Application Note How to Configure the BQ35100 for EOS Mode



Nick Richards

ABSTRACT

This application note examines how to configure the BQ35100 for End of Service (EOS) mode to accurately alert when a primary Li-SoCl2 battery needs to be replaced. To optimize the algorithm, impedance data needs to be collected using a microcontroller or other capable system to help calculate the data flash parameters for the EOS algorithm and alert functions.

Table of Contents

1 Introduction	2
2 EVM and System Setup	2
3 Enabling EOS Mode	3
3.1 Steps for Enabling EOS Mode	3
3.1 Steps for Enabling EOS Mode	5
5 Testing Procedure	
6 EOS Data Example	6
7 Final Configuration of the BQ35100 Data	7
8 Conclusion	8
9 References	9

List of Figures

Figure 2-1. Wire Connection Block Diagram	2
Figure 3-1. UNSEAL and [SEC1,0] in bqStudio	
Figure 3-2. NEW_BATTERY in BQStudio	
Figure 3-3. Operation Config A in BQStudio	
Figure 6-1. Scaled Resistance Profile of LS14500 Battery with EOS Flag Thresholds	

List of Tables

Table 7-1. Initial EOS Learning	7
Table 7-2. EOS Data Flash	7

Trademarks

All trademarks are the property of their respective owners.



1 Introduction

It is difficult to gauge the remaining capacity of a lithium thionyl chloride battery because of the extremely flat open circuit voltage. However, the BQ35100 configured in EOS mode solves this challenge by using impedance data measured during short current pulses. This test shows the data that the BQ35100 can collect, and how that data is used to determine when a lithium thionyl chloride battery is nearing the end of life.

2 EVM and System Setup

Figure 2-1 shows the wiring used for collecting impedance data. The BQ35100 EVM is connected using I2C communication, and data memory is connected using SPI communication, or any other available method. The BQ35100 EVM already implements pull-up resistors on the I2C communication lines so no external pull-up resistors are needed.

Any controller or MCU can be used for collecting the impedance data, there are only a few requirements:

- The ability to save logged data read from the BQ35100
- · Ability to communicate over I2C to read data and send commands
- GPIO functionality for the GE and ALERT functions

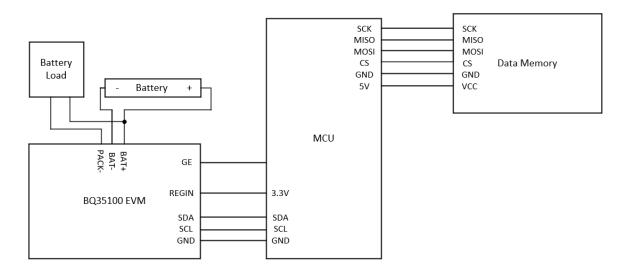


Figure 2-1. Wire Connection Block Diagram



3 Enabling EOS Mode

Scaled resistance and measured impedance values are only updated when the gauge is in EOS mode. Using BQStudio is the easiest way to configure the gauge to EOS Mode.

3.1 Steps for Enabling EOS Mode

First, set the gauge to unsealed mode if it was previously sealed by pressing UNSEAL in the Commands tab. Verify the gauge is unsealed by checking the *[SEC1,0]* bits of *ControlStatus()*. The gauge is unsealed when SEC1 is set high and SEC0 is set low. If the gauge was previously sealed, re-uploading the default .SREC file which was never sealed will stop the gauge from booting up in a sealed state.

Bit Registers Bit Log Log Log Log Bit 15 Bit 13 Bit 13 </th <th>DashBoard</th> <th></th> <th> Commands Registers Page </th> <th></th> <th></th> <th>·</th> <th></th> <th></th> <th>-</th> <th></th> <th>_</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>-</th> <th></th> <th>~</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>23</th> <th></th>	DashBoard		 Commands Registers Page 			·			-		_						-		~						23	
BV USINI 13.111 Fegisters I FW_VERSION I FW_VERSION <td< td=""><td></td><td></td><td>Registers</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>og 🔻</td><td></td><td></td><td>Comman</td><td>ds</td><td></td></td<>			Registers																		og 🔻			Comman	ds	
Ev2400 Version: 0.32 Name Value Units Log Scale Name Value Vinits Log Scale Name Value Vinits Log Scale P Mane Value Vinits Log Scale P P Mane Value Vinits Log Scale P P Mane Value Vinits Log Scale P P P Scale P P P Scale P P Scale P P P Scale P P P Scale P P P P Scale P Scale R Scale R Scale R Scale Scale Scale R Scale Scale Scale Scale Scale Scale Scale Scale </td <td>Studio Versio</td> <td>n: 1.3.111</td> <td>Production of</td> <td></td> <td>Diarte</td> <td>.09</td> <td>Jean</td> <td></td> <td>₽ FW_V</td> <td>ERSION</td> <td></td>	Studio Versio	n: 1.3.111	Production of																	Diarte	.09	Jean		₽ FW_V	ERSION	
Version: 0.32 Name Value Units Log Scale Scale Name Value Value Value Value Value Valu			Registers																					🔮 FW	BUILD	
I2C I2C Image: Ima			Nama		Mahua	Linite	1.00	Case	Name			Mahua	Linite	1.00	Coor	Nem				Mahua	Unite	1.00	Casa			
I2C bq35100 0100_102 22.7 de. P P Design Capacity 2200 mAh P GAUGE_START bq35100 0100_102 Add: 0xAA 2.7 degC 3001 mV P Design Capacity 2200 mAh P GAUGE_START bq35100 0100_102 Add: 0xAA 2.7 degC Makesured Z -932 mO P Design Capacity 2200 mAh P GAUGE_START b010 .02 Add: 0xAA <t< td=""><td>~</td><td>VCI3IO11. 0.52</td><td></td><td>tion</td><td></td><td></td><td></td><td></td><td></td><td>ent</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>mneratu</td><td>re</td><td></td><td></td><td></td><td></td><td>V CHI</td><td>INI_ID</td><td></td></t<>	~	VCI3IO11. 0.52		tion						ent								mneratu	re					V CHI	INI_ID	
i2C i				i on														mperata						GAUG	E_START	
bq35100 0100,102 Add::0xAA 22.7 degC Add::0xAA 22.7 degC Image: Control for the state of the state		I2C	Voltage		3601	mV	P	P	Sca	led R		-932	m0		P	∎ D€	esign Ci	apacity		2200	mAh	V	P	GAUG	E_STOP	
0 i 00 1 02 Addr: 0xAA 22.7 degC Addr: 0xAA 22.7 degC Image: Control of the con	~																							LIFET	IME_EN	
22.7 degC Bit	2200																							BOARE	_OFFSET	
Bit Registers Bit Registers Bit Bit Low RSVD Control 0.22 P P FLA SEC1 SEC0 Cal BCA CCA LT OC. NIT G SO SO EXAMPLE P P PLA SEC1 SEC0 Cal BCA CCA LT OC. NIT G SO SO EXAMPLE P PLA SEC1 SEC0 Cal BCA CCA LT OC NIT G SO SO SO F SO F SO SO NIT G SO SO SO SO F SO SO SO SO NIT F SO SO SO NIT MUNSEAL PUNSEAL PUNSEAL PUNSEAL PUNSEAL SO SO SO SO NUNSEAL SO	S~																							 CC_C 	OFFSET	
Bit Registers Name Value Log Log Log Field Bit 5 Bit 4 Bit 3 Bit 2 Bit 1 Bit 3 Bit 2 Bit 3 Bit 2 Bit 3 Bit 2 Bit 3 Bit 3 Bit 3 Bit 1 Bit 3 Bit 1 Bit 3 Bit 3 <td>U.</td> <td>22.7 degc</td> <td></td> <td>CC_OFF</td> <td>SET_SAVE</td> <td>E</td>	U.	22.7 degc																						CC_OFF	SET_SAVE	E
Bit Registers Bit Age Log Log <thlog< th=""> Log Log</thlog<>	-																							* S	EAL	
Value Log Log Log Log Log Log Log Log Log Bit15 Bit14 Bit13 Bit12 Bit11 Bit10 Bit19 Bit8 Bit7 Bit6 Bit6 Bit3 Bit2 Bit11 Bit13 Bit12 Bit11 Bit10 Bit13 Bit2 Bit11 Bit10 Bit13 Bit2 Bit11 Bit10 Bit13 Bit2 Bit11 Bit13 Bit2 Bit11 Bit10 Bit13 Bit2 Bit11 Bit10 Bit13 Bit2 Bit11 Bit13 Bit2 Bit3 Bit3 Bit2 Bit3 Bit3 Bit2 Bit3 Bit3 Bit3	3601																							 RI 	SET	
2 Control 0x2 # F FIA SEC1 SEC0 Cal BCA CA LTOC NIT G EO RS	mV																			Bit	High B	it Low	RSVD	CAL_1	ioggle	
Image: Status biol Viscol Vi	ALL DISTORT																							NEW_	BATTERY	
AUNSEAL_FULL_ACCES			Battery Status	0x0			F	•	-							RS	RS	RS	RS	RS	ALE	RS	DSG	🔑 UN	SEAL	
Transaction Log American Ame American American A	000		Battery Alert	0x0	M		P.									BAI	1E	IE	SO	EUS	RS	G	INI I	🔎 UNSEAL_F	ULL_ACCE	ESS
Transaction Log Name Cmd Result I GAU 0x11 N/A T	1																							Log Panel	(Clea
Name Cmd Result I GAU 0x11 N/A																								Transaction		
GAU 0x11 N/A 1																									_	Þ
																								GAU 0x11	N/	Α

Figure 3-1. UNSEAL and [SEC1,0] in bqStudio

Next, press NEW_BATTERY in the Commands tab. This resets any previous data stored for resistance and scale factors and needs to always be sent before a new battery is inserted. Never insert a partially drained primary battery for testing.

ashBoard	× □ □	y 😴 Commands @ Registers 🛙 🖛 D			- ////			Crit		 ,		<u></u>	g				en innug		materi		ita oru		Comma	nds 🛙	
Refresh	is ON - Click to Tu																		∑ Start I	•	© Scan	2 Refresh	Comma		
tudio Versio	on: 1.3.111	Registers																	Start	Jog	Jean	Refresh	🔹 FV	W_VERSION	1
	EV2400	Registers																					21	FW_BUILD	
	Version: 0.32	Name		Value	Units	Log	Scan	Name			Value	Units	Log	Scan	Nan	ne			Value	Units	Log	Scan	2	CHEM ID	
		Charge Accumul	ation	0	uAh	R		Curren			1	mA		P			emperatu	re	20.7	de		R R	2.64	- AUGE START	г
	I2C	 Temperature Voltage 		22.7 3601	de mV	₽ ₽		Measu Scaled			-3076 -932	mO mO	N	2	ES ED	iOH)esign C	apacity		16 2200	% mAh	7			AUGE STOP	
	120																							IFETIME EN	
	bq35100																							ARD OFFSE	
\mathbb{C}	0100_1_02 Addr: 0xAA																								
	22.7 degC																							C_OFFSET	
																								OFFSET_SAV	VE
-																								SEAL	
3601																							-	RESET	
mV		Bit Registers																				RSVD	* C	AL_TOGGLE	
NUMBER OF STREET		Name Control	Value 0x2	Log ₽	Log Fie	. Sca ₽		5 Bit14					Bit9	Bit8	Bit7	Bit6	Bit5 SO	Bit4 SO	Bit3 EO	Bit2 RS	Bit1 RS	Bit0 GA	🛷 NE	W_BATTERY	Y
•	<u> </u>	Battery Status	0x0	P		P		5201	JECU	- Cal	DUA			00	RS	RS	RS	RS	RS	ALE	RS	DSG	2	UNSEAL	
00 <mark>-</mark> 1000 000		Battery Alert	0x0	P		P									BAT	TE	TE	SO	EOS	RS	G	INIT		AL_FULL_ACC	CESS
1	Ŧ																								
																							Log Pane	1	Clea
																							Transacti	on Log	
																							Name (Cmd Resu	ilt Re
																							GAU (0x11 N/A	N
																							GAU (0x12 N/A	N

Figure 3-2. NEW_BATTERY in BQStudio

Finally, in the Data Memory Tab, press the *Configuration* button. In *Operation Config A*, set bit GMSEL1 to high and set bit GMSEL0 to low. This configures the gauge for EOS mode. It can also be configured for accumulation and SOH mode for different applications.

DashBoard	~	Registers > Date	Calibration 🍟 /		<u>a</u> chonishij <u>i</u>	1	in ing rogium		activities and a			Commands ≅		
	ON - Click to Tu	Data Memor				Filter	/Search 🕞				+ 2	Commands		
tudio Versior			у				Auto Ex	port Hex Dum	np Export	Import 👗 W	rite_All Read All	Commands		
•		Read/Write Data	Read/Write Data Memory Contents											
1	EV2400		Name		Value	Unit	Physical Star	Data Length	Row Number	Row Offset	Native Units	FW_BUILD		
	Version: 0.32	Calibration	✓ Registers		value	Unit	Physical Stat	Data Length	Row Number	ROW Offset	Native Onits	CHEM ID		
~	CONTRACT OF	Configuration	Operation Confi	g A	82	hex	0x41b1	1	13	17	hex	_		
~		LTFlash	Ale Clk X			Ор	eration Config	j A			-	GAUGE_START		
	I2C	LTFlashDflt	Ba	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	GAUGE_STOP		
~		System Data	✓ Powe Fla	MSB TEMPS	EXTVCELL	WRTEMP	LF_EN	RSVD	GNDSEL	GMSEL1	GMSEL0	LIFETIME_EN		
***~~	bq35100 0100 1 02	Gas Gauging	Off			* \A/ri	te to Data Memo	201				BOARD_OFFSET		
P. J	Addr: 0xAA	Accum_Table	✓ Data								-	CC OFFSET		
Jr I	22.7 degC	Ra Tables	Default Tempera Device Name	ture	298.2 bq35100	K	0x41d4 0x4060	2 8	14	20	0.1K	CC OFFSET SAVE		
0		EOSData	Data Flash Vers	ion	fff	-	0x4068	2	3	8	-	* CC_OFFSET_SAVE		
		Security	✓ Discharge									SEAL		
		Security	OT Dsg		60.0	°C	0x41d6	2	14	22	0.1°C	RESET		
3601			OT Dsg Time		2	S	0x41d8	1	14	24	S	* RESET		
mV			OT Dsg Recove		55.0	°C	0x41d9	2	14	25	0.1°C	CAL TOGGLE		
			BatLow Voltage		2700	mV	0x41db	2	14	27	mV	CAL_TOUGEL		
			BatLow Voltage		2	S	0x41dd	1	14	29	S	NEW BATTERY		
•			BatLow Voltage	Clear Threshold	3000	mV	0x41de	2	14	30	mV	inciri_b/inficiri		
1 3				ure Set Threshold	50	0.1°C	0x41e0	2	15	0	0.1°C	UNSEAL		
100 <mark>-</mark> 1000 -2000			Under Temperat	ure Set Time	2	S	0x41e2	1	15	2	S			
			Under Temperat	ure Clear	100	0.1°C	0x41e3	2	15	3	0.1°C	UNSEAL_FULL_ACCESS		
			SOH Low		5	%	0x41e5	2	15	5	%			
			 Integrity Data 									Log Panel Cle		
			Static Chem DF	Checksum	3a28	hex	0x4056	2	2	22	hex	Cic		
			IF Checksum		4c0b3d70	hex	0x405c	4	2	28	hex	Transaction Log		
			Reset Counter V	/D	0	Num	0x4253	1	18	19	Num			
												Name Cmd Result F		
												GAU 0x11 N/A M		
												GAU 0x12 N/A N		
												0A0 0A12 N/A 1		





4 I²C Communication Between the Microcontroller and the BQ35100 EVM

To gather resistance and impedance data, the microcontroller uses the addresses specified in the Technical Reference Manual (TRM). The I2C 8-bit address for the BQ35100 is 0xAA. The 7-bit address is 0x55. This address cannot be changed.

For both scaled resistance and measured impedance, the data is stored in little-endian format as unsigned integers. The command 0x16 is used to gather the scaled resistance data, and the command 0x22 is used to gather the measured impedance data. This is the most critical data to be extracted to calculate the appropriate EOS configuration for the system.

5 Testing Procedure

While in EOS mode, the gauge needs to be enabled before any major discharge of the battery occurs. For this test, the MCU gathers impedance data and writes the data to a data memory device. The testing procedure consists of the following steps:

- 1. Wake up the gauge before any major discharge using the GE pin
- 2. Send the GAUGE_START command
- 3. Send the GAUGE_STOP command after the major discharge
- 4. Wait for the G_DONE bit to be set to one
- 5. Read the scaled resistance and measured impedance from the gauge
- 6. Save the scaled resistance and measured impedance to a data memory device
- 7. Put the gauge back to sleep using the GE pin

Note

The G_DONE bit is found in bit 6 if the CONTROL_STATUS command

For the gauge to take an accurate measurement of the voltage and current for estimating the resistance of the cell, the pulsed load must be at least 100-ms long and cause a 100-mV drop of the battery voltage. This constitutes the minimum requirement for a major discharge.

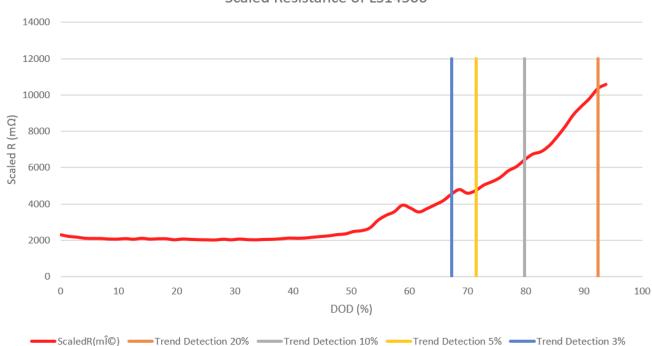
It is common for end equipment to use separate resistors from the expected load burst, which is typically RF dynamic load, to provide consistent current bursts for the gauge to learn the resistance. The gauge thrives on consistency of the measurements and does not require significant drain on the battery to perform the learning load burst.



6 EOS Data Example

Figure 6-1 shows an example of the impedance data that is collected by the gauge. This data shows a lithium thionyl battery starting at full capacity to be completely discharged. Towards the end of the battery's life, there is a spike in the impedance which is characteristic of lithium thionyl chloride batteries and a strong indicator that the battery is nearing the end of battery life.

For testing purposes, the battery was discharged by 1% SOH at the maximum continuous discharge rate specified by the battery manufacturer after each learning pulse. After the 1% SOH discharge the battery was relaxed for 5 hours. Each learning pulse was 500 ms long and the current was set to 100 mA to meet the requirements of the pulse length and amplitude.



Scaled Resistance of LS14500

Figure 6-1. Scaled Resistance Profile of LS14500 Battery with EOS Flag Thresholds



7 Final Configuration of the BQ35100 Data

After performing a complete discharge of the primary cell and logging the resistance, the EOS parameters can be configured.

The only parameter that needs to be updated for initial EOS learning is the *New Batt R Scale Delay*, this needs to be set to a value after the passivisation layer is expected to be gone. The passivisation layer can be seen as the initial resistance measurement being higher than expected, and then decreasing after subsequent pulses. Once resistance stops decreasing and is flat, the passivisation layer has been removed.

					U			
Class	Subclass	Name	Туре	Size	Min Value	Max Value	Default Value	Unit
EOS Data	Values	New batt R scale delay	Unsigned Integer	1	0	255	2	Readings
EOS Data	Values	R Table Scale	Integer	2	-1	-1	-1	-
EOS Data	Values	R Table Scale Update Flag	Hex	1	0×00	0×ff	0×ff	_

Tabla	7 1	Initial	ENG	Learning
rable	7-1.	muai	EUS	Learning

After the initial learning is setup, the most important value to configure from the resistance data is the EOS Trend Detection this determines when the gauge sets the [EOS] flag by comparing the Short Trend Average and Long Trend Average.

			10.010	2. LOO Du				
Class	Subclass	Name	Туре	Size	Min Value	Max Value	Default Value	Unit
EOS Data	Values	R short trend filter	Unsigned Int	1	1	255	251	-
EOS Data	Values	R long trend filter	Unsigned Int	1	1	255	253	-
EOS Data	Values	EOS trend detection	Unsigned Int	1	1	100	20	-
EOS Data	Values	EOS detection pulse count	Unsigned Int	2	1	20000	120	-
EOS Data	Values	EOS detection pulse count Thrhd	Unsigned Int	2	1	20000	120	-
EOS Data	Values	Short trend average	Unsigned Int	4	1	8355712	0	-
EOS Data	Values	Long trend average	Unsigned Int	4	1	8355712	0	-

Table 7-2. EOS Data Flash

To estimate the long and short filtered values we can use the following formulas from the TRM.

Short Trend Average = Impedance × 1/DF1 + Previous Impedance × (1–1/DF1)

Long Trend Average = Impedance × 1/DF2 + Previous Impedance × (1–1/DF2)

Where DF1 = 50, DF2 = 100, and *Previous Impedance* is the previously calculated *Short Trend Average* or *Long Trend Average* value.

To determine when the battery needs to be replaced, the following check is done which triggers the [EOS] flag.

Short Trend Average > Long Trend Average × (1 + EOS Trend Detection / 100)

When this occurs the [EOS] flag is set and cannot be cleared.

After the EOS flag is set, the battery needs to be replaced. The EOS alert indicates the battery is near end of life according to the customer settings of *EOS Trend Detection* and resistance increases.



8 Conclusion

The BQ35100 configured in EOS mode can reliably alert before a remote or deployed long term system will die due to the battery. The alert is the primary function of EOS mode but some SOH data can be read from the gauge, the accuracy of the SOH% in EOS mode is a case by case basis.

The best use cases for this gauge are applications where the gauge can be woken up before the current pulse to learn the resistance, or a learning pulse can be implemented with external resistor and MCU for the gauge to learn resistance. Time considerations for testing should be accounted for during the evaluation period of this part in order to best configure the gauge for the end equipment.



9 References

- 1. Texas Instruments, BQ35100 Technical Reference Manual
- 2. Texas Instruments, Using the BQ35100 with Li-Primary Based Applications
- 3. Texas Instruments, Using I2C Communication With the bq34110, bq35100 and bq34z100-G1 Series of Gas, application note

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2022, Texas Instruments Incorporated