Using the bq35100 with Li-Primary Based Applications

0.1 Why bq35100 ?

The BQ35100 is an accurate low power battery gauge that extends the life of primary batteries through accurate gauging. The gauge offers support for Lithium Thionyl Chloride chemistries with an EOS(end of service) algorithm which only consumes 0.35 uA of current as well as support for Lithium Manganese Dioxide chemistries with an SOH(state of health) algorithm which only consumes .06 uA of current. The device itself only needs to be powered long enough to record voltage, current, and temperature measurements used for computing parameters in SOH and EOS mode. These parameters, for instance, state of health and or impedance can be recorded based on user defined triggering of the GE pin which controls the devices power state. The user can obtain the results of EOS and SOH algorithms via an I2C bus, or use the ALERT output on the gauge as an interrupt to the host system. Additionally, the gauge algorithms support seamless replacement of old batteries and use an SHA-1 authentication to help prevent counterfeit battery usage. This gauge is best suited for use in products such as smoke alarms, flow meters, door access controllers, and similar devices for early fault detection and to maximize runtime.

0.2 Hardware

- EV2400 (Used for communicating over I2C with the BQ35100 IC)
- Power Supply (This can be a battery or power supply, the board is powered from this)
- USB 2.0 Type A to Type B (Connect EV2400 to your PC) I2C data cable (Connect EV2400 to board)

0.3 Software

- bqStudio Software (Program to interface with IC)
- EV2400 Firmware (Firmware for the 2400 must be updated in order to be used)

0.4 EV2400 Setup

 Connect usb from EV2400 to computer and connect data cable from EV2400 to I2C port Texas Instruments

on the board.

- Connect your EV2400 to your PC and navigate to http://www.ti.com/tool/EV2400.
- Download the firmware and execute it in order to update your EV2400.

0.5 bqStudio Setup

 Navigate to http://www.ti.com/tool/BQSTUDIO and install the software.

0.6 Board Setup

- Place Jumpers across ALERT/PULL-UP
- Place Jumpers across GE/PULL-UP (Toggling this turns the device on and off)
- For one cell place jumpers across bottom two "1s".
- For multi-cell you will need to place jumpers on the top two 2-4s pins on J2.
- Following this place pins on J3 indicating the number of cells you have.
- Connect your battery across BAT+ and BAT-
- Connect data cable on J1 to the I2C port on your EV2400.

0.7 Loading Board Firmware (Optional)

- If your board does not come loaded with firmware or you wish to change it. Navigate to the Programming tab at the top.
- Select your .srec file and press PROGRAM. Once programming has finished press Execute FW. See "Programming" image in the Graphics section for reference.

0.8 Starting bqStudio

- Turn on your power supply and make sure you have jumped the GE pin.
- Upon launching bqStudio the software should auto detect the IC you are using. See "Start Screen" in the Graphics section for reference.
- You can use the SCAN button to continuously sample the visible parameters or use REFRESH at your discretion.



0.9 Using bqStudio

1. Press UNSEAL in the Commands tab. Check SEC1 and SEC0 in the Bit Registers window to see that SEC1 is green and SEC0 is red. (10) which means that the device has been unsealed

2. Press RESET in the Commands tab.

3. Press CAL_TOGGLE in the Commands tab.

4. If you are using a pack with more than one cell in series, navigate to the gas gauging tab within the Data Memory tab. Make sure to enter your series cell count and write it the data flash prior to calibration. See "Series Cell Count" in the Graphics section for reference.

5. Navigate to the calibration tab at the top.

6. Check the "calibrate voltage" box and enter the measured voltage. You may get an error related to scanning in which navigate back to the Registers tab and turn scanning off. Once voltage calibration is finished uncheck the box next to it.

7. Repeat this procedure for the current and the temperature.

8. Finally, check Calibrate CC Offset and calibrate.

9. In the Command tab press CAL_TOGGLE so that CalMode in the Bit Registers is Green indicating 0 which is off.

0.10 Cell Chemistry

- Navigate to the Chemistry tab.
- When selecting the Chem ID, primary cell IDs are listed as 6xxx. If you cannot find your specific model contact Texas Instruments on model generation.
- Select the chemistry you are using and press Program selected chemistry. See "Cell Chemistry" in the Graphics section for reference.

0.11 Entering Into SOH Mode

2

This mode is used for tracking capacity of batteries where the capacity decreases steadily with no sharp increases in internal impedance. Moreover this is characteristic of Lithium Manganese Dioxide chemistries.

1. Press UNSEAL in the COMMAND tab. Check SEC1 and SEC0

2. Press NEW_BATTERY in the Commands tab.

3. Navigate to the Data Memory tab.

4. In the Data Memory tab press on the Configuration button.

5. From here press on "Operation Config A".

6. Observe the values of Bit1 (GMSEL1) and Bit0(GMSEL0). To be in SOH mode we need the values to be as such GMSEL1 = 0 =green and GMSEL0 = 1 = red. Press on GMSEL0 so that it turns red and changes what mode we are in and save. Reference the "GM Select" image in the Graphics section for where you should be when changing GM Sel.(NOTE: In the referenced image the operating mode is set to EOS)

7. We are now in SOH mode.

8. Navigate to Gas Gauging in the sidebar. Here are variables the user can modify as needed. Here you can enter the series cell count, etc.

9. Once you SOH decrease it will not increase so you will need to press NEW_BATTERY each time you wish to use a new cell.

0.11.1 SOH Mode Fundamentals

SOH mode takes in the battery voltage and temperature. The gauge uses these two values and references them to the OCV lookup table in order to determine the SOH. One important variable to adjust in the Gas Gauging sidebar is the" Sate of Health Max Delta". This variable determines by how much you SOH can change with every cycle of the GE pin. If you plan on sampling very frequently and reading the voltage lower values will work. However, if your delta value is low and the voltage drops very suddenly you will not observe a change immediately but rather it will take multiple cycles to catch up to the new voltage.

0.11.2 Using SOH Mode

Once you have followed the above steps, using SOH mode is simple. Have your battery connected to the gauge and simply cycle the GE pin in order to get updated values of SOH after you have finished loading and the battery's open circuit voltage has relaxed back up. It is essential to wait for the battery's open circuit voltage to relax up in order to get accurate SOH readings. Make sure to press NEW_BATTERY if you are inserting a new cell.



0.12 Entering Into EOS Mode

EOS is used for devices where the overall capacity doesn't decrease steadily with time but rather drops off sharply at the end of its life due to a sharp increase in impedance. Moreover this is characteristic of Lithium Thionyl Chloride chemistries. Reference the "Battery Impedance at EOS" graph on the Graphics page to see a characteristic curve of impedance increasing at EOS.

1. Press UNSEAL in the COMMAND tab. Check SEC1 and SEC0

2. Press NEW_BATTERY in the Commands tab.

3. Navigate to the Data Memory tab.

4. In the Data Memory tab press on the Configuration button.

5. From here press on "Operation Config A".

6. Observe the values of Bit1 (GMSEL1) and Bit0(GMSEL0). To be in EOS mode we need the values to be as such GMSEL1 = 1=red and GMSEL0 = 0 = green. Press on GMSEL1 so that it turns red and changes what mode we are in and save.

7. We are now in EOS mode.

8. Navigate to the EOSData tab, here there are important variables the user can modify which will be subsequently discussed.

0.12.1 EOS Mode Fundamentals

EOS mode works by tracking the internal impedance of your battery with a short trend and long trend average. The gauge looks for a sharp increase in the short trend average when compared to the long trend average. The EOS Trent Detection average is the % increase of the short trend average in relation to the long trend average. Once the equation below is satisfied an EOS condition is set in the Battery Alert register. Reference the "EOS Usage" diagram on the Graphics page for a flowchart on using the mode.

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

0.12.2 Using EOS Mode

One important parameter to consider is the EOS Detection Pulse Count Thrshd. This threshold is the number of Gauge_Start and Gauge_Stop cycles you must perform before your device will begin calculating the short trend and long trend averages for EOS detection. Adjust this value in accordance with how many times you will cycle your device. Modify the trent detection value based on how sharp of a decline your battery exhibits during EOS. Additionally make sure to adjust your cell terminate value under the Gas Gauging tab. Values for the impedance and SOH become available after the G_DONE bit is set to 1. Reference the "EOS Usage" diagram in the Graphics section for a flowchart on using the mode as well as the "EOS Parameters" image in the Graphics section for modifiable parameters.

0.13 When is my battery empty?

When using EOS or SOH mode it is important to understand when a battery is dead. In general, a battery is considered dead when the relaxed open circuit voltage is at or below the terminate voltage. In SOH mode the decline towards this voltage is easy to see with each successive discharge bringing the relaxed voltage closer to the terminate voltage. Towards the end of a batteries life in SOH mode, the voltage will begin to dip to or below the terminate voltage and relax up to subsequently lower values with successive discharges. With EOS mode, the sharp increase in impedance signals that the battery is close to being unusable and the battery is said to be completely depleted when the voltage drops below the terminate voltage. This change happens rapidly and the battery itself becomes unusable very quickly.

1 Golden Image

Once you have calibrated, loaded the chemistry, and made sure your gauge is operating as you would like. You can extract a "golden image" file which is essentially an image of the flash memory that you can load into additional gauges so that you do not have to perform setup steps repeatedly. The "xxx.srec" file you extract can be used to program gauges as described in the "Loading Board Firmware Section". In order to extract the "xxx.srec" simply press "Create Image Files". See the 'Golden Image" image in the Graphics section for further reference.



Advanced Programming

1.1 Trademarks

All trademarks are the property of their respective owners.

2 Advanced Programming

In the advanced programming tab you can send I2C commands to the gauge to read and write data. See the "Advanced Communications" image in the Graphics section for an example of requesting the voltage.

3 Related Documentation

For information regarding sending I2C commands to your device see the Using I2C Communications Manual .

For more detailed information about the BQ35100 see the Technical Reference Manual.

For more information about the EV2400 see the EV2400 EVM Interface Board manual.

3.1 Trademarks

All other trademarks are the property of their respective owners.



1 Programming

Registers 🗢 Data Memory 🗳 Calibration 🗼 Chemistry 🛎 Programming 🕸 🎯 Authentication View	
Programming	
Perform Programming	
This plug-in will allow you to program image files to a device.	
Select Programmable File	
C:\Users\Name\Desktop\bq35100.srec	✓ Browse
	Program
	Execute FW

Figure 1. Programming xxx.srec file

2 Start Screen

Ev2400 Version.0.05 Name Value Units Log Scan % FW_VERSION % FW_WERSION % FW_WERSION<	iii Version: 1.3.5.1 Start Log Scan Refresh	ashBoard	~	Registers 88																				🗸 🕫 Comr	nands 🛛	
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Figure 2. Start Screen



Series Cell Count

www.ti.com

3 Series Cell Count

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\mathcal{A}		Read/Write Data	Memory Contents								FW VERSIO	
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r .			Cell Design Capacity mAh	2200	mAh	0x41fe	2	15	30	mAh	CHEM_ID	
	I2C	LTFlash	Cell Design Voltage	3700	mV	0x4202	2	16	2	mV	STATIC_CHEM_CH	-
	120	System Data	Cell Terminate Voltage	900	mV	0x4204	2	16	4	mV		
		-	Series Cell Count	1	Counts	0x4206	1	16	6	Counts	GAUGE_STAI	₹T
` ~	bq35100	Gas Gauging	Max Load	50	mA	0x4207	2	16	7	mA	GAUGE_STO	Р
*2°	0100_1_02	Accum_Table	State of Health	0	%	0x4209	1	16	9	%	LIFETIME_EI	N
	Addr: 0xAA 22.1 degC	Ra Tables	State of Health Max Delta	100	%	0x420a	1	16	10	%	BOARD OFFS	
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9		Security									Log Panel	Clear
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0												

Figure 3. Modifying series cell count in data flash



🕽 Calibration 🎯 Advanced Comm 🗼 Chemistry 🔐 Authenticatic	on 🔣 Programming 鼲 Golden Image 闄 Watch 🔚 Data Graph 🛺 Errors
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Select the type of calibration to perform and enter the actual input	
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Gauge Applied Voltage	
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Figure 4. Calibration Screen

5 Cell Chemistry

rd	🕆 🗋 🔍 Registers 👗 Chemistry 🕸 🎯 Authenti	cation View			Commands 🕸
sh is ON - Click to Turr	OFF Chemistry Programming				Commands
ersion: 1.3.54.1	Program Battery Chemistry				DEVICE_NUMBER
Ω	Most Li-ion cells use LiCoO2 cathode a	nd graphitized carbon anode, which is supported by the default firr	nware in the Impedance tra	ick fuel gauges.	* FW VERSION
		et up for various alternate battery chemistries.			
		Iternate chemistry if your cell manufacturer indicates that their cells u			FW_BUILD
	Note : Right Click on the selected of	hemistry to apply it to individual cells. The menu appears on		vidual cell chemistries.	CHEM_ID
	Manufacturer	Model	Chemistry ID	Description	↑ STATIC CHEM CHKSUM
	COSLIGHT	CA4735A6G (2861mAh)	3983	LiMn2O4 (Co,Ni)/carbon, 4.4V	GAUGE START
	⊠LGC	Laminate (2779mAh)	3984	LiMn2O4 (Co,Ni)/carbon, 4.35V	
	Obsolete	Do Not Use (Obsolete)	3985	LiMn2O4 (Co,Ni)/carbon, 4.4V	 GAUGE_STOP
	ATL	542465 (1480mAh)	3986	LiMn2O4 (Co,Ni)/carbon, 4.4V	LIFETIME_EN
<i>w</i>	COSLIGHT ATL	CA327997G (4070mAh)	3987	LiMn2O4 (Co,Ni)/carbon, 4.4V	BOARD OFFSET
	MAIL	396776H (3010mAh)	3988	LiMn2O4 (Co,Ni)/carbon, 4.4V	CC OFFSET
h		434198 (3020mAh)	3989	LiMn2O4 (Co,Ni)/carbon, 4.4V	
1	LGC	Laminate (1853mAh)	3990	LiMn2O4 (Co,Ni)/carbon, 4.35V	CC_OFFSET_SAVE
	ATL	4257A6 (3450mAh)	3991	LiMn2O4 (Co,Ni)/carbon, 4.4V	SEAL
	HighPower ATL	HPP526793AB (5400mAh) 3759D4 (4940mAh)	3992 3993	LiMn2O4 (Co,Ni)/carbon, 4.35V LiMn2O4 (Co,Ni)/carbon, 4.4V	RESET
	ATL .	463239 (760mAh)	3993	LiMn2O4 (Co,Ni)/carbon, 4.4V LiMn2O4 (Co,Ni)/carbon, 4.4V	
	COSLIGHT	CA606072G (4550mAh)	3994	LiMn2O4 (Co,Ni)/carbon, 4.4V LiMn2O4 (Co,Ni)/carbon, 4.4V	 CAL_TOGGLE
0	SDI	Laminate (2894mAh)	3996	LiMn2O4 (Co,Ni)/carbon, 4.35V	NEW_BATTERY
	ATL	Laminate (2854mMi)	3997	LiMn2O4 (Co,Ni)/carbon, 4.35V	UNSEAL
	ATL	386990H (4035mAh)	3998	LiMn2O4 (Co,Ni)/carbon, 4.4V	R UNSEAL FULL ACCESS
	USHEN	LP485780SG-T (3780mAh)	3999	LiMn2O4 (Co,Ni)/carbon, 4.4V	MONSEAL_FOLL_ACCESS
	NIMH	HHR380A	6100	NIMH	las Paul
	Brentronics	(28900mAh)	6101	Ni/Zn	Log Panel
		55750 (500mAh)	6102	NIMH	Transaction Log
	Sanyo	BK-250A (2600mAh)	6103	NIMH	Name Cmd Result Rea.
	Tenergy	HPPF11136248-30245 (24000mAh)	6104	NIMH	
	A123Systems	A123_Pack (20000mAh)	6105	NIMH	
	Headway	E401525 (15000mAh)	6106	NIMH	
	Varta	V500-HT (500mAh)	6107	NIMH	
	MFDK	HR-4-3AU (4000mAh)	6108	NIMH	
	Obsolete	use 6111	6109	NIMH	
	Brentronics	(50000mAh)	6110	Ni/Zn	
	A123Systems	A123 (20000mAh)	6111	NIMH	
	⊠ Sanyo	HR4-3AU (3450mAh)	6112	NIMH	
	MartsEnergy 201	VHT-D-6AH (6000mAh)	6113	NIMH, -20C	
	2 Panasonic	BK-10V (90000mAh)	6114	NIMH, -20C	
	22 Panasonic	BK-06V (60000mAh)	6115	NiMH, -20C	~
	<				>
		Undete Obernleter fo	and Database Undate	Chemistry from External File	

Figure 5. Chemistry Programming Screen

Texas Instruments

www.ti.com

GM Select

6 GM Select

Registers #	Data Memory	之 Commands 🏾	👢 Calibration 🏼 🍟 Advance	Comm 🥼 🥼	Themistry 🔐	Authenticatio	n 🕮 Program	mina 🎹 Gol	den Image 📓	Watch 📰 [Data Graph 📴 E	rrors		
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	EV2400		Name		Value	Unit	Physical St	Data Longth	Row Numb	Pow Offcot	Native Unit 🔨	2	FW_VERS	ION
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		Configuration	Operation Config A		82	hex	0x41h1	1	13	17	hex		CHEM	ID
	12C	LTFlash	Ale X			Ор	eration Confi	ig A					IC_CHEM	
•	120	System Data	Clk	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit O			
		Gas Gauging	Ba V Powe MSB	TEMPS	EXTVCELL	WRTEMP	LF_EN	RSVD	GNDSEL	GMSEL1	GMSEL0		GAUGE_S	IARI
	bq35100		✓ Powe Fla			0 M/r	ite to Data Merr					1	GAUGE_S	TOP
	0100_1_02	Accum_Table	Offset Cal Inhibit Ter	ND LOW	5.0	- vvi	UX41b8	2	13	24	0.1~C	1	LIFETIME	_EN
Addr: 0xAA 22.1 degC		Ra Tables		Offset Cal Inhibit Temp High			0x41ba	2	13	26	0.1°C	✓ B	OARD_O	FFSET
V 22.1 dege		EOSData	✓ Data										CC OFF	SET
		Consults	Default Temperature		298.2	K	0x41d4	2	14	20	0.1K		-	
		Security	Device Name		bq35100	-	0x4060	8	3	0	-	Log Pan	el	Clea
9997 mV 0 1000			Data Flash Version		ffff	-	0x4068	2	3	8	-	Transac	tion Log	
			✓ Discharge									Name	Cmd R	esult Re
			OT Dsg		60.0	°C	0x41d6	2	14	22	0.1°C			
			OT Dsg Time		2	s	0x41d8	1	14	24	s			
			OT Dsg Recovery		55.0	°C	0x41d9	2	14	25	0.1°C			
			BatLow Voltage Set		2700	mV	0x41db	2	14	27	mV			
0 1			Under Temperature S		5.0	°C	0x41e0	2	15	0	0.1°C			
			Under Temperature S		2	S	0x41e2	1	15	2	s			
			Under Temperature (Clear	10.0	°C	0x41e3	2	15	3	0.1°C			
			SOH Low		5	%	0x41e5	2	15	5	%			
			✓ Integrity Data								~			
	>		<								>			

Figure 6. GM select is toggled to change operating modes in this image the operating mode is set to EOS

7 SOH Usage

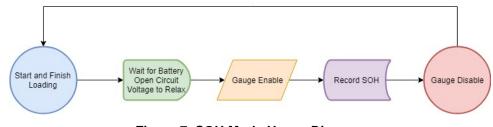


Figure 7. SOH Mode Usage Diagram



8 EOS Parameters

EOS Parameters

	nagement Studio											
shBoard	~	Registers Tota	Memory 🛛								Comman	ds 🛙
Refresh is idio Version:	ON - Click to Tu 13541	Data Memory			Filter	/Search Auto E	xport Hex Dur	mp Export	Import	◆ 2 Write_All Read All	Comma	nds
	1010 111	Read/Write Data I	Memory Contents								🦻 DEV	ICE_NUMBER
n	EV2400		-				D () (D N	D 011	N	🕈 FV	V VERSION
	Version:0.05	Calibration	Name Values	Value	Unit	Physical St	Data Length	Row Num	Row Offset	Native Units		- W BUILD
		Configuration	R Data Seconds	15	Num	0x4255	2	18	21	Num		-
		LTFlash	R Table Scale	1292	Num	0x4255 0x4257	2	18	23	Num	20	CHEM_ID
	I2C	LIFIdSI	New Batt R Scale Delay	2	Num	0x4259	1	18	25	Num	STATIC_	CHEM_CHKSU
-		System Data	R Table Scale Update Flag	00	hex	0x4255	1	18	26	hex	✓ GA	UGE START
		Gas Gauging	R Short Trend Filter	251	Num	0x425b	1	18	27	Num		-
	bq35100		R Long Trend Filter	253	Num	0x425c	1	18	28	Num	≁ GA	AUGE_STOP
	0100_1_02 Addr: 0xAA	Accum_Table	EOS Trend Detection %	20	Num	0x425d	1	18	29	Num	 U 	FETIME_EN
	22.1 degC	Ra Tables	EOS Detection Pulse Count Thrshd	120	Num	0x425e	2	18	30	Num	✓ BO/	ARD OFFSET
	LL. I dege	EOSData	Short Trend Average	0	Num	0x4260	4	19	0	Num		C OFFSET
			Long Trend Average	126	Num	0x4264	4	19	4	Num		C_OFFSET
		Security	EOS Trend Detection Pulse Counts	815	Num	0x4268	2	19	8	Num	Log Panel	Cle
997			EOS Not Detected Flag	00	hex	0x426a	1	19	10	hex	Transactio	n Log
mV			EOS SOH smooth Start Voltage	2800	mV	0x426b	2	19	11	mV	Name C	nd Result F
			EOS SOH Smoothing Margin	128	Num	0x426d	1	19	13	Num		
0			EOS Relax V Hi Max Counts	10	Num	0x426e	1	19	14	Num		
0-1000												
00												
0												

Figure 8. EOS parameters that can be modified

9 EOS Usage

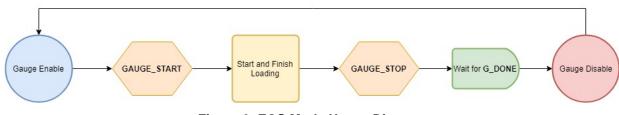


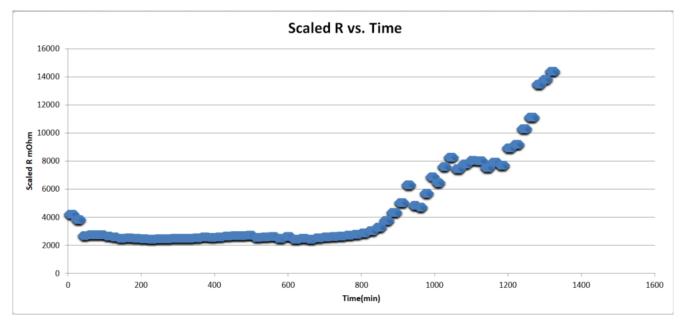
Figure 9. EOS Mode Usage Diagram



Battery Impedance at EOS

www.ti.com

10 Battery Impedance at EOS





11 Golden Image

Battery Management Studio (Dq	5000 J 1.5.54.1		– 0 ×
File View Window Help			
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	🕲 Registers 🗢 Data Memory 😻 Advanced Comm 🗼 Chemistry 🧮 Golden Image 🛛 🎒 Authentication View	- 8	Commands ≈
Auto Refresh is ON - Click to Tu bqStudio Version: 1.3.54.1	Golden Image		Commands
bqstudio version. 1.5.54.1	Golden Image Export		DEVICE_NUMBER
EV2400 Version:0.05	This plug-in will allow you to export image files. It will read the data memory contents of the connected gauge and save it to your hard drive in various formats.		✓ FW_VERSION ✓ FW BUILD
	Output Location		-
	Output Directo C:\ti\BatteryManagementStudio\OutputFiles	Browse	CHEM_ID
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	Output Formats		GAUGE_START
bq35100	SREC File (.s 0100_1_02-bq35100.srec	Options	GAUGE_STOP
0100_1_02 Addr: 0xAA	☑ BQFS File (.f 0100_1_02-bq35100.bq.fs	Options	LIFETIME_EN
22.1 degC	DFFS File (.f: 0100_1_02-bq35100.df.fs	Options	BOARD_OFFSET
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12 Advanced Communications

attery Management Studic Board	· · · · · · · · · · · · · · · · · · ·	Memo	ny 🐲 Ac	vanced	Comm	🛛 🛦 Chemistry 🗐 Golden Image 🎯 Authentication View		🕏 Commands 🛛	3
efresh is ON - Click to Tu							Clear Log Save Log Calculator	Commands	
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bq35100	Number of Bytes	to Rea	d (Decim	al) 2		Read		GAUGE	STOP
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97 V	2018-06-15 10:	Rd	aa	08	2	9D 0F		Transaction Lo	g
	2018-06-15 10:	Rd	aa	08	2	9D 0F		Name Cmd	Result Re
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Figure 12. Reading the register 0x08 which is voltage

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