bq27541EVM Single-Cell Impedance Track™ Technology Evaluation Module

This evaluation module (EVM) is a complete evaluation system for the bq27541. The EVM includes one bq27541 circuit module, a current sense resistor, one thermistor, an EV2300 personal computer (PC) interface board for gas gauge interface, a PC USB cable, and Windows™-based PC software. The circuit module includes one bq27541 integrated circuit (IC), and all other onboard components necessary to monitor and predict capacity. The circuit module connects directly across the cell in a battery. With the EV2300 interface board and software, the user can read the bq27541 data registers, program the chipset for different pack configurations, log cycling data for further evaluation, and evaluate the overall functionality of the bq27541 solution under different charge and discharge conditions.

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1   Features

- Complete evaluation system for the bq27541 gas gauge with Impedance Track™ Technology
- Populated circuit module for quick setup
- PC software and interface board for easy evaluation
- Software that allows data logging for system analysis

1.1   Kit Contents

- bq27541 circuit module
- EV2300 (specifically labeled as only to be used with bq27541 EVMs) PC interface board
- USB connection cable to interface board
- Set of support documentation

1.2   Ordering Information

Table 1. Ordering Information

EVM PART NUMBER	CHEMISTRY	CONFIGURATION	CAPACITY
bq27541EVM-001	Li-ion	1 cell	Any

2   bq27541-Based Circuit Module

The bq27541-based circuit module is a complete and compact example solution of a bq27541 circuit for battery management. The circuit module incorporates a bq27541 battery gas gauge IC, and all other components necessary to accurately predict the capacity of a 1-series Li-Ion cell.

2.1   Circuit Module Connections

Contacts on the circuit module provide the following connections:

- Direct connection to the cells: CELL+ and CELL-
- To the serial communications ports (SDA, SCL) or HDQ
- The system load and charger connect across PACK+ and PACK-

Single-Cell Solution Impedance Track, Impedance Track, bqEasy are trademarks of Texas Instruments.
Windows is a trademark of Microsoft Corporation.

2.2 Pin Descriptions

PIN NAME	DESCRIPTION
PACK+	Pack positive terminal
PACK-	Pack negative terminal
CELL+	Cell positive terminal
CELL-	Cell negative terminal
SDA	I2C communication data line
SCL	I2C communication clock line
HDQ	Single wire communication line

3 bq27541 Circuit Module Schematic

This section contains schematic information.

3.1 Schematic

The schematic follows the bill of materials in this user's guide.

4 Circuit Module Physical Layouts and Bill of Materials

This section contains the printed-circuit board (PCB) layout, bill of materials, and assembly drawings for the bq27541 circuit module.

4.1 Board Layout

This section shows the PCB layers (Figure 1 through Figure 4), and assembly drawing for the bq27541 module.
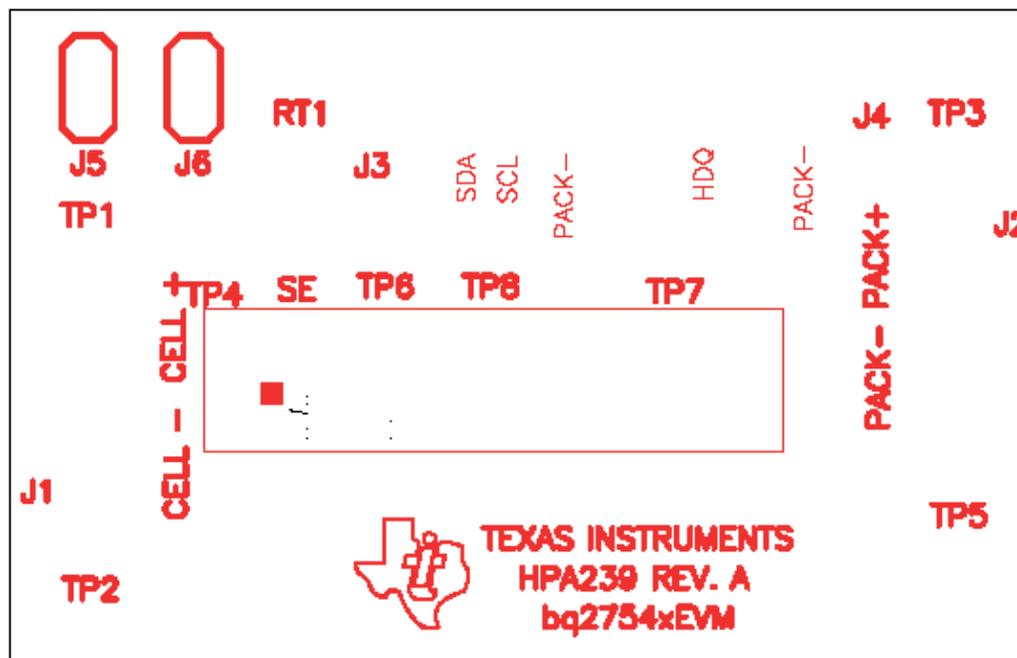

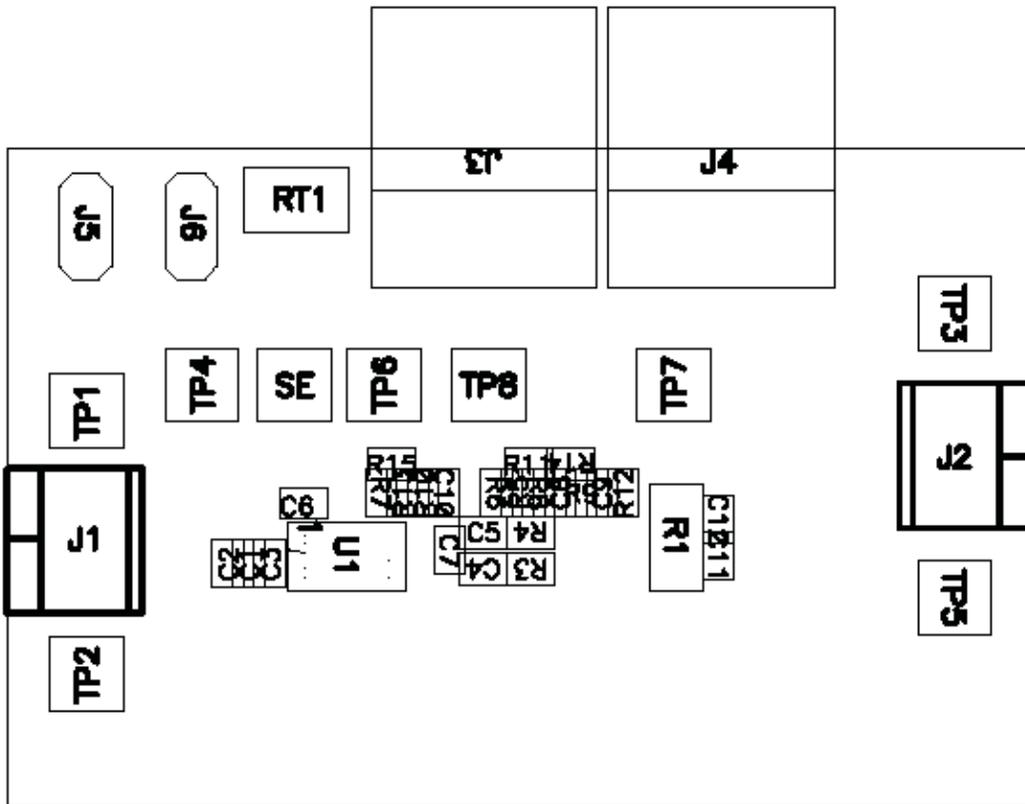**Figure 1. bq27541EVM-001 Layout, Silk Screen**
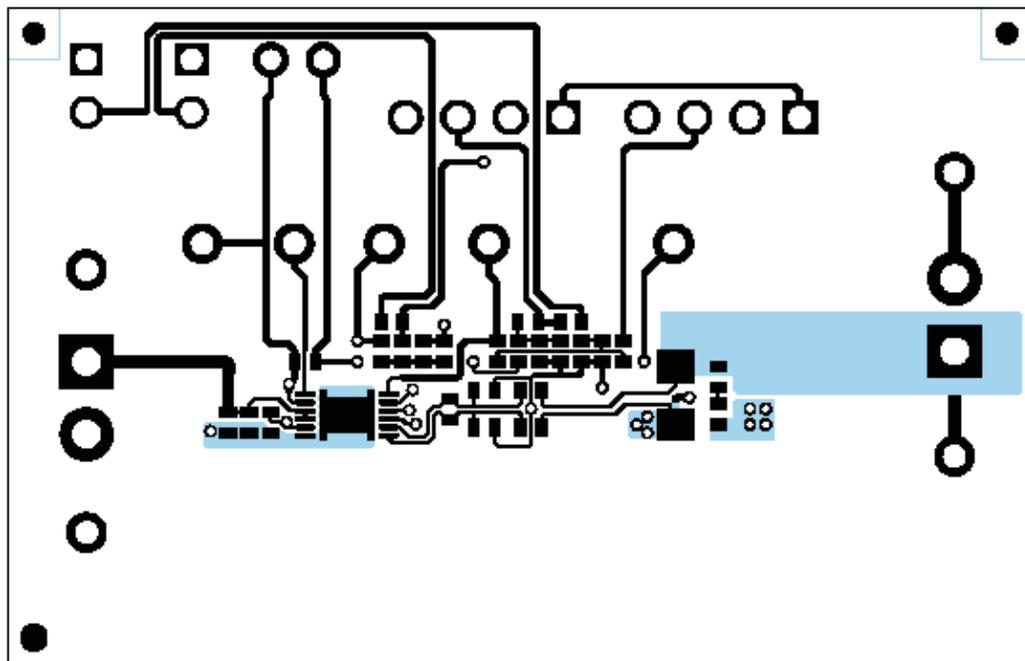
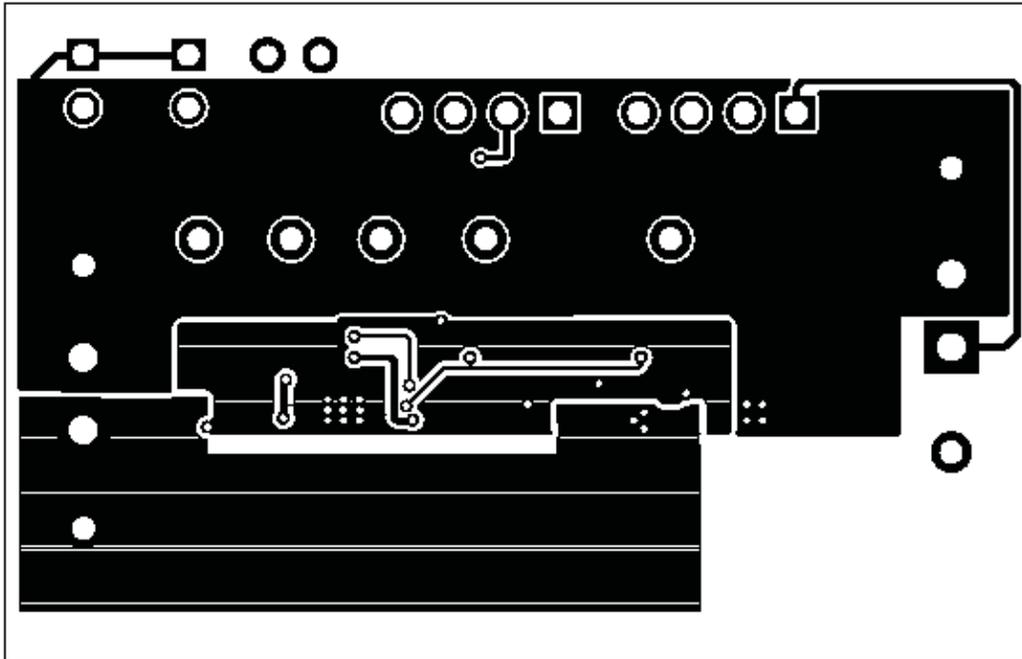**Figure 2. Top Assembly**

Figure 3. Top Layer

Figure 4. Bottom Layer

4.2 Bill of Materials and Schematic

Table 2. Bill of Materials

Count	Ref Des	Description	Size	MFG	Part No.
7	C1, C2, C4, C5, C7, C11, C12	Capacitor, Ceramic, 0.1uF, 10V, X5R	402	Murata	GRM155R61A104KA01D
2	C3, C6	Capacitor, Ceramic, 0.47uF, 6.3V, X5R	402	Murata	GRM155R60J474KE19D
3	C8, C9, C10	Capacitor, Ceramic, 150pF, 50V, NPO, 5%	402	Murata	GRM1555C1H151JA01D
2	J1, J2	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 x 0.25 inch	OST	ED1514
2	J3, J4	Header, Friction Lock Ass'y, 4-pin Right Angle,	0.400 x 0.500	Molex	22-05-3041
2	J5, J6	Header, Male 2-pin, 100mil spacing, (36-pin strip)	0.100 inch x 2	Sullins	PTC36SAAN
1	R1	Resistor, Chip, 0.01-Ohms, 0.25W, 1%	1206	Vishay	WSL1206R0100FEA
2	R14, R15	Resistor, Chip, 10k-Ohms, 1/16W, 5%	402	Std	Std
5	R3, R4, R11, R12, R13	Resistor, Chip, 100-Ohms, 1/16W, 5%	402	Std	Std
3	R5, R6, R7	Resistor, Chip, 300-Ohms, 1/16W, 5%	402	Std	Std
3	R8, R9, R10	Resistor, Chip, 1M-Ohms, 1/16W, 5%	402	Std	Std
1	RT1	Thermistor, 10K ohms	0.095 X 0.150 inch	Semitec	NTC103AT
9	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, SE	Test Point, Black, Thru Hole Color Keyed	0.100 x 0.100 inch	Keystone	5001
1	U1	IC, Single-Cell Impedance Track Gas Gauge	QFN12	TI	BQ27541DRZ

Figure 5. Schematic

4.3 bq27541 Circuit Module Performance Specification Summary

This section summarizes the performance specifications of the bq27541 circuit module.

Table 3. Performance Specification Summary

Specification	Min	Typ	Max	Units
Input voltage Pack+ to Pack–	2.7	3.6	4.3	V
Input voltage CELL+ to CELL-	2.7	3.6	4.3	
Charge and discharge current	0	1	2	A

5 EVM Hardware and Software Setup

This section describes how to install the bq27541EVM-001 PC software, and how to connect the different components of the EVM.

5.1 System Requirements

The bq27541EVSW software requires Windows™ 2000 or Windows XP. Drivers for Windows 98SE are provided, but Microsoft no longer supports Windows 98; Windows 98 may have issues with USB driver support. The EV2300 USB drivers have been tested for Windows 98SE, but no assurance is made for problem-free operation with specific system configurations.

5.2 Software Installation

Find the latest software version in the bq27541 tool folder on power.ti.com. Make a search by Part Number for bq27541 to access the tool folder. Use the following steps to install the bq27541EVSW software:

1. Ensure that the EV2300 is not connected to the PC through a USB cable before starting this procedure.
2. Browse for the Supported Software link within the bq27541 TI Web site product folder to find the downloadable evaluation software installation files.
3. Open the software file that was downloaded from the TI Web site.
4. Follow the instructions on screen until the software installation is completed.
5. Before starting the evaluation software, connect the EV2300 to the computer using the USB cable.
6. Wait until the system prompt "new hardware found" appears. Choose "select location manually", and use the "browse" button to point to subdirectory TIUSBWin2K-XP-1.
7. Answer "continue" to the warning that drivers are not certified with Microsoft™.
8. After installation finishes, another system prompt "new hardware found" appears. Repeat steps 6 and 7, but specify the directory as TIUSBWin2K-XP-2.
9. Answer "continue" to the warning that drivers are not certified with Microsoft. Driver installation is now finished.

6 Troubleshooting Unexpected Dialog Boxes

The user that is downloading the files must be logged in as the administrator. The driver is not signed, so the administrator must allow installation of unsigned drivers in the operating system policy.

7 Hardware Connection

The bq27541EVM-001 comprises three hardware components: the bq27541 circuit module, the EV2300 PC interface board, and the PC.

7.1 Connecting the bq27541 Circuit Module to a Battery Cell

Figure 6 shows how to connect the bq27541 circuit module to the cell and system load/charger.
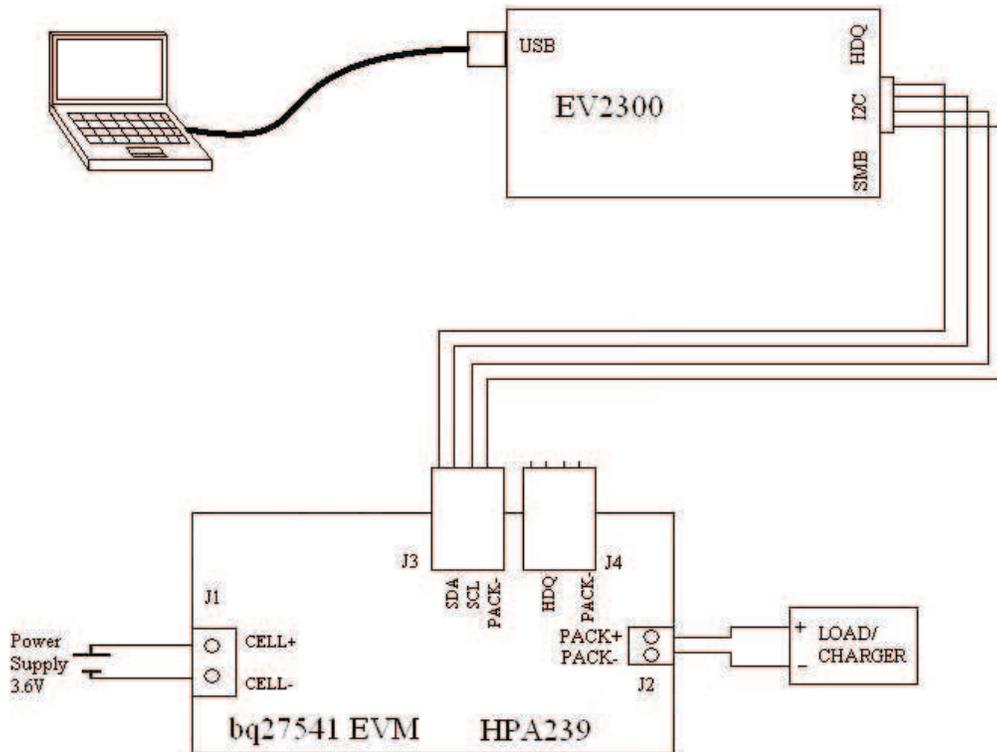

Figure 6. bq27541 Circuit Module Connection to Cell and System Load/Charger

7.2 PC Interface Connection

The bq27541 can be configured as an HDQ communication device or left in default as an I2C device. Once the bq27541 is configured for HDQ communication, it cannot be reverted to I2C mode. Refer to chapter 12 of this document for information on configuring the bq27541 to HDQ mode.

The following steps configure the hardware for interfacing to the PC:

1. Connect the bq27541-based pack to the EV2300 using wire leads as shown in Table 4.

Table 4. Circuit Module to EV2300 Connections – I2C

bq27541-Based Battery (I2C mode)	EV2300 (I2C port)
SDA	SDA
SCL	SCL
PACK-	GND

Table 5. Circuit Module to EV2300 Connections – HDQ

bq27541-Based Battery (HDQ mode)	EV2300 (HDQ port)
HDQ	HDQ
PACK-	GND

2. Connect the PC USB cable to the EV2300 and the PC USB port.

The bq27541EVM-001 is now set up for operation.

8   Operation

This section details the operation of the bq27541 EVSW software.

8.1   *Starting the Program*

Run bq27541 EVSW from the Start | Programs | Texas Instruments | bq Evaluation Software menu sequence. The DataRAM screen (Figure 7) appears. Data begins to appear once the <Refresh> (single time scan) button is clicked, or when the <Keep Scanning> check box is checked. To disable the scan feature, deselect <Keep Scanning>.

The continuous scanning period can be set via the | Options | and | Set Scan Interval | menu selections. The range for this interval is 0 ms to 65,535 ms. Only items that are selected for scanning are scanned within this period.

The bq27541 EVSW provides a logging function which logs the values that were last scanned by the EVSW. To enable this function, select the *Start Logging* button, which causes the *Keep Scanning* button to be selected. When logging is *Stopped*, the keep scanning button is still selected and has to be manually unchecked.

The logging intervals are specified under the | Options | menu with the maximum value of 65,535 ms. The *Log* interval cannot be smaller than scan interval because this results in the same value being logged at least twice.

Figure 7. DataRAM Screen

This screen (Figure 7) shows the DataRAM data set. Additional Flags/Status Bits data can be viewed at the bottom of the DataRAM screen.

Dragging the splitter bar (line that separates the Flags/Static Bits data from SBS values) changes the height of the Flags/Static Bits data display. Selecting | View |, then | Auto Arrange | returns the splitter bar to its original location.

8.2 Setting Programmable bq27541 Options

The bq27541 data flash comes configured per the default settings detailed in the bq27541 data sheet (SLUS861). Ensure that the settings are correctly changed to match the pack and application for the bq27541 solution being evaluated.

IMPORTANT: The correct setting of these options is essential to get the best performance.

The settings can be configured using the Data Flash screen (Figure 8).
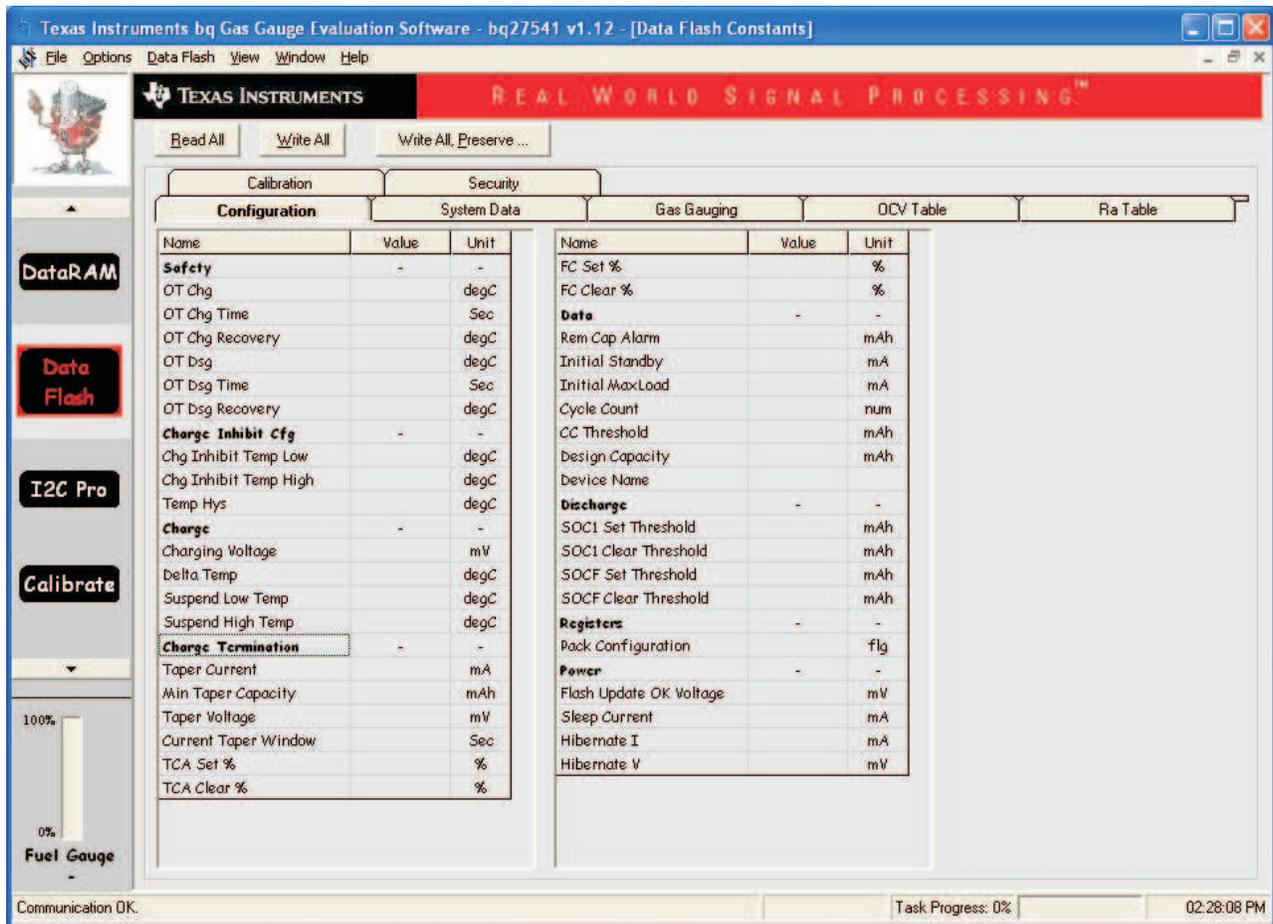
Figure 8. Data Flash Screen

To read all the data from the bq27541 data flash, click on menu option | Data Flash | Read All |.

To write to a data flash location, click on the desired location, enter the data and press <Enter>, which writes the entire tab of flash data, or select menu option | Data Flash | Write All |. The data flash must be read before any writes are performed to avoid any incorrect data being written to the device.

The | File | Special Export | menu options allows the data flash to be exported, but it configures the exported data flash to a learned state ready for mass production use.

The data flash configuration can be saved to a file by selecting | File | Export | and entering a file name. A data flash file can also be retrieved in this way, imported, and written to the bq27541 using the | Write All | button.

The module calibration data is also held in the bq27541 data flash.

The bq27541 allows for an automatic data flash export function, similar to the DataRAM logging function. This feature, when selected via | Options | Auto Export |, exports Data Flash to a sequential series of files named as *FilenameNNNNN.gg* where N = a decimal number from 0 to 9.

The AutoExport interval is set under the | Options menu | with a minimum value of 15 s. The AutoExport filename is also set under the | Options menu |.

When a check is next to | AutoExport |, the AutoExport is in progress. The same menu selection is used to turn on/off AutoExport.

If the data flash screen is blank, then the bq27541 that is being used may not be supported by the bqEVSW version that is being used. An upgrade may be required.

9   Calibrate Screen

To ensure proper calibration, proceed in the order that follows. These steps may or may not be required, depending on the type of calibration being performed.

9.1   To Calibrate the bq27541

Select the types of calibration to be performed (see Figure 9).

Enter the measured values for the types selected.

If *Voltage Calibration* is selected, then ensure that cell count is 1.

If *Temperature Calibration* is selected, then select the sensor that is to be calibrated.

Press the *Calibrate Part* button.

9.2   CC Offset Calibration

This performs the internal calibration of the coulomb counter input offset.

9.3   Board Offset Calibration

This performs the offset calibration for the current offset of the board.

It is expected that no current is flowing through the sense resistor while performing this calibration step. Remove load/external voltage and short Pack- to Batt-.

Press the *CC Board Offset Calibration* button.

9.4   Voltage Calibration

Remove the load applied between Pack+ and Pack-.

Ensure that voltage is stable before performing voltage calibration. Measure the voltage across Pack+ and Pack-. Type the voltage value in mV into Enter Actual Voltage .

Press the *Calibrate Part as indicated below* button to calibrate.

9.5   Temperature Calibration

Measure the temperature for PACK. Type the temperature value into Enter Actual Temperature. Select if the temperature sensor to calibrate is the internal or the external.

Press the *Calibrate Part as indicated below* button.

9.6   Pack Current Calibration

Connect a load to LOAD− and LOAD+ that draws approximately 1 A, or connect a current source to LOAD− and Pack-. Measure the current and type value into Enter Actual Current using (-) for current in discharge direction.

Press the *Calibrate Part as indicated below* button.
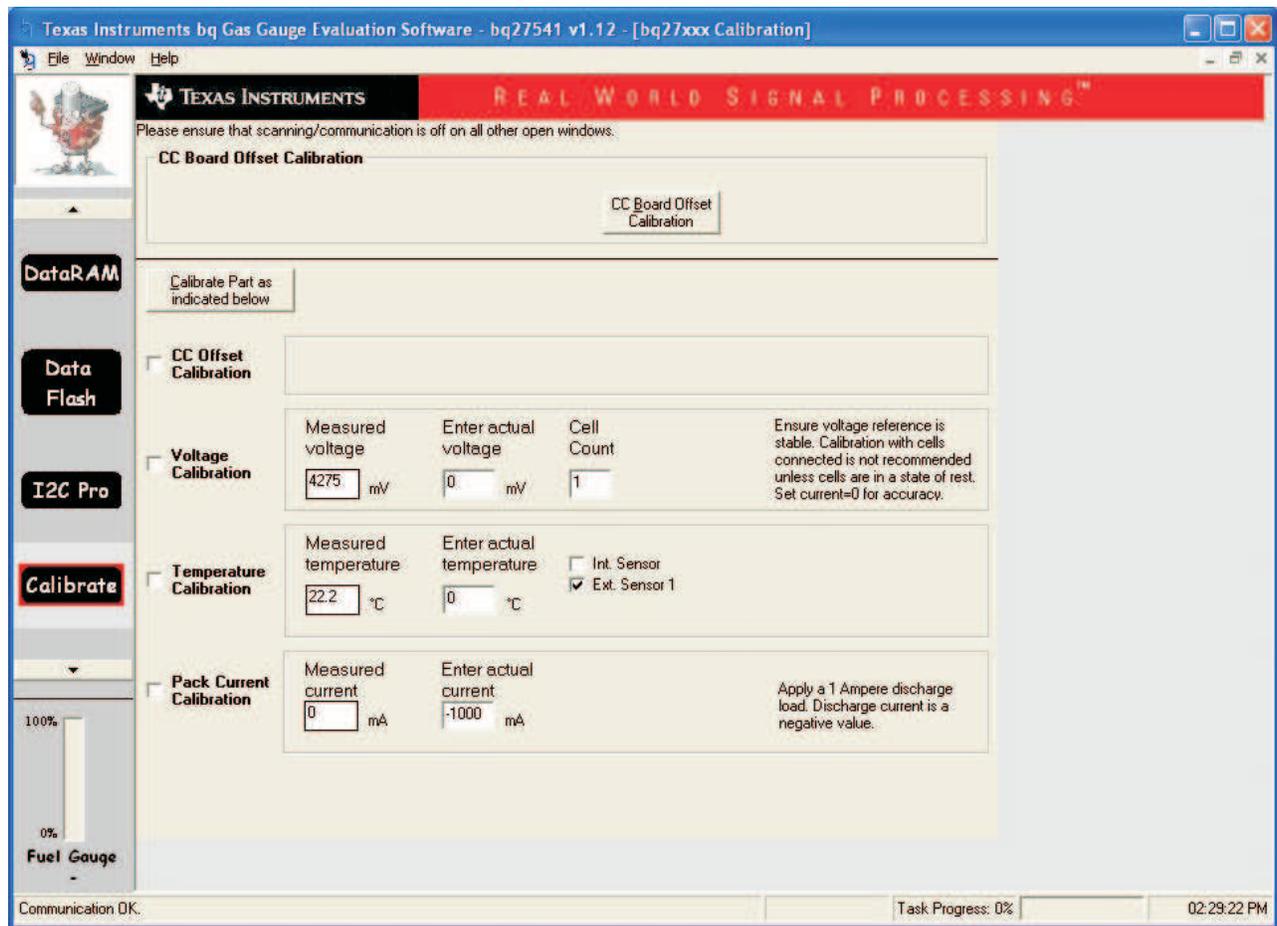
Figure 9. Calibration Screen

10   I2C Pro Screen

10.1 I2C Communication

The set of read/write operations over I2C are not specific to any gas gauge. These are provided as general-purpose communication tools (Figure 10).
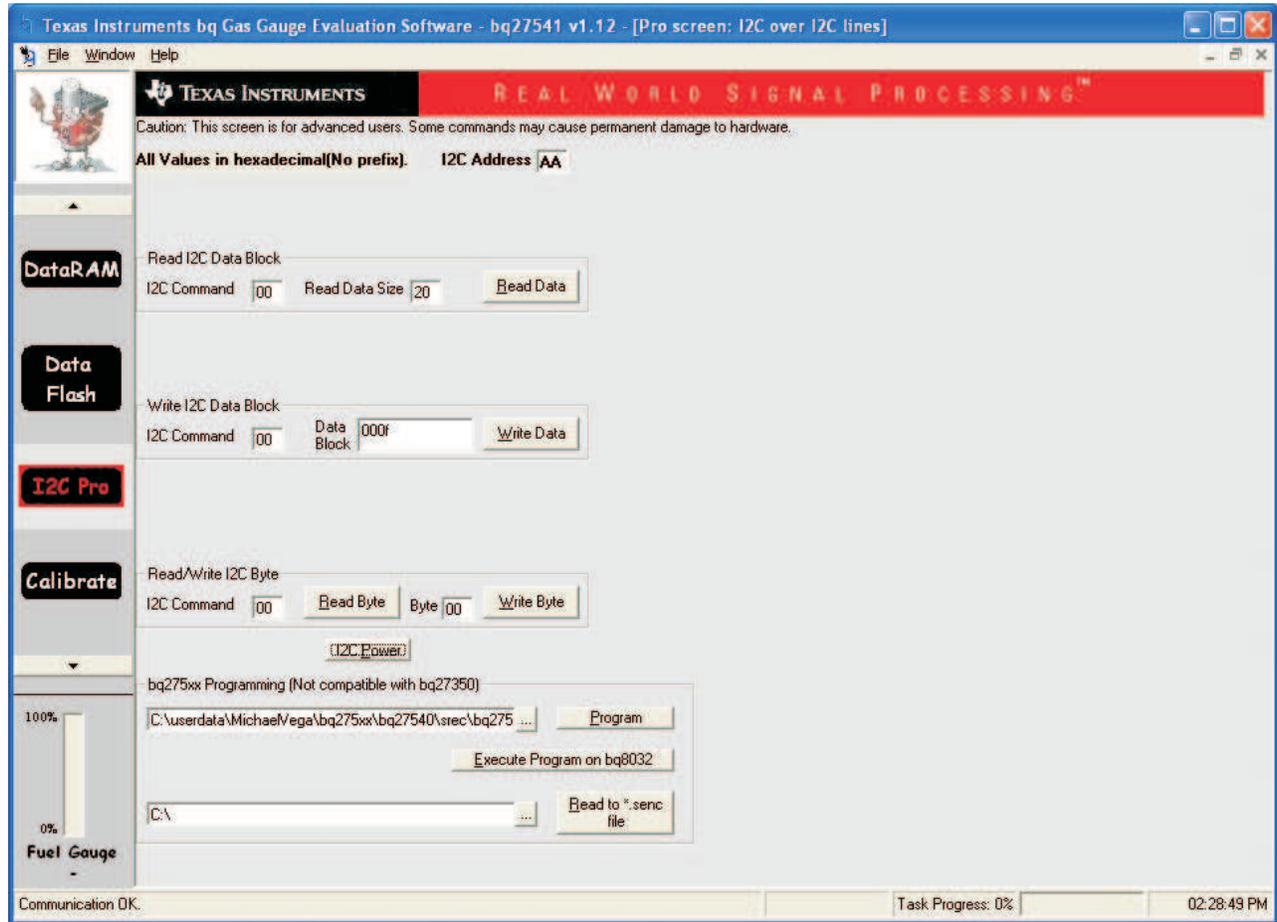
Figure 10. I2C Pro Screen

11   bqEasy™ Software

11.1   Introduction

Texas Instruments fuel gauges, employing the Impedance Track™ algorithm, offer an unmatched array of features and benefits. Sometimes, however, the wide range of configuration settings can make it seem a bit challenging to get started with the evaluation process. In addition, determining the correct chemistry model and producing the 'golden image' file can be time consuming. The bqEASY™ program is designed to greatly simplify the process of configuring, calibrating, selecting chemistry, and performing learning cycles through the step-by-step use of a wizard program.

The bqEasy™ software runs inside the current EV software when it is executed by clicking the bqEasy™ button in the left column of buttons below the Calibrate button in the EV software.

11.2   Program Navigation and Flowchart

The sequence of operation of bqEASY™ can be understood by reviewing the basic flowchart in Figure 11. Using the program is simple – just start a new project, and follow the steps sequentially from 1A to 5C. You can use the Next button, or click on the top tabs and left subsection labels to move to any desired page. Some operations must be completed in sequence due to data dependencies, or to implement the proper flow. Therefore, it is recommended that the prescribed sequence be followed, at least at first.
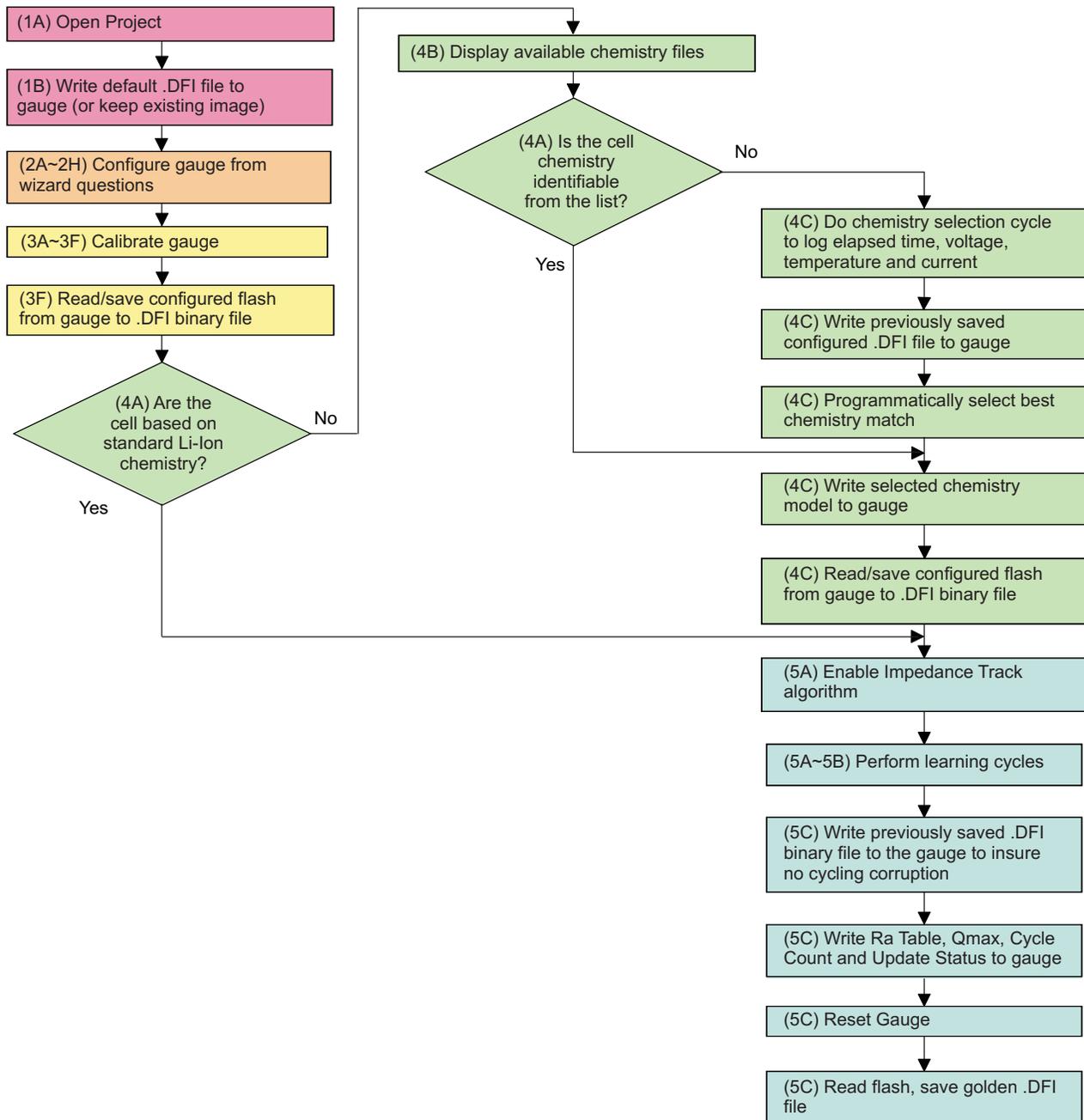
Figure 11. bqEasy™ Flowchart

11.3 Simplified Configuration Procedures

These simplified configuration procedures can be used to quickly set up the parameters without navigating through the entire user interface.

1. Simple configuration of the gas gauge with default or custom data:
   a. Open the current EV software and click the bqEasy button in the left column of buttons below the "Calibrate" button in the EV software.
   b. Click the "2. Configure" tab at the top row of bqEASY tabs. (Note: You can skip the **1st** tab)

c. Answer all questions or leave defaults for all of tab "2", but be sure to click the ok button at the bottom of each tab "2" page to ensure that a Completion checkmark appears for each page.

d. On page 2H, when you click the "OK" button, the software asks you to write to the data flash memory. Click "Yes" for OK to write to the data flash.

2. Simple installation of the Chemistry data using bqEASY if the chemistry is a known chemistry available in the bqEASY software:

a. Open the current EV software and click the bqEasy button in the left column of buttons below the "Calibrate" button in the EV software.

b. Click the "4. Chemistry" tab at the top row of bqEASY tabs. (Note: You can skip all tabs prior to this.)

c. Either select "Use Default Chemistry", or click "Enable Chemistry Selection" and select the correct chemistry from the list.

d. If you cannot find the proper chemistry, check the device EVM tool folder on the TI Web site for any new bqChemistry file updates. These are updated more frequently than the EV software; so, between EV software updates, TI creates a self-extracting installer and posts it in the EVM tool folder for the part being used. Install these updates if they are in the folder.

The software now configures all data flash locations on your gas gauge module that deal with chemistry functions. No other data flash locations are modified.

11.4 Files

bqEASY uses four types of files to configure a fuel gauge.

1. **.ENCR –** These are default data-flash definition files found in the \bq_Evaluation_Software folder. The ENCR file is basically a copy of the entire data flash from a fresh gas gauge prior to any data-flash updates either by the user or the gas gauge. They are unique for each version of each TI fuel gauge product. If you are working with a new version fuel gauge and an older version of bqEASY, the correct file may not be present. This requires a new version of the EV software with bqEASY. Navigate to the TI Web site in the EVM tool folder for the device being used, and download the latest version, or contact TI. For bqEASY, the ENCR files act mainly as a dictionary to look up the address for a given data-flash location. For bqEVSW, they define screen parameters including address, display formulas, and data type. An error message appears if the correct .ENCR file cannot be found.

2. **.CHEM (Chemistry Files) –** These are read-only files found in the ..\bq_Evaluation_Software\Plugins\Chemistry folder of the application. When a new Li-ion battery chemistry is developed, a new Impedance Track™ model is required to define the chemical model. During automated chemistry selection, each of these files is scanned in order to select the best match with the recorded data. If you are working with a newly developed chemistry, it is possible that an acceptable match may not be found. If this is the case, check for updated bqEasy software or bqChemistry files on the TI Web site in the EVM tool folder for the part being used.

3. **.DFI (Data-Flash Image Files) –** These are binary images of the fuel gauge data-flash with modified values based on the application. Because of the binary format, it is quick and easy to transfer them to and from a gauge. Each fuel gauge model and firmware version has a unique read-only .DFI which is found in the ..\bq_Evaluation_Software\Plugins\Device_Defaults folder of the application. During the bqEASY process, intermediate versions of .DFI files are recorded with current updated data in order to prevent the possibility of corruption. Then, the final output of bqEASY is also a .DFI file which is the 'golden image' that will be programmed into each production unit. This output file is placed in the ..\bq_Evaluation _Software\Plugins\Projects folder.

4. **.EZY (bqEASY Project Files) –** These are read-write text files which record header information regarding a project, answers to the wizard questions, and status regarding the stage of completion (the red checkmarks). They are kept in the ..\bq_Evaluation _Software\Plugins\Projects folder.

11.5 Completion Checkmarks

As the wizard questions and tasks are completed, completion checkmarks appear in two places – along the task list on the left and on the category tabs on top. A checkmark on a top tab only appears after all tasks in the category have been completed. Completion marks are saved in the .EZY project text file. When a completed or partially completed project file is opened, the user is given the chance to erase the checkmarks.

11.6 Device Detection

BqEASY is designed to work with a fuel gauge present and already communicating with the bqEVSW evaluation software through the EV2300 USB interface. When the evaluation software is started, it reads the device type and displays it on the upper title block. This information is used by bqEASY to select the correct default data-flash image (.DFI) and data-flash configuration file (.ENCR) for this particular device. To ensure that the device has not changed, bqEASY also checks the device type when the bqEASY button is pressed. If the correct files are not found, first check the TI Web site in the EVM tool folder for the part being used, and download the latest version of EV software with bqEASY support. If that does not help, then contact Texas Instruments.

1. **Setup**

   As the wizard questions and tasks are completed, completion checkmarks appear in two places – along the task list on the left and on the category tabs on top. A checkmark on a top tab only appears after all tasks in the category have been completed. Completion marks are saved in the .EZY project text file. When a completed or partially completed project file is opened, the user is given the chance to erase the checkmarks.

2. **Configure**

   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.

3. **Calibrate**

   If you proceed with either automatic chemistry selection or 'golden' unit learning cycles, the Impedance Track™ fuel gauge must be accurately calibrated. The bqEASY screens simply ask the user to use the calibration screen of the bqEVSW for this purpose.

4. **Chemistry**

   The chemistry choices presented in section 4B are based on files in the \Chemistry folder of the bqEASY application. The latest files are available for downloading from the TI Web site. Automation of the chemistry-selection cycle is made possible using a simple load and switch as depicted in Figure 12. The VOUT pin of the EV2300 may require a 1-MΩ pulldown resistor to ensure that switch is turned off when signaled to do so. The switch can be implemented with either a low VGS-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. The load can be either a power resistor or an electronic load set to a discharge rate of C/5. Hint: Follow the instructions exactly, or errors may result.

5. **Cycle**

   When preparing for mass production, cell learning is required, but only on one 'golden' pack. The chemical information learned from one pack is quickly transferred to all production units prior to calibration. Doing this correctly requires a series of charge and discharge cycles. The discharge part can be automated with bqEASY if the simple load circuit for the chemistry selection is available. Follow the screen instructions.
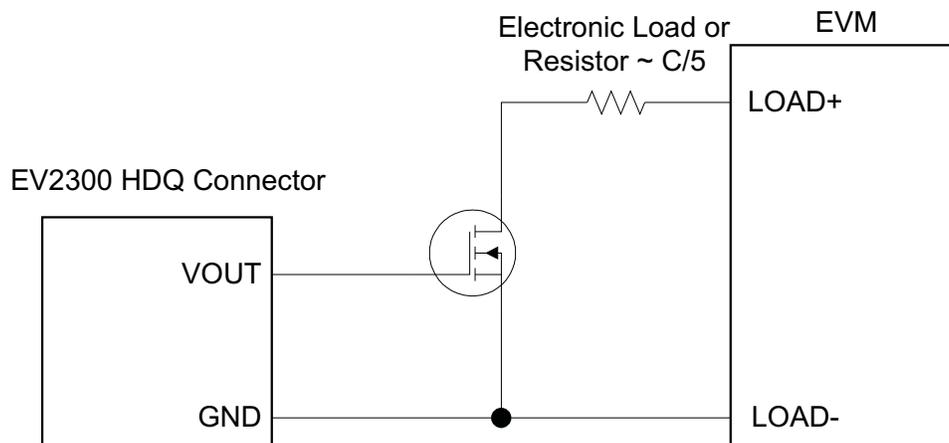
Figure 12. Load and Switch
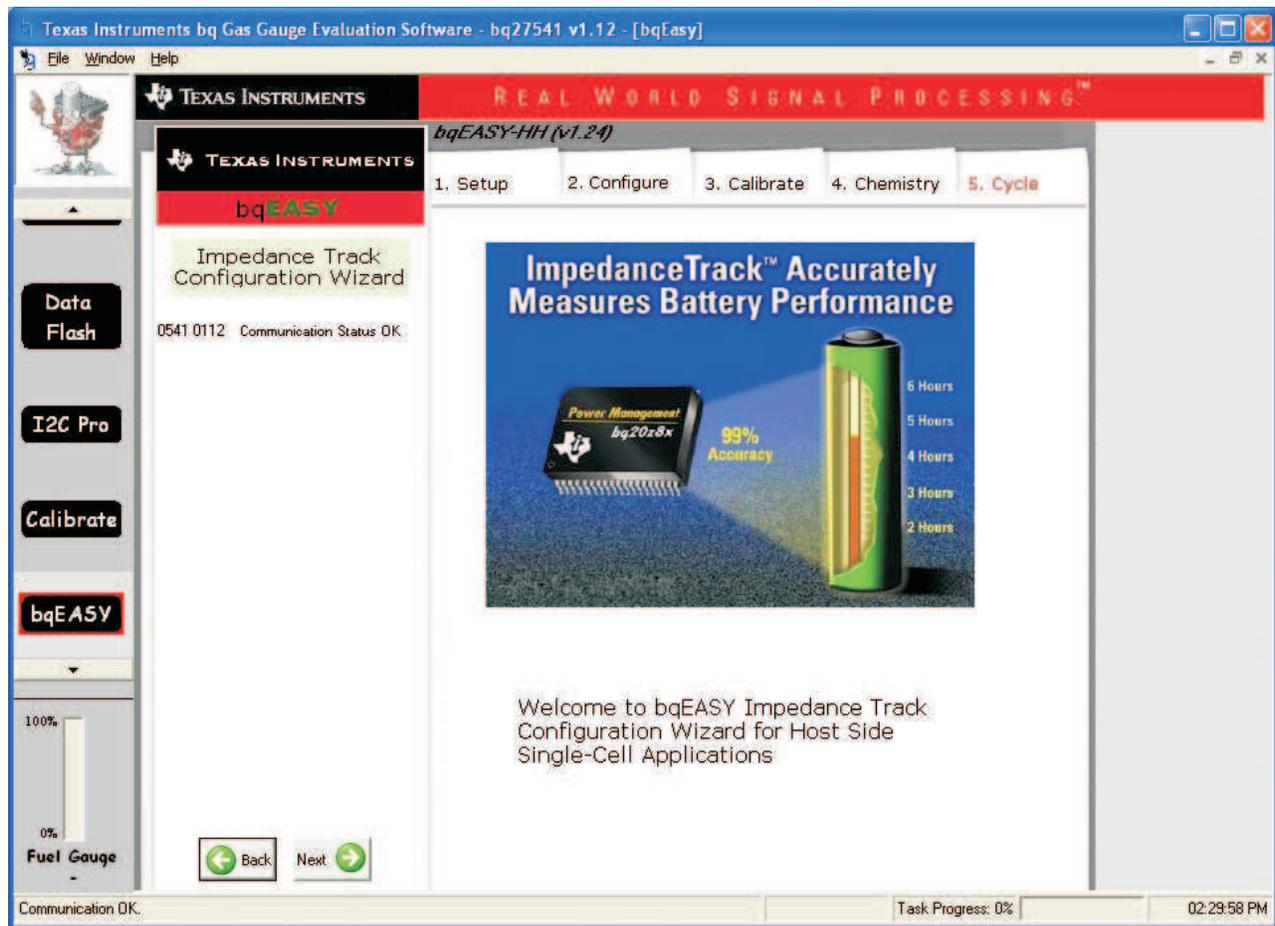
Figure 13. bqEasy Welcome Screen

12 Send HDQ Screen

To configure a bq27541 into HDQ mode, navigate to the *Send HDQ* screen. It is possible that all the screen options on the left are not visible depending on screen resolution. If needed scroll within the left menu to access the *Send HDQ* link. Click on the "Change comm to HDQ8" button while having the bq27541 connected to the EV2300 via I2C. Clicking on the button causes a message to appear indicating that the process is not reversible and to confirm if the actions are desired. Also, it explains what to do once the HDQ mode has been activated.

Once converting the bq27541 into HDQ mode, it is required that you connect the HDQ terminal of the EV2300 with the HDQ connector (J4) of the bq27541 EVM, then restart the EVSW, and select the "bq27541HDQR1" with the proper firmware version from the list of supported devices within the EVSW.
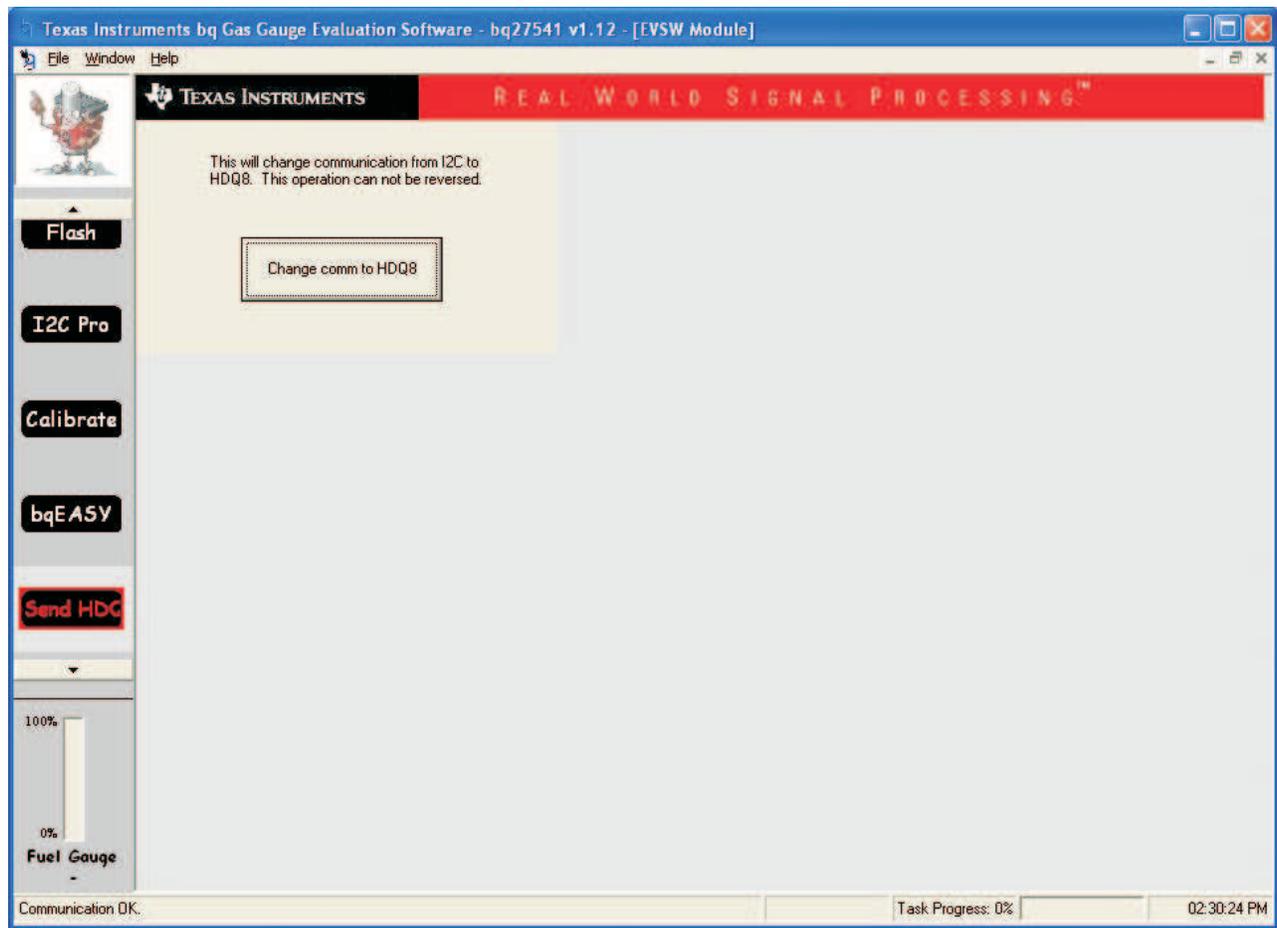
Figure 14. Send HDQ Screen

13 Related Documentation From Texas Instruments

- *bq27541, Single Cell Li-Ion Battery Fuel Gauge for Battery Pack Integration* data sheet (SLUS861)

EVALUATION BOARD/KIT IMPORTANT NOTICE

FCC Warning

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 6 V to 25 V and the output voltage range of 0 V to 16.4 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

IMPORTANT NOTICE