bq40z80EVM Li-Ion Battery Pack Manager Evaluation Module

This evaluation module (EVM) is a complete evaluation system for the bq40z80 battery management system. The EVM includes one bq40z80, two bq771807 secondary protectors, and a link to Microsoft® Windows® based PC software. The circuit module includes one bq40z80 integrated circuit (IC), two bq771807 secondary protectors, and all other onboard components necessary to monitor and predict capacity, perform cell balancing, monitor critical parameters, protect the cells from overcharge, over-discharge, short-circuit, and overcurrent in 2-, 3-, 4-, 5-, 6-, or 7-series cell Li-ion or Li-polymer battery packs. The circuit module connects directly across the cells in a battery. The bq40z80EVM can use the on-board EV2400 or an external EV2400 interface board and software to read the bq40z80 data registers, program the chipset for different pack configurations, log cycling data for further evaluation, and evaluate the overall functionality of the solution under different charge and discharge conditions.

Contents

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1 Features

- Complete evaluation system for the bq40z80EVM Li-Ion Battery Pack Manager Evaluation Module and bq771807 independent overvoltage protection ICs
- Populated circuit module for quick setup
- Jumpers for configuring multifunction pins
- Software that allows data logging for system analysis

1.1 Kit Contents

- bq40z80 and bq771807 circuit module
- Cable to connect the EVM to a PC using the on-board EV2400. If an external EV2400 is used, it can be purchased separately.

1.2 Ordering Information

For complete ordering information, see the product page at *www.ti.com*.

Table 1. Ordering Information

EVM PART NUMBER	CHEMISTRY	CONFIGURATION	CAPACITY
bq40z80EVM	Li-ion	1-, 2-, 3-, 4-, 5-, 6-, or 7-cell	Any

1.3 Documentation

See the device data sheets for bq40z80 and bq771807 and technical reference manuals (TRMs) on *www.ti.com* for information on device firmware and hardware.

1.4 bq40z80 and bq771807 Circuit Module Performance Specification Summary

This section summarizes the performance specifications of the bq40z80 and bq881707 EVM.

Table 2. Performance Specification Summary

Specification	Minimum	Typical	Maximum	Units
Input voltage Pack+ to Pack–	3	15	32	V
Charge and discharge current	0	2	7	A

2   bq40z80EVM Quick Start Guide

This section provides the step-by-step procedures required to use a new EVM and configure it for operation in a laboratory environment.

2.1   Items Needed for EVM Setup and Evaluation

- bq40z80 and bq771807 circuit module
- EV2400 communications interface adapter or use on-board EV2400 function
- Cable to connect the EVM to an EV2400 communications interface adapter OR micro-USB cable to connect EVM directly to a computer
- If using an external EV2400 communications adapter, it requires a USB cable to connect the communications interface adapter (EV2400 or on-EVM) to the computer
- Computer setup with Windows XP, or higher, operating system
- Access to the Internet to download the Battery Management Studio software setup program
- One-to-seven battery cells or 1-kΩ resistors to configure a cell simulator
- A DC power supply that can supply 32 V and 2 A (constant current and constant voltage capability is desirable). Caution: Some power supplies can be damaged by application of external voltages. If using more than 1 power supply check your equipment requirements and use blocking diodes or other isolation techniques, as needed, to prevent damage to your equipment.

2.2   Software Installation

Find the latest software version in the bq40z80 tool folder on www.ti.com. Version 1.3.83 or greater is required to use all the bq40z80 features. Use the following steps to install the bq40z80 Battery Management Studio software:

1. Download and run the Battery Management Studio setup program from the Development Tools section of the bq40z80EVM product folder on www.ti.com. See Section 3 for detailed information on using the tools in the Battery Management Studio.

2. If the communications interface adapter was not previously installed, after the Battery Management Studio installation, a TI USB driver installer pops up. Click "Yes" for the agreement message and follow its instructions.

3. Plug the EVM into a USB port using the USB cable. The Windows system may show a prompt that new hardware has been found. When asked, "Can Windows connect to Windows Update to search for software?", select "No, not this time", and click "Next". In the next dialog window, it indicates "This wizard helps you install software for: TI USB Firmware Updater". Select "Install the software automatically (Recommended)" and click "Next". It is common for the next screen to be the Confirm File Replace screen. Click "No" to continue. If this screen does not appear, then go to the next step. After Windows indicates that the installation was finished, a similar dialog window pops up to install the second driver. Proceed with the same installation preference as the first one.

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2.3 EVM Connections

This section covers the hardware connections for the EVM. See Figure 1.
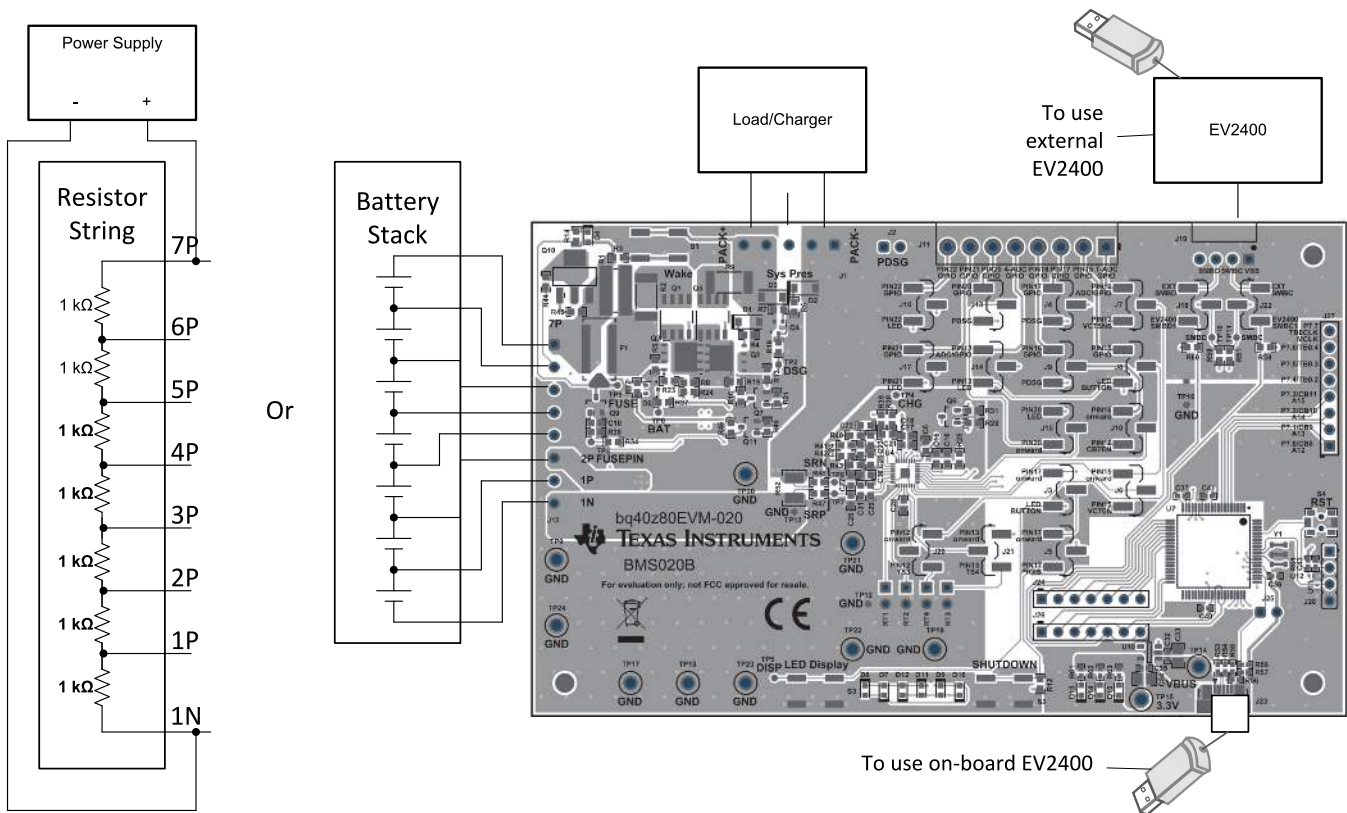
Figure 1. bq40z80 Circuit Module Connection to Cells and System Load or Charger

- Direct connection to the cells: 1N (BAT–), 1P, 2P, 3P, 4P, 5P, 6P, 7P (BAT+)

  Attach the cells to the J12 terminal block. A specific cell connection sequence is not required; although, it is good practice to start with lowest cell in the stack (cell 1), then attach cells 2 through 7 in sequence. The U1 and U2 devices should not be damaged by other cell connection sequences, but there is a possibility that the bq771807 could blow the fuse. Attaching cells starting with cell 1 should eliminate this risk. A short should be placed across unused voltage sense inputs up to 7P.

Table 3. Cell Connection Configuration

Number of Cells	J12 Terminal Block Connections													
	1N		1P		2P		3P		4P		5P		6P		7P
1	⊕	-cell1+	⊕	short	⊕	short	⊕	short	⊕	short	⊕	short	⊕	short	⊕
2	⊕	-cell1+	⊕	-cell2+	⊕	short	⊕	short	⊕	short	⊕	short	⊕	short	⊕
3	⊕	-cell1+	⊕	-cell2+	⊕	-cell3+	⊕	short	⊕	short	⊕	short	⊕	short	⊕
4	⊕	-cell1+	⊕	-cell2+	⊕	-cell3+	⊕	-cell4+	⊕	short	⊕	short	⊕	short	⊕
5	⊕	-cell1+	⊕	-cell2+	⊕	-cell3+	⊕	-cell4+	⊕	-cell5+	⊕	short	⊕	short	⊕
6	⊕	-cell1+	⊕	-cell2+	⊕	-cell3+	⊕	-cell4+	⊕	-cell5+	⊕	-cell6+	⊕	short	⊕
7	⊕	-cell1+	⊕	-cell2+	⊕	-cell3+	⊕	-cell4+	⊕	-cell5+	⊕	-cell6+	⊕	-cell7+	⊕

A resistor cell simulator can be used instead of battery cells. Connect a resistor between each of the contacts on the J12 connector. For example, from 1N to 1P, from 1P to 2P, and so forth, until the desired number of cells has been achieved. A power supply can provide power to the cell simulator. Set the power supply to the desired cell voltage × the number of cells and attach the ground wire to 1N and the positive wire to 4P. For example, for a 6S configuration with a 3.6-V cell voltage, set the power supply to 6 × 3.6 = 21.6 V.

• Serial communications port (SMBC, SMBD)

If the external EV2400 is used, attach the communications interface adapter cable to J19 and to the SMB port on the EV2400. The jumper settings for J18 should be to connect pins 2 and 3, and the jumper settings for J should be to connect pins 1 and 2. This allows the external EV2400 to talk to the bq40z80 over SMBus.

Alternately, the on-board EV2400 can be used by connecting a micro-USB cable to the EVM at J directly to a computer. To use the on-board EV2400, the jumper settings for J18 should be to connect pins 1 and 2, and the jumper settings for J should be to connect pins 2 and 3. This allows the on-board EV2400 to talk to the bq40z80 over SMBus.

• System load and charger connections across PACK+ and PACK−

Attach the load or power supply to the J terminal block. The positive load or power supply wire should be connected to at least one of the first two terminal block positions labeled PACK+. The ground wire for the load or power supply should be connected to the last terminal block positions labeled PACK−.

• System-present pin (SYS PRES)

To start charge or discharge test, connect the SYS PRES position on the J terminal block to PACK−. The SYS PRES can be left open if the non-removable (NR) bit is set to 1 in the Pack Configuration A register. To test sleep mode, disconnect the SYS PRES pin.

• Wake-up the device up from shutdown (WAKE)

Press the Wake pushbutton switch (S1) to temporarily connect Bat+ to Pack+. This applies voltage to the PACK pin on the bq40z80 to power-up the regulators and start the initialization sequence.

• Parameter setup

The default data flash settings configure the device for 7-series Li-Ion cells. The user should change the | Data Flash | Settings | DA Configuration register to set up the number of series cells to match the physical pack configuration. This provides basic functionality to the setup. Other data flash parameters should also be updated to fine tune the gauge to the pack. See the bq40z80 TRM for help with setting the parameters.

2.4 Update Firmware

The bq40z80 may need updated firmware. Contact TI support if the device is pre-release, or find the latest firmware version in the appropriate bq40z80 folder on www.ti.com. Use the following steps to install the bq40z80 *Battery Management Studio* software:

1. Run *Battery Management Studio* from the **Start** | **Programs** | **Texas Instruments** | **Battery Management Studio** menu sequence, or the *Battery Management Studio* shortcut.
2. Follow the directions in Section 3.5, select the firmware .srec file downloaded from www.ti.com, and click the **Program** button.
3. Once programming is finished, the EVM is ready to use with the latest firmware.

3 Battery Management Studio

3.1 Registers Screen

Run Battery Management Studio from the Start | Programs | Texas Instruments | Battery Management Studio menu sequence, or the Battery Management Studio shortcut. The Registers screen (see Figure 2) appears. The Registers section contains parameters used to monitor gauging. The Bit Registers section provides bit level picture of status and fault registers. A green flag indicates that the bit is 0 (low state) and a red flag indicates that the bit is 1 (high state). Data begins to appear once the *Refresh* (single-time scan) button is selected, or it scans continuously if the *Scan* button is selected.
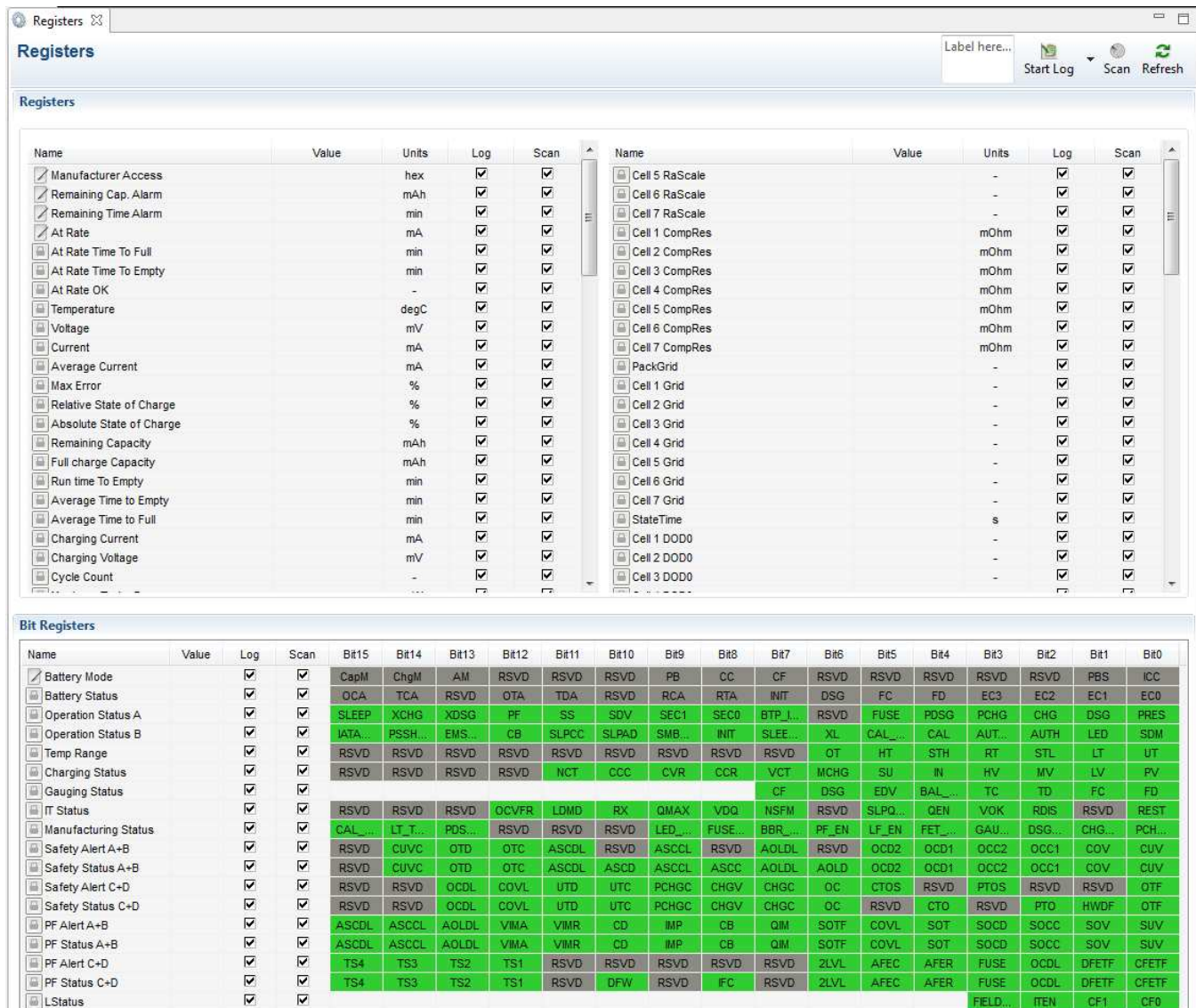

Figure 2. Registers Screen

The Battery Management Studio program provides a logging function which logs the values that are selected by the Log check boxes located beside each parameter in the Register section. To enable this function, select the *Log* button; this causes the *Scan* button to be selected. When logging is stopped, the *Scan* button is still selected and has to be manually deselected.

The Log Interval can be set by opening a Watch tab, and using the pull-down at the far right to select the desired Log Interval in milli-seconds.

3.2 Setting Programmable bq40z80 Options

The bq40z80 data memory comes configured per the default settings detailed in the bq40z80 TRM. Ensure that the settings are correctly changed to match the pack and application for the solution being evaluated.

NOTE: The correct setting of these options is essential to get the best performance. The settings can be configured using the Data Memory screen (see Figure 3).

Figure 3. Data Memory Screen

3.3 Calibration Screen

The voltages, temperatures, and currents should be calibrated to provide good gauging performance.

Press the *Calibration* button to select the Advanced Calibration window. See Figure 4.
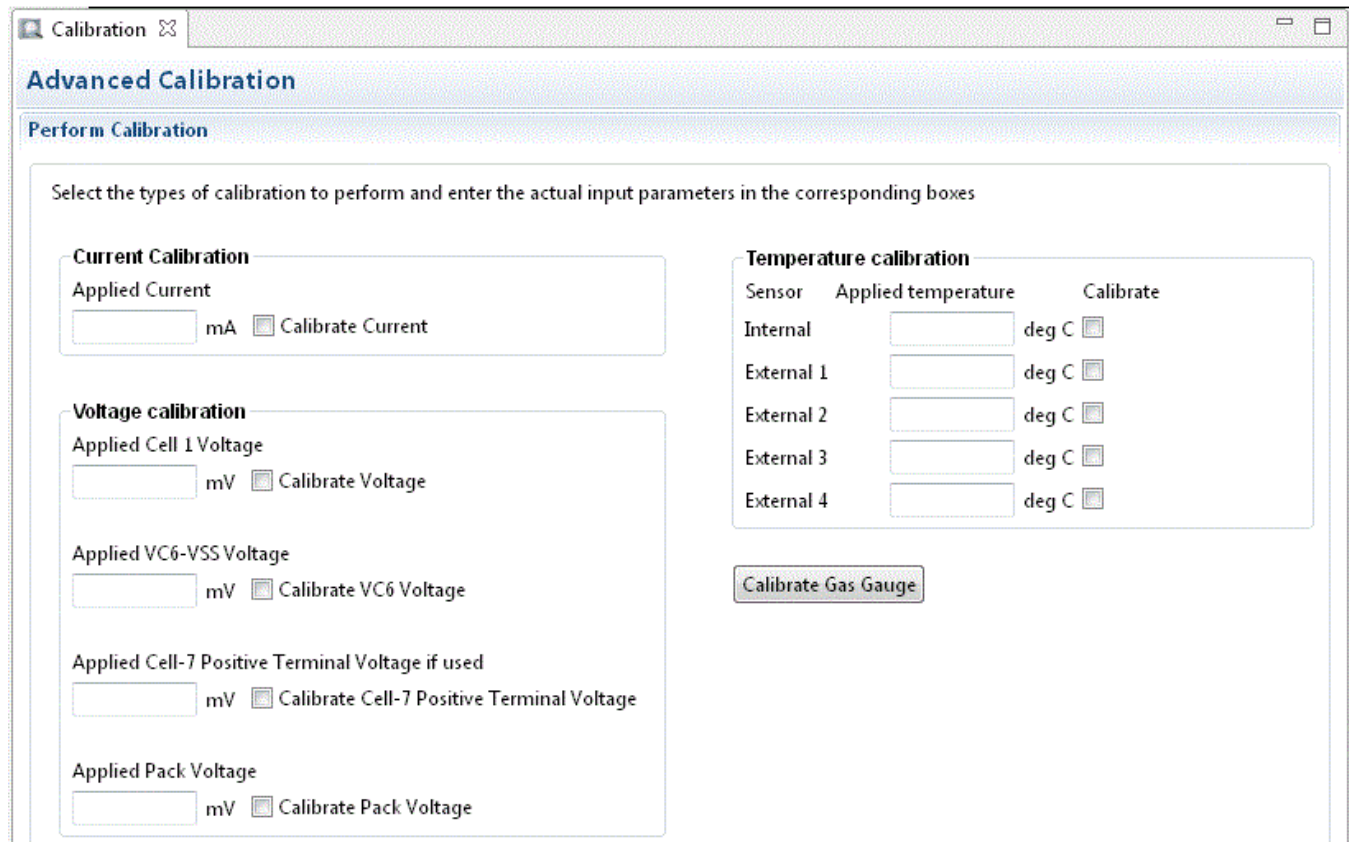
Figure 4. Calibration Screen

3.3.1 Voltage Calibration

- Measure the voltage from 1P to 1N (VSS) and enter this value in the Applied Cell 1 Voltage field and select the Calibrate Voltage box.
- Measure the voltage from 6P to 1N (VSS) and enter this value in the Applied Battery Voltage field and select the Calibrate Battery Voltage box.
- Measure the voltage from Pack+ to Pack– and enter this value in the Applied Pack Voltage field and select the Calibrate Pack Voltage box. If the voltage is not present, then turn the charge and discharge FETs on by entering a 0x0022 command in the Manufacturer Access register on the Register screen.
- If the device is configured for 7S, measure the voltage from 7P to 1N (VSS) and enter this value in the Applied Cell-7 Positive Terminal Voltage field and select the Calibrate Battery Voltage box.
- Press the *Calibrate Gas Gauge* button to calibrate the voltage measurement system.
- Deselect the Calibrate Voltage boxes after voltage calibration has completed.

3.3.2 Temperature Calibration

- Enter the room temperature in each of the Applied Temperature fields and select the Calibrate box for each thermistor to be calibrated. The temperature values must be entered in degrees Celsius.
- Press the *Calibrate Gas Gauge* button to calibrate the temperature measurement system.
- Deselect the Calibrate boxes after temperature calibration has completed.

3.3.3   Current Calibration

The Board Offset calibration option is not offered in Battery Management Studio, because it is not required when using the bq40z80EVM. The Board Offset calibration option is available in bqProduction.

- Connect and measure a 2-A current source from 1N (–) and Pack– (+) to calibrate without using the FETs. (TI does not recommend calibration using the FETs.)
- Enter –2000 in the Applied Current field and select the Calibrate Current box.
- Press the *Calibrate Gas Gauge* button to calibrate.
- Deselect the Calibrate Current box after current calibration has completed.
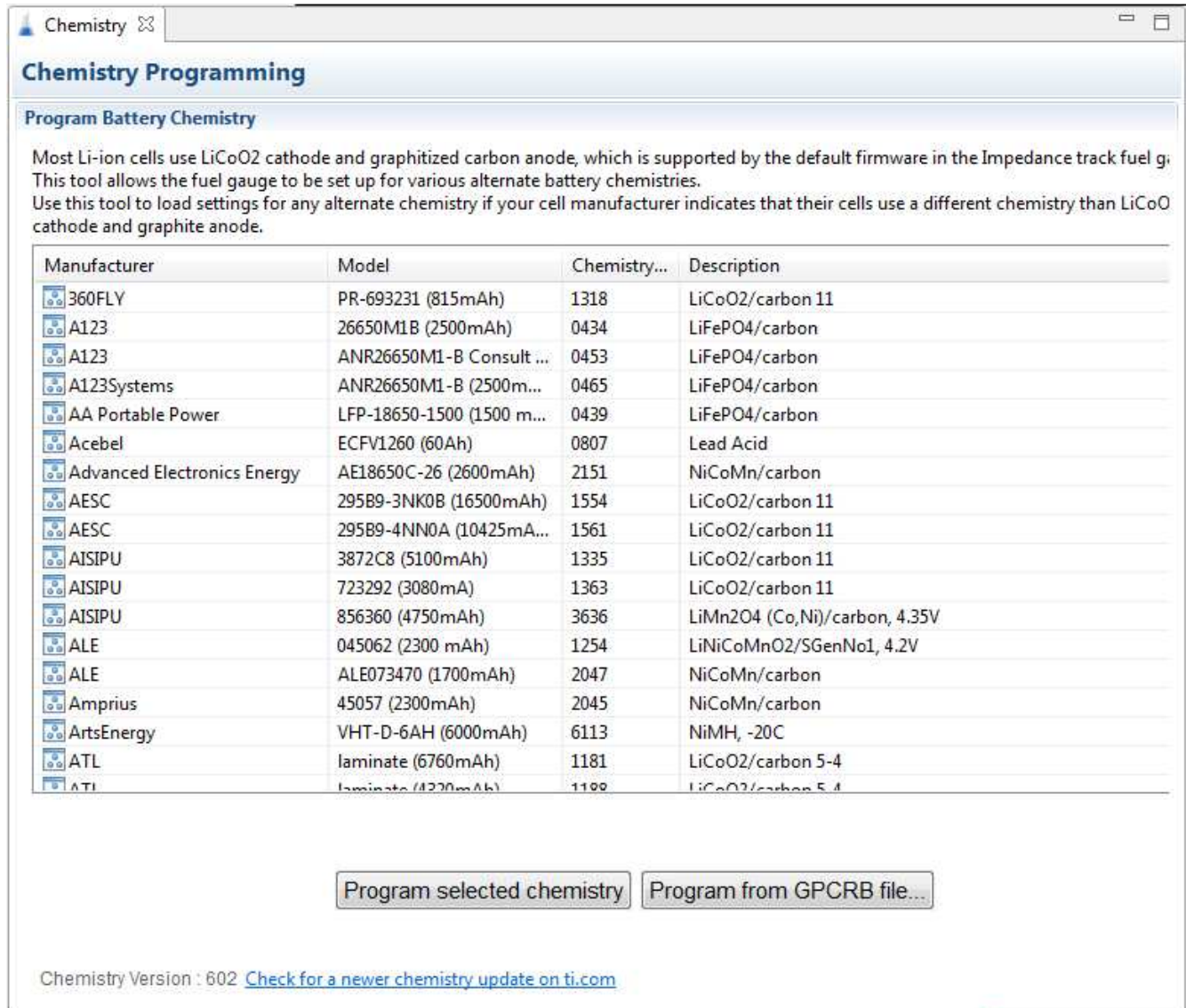

NOTE: Current can also be calibrated using the FETs. Measure the current in the discharge path and enter this value in the Applied Current field.

3.4 Chemistry Screen

The chemistry file contains parameters that the simulations use to model the cell and its operating profile. It is critical to program a Chemistry ID that matches the cell into the device. Some of these parameters can be viewed in the Data Flash section of the Battery Management Studio.

Press the *Chemistry* button to select the Chemistry window.

Manufacturer	Model	Chemistry...	Description
360FLY	PR-693231 (815mAh)	1318	LiCoO2/carbon 11
A123	26650M1B (2500mAh)	0434	LiFePO4/carbon
A123	ANR26650M1-B Consult ...	0453	LiFePO4/carbon
A123Systems	ANR26650M1-B (2500m...	0465	LiFePO4/carbon
AA Portable Power	LFP-18650-1500 (1500 m...	0439	LiFePO4/carbon
Acebel	ECFV1260 (60Ah)	0807	Lead Acid
Advanced Electronics Energy	AE18650C-26 (2600mAh)	2151	NiCoMn/carbon
AESC	295B9-3NK0B (16500mAh)	1554	LiCoO2/carbon 11
AESC	295B9-4NN0A (10425mA...	1561	LiCoO2/carbon 11
AISIPU	3872C8 (5100mAh)	1335	LiCoO2/carbon 11
AISIPU	723292 (3080mA)	1363	LiCoO2/carbon 11
AISIPU	856360 (4750mAh)	3636	LiMn2O4 (Co,Ni)/carbon, 4.35V
ALE	045062 (2300 mAh)	1254	LiNiCoMnO2/SGenNo1, 4.2V
ALE	ALE073470 (1700mAh)	2047	NiCoMn/carbon
Amprius	45057 (2300mAh)	2045	NiCoMn/carbon
ArtsEnergy	VHT-D-6AH (6000mAh)	6113	NiMH, -20C
ATL	laminate (6760mAh)	1181	LiCoO2/carbon 5-4
ATL	laminate (4320mAh)	1188	LiCoO2/carbon 5-4

Figure 5. Chemistry Screen

- The table can be sorted by clicking the desired column. for example: Click the Chemistry ID column header.
- Select the ChemID that matches your cell from the table (see Figure 5).
- Press the Update Chemistry in the *Data Flash* button to update the chemistry in the device.

3.5   Firmware Screen

Press the *Firmware* button to select the Firmware Update window. This window allows the user to export and import the device firmware.
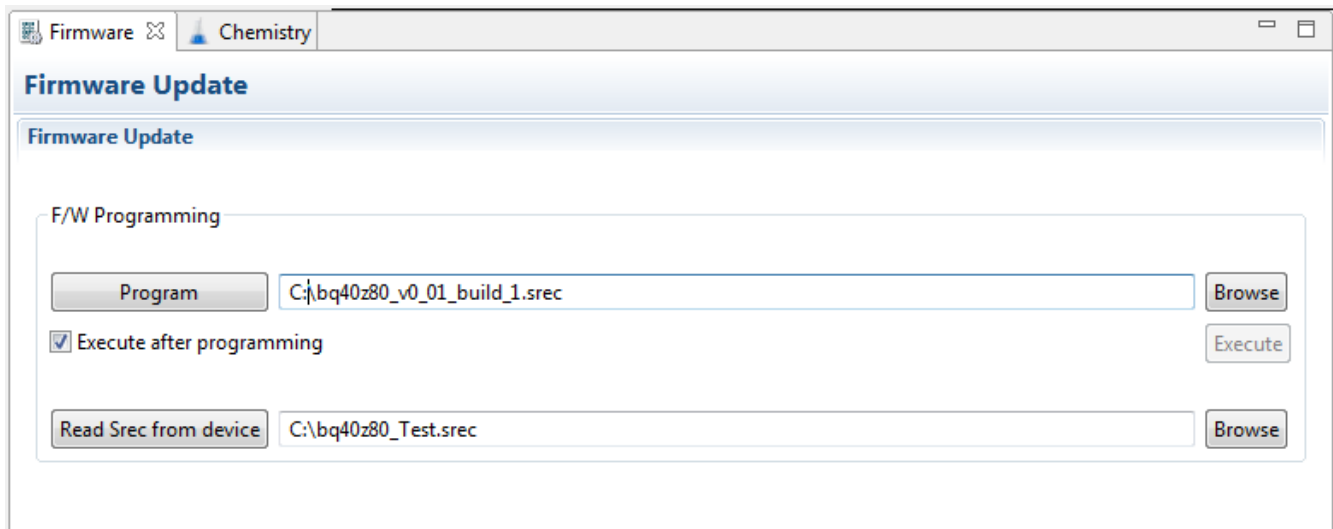
Figure 6. Firmware Screen

3.5.1   Programming the Flash Memory

The upper section of the Firmware screen is used to initialize the device by loading the default .srec into the flash memory (see Figure 6).

- Search for the .srec file using the *Browse* button.
- Select the *Execute after programming* box to automatically return the device to Normal mode after programming has completed.
- Press the *Program* button and wait for the download to complete.

3.5.2   Exporting the Flash Memory

The lower section of the Firmware screen is used to export all of the flash memory from the device (see Figure 6).

- Press the *Browse* button and enter an .srec filename.
- Press the *Read Srec* to save the flash memory contents to the file. Wait for the download to complete.

3.6 *Advanced Comm SMB Screen*

Press the *Advanced Comm SMB* button to select the Advanced SMB Comm window. This tool provides access to parameters using SMB and Manufacturing Access commands. See Figure 7.
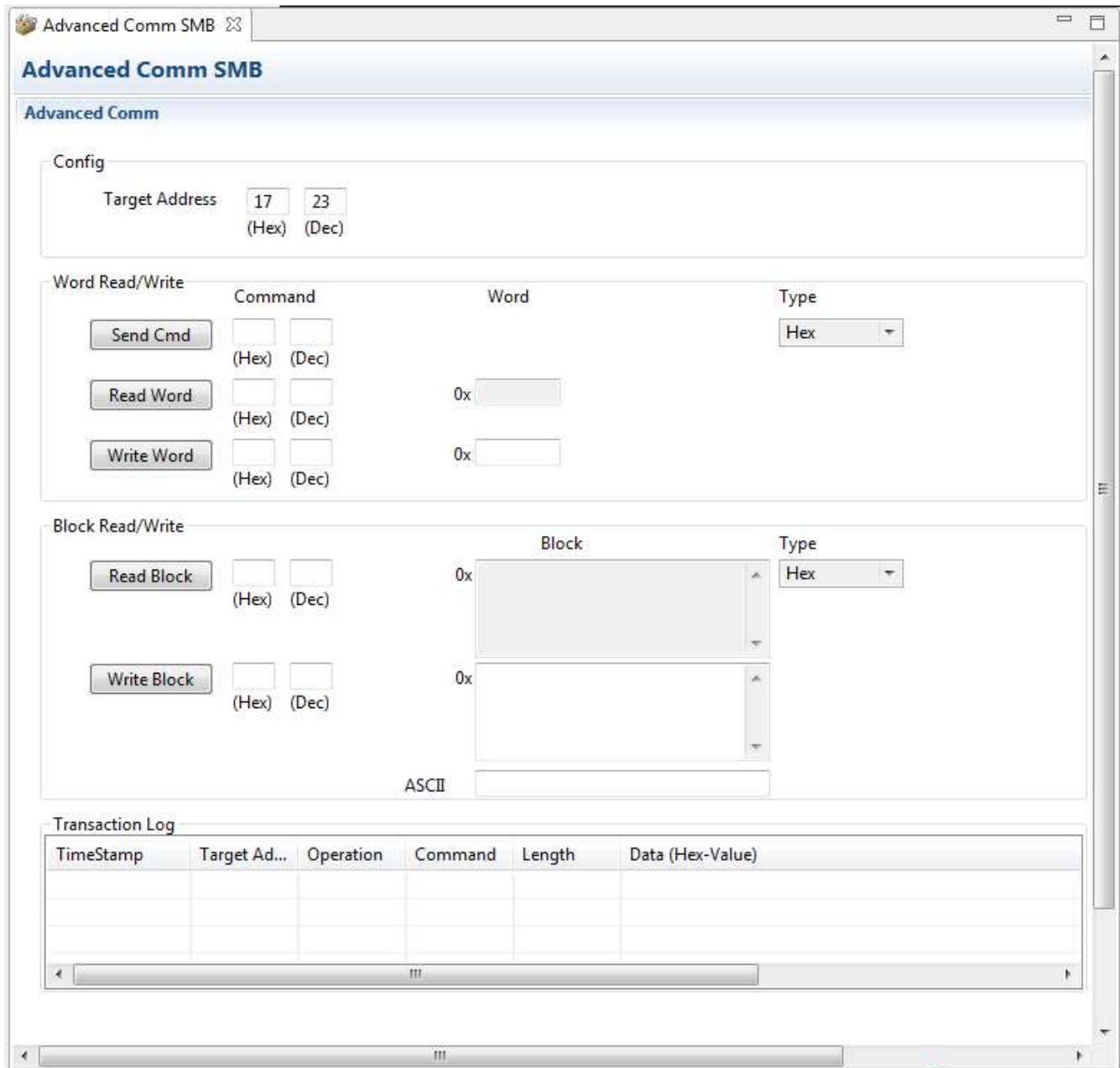
Figure 7. Advanced Comm Screen

Examples:

Reading an SMB Command.

- Read SBData Voltage (0x09)
  - SMBus Read Word. Command = 0x09
  - Word = 0x3A7B, which is hexadecimal for 14971 mV

Sending a MAC Gauging() to enable IT via ManufacturerAccess().

- With Impedance Track™ disabled, send Gauging() (0x0021) to ManufacturerAccess().
  - SMBus Write Word. Command = 0x00. Data = 00 21

Reading Chemical ID() (0x0006) via ManufacturerAccess()

- Send Chemical ID() to ManufacturerAccess()
  - SMBus Write Word. Command = 0x00. Data sent = 00 06
- Read the result from ManufacturerData()
  - SMBus Read Block. Command = 0x23. Data read = 00 01
  - That is 0x0100, chem ID 100

4   bq40z80EVM Circuit Module Schematic

This section contains information on modifying the EVM and using various features on the reference design. The jumpers on the board allow different pin configurations. The pin configuration in the registers must match the jumper configuration on the bq40z80EVM . The Pin Configuration register can be set in the Data Memory section of bqStudio. If a register is set to an undefined setting, the output is configured as high-Z.

Table 4. bq40z80 EVM-RevB Jumper and Pin Configuration Register Settings

General Description		Pin Configuration Register Setting	Jumper Connections	Comments
Pack connector with SYS_PRES			J1	Connect PACK+ and PACK– to the appropriate pins on the battery pack
Header for cell connections			J12	Pin 1: 7P, Pin2: 6P, Pin3: 5P, Pin4: 4P, Pin5: 3P, Pin6: 2P, Pin7: 1P, Pin8: 1N(GND). If using less than 7 cells, tie the unused cell pins (6P, 5P, etc) to the highest cell in the stack
Pin 12	V7SENSE	[MFP12_SEL2:MFP12_SEL0]=000 (EVM DEFAULT)	J20[1,2], J7[1,2]	Connects Pin 12 as V7SENSE to the middle of the voltage divider
	TS3	[MFP12_SEL2:MFP12_SEL0]=001	J20[2,3]	Connects Pin 12 as TS3 to a 10k NTC
	ADCIN1	[MFP12_SEL2:MFP12_SEL0]=010	J20[1,2], J7[2,3]	Connects Pin 12 to Pin 1 of J11. Connect a voltage between 0 V and 1 V to have the ADC read the voltage at this pin
	GPIO	[MFP12_SEL2:MFP12_SEL0]=011 (DEVICE DEFAULT)	J20[1,2], J7[2,3]	Connects Pin 12 to Pin 1 of J11. Use this pin as a GPIO
Pin 13	/DISP	[MFP13_SEL2:MFP13_SEL0]=000 (EVM DEFAULT)	J21[1,2], J14[1,2]	Connects Pin 13 (/DISP) to TP5 and S3
	TS4	[MFP13_SEL2:MFP13_SEL0]=001	J21[2,3]	Connects Pin 12 as TS4 to a 10k NTC
	ADCIN2	[MFP13_SEL2:MFP13_SEL0]=010	J21[1,2], J14[2,3]	Connects Pin 13 to Pin 5 of J11. Connect a voltage between 0 V and 1 V to have the ADC read the voltage at this pin
	GPIO	[MFP13_SEL2:MFP13_SEL0]=011 (DEVICE DEFAULT)	J21[1,2], J14[2,3]	Connects Pin 13 to Pin 5 of J11. Use this pin as a GPIO
Pin 15	VC7EN	[MFP15_SEL1:MFP15_SEL0]=00 (EVM DEFAULT)	J6[1,2]	Connects Pin 15 (VC7EN) to the gate of Q6 to enable the voltage divider so a scaled voltage of the top of stack is applied to VC7SENSE
	/DISP	[MFP15_SEL1:MFP15_SEL0]=01	J6[2,3], J8[1,2]	Connects Pin 15 (/DISP) to TP5 and S3
	GPIO	[MFP15_SEL1:MFP15_SEL0]=10 (DEVICE DEFAULT)	J6[2, 3], J8[2, 3]	Connects Pin 15 (GPIO) to Pin 2 of J11
Pin 16	CB7EN	[MFP16_SEL1:MFP16_SEL0]=00 (EVM DEFAULT)	J10[1,2]	Connects Pin 17 (CB7EN) to the gate of Q11 for external cell balancing for the 7th cell
	PDSG	[MFP16_SEL1:MFP16_SEL0]=01	J10[2, 3], J9[1,2]	Connects Pin 16 (PDSG) to the gate of Q7 to enable pre-discharge through Q5
	GPIO	[MFP16_SEL1:MFP16_SEL0]=10 (DEVICE DEFAULT)	J10[2,3], J9[2,3]	Connects Pin 62 to Pin 4 of J11. Use this pin as a GPIO
Pin 17	/PRES	[MFP17_SEL2:MFP17_SEL0]=000 (EVM DEFAULT)	J5[1,2]	Connects Pin 17 (/PRES) to Pin 3 of J2
	SHUTDN	[MFP17_SEL2:MFP17_SEL0]=001	J5[1,2]	Connects Pin 17 (/SHUTDN) to S3 pushbutton
	/DISP	[MFP17_SEL2:MFP17_SEL0]=010	J5[2,3], J3[1,2]	Connects Pin 17 (/DISP) to TP5 and S2
	PDSG	[MFP17_SEL2:MFP17_SEL0]=011	J5[2,3], J3[2, 3], J4[1,2]	Connects Pin 17 (PDSG) to the gate of Q7 to enable pre-discharge through Q5
	GPIO	[MFP17_SEL2:MFP17_SEL0]=100 (DEVICE DEFAULT)	J5[2,3], J3[2,3], J4[2,3]	Connects Pin 17 (GPIO) to Pin 3 of J11
Pin 20	LEDCNTLA	[MFP20_SEL2:MFP20_SEL0]=000 (EVM DEFAULT)	J15[2,3]	Connects pin 20 to LEDs to be used as LEDCNTLA. Must be used with LEDCNTLB and LEDCNTLC
	PDSG	[MFP20_SEL2:MFP20_SEL0]=010	J15[1,2], J13[1,2]	Connects pin 20 (PDSG) to the gate of Q7 to enable pre-discharge through Q5. In this mode, Pins 21 and Pin 22 are used as GPIOs.
	GPIO	[MFP20_SEL2:MFP20_SEL0]=001 (DEVICE DEFAULT)	J15[1,2], J13[2,3]	Connects Pin 20 to Pin 6 of J11. Use this pin as a GPIO

General Description		Pin Configuration Register Setting	Jumper Connections	Comments
Pin 21	LEDCNTLB	[MFP20_SEL2:MFP20_SEL0]=000 (EVM DEFAULT)	J17[1,2]	Connects pin 21 to LEDs to be used as LEDCNTLB. Must be used with LEDCNTLA and LEDCNTLC
	GPIO	[MFP20_SEL2:MFP20_SEL0]=010 or [MFP20_SEL2:MFP20_SEL0]=001 (DEVICE DEFAULT)	J17[2,3]	Connects Pin 21 to Pin 7 of J11. Use this pin as a GPIO
Pin 22	LEDCNTLC	[MFP20_SEL2:MFP20_SEL0]=000 (EVM DEFAULT)	J16[1,2]	Connects pin 22 to LEDs to be used as LEDCNTLC. Must be used with LEDCNTLA and LEDCNTLB
	GPIO	[MFP20_SEL2:MFP20_SEL0]=010 or [MFP20_SEL2:MFP20_SEL0]=001 (DEVICE DEFAULT)	J16[2,3]	Connects Pin 22 to Pin 8 of J11. Use this pin as a GPIO

4.1 Pre-Charge

The EVM provides a power resistor and FET to support a reduced current pre-charge path to charge the pack when cell voltages are below the pre-charge voltage threshold. This reduces heating that could lead to cell damage or reduced operating lifetime. For a 7-series cell application, the FET must be rated above the max voltage, and for this reason the CSD18504Q5A was chosen. The TI CSD18504Q5A is a 50A, 40-V device with $R_{ds(on)}$ of 5.3 mΩ when the gate drive voltage is 10 V. The user can change R1 to setup the pre-charge current to a different value. R1 is calculated to limit the precharge current to the desired rate. Be sure to account for the power dissipation of the series resistor. The pre-charge current is limited to $(V_{CHARGER} - V_{BAT})/R1$ and maximum power dissipation is $(V_{charger} - V_{bat})^2/R1$.

4.2 Pre-Discharge

The EVM provides a pre-discharge FET (Q5) and control options through jumpers to enable a pin to function as PDSG to turn the FET on and off. The pre-discharge FET is used in applications where there is a need to soft-start into a large capacitive load, such as a starter cap for a motor, in order to reduce the instantaneous load current. The pre-discharge FET will slowly charge the cap based on voltage or time. See the bq40z80 *Technical Reference Manual*, SLUUBT5 for full details.

4.3 LED Control

The EVM is configured to support six LEDs to provide state-of-charge information for the cells. If configured with the correct jumpers, press the *LED DISPLAY* button to illuminate the LEDs for approximately 4 seconds. Alternately, the LED's can be turned on with in the Commands tab with the LED_TOGGLE to test the LED function, or DISPLAY_PRESS to display the Relative State of Charge.

4.4 Emergency Shutdown

The Emergency Shutdown function allows the user to disable the charge and discharge FETs with an external GPIO pin. The EMSHUT and NR bits must be set high in the DA Configuration register to enable this feature. Press the SHUTDOWN pushbutton switch for one second to disable these FETs, and press it again for one second to enable them.

NOTE: Remember to remove the SYS PRES-to-PACK– short, if present.

4.5 Testing Fuse-Blowing Circuit

To prevent the loss of board functionality during the fuse-blowing test, the actual chemical fuse is not provided on the EVM. FET Q drives the FUSE test point low if a fuse-blow condition occurs. FUSE is attached to an open drain FET, so a pull-up resistor is required to check whether the FUSE pulls low. A FUSEPIN test point is attached to the gate of Q; so, monitoring FUSEPIN can be used to test this condition without adding a pull-up resistor. Fuse placement on the application board is shown in the bq40z80 data sheet. A chemical fuse can also be soldered to the EVM for in-system testing. When using the chemical fuse, remove the shorting resistor R1 from the board.

5   Circuit Module Physical Layouts

This section contains the printed-circuit board (PCB) layout, assembly drawings, and schematic for the bq40z80 and bq771807 circuit modules.

5.1   Board Layout

This section shows the dimensions, PCB layers (see through), and assembly drawing for the bq40z80 modules.
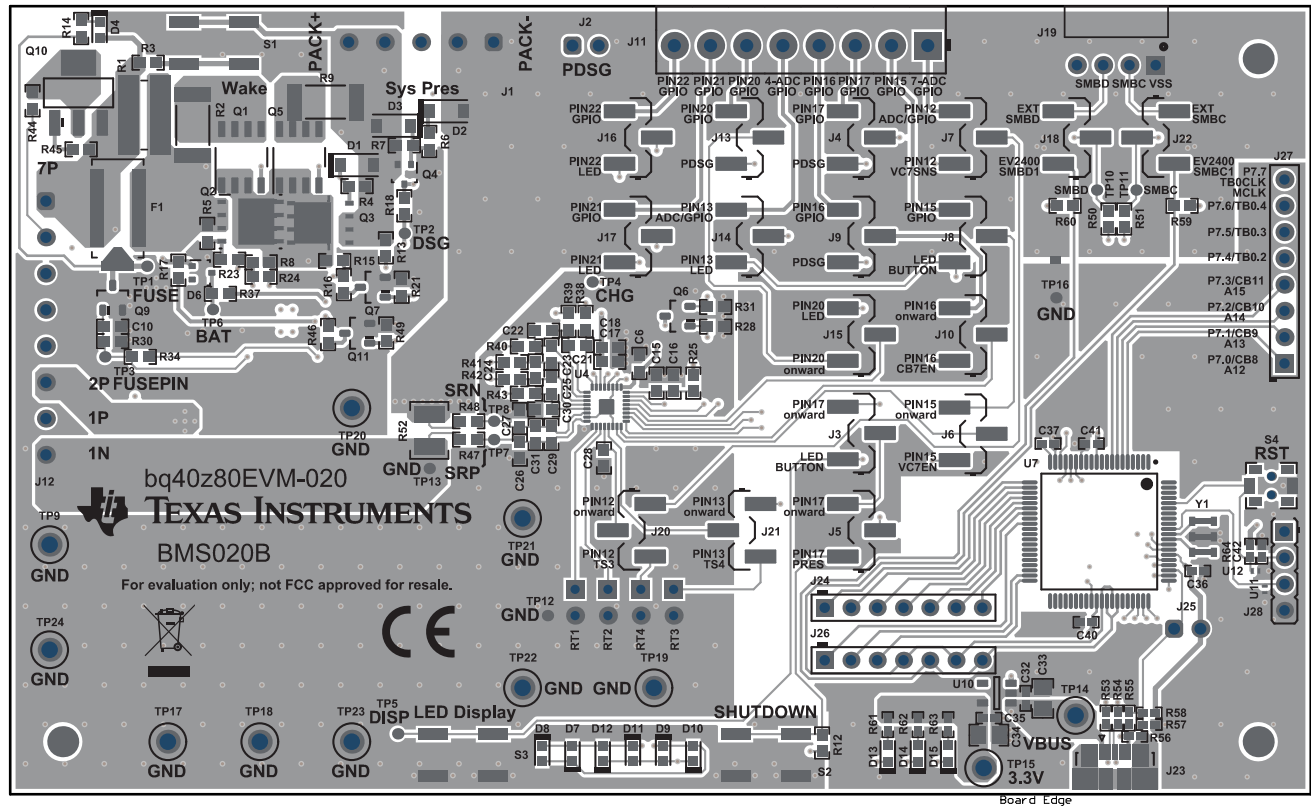
Figure 8. bq40z80EVM RevB Top Composite
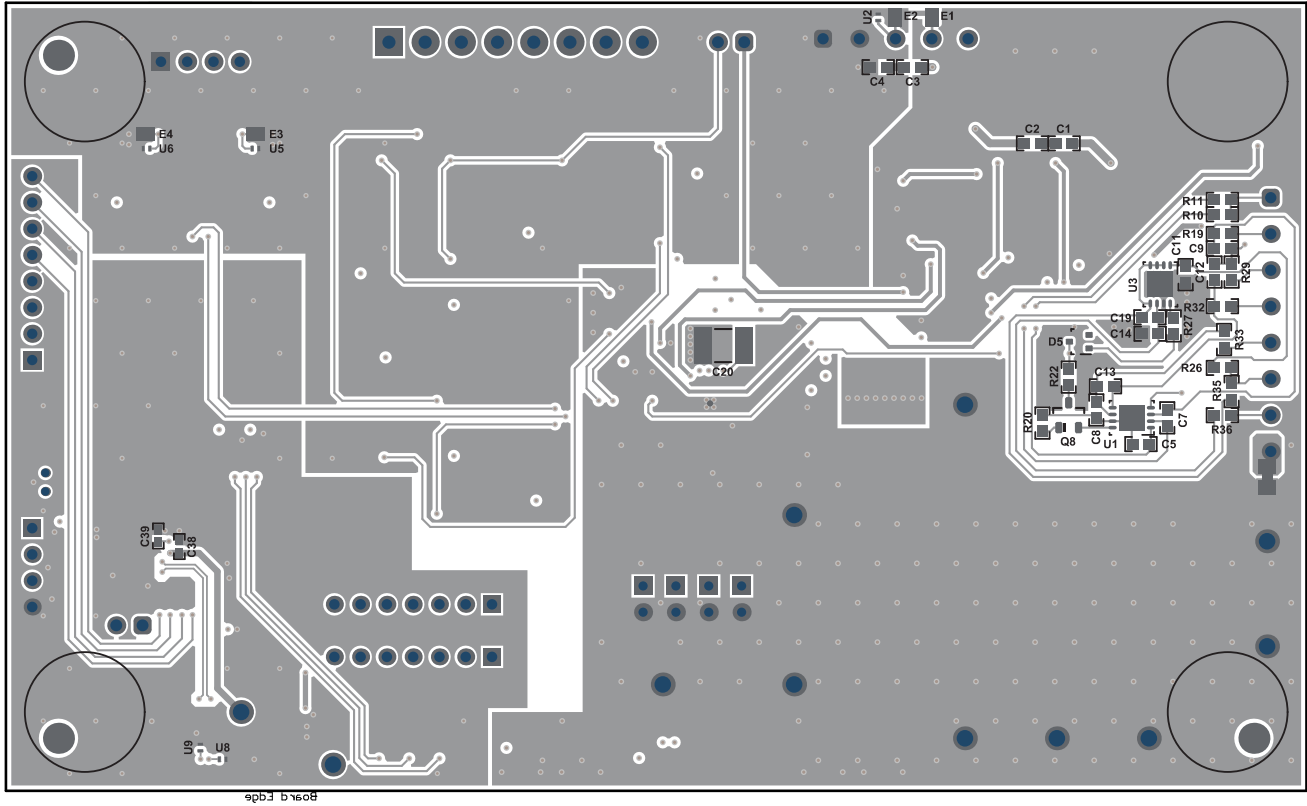
Figure 9. bq40z80EVM RevB Bottom Composite

Board Edge
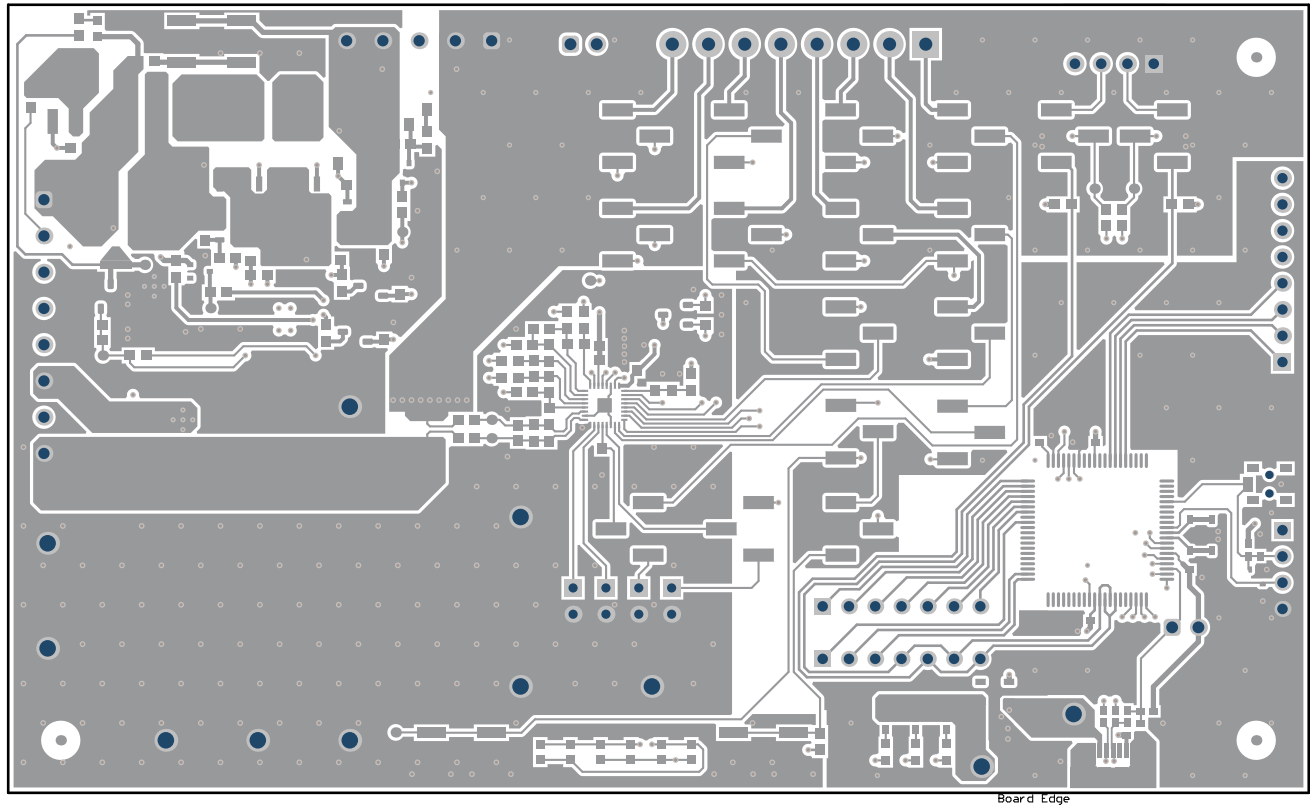
Figure 10. bq40z80EVM RevB Top Layer
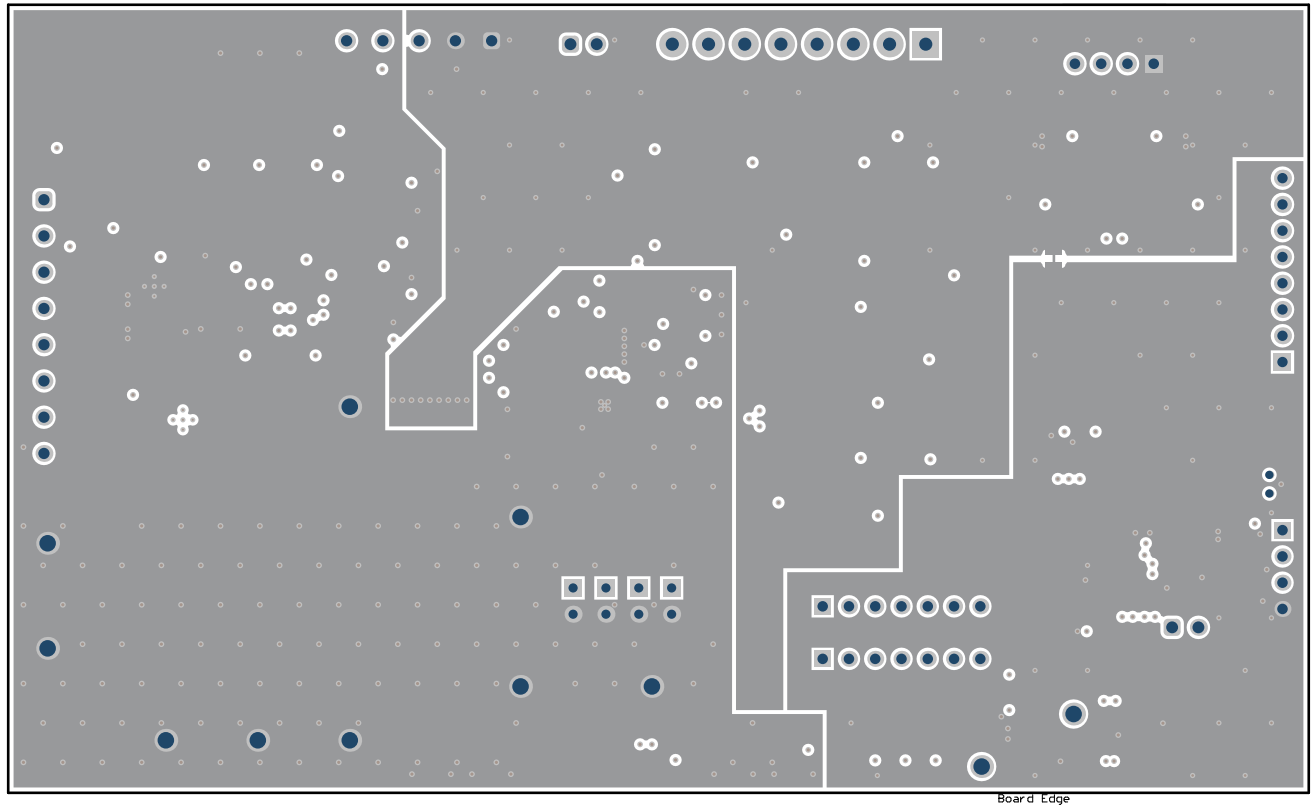
Figure 11. bq40z80EVM RevB Internal Layer 2 - GND

Board Edge
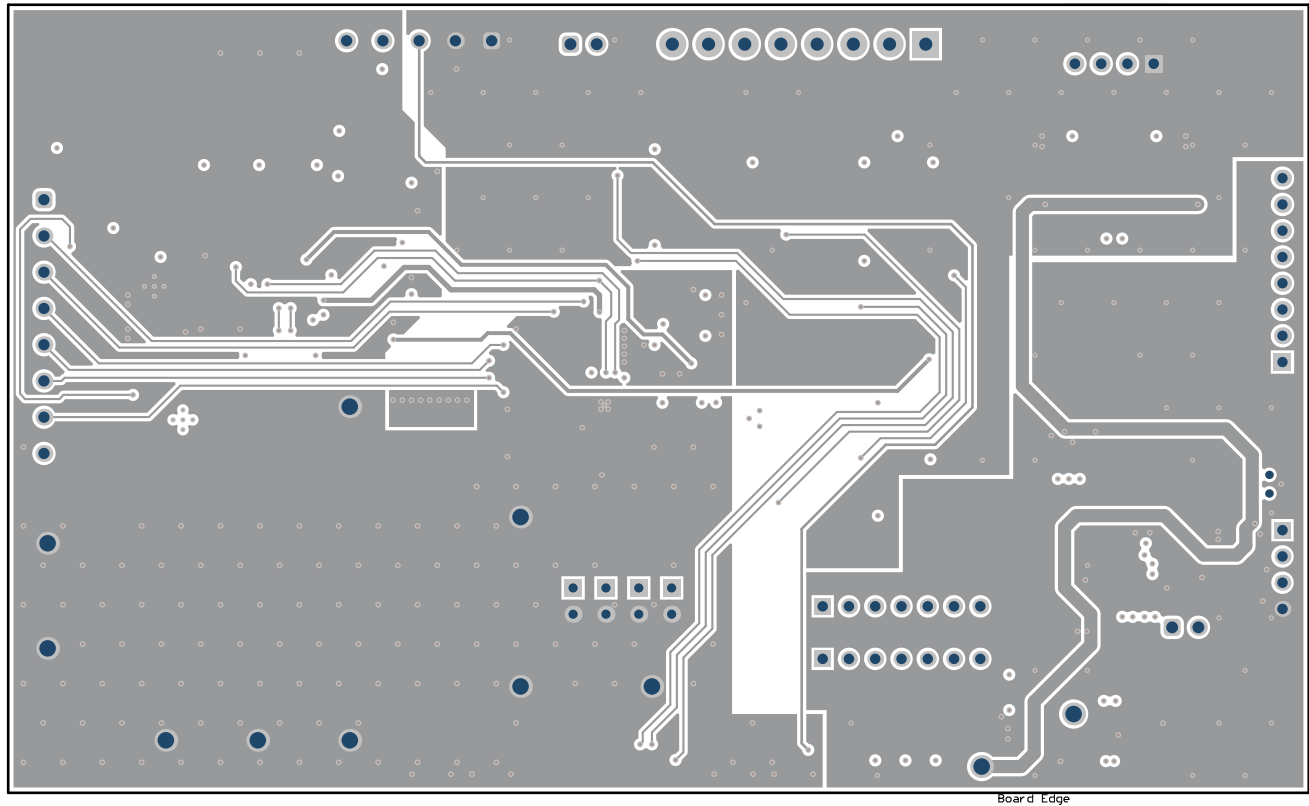
Figure 12. bq40z80EVM RevB Internal Layer 3 - Signal
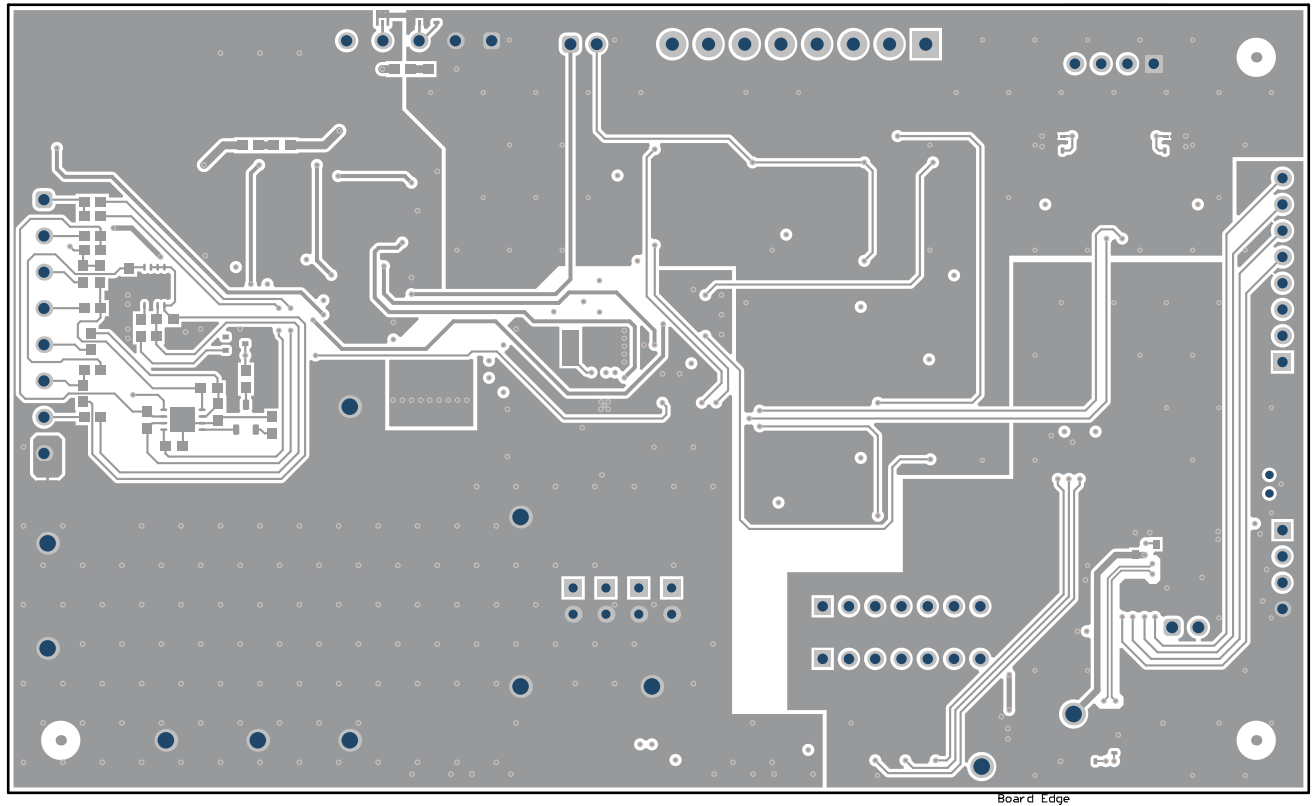
Figure 13. bq40z80EVM RevB Bottom Layer

5.2 bq40z80 RevBSchematic

NOTE: The bq40z80EVM-020 has an incorrect implementation for the reverse polarity circuit. For proper charge and discharge behavior, D3 and R7 should be removed. This will be corrected on a future version of the EVM.

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6 bq40z80EVM Bill of Materials

Table 5. bq40z80EVM RevB

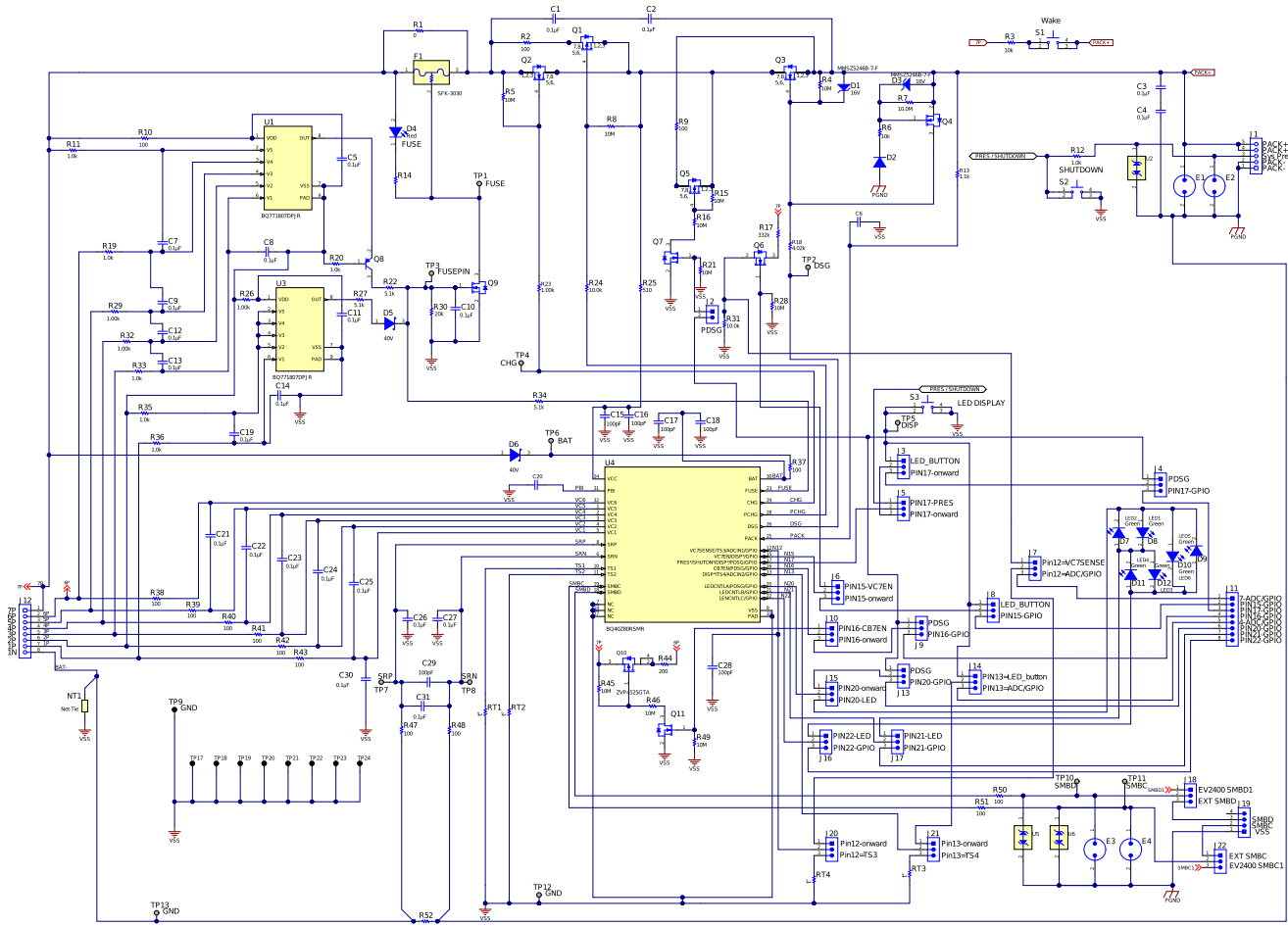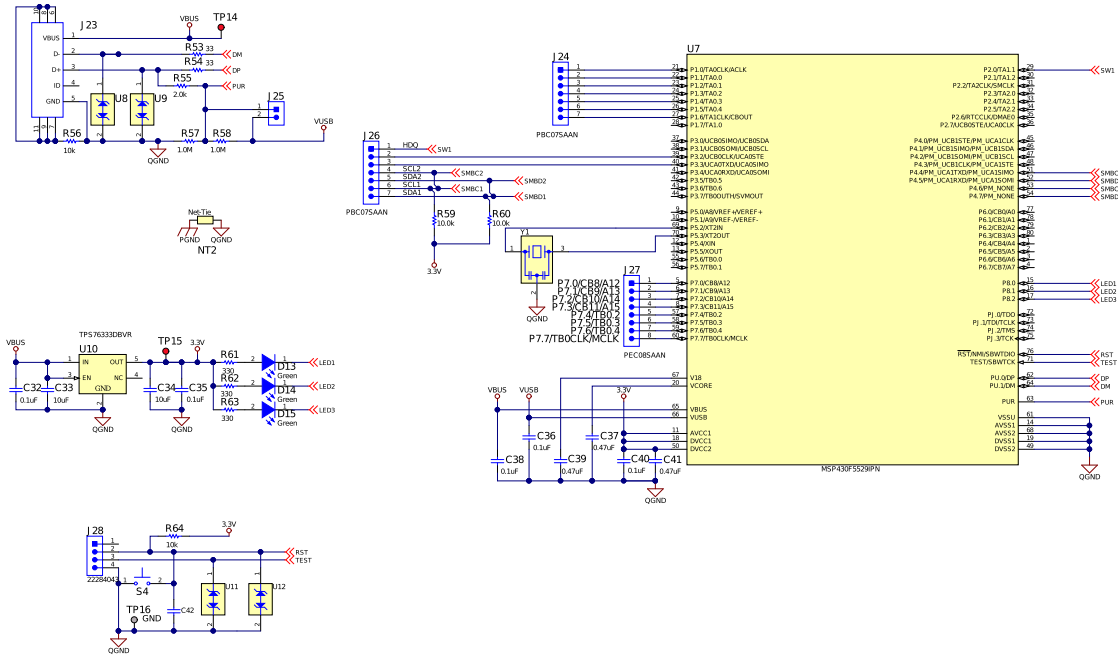| Count	Designator	Value	Description	Package Reference	Part Number	Manufacturer
23	C1, C2, C3, C4, C5, C7, C8, C9, C10, C11, C12, C13, C14, C19, C21, C22, C23, C24, C25, C26, C27, C30, C31	0.1uF	CAP, CERM, 0.1 µF, 50 V,+/- 10%, X7R, AEC-Q200 Grade 0, 0603	0603	06035C104K4Z4A	AVX
1	C6	0.01uF	CAP, CERM, 0.01 µF, 100 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R72A103KA37J	MuRata
6	C15, C16, C17, C18, C28, C29	100pF	CAP, CERM, 100 pF, 50 V,+/- 5%, C0G/NP0, 0603	0603	VJ0603A101JXAAC	Vishay-Vitramon
1	C20	2.2uF	CAP, CERM, 2.2 µF, 100 V,+/- 10%, X7R, 1812	1812	C1812C225K1RACTU	Kemet
5	C32, C35, C36, C38, C40	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X5R, 0402	0402	GRM155R61A104KA01D	MuRata
2	C33, C34	10uF	CAP, CERM, 10 uF, 16 V, +/- 10%, X5R, 0805	0805	0805YD106KAT2A	AVX
3	C37, C39, C41	0.47uF	CAP, CERM, 0.47 uF, 6.3 V, +/- 10%, X5R, 0402	0402	04026D474KAT2A	AVX
1	C42	2200pF	CAP, CERM, 2200 pF, 10 V, +/- 10%, X5R, 0402	0402	GRM155R61A222KA01D	MuRata
2	D1, D3	16V	Diode, Zener, 16 V, 500 mW, SOD-123	SOD-123	MMSZ5246B-7-F	Diodes Inc.
1	D2	100V	Diode, Ultrafast, 100 V, 0.15 A, SOD-123	SOD-123	1N4148W-7-F	Diodes Inc.
1	D4	Red	LED, Red, SMD	LED_0603	150060RS75000	Wurth Elektronik
2	D5, D6	40V	Diode, Schottky, 40 V, 0.2 A, SOT-323	SOT-323	BAS40W-7-F	Diodes Inc.
6	D7, D8, D9, D10, D11, D12	Green	LED, Green, SMD	1.6x0.8x0.8mm	LTST-C190GKT	Lite-On
3	D13, D14, D15	Green	LED, Green, SMD	LED_0603	150060VS75000	Wurth Elektronik
1	F1		Fuse, 30 A, 62 VDC, SMD	9.5x2x5mm	SFK-3030	Dexerials Corporation
4	H1, H2, H3, H4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
1	H5		USB to micro USB cable		102-1092-BL-00100	CNC Tech
1	J1		Terminal Block, 3.5mm, 5x1, Tin, TH	Terminal Block, 3.5mm, 5x1, TH	393570005	Molex
2	J2, J25		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth Elektronik
17	J3, J4, J5, J6, J7, J8, J9, J10, J13, J14, J15, J16, J17, J18, J20, J21, J22		Header, 2.54mm, 3x1, Gold, SMT	Header, 2.54mm, 3x1, SMT	87898-0304	Molex
1	J11		Terminal Block, 3.5mm, 8-Pos, TH	Terminal Block, 3.5mm, 8-Pos, TH	ED555/8DS	On-Shore Technology

Table 5. bq40z80EVM RevB (continued)

Count	Designator	Value	Description	Package Reference	Part Number	Manufacturer
1	J12		Terminal Block, 3.5mm, 8x1, Tin, TH	Terminal Block, 3.5mm, 8x1, TH	393570008	Molex
1	J19		Header (friction lock), 100mil, 4x1, R/A, TH	4x1 R/A Header	22/05/3041	Molex
1	J23		Receptacle, Micro-USB Type B, 0.65 mm, 5x1, R/A, Bottom Mount SMT	Receptacle, 0.65mm, 5x1, R/A, SMT	47346-1001	Molex
1	J28		Header, 2.54mm, 4x1, Tin, TH	Header, 2.54mm, 4x1, TH	22284043	Molex
2	Q1, Q5	-40V	MOSFET, P-CH, -40 V, -8.2 A, SOIC-8	SO-8	FDS4685	ON Semiconductor
1	Q2	40V	MOSFET, N-CH, 40 V, 15 A, DQJ0008A (VSONP-8)	DQJ0008A	CSD18504Q5A	Texas Instruments
1	Q3	60V	MOSFET, N-CH, 60 V, 100 A, DNK0008A (VSON-CLIP-8)	DNK0008A	CSD18540Q5B	Texas Instruments
1	Q4	60V	MOSFET, N-CH, 60 V, 0.31 A, SOT-323	SOT-323	2N7002KW	Fairchild Semiconductor
3	Q6, Q7, Q11	50V	MOSFET, N-CH, 50 V, 0.28 A, SOT-23	SOT-23	CMPDM7003 TR	Central Semiconductor
1	Q8	40V	Transistor, PNP, 40 V, 0.2 A, SOT-23	SOT-23	CMPT3906 LEAD FREE	Central Semiconductor
1	Q9	60V	MOSFET, N-CH, 60 V, 2 A, AEC-Q101, SOT-23	SOT-23	DMN6075S-7	Diodes Inc.
1	Q10	-250V	MOSFET, P-CH, -250 V, -0.265 A, AEC-Q101, SOT-223	SOT-223	ZVP4525GTA	Diodes Inc.
1	R1	0	RES, 0, 5%, 2 W, 2512 WIDE	2512 WIDE	RCL12250000Z0EG	Vishay Draloric
2	R2, R9	100	RES, 100, 5%, 1 W, AEC-Q200 Grade 0, 2512	2512	CRCW2512100RJNEG	Vishay-Dale
2	R3, R6	10k	RES, 10 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0JNEA	Vishay-Dale
10	R4, R5, R8, R15, R16, R21, R28, R45, R46, R49	10Meg	RES, 10 M, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310M0JNEA	Vishay-Dale
1	R7	10.0Meg	RES, 10.0 M, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310M0FKEA	Vishay-Dale
12	R10, R37, R38, R39, R40, R41, R42, R43, R47, R48, R50, R51	100	RES, 100, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100RJNEA	Vishay-Dale
8	R11, R12, R14, R19, R20, R33, R35, R36	1.0k	RES, 1.0 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031K00JNEA	Vishay-Dale
1	R13	1.1k	RES, 1.1 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031K10JNEA	Vishay-Dale
1	R17	332k	RES, 332 k, 0.1%, 0.1 W, 0603	0603	RG1608P-3323-B-T5	Susumu Co Ltd
1	R18	4.02k	RES, 4.02 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06034K02FKEA	Vishay-Dale
3	R22, R27, R34	5.1k	RES, 5.1 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06035K10JNEA	Vishay-Dale

Table 5. bq40z80EVM RevB (continued)

Count	Designator	Value	Description	Package Reference	Part Number	Manufacturer
1	R23	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	ERJ-3EKF1001V	Panasonic
1	R24	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	RCG060310K0FKEA	Vishay-Draloric
1	R25	510	RES, 510, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603510RJNEA	Vishay-Dale
3	R26, R29, R32	1.00k	RES, 1.00 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
1	R30	20k	RES, 20 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060320K0JNEA	Vishay-Dale
3	R31, R59, R60	10.0k	RES, 10.0 k, 0.1%, 0.1 W, 0603	0603	RG1608P-103-B-T5	Susumu Co Ltd
1	R44	200	RES, 200, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603200RFKEA	Vishay-Dale
1	R52	0.001	RES, 0.001, 1%, 1 W, 1210	1210	PMR25HZPFV1L00	Rohm
2	R53, R54	33	RES, 33, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040233R0JNED	Vishay-Dale
1	R55	2.0k	RES, 2.0 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04022K00JNED	Vishay-Dale
2	R56, R64	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0JNED	Vishay-Dale
2	R57, R58	1.0Meg	RES, 1.0 M, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021M00JNED	Vishay-Dale
3	R61, R62, R63	330	RES, 330, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF3300X	Panasonic
4	RT1, RT2, RT3, RT4	10k	Thermistor NTC, 10.0k ohm, 1%, Disc, 5x8.4 mm	Disc, 5x8.4 mm	103AT-2	SEMITEC Corporation
3	S1, S2, S3		Switch, Tactile, SPST-NO, SMT	Switch, 6.2X5X6.2 mm	KST221JLFS	C&K Components
1	S4		Switch, SPST-NO, Off-Mom, 0.05A, 12VDC, SMD	3.9x2.9mm	PTS820 J20M SMTR LFS	C&K Components
20	SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8, SH-J9, SH-J10, SH-J11, SH-J12, SH-J13, SH-J14, SH-J15, SH-J16, SH-J17, SH-J18, SH-J19, SH-J20	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
9	TP9, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24		Test Point, Compact, Black, TH	Black Compact Testpoint	5006	Keystone
2	TP14, TP15	Red	Test Point, Compact, Red, TH	Red Compact Testpoint	5005	Keystone
2	U1, U3		Family 2-5S Overvoltage Protector with Internal Delay Timer, DPJ0008A (WSON-8)	DPJ0008A	BQ771807DPJR	Texas Instruments

Table 5. bq40z80EVM RevB (continued)

Count	Designator	Value	Description	Package Reference	Part Number	Manufacturer
7	U2, U5, U6, U8, U9, U11, U12		Single-Channel ESD in 0402 Package With 10pF Capacitance and 6V Breakdown, DPY0002A (X1SON-2)	DPY0002A	TPD1E10B06DPYR	Texas Instruments
1	U4		Catalog 2S-7S Battery Gauge + Protector Based on bqExtend, RSM0032A (VQFN-32)	RSM0032A	BQ40Z80RSMR	Texas Instruments
1	U7		25 MHz Mixed Signal Microcontroller with 128 KB Flash, 8192 B SRAM and 63 GPIOs, -40 to 85 degC, 80-pin QFP (PN), Green (RoHS & no Sb/Br)	PN0080A	MSP430F5529IPN	Texas Instruments
1	U10		Single Output LDO, 150 mA, Fixed 3.3 V Output, 2.7 to 10 V Input, with Low IQ, 5-pin SOT-23 (DBV), -40 to 125 degC, Green (RoHS & no Sb/Br)	DBV0005A	TPS76333DBVR	Texas Instruments
1	Y1		Resonator, 4 MHz, 39 pF, AEC-Q200 Grade 1, SMD	4.5x1.2x2 mm	CSTCR4M00G55B-R0	MuRata
0	FID1, FID2, FID3, FID4, FID5, FID6		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
0	J24, J26		Header, 2.54 mm, 7x1, Gold, TH	Header, 2.54 mm, 7x1, TH	PBC07SAAN	Sullins Connector Solutions
0	J27		Header, 100mil, 8x1, Tin, TH	Header, 8x1, 100mil, TH	PEC08SAAN	Sullins Connector Solutions

7   Related Documentation from Texas Instruments

- bq40z80 data sheet, *1-Series, 2-Series, 3-Series, 4-Series, 5-Series, 6-Series, and 7-Series Li-Ion Battery Pack Manager*, SLUSCT4
- bq40z80, *Technical Reference Manual*, SLUUBT5
- bq40z80, *Manufacture, Production, and Calibration*, SLUA868
- bq40z80, *How to Complete a Successful Learning Cycle*, SLUA848
- bq771807, *BQ7718XY Overvoltage Protection for 2-Series, 3-Series, 4-Series, and 5-Series Cell Li-Ion Batteries with Regulated Output Supply*, SLUSBU5

STANDARD TERMS FOR EVALUATION MODULES

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2. *Limited Warranty and Related Remedies/Disclaimers*:

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    2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3. *Regulatory Notices:*

    3.1 *United States*

        3.1.1 *Notice applicable to EVMs not FCC-Approved:*

        FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

        3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

        CAUTION

        This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

        Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

        FCC Interference Statement for Class A EVM devices

        NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 Japan

3.3.1 Notice for EVMs delivered in Japan: Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。 http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 Notice for Users of EVMs Considered "Radio Frequency Products" in Japan: EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,

2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
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上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・イ
ンスツルメンツ株式会社
東京都新宿区西新宿６丁目２４番１号
西新宿三井ビル

    3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

        電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

  3.4 *European Union*

    3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

        This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

  4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

  4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

  4.3 *Safety-Related Warnings and Restrictions:*

    4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

    4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

  4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

    6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

    6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

    8.1 *General Limitations.* IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

    8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMNITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

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

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.