bq28400EVM-001 SBS 1.1 Compliant Tablet PC and Netbook 2-Series Cell Li-Ion Battery Gas Gauge and Protection

The bq28400EVM-001 is a complete evaluation system for the bq28400/bq29200 battery management system. The evaluation module (EVM) includes one bq28400/bq29200 circuit module. Windows™-based PC software can be downloaded from the bq28400EVM product web page. The circuit module includes one bq28400 integrated circuit (IC), one bq29200 IC, and all other onboard components necessary to monitor and predict capacity, perform cell balancing, monitor critical parameters, and protect the cells from overcharge, over-discharge, short-circuit, and overcurrent in 2-series cell Li-ion or Li-Polymer battery packs. The circuit module connects directly across the cells in a battery. With the EV2x00 interface board and software, the user can read the bq28400 data registers, program the chipset for different pack configurations, log cycling data for further evaluation, and evaluate the overall functionality of the bq28400/bq29200 solution under different charge and discharge conditions.

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1 Features

- Complete evaluation system for the bq28400 SBS 1.1-compliant advanced gas gauge and the bq29200 independent overvoltage protection IC
- Populated circuit module for quick setup
- PC software and interface board for easy evaluation
- Software that allows data logging for system analysis

1.1 Kit Contents

- bq28400/bq29200 circuit module
- Set of support documentation (to be downloaded from the bq28400EVM product web page)

1.2 Ordering Information

Table 1. Ordering Information

EVM PART NUMBER	CHEMISTRY	CONFIGURATION	CAPACITY
bq28400EVM-001	Li-ion	2 cell	Any

2 bq28400-Based Circuit Module

The bq28400/bq29200-based circuit module is a complete and compact example solution of a bq28400 circuit for battery management and protection of Li-ion or Li-Polymer packs. The circuit module incorporates a bq28400 battery monitor IC, bq29200 independent overvoltage protection IC with automatic cell balancing, and all other components necessary to accurately predict the capacity of 2-series cells.

2.1 Circuit Module Connections

Contacts on the circuit module provide the following connections:

- Direct connection to the cells: 1N (BAT–), 1P, 2P (BAT+)
- To the serial communications port (SMBC, SMBD)
- The system load and charger connect across PACK+ and PACK–
- To the system-present pin ($\overline{\text{PRES}}$)

2.2 Pin Descriptions

PIN NAME	DESCRIPTION
1N	–ve connection of first (bottom) cell
1P	+ve connection of first (bottom) cell
2P	+ve connection of second (top) cell
SMBC	Serial communication port clock
SMBD	Serial communication data port
$\overline{\text{PRES}}$	System present pin (if low, system is present)
PACK–	Pack negative terminal
VSS	Pack negative terminal
PACK+	Pack positive terminal

3 bq28400 Circuit Module Schematic

This section contains information for modifying and choosing a pre-charge mode for bq28400/bq29200 implementation.

3.1 Schematic

The schematic follows the bill of materials in this user's guide (see Section 4.2).

NOTE: The optional Zener diode (D3) and resistor (R21) on the $\overline{\text{PRES}}$ pin, which are only required if $\overline{\text{PRES}}$ has a chance to short to PACK+.

3.2 Testing Fuse-Blowing Circuit

To prevent the loss of board functionality during the fuse-blowing test, the actual chemical fuse is not provided in the circuit. FET Q1 drives TP8 low if a fuse-blow condition occurs (a pull-up at TP8 is required); so, monitoring TP8 can be used to test this condition.

4 Circuit Module Physical Layouts and Bill of Materials

This section contains the board layout, bill of materials, and assembly drawings for the bq28400/bq29200 circuit module.

NOTE: The optional zener diode (D3) and resistor (R21) on the $\overline{\text{PRES}}$ pin are only required if $\overline{\text{PRES}}$ has a chance to short to PACK+.

4.1 Board Layout

This section shows the dimensions, PCB layers (Figure 1 through Figure 7), and assembly drawings for the bq28400 module.

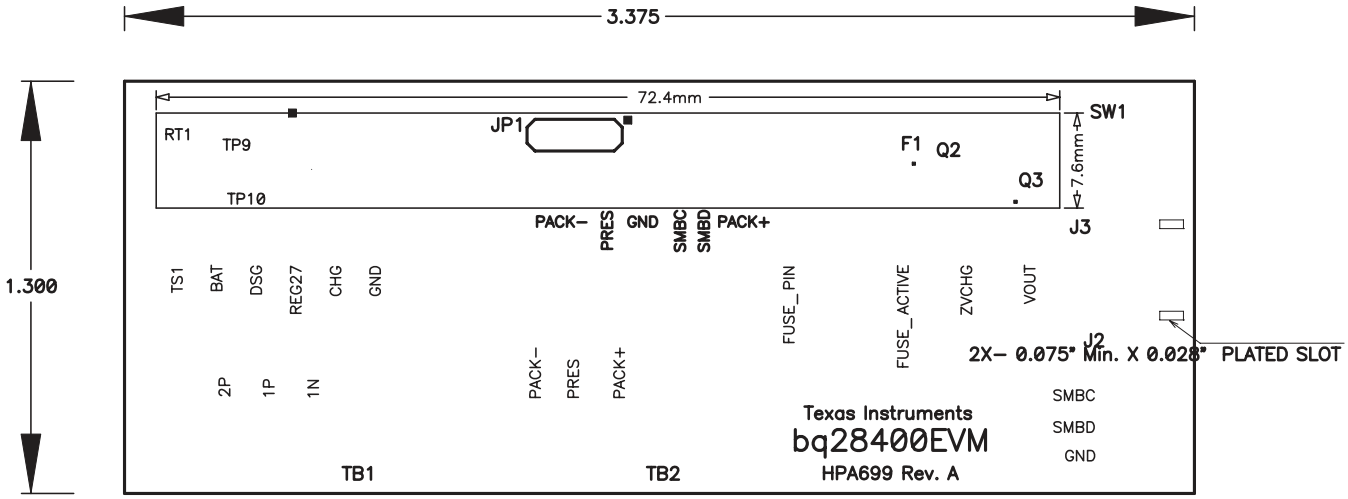


Figure 1. bq28400EVM-001 Layout (Silk Screen)

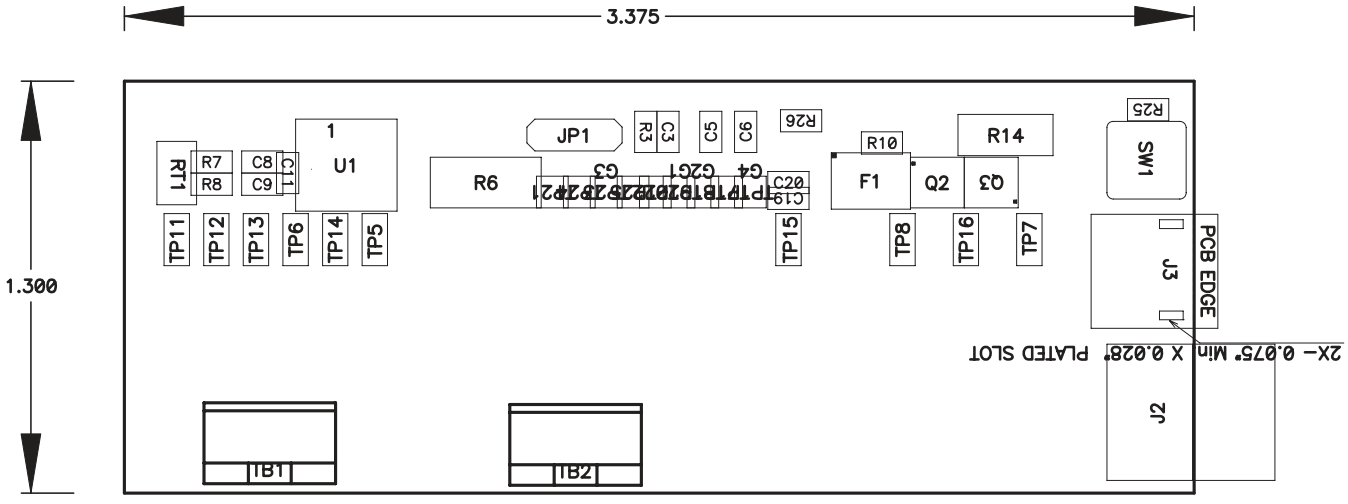


Figure 2. Top Assembly

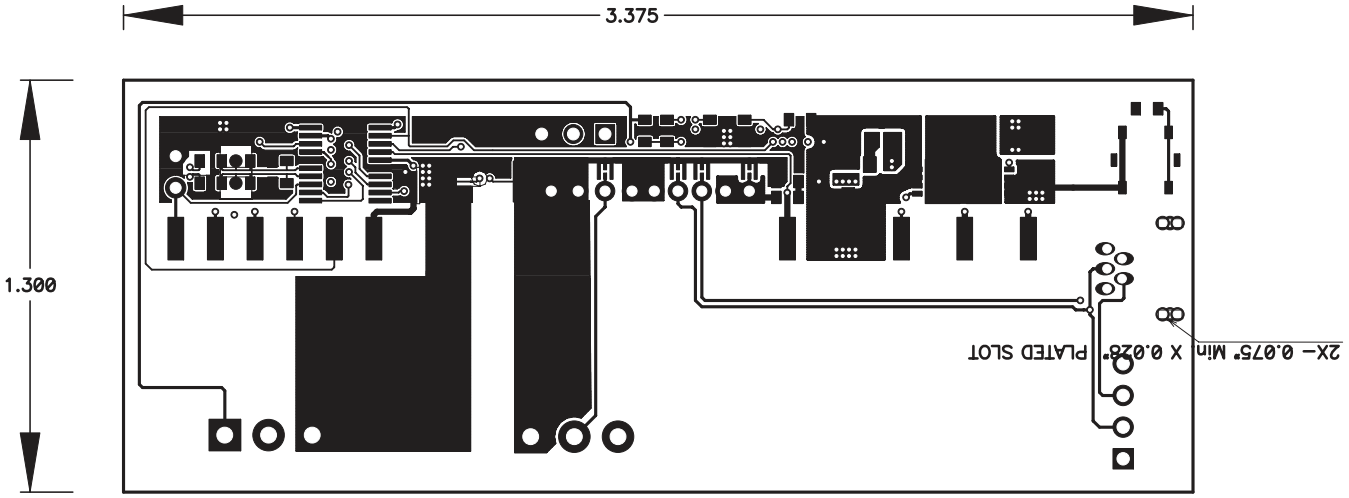


Figure 3. Top Layer

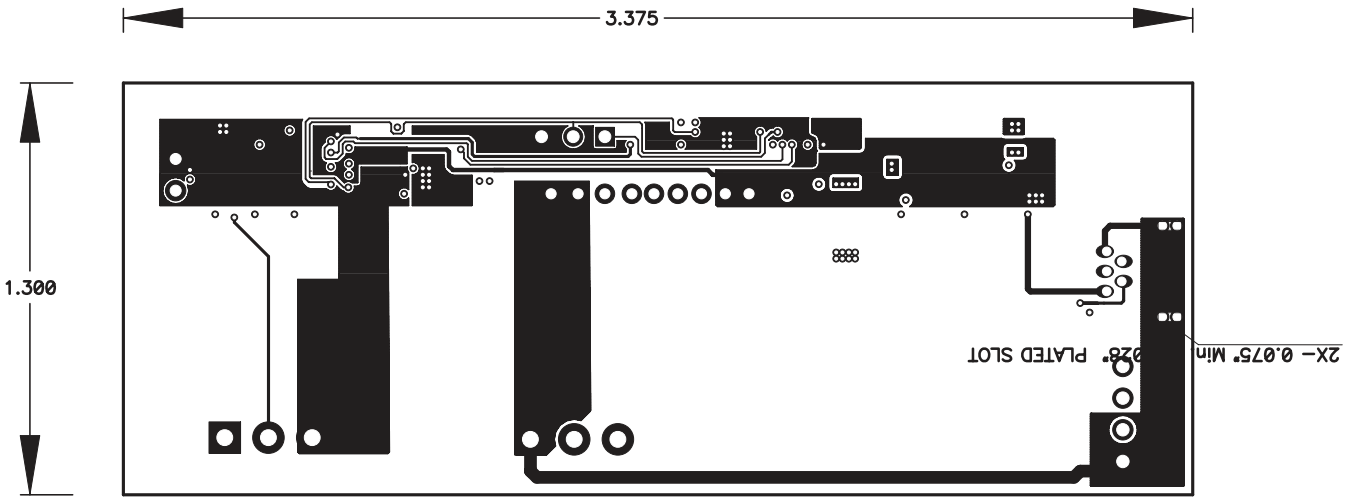


Figure 4. Internal Layer 1

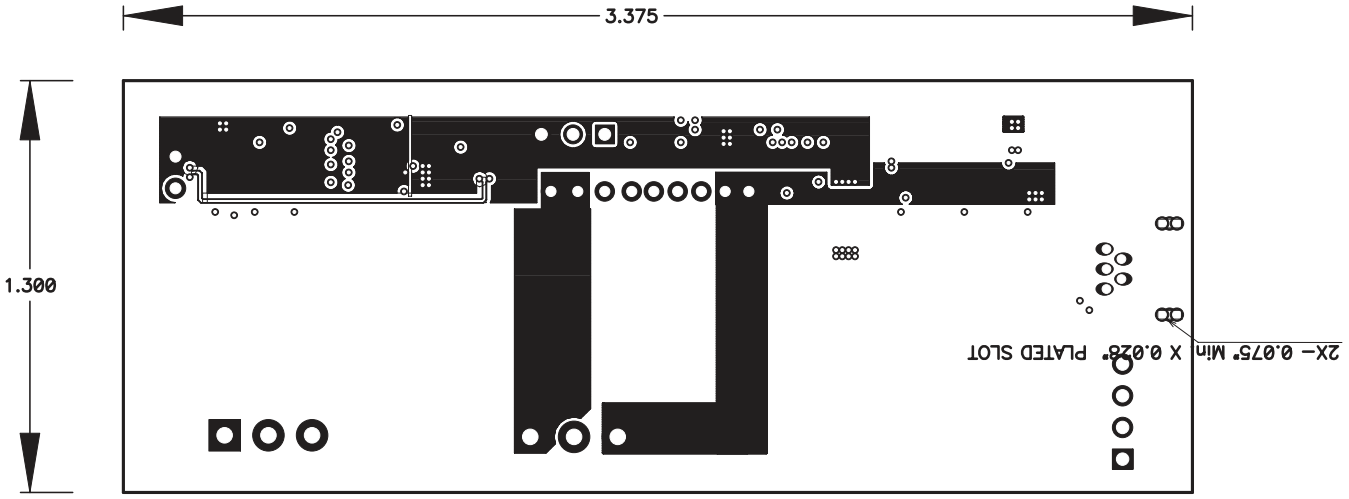


Figure 5. Internal Layer 2

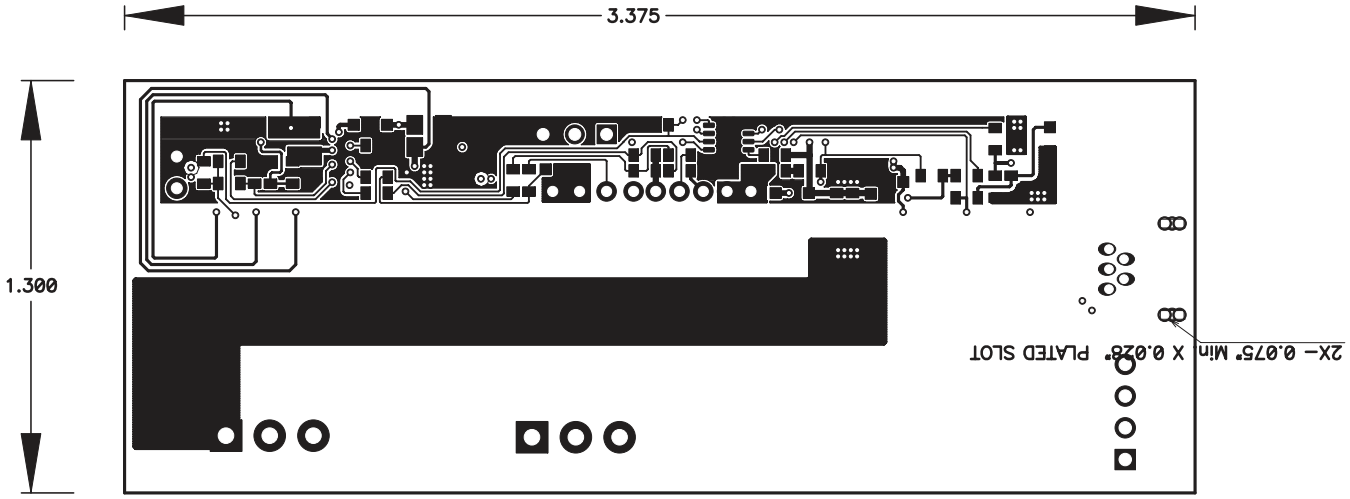


Figure 6. Bottom Layer

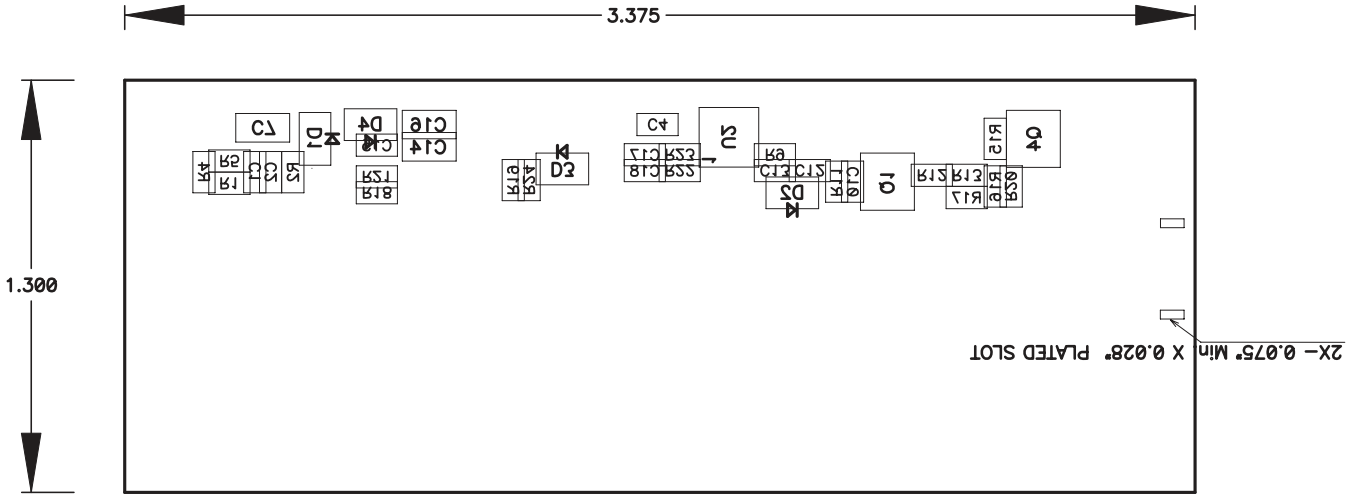


Figure 7. Bottom Assembly

4.2 Bill of Materials and Schematic

Table 2. Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	Mfr
14	C1, C2, C3, C4, C6, C8, C9, C10, C11, C12, C13, C15, C19, C20	0.1 µF	Capacitor, Ceramic, 50 V, X7R, 20%	0603	STD	Any
2	C17, C18	100 pF	Capacitor, Ceramic, 50 V, X7R, 20%	0603	STD	Any
1	C5	0.22 µF	Capacitor, Ceramic, 25 V, X7R, 20%	0603	STD	Any
3	C7, C14, C16	1.0 µF	Capacitor, Ceramic, 25 V, X7R, 20%	0805	STD	Any
3	D1, D2, D4	1SS355	Diode, Switching, 90 V, 225 mA Ifm, High speed	SOD-323	1SS355	Rohm
1	D3	MM3Z5V6C	Diode, Zener, 5.6 V, 200 mw	SOD323	MM3Z5V6C	Fairchild
1	F1	Un-install	Fuse, Chemical, Thermal, xxA	SFDxxx	SFDxxxx	Sony
1	J2	22-05-3041	Header, Friction Lock Ass'y, 4-pin Right Angle,	0.400 x 0.500	22-05-3041	Molex
1	J3	56579-0519	Connector, USB, Mini AB 5-pins	0.354 X 0.307 Inches	56579-0519	Molex
1	JP1	PEC03SAAN	Header, Male 3-pin, 100 mil spacing,	0.100 inch x 3	PEC03SAAN	Sullins
1	Q1	FDN339AN	MOSFET, N-ch, 20-V, 3A, 0.05-Ohms	SOT23	FDN339AN	Fairchild
2	Q2, Q3	Si7409ADN	MOSFET, Fast Switching, PChan, -30 V, 7A, 0.031 ohm	PWRPAK 1212	Si7409ADN	Vishay
1	Q4	Si2343DS	MOSFET, Pch, -30 V, 4 A, 53 milliohm	SOT23	Si2343DS	Vishay
6	R1, R2, R3, R4, R24, R26	1K	Resistor, Chip, 1/16-W, 5%	0603	Std	Std
1	R10	0	Resistor, Chip, 1/16-W, 5%	0603	Std	Std
2	R12, R16	3M	Resistor, Chip, 1/16-W, 5%	0603	Std	Std
3	R13, R15, R17	5.1K	Resistor, Chip, 1/16-W, 5%	0603	Std	Std
1	R14	221	Resistor, Chip, 1/2W, 5%	2010	CRCW2010221RFKEF	Vishay-Dale
2	R18, R19	200	Resistor, Chip, 1/16-W, 5%	0603	Std	Std
1	R20	1M	Resistor, Chip, 1/16-W, 5%	0603	Std	Std
1	R25	10K	Resistor, Chip, 1/16-W, 5%	0603	Std	Std
1	R5	360	Resistor, Chip, 1/16-W, 5%	0603	Std	Std

Table 2. Bill of Materials (continued)

Count	RefDes	Value	Description	Size	Part Number	Mfr
1	R6	0.010 75ppm	Resistor, Chip, 1-W, 1%	2512	WSL2512R0100FEA	Vishay
5	R7, R8, R21, R22, R23	100	Resistor, Chip, 100-Ohms, 1/16-W, 5%	0603	Std	Std
2	R9, R11	220K	Resistor, Chip, 220K-Ohms, 1/16-W, 5%	0603	Std	Std
1	RT1	10K	Thermistor, 10K ohms	0.095 X 0.150	BN35-3H103 or 103AT-2	Mitsubishi Material or Semitec
1	SW1	EVQ-PLHA15	Switch, 1P1T, 50-mA, 12-V, 160g	0.200 x 0.200 inch	EVQ-PLHA15	Panasonic
2	TB1, TB2	ED1515	Terminal Block, 3-pin, 6-A, 3.5mm	0.41 x 0.25	ED555/3DS	OST
10	TP5, TP6, TP7, TP8, TP11, TP12, TP13, TP14, TP15, TP16	5015	Test Point, SMT	0.105 x 0.040 inch	5015	Keystone
1	U1	BQ28400PW	IC, Battery Charger Controller	TSSOP	BQ28400PW	TI
1	U2	BQ29200DRB	IC, Voltage Protection with Auto Cell Balance For 2-Cell Li-Ion Batteries	VSON	BQ2920xDRB	TI
1	–		PCB		HPA699	Any
Qty		**Connector**				
2	J1 mate	Connector, Female, 0.100 Centers		Molex	22-01-3047	
8	N/A	Terminals, Crimp, Tin		Molex	08-50-0114	
	N/A	Wire, Insulated 24 Awg, Red, 18 Inches (+/- 3 inches)(USB_5V)		Alpha	1854-3	
	N/A	Wire, Insulated 24 Awg, White, 18 Inches (+/- 3 inches)(SCL)		Alpha	1854-1	
	N/A	Wire, Insulated 24 Awg, Black, 18 Inches (+/- 3 inches)(GND)		Alpha	1854-2	
	N/A	Wire, Insulated 24 Awg, Brown, 18 Inches (+/- 3 inches) (SDA)		Alpha	1854-7	
1	N/A	Heatshrink 1"		Any	Any	

Notes:	
	1. These assemblies are ESD sensitive: ESD precautions shall be observed. 2. These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable. 3. These assemblies must comply with workmanship standards IPC-A-610 Class 2. 4. Ref designators marked with an asterisk ('**') cannot be substituted. All other components can be substituted with equivalent MFG's components. 5. Make one SMBus connector wire assembly for each assembly produced, from J1 mate, 4 - 24 Awg wires and Crimp terminals. Wire colors for Pin numbers are listed below. The wire assembly shall have a J1 mate on each end. Red - Pin # 4 (Signal USB_5V) Brown - Pin # 3 (Signal SDA) White - Pin # 2 (Signal SCL) Black - Pin # 1 (GND)

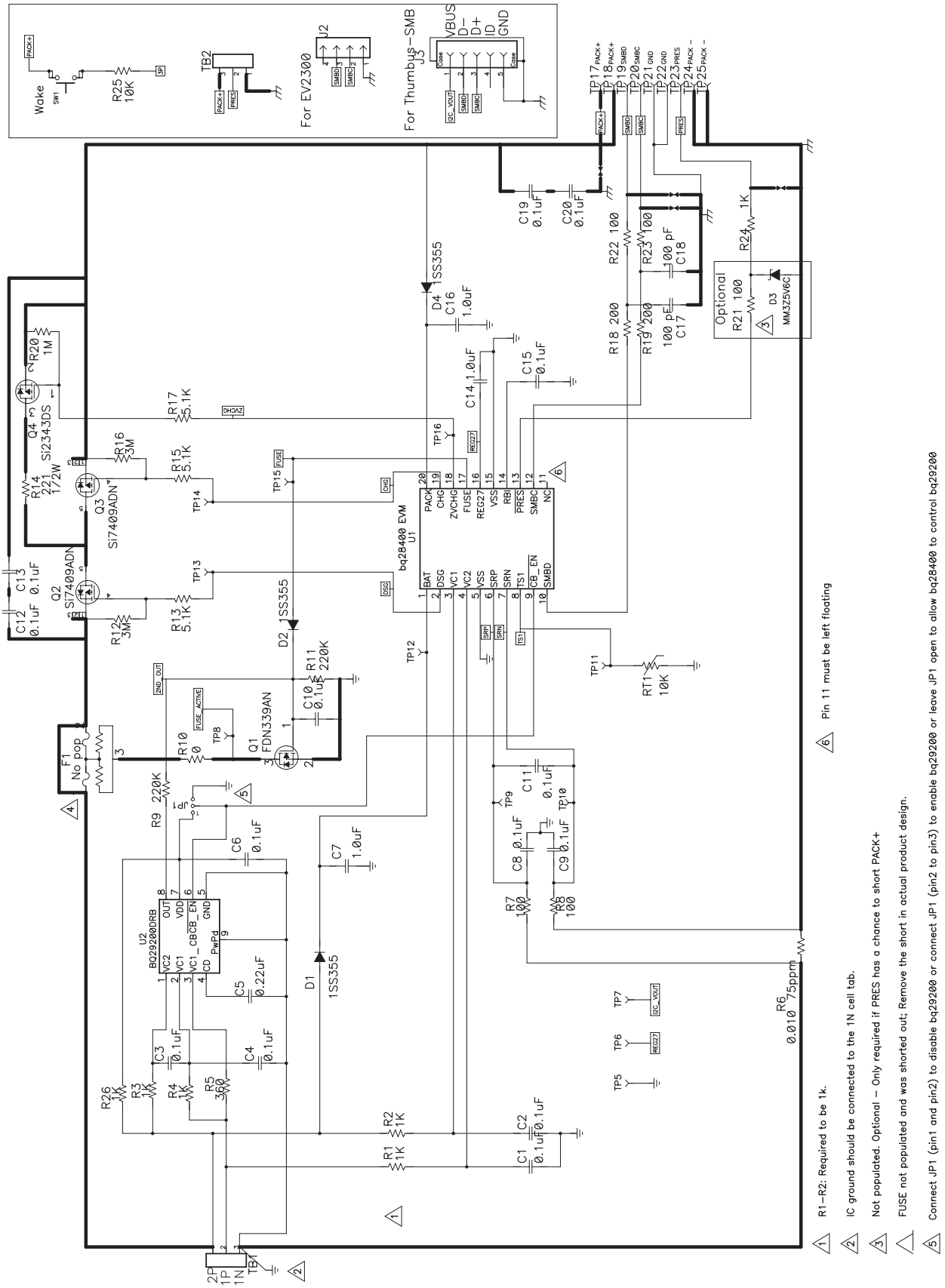


Figure 8. Schematic

4.3 bq28400/bq29200 Circuit Module Performance Specification Summary

Table 3 summarizes the performance specifications of the bq28400/bq29200 circuit module.

Table 3. Performance Specification Summary

Specification	Minimum	Typical	Maximum	Units
Input voltage Pack+ to Pack–	—	8	—	V
Charge and discharge current	0	2	7	A

5 EVM Hardware and Software Setup

This section describes how to install the bq28400EVM-001 PC software, and how to connect the components of the EVM.

5.1 System Requirements

The bq28400 EVSW software requires Windows™ 2000 or Windows XP. Drivers for Windows 98SE are provided, but Microsoft™ no longer supports Windows 98; and there may be issues in Windows 98 with USB driver support.

NOTE: The EV2x00 USB drivers have been tested for Windows 98SE, but no assurance is made for problem-free operation with specific system configurations.

5.2 Software Installation

Go to the bq28400 tool folder on power.ti.com to find the latest bq28400 EVSW software version.

To install the bq28400 EVSW software, follow these steps:

1. Log in as the administrator.
2. Save the archive to a temporary directory. Open the archive with the installation package, and copy its contents in a temporary directory. The executable filename can consist of several component names and versions. Double-click on the executable filename, and follow the installer instructions to complete the bq28400 EVM installation.
3. If the EV2x00 was not previously installed, after bq28400 EVM installation, a *TI USB DRIVER INSTALLER* pops up. Click **Yes** for the agreement message and follow its instructions.
4. Plug the EV2x00 into a USB port.

6 Troubleshooting Unexpected Dialog Boxes

The user that is downloading the files must be logged in as the administrator.

Ensure that the files were extracted from the zip file using the **Preserve Folder names** option.

Ensure that all the files were extracted from the zip file.

The driver is not signed, so the administrator must allow installation of unsigned drivers in the operating system policy.

7 Hardware Connection

The bq28400 comprises three hardware components: the bq28400/bq29200 circuit module, the EV2x00 PC interface board, and the PC.

7.1 Connecting bq28400/bq29200 Circuit Module to Battery Pack

Figure 9 shows how to connect the bq28400/bq29200 circuit module to the cells and system load/charger.

The cells should be connected in the following order:

- 2-Cell Pack: 1N (BAT–), 1P, and then 2P

To start charge or discharge test, connect the $\overline{\text{PRES}}$ pin to the Pack– pin to set $\overline{\text{PRES}}$ state. To test sleep mode, disconnect the $\overline{\text{PRES}}$ pin.

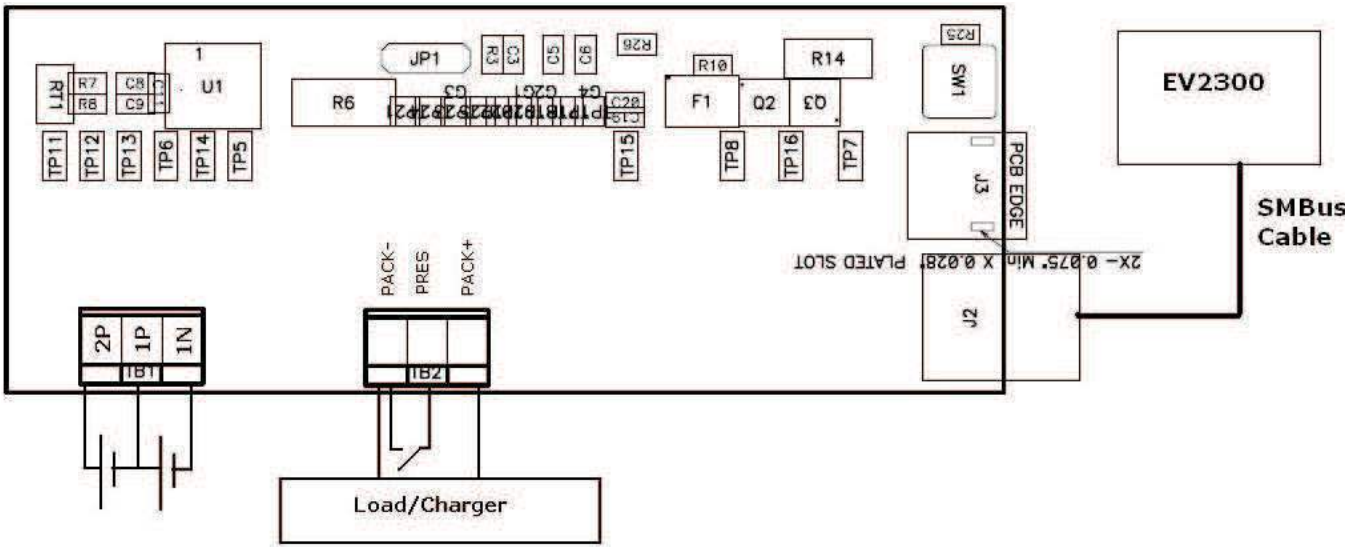


Figure 9. bq28400 Circuit Module Connection to Cells and System Load/Charger

7.2 PC Interface Connection

To configure the hardware to interface to the PC, follow these steps:

1. Connect the bq28400-based smart battery to the EV2x00 using wire leads, as shown in Table 4.

Table 4. Circuit Module to EV2x00 Connections

bq28400-Based Battery	EV2x00
SMBD	SMBD
SMBC	SMBC
VSS	GND

2. Connect the PC USB cable to the EV2x00 and the PC USB port.

The bq28400 is now set up for operation.

8 Operation

This section details the operation of the bq28400 EVSW software.

8.1 Starting the Program

Run the *bq Gas Gauge Evaluation Software* from the **Start** | **Programs** | **Texas Instruments** | **bq28400 EVSW** menu sequence. The **SBS Data** screen (Figure 10) appears. Data begins to appear once the user clicks the **Refresh** (single time scan), or when the **Keep Scanning** checkbox is checked. To disable the scan feature, deselect **Keep Scanning**.

The continuous scanning period can be set via the | **Options** | and | **Set Scan Interval** | menu selections. The range for this interval is 0 ms to 65535 ms. Only items that are selected for scanning are scanned within this period.

The *bq Gas Gauge Evaluation Software* provides a logging function that logs the values that were last scanned by the EVSW. To enable this function, select the **Start Logging** button, which causes the **Keep Scanning** button to be selected. When logging is **Stopped**, the **Keep Scanning** button is still selected and must be manually unchecked.

The logging intervals are specified under the | **Options** | menu with the maximum value of 65535 ms. The log interval cannot be smaller than scan interval because this results in the same value being logged at least twice.

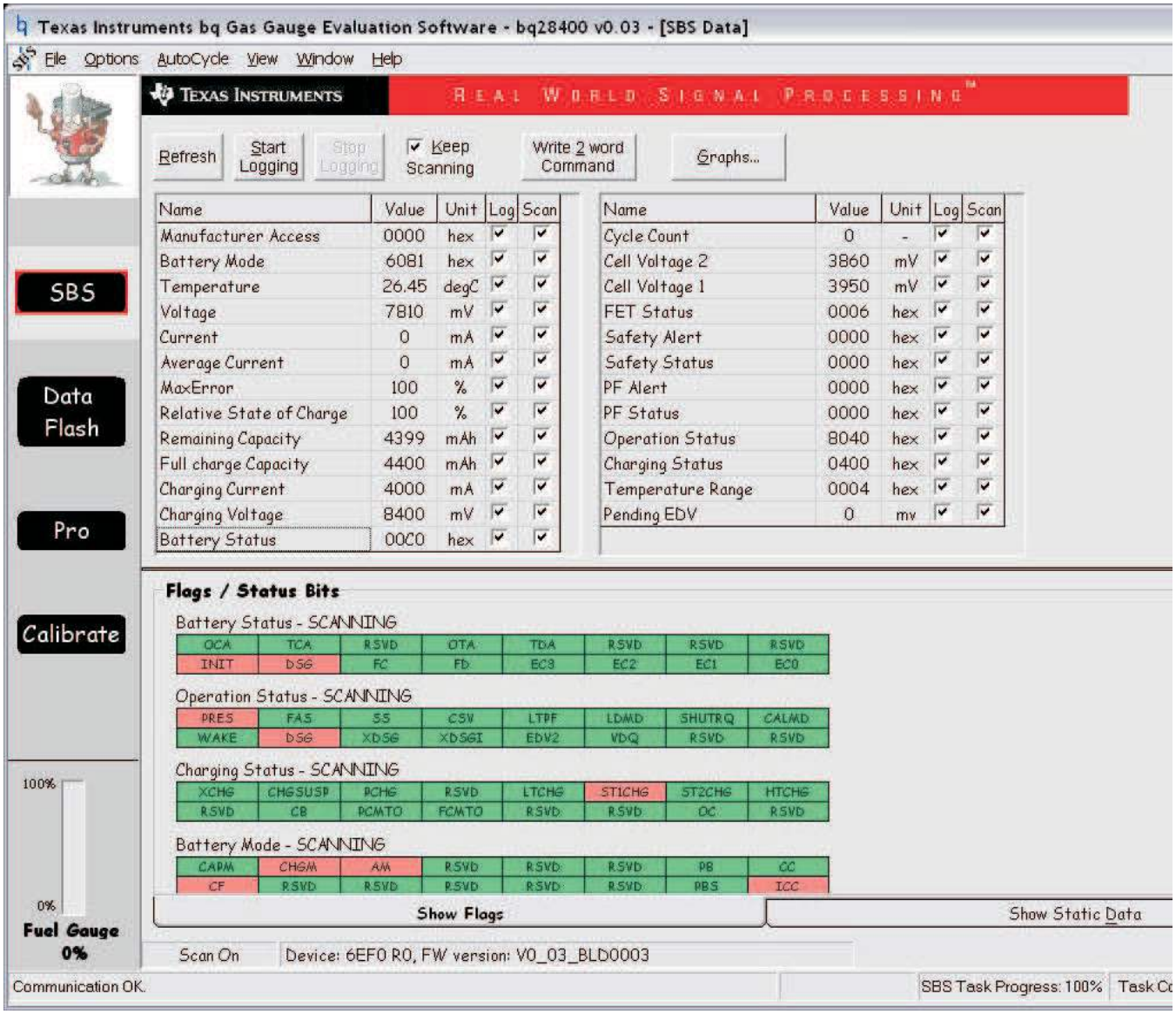


Figure 10. SBS Data Screen

Figure 10 shows the SBS data set along with additional ManufacturersAccess() command information such as individual cell measurements. To view additional Flag and Static data, select the appropriate tab at the bottom of the **SBS Data** screen.

Data such as SBS.ManufacturerName( ) is static and does not change. This data is viewed separately using the **Static Data** tab available at the bottom of the screen.

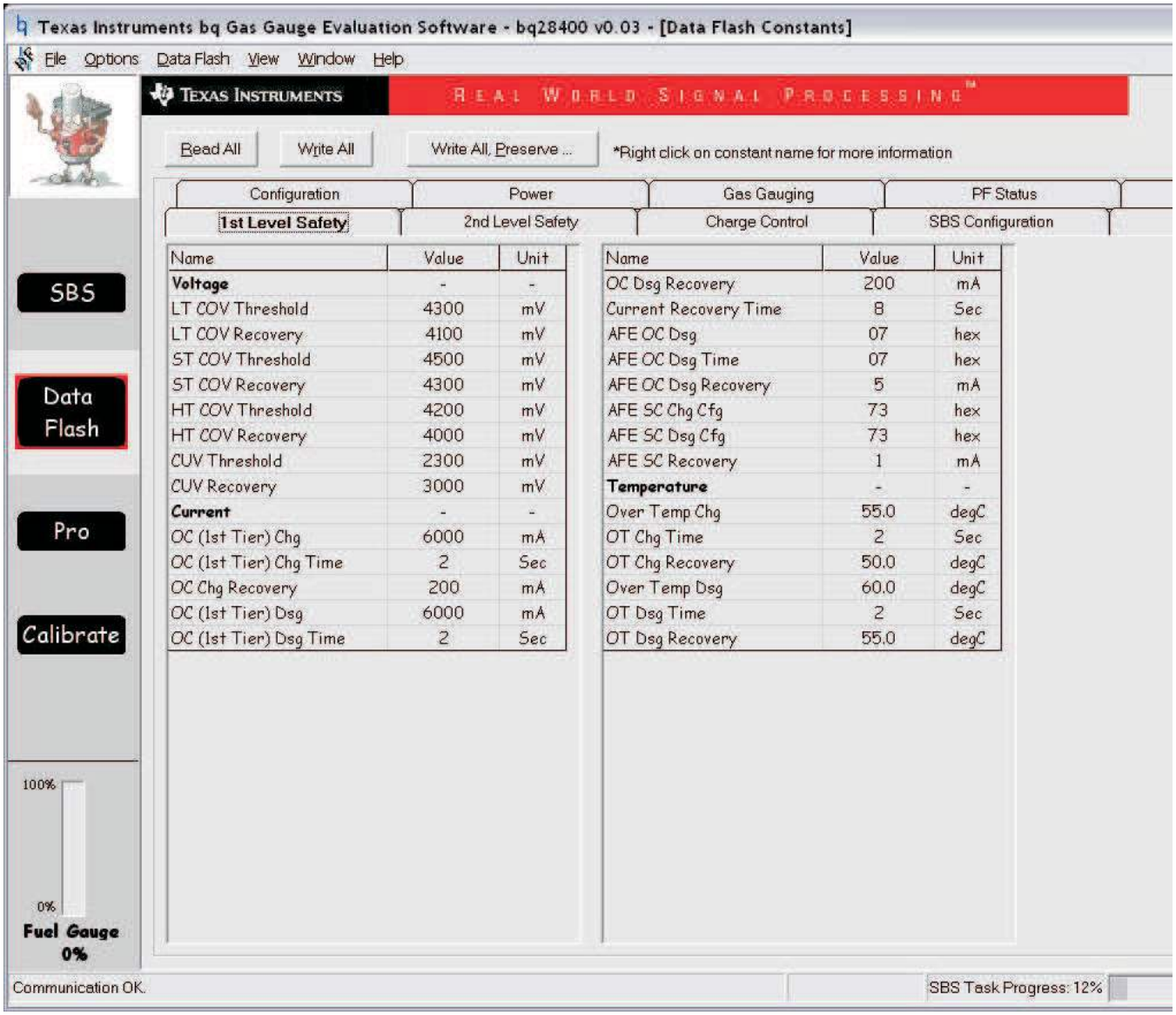
To change the height of the Flags/Static Data display, drag the splitter bar (the line that separates the Flags/Static data from SBS values). To return the splitter bar to its original location, select | **View** |, then | **Auto Arrange** |.

8.2 Setting Programmable bq28400 Options

NOTE: It is very important to have the correct setting of these options to get the best performance.

The bq28400 data flash is configured per the default settings detailed in the bq28400 data sheet (SLUSA61A). Ensure that the settings are correctly changed to match the pack and application for the bq28400 solution being evaluated.

Use the **Data Flash** screen (Figure 11) to configure the settings.



Name	Value	Unit
Voltage	-	-
LT COV Threshold	4300	mV
LT COV Recovery	4100	mV
ST COV Threshold	4500	mV
ST COV Recovery	4300	mV
HT COV Threshold	4200	mV
HT COV Recovery	4000	mV
CUV Threshold	2300	mV
CUV Recovery	3000	mV
Current	-	-
OC (1st Tier) Chg	6000	mA
OC (1st Tier) Chg Time	2	Sec
OC Chg Recovery	200	mA
OC (1st Tier) Dsg	6000	mA
OC (1st Tier) Dsg Time	2	Sec

Name	Value	Unit
OC Dsg Recovery	200	mA
Current Recovery Time	8	Sec
AFE OC Dsg	07	hex
AFE OC Dsg Time	07	hex
AFE OC Dsg Recovery	5	mA
AFE SC Chg Cfg	73	hex
AFE SC Dsg Cfg	73	hex
AFE SC Recovery	1	mA
Temperature	-	-
Over Temp Chg	55.0	degC
OT Chg Time	2	Sec
OT Chg Recovery	50.0	degC
Over Temp Dsg	60.0	degC
OT Dsg Time	2	Sec
OT Dsg Recovery	55.0	degC

Figure 11. Data Flash Screen, 1st Level Safety Class

To read all of the data from the bq28400 data flash, click on menu option | **Data Flash** | **Read All** |.

To write to a data flash location, click on the desired location, enter the data and click **Enter**, which writes the entire tab of flash data, or select the menu option | **Data Flash** | **Write All** |. The data flash must be read before any writes are performed to avoid any incorrect data being written to the device.

The | **File** | **Special Export** | menu options allow the data flash to be exported, but it configures the exported data flash to a learned state ready for mass production use.

The data flash configuration can be saved to a file by selecting | **File** | **Export** | and entering a file name. A data flash file also can be retrieved in this way, imported, and written to the bq28400 using the | **Write All** | button.

The configuration information of the bq28400 and module calibration data also is held in the bq28400 data flash.

The bq28400 allows for an automatic data flash export function, similar to the SBS Data logging function. This feature, when selected via | **Options** | **Auto Export** |, exports data flash to a sequential series of files named as *FilenameNNNNN.gg* where N = a decimal number from 0 to 9.

The **AutoExport** interval is set under the | **Options** | menu with a minimum value of 15 s. The *AutoExport* filename also is set under the | **Options** | menu.

When a checkmark is next to | **AutoExport** |, the Auto Export is in progress. The same menu selection is used to turn on / off **AutoExport**.

NOTE: If the data flash screen is blank, the bqEVSW version in use may not support the bq28400 in use. An upgrade may be required.

9 Calibration Screen

9.1 How to Calibrate

Before calibrating the bq28400, do the following:

- Connect a load to Pack– and Pack+ that draws approximately 2 A, and measures discharge current to use the FETs. Connect a current source to Batt–(1N) and Pack– to calibrate without using the FETs by forcing current through the sense resistor directly.
- Measure individual cell stack voltage from Batt–(1N), to Cell1(1P), Cell1+2(2P).
- Measure the temperature of the pack.

These steps may not be required, depending on the calibration type.

NOTE: Voltage calibration with cells attached requires special consideration. Cells must be in a resting state.

9.2 To Calibrate the bq28400

1. Select the types of calibration (see Figure 12).
2. Enter the measured values for the types selected.
3. If **Voltage Calibration** is selected, enter the number of cells on the pack, and individual cell voltage.
4. For *Temperature Calibration*, select the sensor that is to be calibrated and enter the actual temperature. Select **Calibrate Voltage and Temperature** to start calibration.
5. For CC offset, board offset, and pack current calibration, use **Continue Calibrations** on the second page or click the **Current** tab.
6. Do not apply any load current for CC offset and board offset calibration.
7. For pack current calibration, apply a 2-A current between PACK+ and PACK–. Ensure the CHG/DSG FETs are on. Alternatively, apply the load current between Cell– and PACK–. This will force the current through the sense resistor and allow the FETs to remain off. This is a more accurate current calibration than applying current through PACK+ and PACK–.

9.3 Pack Calibration

Pack Calibration calibrates the voltage of the PACK pin. This is optional, because the accuracy of PACK voltage is not required. The voltage reading is used for the gas gauge to sense the presence of a charger.

Make sure *Voltage Calibration* has been performed for the pack. If *Voltage Calibration* is not performed, then **Pack Calibration** calibrates incorrectly.

Apply a known voltage between PACK+ and PACK–. Enter the actual voltage in the textbox.

Click **Calibrate Pack Voltage**.

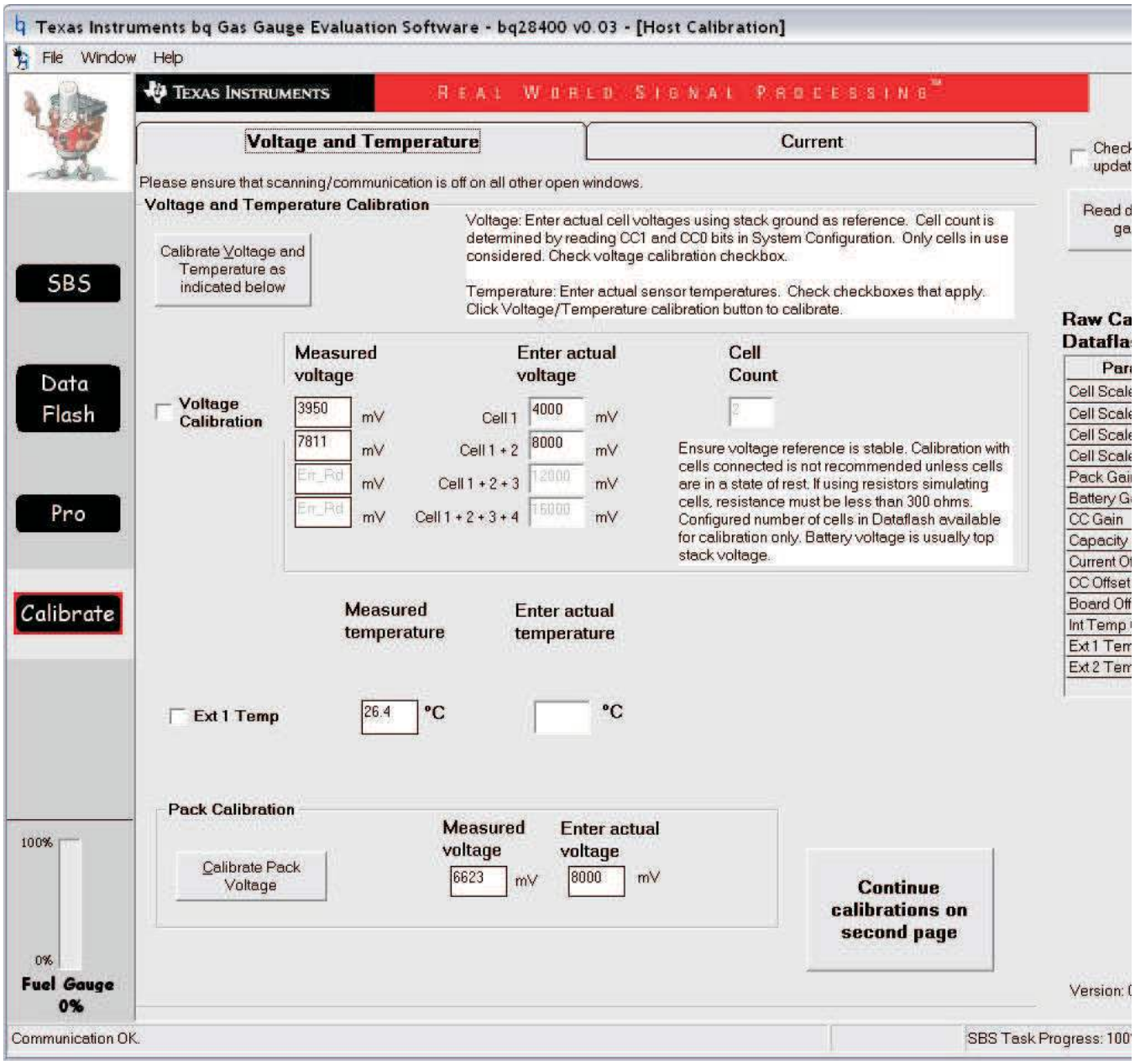


Figure 12. Calibration Screen

10 Pro (Advanced) Screen

10.1 SMB Communication

The set of read/write operations over the SMBus are not specific to any gas gauge. These are provided as general-purpose communication tools (Figure 13).

10.2 Hexadecimal/Decimal Converter

Hexadecimal value and **Decimal value** convert between hexadecimal and decimal as soon as values are typed into the boxes. Invalid values may cause erroneous results.

When scaling converted hexadecimal values to a higher number of bytes, follow these rules:

- When unsigned is selected, the left pad contains zeroes.
- When signed is selected, the left pad contains zeroes for a positive number, or the left pad contains *F* for negative numbers.

10.3 Programming

The **Pro (Advanced) Screen** enables device reprogramming from unencrypted and encrypted files.

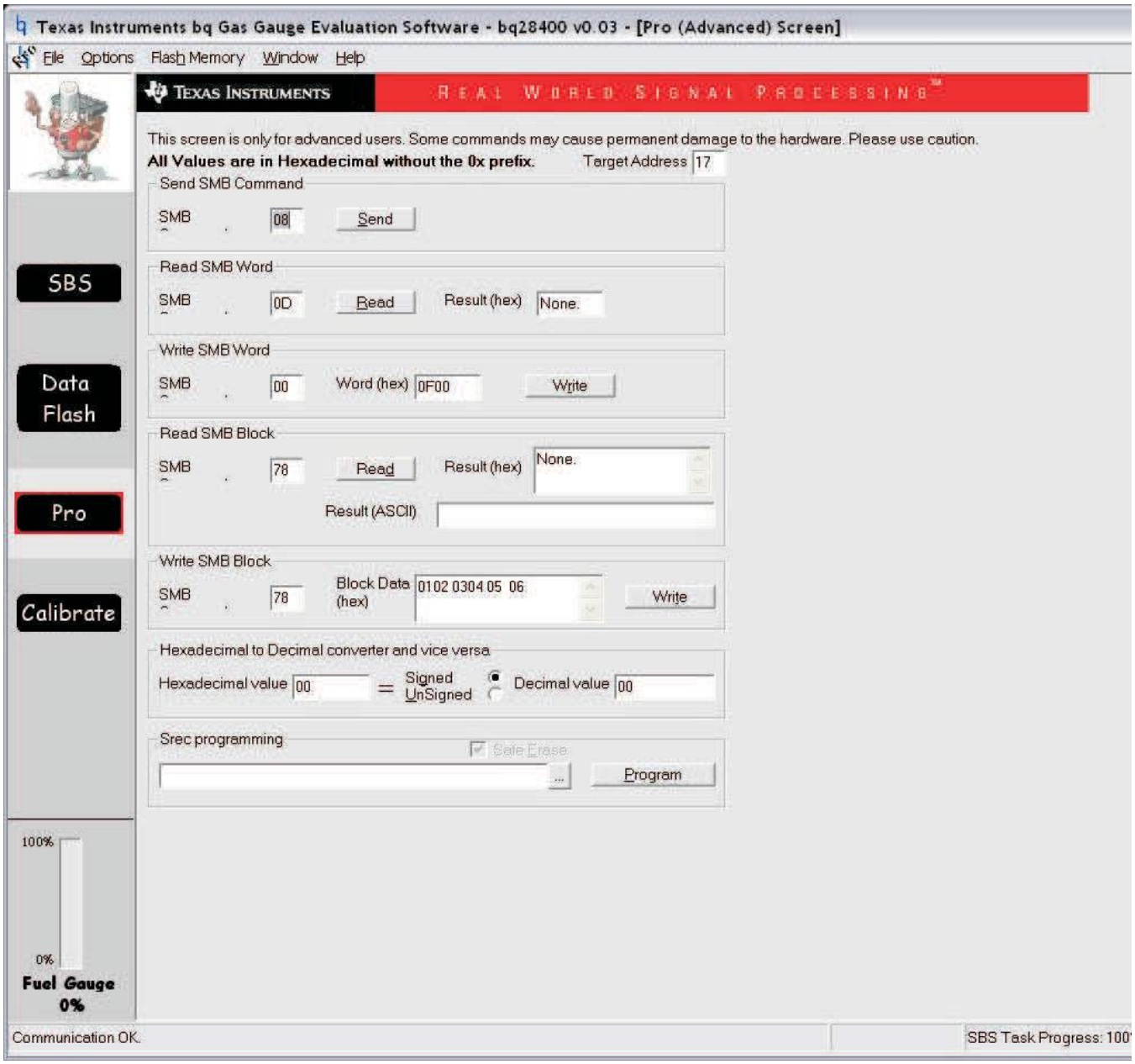


Figure 13. Pro (Advanced) Screen

11 Pack Assembly and the bq28400

This section describes the recommended assembly sequence for a bq28400-based battery pack. This procedure results in the most time-efficient setup of the battery pack.

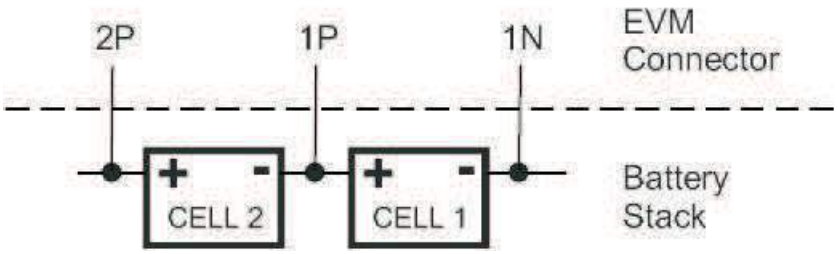


Figure 14. Connection Sequence

Follow these steps to connect a 2-series cell battery to the bq28400EVM board.

1. Connect the most negative terminal (– terminal of cell 1) of the serially connected, 2-cell battery stack to the 1N PIN of the TB1 connector, as shown in Figure 14. (See also Figure 9 for the TB1 location).
2. Connect the positive terminal of cell 1 to 1P.
3. Connect the positive terminal of cell 2 to 2P.
4. Press the SW1 switch on the EVM. This will apply the battery voltage on the PACK+ pin and wake up the EVM from shutdown mode.
5. Connect the SMBus connector (J2) to the EV2x00 adapter and start the EV software.
6. Navigate to the **Flash Screen**. Change the flash constants that correspond to the specific parameters of your application (refer to the data sheet or other application reports). For the first evaluation, the default values may be used.
7. Navigate to the **Calibration screen**. Follow the procedures in Section 9 to calibrate the EVM.

To enable certain features and for gauging, refer to the Technical Reference Manual (SLUU431).

EVALUATION BOARD/KIT IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 6 V to 25 V and the output voltage range of 0 V to 16.4 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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