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

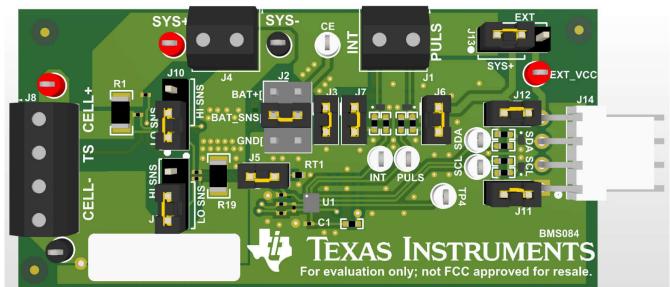
 Complete evaluation system for the BQ27Z558 gas gauge with Impedance Track[™] technology



- Populated circuit module for quick setup
- Personal computer (PC) software that allows configuring and data logging for system analysis
- 1.2V I/O I²C 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.

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BQ27Z558 Specification	Min	Тур	Мах	Units
Input voltage SYS+ to SYS-	-0.3	3.6	6	V
Input voltage Bat+ to Bat-	-0.3	3.6	6	V

Table 1-1. Performance Specification Summary

1.4 Device Information

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The Texas Instruments' BQ27Z558 Impedance Track gas gauge design is a highly integrated, accurate 1series 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.

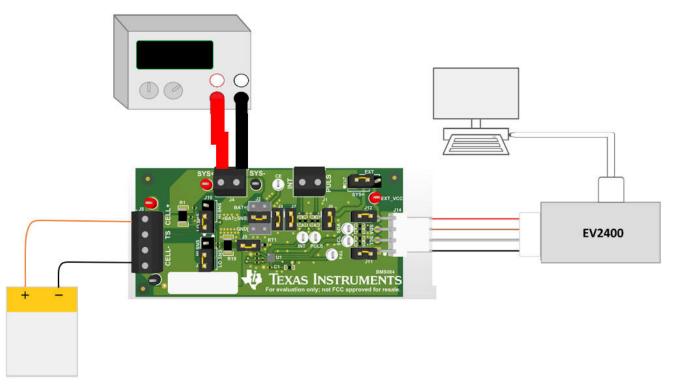


Figure 2-1. Connect the BQ27Z558 Circuit Module to a 1SxP



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** I²C Clock Pull-up (SCL): This jumper applies a 10k pullup to J13 on the I²C communication line.
- 3. J12 I²C Data Pull-up (SDA): This jumper applies a 10k pullup to J13 on the I²C 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.

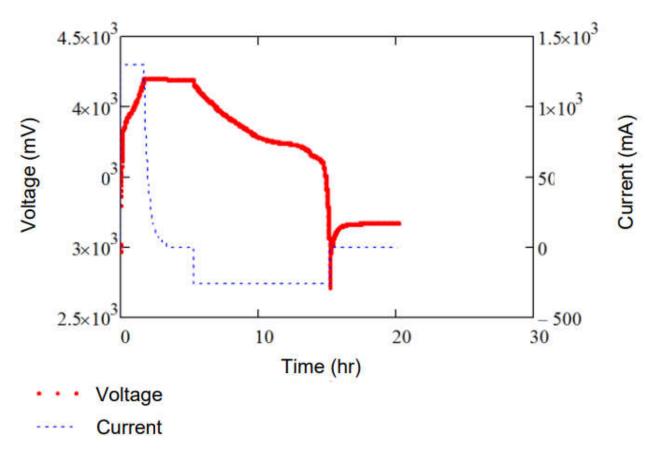


Figure 2-2. Graph of IV Data in Charge-Relax-Discharge-Relax



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.

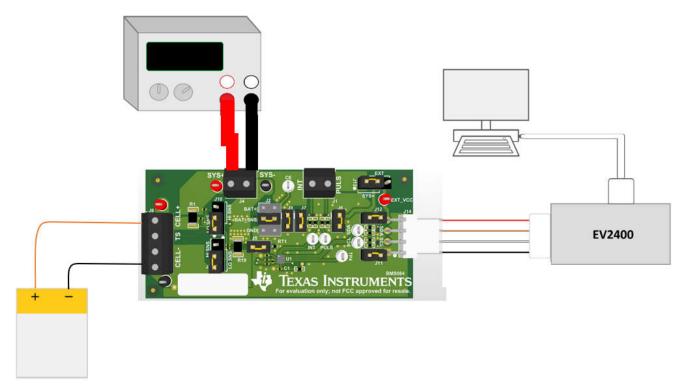


Figure 2-3. ChemID Hardware Setup



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.

Board	□ 0 Registers =	Commands 31	
efresh is ON - Click to Turn OFF	Registers	Commands	
io Version: 1.3.124	Registers	DEVICE NUMBER	
EV2400	Registers	# HW VERSION	
Version: 0.18	Name Value Un. Log Sc., Name Value Un., Log Sc	FW_VERSION	
	2 Manufacture Access 0.0002 best P Emanufacture Access 0.0002 best P P Water Comparator 0 mA P P Emanufacture Access 0.0002 P P P P Water Comparator 0 mA P P Emandacture Access 0.0002 P	FW_BUILD	
12C	■ A Rata Time 10 = 05535 min P ■ Maximum Tubo C 0 mA P ■ C Reme 2025 C. P ■ Gatative ■ Remeter 237.0 M P ■ C Regrap Output 0 mA P ■ C Remeter 2325 C. P P ■ Gatative 133 S P P ■ Remeter 237.0 M. P P ■ Gatative 137 P P ■ Gatative 137 S P P ■ Gatative 100 0 P P ■ Gatative	CHEM ID	
	UVoltage 3794 mV P P UTurbo RM 0 m. P P UCycle Court 0 - P P UFR Full Chg E 2025 c. P P UD000 Passed 0 0 mAh P P	Ø QMAX DAY	
bq27z558 1561 2 01	Average Current 0 mA P P 2VoltHi Set 4500 mV P P Cell 1 Voltage 3794 mV P P Thue Rem E 2025 cVh P P DOD0 Time 0 h/16 P P	GAUGE EN	
Addr: 0xAA	■ Average Power 0 CV P P 2VeH Cear 4400 mV P P 2Etagest Time 0 sec P P Enthald 0 mA P P Cet 1000E0C 0 - P P ■ Redness Bard C 100 % P P VeH Los 2 200 mV P P Cet Curret 0 mA P P Enthald 0 mA P P Cet 100Me 5559 mA P P	LIFETIME_EN	
Z 23.2 degC	■ Remaining Capacity 5290 m/h 9 P 2/Veta Galer 2200 m/ 9 P ⊡Cell 19weer 0 cW 9 P There Full Cipit 2520 m/h 9 P Cell 10Mas CODO 0 - P P P	 LT_RESET 	
		LT_FLUSH	
33	Marca d Current - 50 mA P P Ziemp Lo Ciest - 5 de P P Collemperature 2-37 de P P Collel 1 RaScale 1000 - P P Ciemperature - 237 de - 100 - P P	 LT_TEST 	
93 V	MaxLoad Time to _ 635 min P P SOC Deta Set 1 % P P Cell 1 Raw Voltage 3794 mV P P Cell 1 CompRes 0 m. P P	 CAL_TOGGLE 	
III		RESET	
		SMOOTH_SYNC	
		SET_DP_SLP	
0		CLEAR_DP_SLP	
		HIBERNATE_TOGL	
		PULSE_GPIO	
	Bit Registers Bit Registers	SET_GPIO	
	Name Value Log LogField Scan Bit15 Bit14 Bit12 Bit10 Bit9 Bit9 Bit3 Bit4 Bit3 Bit12 Bit10 Bit9 Bit9 Bit9 Bit3 Bit4 Bit3 Bit12 Bit11 Bit10 Bit9 Bit9 Bit3 Bit4 Bit3 Bit12 Bit11 Bit10 Bit9 Bit3 Bit3 Bit12 Bit11 Bit10 Bit9 Bit3 Bit3 Bit13 Bit12 Bit11 Bit10 Bit9 Bit3 Bit4 Bit3 Bit13 Bit12 Bit11 Bit10 Bit9 Bit3 Bit3 Bit13 Bit12 Bit11 Bit10 Bit9 Bit3 Bit3 Bit3 Bit3 Bit3 Bit3 Bit13 Bit12 Bit11 Bit10 Bit3 Bit3 <td>CLEAR_GPIO</td> <td></td>	CLEAR_GPIO	
	Battery Status 0x0000 P C P RSVD TCA RSVD TDA RSVD TDA RSVD RCA RSVD INIT DSG FC FD RSVD RSVD RSVD RSVD	* TAMBIENT_SYNC	
	Coperation Status P 00100 P P RSVD RSVD RSVD RSVD RSVD RSVD RSVD RSVD	✓ SEAL	
	□ Temp Pange 0.08 P Γ P R8V0 R8V0 R8V0 R8V0 R8V0 R8V0 R8V0 R8V0	GO_TO_HDQ	
	Cauging Status 0x40 P C P RSVD DSG EDV RSVD TC TO FC FD	UNSEAL	
	Manufacturing Status 0x8000 P C P CALEN LITTEST RSVD RSVD RSVD RSVD RSVD RSVD RSVD RSVD	RUNSEAL_FULL_ACCESS	
	ILStatus 0 P F P PELDTREN CF3 C	Log Panel	Clear
		Transaction Log	Clear
		Name Cmd Result Rea	

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 $Excel^{M}$ 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.

	А	В	С	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

8

- 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.

shBoard		G Registers Chemistry	stry 🔐 Authentication 🔣 Programming 🧱 Golden Image 👪 I2C To	-		Commands 22	-
	ON - Click to Turn OFF	Chemistry Programming				Commands	
idio Version	n: 1.3.124	Program Battery Chemistry					
0						DEVICE_NUMBER	
- ·	EV2400		zed carbon anode, which is supported by the detault firmware in the Impeda Il manufacturer indicates that their cells use a different chemistry than LiCoO2		allows the fuel gauge to be set up for various alternate battery chemistries. Use this tool to	# HW_VERSION	
7	Version: 0.18	Include chemistry IDs that do not support Turb		cauloue and graphite anode.		FW_VERSION	
		Manufacturer	Model	Chemistry ID	Description	FW_BUILD	
4	12C	360FLY	PR-693231 (815mAh)	1318	UCoO2/carbon 11	CHEM ID	
	IZC.	MA123	26650M1B (2500mAh)	0434	LiFePO4/carbon	-	
2	bg27z558	A123	ANR26650M1-B Consult TI before use (2500mAh)	0453	LiFePO4/carbon	S QMAX DAY	
	1561_2_01	A123Systems	ANR26650M1-B (2500mAh)	0465	LiFePO4/carbon	GAUGE_EN	
	Addr: 0xAA	AA Portable Power	LFP-18650-1500 (1500 mAh)	0439	UFePO4/carbon	 LIFETIME EN 	
z	23.2 degC	Acebel	ECFV1260 (60Ah)	0807	Lead Acid		
-		Advanced Electronics Energy	AE18650C-26 (2600mAh)	2151	NiCoMn/carbon	LT_RESET	
		AESC	29589-3NK0B (16500mAh)	1554	LiCoO2/carbon 11	LT_FLUSH	
3		MAESC	29589-4NN0A (10425mAh)	1561	LiCoO2/carbon 11	LT_TEST	
	I	AISIPU	3872C8 (5100mAh)	1335	LICoO2/carbon 11	CAL_TOGGLE	
		AISIPU	723292 (3080mA)	1363	LiCoO2/carbon 11		
Do.		MAISIPU	856360 (4750mAh)	3636	UMn2O4 (Co,Ni)/carbon, 4.35V	RESET	
000)	MALE	045062 (2300 mAh)	1254	LiNiCoMnO2/SGenNo1, 4.2V	SMOOTH_SYNC	
~ 4		MALE	ALE073470 (1700mAh)	2047	NiCoMn/carbon	SET_DP_SLP	
14		Ampace	583869 (2635mAh)	7174	LiMn2O4 (Co,Ni)/carbon, 4.3V		
-		Amprius	45057 (2300mAh)	2045	NiCoMn/carbon	CLEAR_DP_SLP	
		APOWER	AEC624052(1500mAh)	2346	LiCoO2/carbon, 4.20V	HIBERNATE_TOGL	
		ArtsEnergy	VHT-D-6AH (6000mAh)	6113	NiMH, -20C	PULSE GPIO	
		MATL	laminate (6760mAh)	1181	LiCoO2/carbon 5-4	 SET_GPIO 	
		MATL	laminate (4320mAh)	1188	LiCoO2/carbon 5-4		
		MATL	laminate (8460mAh)	1189	LiCoO2/carbon 5-4	CLEAR_GPIO	
		MAIL	486789 (3700mAh)	1190	LiCoO2/carbon 5-4	TAMBIENT_SYNC	
		MATL	ATL_GMB_Mix (7100mAh)	1203	LiCoO2/carbon 11	SEAL	
		MATL	Laminate (8568mAh)	1219	LiCoO2/carbon 11		
		MATL	316368 (1760mAh)	1222	LiCoO2/carbon 11	<pre> GO_TO_HDQ</pre>	
		MATL.	355762 (1572mAh)	1222	LiCoO2/carbon 11	UNSEAL	
		TATL .	Laminate (3216mAh)	1224	LiCoO2/carbon 11, 4.3v	Reveal Full Access	
		ITA III	Laminate (6634mAh)	1225	LiCoO2/carbon 11, 4.3v		
		TATL.	3083A3 (3380mAh)	1226	LiCoO2/carbon 11	Log Panel	Clear L
		I ATL	632531 (590mAh)	1309	LiCoO2/carbon 11	Transaction Log	
		MATL	1762A5 (1290mAh)	1310	LiCoO2/carbon 11	Name Cmd Result Rea	
		MATL	853568 (2200mAh)	1346	LiCoO2/carbon 11	Constraint and the second second	
		MATL	GP-S41-5264D9-010H (5100mAh)	1358	LiCoO2/carbon 11, -20C		
		™ATI <	ATI -566689 (4130mAh)	1379	LiCoO2/carbon 11.5C		

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.

	🔍 🔍 Registers 🗢 Data Memory 🕮 Calibration 🗉		Commands #
is ON - Click to Turn OFF ion: 1.3.124	Advanced Calibration		Commands
010 1.3.124	Perform Calibration		© DEVICE_NUMBER
EV2400	Select the types of calibration to perform a	ad aster the actual issuet	# HW_VERSION
Version: 0.18	Current Calibration	Temperature calibration	# FW_VERSION
	Applied Current	Sensor Applied temperature Calibrate	# FW_BUILD
12C	mA Calibrate Current	Internal deg C	¢ OHEM_ID
bq27z558		External 1 deg C	© QMAX DAY
1561_2_01	Voltage calibration		 GAUGE_EN
Addr: 0xAA 23.3 degC	Applied Cell 1 Voltage 3794 mV 🗹 Calibrate Voltage	Calibrate Gas Gauge	✓ LIFETIME_EN
25.5 orgc	and the canada volage		* LT_RESET
			✓ LT_FLUSH
			* UT_TEST
			* CAL TOGGLE
			* RESET
			* SMOOTH SYNC
			* SET_DP_SLP
			* CLEAR DP_SLP
			* HIBERNATE_TOGL
			* PULSE GPIO
			* SET_GPIO
			* CLEAR GPIO
			* TAMBIENT_SYNC
			* SEAL
			* GO_TO_HDQ
			P UNSEAL
			A UNSEAL FULL ACCESS
			Log Panel Clas
			Transaction Log
			Name Crnd Result Rea

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.

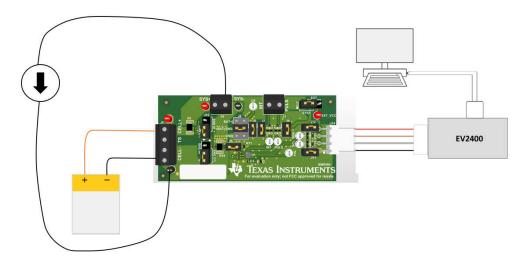


Figure 2-8. Current Calibration Hardware Setup

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.



ard	T ** D Registers = Data Memory Calibration =	in 🐰 Programming 🇱 Golden Image 🎎 IZC To HDQ 🕌 GPCPackager 🕌 Watch 🔤 Data Graph 🧫 Errors	™ □ Commands ∺
resh is ON - Click to Turn OFF	Advanced Calibration		Commands
Version: 1.3.124	Perform Calibration		# DEVICE NUMBER
EV2400			# HW_VERSION
Version: 0.18	Select the types of calibration to perform and enter the actual input		FW_VERSION
	Current Calibration Temperature calibra Applied Current Sensor Applied ter		FW_BUILD
120	100 mA Calibrate Current Internal	deg C	CHEM ID
	External 1	deg C	© QMAX DAY
bq27z558 1561_2_01	Voltage calibration		GAUGE EN
Add:: 0xAA	Applied Cell 1 Voltage Calibrate Gas Gauge		 UFETIME EN
2 23.2 degC	mV Calibrate Voltage		· LT_RESET
			* LT_FLUSH
			LT TEST
			 CAL TOGGLE
			* CAL_IODOLE
			* SMOOTH SYNC
			* SET_DP_SLP
ALC: NO.			CLEAR DP SLP
			 HIBERNATE_TOGL
			* PULSE_GPIO
			SET_GPIO
			* CLEAR_GPIO
			TAMBIENT_SYNC
			* SEAL
			* GO_TO_HDQ
			P UNSEAL
			A UNSEAL FULL ACCESS
			Log Panel
			Transaction Log
			Name Cmd Result Rea

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 μ V/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.

View Winde	ow Help											
Registers	🐲 Data Memory 💈 Comman	ds 🔲 Calibration 🎯 Advanced	Comm 🛓 Chemistry 🔐 Authentication 🗒 Pro	gramming 🔃 Golden Image 🐰	IZC TO HDQ 📙 G	PCPackager 🛃 Watch 🛔	🔄 Data Graph	Errors				
ashBoard		C Registers Tota Memory									Commands 22	
	ON - Click to Turn OFF	Data Memory					Filter/Search	Auto Export Hex Dum	p Export Timport	• 2 Write_All Read All	Commands	
udio Version	: 1.3.124	Read/Write Data Memory Co	ontents								DEVICE_NUMBER	
- ⁴	EV2400	Calibration	Name	Value	Unit	Physical Start Address	Data Length	Row Number	Row Offset	Native Units	HW_VERSION	
	Version: 0.18		✓ Current Thresholds								FW_VERSION	
		Settings	Dsg Current Threshold Cha Current Threshold	60 75	mA	0x4725 0x4727	2	57 57	5	mA		
		Advanced Charge Algorithm	Chg Current Threshold Quit Current	40	mA	0x4727 0x4729	2	57	7	mA mA	FW_BUILD	
	I2C	Gas Gauging	Dsg Relax Time	40	s	0x472b	1	57	11	s	CHEM_ID	
			Chg Relax Time	60	5	0x472c	1	57	12	5		
~		Power	~ Max Load								QMAX DAY	
5	bq27z558	System Data	Max Load Current	-500	mA	0x4663	2	51	3	mA	GAUGE_EN	
	1561_2_01	I2C Configuration	Max Load Rsoc	50	5	0x4665	1	51	5	%	· GAUGE_EN	
-	Addr: 0xAA		✓ Design								LIFETIME_EN	
J Z	23.0 degC	Lifetimes	Design Capacity mAh	5300 2040	mAh cWh	0x4666 0x4668	2	51 51	6	mAh		
		Ra Table	Design Capacity cWh Design Voltage	2040 3850	mV	0x466a	2	51	8	cWh mV	LT_RESET	
			 Cycle 	5550		044008			10		LT_FLUSH	
			Cycle Count Percentage	90	5	0x466c	1	51	12	5		
93			✓ FD								 LT_TEST 	
N			Set Voltage Threshold	3000	mV	0x4671	2	51	17	mV	CAL_TOGGLE	
			Clear Voltage Threshold	3100	mV	0x4673 0x4675	2	51 51	19	mV	CAL_TOGULE	
TTTP-			Set % RSOC Threshold Clear % RSOC Threshold	0	% %	0x4676	1	51	21	<u>.</u>	RESET	
			✓ FC	5		0.4070		51	~~~			
1000			Set Voltage Threshold	4400	mV	0x4677	2	51	23	mV	SMOOTH_SYNC	
0 7			Clear Voltage Threshold	4300	mV	0x4679	2	51	25	mV	SET_DP_SLP	
			Set % RSOC Threshold	100	%	0x467b	1	51	27	~		
			Clear % RSOC Threshold	95	%	0x467c	1	51	28	%	CLEAR_DP_SLP	
			✓ TD				2				HIBERNATE_TOGL	
			Set Voltage Threshold Clear Voltage Threshold	3200 3300	mV mV	0x467d 0x467f	2	51 51	29 31	mV mV		
			Set % RSOC Threshold	6	%	0x4681	1	52	1	%	PULSE_GPIO	
			Clear % RSOC Threshold	8	5	0x4682	1	52	2		SET_GPIO	
			✓ TC								* SEI_GPIO	
			Set Voltage Threshold	4400	mV	0x4683	2	52	3	mV	CLEAR GPIO	
			Clear Voltage Threshold	4300	mV	0x4685	2	52	5	mV		
			Set % RSOC Threshold	100	%	0x4687	1	52	7	%	 TAMBIENT_SYNC 	
			Clear % RSOC Threshold V State	95	5	0x4688	1	52	8	%	* SEAL	
			Cycle Count	0		0x41c0	2	14	0			
			Qmax Cell 1	5359	mAh	0x4186	2	12	6	mAh	GO_TO_HDQ	
			Qmax Day	0	-	0x4188	2	12	8		UNSEAL	
			Qmax Cycle Count	0		0x418a	2	12	10		- UNSEAL	
			Update Status	00		0x418c	1	12	12		UNSEAL_FULL_ACCESS	
			Cell 1 Chg Voltage at EoC	4375	Wm	0x418d	2	12	13	W		
			Current at EoC	100	mA	0x418f	2	12	15	mA	Log Panel	C
			Avg I Last Run Avg P Last Run	-500 -192	mA cW	0x4191 0x4193	2	12	17	mA cW		-
			Delta Voltage	-192	mV	0x4195	2	12	21	mV	Transaction Log	
			Temp k	2.00	*C/256mW	0x4197	2	12	23	0.1 *C/256cW	Name Cmd Result Rea	
			Temp a	1000	s	0x4199	2	12	25	s		
			Max Avg I Last Run	-500	mA	0x419b	2	12	27	mA		
			Max Avg P Last Run	-192	cW	0x419d	2	12	29	cW		
			SOH Temp k	1.00	*C/256mW	0x46a6	2	53	6	0.1 *C/256cW		
			SOH Temp a v Turbo Cfg	1000	5	0x46a8	2	53	8	5		
			 Turbo Clg Min System Voltage 	3000	mV	0x4343	2	26	3	mV		
			Ten Second Max C Rate	-2.0	C	0x4345	1	26	5	0.10		
			Ten Millisecond Max C Rate	-40	c	0x4346	1	26	6	0.10		
			High Frequency Resistance	36	mOhm	0x4347	2	26	7	mOhm		
			Reserve Energy %	0	%	0x4349	1	26	9	%		
			Turbo Adjustment Factor	1.00		0x434a		26	10	* ×		

Figure 2-10. Data Memory View in bqStudio

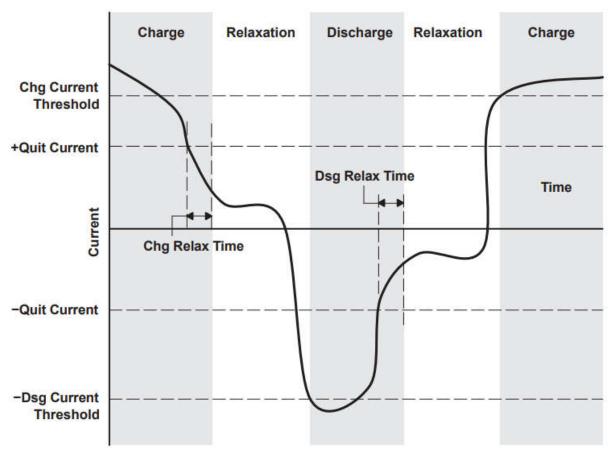
The necessary data memory configurations are made in this screen, using only the [Advanced Charging Algorithm] and [Gas Gauging] sections of the data memory window. Use the Filter/Search box to find specific parameters. Use the Write All button to write data memory parameters that have been changed on 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.







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 ² C communication data line
SCL	External I ² C 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.
- 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.

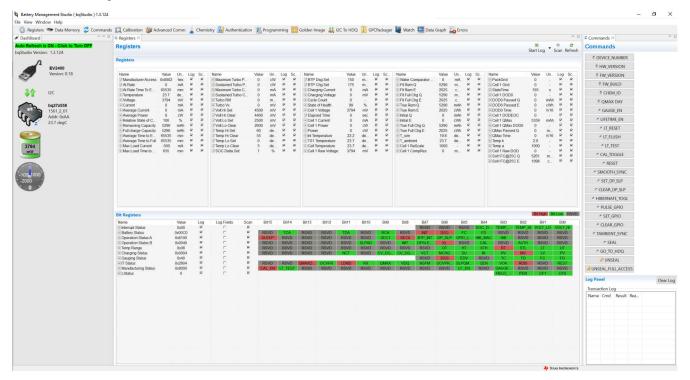


Figure 3-1. Registers Screen



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).

w Window Help	and the collection of the second	d Comm 👗 Chemistry 📆 Authentication 🗒 Prog	anna 📅 Caldar Innan 👪	126 T- 1100	non-data III utat I	Data Carab.	P				
	Calibration Advanced " Data Memory 2		gramming Bar Golden image Hoo		rerackager water	Data Graph	citois			Commands ≅	
tefresh is ON - Click to Turn OFF						Filter/Search			• 0		
io Version: 1.3.124	Data Memory					Filter/Search	Auto Export Hex Dum	p Export Import	Write_All Read All	Commands	
io version. 1.5.124	Read/Write Data Memory C	entente								DEVICE_NUMBER	
EV2400						Provide and a second second		0 00 1	-	# HW_VERSION	
Version: 0.18	Calibration	Name Voltage	Value	Unit	Physical Start Address	Data Length	Row Number	Row Offset	Native Units	FW_VERSION	
	Settings	Cell Gain	12101		0x4000	2	0	0			
	Advanced Charge Algorithm	✓ Current CC Gain	1.000	mOhm	0x4006	4	0	6		FW_BUILD	
A 12C	Gas Gauging	Capacity Gain	1.000	mOhm	0x400a	4	0	10		CHEM_ID	
	Power	 Temperature Internal Temp Offset 	0.0	*C	0x4014	1	0	20	0.1°C	S QMAX DAY	
bq27z558	System Data	External1 Temp Offset	0.0	*C	0x4015	i	0	21	0.1°C	GAUGE_EN	
1561_2_01 Addr: 0xAA	I2C Configuration	 Internal Temp Model Int Gain 	-13908		0x4440	2	34	0			
23.5 degC	Lifetimes	Int base offset	6959		0x4442	2	34	2		LIFETIME_EN	
	Ra Table	Int Minimum AD	0 6959	0.1degK	0x4444 0x4446	2	34 34	4	0.1degK	LT_RESET	
	ra labe	Int Maximum Temp V Cell Temperature Model		0.1degK		2		0	0. roegik	LT_FLUSH	
764 htt		Coeff a1	-17447		0x4448 0x444a	2	34 34	8 10		 LT_TEST 	
794 nV		Coeff a2 Coeff a3	29322 -25430	-	0x444a 0x444c	2	34	10	2		
		Coeff a4	29836		0x444e	2	34	14		CAL_TOGGLE	
		Coeff a5 Coeff b1	1200 -293		0x4450 0x4452	2	34 34	16 18		RESET	
		Coeff b2	552		0x4454	2	34	20		SMOOTH SYNC	
000		Coeff b3 Coeff b4	-2887 4591		0x4456 0x4458	2	34 34	22 24		* SET_DP_SLP	
0		Rc0	11703		0x445a	2	34	26			
0		Adc0 Rpad	11703	-	0x445c 0x445e	2	34 34	28 30		CLEAR_DP_SLP	
		Rint	0		0x4460	2	35	0		HIBERNATE_TOGL	
		 Current Deadband Deadband 		mA	0x4465	1	35	5	mA	PULSE GPIO	
		Coulomb Counter Deadband	3	116nV	0x4465 0x4466	1	35	6	116nV	* SET_GPIO	
										CLEAR_GPIO	
										TAMBIENT_SYNC	
										SEAL	
										GO_TO_HDQ	
										P UNSEAL	
										RUNSEAL_FULL_ACCESS	
										Log Panel	Clea
										Transaction Log	Crei
										Name Cmd Result Rea	

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.

EV2400 Version: (2C bq27z55	Byte Read/Write	mm I Pane	I2C				1 W B	Commands				
EV2400 Version: (2C 0q27z55i	Byte Read/Write		el					Commanus				
Version: (2C 0q27z55 i	Byte Read/Write			IzC Master Control Panel								
Version: (2C 0q27z55 i	I		Byte Read/Write									
bq27z551		2C Ad	Idress (H	ex) AA				# HW_VERSION # FW_VERSION				
bq27z551		FW_BUILD										
bq27z55i 1561_2.0 Addr: 0xA 23.2 deg(By		Write (He			Write		CHEM_ID				
								© QMAX DAY				
	Number of Bytes	to Per	d (Docim	2 (14)	1	Read		GAUGE_EN				
	<u></u>	to nea	iu (Decini		-	- Neau		LIFETIME_EN				
		Rd	Addr	Regi	Le	Data		LT_RESET				
			AA	2C	2	64 00		 LT_FLUSH 				
3793 mV 100%								 LT_TEST 				
								CAL_TOGGLE				
								RESET				
								SMOOTH_SYNG				
								SET_DP_SLP				
								CLEAR_DP_SLP				
								HIBERNATE_TOO				
								* PULSE_GPIO				
								SET_GPIO				
								CLEAR_GPIO				
								Log Panel Clear L				
								Transaction Log				
								Name Cmd Resul				
				TimeStamp Rd Addr	TimeStamp Rd Addr Regi	TimeStamp Rd Addr Regi Le	TimeStamp Rd Addr Regi Le Data	TimeStamp Rd Addr Regi Le Data				

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**.

shBoard	nds 🛄 Calibration 🐲 Advanced Comm 🗼 Chemistry 🄐 Authentication 🐰 Programming 🧱 Golden Image 🞎 12C To HDQ 📙 GPCPackager 🐙 Watch 🖼 Data Graph 🏣 Errors	" D	Commands 12	
Refresh is OFF - Click to Turn On	Advanced Comm I2C		Commands	
dio Version: 1.3.124	IZC Master Control Panel	g culculator	DEVICE_NUMBER	
EV2400	Byte Read/Write		# HW VERSION	
Version: 0.18	I2C Address (Hex) AA		FW_VERSION	
	Start Register (Hex) 3E		FW_BUILD	
12C	Bytes to Write (Hex) 06 00 A Write		CHEM ID	
			OMAX DAY	
bq27z558			GAUGE_EN	
Addr: 0xAA			LIFETIME_EN	
23.2 degC			* LT_RESET	
15612,01A 4322,2 degC	sea Image:		 LT_FLUSH 	
1702			* LT_TEST	
mV			 CAL_TOGGLE 	
			* RESET	
			 SMOOTH_SYNC 	
00			* SET_DP_SLP	
0			CLEAR_DP_SLP	
			* HIBERNATE_TOGL	
			* PULSE_GPIO	
			* SET_GPIO	
			CLEAR_GPIO	
			* TAMBIENT_SYNC	
			* SEAL	
			. GO_TO_HDQ	
			P UNSEAL	
			BUNSEAL_FULL_ACCESS	
			Log Panel	Clear
			Transaction Log	
			Name Cmd Result Rea	

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.

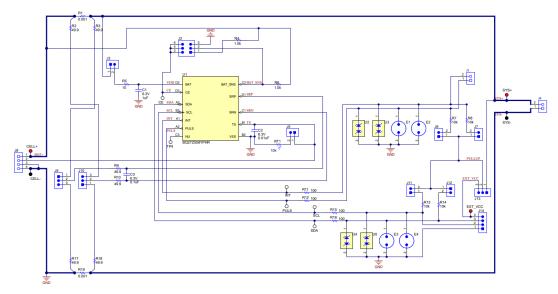


Figure 4-1. BQ27Z558 Reference Schematic



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.

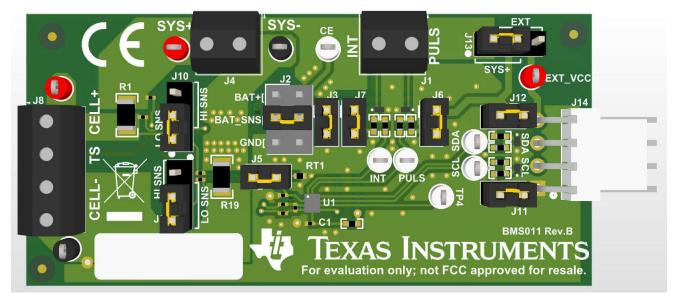


Figure 4-2. EVM Image

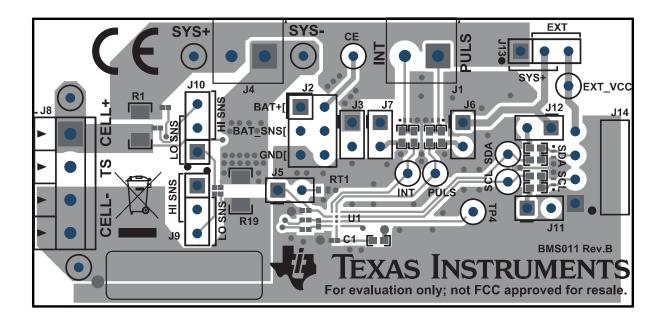


Figure 4-3. Top Layer Composite



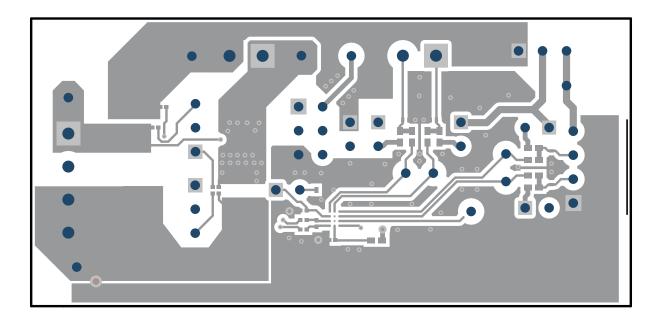


Figure 4-4. Top Layer

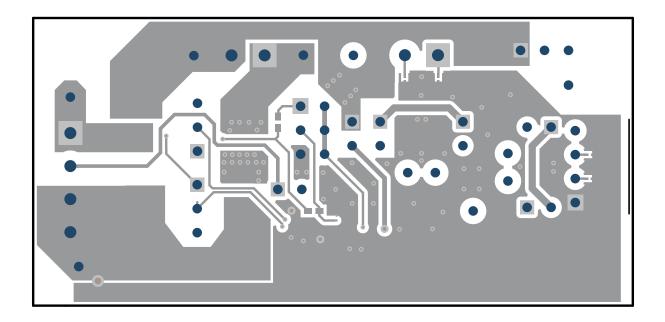


Figure 4-5. Bottom Layer



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 Technolog
J2	J2 1		Header, 100mil, 3x2, Tin, TH	3x2 Header	PEC03DAAN	Sullins Connector Solutions
13, 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 Technolog
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	L1 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 Electronic
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 Electronic
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



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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.

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