How to Generate Golden Image for Single-Cell Impedance Track™ Devices

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ABSTRACT

Texas Instruments advanced fuel gauges, employing the Impedance Track™ algorithm, offer an unmatched array of features and benefits. Sometimes, however, the learning cycle to generate the golden image may seem a little challenging. In addition, determining the correct chemistry model and producing the golden image file can be time consuming. This application report describes the necessary process of configuring, calibrating, selecting chemistry, and performing learning cycles.
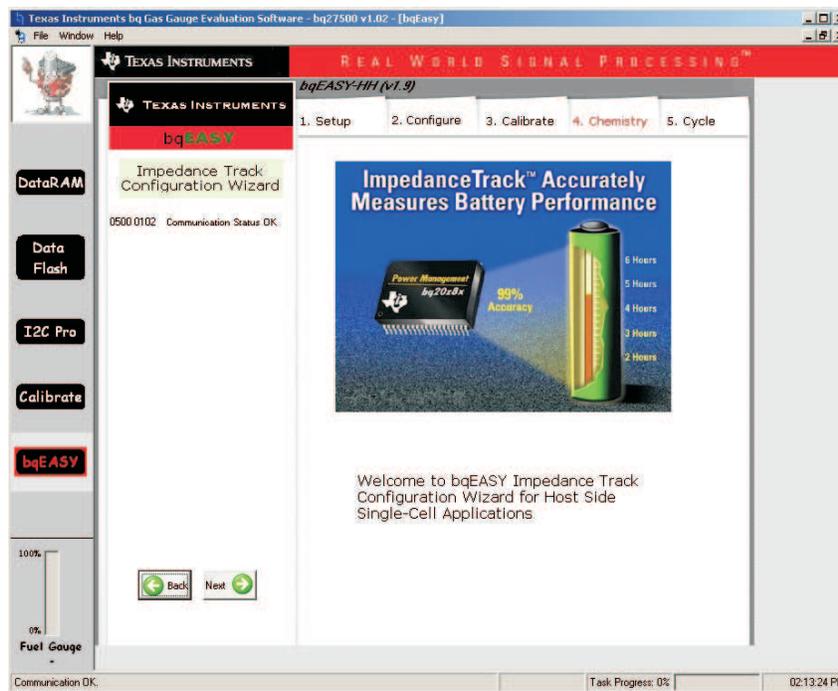
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1   Introduction

Texas Instruments advanced fuel gauges are shipped from the factory with default data flash parameters. Due to the wide range of possible cells and system designs, it is unlikely to use the gauges with the default parameters. Different applications and different battery types require different optimized data flash parameter settings to achieve higher gauging accuracy. The final optimized data flash parameters are contained in a file called the Golden Data Flash Image (DFI). The challenges of generating the golden image can be simplified by using the bqEASY™ program. bqEASY™ (Figure 1) is a wizard tool embedded within the EV Software (EVSW) that provides detailed instructions. As an additional feature, the discharge portion of the chemistry and learning cycles may be performed automatically with the use of a simple add-in circuit connected between the target device or evaluation module (EVM) and the EV2300 USB-based PC interface board. On completion of the automated processes, a golden image is generated that can be used at production to mass program all devices for a given application.

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Figure 1. bqEASY™ Program in EV Software

2   What Needs to Be Learned in Learning Cycle

The purpose of the learning (optimization) cycle is to learn the battery chemical Information that is related to the Impedance Track™ algorithm. The learning cycle can be done using a TI EVM. Two sets of parameters are learned during the learning cycle, and they are all related to the particular battery cell being used. One is the cell chemical capacity (Qmax), and the other is the cell impedance profile.

In order to properly optimize the cell's chemical information, the cell chemistry has to be selected correctly before starting the learning cycle.

3   Setting Up Pre-Optimization Parameters

The bqEASY™ wizard provides an easy way to set up the pre-optimization parameters by answering the questions (SLUA307). A series of eight screens is used to collect information about the battery pack application to enable automatic configuration of the most critical data flash parameters. After these questions are answered and the corresponding data flash items are updated, the pre-optimization parameters are saved in the fuel gauge.

1. Start the EVSW (**Start → Programs → Texas Instruments → bq Evaluation Software**), and click the **bqEASY** button in the left column (below **Calibrate**) in the user interface.
2. Click the **2. Configure** dialog tab at the top of bqEASY tabs. Note that the first dialog tab can be skipped if desired.
3. Answer all questions or leave defaults for the **2. Configure** dialog tab. Be sure to click OK at the bottom of each **2. Configure** dialog to ensure that a completion check mark displays for each page.
4. On dialog **2H**, when clicking the **OK** button, the software asks if the user wants to write the information to the data flash memory. Click **Yes** to write the information to the data flash.

The Gas Gauge module now has the data flash configured with the information entered in **2. Configure** bqEASY dialogs.

4 Calibration

To proceed with learning cycles, the Impedance Track™ fuel gauge must be accurately calibrated. The bqEASY™ dialogs ask the user to use the calibration window of the EVSW for this purpose.
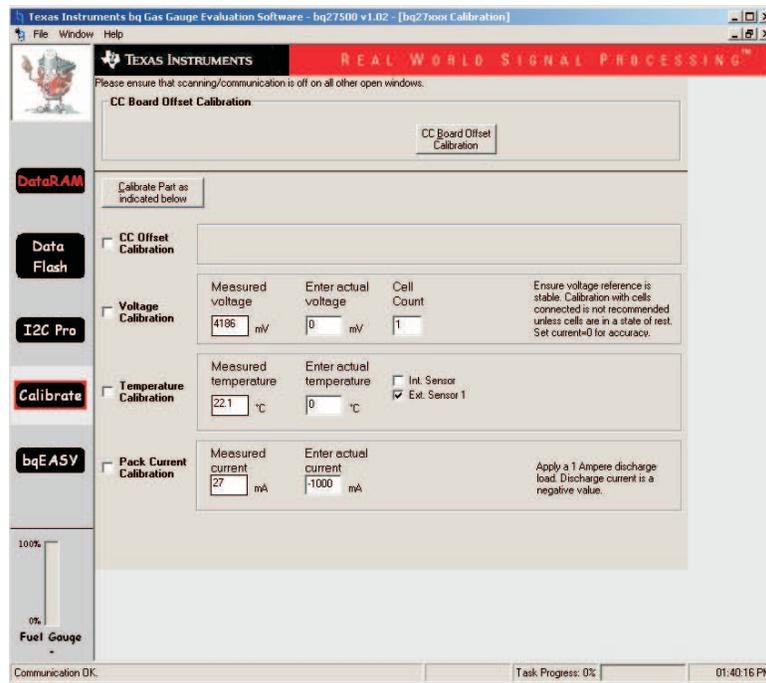
Figure 2. EV Software Calibration Screen

With the Impedance Track™ devices, most calibration routines can be incorporated into firmware algorithms, which can be initiated with communication commands. The hardware necessary for calibration is simple. One current source, one voltage source, and one temperature sensor are required. The source stability is important, and the accuracy is a secondary concern. However, accurately calibrated reference measurement equipment must be used for determining the actual arguments to the function. For periodic voltage measurement, a digital voltmeter with better than a 1-mV accuracy is required. At the time of calibration, access is required to the communication pins, both ends of the sense resistor, and battery power. The calibration process has to be completed inside the EVSW Calibrate dialog window. The calibration consists of performing Coulomb Counter Offset Calibration, CC Board Offset Calibration, Voltage Calibration, Temperature Calibration, and Pack Current Calibration one at a time. The EVSW used to perform all calibrations is shown in Figure 2. Each calibration has to be completed separately. Be sure to complete the Pack Current Calibration step last, as the CC Offset and CC Board Offset items must be done first to set the offsets, then the Pack Current Calibration sets the gain.

After the calibration is completed, click the close window control **X** in the upper right corner of the calibration window to close it.

CAUTION

The Calibration window **must be closed** after the calibration completes. Otherwise, it interferes with the bqEASY™ learning cycle.

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5 Cell Chemistry Selection

bqEASY™ software provides a simple way to select the chemistry identification (ID). The chemistry ID database can be updated by downloading and running the latest Chemistry Updater Setup executable file available from the TI product Web site. A link is included in every advanced fuel gauge Web page.
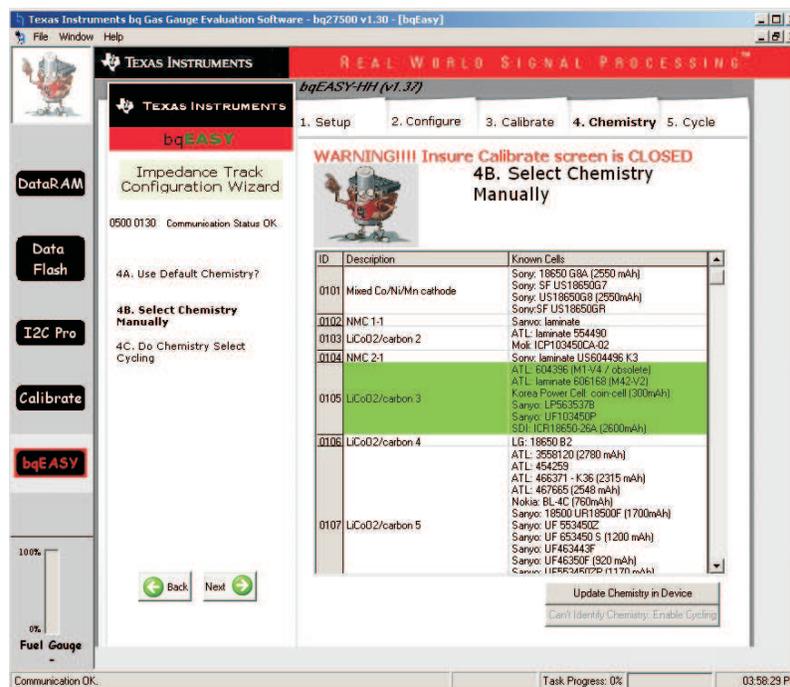

Figure 3. Manually Selecting the Chemistry ID Using bqEASY™ Software

The cell chemistry can be determined by the following steps:

1. If the cell is listed in the bqEASY™ software, then the chemistry ID can be selected directly (Figure 3).

    (a) Start the EVSW (**Start → Programs → Texas Instruments → bq Evaluation Software**), and click the bqEasy button in the left column (below Calibrate) in the user interface.
    (b) Click the **4. Chemistry** dialog tab at the top of bqEASY tabs. Note that the initial three dialog tabs can be skipped to jump to this point.
    (c) Select Use Default Chemistry or click Select Chemistry Manually, and select the correct chemistry from the list.

2. If the cell is an unknown type, follow these steps to complete a Cell Chemistry Selection Cycle. This cycle is known as a "rel-dis-rel" cycle for more accurate chemistry selection. The bqEASY™ software (version 1.36 and older) uses a 4-point chemistry auto-selection cycle, and sometimes it is not accurate enough for some applications. It is recommended to use "rel-dis-rel" cycle instead.

    (a) Start EVSW (**Start → Programs → Texas Instruments → bq Evaluation Software**), and click the **DataRAM** button.
    (b) Start data logging with a time interval of 10 seconds (SLAU448).
    (c) Charge the cell to full (4.2 V) to a taper current less than C/100.
    (d) Let the cell relax for 2 hours.
    (e) Discharge the cell at a C/10 rate until the cell voltage reaches 100 mV above cell cutoff voltage.
    (f) Let the cell relax for 5 hours.
    (g) Save the log file.
    (h) Download and install the Mathcad™ Chemistry Selection Tool from the TI Product Folder to calculate the closest matching chemistry ID. This is a Mathcad worksheet and requires you to have Mathcad installed on your computer. The Mathcad worksheet needs to be modified to move the "EVSW format for bq27500" section copied below the "Arbin Columns Assignment" section in order to match the EVSW datalog format. You also need to select your log file as the input file instead of the default. Instructions are included in-line inside the Mathcad worksheet.
    (i) Run the Mathcad worksheet tool on your log file to get the closest matching chemistry ID.

6   Battery Learning (Optimization) Cycle

Cell learning can be done on one *golden* pack. The Chemical Information learned from one pack can be

transferred to all production units, prior to calibration. Doing this correctly requires a series of charge and discharge cycles. To implement the learning cycle, the fuel gauge has to be configured and calibrated; the correct chemistry profile has to be identified and programmed in the gauge. The cell is discharged to empty first and relaxed before starting the learning cycle. The charge and discharge rate has to be properly set.

During the charge cycle, the first update to Qmax is learned. Based on this correctly learned initial Qmax, the impedance is learned during the discharge cycle (Figure 4). Once the second update to Qmax is done after the discharge cycle and relaxation, the **Update Status** in the fuel gauge data flash is set to the proper value as an indication of completion of a successful learning cycle. For host- or system-side fuel gauge, such as bq27500, bq27505, and bq27510, the **Update Status** must be set to "02". For pack side fuel gauge such as bq2754x, the update status must set to "06".
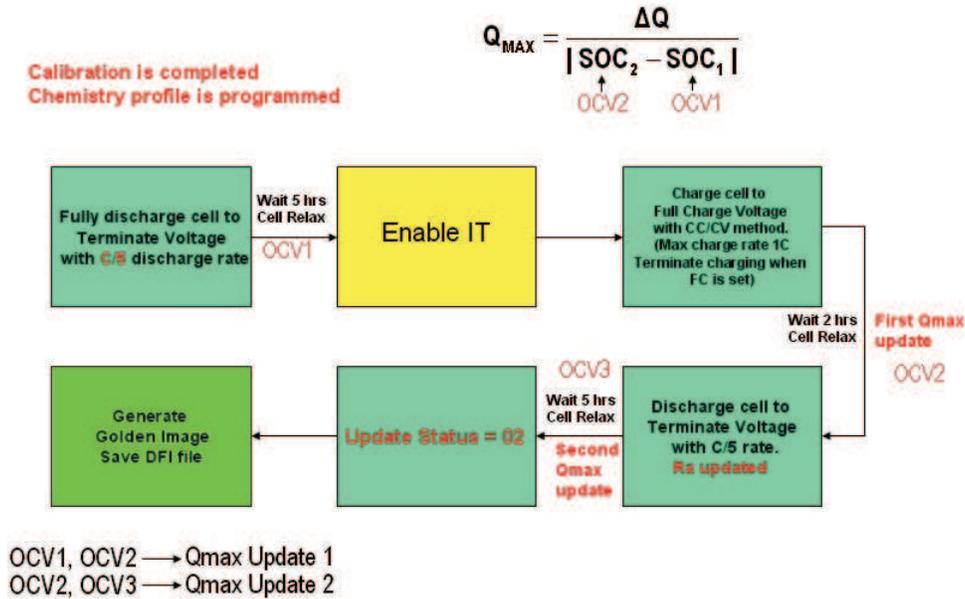

Figure 4. Learning Cycle Implementation

The automation of the cycle is made possible using a simple load and switch as depicted in Figure 5. The switch can be implemented with either a low V_{GS}-threshold FET or a small relay such as the OMICRON G6RN-1 with a 5-Vdc coil. Multiple 2N7000 FETs can be paralleled if nothing else is available.
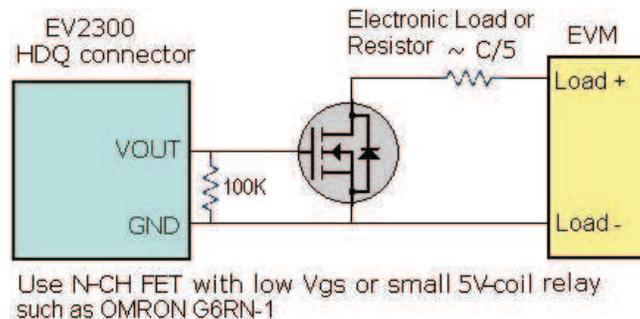

Figure 5. Example Load

The load can be either a power resistor or an electronic load set to a discharge rate of C/5. The discharge cycle can be automated with bqEASY™ software if the simple load circuit is available. To do this, simply follows the bqEASY™ dialog instructions as shown in Figure 6.

The bqEASY™ wizard provides two ways to complete the learning cycle. The first method is to use the bqEASY™ semi-automatic cycle to complete the leaning cycle. This includes:

• Auto-discharge the cell to terminate voltage and auto-relax for 5 hours

- Manually initialize the Impedance Track™ algorithm in the gauge
- Manually charge the cell to full at a C/2 rate and terminate when current is less than C/100, then manually wait for 2 hours
- Auto-discharge to empty at a C/5 rate, and auto-wait for 5 hours

Another way to complete the cycle is to complete the preceding steps 1 to 4 manually. The second method does not involve a constant voltage check by the bqEASY™ software and can be used with datalogging without any interference.

Figure 6. bqEASY™ Semi-Automatic Cycle

7 Generate Golden Image

Once the learning cycle is successfully completed with Update Status set to correct value, the golden image can be generated using the bqEASY™ software (Figure 7). In some cases, the learning cycle may be completed using a different computer. It is necessary to read the data flash image from the learned gauge to the local computer first before proceeding with golden image generation.
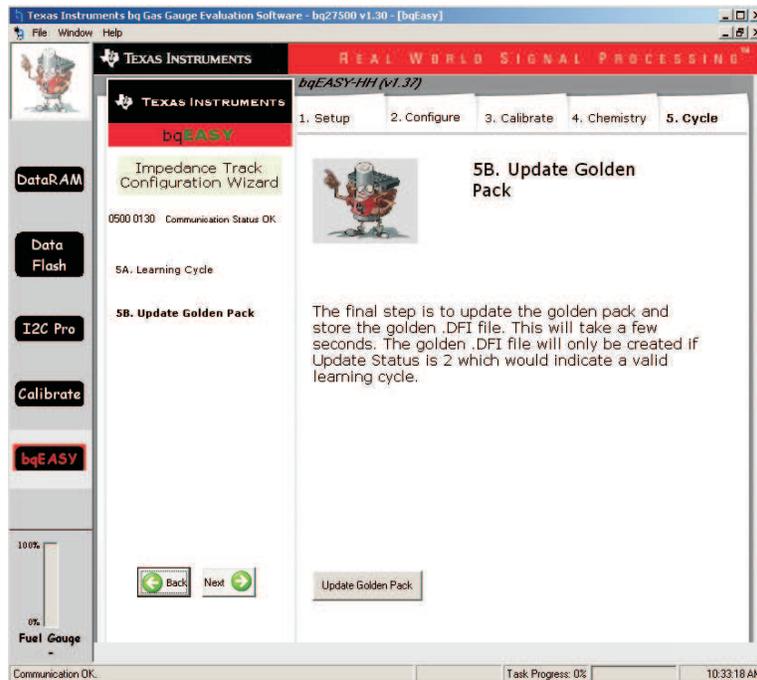
Figure 7. Generating Golden Image

Once the Update Golden Pack button is clicked, the bqEASY™ software generates the golden image based on learned Qmax and impedance values. Several changes are made to the fuel gauge data flash:

1. IT enable is cleared so that the golden image can be used in mass production flow.
2. Impedance Flag and Status are updated to reflect that they are learned values and not defaults.
3. Learned Impedance is copied to other R tables.

The golden image generated using an EVM has the calibration value for that particular EVM. In order to use it for mass production, the actual system board calibration values needs to be used. This can be accomplished by calibrating with a small number of actual production boards and noting the corresponding data flash values that are updated after calibration. If they vary from board to board, then the average can be taken and manually typed into the Data Flash screen to update the values in the fuel gauge before generating the golden image based on its contents.

8   Common Issue and Solution

The most common issue for preventing a successful learning is that the *Update Status* is not updated to the correct value due to the following reasons.

1. FC bit is not set in the charge cycle, and the charge is terminated too early.
2. RUP_DIS is set during the discharge, and R did not learn.
3. Discharge was interrupted during the discharge cycle; the discharge needs to be continuous without any interruption.

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