EVM User's Guide: BQ27Z846

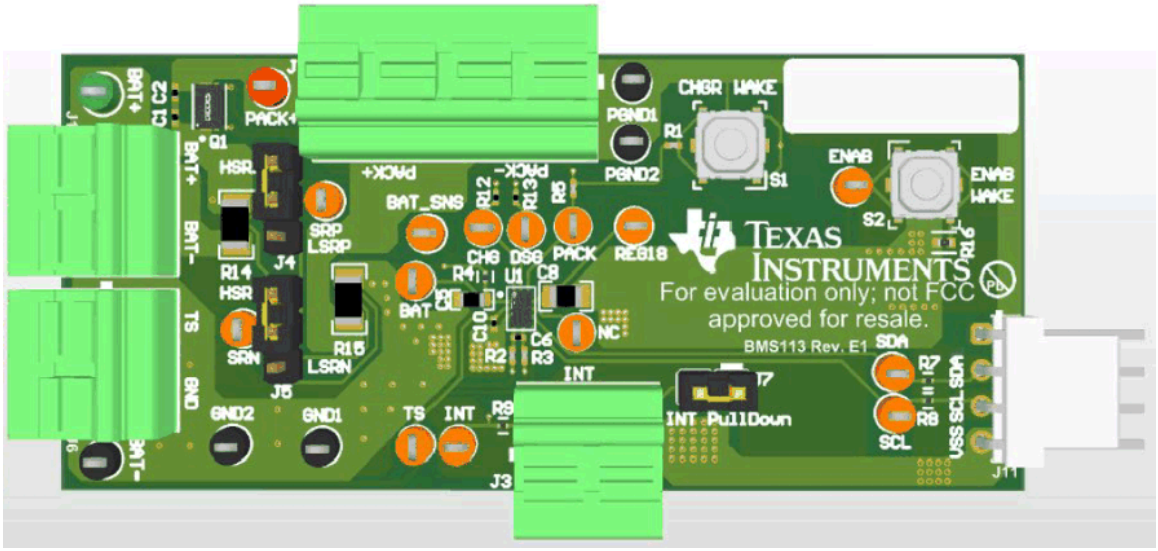
BQ27Z846 Single Cell Battery Fuel Gauge Evaluation Module

Description

The BQ27Z846 evaluation module (EVM) is a system-level board created to enable users to evaluate the functionalities of the BQ27Z846 fuel gauge within a system. The BQ27Z846 EVM is suitable for applications in which the battery pack is 1-S cell, meaning one series cell. The EVM includes a BQ27Z846 battery fuel gauge, a high-side and low-side current sense resistor, integrated high-side protections, an ENAB wake button, a charger wake button, and other header options to allow for some modifications to meet the intended application.

Features

- Complete evaluation system for the BQ27Z846 Li-Ion Battery Pack Manager Evaluation Module.
- Populated circuit module for quick setup
- Software that allows data logging for system analysis
- Integrated high-side and low-side current sense resistor
- Integrated high-side protections
- Dynamic Z-Track™ algorithm



Note

This EVM is intended for basic product functionality evaluation and does not reflect the full performance capacity of the device. This EVM is not designed to be included in part of the manufacturing cycle.

1 Evaluation Module Overview

1.1 Introduction

The BQ27Z846EVM comes with the BQ27Z846 integrated gas gauge and protection IC with external high-side protection N-Channel FETs. This user's guide gives directions for the following tasks:

- Connect the necessary components together to power up the EVM
- Installation of the necessary Texas Instruments software tools
- Setup of the EVM with additional hardware and software
- Calibrate the BQ27Z846 voltage and current readings
- Perform the Chemical ID selection process
- Optimize gauge reporting with a Learning Cycle
- Create and upload a Golden Image
- Use Advanced Communication with the gauge

These tasks direct the user of the BQ27Z846EVM through the process required to prepare for production with the BQ27Z846 by creating a "Golden Pack". A Golden Pack is a single gauge and battery that has had optimization and configuration processes performed during the development stage. The resulting values are extracted from the Golden Pack gauge into the "Golden File" or "Golden Image". The Golden File is a flash image programmed into every gauge used in mass production because there is minimal pack-to-pack variation during a well-controlled manufacturing process. The Dynamic Z-Track algorithm enables the gauge to continue to learn once a pack is deployed to account for manufacturing differences, field conditions, and lifetime battery degradation.

1.2 Kit Contents

- BQ27Z846 evaluation module
- Cable to connect the EVM to an EV2400 communications interface adapter

1.3 Specifications

Table 1-1. Performance Specification Summary

BQ27Z846 Specification	Min	Typ	Max	Units
Input Voltage Pack+ to Pack-	–0.3		24	V
Input Voltage Bat+ to Bat-	–0.3		6.0	V
Hardware Protection Specification				
Overvoltage protection	3500	4300	5000	mV
Undervoltage protection	2000	2300	4000	mV
Overcurrent in charge protection	4	14	100	mV(1)
Overcurrent in discharge protection	–4	–16	–100	mV(1)

(1) Based on 1mΩ sense resistor.

1.4 Device Information

EVM part Number	Chemistry	Configuration	Capacity
BQ27Z846EVM	Li-ion	Single cell	Any

For information on device firmware and hardware, see the BQ27Z846 Dynamic Z-Track™ Gauge with Integrated Protection and Authentication for 1 Cell Battery Packs datasheet and the BQ27Z846 Technical Reference Manual.

2 Hardware Setup

The BQ27Z846 with integrated protection module requires hardware connections for using the evaluation module and creating a Golden File.

2.1 Hardware Requirements

The following hardware is required to complete the steps for creating a Golden File outlined in this guide:

- A PC with Windows® 10 or later
- EV2400 and USB cable
- BQ27Z846 Evaluation Board (EVM)
- Constant-Voltage and Constant-Current Power Supply (preferable 1mV and 1mA accuracy for the power supply)
- Single-cell battery (Golden Pack battery identical to those to be used in production)

2.2 Connecting the BQ27Z846 Circuit Module to a Battery Pack

Figure 2-1 shows how to connect the BQ27Z846 circuit module to the battery, personal computer (PC), and a system load/charger.

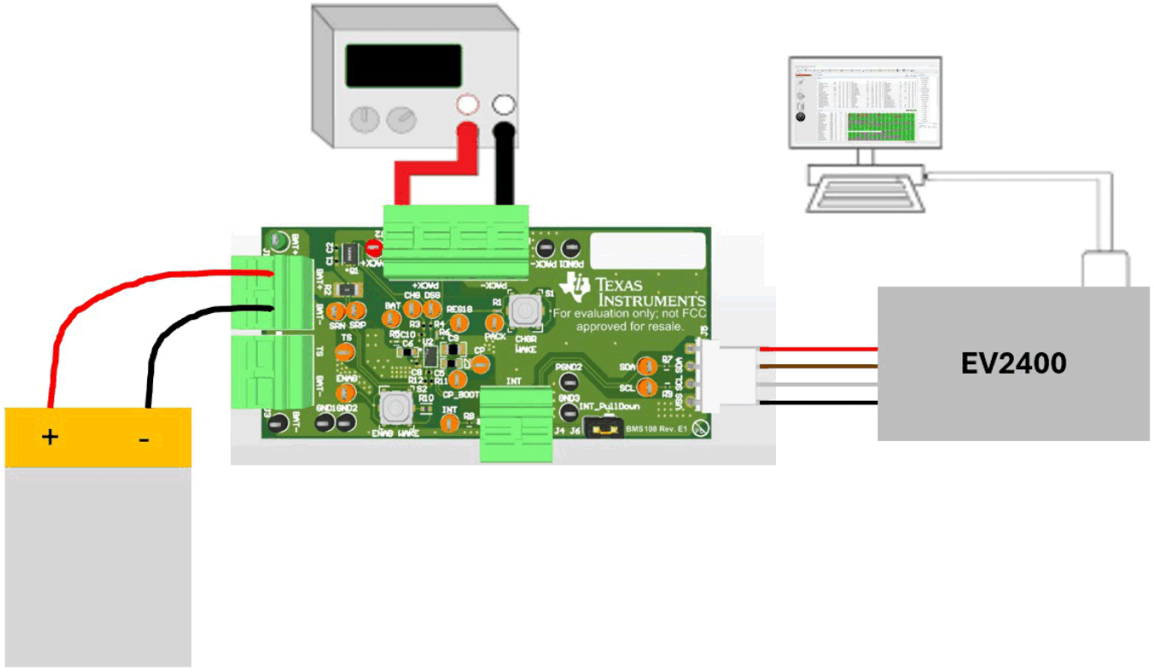


Figure 2-1. Connect the BQ27Z846 Circuit Module to a 1Sx1P

2.3 EVM Jumpers and Terminal Block Description

The following section describes the configurable jumpers and terminal blocks and their purpose on this board:

1. J1 – Battery Input: This terminal block is the input for the positive and negative leads of your 1SXP battery pack.
2. J2 – Charger/Load Connection: This terminal block is the input/output for the charger/load. Two of the connections are for PACK- and two of the connections are for PACK+.
3. J3 – Interrupt Pin Output (INT): This terminal block connects to the INT pin of the BQ27Z846. Both connections on this terminal block connect to the INT pin.
4. J4 - Current Sense Resistor Positive Input (SRP): This jumper selects high-side or low-side current sensing for the SRP pin of the BQ27Z846. Install this shunt in the "LO" position for low-side current sensing or "HI" position for high-side current sensing. This shunt must be in the same position on both J4 and J5 jumpers.
5. J5 - Current Sense Resistor Negative Input (SRN): This jumper selects high-side or low-side current sensing for the SRN pin of the BQ27Z846. Install this shunt in the "LO" position for low-side current sensing or "HI" position for high-side current sensing. This shunt must be in the same position on both J4 and J5 jumpers.
6. J6 – External Temperature Sensor Connection: This terminal block connects one lead of an external temperature sensor to the TS pin of the BQ27Z846 and the other lead to BAT- (GND). An external temperature sensor must be present for the gauge to report an accurate temperature if the gauge is configured for an external temperature measurement. Refer to the BQ27Z846 Technical Reference Manual for directions on how to configure the BQ27Z846 for an external temperature sensor.
7. J11 – I2C Header Connection: This connector is used for I2C communication with the BQ27Z846 and is used to interface with the EV2400.

3 Software Setup

This section describes the installation of the BQ27Z846EVM PC software, and how to connect the different components of the EVM.

3.1 System Requirements

The bqStudio software requires Windows 7 or later. Using earlier versions of Windows operating system may not work with the USB driver support.

3.2 Software Installation

Find the latest software version of bqStudio-test and the EV2400 driver on ti.com. Search for the BQ27Z846 part number to get to the tool folder for the device. Following these steps to install the BQ27Z846 bqStudio software.

1. Run the Firmware updater tool installer. Take note of the location where the Firmware Updater tool is installed on the computer.
2. Connect the EV2400 that is to be updated to the computer.
3. Verify that no other EV2400 is connected to the computer being used for the firmware update.
4. Go to the location of the Firmware Updater tool installed. Run the Firmware Updater tool.
5. The updater tool detects the connected EV2400, displays the current firmware version, and prompts the user to continue to update the EV2400 firmware.
6. Type Y and press Enter.
7. The Firmware Updater tool places the EV2400 into FW Update mode, performs a mass erase of the older version of EV2400 firmware, programs the EV2400, and then resets the device. The tool prompts the user to continue when finished.
8. Press Enter to close the Firmware Updater tool.
9. Unplug the EV2400 from the personal computer (PC).
10. Open the archive containing the installation package of bqStudio and copy the contents into a temporary directory.
11. Rename any previous Battery Management Studio folder by adding a version to the end.
12. Open the bqStudio installer file that was downloaded from the TI website.
13. Follow the instructions on-screen until completing the software installation.
14. Before launching the evaluation software, connect the EV2400 USB cable to the computer and I2C port to the EVM board (J11).

Note

Keep the EV2400 plugged into the computer during the entire firmware updating process.

3.3 Updating Firmware

Find the latest firmware version in the appropriate BQ27Z846 folder on www.ti.com. Use the following steps to install the BQ27Z846 Battery Management Studio software:

1. Run Battery Management Studio from the Start | Programs | Texas Instruments | Battery Management Studio menu sequence, or the Battery Management Studio shortcut.
2. Follow the directions in Programming Screen, select the firmware .bq.fs file downloaded from www.ti.com, and click the Program button.
3. Once programming is finished, restart Battery Management Studio, then the EVM is ready to use with the latest firmware.

3.4 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. If using Windows 7, install the software with administrator privileges.

3.5 Using bqStudio

This section details the operation of the BQ27Z846 with the bqStudio software.

3.5.1 Starting the Program

Run bqStudio from the desktop. The window consists of a tools panel at the top, and other child windows that can be hidden, docked in various positions or allowed to float as separate windows. When bqStudio first starts up, the main window displays the Gauge Dashboard window, the Registers window, and Data Memory window. Registers, Data Memory, Commands, and other windows can be added to the main window by clicking on the corresponding icon in the tools panel at the top of the main window.

The data appears initially in the Gauge Dashboard, Registers and Data Memory sections. Click the Refresh (single time scan) or the Scan (continuous scan) buttons to update the data in the Registers and Data Memory windows. Continuous scan is enabled when the Scan checkbox is highlighted green and disabled when the Scan checkbox is not highlighted. Set the continuous scanning interval with the stopwatch icon next to the Scan button. When the stopwatch icon is clicked, a drop-down menu appears, and the desired scanning interval can be selected. The scan interval value appears next to the stopwatch icon.

Another way to collect a log file is through the Registers page. To start a log file the "Start Log" button can be pressed, then the desired file name and file location can be chosen. The log file will periodically log everything present in the Registers page.

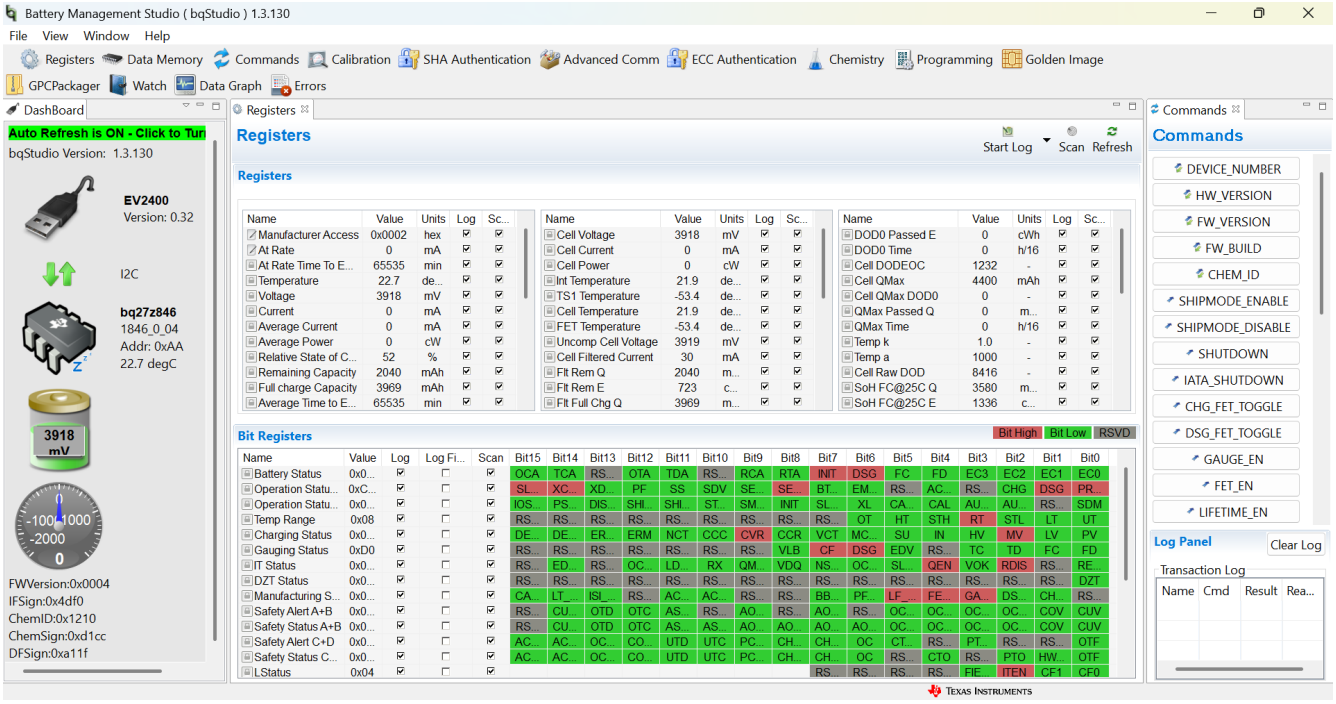


Figure 3-1. Register Screen

Figure 3-1 shows the main bqStudio window. Additional Flag and Control Status data can be viewed at the bottom of the registers window.

3.5.2 Setting Programmable BQ27Z846 Options

The BQ27Z846 comes configured in accordance with the default settings detailed in the BQ27Z846 technical reference manual. Verify that the settings are correctly changed to match the pack and application for the BQ27Z846 design being evaluated.

Note

The correct setting of these options is essential for best performance. Configure these settings using the Data Memory window seen in the main bqStudio window (Figure 3-2).

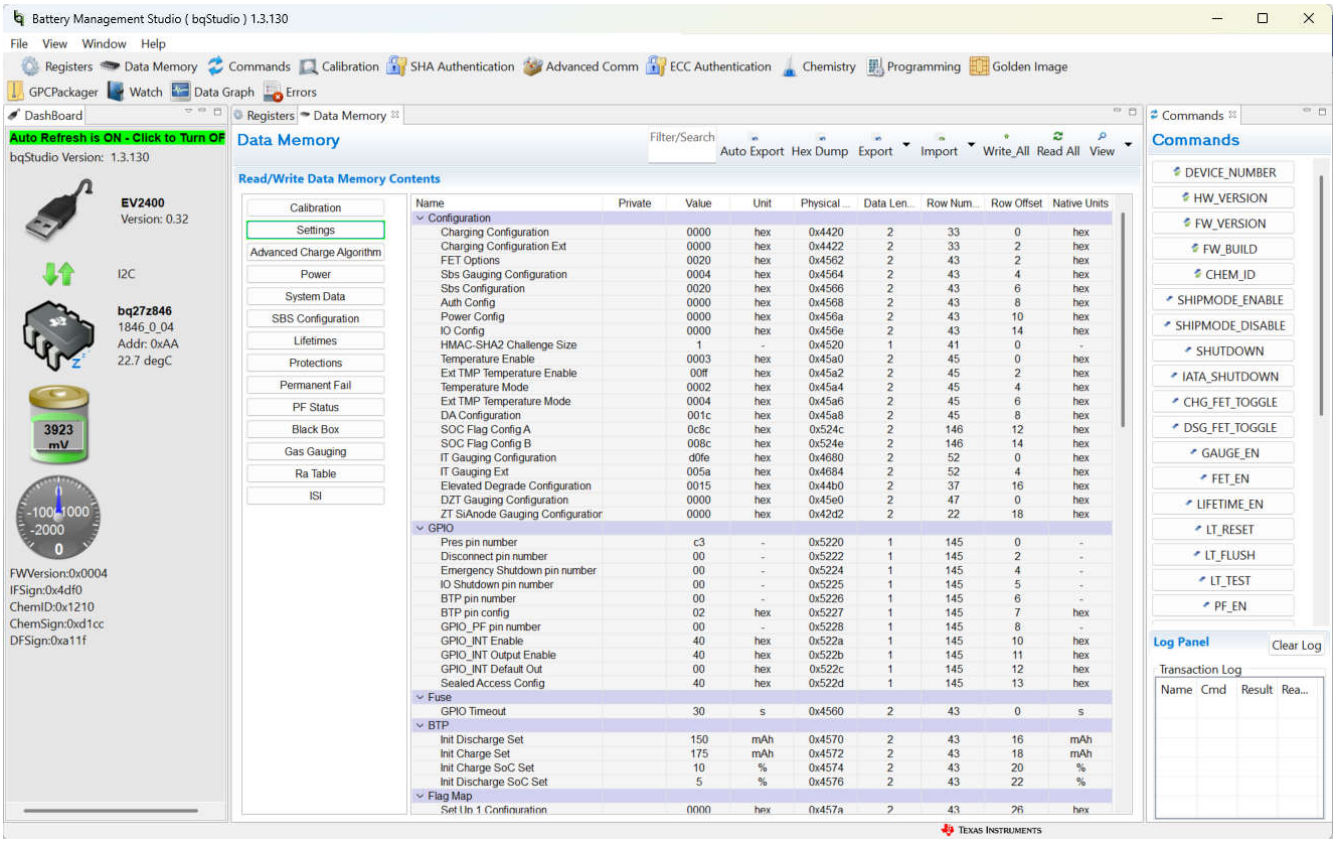


Figure 3-2. Data Memory Screen

To read all of the data from the BQ27Z846, click the Read All button in the Data Memory window. For ease of configuration, a text file with a .gg.csv extension can be extracted, modified, and imported back onto the device. Use the export and import buttons as seen in Figure 3-2 to export and import .gg.csv files. The auto export button enables gg files to be exported periodically at intervals. This feature is useful when debugging issues with the gauge. A write command is necessary if a .gg.csv file is imported so that all changes made on the .gg.csv file are affected on the gauge. Use the read command to read back all the data written to the gauge to verify the changes were made. The filter/search field enables the user to search for a particular parameter in the data memory content.

Note

Do not make modifications to the .gg.csv file using Microsoft Excel because the software makes changes to the file, which bqStudio rejects. Make sure to use a text editor like notepad or similar to edit a .gg.csv file.

4 Calibrating Gauge Measurements

This section describes the process of using bqStudio and the hardware setup required to calibrate the voltage and current readings of a gauge. Having a calibrated gauge is important for rest of the processes inside of this guide.

4.1 Voltage Calibration

Set up the EVM and other hardware as pictured in Figure 2-1. The BAT pins can be connected to a battery or a power supply, but the voltage of this source must be known to millivolt precision for accurate calibration. Inside of bqStudio, navigate to the Calibration window. Then, as shown in Figure 4-1, enter the precise value of the voltage source used, check Calibrate Voltage, and then press the Calibrate Gas Gauge button.

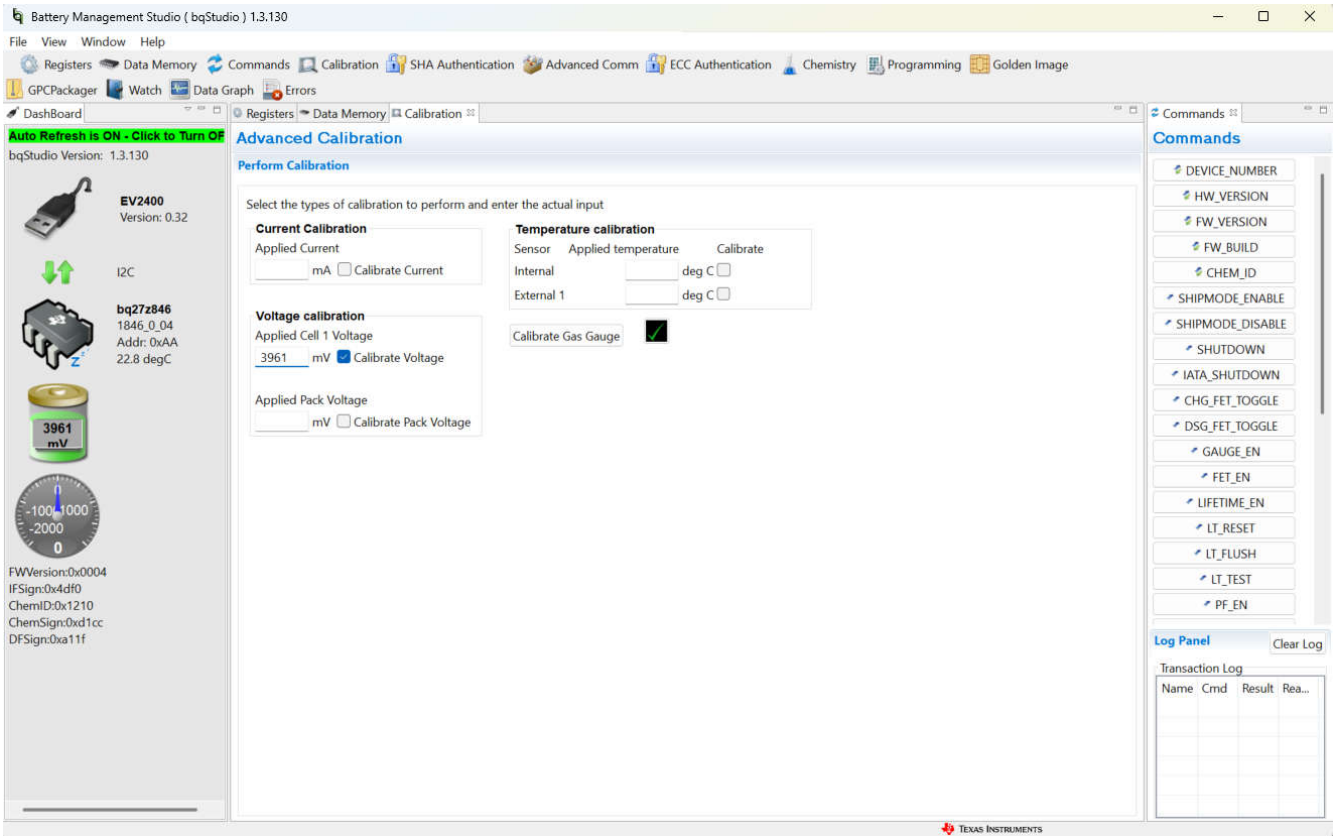


Figure 4-1. Voltage Calibration in bqStudio

4.2 Current Calibration

Set up the EVM, a voltage power supply (use a battery or a bench power supply), and a power supply capable of supplying a constant current with milliamp precision. Connect the constant-current supply to the BAT- and PACK- headers. The exact circuit layout is shown in Figure 4-2. The constant-current supply is shown as being attached to the test point of BAT- but can also be attached to the BAT- header, as well.

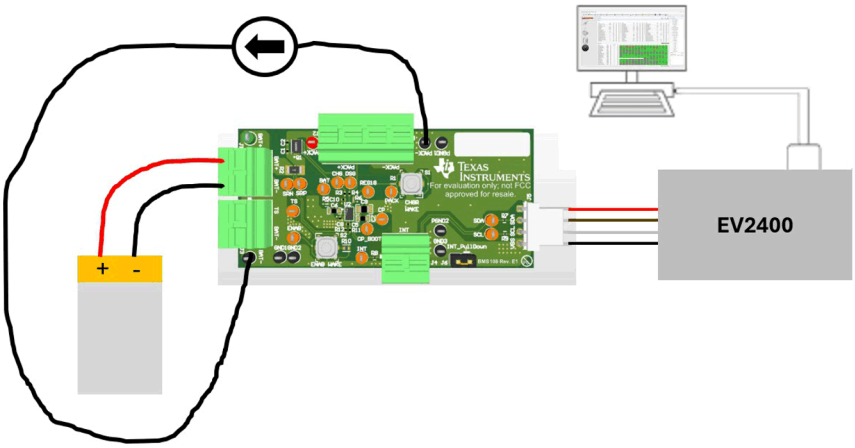


Figure 4-2. Current Calibration Hardware Setup

As shown in Figure 4-3, from the Calibration window in bqStudio, enter the precise value of current being supplied, click to check the Calibrate Current box, and then press the Calibrate Gas Gauge button.

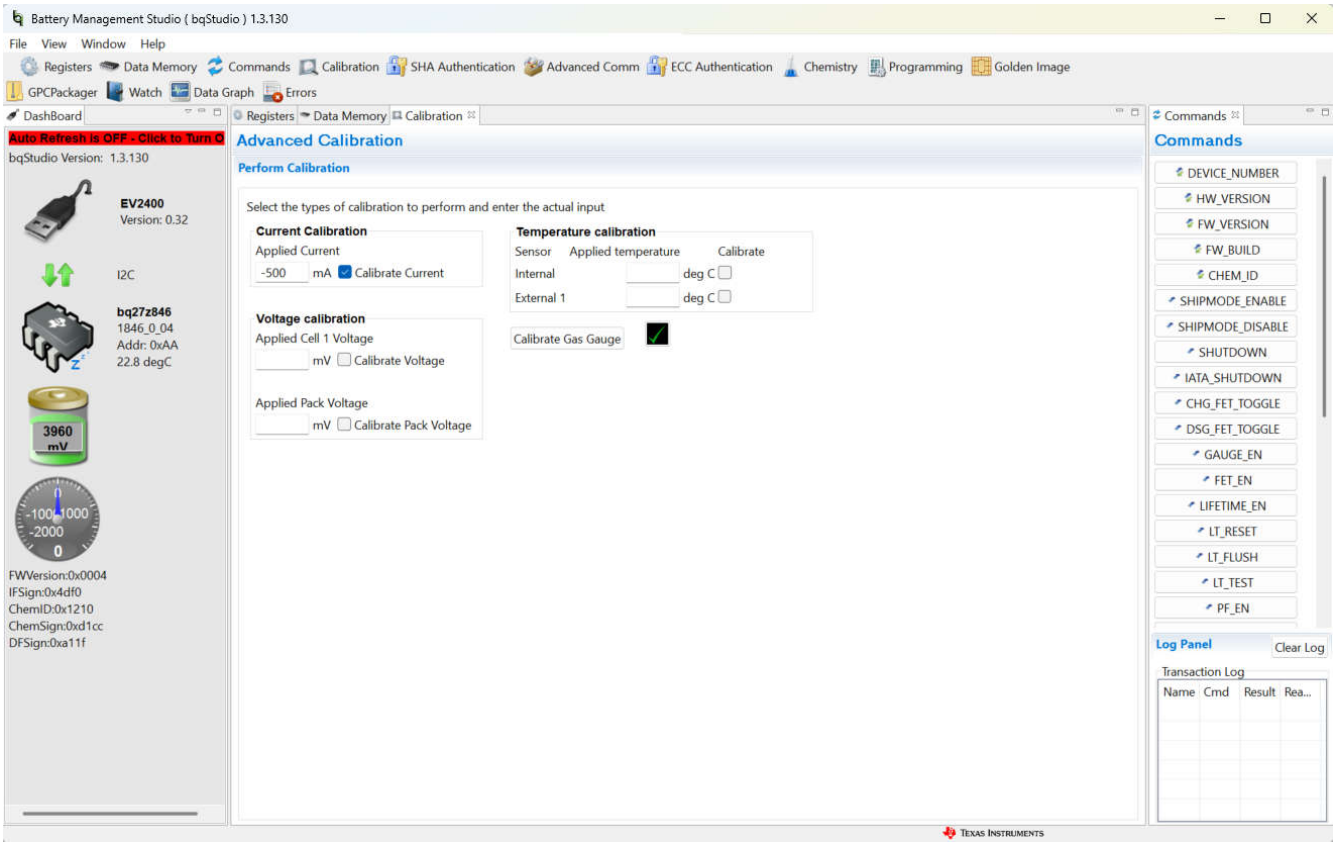


Figure 4-3. Current Calibration in bqStudio

5 Chemical ID

This section describes the process of finding the chemistry identifier, sometimes referred to as "Chemical ID" or "ChemID", of a battery that will be used. The ChemID is a necessary element of the Dynamic Z-Track algorithm that needs to be identified before performing a learning cycle. For the Golden File creation process, this battery must be the same type as the battery that will be used in production. Also use this battery for the proceeding sections.

Texas Instruments has a database of thousands of battery profiles, and the ChemID selection process identifies the exact battery profile or the most similar profile. This ChemID is programmed into the gauge, updating dataflash with the battery profile. The IT algorithm uses this profile for capacity learning, resistance learning, capacity prediction, and other features.

The Chemical ID selection process consists of recording the current, voltage, and temperature (IVT) of a battery during a charge and discharge. This data is submitted to the online Gauging Parameter Calculator (GPC) Tool, which gives the customer a report with a best-fit Chemistry ID to program into their gauge. The process performed with this hardware is a charge-relaxation-discharge-relaxation test. A programmable power supply is recommended for this process.

5.1 Chemical ID Selection Process

The test consists of the following steps:

1. Test is performed at room temperature. If the cell was at a different temperature, let the cell relax for two hours at room temperature prior to the test.
2. Charge using CC or CV charging to full using taper current (for example, C/100). Use nominal CC charge rate and CV voltage. If another charging method is specified by the cell maker, use that method.
3. Let the battery relax for two hours to reach full equilibrium open circuit voltage (OCV).
4. Discharge the battery at C/10 rate until the minimal voltage (as specified by the cell manufacturer) is reached.
5. Let the battery relax for five hours to reach full equilibrium OCV.

Figure 5-1 shows an example of what this process looks like graphically.

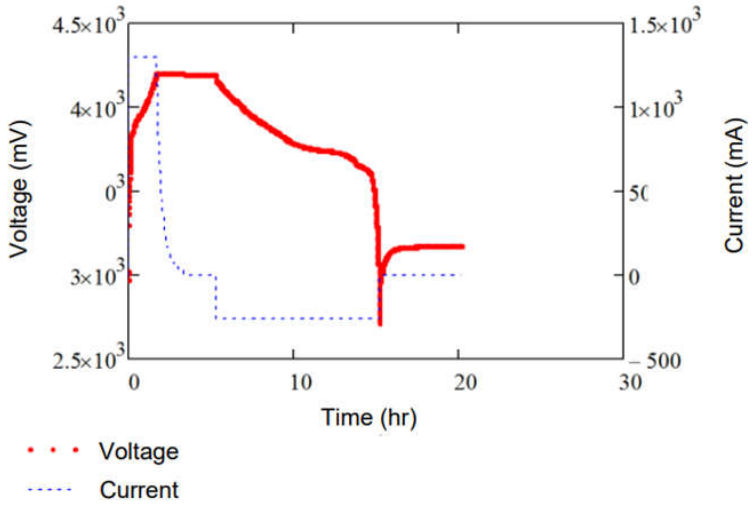


Figure 5-1. Graph of IV Data in Charge-Relax-Discharge-Relax

5.2 Hardware Requirements and Setup

Performing the charge and discharge cycle and recording the IVT characteristics of a battery can be done using a battery, a constant-voltage and constant-current power supply, bqStudio, and a BQ27Z846EVM.

Start by setting this hardware up as shown in Figure 5-2. This setup is identical to Figure 2-1.

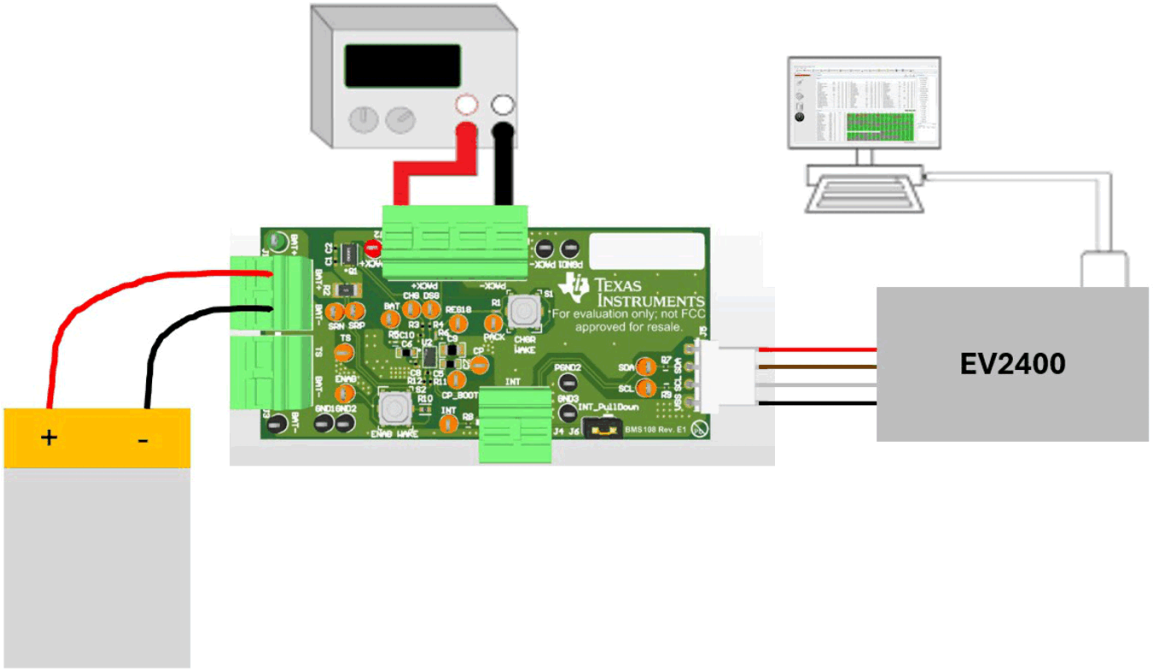


Figure 5-2. ChemID Hardware Setup

5.3 Logging Data in bqStudio

The recording of voltage, current, and temperature can be done with bqStudio. The logging functionality in bqStudio allows a constant capture and recording of the registers of a connected gauge. The default elapsed interval is 4000 milliseconds.

To change this interval:

1. Go to Window
2. Select Preferences
3. Choose Registers
4. Change Scan/Log Interval from 4000 to a minimum of 1000 milliseconds

There is no need to log faster than one second because the gas gauge updates the registers once every second.x

To begin recording the battery's IVT properties during charge and discharge, use the Start Log button on the Registers window in bqStudio as shown in Figure 5-3.

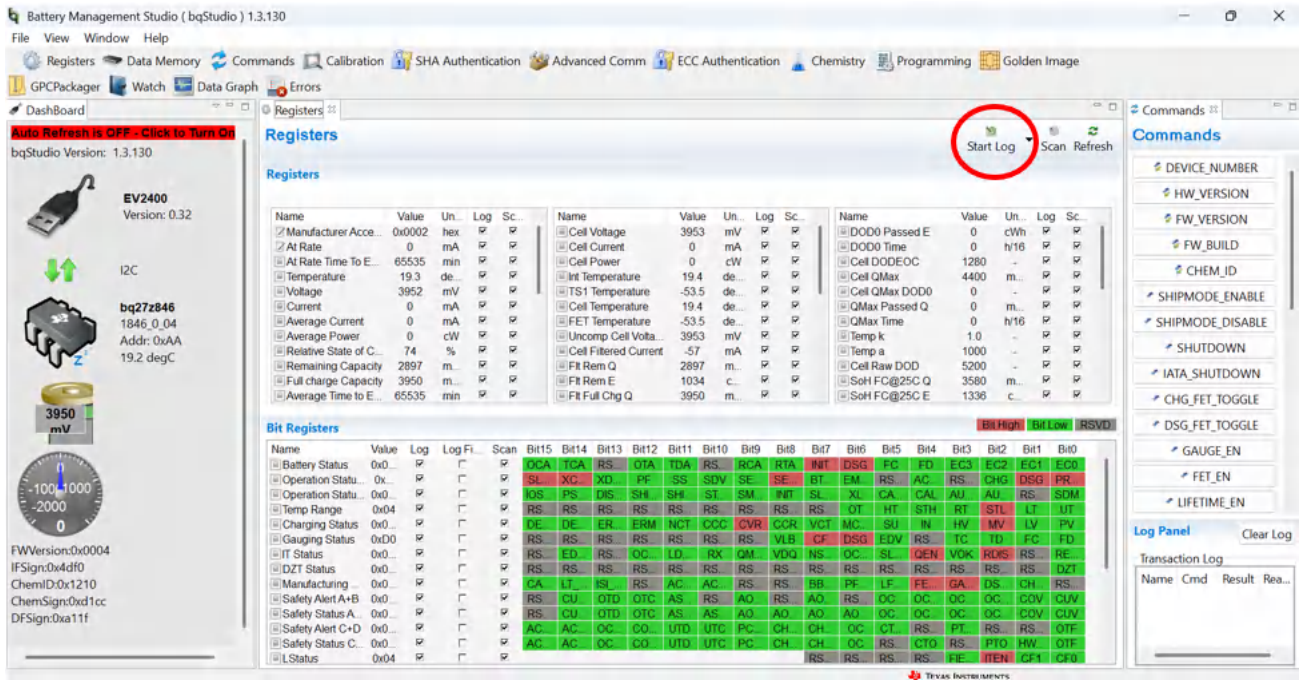


Figure 5-3. Start Log Button in bqStudio

Upon pressing the Start Log button, a prompt to select a location for the .log file to save is shown. Select a location to save this file. The .log file type can be changed to the .csv format and viewed inside of Microsoft Excel™ or a similar application to facilitate debugging of the register states through the course of the logging period. At the end of the relaxation period after the gauge has been allowed to discharge, use the Stop Log button in bqStudio to end logging.

5.4 GPCCHEM Tool

Convert the .log file to a .csv file by renaming the file format. Create a blank .csv file and copy into the first, second, third, and fourth columns the time, voltage, current, and temperature, respectively. Verify that the units for each column are seconds, millivolts, milliamps, and Celsius. The first row can be names for each of the columns, which the tool skips assuming there is only one row of names before the data begins. Figure 5-4 is an example of the required .csv file formatting as well as the first few rows of data.

	A	B	C	D
1	ElapsedTime (sec)	Voltage (mV)	Current (mA)	Temperature (°C)
2	1.01	3950	0	19.6
3	2.401	3950	0	19.6
4	3.766	3950	0	19.6
5	5.156	3950	0	19.7
6	6.485	3950	0	19.7
7	7.949	3950	0	19.7
8	9.21	3950	0	19.7
9	10.405	3950	0	19.7
10	11.838	3950	0	19.7
11	13.138	3950	0	19.7
12	14.374	3950	0	19.7
13	15.738	3950	0	19.7
14	16.994	3950	0	19.7
15	18.263	3950	0	19.7
16	19.573	3950	0	19.7
17	20.704	3950	0	19.7
18	22.06	3950	0	19.7
19	23.326	3950	0	19.7
20	24.649	3950	0	19.7
21	25.878	3950	0	19.7
22	27.091	3950	0	19.7
23	28.389	3950	0	19.7

Figure 5-4. Cell Formatting for .csv

1. Save this created file with the name "roomtemp_rel_dis_rel.csv".
2. Create a second file "config.txt" and write the following:
   a. ProcessingType = 2
   b. NumCellSeries = 1
   c. ElapsedTimeColumn = 0
   d. VoltageColumn = 1
   e. CurrentColumn = 2
   f. TemperatureColumn = 3
3. Create a folder with any name. Put both the roomtemp_rel_dis_rel.csv and config.txt files in this folder, and convert the folder to a .zip file. Submit this .zip file to the GPC Tool through the web interface found on ti.com.

After processing, an e-mail with a report that indicates the results of the process of the tool is sent to the e-mail address you provided when logging into ti.com to use the GPC Tool. The report contains the selected ChemID and a list of additional ChemIDs that satisfy the "less than 3%" error criteria. For example, this report can be useful to verify that a ChemID used previously is still suitable. The report shows any formatting mistakes or other errors.

5.5 Programming a Chemical ID

The ChemID is programmed into the gauge using bqStudio. Navigate to the "Chemistry" window in bqStudio. A view of this window is shown in Figure 5-5.

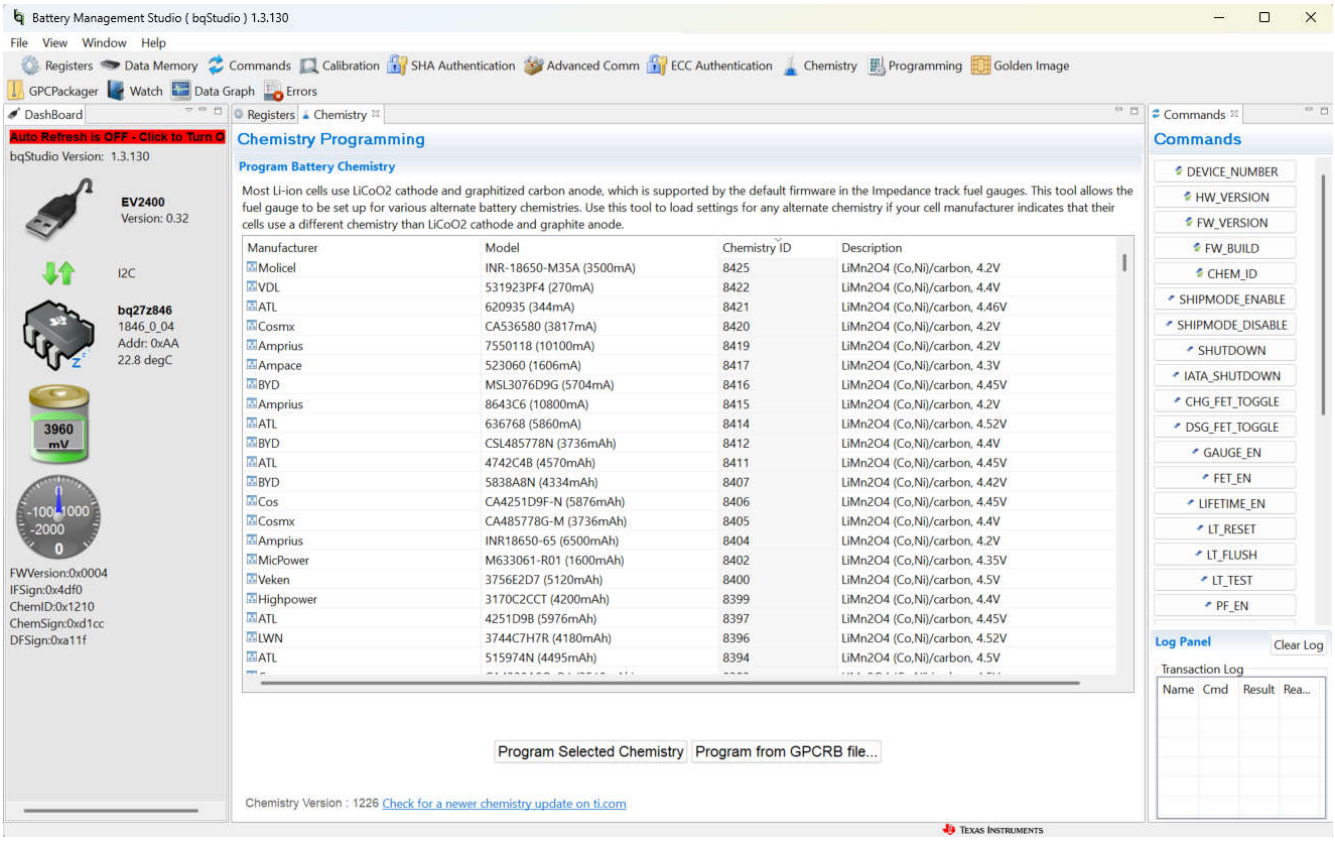


Figure 5-5. Chemistry Window View in bqStudio

Sort by a given parameter by clicking the top of that column once. Consider sorting the table by Chemistry ID so that the ChemIDs are ordered numerically. Scroll down to the Chemistry ID that was reported as the best fit in the GPC Tool report, select this Chemistry ID, and then press the Program Selected Chemistry button.

If you do not see your Chemistry ID in this list, update the Chemistry version in bqStudio. To do so, see to the gas gauge chemistry resources found on ti.com.

Once the gauge is programmed with this chemistry, the ChemID can be confirmed by pressing the CHEM_ID button in the Commands window, shown on the right side of Figure 5-5. Check the Log Panel window,

5.6 Further Resources for Chemical ID Process

For further details and more instruction on finding a Chemistry ID with the GPC Tool, refer to the "Simple Guide to Chemical ID Selection Tool (GPC) (Rev. A)" document found on ti.com.

6 Learning Cycle and Golden Image

The learning cycle process is the initial optimization that Dynamic Z-Track™ gauges perform to support the accuracy of the gauge in reporting state of charge. The learning cycle allows the gauge to learn a specific battery's resistance and maximum chemical capacity, helping to maintain accuracy as the cell ages. Identifying and programming a correct ChemID, with less than 3% of error, into the gauge before attempting a learning cycle is necessary

6.1 Learning Cycle Process Description

The learning cycle process consists of charge – relaxation – discharge – relaxation – charge while certain data memory parameters are set in the gauge, enabling the gauge to begin the cycle and accurately recognize when state changes have occurred over the charge/discharge process. Through the course of the learning cycle, the [LStatus] register updates as different states are achieved, marking three points in the progression of the learning cycle.

The first [LStatus] update goes from 0x00 to 0x04 when the gauge has had the Impedance Track™ bit enabled, allowing the learning cycle to begin. [LStatus] goes from 0x04 to 0x05 when the post-charge relaxation has allowed the battery to relax enough so that the change in voltage is very low (dV/dt < 1µV/s). The [REST] flag will be set indicating that the battery has adequately relaxed. The final [LStatus] update to 0x06 happens after the second discharge when the change in voltage is very low.

For more details on the register updates and flags set at each point in the learning cycle, see the *Learning Cycle Procedure* section of the Achieving the Successful Learning Cycle application note.

For more details on the learning cycle registers, see the *Gauging* chapter of the *BQ27Z846 Technical Reference Manual*.

6.2 Data Memory Configuration

The data memory of the gauge is configured in bqStudio from the Data Memory window. Figure 6-1 shows the Data Memory window.

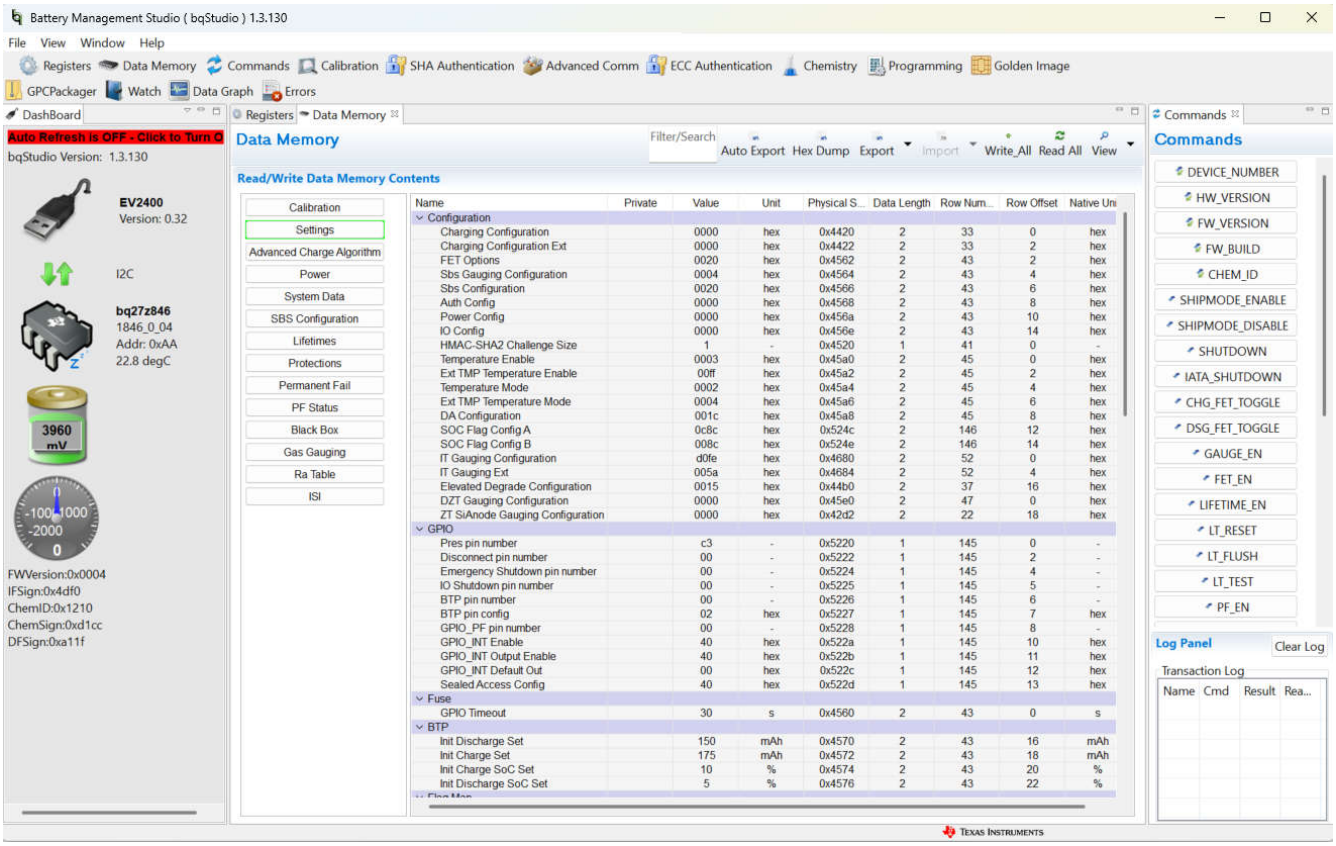


Figure 6-1. Data Memory View in bqStudio

Make the necessary data memory configurations in the [Advanced Charging Algorithm] and [Gas Gauging] sections of the data memory window. Use the Filter/Search box to find specific parameters. Use the Write All button to write data memory parameters that have been changed on this screen to the gauge. Use the Read All button to read the current data memory configurations from the gauge and verify a successful write. Verify that each value is programmed in the correct unit, indicated in the third column for each data memory parameter.

Program the following data memory values:

- [Advanced Charging Algorithm][Termination Config][Charge Term Taper Current]: Set this value slightly higher than the actual taper current between C/10 and C/100. Also, set this value higher than the [Chg Current Threshold] value.
- [Gas Gauging][Design][Design Voltage]: This value can be found in the battery data sheet as the nominal or average voltage.
- [Gas Gauging][Design][Design Capacity mAh]: This value can be found in the battery data sheet as battery capacity and is often referred to as C.
- [Gas Gauging][Design][Design Capacity cWh]: This value is the battery capacity in centiwatt hours. Find this value in the battery datasheet or by multiplying the capacity in mAh by the terminal voltage in Volts, then dividing by 10.
- [Gas Gauging][IT Cfg][Term Voltage]: Find this value in the battery datasheet as the terminal voltage. This value is the lowest voltage to charge the gauge.
- [Gas Gauging][Current Thresholds][Dsg Current Threshold]: This current value is where the gauge recognizes that the battery is being discharged. Set this value below C/10, as a positive number. The gauge interprets the value as a negative.
- [Gas Gauging][Current Thresholds][Chg Current Threshold]: This current value is where the gauge recognizes that the battery is being charged. Set this value below C/10 and also lower than the Charge Term Taper Current.
- [Gas Gauging][Current Thresholds][Quit Current Threshold]: This value is where the gauge enters relax mode. Set the value less than C/20 and lower than the [Dsg Current Threshold] and [Chg Current Threshold].

Figure 6-2 shows a visual representation of the current during the course of a learning cycle relative to the data memory current parameters set.

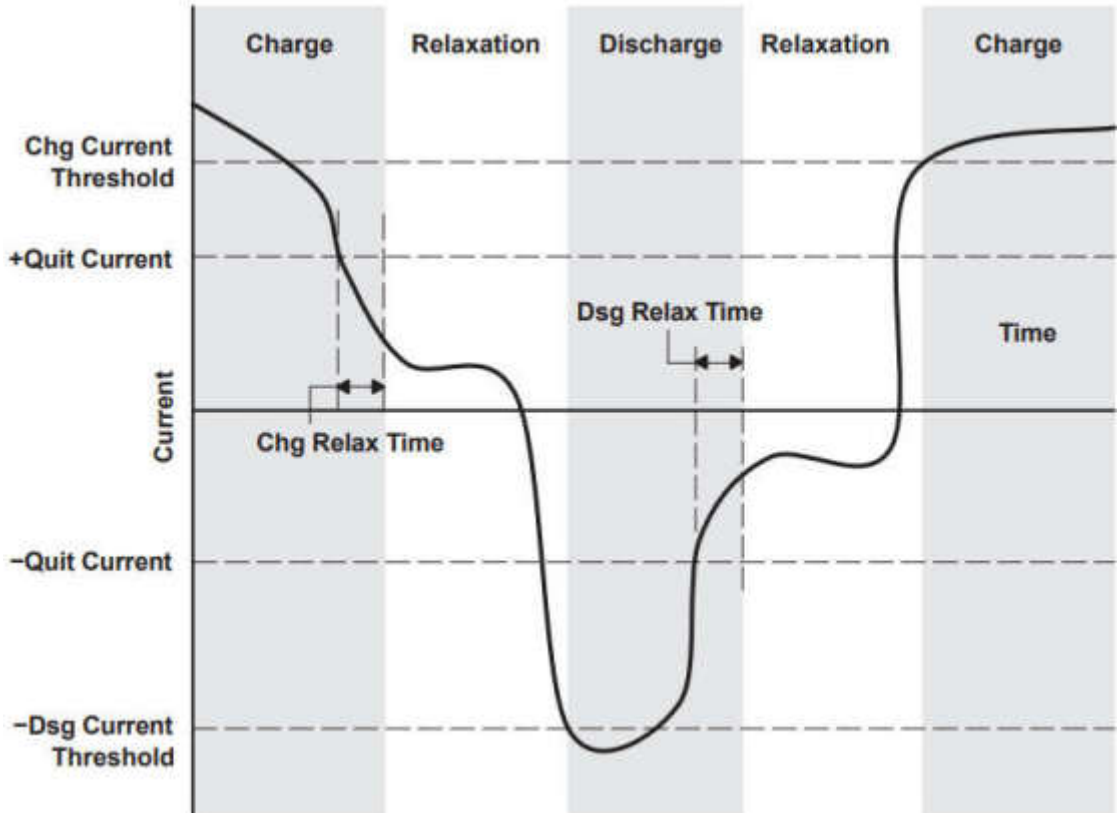


Figure 6-2. Graph of Learning Cycle Current

6.3 Learning Cycle Steps

The hardware setup for performing a learning cycle consists of the same setup as used in the Chemical ID process. This setup is described in Section 5.2 and shown in Figure 5-2. The charging and discharging process is very similar to a ChemID, except the first step is an initial discharge of the battery to the terminal voltage.

Before beginning the learning cycle process, start a log in bqStudio to debug any issues that occur during the learning cycle.

Conducting a learning cycle consists of the following steps:

1. Test is performed at room temperature. If the cell was at a different temperature, let the cell relax for two hours at room temperature prior to the test.
2. Use the GAUGE_EN command in the Command window. Use the RESET command in the Command window. Confirm that the [LStatus] register has updated to 0x04.
3. Discharge the battery at C/5 until the battery reaches Term Voltage.
4. Relax the battery for five hours.
5. Charge using CC until the battery reaches the Full Charge Voltage.
6. Charge using CV at the Full Charge Voltage. Cut off CV charging at a point in between [CHG Current Threshold] and [Quit Current Threshold].
7. Let the battery relax for two hours to reach full equilibrium open circuit voltage (OCV). The [LStatus] register updates to 0x05.
8. Discharge the battery at C/10 rate until the [Term Voltage] is reached.
9. Let the battery relax for five hours to reach full equilibrium OCV. The [LStatus] register updates to 0x06.

6.4 Low Temperature Optimization

Gauge State of Charge (SOC) reporting often loses accuracy in low temperatures due to higher cell impedances. Impedance Track gauges allow SOC reporting to be improved significantly for gauges that will experience low temperatures by using the GPCRB Tool. This simple test requires a similar process to the Chemical ID process but adds a much greater degree of accuracy for low temperature gauging.

The test setup required to use the GPCRB Tool is very similar to the setup shown in Figure 5-2. The only difference is that the EVM thermistor must be connected to the surface of the battery and a temperature-controlled chamber, such as Arbin or Maccor, is required to create a low-temperature environment where the gauge can monitor the IVT characteristics of the battery.

For more information about this process, see the GPCRB tool page.

6.5 Creating the Golden Image File

The current EVM has completed all optimization steps at this point. The Golden Gauge can program all other gauges in production using a Golden Image and means that all gauges start with an accurate starting point to begin reporting on and further learning about battery chemistry.

To get the necessary file for programming gauges, follow these steps:

1. Navigate to the Programming window in bqStudio.
2. Choose the output directory and file name for the Golden Image under the "Path for combined .bq.fs:" row, this becomes the .bq.fs file that contains the encrypted firmware and the custom configuration in data flash.
3. Choose the input directory and .bq.fs file for the encrypted firmware downloaded from ti.com under the "Path for encrypted .bq.fs:" row.
4. Select "Read FS from DM" to create the combined .bq.fs Golden Image file that can be programmed onto other battery packs in production

6.6 Programming the Golden Image File

An exported Golden Image file can be uploaded to another gauge in bqStudio or through custom production processes. To upload a Golden Image file to a new gauge in bqStudio, connect the new gauge to bqStudio and open the Programming window. Click Browse and navigate to and select the Golden Image file, or enter the Golden Image's file address. Click Program to upload Golden Image files to the gauge.

To use Golden Image files in production, the .bq.fs file format is recommended. For further guidance on using the .bq.fs file format, refer to Section 7 Section 5 of the "Gauge Communication" document found on ti.com.

7 Gauge Communication

This section introduces host-processor communication with the BQ27Z846. The BQ27Z846 gauge uses an I2C communication interface with communication speeds up to 1MHz. Further hardware and software specifications for the I2C interface for this gauge can be found in the device-specific data sheet and the BQ27Z846 Technical Reference Manual.

7.1 Advanced Communication in bqStudio

To communicate with the gauge in bqStudio, navigate to the Advanced Communication window. This window allows the user to send read and write commands to the gauge for easy communication with the gauge over I2C. The I2C Address of the gauge, visible in the DashBoard window in bqStudio, and the Start Register are needed for each Read and Write command and can be written in the text field. Read commands require the Number of Bytes to Read and Write commands require the Bytes to Write to be specified.

7.2 Standard Data Commands

Standard commands are common commands from the Smart Battery Specification (SBS) industry-standard which defines smart battery interfacing. Standard commands use a command code pair to associate the registers associated with each command. Address read and write commands to the LSB of the command code.

Example: Read the RelativeStateOfCharge.

1. Perform a Read Operation:
   a. I2C Address (Hex) = AA
   b. Start Register (Hex) = 2C
   c. Number of Bytes to Read (Decimal) = 2
2. View the results in Transaction Log:
   a. The Data window shows the hex value of the SOC of the battery in little endian format.

Figure 7-1 shows 0x17 00 in the Data column of the Transaction Log sub-window. This value is 23 in decimal, corresponding to the RSOC%.

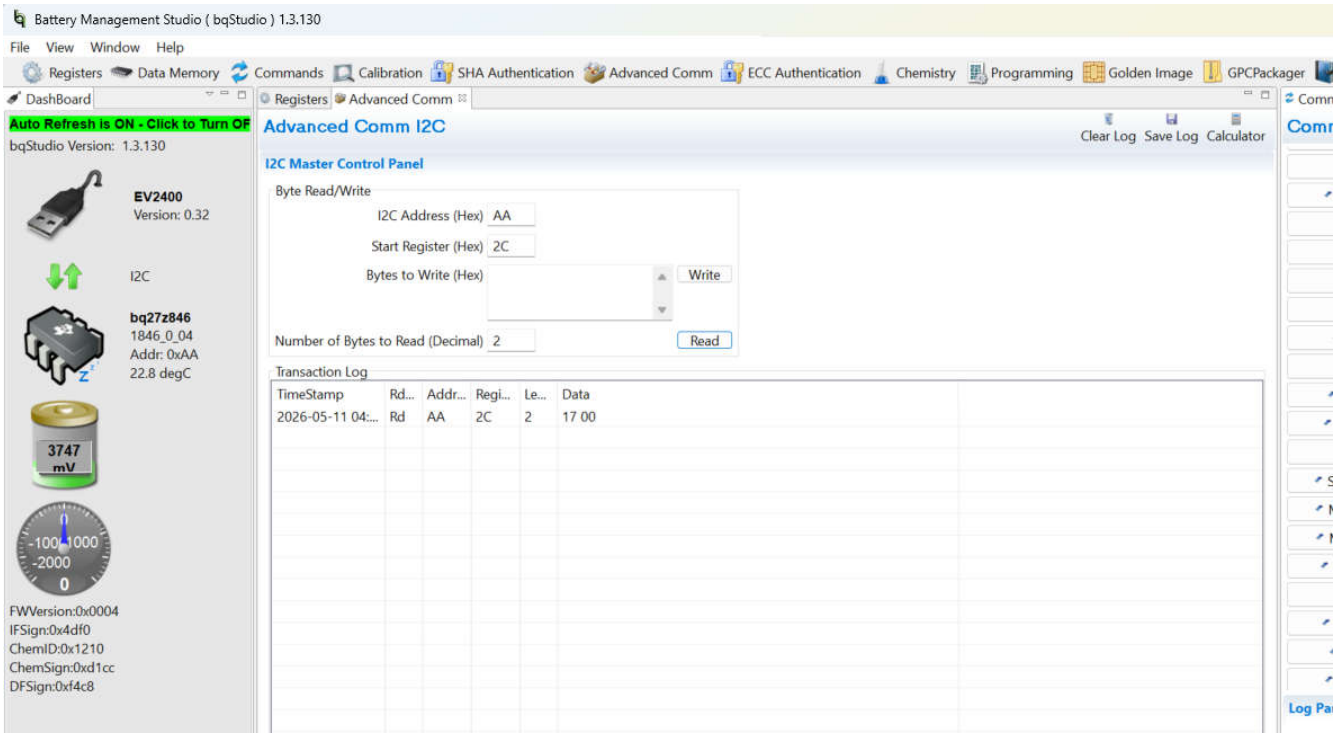


Figure 7-1. Standard Data Command Example

7.3 Manufacturer Access Commands

Manufacturer Access (MAC) commands are defined by Texas Instruments. MAC commands require a write to the AltManufacturerAccess() registers at 0x3E and 0x3F, and then an additional write to the AltManufacturerAccess() sub-command being used. The complete list of all MAC commands in the BQ27Z846 and an example of a Command Write operation with MAC commands can be found in the 0x00, 0x01 ManufacturerAccess() and 0x3E, 0x3F AltManufacturerAccess() chapter of the BQ27Z846 Technical Reference Manual.

Example: Read Chemical ID() to AltManufacturerAccess().

1. Send Chemical ID() to AltManufacturerAccess().
   a. I2C Address (Hex) = AA
   b. Start Register (Hex) = 3E
   c. Bytes to Write (Decimal) = 06 00 (this write data must be written in little endian)
2. Read the result from AltManufacturerAccess() and MACData().
   a. I2C Address (Hex) = AA
   b. Start Register (Hex) = 3E
   c. Number of Bytes to Read (Decimal) = 36
3. View the results in Transaction Log.
   a. The first two bytes "06 00" are the MAC command (for verification)
   b. The second two bytes "10 12" are the ChemID in little-endian (the ChemID can be seen if the CHEM_ID button is checked in the Command window)
   c. The final two bytes are the checksum and length. The length here is 6. The checksum is 0xFF - (sum of the first length - 2 bytes). The length and checksum are used to validate the block response.

Figure 7-2 shows this in bqStudio. To perform this process, fill out all the fields as shown, then click Write and Read.

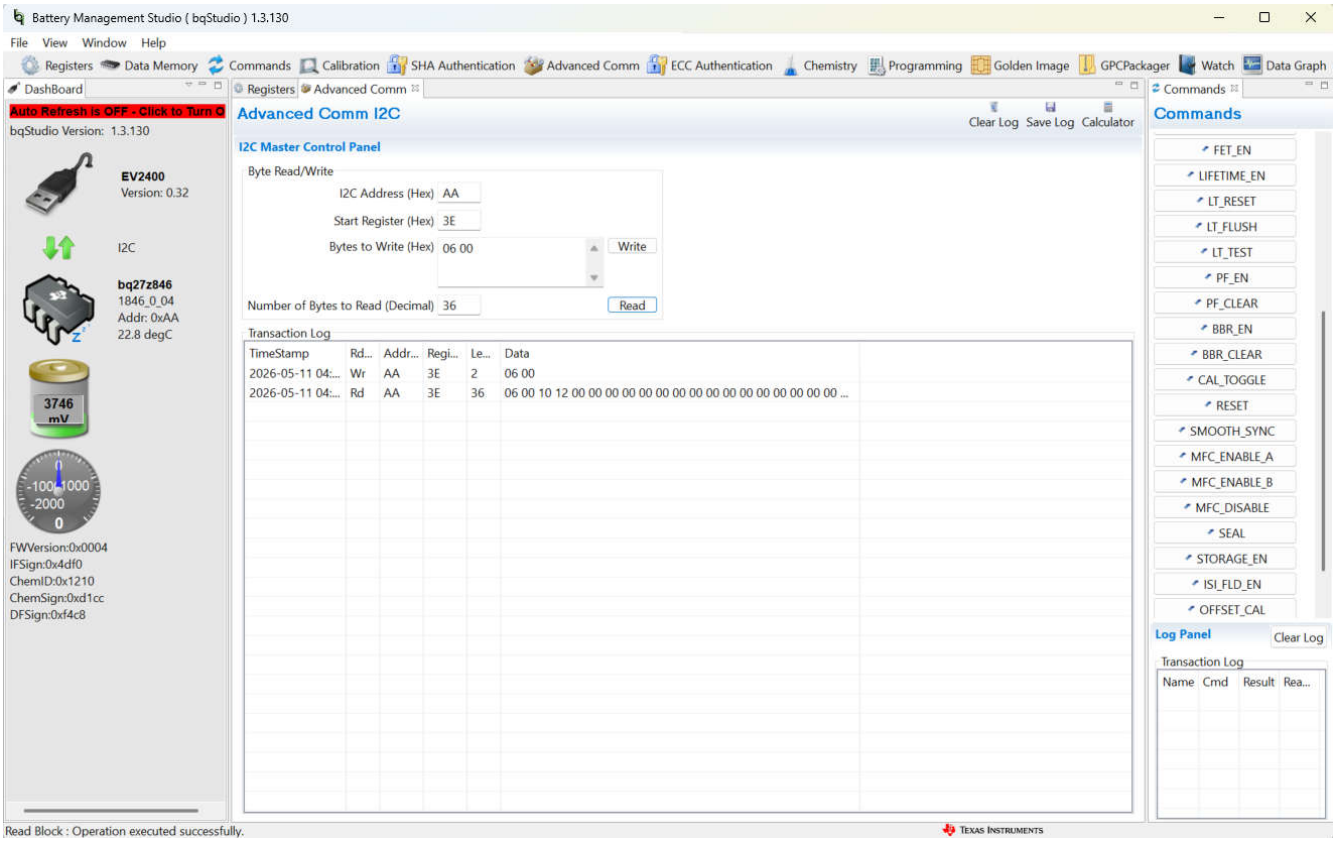


Figure 7-2. MAC Command Example

7.4 Further Resources on Gauge Communication

For more information about communicating with gauges, including host controller driver development, see the *Gauge Communication* application note.

8 BQ27Z846-Based Circuit Module

The BQ27Z846 based circuit module is an example design of a BQ27Z846 circuit for battery management. The circuit module incorporates a BQ27Z846 battery gas gauge and protection integrated circuit (IC) with external sense resistor to accurately predict the capacity of a 1-series Li-ion cell. In addition, the circuit includes external N-channel FETs for high-side battery protection.

8.1 Circuit Module Connections

Contacts on the circuit module provide the following connections:

- Direct cell connection to the battery pack (J1): BAT+, BAT–
- Direct system connection for charging and discharging (J2): PACK+, PACK–
- I2C communications through external EV2400 to Windows-based PC USB port (J11): SDA, SCL, VSS
- Interrupt pin connection (J3): INT
- External temperature sensor connection (J6): TS

8.2 Pin Descriptions

Table 8-1. Pin Descriptions

Pin Name	Description
PACK+	Pack positive terminal
PACK-	Pack negative terminal
BAT+	Battery positive terminal
BAT-	Battery negative terminal
SDA	External I2C communication data line
SCL	External I2C communication clock line
VSS	Device ground
INT	Programmable output interrupt to host
TS	External temperature sensor connection

9 Hardware Design Files

This section contains the board layout, bill of materials, and schematic for the BQ27Z846 circuit module.

9.1 Board Layout

This section shows the printed-circuit board (PCB) layers and assembly drawing (Figure 9-1 through Figure 9-3) for the BQ27Z846 evaluation module.

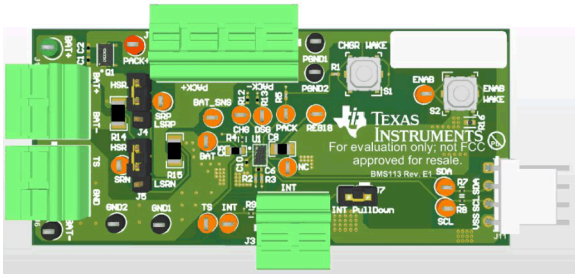


Figure 9-1. EVM Image

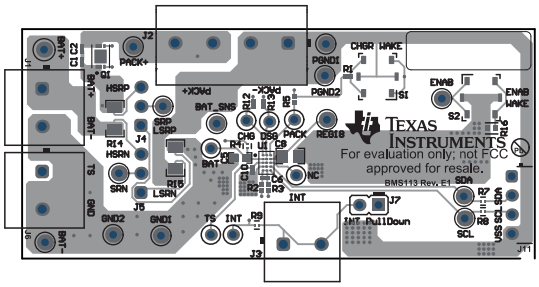


Figure 9-2. Top Layer Composite

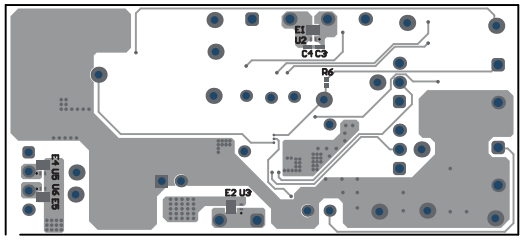


Figure 9-3. Bottom Layer

9.2 Schematic

This section contains the schematic of the different (PCB) components.

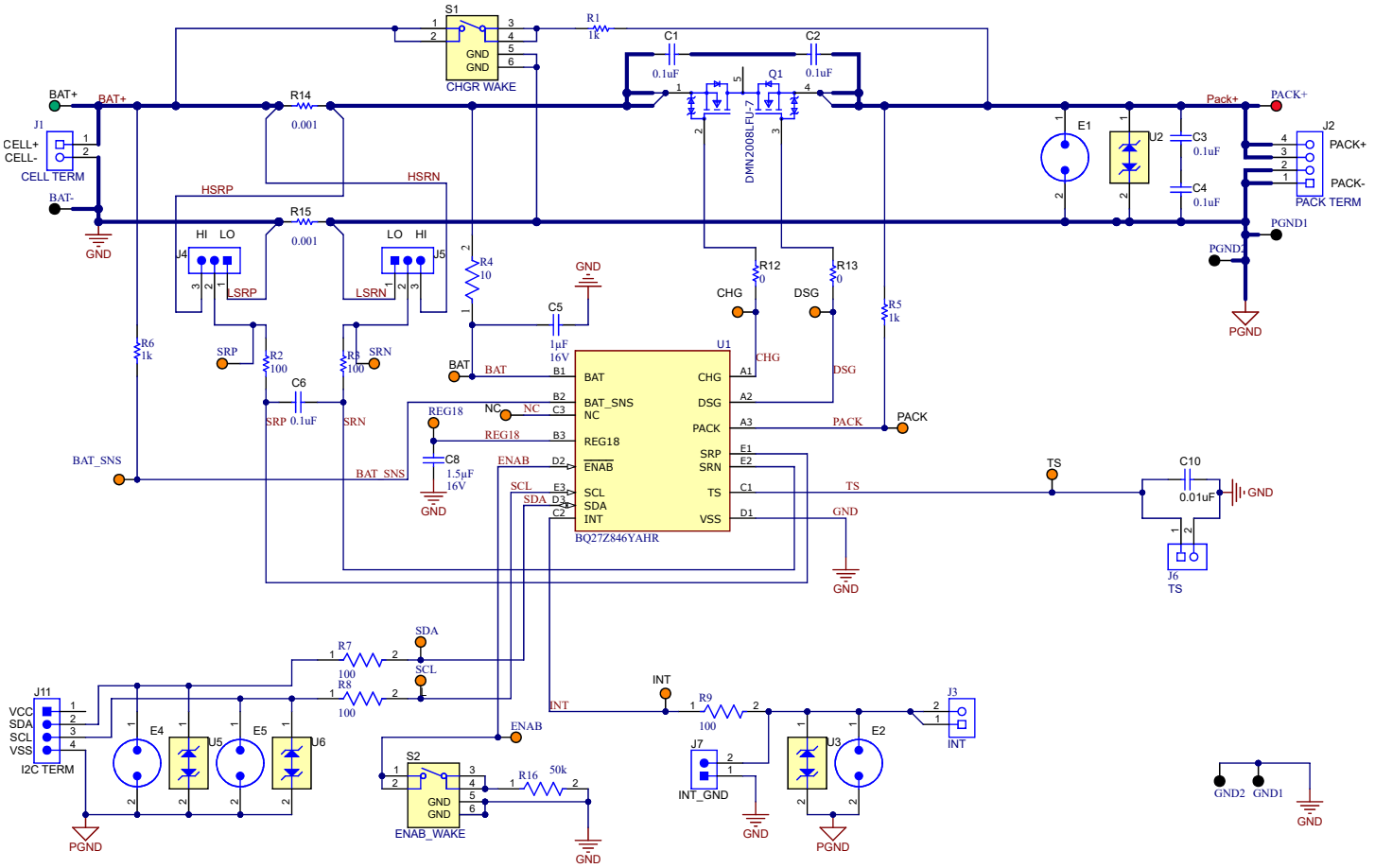


Figure 9-4. BQ27Z846 Reference Schematic

9.3 Bill of Materials

Fitted	Description	Designator	Part Number	Quantity	Manufacturer	Package	Value
Fitted	Printed Circuit Board	!PCB1	BMS113	1	Any		
Fitted	Test Point, Orange, 1-Pin THD, RoHS	BAT, CHG, DSG, INT, NC, PACK, TS	5003	7		5003	
Fitted	Test Point, Miniature, Black, TH	BAT-, GND1, GND2, PGND1, PGND2	5001	5	Keystone	Black Miniature Testpoint	
Fitted	Test Point, Miniature, Orange, TH	BAT_SNS, ENAB, REG18, SCL, SDA, SRN, SRP	5003	7	Keystone	Orange Miniature Testpoint	
Fitted	Test Point, Miniature, Green, TH	BAT+	5116	1	Keystone	Green Miniature Testpoint	
Fitted	CAP, CERM, 0.1uF, 25V, ±10%, X5R, 0201	C1, C2, C3, C4	GRM033R61E104KE14J	4	muRata™	0201	0.1uF
Fitted	CAP, CERM, 1uF, 16V, ±10%, X7R, 0603	C5	EMK107B7105KA-T	1	Taiyo Yuden™	0603	1uF
Fitted	CAP, CERM, 0.1uF, 16V,±10%, X7R, 0201	C6	GRM033Z71C104KE14D	1	muRata	0201	0.1uF
Fitted	CAP, CERM, 1.5uF, 16V, ±10%, X7R, 0805	C8	C0805C155K4RACTU	1	Kemet™	0805	1.5uF
Fitted	CAP, CERM, 0.01uF, 10V, ±10%, X5R, 0201	C10	GRM033R61A103KA01D	1	muRata	0201	0.01uF
Fitted	Fiducial mark. There is nothing to buy or mount.	FID1, FID2, FID3	N/A	3	N/A	N/A	
Fitted	Terminal Block, 5mm, 2x1, R/A, TH	J1, J3, J6	1792863	3	Phoenix Contact™	Terminal Block, 5mm, 2x1, R/A, TH	
Fitted	Terminal Block, 5mm, 4x1, R/A, TH	J2	1792889	1	Phoenix Contact	Terminal Block, 5mm, 4x1, R/A, TH	
Fitted	Header, 2.54mm, 3x1, Gold, TH	J4, J5	61300311121	2	Würth Elektronik™	Header, 2.54mm, 3x1, TH	
Fitted	Header, 2.54mm, 2x1, Gold, TH	J7	GBC02SAAN	1	Sullins Connector Solutions™	Header, 2.54mm, 2x1, TH	
Fitted	Header, 2.54mm, 4x1, R/A, Tin, TH	J11	640455-4	1	TE Connectivity™	Header, 2.54mm, 4x1, R/A, TH	
Fitted	Thermal Transfer Printable Labels Width: 0.650in Height: 0.200in 10,000 per roll	LBL1	THT-14-423-10	1	Brady™	PCB Label 0.650 x 0.200 inch	
Fitted	Test Point, Miniature, Red, TH	PACK+	5000	1	Keystone Electronics™	Red Miniature Testpoint	
Fitted	Transistor MOSFET Array Dual N-CH 20V 14.5A 6-Pin uDFN2030 T/R	Q1	DMN2008LFU-7	1	DIODES®	U-DFN2030-6	
Fitted	1kΩ resistor	R1, R5, R6	CRCW02011K00FNED	3	Vishay® Dale, [NoParam]	0201	

Fitted	Description	Designator	Part Number	Quantity	Manufacturer	Package	Value
Fitted	10Ω resistor	R4	ERJ1GNF10R0C	1	Panasonic® Electronic Components		
Fitted	CRCW0201100RFKED	R2, R3	CRCW0201100RFKED	2	Vishay		
Fitted	RES SMD 100Ω 1% 1/20W 0201, ERJ-1GNF1000C	R7, R8, R9	ERJ-1GNF1000C	3	Panasonic Electronic Components		100Ω
Fitted	RES, 0, 5%, 0.05W, 0201	R12, R13	CRCW02010000Z0ED	2	Vishay-Dale	0201	0
Fitted	RES, 0.001, 1%, 1W, AEC-Q200 Grade 0, 1206	R14, R15	CSNL1206FT1L00	2	Stackpole Electronics Inc	1206	0.001
Fitted	RES Thick Film, 50kΩ, 1%, 0.063W, 100ppm/°C, 0402	R16	CRCW040250K0FKED	1	Vishay	0402	
Fitted	Switch, SPST-NO, Off-Mom, 0.02A, 15 VDC, SMD	S1, S2	EVQ-PLHA15	2	Panasonic	4.9mm × 4.9mm	
Fitted	Shunt, 100mil, Gold plated, Black	SH-J1, SH-J2, SH-J3	SNT-100-BK-G	3	Samtec®	Shunt	1x2
Fitted	BQ27Z846YAHR	U1	BQ27Z846YAHR	1	Texas Instruments	DSBGA15	
Fitted	Single-Channel ESD in 0402 Package With 10pF Capacitance and 6V Breakdown, DPY0002A (X1SON-2)	U2, U3, U5, U6	TPD1E10B06DPYR	4	Texas Instruments	DPY0002A	
Fitted	Thermistor NTC, 10.0kΩ, 1%, Disc, 5mm × 8.4mm, Fitted in T6 header	RT1	103AT-2	1	SEMITEC®	Disc, 5mm × 8.4mm	10k

10 Additional Information

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11 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
May 2026	*	Initial Release

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2 *Limited Warranty and Related Remedies/Disclaimers*:

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   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

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Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

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3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

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