EVM User's Guide: BQ27Z558EVM-084

BQ27Z558EVM-084 Single-Cell Impedance Track™ Technology

Description

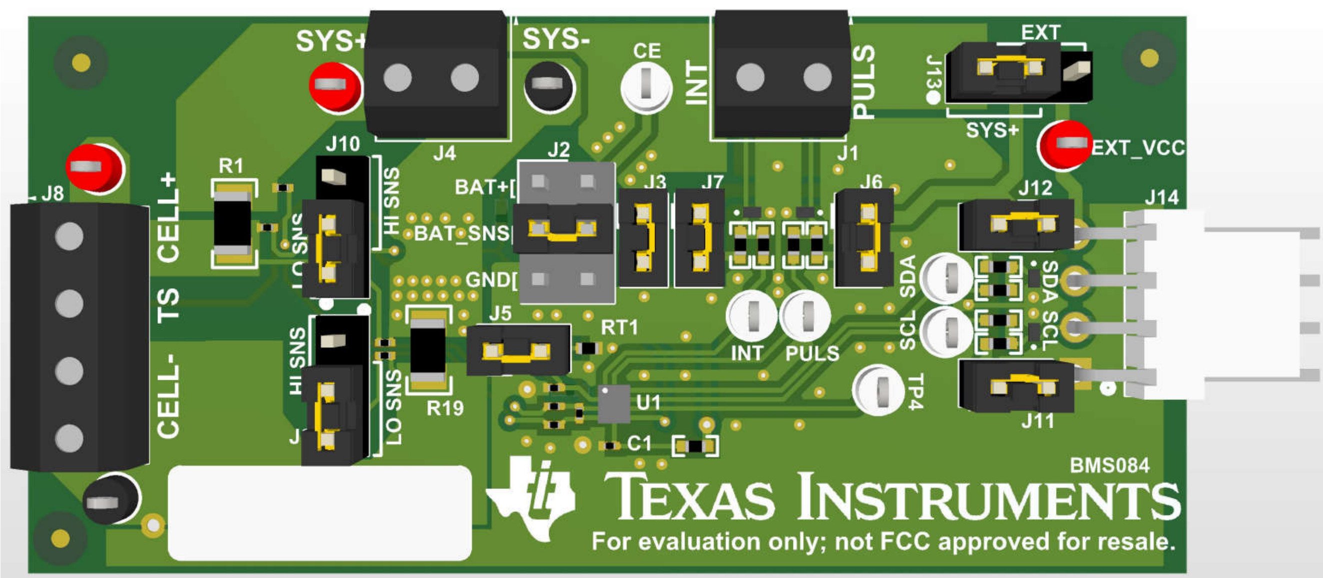
The BQ27Z558EVM evaluation module (EVM) is an evaluation system for the BQ27Z558 battery gauge. The circuit module includes the BQ27Z558 integrated circuit (IC), and all other components necessary to monitor and predict capacity for 1-series cell Li-Ion or Li-Polymer batteries.

Features

- Complete evaluation system for the BQ27Z558 gas gauge with Impedance Track™ technology
- Populated circuit module for quick setup
- Personal computer (PC) software that allows configuring and data logging for system analysis
- 1.2V I/O I^2C communication

Applications

- Smartphones
- Digital still cameras and video cameras
- Tablet computing
- Portable and wearable health devices
- Portable audio devices



1 Evaluation Module Overview

1.1 Introduction

This user's guide guides through 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 BQ27Z558 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.
- Bring up the EVM for a basic chemistry and accuracy cycle check.
- Evaluate the functionality of the BQ27Z558 design under different charge and discharge conditions.

These tasks guide users of the BQ27Z558EVM through the process required to prepare for production with the BQ27Z558 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 as there is minimal pack-to-pack variation during a well-controlled manufacturing process. The Impedance Track™ algorithm enables the gauge to continue to learn once a pack is deployed to account for manufacturing differences, field conditions, and battery degradation over the lifetime.

1.2 Kit Contents

- BQ27Z558 circuit module (BMS084A)

This EVM is used for the evaluation of BQ27Z558. Visit the product web folder at *www.ti.com* to properly configure the BQ27Z558.

1.3 Specification

This section summarizes the performance specifications of the BQ27Z558 circuit module.

Table 1-1. Performance Specification Summary

BQ27Z558 Specification	Min	Typ	Max	Units
Input voltage SYS+ to SYS–	-0.3	3.6	6	V
Input voltage Bat+ to Bat–	-0.3	3.6	6	V

1.4 Device Information

The Texas Instruments' BQ27Z558 Impedance Track gas gauge design is a highly integrated, accurate 1-series cell gas gauge with a flash programmable custom reduced instruction-set CPU (RISC) and SHA-256 authentication for Li-ion and Li-polymer battery packs. The 1-series cell capability includes parallel cells for increased capacity.

The BQ27Z558 gas gauge communicates through I 2C-compatible and HDQ one-wire interfaces and includes several key features that can help facilitate accurate gas gauging applications. Integrated temperature sense functions (internal and external options) enable system and battery temperature measurements

2 Hardware

2.1 Hardware Setup

The BQ27Z558 requires hardware connections for using the evaluation module and creating a Golden File.

2.1.1 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
- BQ27Z558 Evaluation Board (EVM)
- Constant-voltage and constant-current power supply (preferably 1 mV and 1 mA accuracy for the power supply)
- Lithium-chemistry 1-cell battery (Golden Pack battery identical to those to be used in production)

2.1.2 Connecting the BQ27Z558 Circuit Module to a Battery Pack

Figure 2-1 shows how to connect the BQ27Z558 circuit module to the battery, personal computer (PC), and a system load/charger.

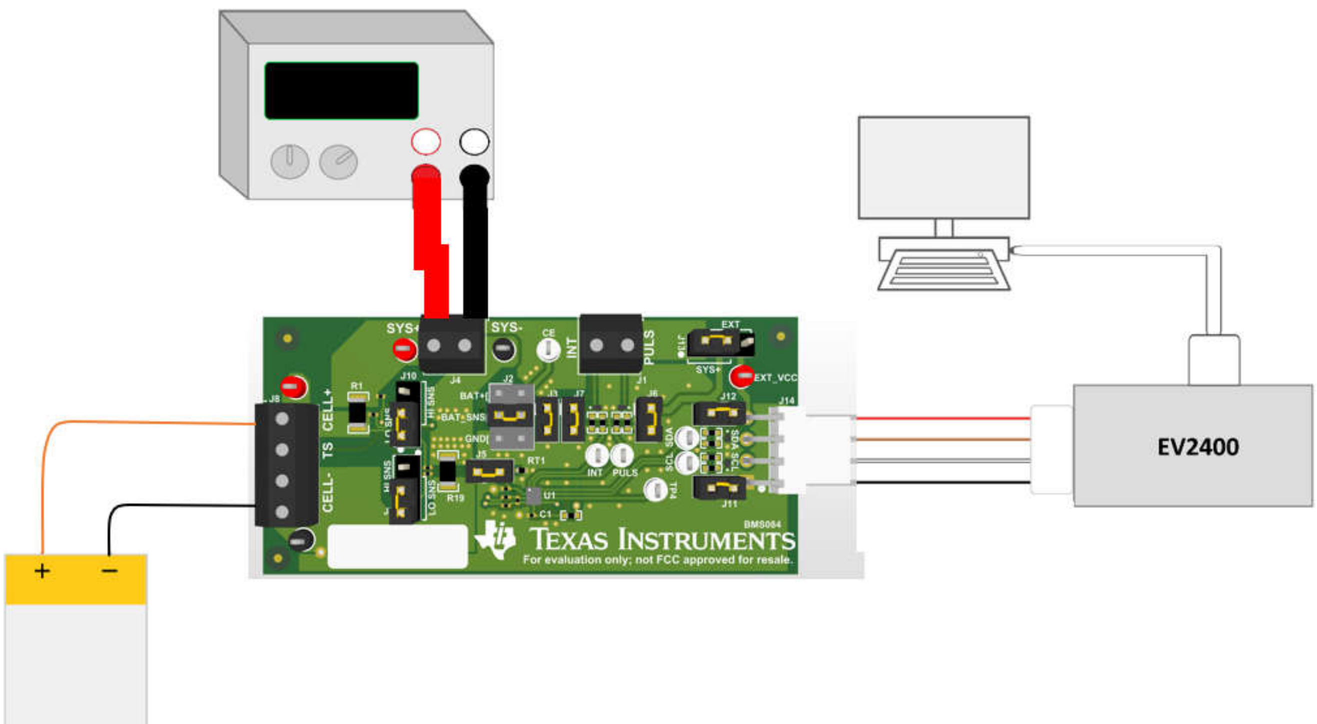


Figure 2-1. Connect the BQ27Z558 Circuit Module to a 1SxP

2.1.3 EVM Jumpers Description

The following section describes the critical jumpers and their purpose on this board.

1. **J2 - Chip Enable (CE):** This jumper allows the user to connect the CE pin to ground, BAT_SNS, or directly to BAT+. Grounding or floating the CE pin disables and resets the device. Connect the jumper across positions 4-3 or 2-1 to enable the device. Alternatively, the jumper can be tied directly to a host system for an additional low-power state, if needed.
2. **J11 - I^2C Clock Pull-up (SCL):** This jumper applies a 10k pullup to J13 on the I^2C communication line.
3. **J12 - I^2C Data Pull-up (SDA):** This jumper applies a 10k pullup to J13 on the I^2C communication line.
4. **J6 - BQ27Z558 Pulse Pull-up (PULS):** This jumper applies a 10k pullup to J13 on the PULS pin of the BQ27Z558.
5. **J7 - BQ27Z558 Interrupt Pull-up (INT):** This jumper applies a 10k pullup to J13 on the INT pin of the BQ27Z558.
6. **J9 & J10 - Sense Resistor:** These jumpers can be configured to use either a high-side or low-side sense resistor. Set the shunt on J9 to position 2-3 and set the shunt on J10 to 1-2 to use a low-side sense. Set the shunt on J9 to position 1-2 and set the shunt on J10 to position 2-3 to use a high-side sense.
7. **J3 - BQ27Z558 VDD Connection:** This jumper ties the BQ27Z558 BAT pin to CELL+. This shunt can be removed to allow the use of another instrument to monitor the current consumption of the device under various operating conditions.
8. **J5 - BQ27Z558 TS Connection:** This jumper allows the use of the external RT1 thermistor. Removing the shunt allows the use of either the internal temperature sense or an external sense connected to pins 2-3 of J8.
9. **J13 - Pullup Level Selector:** This jumper allows the user to choose between using the SYS+ or external voltage as the pullup voltage. Set the shunt to position 1-2 to use SYS+, and set the shunt to position 3-2 to use EXT_VCC. Use caution when applying voltage to EXT_VCC as EXT_VCC is connected to the EV2400.

2.2 Chemical ID

This section describes the process of finding the chemistry identifier, sometimes referred to as Chemical ID or ChemID, of a battery that is used. The ChemID is a necessary element of the Impedance Track™ algorithm that needs to be identified before performing a learning cycle. For the Golden File creation process, using the exact same type of battery that is used in production is necessary. Use this battery for the proceeding sections, as well.

Texas Instruments has a database of thousands of battery profiles, and the ChemID selection process identifies either the exact battery profile or the most similar. This ChemID is then programmed into the gauge, updating dataflash with the battery profile. This profile is used in the Impedance Track™ algorithm for capacity and resistance learning as well as for 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 then submitted to the online Gauging Parameter Calculator (GPC) Tool, which then 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.

2.2.1 Chemical ID Selection Process Description

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 2-2 shows an example of what this process looks like graphically.

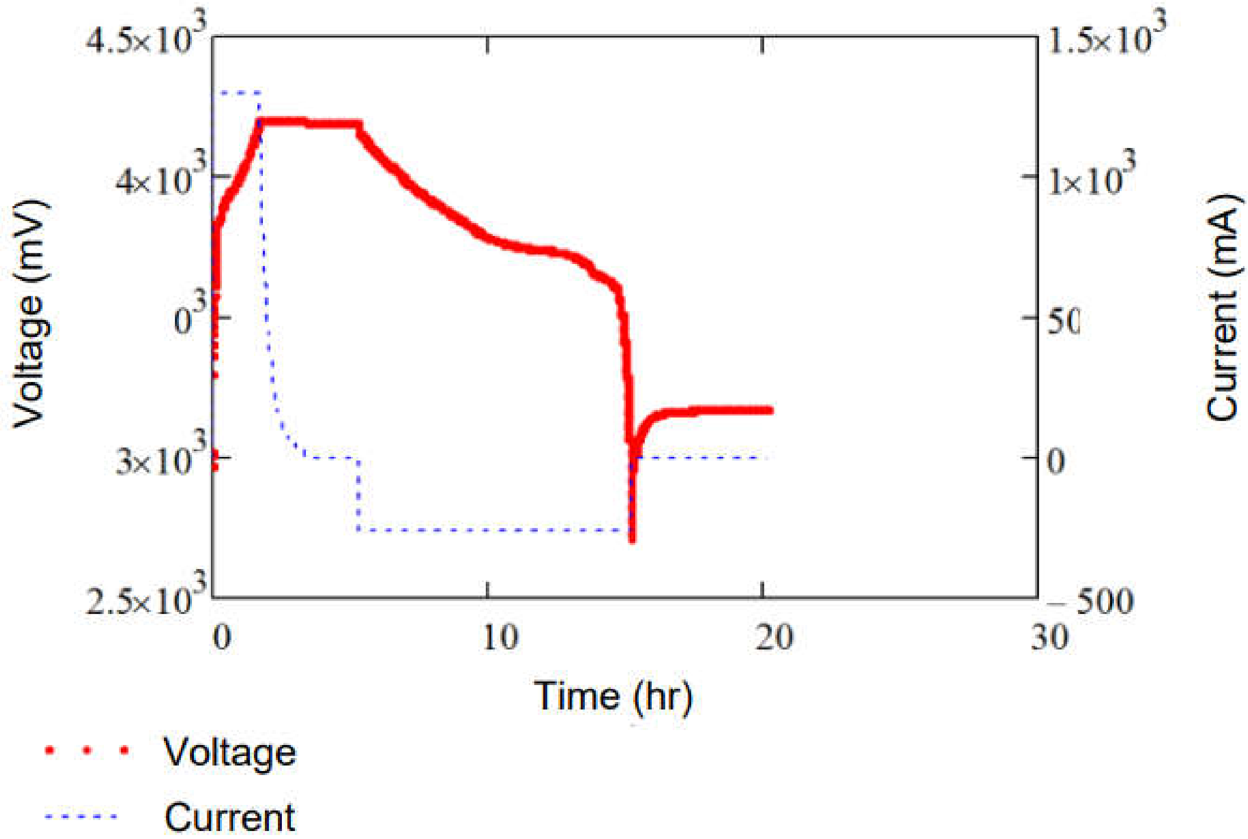


Figure 2-2. Graph of IV Data in Charge-Relax-Discharge-Relax

2.2.2 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 BQ27Z558EVM.

Start by setting this hardware up as shown in Figure 2-3. This setup is identical to Figure 2-1.

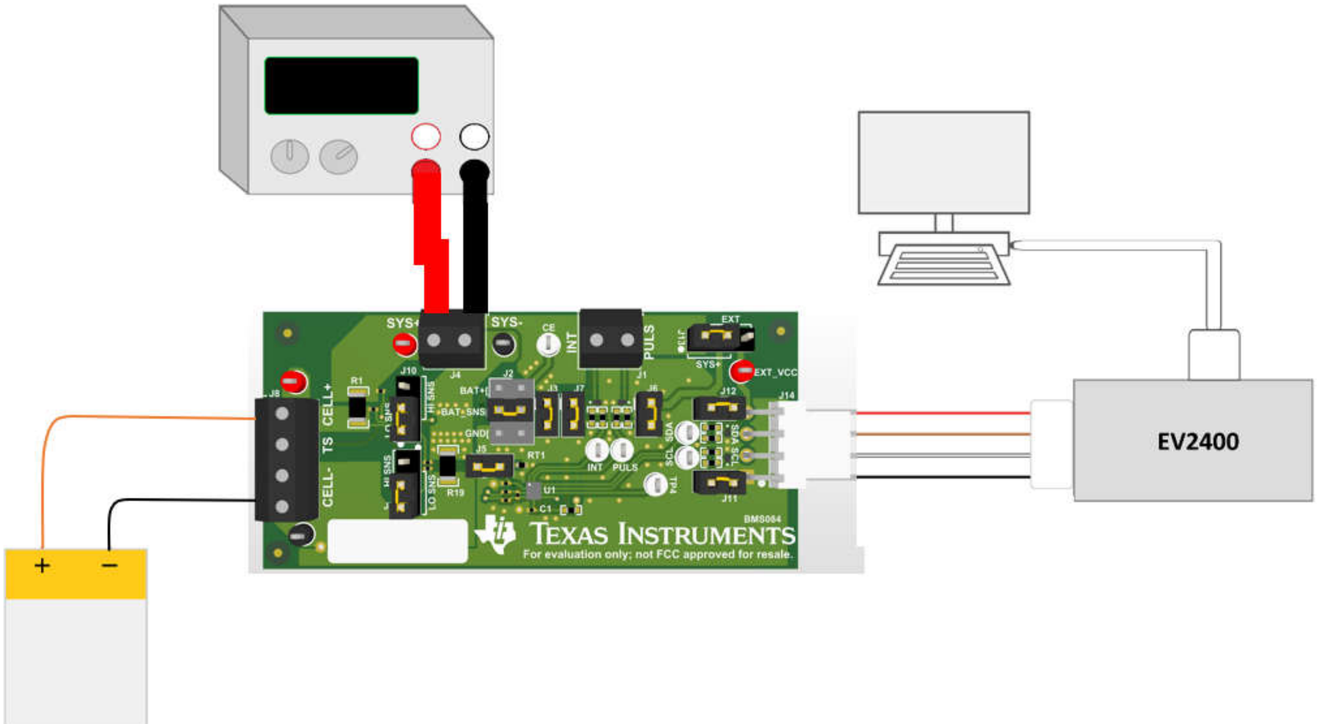


Figure 2-3. ChemID Hardware Setup

2.2.3 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, go to Window, select Preferences, choose Registers, and change Scan/Log Interval from 4000 to a minimum of 1000 milliseconds. There is no need to log faster than 1 second as the gas gauge updates the registers once every second.

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 2-4.

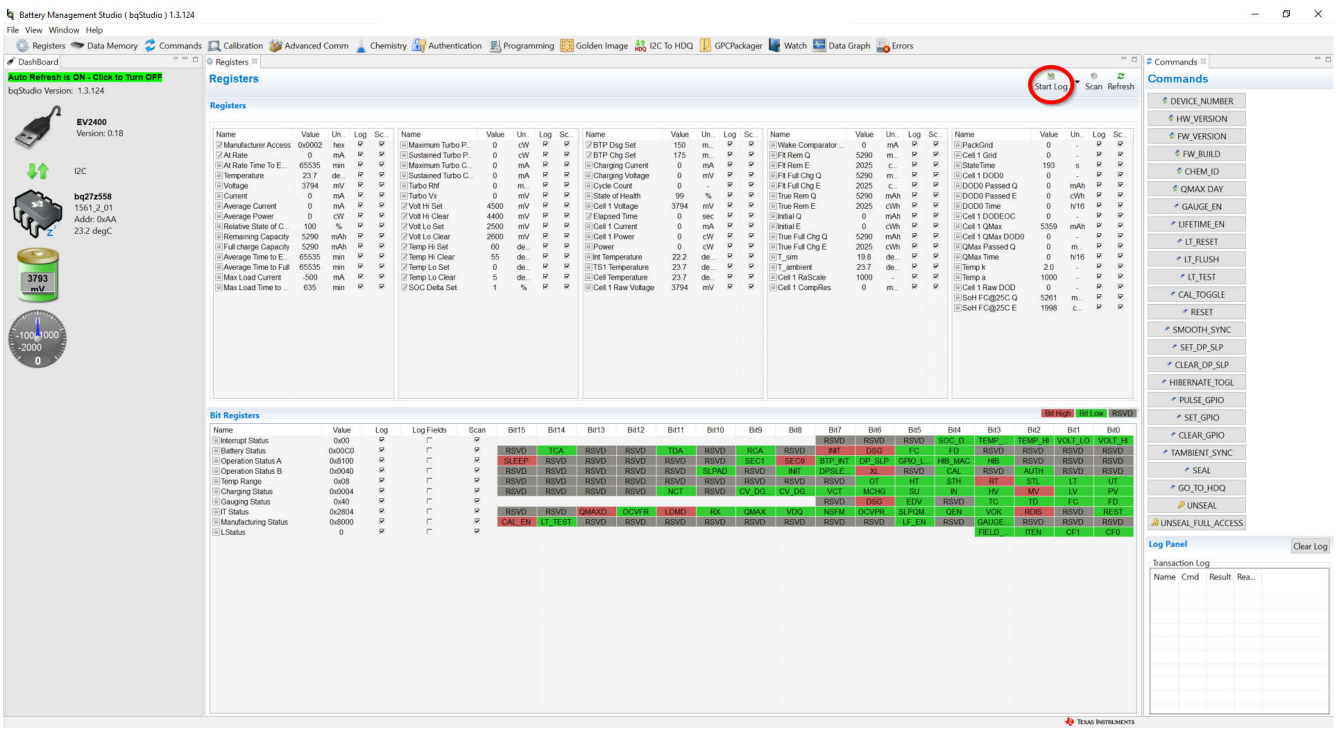


Figure 2-4. Start Log Button in bqStudio

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.

2.2.4 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. Make sure that your units for each of these 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 2-5 is an example of the required .csv file formatting as well as the first few rows of data.

	A	B	C	D
1	elapsed time (sec)	voltage (mv)	current (mA)	temperature (C)
2	10.0004	3498.071671	0	24.07476807
3	20.0012	3497.159958	0	24.07457924
4	30.0002	3497.159958	0	24.10800362
5	40.001	3497.159958	0	24.04404068
6	50.0002	3498.987198	0	24.05429077
7	60.0001	3498.071671	0	24.08539391
8	60.0022	3498.071671	0	24.08539391
9	62.1557	3593.915939	853.401184	24.08539391
10	63.2021	3665.113449	2212.631226	24.09855461
11	64.2035	3669.679642	2212.358475	24.09855461
12	65.2026	3672.418594	2212.413788	24.09855461
13	66.2026	3675.157547	2212.303162	24.14687157
14	67.2036	3677.892685	2212.083817	24.14687157
15	68.2022	3679.719925	2212.030411	24.09255028
16	69.203304	3680.631638	2212.413788	24.09255028
17	70.2022	3684.282303	2212.631226	24.09255028
18	71.2028	3687.021255	2212.194443	24.11014557
19	72.202304	3688.848495	2212.247849	24.11014557
20	73.202696	3691.587448	2212.358475	24.11014557

Figure 2-5. 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 is sent to the e-mail address provided when logging into ti.com to use the GPC Tool with a report that indicates the results of the tool’s process. The report contains the selected ChemID and a list of additional ChemIDs that satisfy the “less than 3%” error criteria. For example, this can be useful to verify that a ChemID used previously is still good. If any formatting mistakes or other errors are present, then those are reflected in the report.

2.2.5 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 2-6.

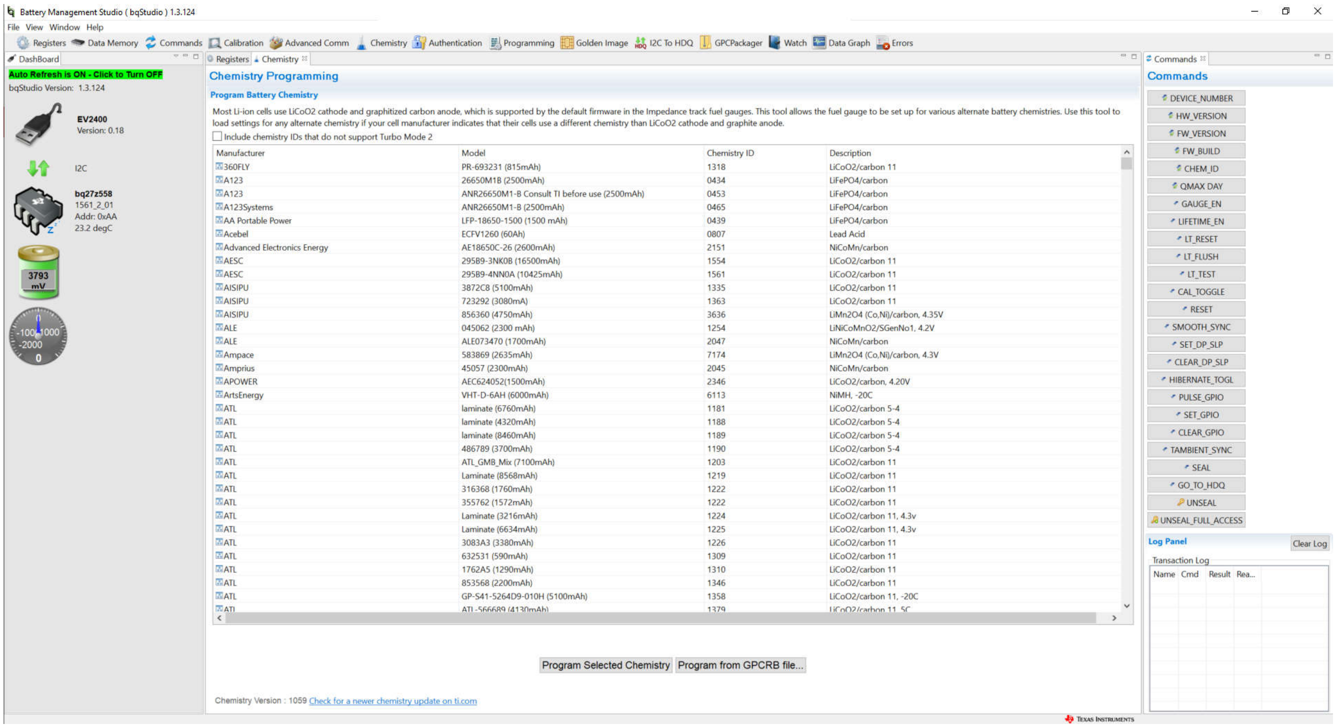


Figure 2-6. Chemistry Window View in bqStudio

Sort by a given parameter by clicking the top of that column once. TI recommends to sort 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 the Chemistry ID is not in this list, then update the Chemistry version in bqStudio. To do so, see 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 2-6. Check the *Log Panel* window, shown in the bottom-right corner of Figure 2-6, and confirm that the correct Chemistry ID was returned.

2.2.6 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.

2.3 Calibrating Gauge Measurements

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

2.3.1 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 2-7, enter the precise value of the voltage source used, check *Calibrate Cell Voltage*, and then press the *Calibrate Gas Gauge* button.

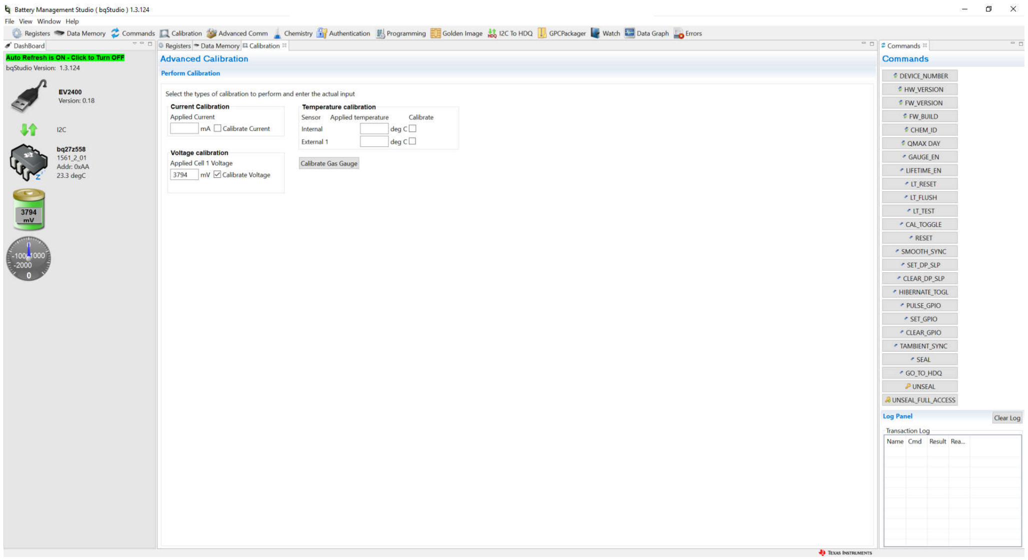


Figure 2-7. Voltage Calibration in bqStudio

2.3.2 Current Calibration

Set up the EVM, a voltage power supply (either a battery or a bench power supply can be used), and a power supply capable of supplying a constant current with milliamp precision. The constant-current supply is connected to the CELL- and SYS- headers. The exact circuit layout is shown in Figure 2-8. The constant-current supply is shown as being attached to the test point of CELL-, but can also be attached to the CELL- header, as well.

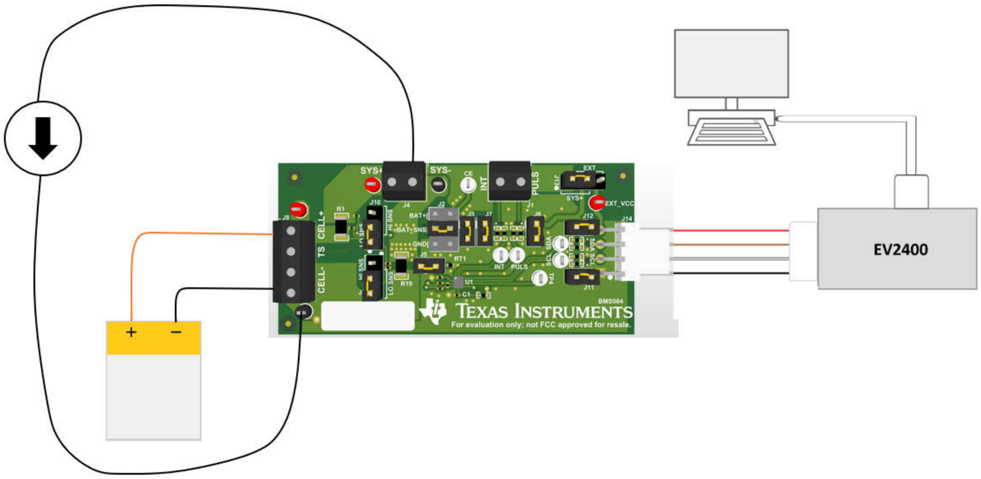


Figure 2-8. Current Calibration Hardware Setup

As shown in Figure 2-9, 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.

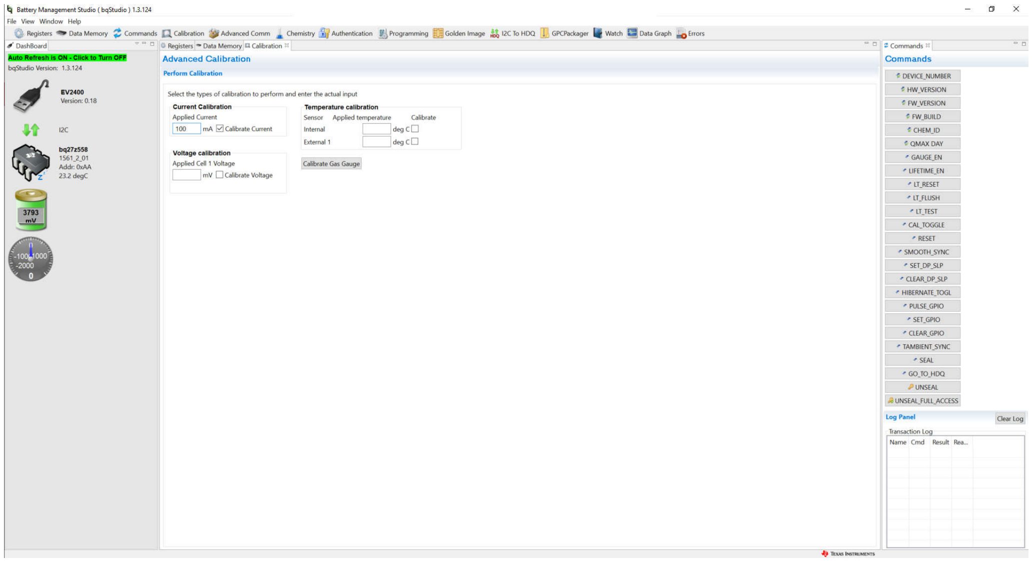


Figure 2-9. Current Calibration in bqStudio

2.4 Learning Cycle and Golden Image

The learning cycle process is the initial optimization that Impedance Track gauges perform to verify accuracy of the gauge in reporting state of charge. The learning cycle allows the gauge to learn the resistance and maximum chemical capacity of a specific battery to verify accuracy as the cell ages. A correct ChemID, with less than 3% of error, is necessary to be identified and programmed into the gauge before attempting a learning cycle.

2.4.1 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 < 1 µV/s). The *[REST]* flag is 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, refer to Section 3.2 of the *Achieving the Successful Learning Cycle* document found on ti.com.

For more details on the learning cycle registers for the BQ27Z558 specifically, see the BQ27Z558 Technical Reference Manual found on ti.com.

2.4.2 Data Memory Configuration

The gauge's Data Memory is configured in bqStudio from the Data Memory window. This window is shown below in Figure 2-10.

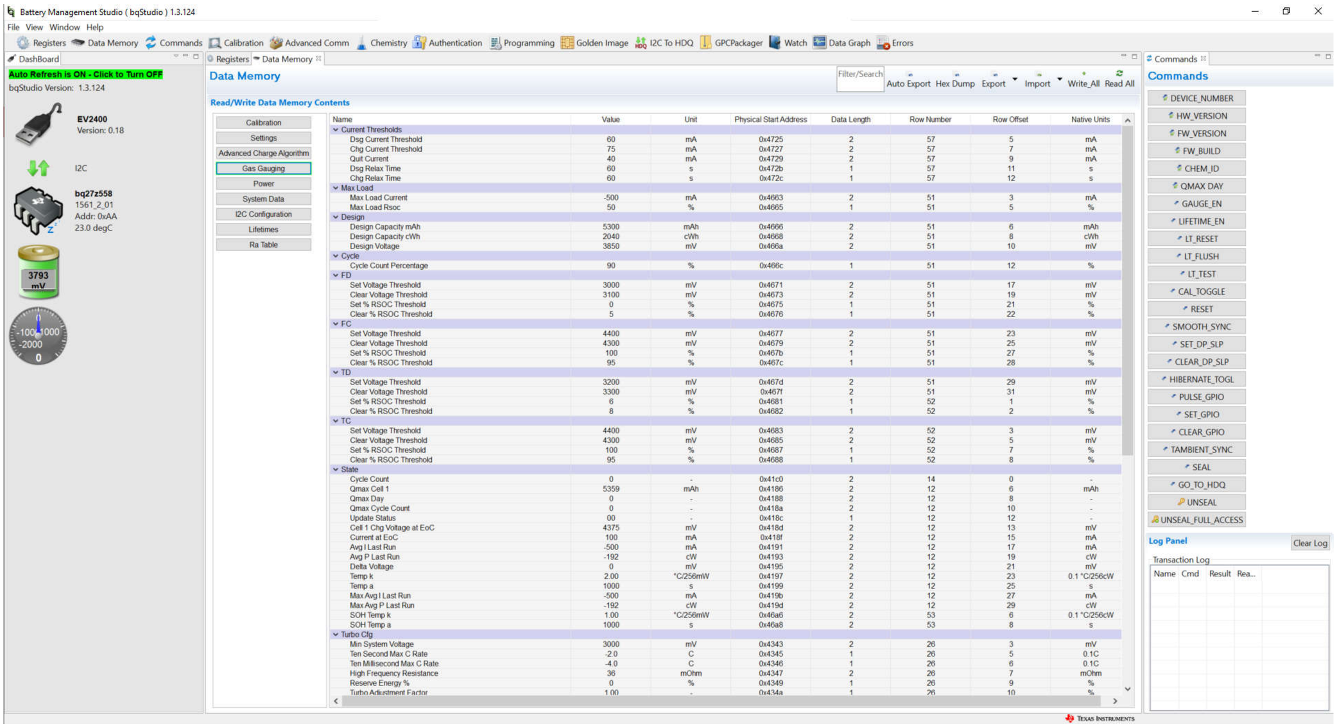


Figure 2-10. Data Memory View in bqStudio

The necessary data memory configurations are made in this screen, using only 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. Make sure that each value is programmed in the correct unit, indicated in the third column for each data memory parameter.

The following are the data memory values that are programmed:

- **[Advanced Charging Algorithm][Termination Config][Charge Term Taper Current]:** This value os set slightly higher than the actual taper current between C/10 and C/100. This value is also 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. This value in the battery data sheet. Or can be found by multiplying the capacity in mAh by the terminal voltage in Volts, then dividing by 10.
- **[Gas Gauging][IT Cfg][Term Voltage]:** This value can be found in the battery data sheet as the terminal voltage. This is the lowest voltage that the gauge charges to.
- **[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 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]:** This value is where the gauge enters relax mode and is less than C/20 and lower than the **[Dsg Current Threshold]** and **[Chg Current Threshold]**.

Figure 2-11 shows a visual representation of the current during the course of a learning cycle relative to the data memory current parameters set.

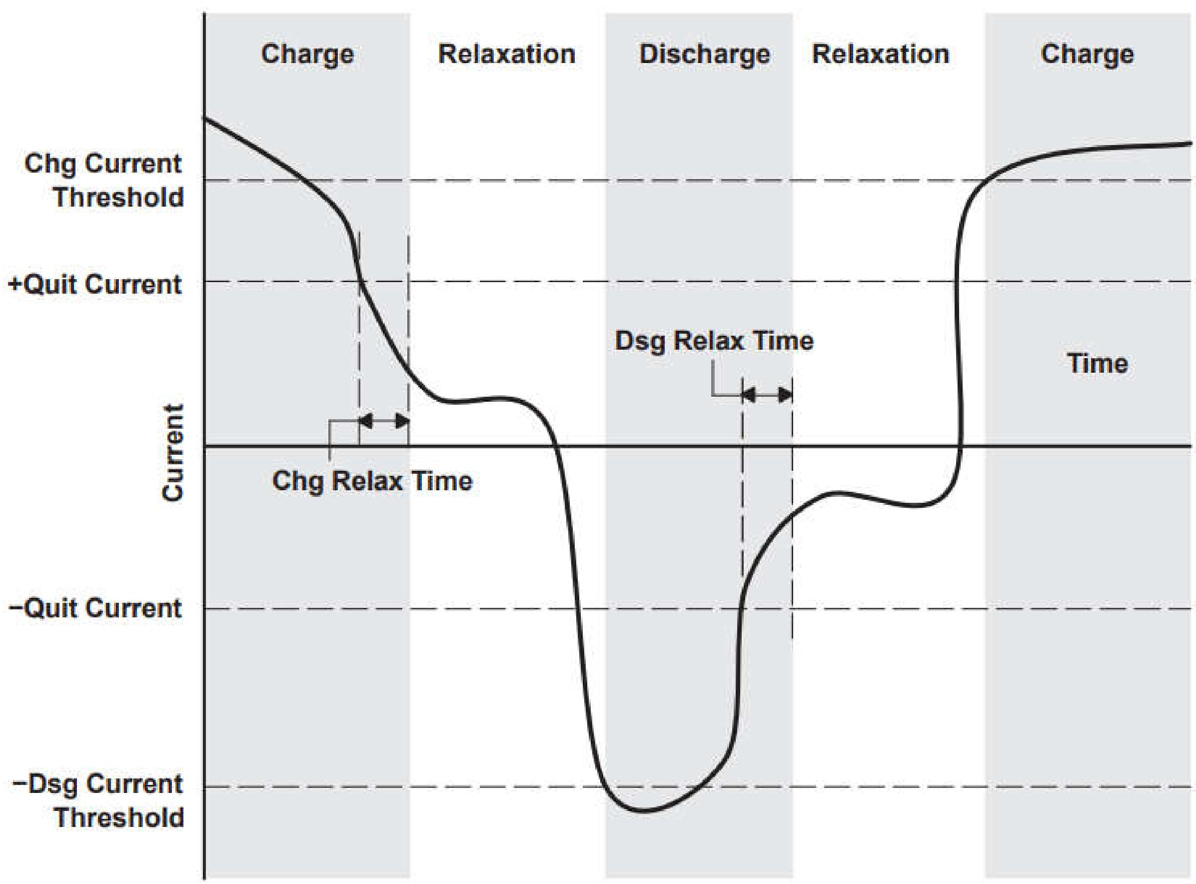


Figure 2-11. Graph of Learning Cycle Current

2.4.3 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 2.2.2 and shown in Figure 2-3. 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, starting a log in bqStudio is recommended to allow for debugging of any issues that can 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, then 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 5 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]**.
7. Let the battery relax for two hours to reach full equilibrium open circuit voltage (OCV). The **[LStatus]** register updated 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 has updated to 0x06.

2.4.4 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 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 2-3. 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 battery's IVT characteristics.

For more information about this process, see the GPCRB page on ti.com.

2.4.5 Creating the Golden Image File

The current EVM has completed all optimization steps at this point. The Golden Gauge can be used to program all other gauges in production using a Golden Image. This makes sure that the gauges begin with an accurate starting point to begin reporting on and further learning about a battery's chemistry.

To get the necessary file for programming gauges, navigate to the *Golden Image* window in bqStudio. Change the output directory and base file name if needed. FlashStream is a file type created by Texas Instruments, though SREC files are preferred in some production environments. BQFS files are used when updating the flash memory as well as the firmware; this is an alternative to an SREC file for production. DFFS files are used for transferring data flash parameters.

Uncheck the undesired output formats and click *Create Image Files* to export the selected output format to the chosen output directory.

2.4.6 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 FlashStream file format is recommended. For further guidance on using the FlashStream file format, refer to Section 5 of the "Gauge Communication" document found on ti.com.

2.5 BQ27Z558-Based Circuit Module

The BQ27Z558 based circuit module is an example design of a BQ27Z558 circuit for battery management. The circuit module incorporates a BQ27Z558 battery gas gauge integrated circuit (IC) with external sense resistor to accurately predict the capacity of a 1-series Li-ion cell.

2.5.1 Circuit Module Connections

Contacts on the circuit module provide the following connections:

- Direct connection to the battery pack (J8): CELL+, CELL–
- Direct connection to the system connections for charging and discharging (J4): SYS+ / CELL+, SYS–
- I2C™ communications via external EV2400 to Windows-based PC USB port (J14): SDA, SCL, VSS
- Access to various signal outputs (J1): INT, PULS

2.5.2 Pin Description

Pin Name	Description
SYS+	System positive terminal
SYS–	System negative terminal
CELL+	Battery positive terminal
CELL–	Battery negative terminal
SDA	External I^2C communication data line
SCL	External I^2C communication clock line
VSS	Device ground
INT	General purpose output
PULS	General purpose output

3 Software

3.1 Software Setup

This section describes the installation of the BQ27Z558EVM PC software, and how to connect the different components of the EVM.

3.1.1 System Requirements

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

3.1.2 Software Installation

Find the latest software version of bqStudio-test and the EV2400 driver on ti.com. Search for the BQ27Z558 part number to get to the tool folder for the device. Following these steps to install the BQ27Z558 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. Make sure 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, display the current firmware version, and prompt 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, perform a mass erase of the older EV2400 version firmware, program the EV2400, and then reset 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 (J14).

Note

The EV2400 remains plugged into the computer during the entire firmware updating process.

3.2 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.

3.3 Using bqStudio

This section details the operation of the BQ27Z558 bqStudio software.

3.3.1 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 *Gauge Dashboard* window, the Registers window, and *Data Memory* window are seen in the main 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.
- Data appears initially in the *Gauge Dashboard, Registers* and *Data Memory* sections.
- The **Refresh** (single time scan) or the **Scan** (continuous scan) buttons can be clicked 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. The continuous scanning interval can be set 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 shows up next to the *stopwatch* icon.

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

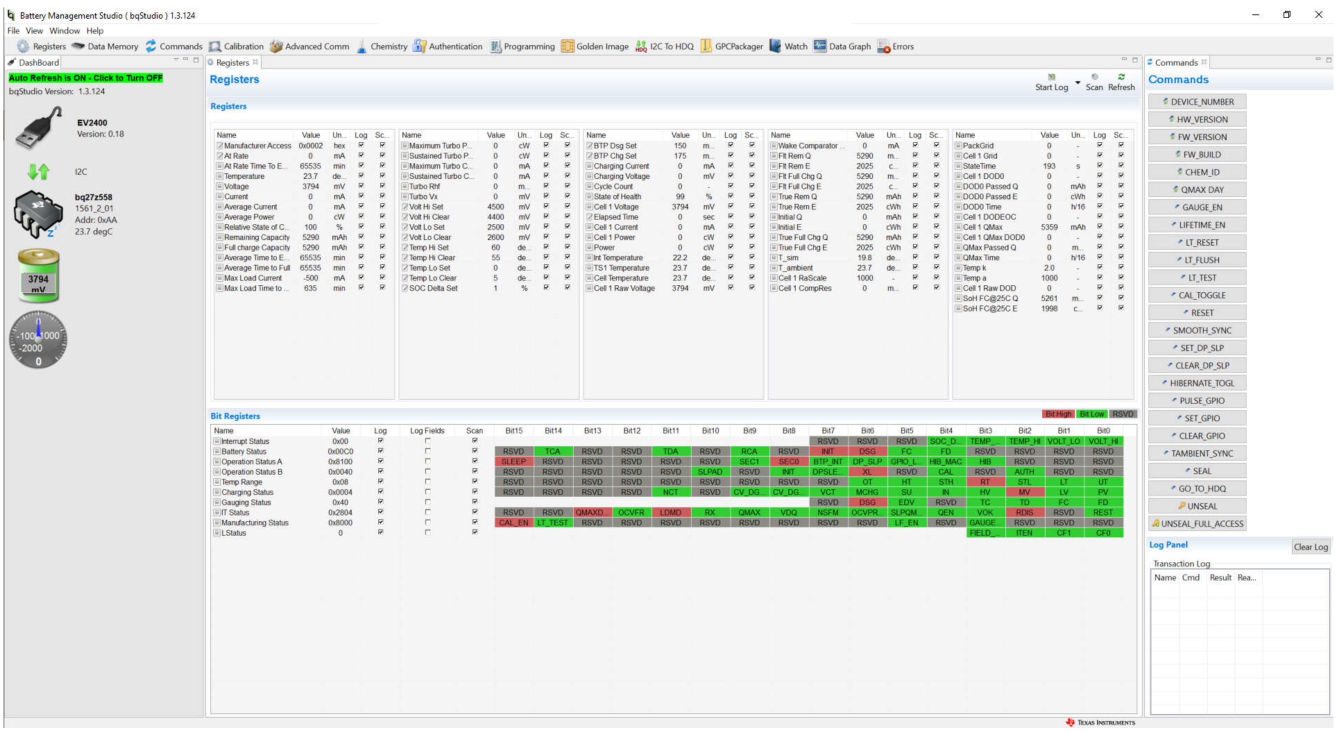


Figure 3-1. Registers Screen

3.3.2 Setting Programmable BQ27Z558 Options

The BQ27Z558 comes configured per the default settings detailed in the **BQ27Z558 Technical Reference Manual**. Make sure that the settings are correctly changed to match the pack and application for the BQ27Z558 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).

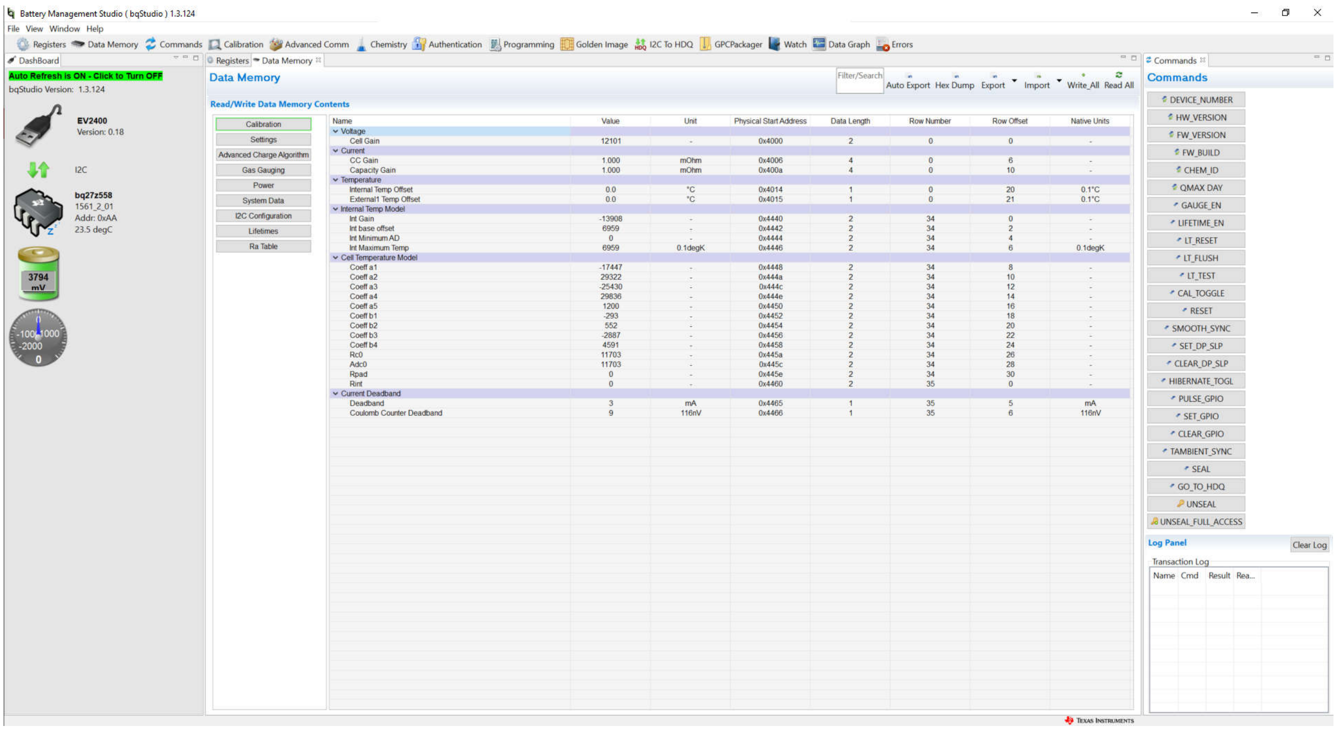


Figure 3-2. Data Memory Screen

To read all of the data from the BQ27Z558, 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 on 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 to make sure that all changes made on the .gg.csv file are affected on the gauge. Use the read command to read back all of 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® as bqStudio rejects changes made to the file. Make sure to use a text editor like notepad or similar to edit a .gg.csv file.

3.4 Gauge Communication

This section introduces host-processor communication with the BQ27Z558. The BQ27Z558 gauge uses an I2C communication interface with communication speeds up to 400kHz. Further hardware and software specifications for the I2C interface for this gauge can be found in the device-specific data sheet and the BQ27Z558 Technical Reference Manual located on ti.com.

3.4.1 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.

3.4.2 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. Read and write commands are addressed to the LSB of the command code.

Example: Read the *Relative State Of Charge*.

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 battery's SOC.

Figure 3-3 shows 0x64 00 in the Data column of the *Transaction Log* sub-window. This value is 100 in decimal, corresponding to the SOC% shown in the *Dash Board* window to the left.

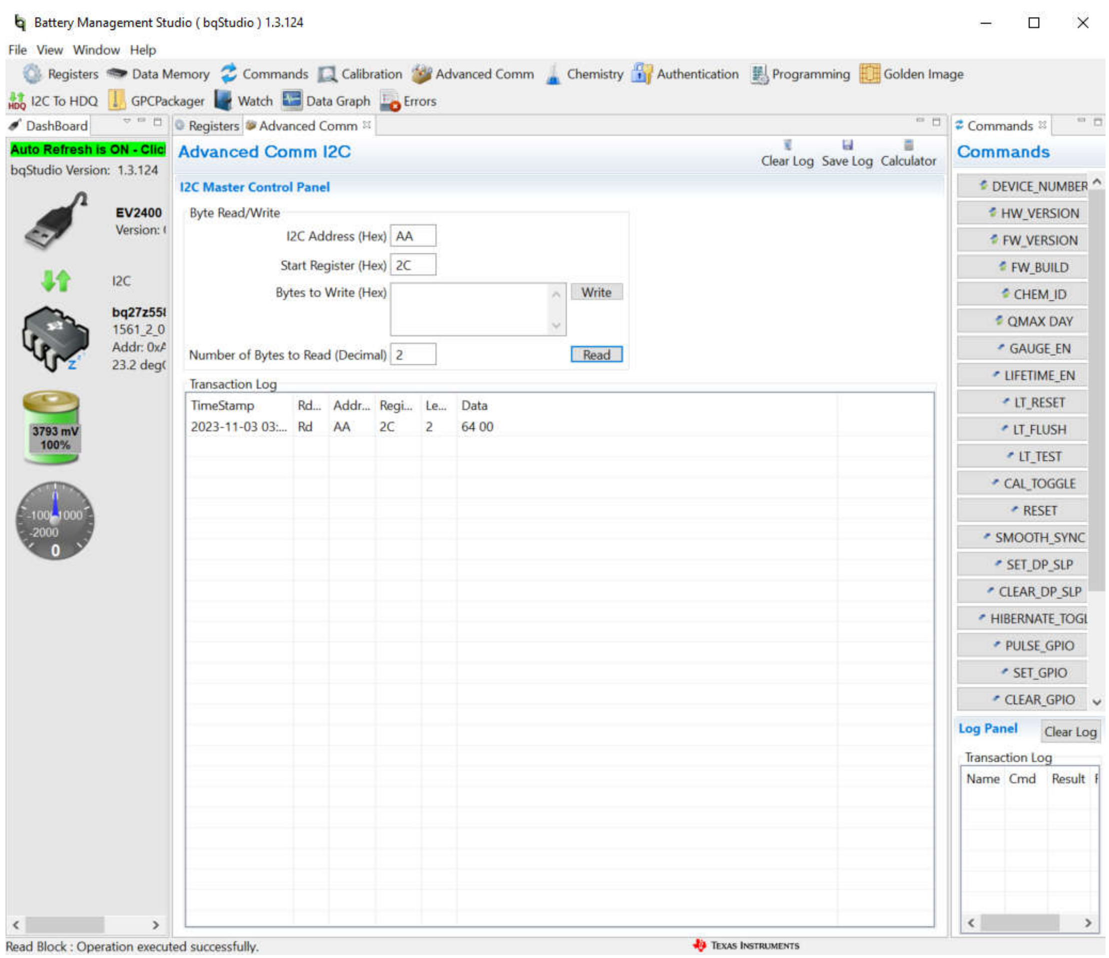


Figure 3-3. Standard Data Command Example

3.4.3 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 BQ27Z558 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 *BQ27Z558 Technical Reference Manual* located on ti.com.

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" is 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 is 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 3-4 shows this in bqStudio. To perform this process, fill out all of the fields as shown, then click **Write** and **Read**.

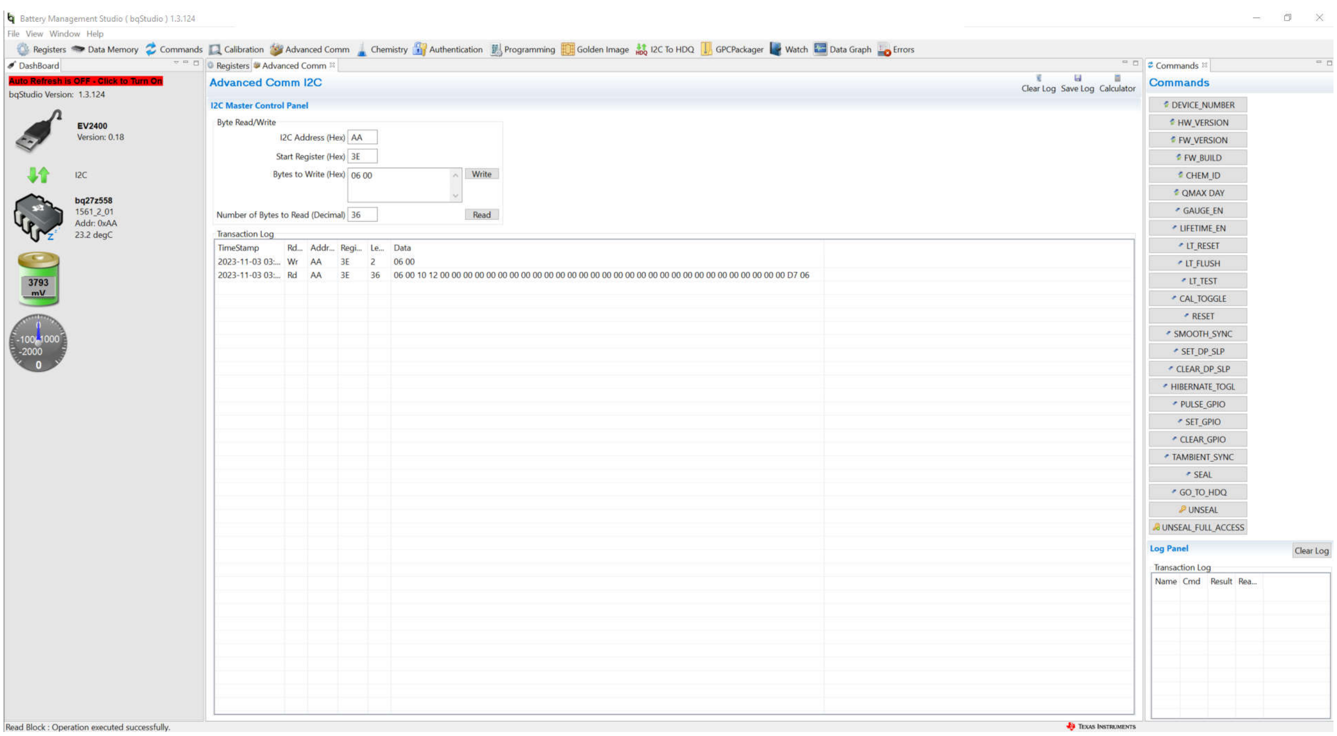


Figure 3-4. MAC Command Example

3.4.4 Further Resources on Gauge Communication

Further resources for communicating with gauges, including host controller driver development, can be found in the *Gauge Communication* document found on ti.com.

4 Hardware Design Files

This section contains the board layout, bill of materials, and schematic for the BQ27Z558 circuit module.

4.1 Schematic

This section contains the schematic of the PCB design.

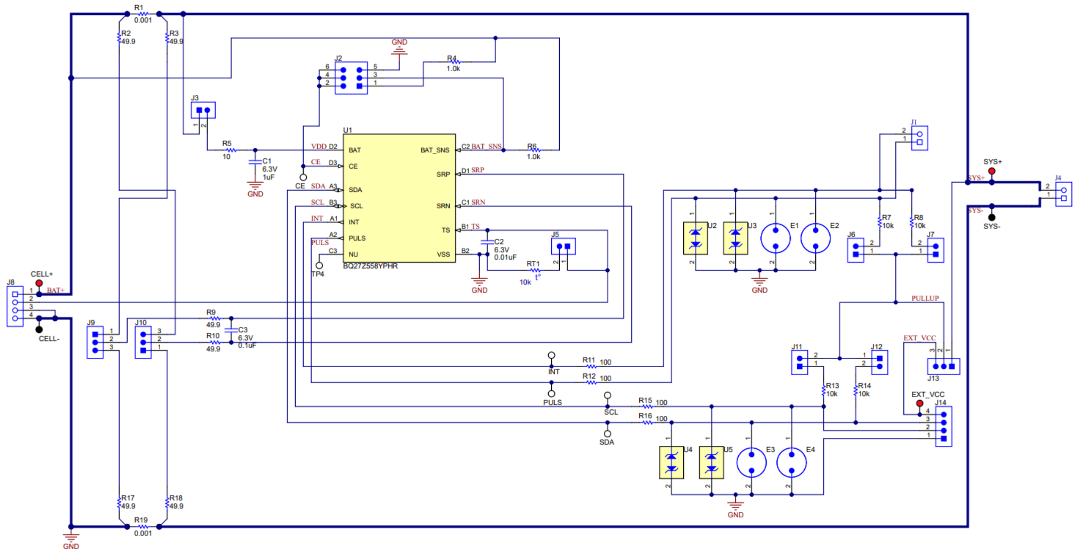


Figure 4-1. BQ27Z558 Reference Schematic

4.2 PCB Layout

This section shows the printed-circuit board (PCB) layers (Figure 4-3 through Figure 4-5), and assembly drawing for the BQ27Z558 module.

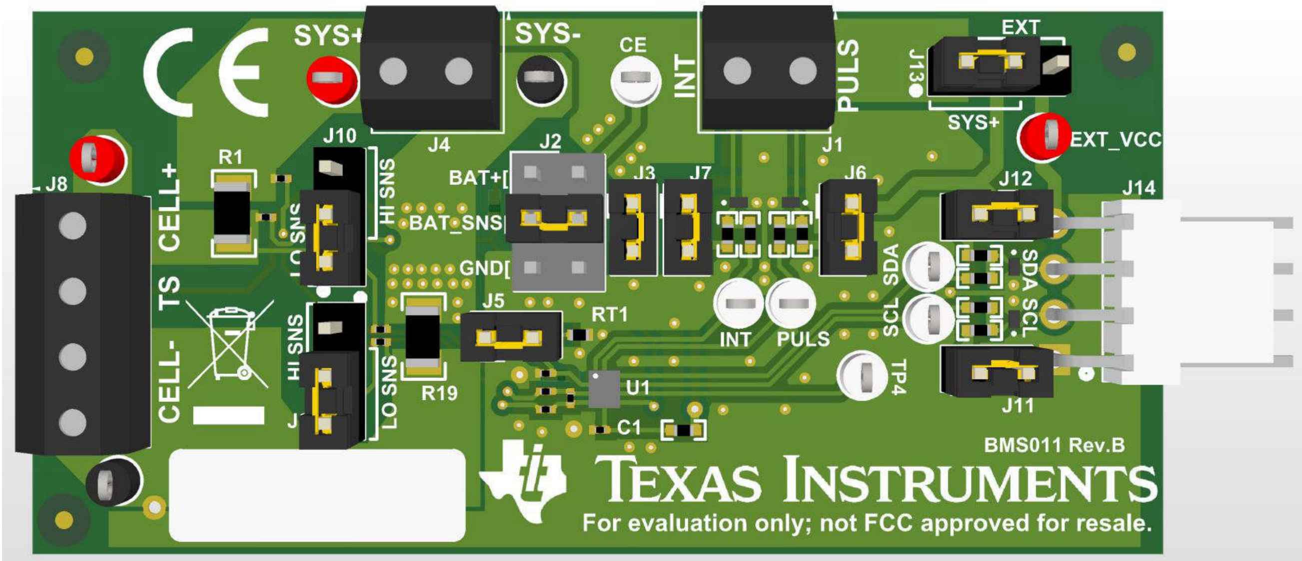


Figure 4-2. EVM Image

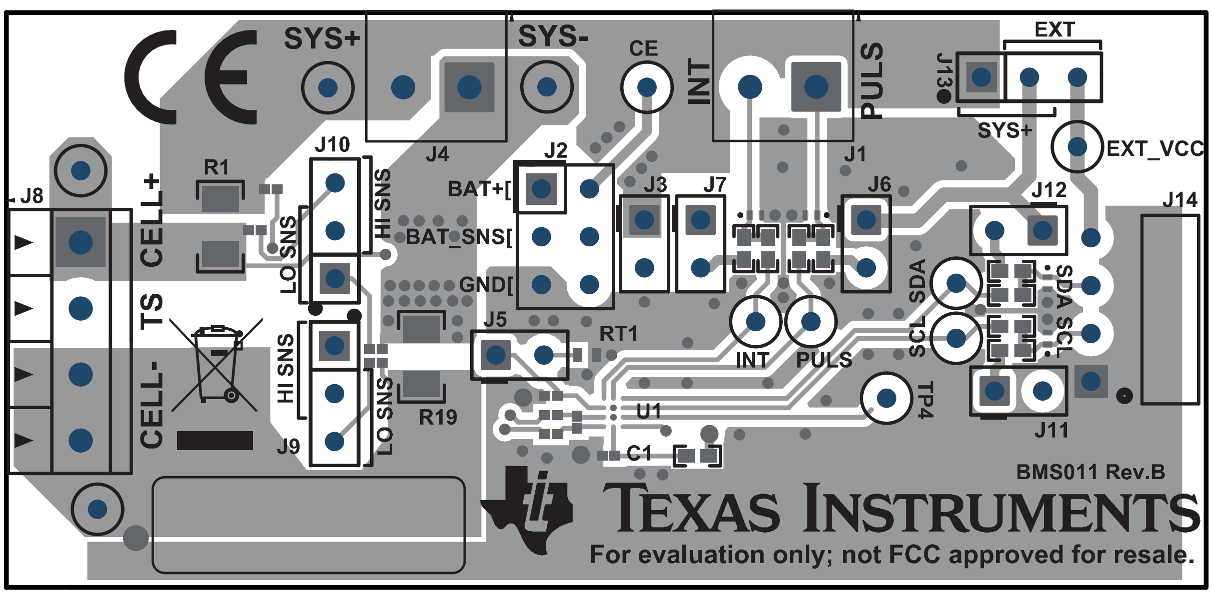


Figure 4-3. Top Layer Composite

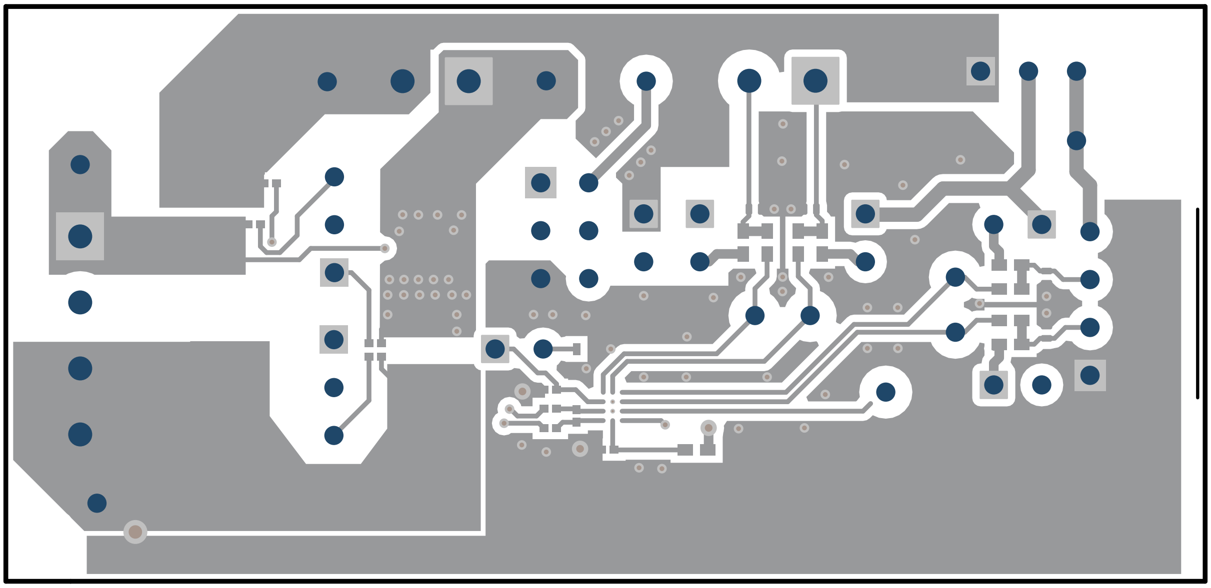


Figure 4-4. Top Layer

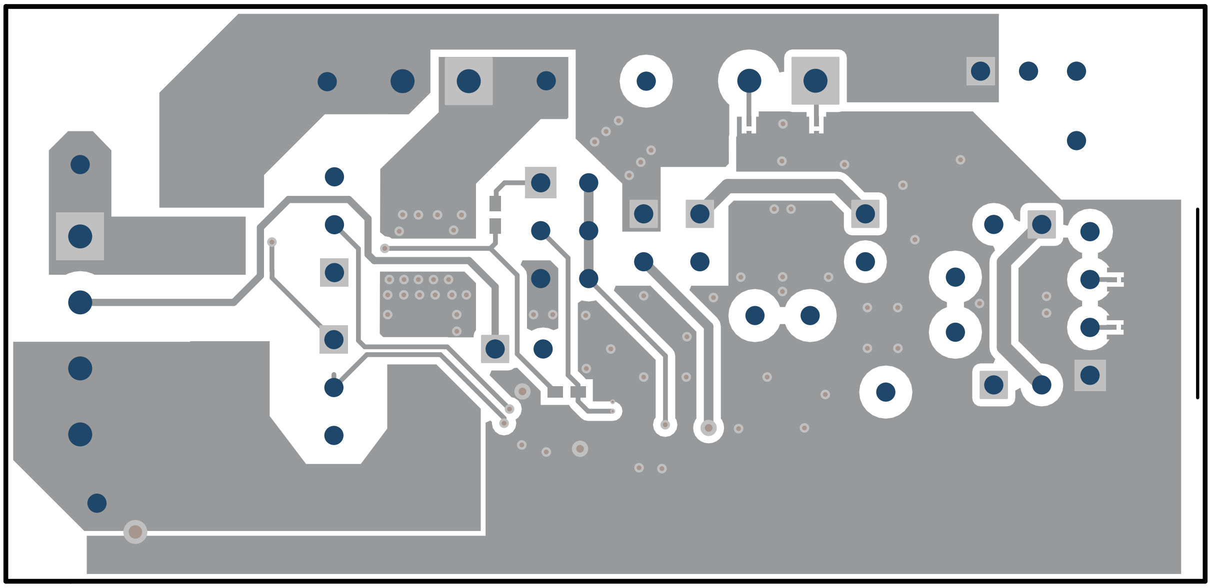


Figure 4-5. Bottom Layer

4.3 Bill of Material

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		BMS084	Any
C1	1	1uF	CAP, CERM, 1 uF, 6.3 V, +/- 20%, X5R, 0201	0201	GRM033R60J105MEA2D	MuRata
C2	1	0.01uF	CAP, CERM, 0.01 uF, 6.3 V, +/- 10%, X5R, 0201	0201	GRM033R60J103KA01D	MuRata
C3	1	0.1uF	CAP, CERM, 0.1 uF, 6.3 V, +/- 10%, X5R, 0201	0201	GRM033R60J104KE84D	MuRata
J1, J4	2		Terminal Block, 3.5mm Pitch, 2x1, TH	7.0x8.2x6.5mm	ED555/2DS	On-Shore Technology
J2	1		Header, 100mil, 3x2, Tin, TH	3x2 Header	PEC03DAAN	Sullins Connector Solutions
J3, J5, J6, J7, J11, J12	6		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
J8	1		Terminal Block, 3.5mm Pitch, 4x1, TH	14x8.2x6.5mm	ED555/4DS	On-Shore Technology
J9, J10, J13	3		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
J14	1		Header (friction lock), 100mil, 4x1, R/A, TH	4x1 R/A Header	22/05/3041	Molex
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
R1, R19	2	0.001	RES, 0.001, 1%, 1 W, AEC-Q200 Grade 0, 1206	1206	CSNL1206FT1L00	Stackpole Electronics Inc
R2, R3, R9, R10, R17, R18	6	49.9	RES, 49.9, 1%, 0.05 W, 0201	0201	CRCW020149R9FKED	Vishay-Dale
R4, R6	2	1.0k	RES, 1.0 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K00JNED	Vishay-Dale
R5	1	10	RES, 10, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210R0JNED	Vishay-Dale
R7, R8, R13, R14	4	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0JNED	Vishay-Dale
R11, R12, R15, R16	4	100	RES, 100, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402100RFKED	Vishay-Dale
RT1	1	10k	Thermistor NTC, 10.0k ohm, 1%, 0402	0402	ERT-J0EG103FA	Panasonic
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J9, SH-J10, SH-J11	10	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP5, TP9	3		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone Electronics
TP2, TP4, TP7, TP8, TP10, TP11	6		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone Electronics
TP3, TP6	2		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone Electronics
U1	1		Impedance Track Battery Gas Gauge Solution for 1-Series Cell Li-Ion Battery Packs, YPH0012ARAK (DSBGA-12)	YPH0012AUAM	BQ27Z558YPHR	Texas Instruments
U2, U3, U4, U5	4		Automotive 1-Channel ESD in 0402 Package With 12 pF Capacitance and 6 V Breakdown, DPY0002A (X1SON-2)	DPY0002A	TPD1E10B06QDPYRQ1	Texas Instruments
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A

5 Additional Information

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   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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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:*

3.1 *United States*

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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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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8. *Limitations on Damages and Liability:*

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9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

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