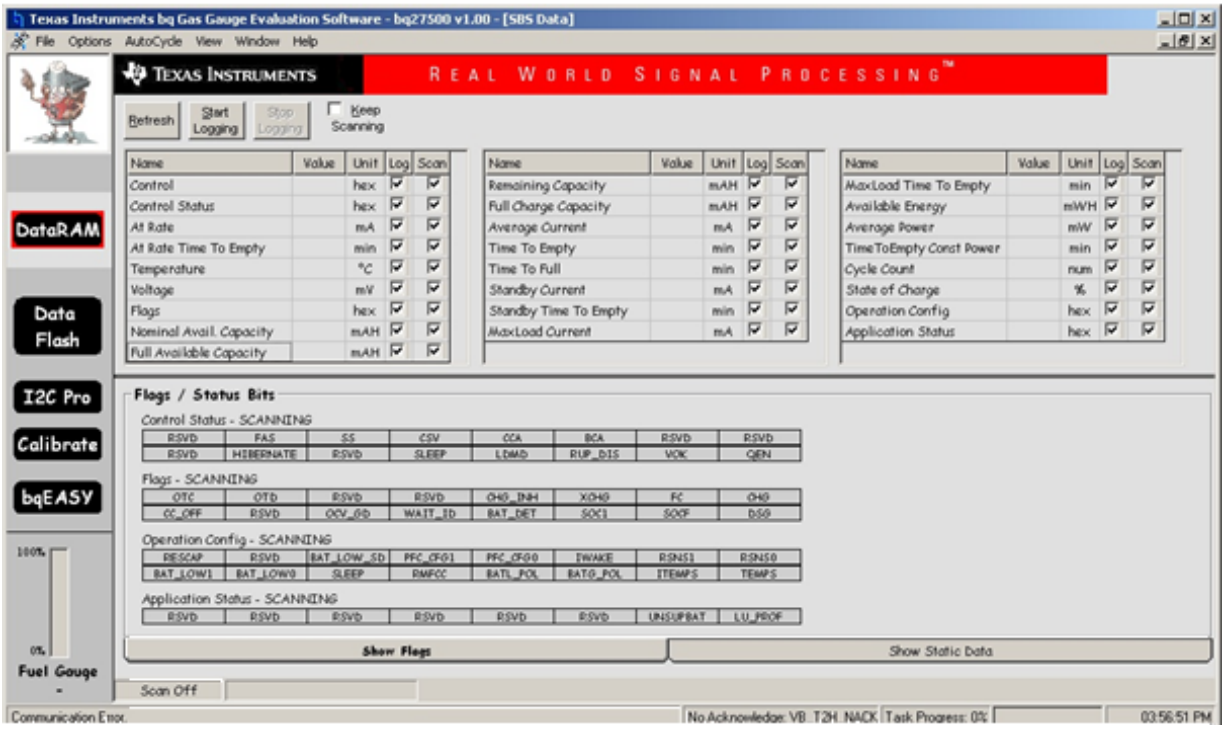
Click **OK** and the software requests you to choose a device in use. If you get to this point, you are not going to have proper communication with the EVM.

Figure 6. Select bq2750x device



If you choose one of the devices and firmware revisions, you eventually can display the DataRAM window; however key flags and status bits are grayed-out (Figure 7). The bq2750x EVM software uses color codes to describe the current status for the DataRam Flags and Status bits. Please familiarize yourself with the legend in Figure 4 and Figure 10.

Figure 7. DataRAM Window displaying No EV2300 Communication



3.1 Troubleshooting USB Communication Issues

If you are having EVM communication issues, try these steps:

- Do you have the EV2300 USB cable connected (Figure 8) as shown in the Basic bq2750xEVM Configuration?
- Have you properly installed the required *TI USB Firmware Updater* and the *TI USB bq2750x* drivers, as discussed in Install USB Drivers for EV2300 Communication?
- Did you *kick start* the EVM by connecting power momentarily to PACK+ and PACK– to simulate a charger insertion?
- Are the I^2C lines connected to the EVM (Figure 2)?
- Is there another instance of the software already running? Press Cntl+Alt+Delete keys to display the Task Manager and look for another instance of the bq2750x EVM software (**bqEVSW**) running.
- Try restarting your computer if you do not see the *TI USB bq2750x driver* displayed in the **System Properties** → **Hardware dialog tab** → **Device Manager** window.

Figure 8. bqEVSW software shows no USB board if EV2300 is not connected

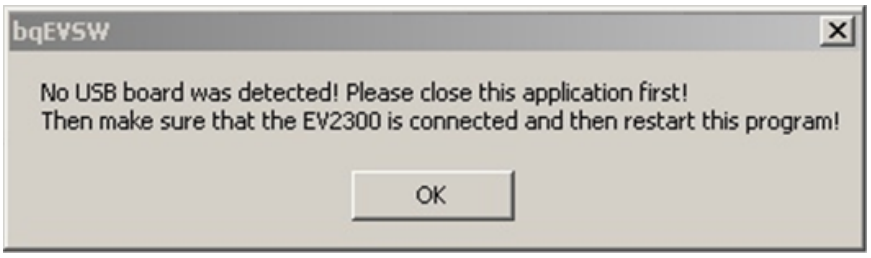
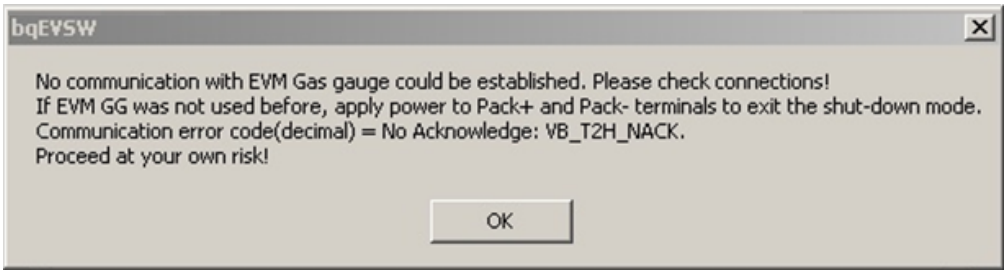


Figure 9. bqEVSW Complains if no EVM or EVM not powered up



4 bq2750x Evaluation Software Sections

The DataRAM screen displays as the default window, providing you access to the context-sensitive help and the five windows used to organize the software GUI controls:

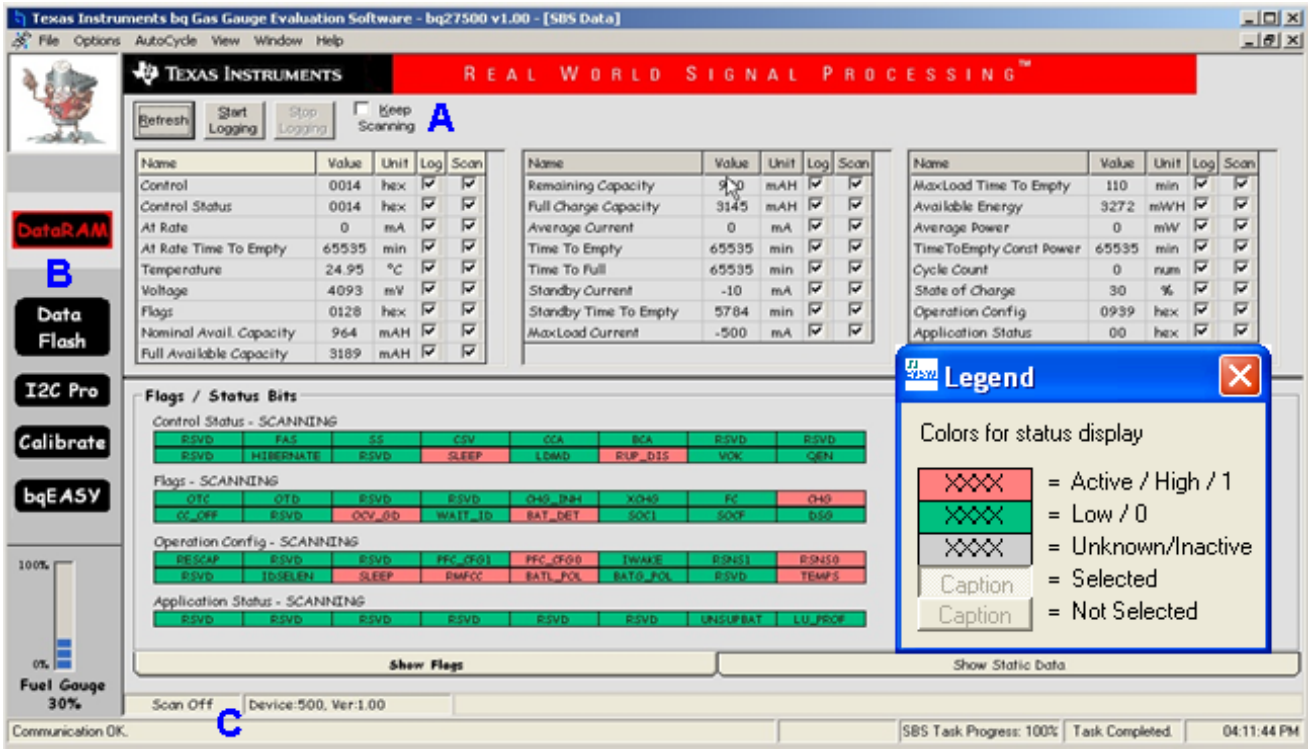
- DataRAM
- Data Flash, with context-sensitive (right-mouse) help
- I2C Pro
- Calibrate
- bqEASY Wizard

4.1 DataRam window

If everything is working OK, a DataRAM window similar to Figure 10 displays with green/orange indicators in the status registers. Also, *Communication OK* will be in the lower left-hand corner. Click on the *Keep Scanning* box at the top of the window. The software will keep updating these values throughout your testing process.

The DataRAM window shows the standard I^2C information you can read from the pack when it is sealed, as well as showing important status registers on the IC which can only be seen when the pack is unsealed or in full access mode (no FAS or SS bit set in Control Status register). By default, the IC is configured in full access mode.

Figure 10. DataRAM Displaying Appropriate Communication with EV2300



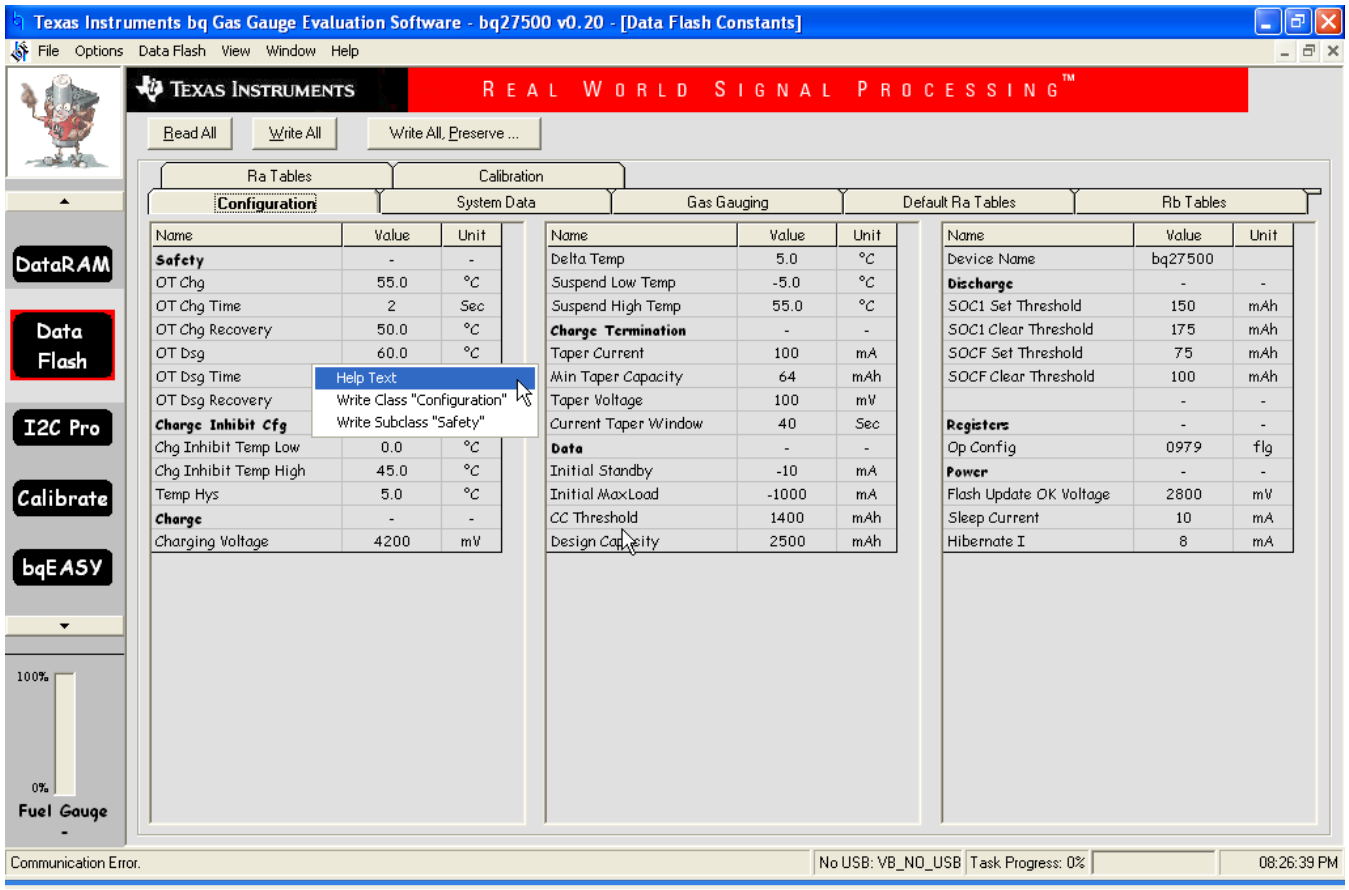
You can issue Manufacture Access commands (MAC) from this window by clicking in the **Control** field under the *Value* column (see Issuing MACs procedures). For example, this issue arises when writing the Unseal or Full Access commands. Examples of how to complete these processes is included in Seal and Unseal Process.

4.2 Data Flash Window

The Data Flash window (Figure 11) shows all the parameters you can change when designing your system. To begin, you can load the default values stored which shows the single cell pack configuration.

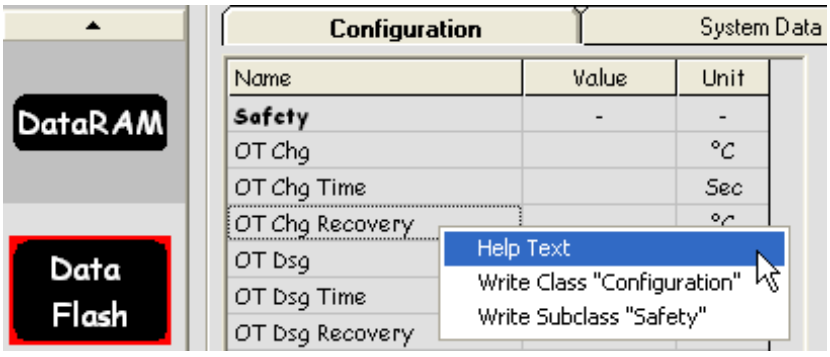
For detailed information on configuring the Data Flash for your particular design, see *Configuring the bq27500 Data Flash* (SLUA432)—a comprehensive resource for all Data Flash parameters.

Figure 11. Data Flash Window Displaying Default Parameters



Remembering all the nuances of the Data Flash parameters is not practical. However, all of the Data Flash definitions are listed in the *bq2750x Technical Reference Manual*. Additionally, you can right-click on any Data Flash parameter and choose *Help Text* (Figure 12), which displays an appropriate definition.

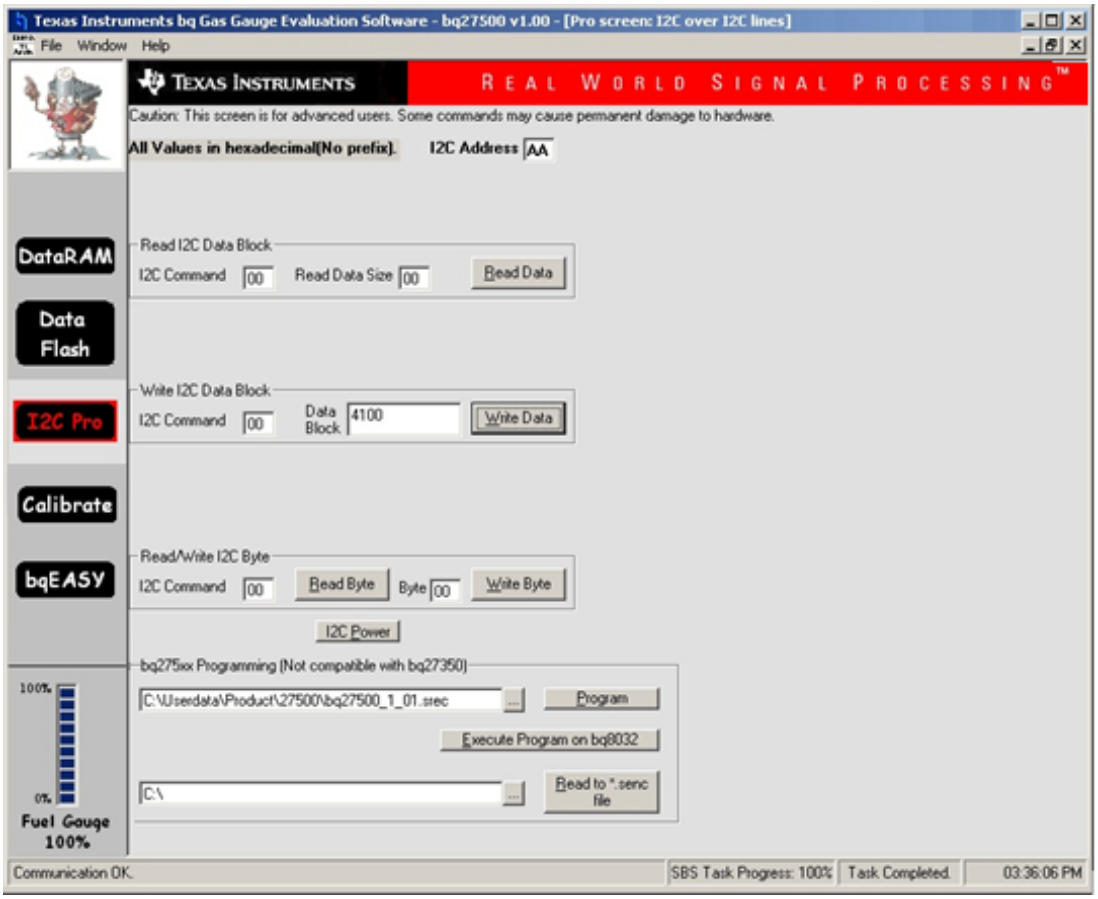
Figure 12. Data Flash Definitions Display with Right-click and Choosing Help Text



4.3 I2C Pro Window

The I2C Pro window helps you communicate with bq2750x IC. It is here where you can read and write byte, work, and block information. Also, you can upload a new **.SENC** file from this window by following the steps in the *Data Flash Programming and Calibrating the bq27500 Gas Gauge* (SLUA440).

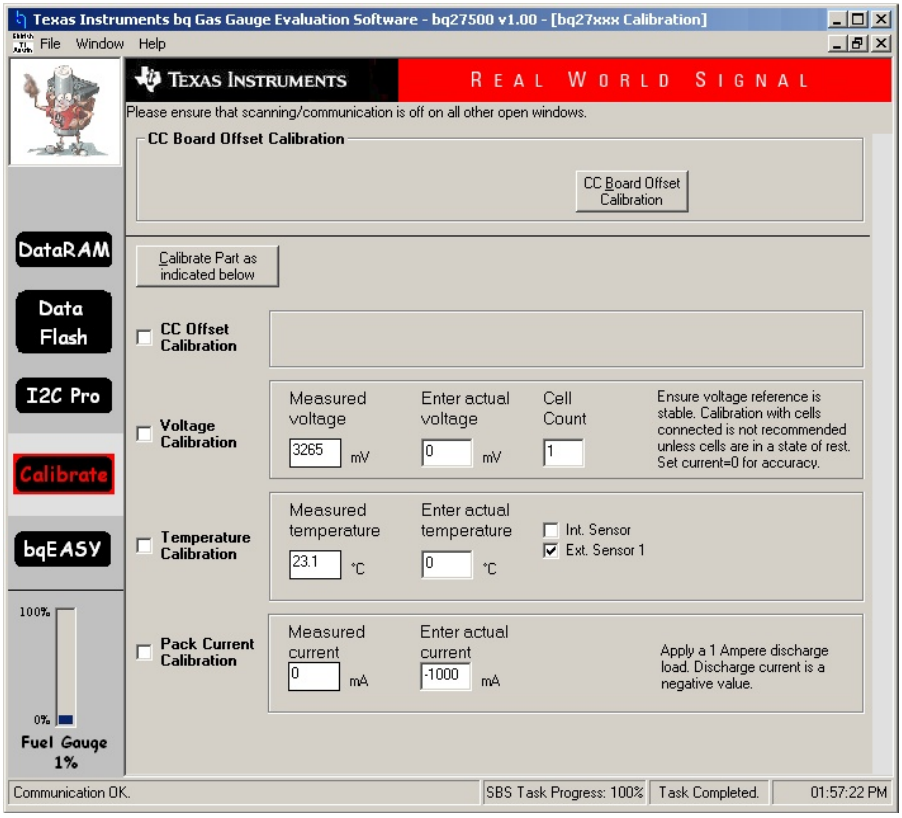
Figure 13. I2C Pro Window



4.4 Calibrate Window

The Calibrate window (Figure 14) helps you calibrate gas gauge voltage, current, temperature, and offsets. See similar procedures in the *Data Flash Programming and Calibrating the bq27500 Gas Gauge* (SLUA440).

Figure 14. Calibrate Window



4.5 bqEASY Wizard

The bqEASY window (Figure 15) is a new feature in the bq Evaluation Software, used to program the Data Flash parameters, choose the proper battery chemistry, and perform the two cycle tests to create your Golden Image. If you are new to the Impedance Track™ technology, this is a great way to have a structured workflow to follow. (See details in Production Flow section.)

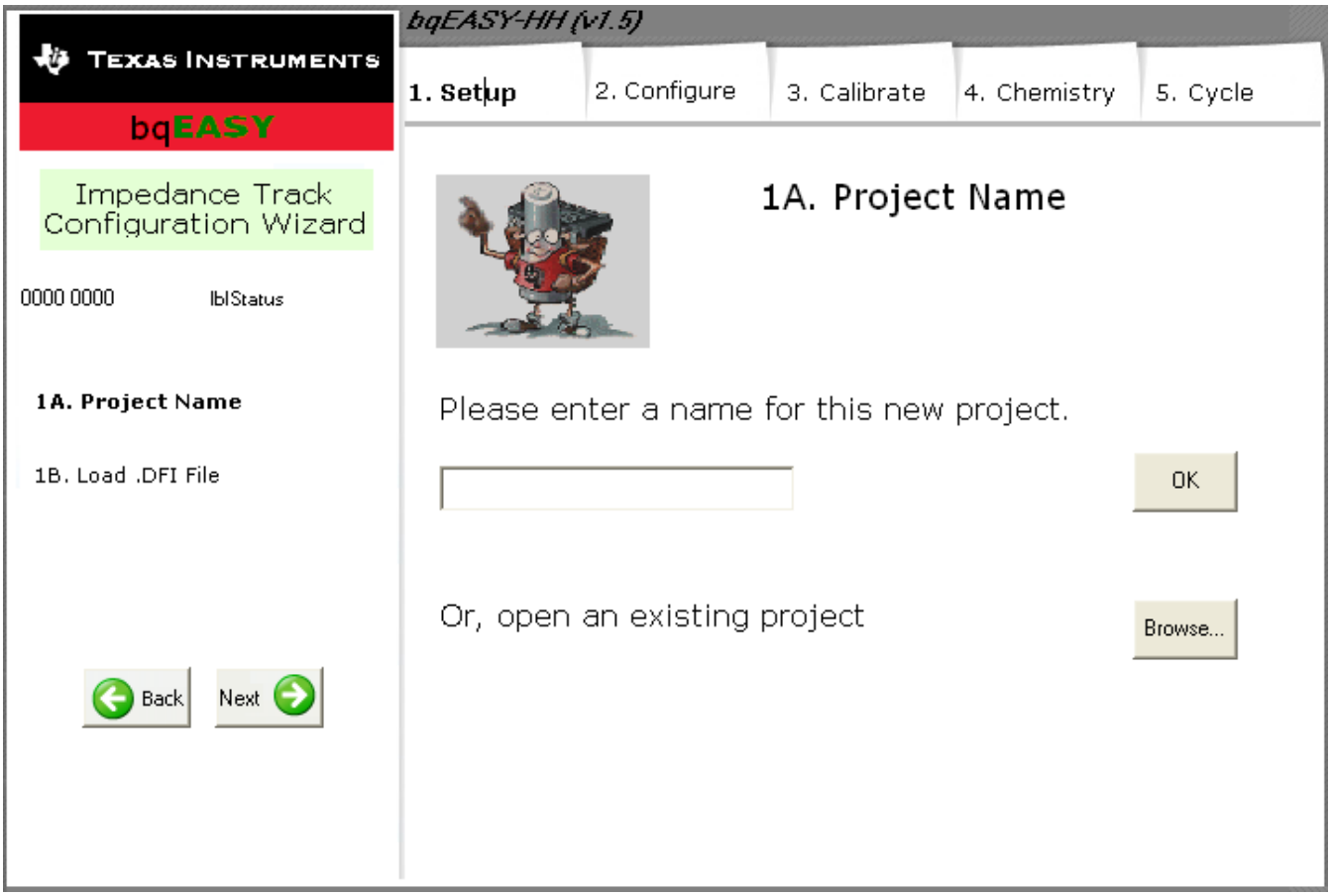
The bqEASY Wizard uses data entry dialogs to gather information and perform production tasks:

1. **Setup**—Impedance Track Configuration Wizard Splash screen
2. **Configure**—choose Data Flash parameters
   a. Cell Characteristics
   b. Charge Parameters
   c. Discharge Parameters
   d. Reserve Capacity
   e. Load Characteristics
   f. Application Configuration
   g. Remaining Capacity Method
   h. Miscellaneous Information
3. **Calibrate**
   a. CC Offset
   b. Voltage

c. Temperature
d. Pack Current
e. Board Offset
f. Review / Read DFI file

4. **Chemistry**
   a. Use Default Chemistry
   b. Select Chemistry Manually
   c. Do Chemistry Select Cycling
5. **Cycle**
   a. Learning Cycle
   b. Update Golden Pack

Figure 15. bqEASY Wizard



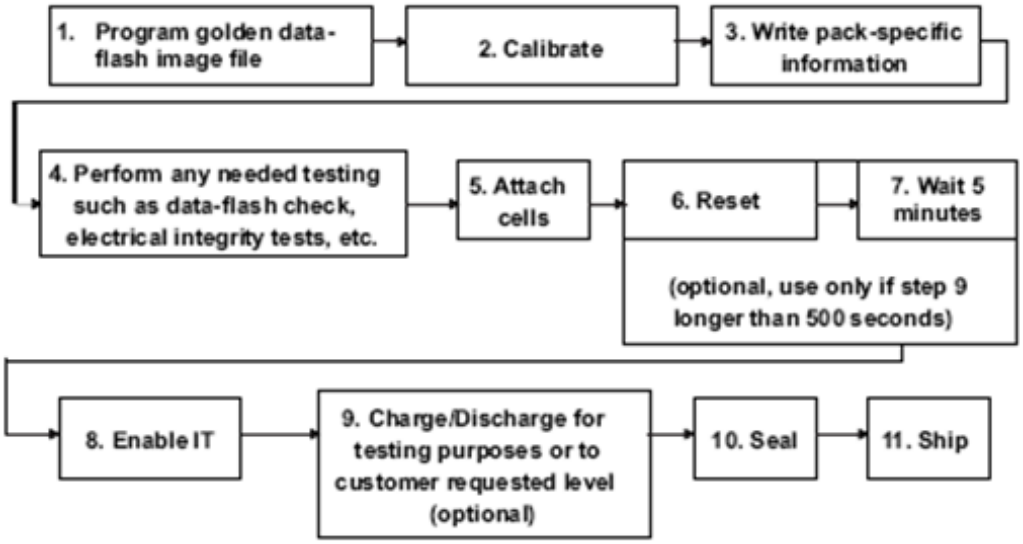
5 Creating Your Golden Image

One of the major benefits of using the Impedance Track technology, aside from super accurate gas gauging, is a simplified manufacturing process. No charge or discharge cycles are required after assembling the pack, which can take many hours.

5.1 Production Flow

Figure 16 is a procedure diagram showing the normal production flow of the bq2750x chipset. A detailed description of these states can be found in the *Going to Production with the bq27500* application report (SLUA449).

Figure 16. Production Flow Diagram



These are different steps in design, preproduction, and production.

5.2 Design and Evaluation

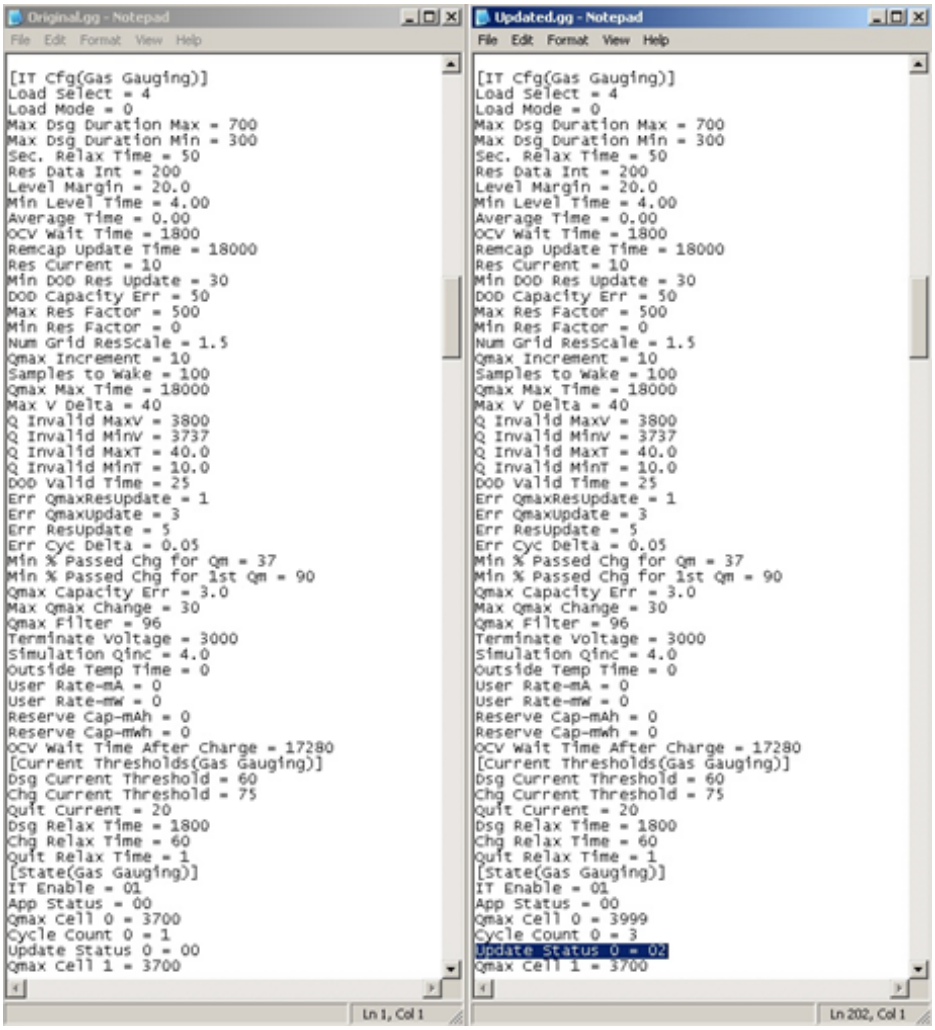
1. Install the bqEVSW software and EV2300 communication USB drivers.
2. Connect resistors and power supply to simulate battery pack.
3. "Kick-start" the EVM (connect power momentarily to the PACK+ and PACK– to simulate charger insertion).
4. Start bqEVSW software
5. Explore the different features of the software.
6. Load the correct .chem file corresponding to the chemistry of your battery cells using the bqEASY wizard (see Choosing the Correct Chemistry).
7. Program the necessary Data Flash constants specific to your design.
8. Connect a real battery cell to the EVM
9. Fully charge the cells and let reset for 2 hours.
10. Start Data Logging – both DataRAM parameters and the .GG gas gauge files.
11. Repeat these steps as often as necessary:
    - Enable Impedance Track Algorithm
    - Discharge Pack to termination voltage and let reset.
    - Repeat this process
12. Look for updated resistances and Update Status = 02 in the final .GG file.

    Once you have a properly cycled pack with updated values, we need to create a Golden image file that is programmed and incorporated into every pack coming off the production line.
13. Export the .GG file and make a few changes (disable IT and change cycle count to 0).
14. Reload the .DFI file to clear out Data Flash hidden values.
15. Import your changed .GG file.
16. Now you are ready to create the .DFI file used to program production packs.

5.3 The Gas Gauge File

The Gas Gauge (.GG) file stores all programmable Data Flash parameters as well as the updated cell resistance profile after doing the two cycle tests. Figure 17 displays a gas gauge file, showing its default values (specific to this chemistry) and it's updated values after the cycle tests.

Figure 17. Gas Gauge File (Default and Cycled Values)



(1) Update Status as changed from 0x00 to 0x02

(2) QMAX for the individual cells and pack has been updated

(3) Resistance table (Ra Table) updated for each of the cells.

6 Example Procedures

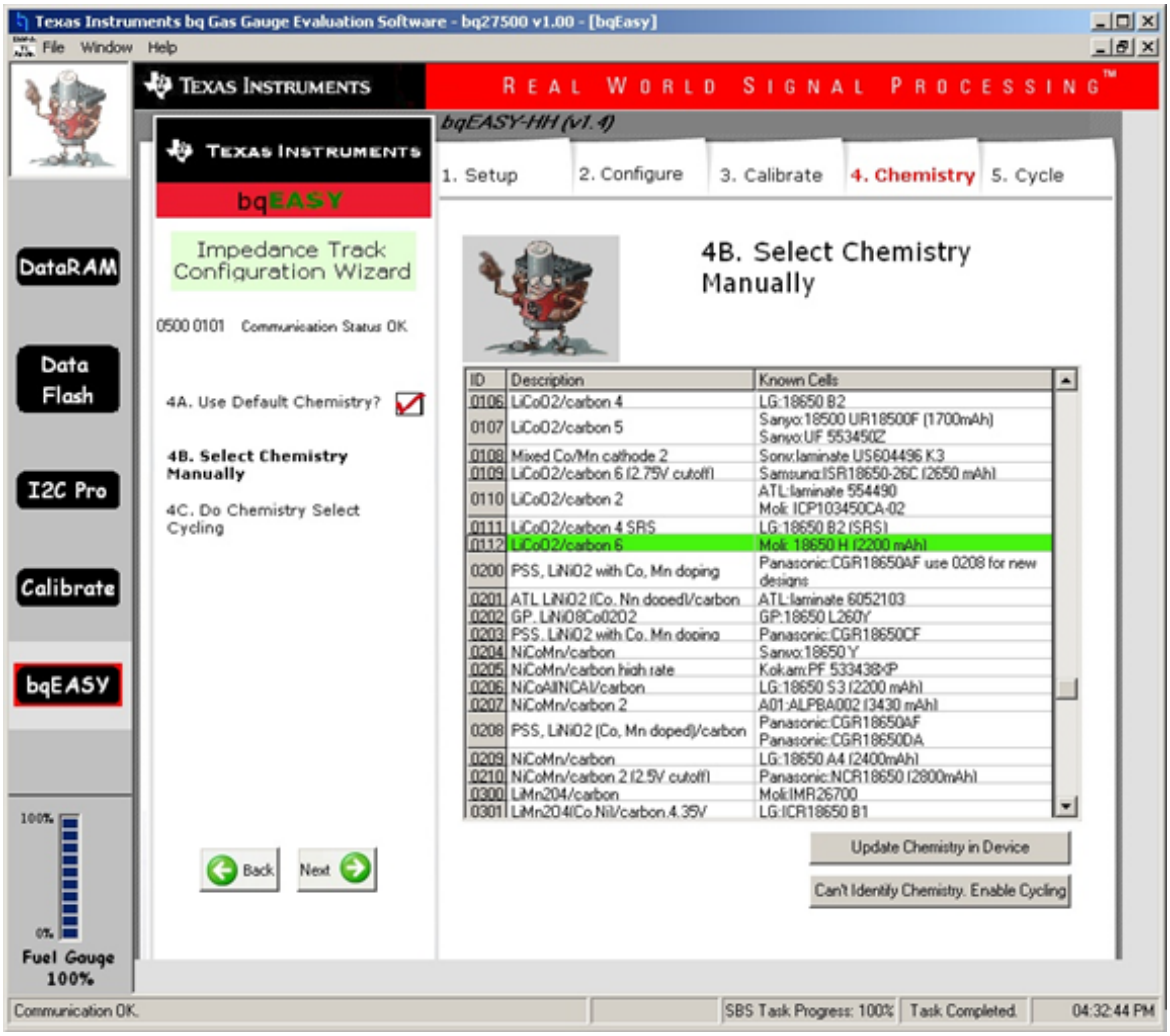
6.1 Choosing the Correct Chemistry

For the impedance track algorithm to work properly, the exact chemistry of the Lithium cells needs to be known and the correct .SENC file needs to be loaded.

The most updated chemistry files can be found installing the latest version of the bqEVSW software, which you found on the TI Internet site in the bq2750x Product Folder (Figure 3). The files are stored in the folder named: C:\Program FIles\Texas Instruments\bq Evaluation Software\Plugins\Chemistry The **Chem.ini** file describes the chemistry, manufacturer, and model numbers for the *.CHEM files in this folder.

You can use the bqEASY wizard (Figure 18) to display the chemistry information in an easy-to-use and organized manner. If you are using the bqEASY Wizard, it asks you to choose the correct chemistry from a list of manufacturers and model numbers. Alternatively, you can test for a compatible chemistry using a *4 point test*.

Figure 18. Chemistry Selection Table in bqEASY Wizard



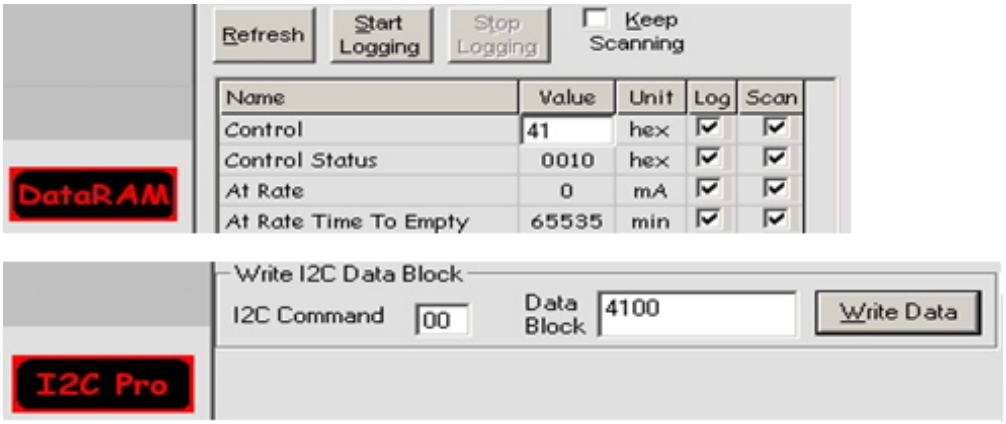
A unique chemical ID indicates a different battery chemistry being used.

6.2 Resetting the Pack

Vary the voltage of the power supply (careful not to exceed maximum voltages) and issue a **RESET** Manufacture Access Command (MAC) to the bq2750x. The I^2C double-word command is *0x00*, data *0x0041*.

There are two ways to do this (see Figure 19). The shortcut is to type *41* into the Manufacture Access **Value** of the DataRAM window. Alternatively, use the I2C Pro window to issue a reset command *00*, data *4100* from the **Write I2C Data Block** and click the **Write Data** button.

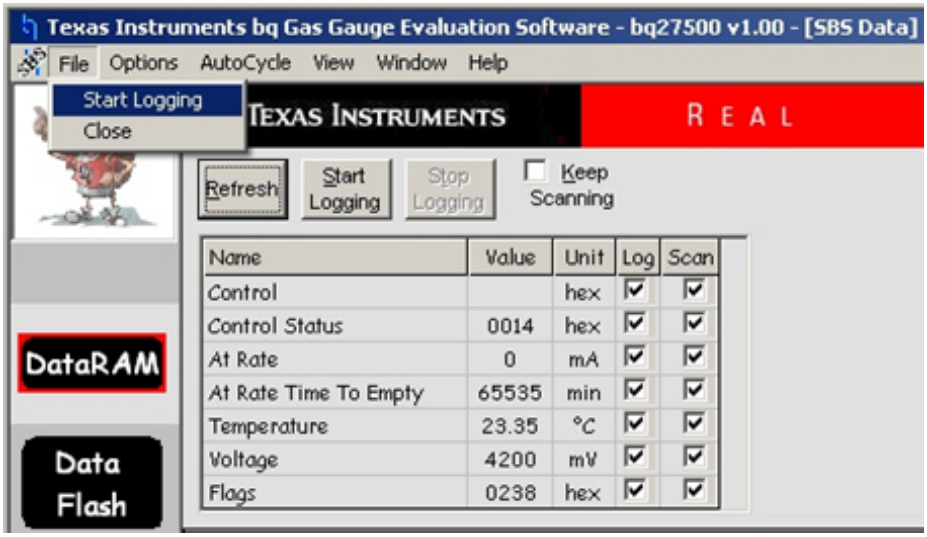
Figure 19. Sending MACs - DataRAM and I2C Pro Windows



6.3 Data Logging

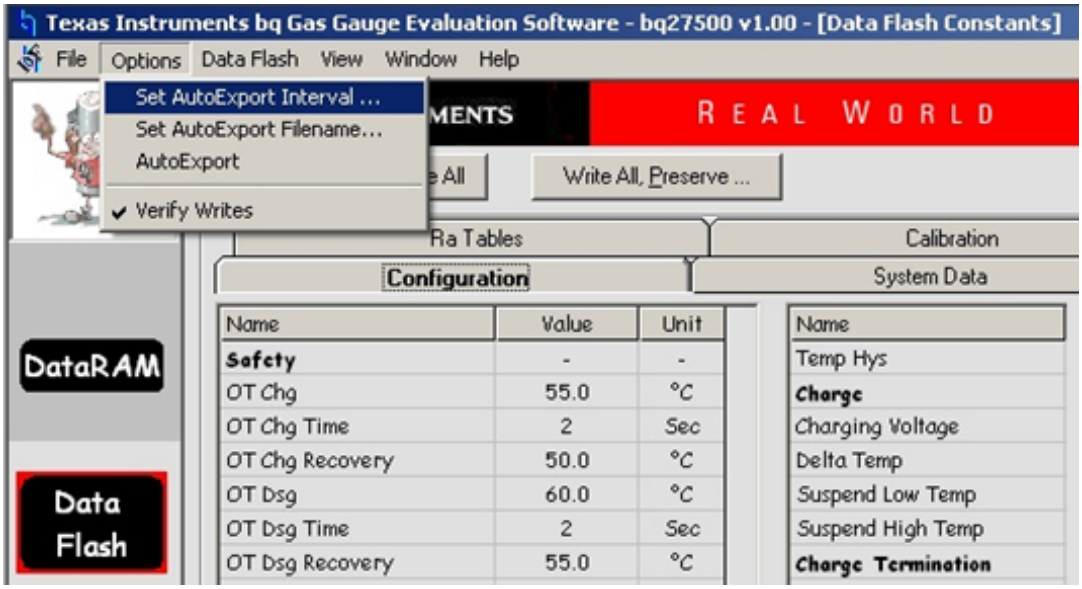
While you are running your charge and discharge tests you may want to log the DataRAM and gas gauge (.GG) flash data. This is done in two steps. The DataRAM data is logged by selecting the **File** → **Start Logging** menu command (Figure 20). The **Save As (Log File Name)** dialog asks what folder and what file name to use for the Log File.

Figure 20. DataRAM Data Logging Command



To save the iterations of the Gas Gauge (.GG) file, go to the **Data Flash** window and select the **Options** → **Set AutoExport Filename** command. A series of Gas Gauge files is created in the folder specified throughout the testing. You can adjust the save interval of AutoExport (every 15 minutes is usually acceptable) using the **Options** → **Set Export Interval** command. To start the logging, select the **Options** → **AutoExport** command (Figure 21) to begin saving the Gas Gauge files.

Figure 21. Gas Gauge Logging Setup and Start Commands



6.4 Seal and Unseal Process

Once you are finished with the production flow (see Figure 16) and have programmed the correct gas gauge (.gg) file for your "golden pack", you will want to seal the pack. If you do seal the pack, you can issue the Unseal command, followed by the Full Access command to make changes. However, if you removed power to IC, it returns to sealed mode and you would have to repeat this process again to unseal and subsequently move to full access mode. The only way to *reset* the IC to automatically come up in full access mode is to reload the .SENC file with defaults.

Note: Be careful when reloading the .SENC file as it can erase any Data Flash constants or resistance updates through cycling that you may have made.

If you Seal your battery pack and later you decide to unseal it (for example, diagnosing a field failure), you must perform these steps to move from **Sealed**, to **Unsealed**, and finally to **Full Access** mode.

1. During production, you will want to change the default Unseal and Full Access Keys settings in the IC. To read the default Unseal and Full Access Key, the data flash portion of the device needs to be opened by the configuration file **.encr** and the *Security* dialog tab (Figure 22) can be accessed. The default Unseal Key and Full Access Key can be modified.
2. When the IC is sealed, and you connect the EV2300 and start the bq2750x evaluation software, the DataRAM window displays as in Figure 23. (Not all the status registers are accessible. These are grayed out in the DataRAM window.) Sealing the pack is done using Manufacture Access *0x0020*.

Note: Do **not** seal your pack until after production.

3. The FAS (Full Access Seal Mode) and SS (Sealed State) bits are set when seal command is issued through control register. To move from Sealed to Unsealed mode, write to the bq2750x device with the UNSEAL Key (04from the previous step. After this command is issued you are able to read all the status registers, as shown in Figure 25. We still need to move from Unsealed to Full Access mode using the FullAccessKey.

Note: The SS bit (Sealed) is cleared; however the FAS bit (Full Access) is still set in Figure 25.

4. After issuing the two *0xFFFF* Full Access Key through control register, the FAS bit (Figure 26) is also cleared.

Figure 22. Default Unseal Key and Full Access Key

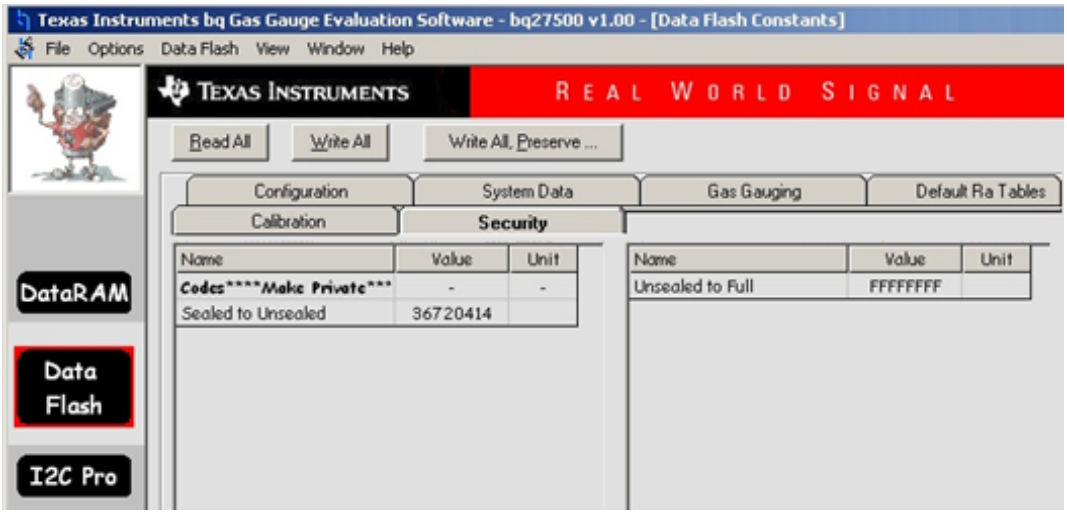


Figure 23. Sealed Mode for the bqEVSW DataRAM window

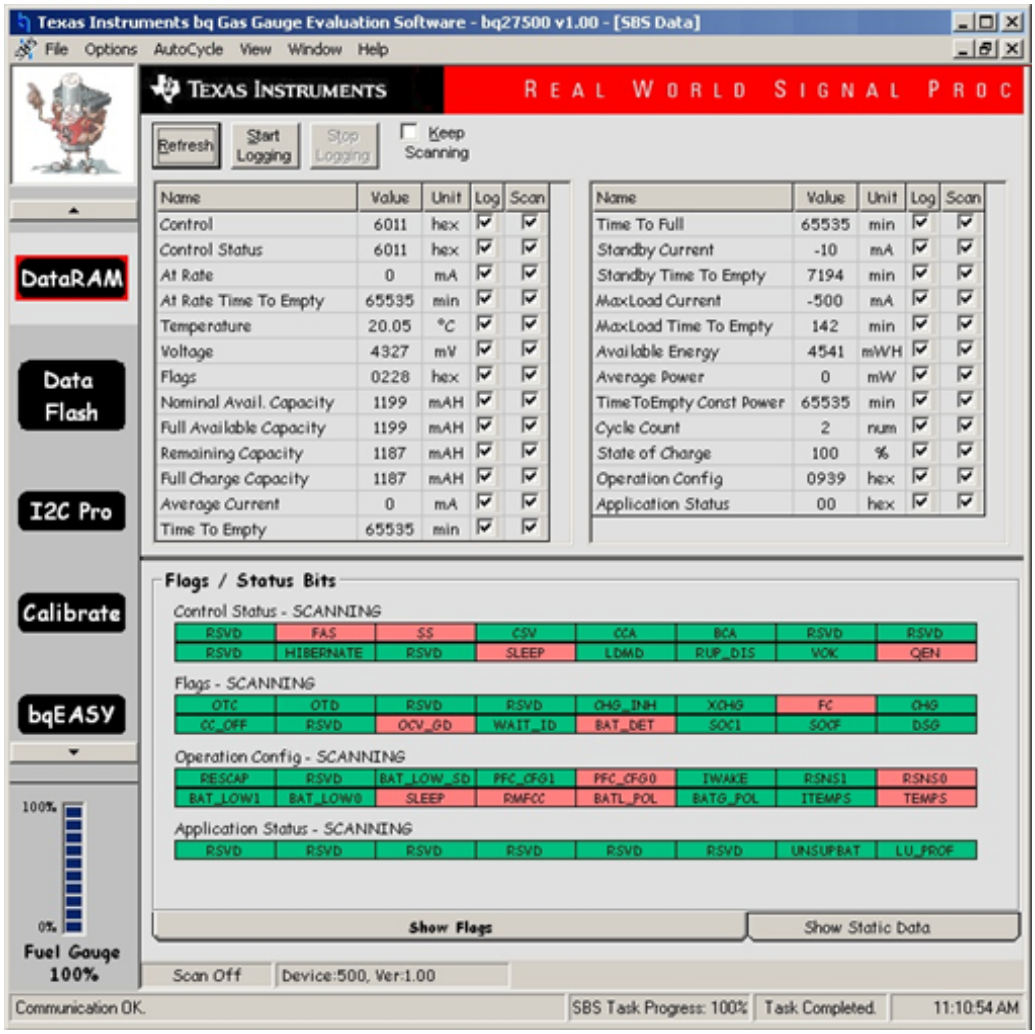


Figure 24. Default Unseal Command Using Control Register

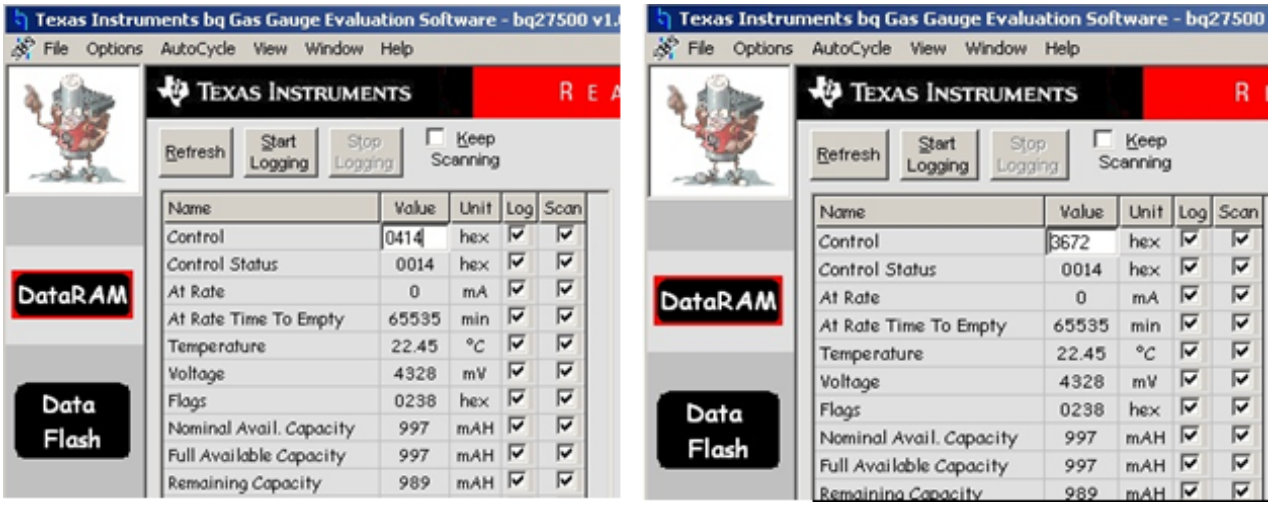


Figure 25. Status Showing Unsealed Mode With Full Access FAS Bit Set

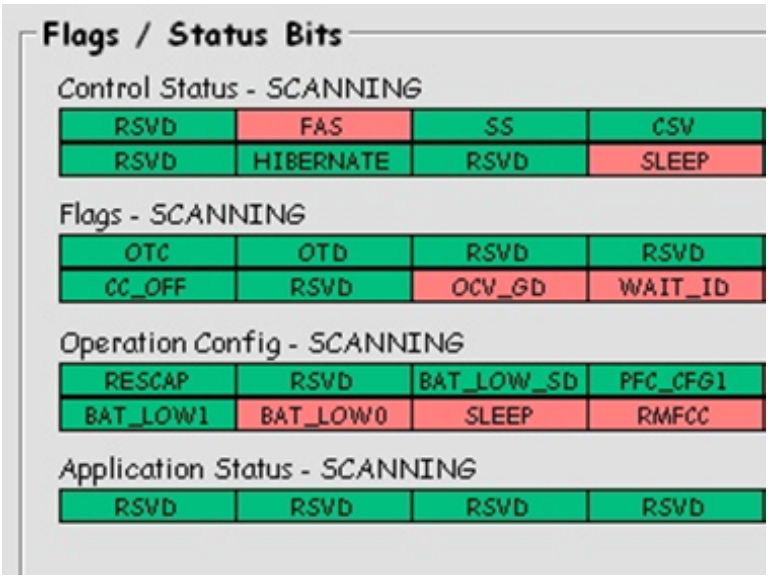
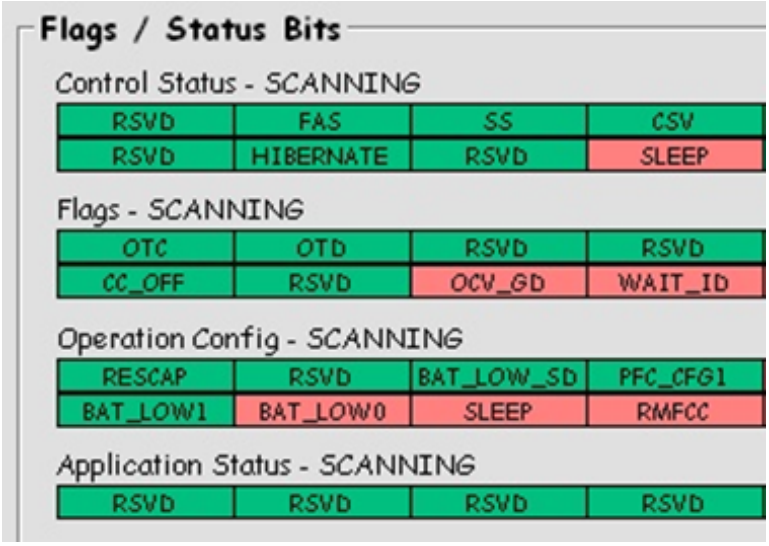


Figure 26. FAS and SS Bits are Cleared



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