bq77PL900EVM-001

This evaluation module (EVM) is a complete evaluation system for the bq77PL900, a five- to ten-cell Li-ion battery protection and AFE integrated circuit. The EVM includes one bq77PL900 circuit module. Microsoft® Windows® based PC software is available for download. An communication adapter is required to interface this EVM with the PC and can be purchased separately. The circuit module includes one bq77PL900 integrated circuit (IC), sense resistor, power FETs and all other onboard components necessary to protect the cells from overcharge, over discharge, short circuit, and over current discharge in 5 to 10 series cell Li-ion or Li-polymer battery packs. The circuit module connects directly across the cells in a battery. With the EV2300 interface board and software, the user can read the bq77PL900 data registers, program the IC protection limits, and evaluate the overall functionality of the bq77PL900 solution under different operational conditions.

Contents

List of Figures

List of Tables

Trademarks

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1 Features

- Complete evaluation system for the bq77PL900 five to ten series cell lithium-ion or lithium-polymer battery protector and analog front end IC in stand-alone mode
- Populated circuit module for quick setup
- PC software and interface board available separately for easy evaluation
- Connections for attaching a the circuit module to a host system

1.1 Kit Contents

- bq77PL900 circuit module
- 4 wire cable

Table 1. Ordering Information

EVM Part Number	Chemistry	Configuration	Capacity
bq77PL900EVM-001	Li-ion	Five to ten cells	Any

2   bq77PL900 Circuit Module and Interfaces

The bq77PL900 circuit module contains the bq77PL900 IC and related circuitry to demonstrate the features of the IC. Two FETs are paired for the high current charge and discharge to reduce resistance in the FETs. A zero volt charge FET and current limit resistor is provided. A thermistor provides temperature sensing for the device. Other components provide support for the IC and connections to the board.

2.1   Circuit Module Connections

Connections are provided for the following interfaces:

- Direct cell connections
- PACK connection
- Evaluation and programming interface (I^{2}C)
- Host monitoring and control
- Regulated power

2.2   Signal Descriptions

Signals available on the EVM are described in this section. For details on the location and connector types, refer to the physical construction section.

Cell connections are described in Table 2. Cell connection sequence is described in Section 4.2.

Table 2. Cell Connections

Reference Designator	Pin Number	Signal	Description
J5	1, 2	BATTERY–	–ve connection of first (bottom) cell, high current connection
J4	3	1N	–ve connection of first (bottom) cell, connected to BATTERY– with R2
	2	1P	+ve connection of first (bottom) cell
	1	2P	+ve connection of second cell
J3	4	3P	+ve connection of third cell
	3	4P	+ve connection of fourth cell
	2	5P	+ve connection of fifth cell
	1	6P	+ve connection of sixth cell
J2	4	7P	+ve connection of seventh cell
	3	8P	+ve connection of eighth cell
	2	9P	+ve connection of ninth cell
	1	10P	+ve connection of tenth cell, connected to BATTERY+ with R1
J1	1, 2	BATTERY+	Most positive cell output, high current connection

Load connections are described in Table 3.

Table 3. PACK Connections

Reference Designator	Pin Number	Signal	Description
J15	1, 2	PACK+	Positive output of evaluation board
J14	1, 2	PACK–	Negative output of evaluation board

Evaluation and programming I2C interface signals are provided on J12 and are described in Table 4.

Table 4. Serial Interface Connections

Reference Designator	Pin Number	Signal	Description
J12	1	GND	Signal reference for the IC
	2	SCLK	Serial interface clock connection
	3	SDATA	Serial interface data connection
	4	EEPROM	EEPROM write enable pin connection

Host monitoring and control signals are described in Table 5.

Table 5. Host Connections

Reference Designator	Pin Number	Signal	Description
J13	1	EEPROM	EEPROM write enable pin connection
	2	SDATA	Serial interface data connection
	3	SCLK	Serial interface clock connection
	4	GND	Signal reference for the IC
	5	XRST	Active low reset from the IC
	6	TS1	Thermistor voltage input to TIN of IC
	7	XALERT	Status register change signal from IC
	8	IOUT	Current monitor output from IC
	9	VOUT	Voltage monitor output from IC
	10	GND	Signal reference for the IC

Regulated power signals are provided for monitoring or connection to a host board. Signals are described in Table 6.

Table 6. Power Output Connections

Reference Designator	Pin Number	Signal	Description
J11	1	GND	Signal reference for the IC
	2	5V	5V output from VREG1
	3	GND	Signal reference for the IC
	4	3.3V	3.3V output from VREG2

3 bq77PL900 Circuit Module Configuration

This section describes how to configure the bq77PL900 circuit module to operate in the desired mode for evaluation, and changes the user may want to make to the board for specific evaluations.

3.1 Cell Count Configuration

Cell count for the bq77PL900 is selected using J6 through J8 to set the level of the CNF pins. Positioning the shunt toward the top of the board (VSEL, connecting pins 2-3) provides a logic high, positioning toward the bottom of the board (GND, connecting pins 1-2) provides a low. Table 7 shows configuration settings for different cell counts.

Table 7. Cell Count Configuration Jumper Position

Cell Count	J8 Position/CNF2	J7 Position /CNF1	J6 Position /CNF0
10	GND/0	GND/0	GND/0
9	GND/0	GND/0	VSEL/1
8	GND/0	VSEL/1	GND/0
7	GND/0	VSEL/1	VSEL/1
6	VSEL/1	GND/0	GND/0
5	VSEL/1	GND/0	VSEL/1

3.2 Logic Level Selection

Selection of the VLOG voltage for the bq77PL900 is provided by J10. The VLOG selection sets the interface voltage for the logic signals on the IC. Selecting the shunt position is described in Table 8. Set VLOG to 5V for EEPROM programming with the EV2300.

Table 8. Logic Level Configuration Jumper Position

Shunt Position	J10 Pins Connected	VLOG Selection
Up	1-2	5V
Down	2-3	3.3V

3.3 Pre-Charge Configuration

The bq77PL900EVM-001 circuit module includes a pre-charge current path. The IC PMS pin is configured by J9. Table 9 shows configuration selections. Refer to the bq77PL900 datasheet for more information. The current path is made up of the pre-charge FET Q5 and resistor R19. The value of R19 on the EVM was selected to meet its power rating with 42V and nominal resistance. The resulting current is low, consider the conditions relevant to your evaluation and replace the resistor with a different value if needed.

Table 9. PMS Pin Selection

Shunt Position	J9 Pins Connected	PMS Selection	Comment
Up	2-3	PACK+	Pre-charge FET not used
Down	1-2	GND	Pre-charge FET used if enabled in EEPROM

3.4 Ground Connection

The IC ground reference on the bq77PL900EVM-001 circuit module is connected to the BATTERY– net near J5 using a zero ohm resistor R39. Due to the voltages which can be induced during high current discharge, ground on the bq77PL900 is recommended on the battery side of the sense resistor. This causes the voltage at the SRP pin to be above ground during discharge. Board resistance will also cause SRB to be above ground during discharge.

The ground connection on the battery side of the sense resistor causes the ground reference of the IC to be modulated from the PACK– terminal by the load current. When connecting to the analog signals, the user should reference the signal ground. For digital signals, the circuitry will need to use the digital ground or accept the modulation of current in the ground reference.

R40 provides an optional grounding position on the battery side of the sense resistor. Although not recommended, R41 provides a grounding option on the pack side of the sense resistor. Be sure to verify that the check voltages at the IC pins are within acceptable datasheet limits during all modes of operation. Note that grounding on the pack side of the sense resistor will not eliminate modulation of the signals due to current, only reduce them by the sense resistor drop. The user should be certain only 1 of R39, R40 or R41 is shorted and that the sense resistor is not bypassed by a connection between PACK– and system ground.

3.5 Cell Monitor Connections

Resistors R1 and R2 are installed by default and allow the high current connections to be used for cell monitoring. If separate connections are desired for cell monitoring, remove the R1 and R2 resistors and make connection from 1N and 10P back to the cells when the equivalent high current connection is made during the cell connection sequence.

3.6 FET Use

The circuit module provides FETs for charge and discharge control. If your evaluation does not require charge FETs, openings are provided in the solder mask near J15 on both the top and bottom side to short the charge FET. An added connection should be large enough to carry the current used in your evaluation. If your evaluation does not require charge or discharge FETs, the BATTERY+ and PACK+ connections should be connected together and to the top of the cell stack to provide power and wake up voltage to the bq77PL900.

3.7 Current Sense Connections

Components R17, R20 and C17 provide a 40 μs time constant between the sense resistor and current sense terminals. If this delay is objectionable, C17 may need to be reduced or removed for the evaluation.

3.8 Other Circuit Configurations

A reverse clamp diode D12 is provided at the pack outputs to prevent board damage during turn off of inductive loads. This diode will also provide reverse charger protection within the capability of the part. The part used is rated at 3A, be sure this is sufficient for your evaluation. A larger diode may be connected to the pack terminals if needed.

The EVM could be used in a variety of systems. Capacitors C26 to C35 provide some transient protection, by absorbing impulses present from the load. Several capacitors are used rather than one due to the size and the decrease in capacitance at high voltage. If the capacitance is not needed in evaluation, it could be removed. In some applications, the capacitance may not be sufficient for transient suppression. Holes X1 to X6, D9 and RT2 are provided between the pack terminal traces for installation of additional transient suppression components that may be needed for specific system evaluations.

Suppression of transients to the EVM is important both to prevent exceeding the IC voltage ratings, and for proper operation of the system due to the power supply hold up circuit used for the IC on the EVM:

- Diodes D1 and D8 are necessary to prevent rapid loss of supply voltage to the IC during short circuit events, and to prevent negative voltage at the BAT and PACK pins during a reversed charger connection.
- The DSG and CHG gate drive signals from the IC are driven to approximately 12V below the value of the BAT and PACK voltages as seen by the IC. This provides sufficient gate drive to bias the P-Channel FETs fully ON. Under steady-state operating conditions, the voltages at the IC pins will be the same as the voltages at the external terminals.
- Under transient conditions (typically caused by dynamic system loads), the D1/C11 and D8/C24 components will store the peak voltages seen at the external pins. There may be instantaneous differences in the voltages seen at the BAT and PACK pins of the IC relative to the source terminals of the power FETs.
- If these transients are very large, the power FETs may briefly shut off. This happens because the gate drive voltages are referenced to the value of BAT and/or PACK voltage seen at the IC pin, which may be momentarily higher than the actual BAT or PACK voltage in the actual system. The resulting actual Vgs differential may not be sufficient to maintain the ON state of the power FETs when the sensed BAT or PACK voltage is higher than the actual BAT or PACK voltage.
- The circuit used for maintaining the supply voltage to the IC may need to be modified in a system that has significant voltage transients to prevent momentary shutoff of the power FETS during these conditions. See Figure 1 for further explanation.
- If your system does not require D1 and D8, these are located on the bottom side of the board and may be shorted. Refer to section 9 for location of these components.
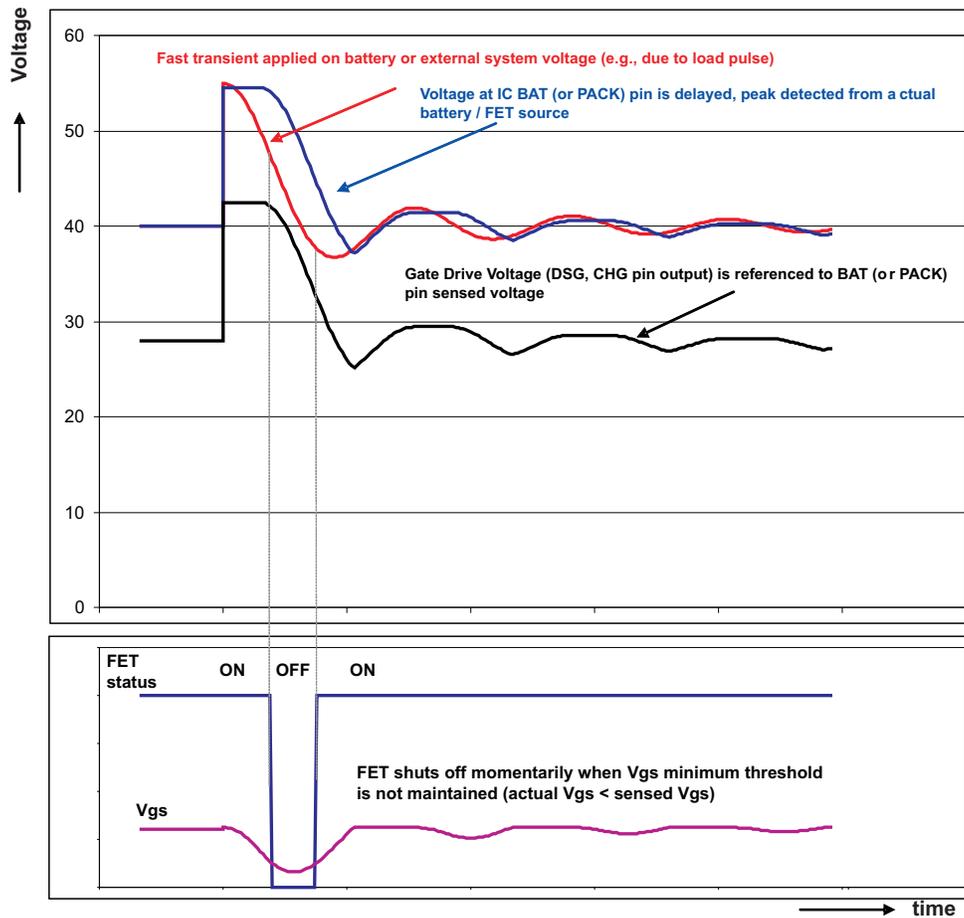
Figure 1. Transient Effect of FET Operation

4 bq77PL900 EVM Hardware Connection and Operation

This section describes the connection of the circuit module and EVM. Simple operation is also described.

4.1 Initial Considerations

Boards are tested after assembly with a basic functional test. This test may not check every connection on the board. Boards should be checked for function in the user's environment before relying on the safety features of the board.

Before connecting the board for operation, configure it for the desired state as described in Section 3.

Be sure to observe the cautions and warnings in this document.

The connection of the EVM will look similar to Figure 2. The manufacturer's rating for the terminal blocks for Pack and Battery connections is 24A nominal per terminal. Parallel connections are provided for high current operation. Note that the EV2300 is not required for basic operation, and it should be connected to the computer and EVM circuit module only after proper installation of software. The software along with the EV2300 allows monitoring of the IC status, setting the programmable safety limits and controlling the device in host mode. Installation of the software and its use are described in a later section.
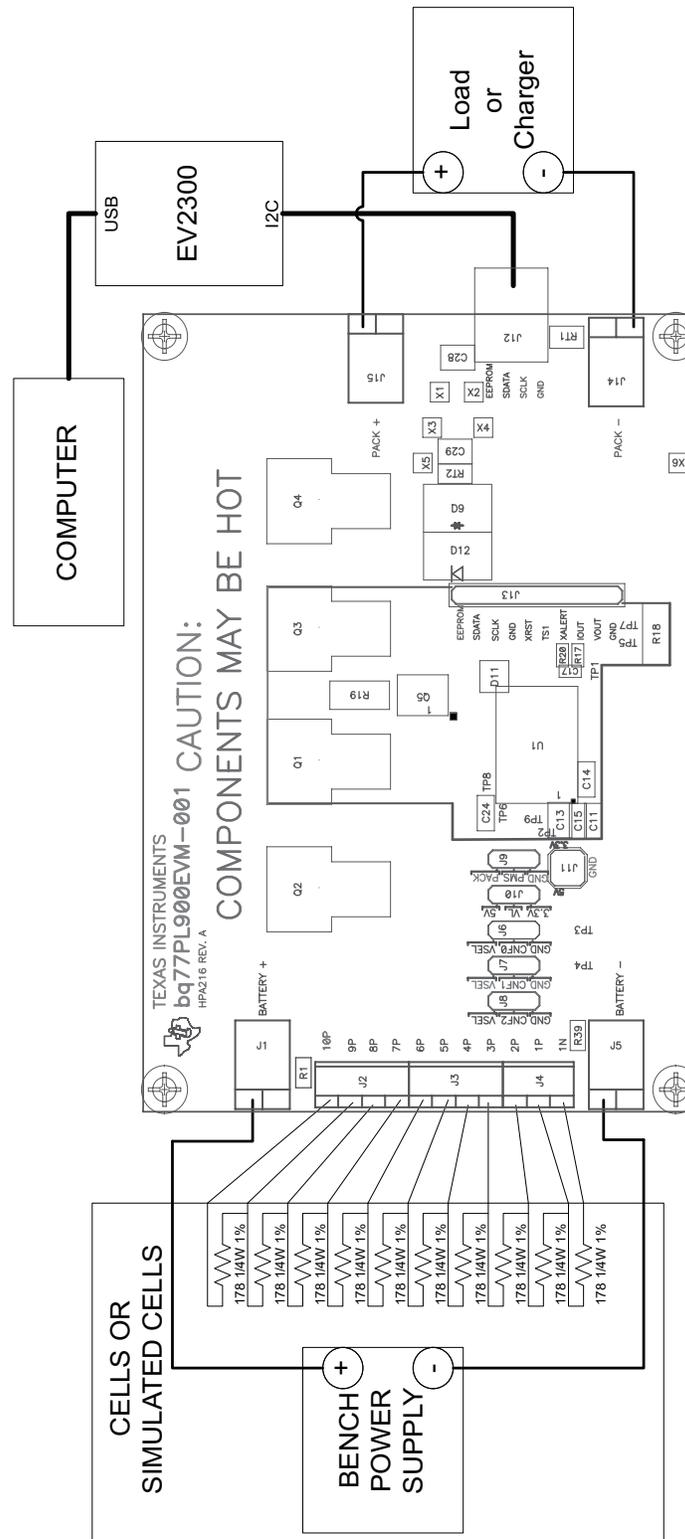
Figure 2. Basic Connections

4.2 Cell Connections

Unused cell inputs should be shorted together. For example, if 8 cells are used, the 10P, 9P and 8P terminals should be connected together.

For initial evaluation, it is suggested power supplies be used for cell simulation to observe the behavior of the device. Resistors can be used for cell voltage simulation to reduce the number of power supplies needed, 180 Ω or similar resistors are suggested. Tolerances can be selected or resistances adjusted to provide desired variations in simulated voltage. Smaller values will work also, the smaller the value, the more current is required from the battery simulator power supply and the smaller the influence on the voltages if cell balancing is operated.

If power supplies or cells are used, inductance in the high current path should be minimized. Inductance in this path can cause inductive transients at the board when the load current is stopped or the bq77PL900 opens the discharge FET with current flow. Use heavy gauge wires for the high current connections; minimize inductances by keeping leads close together.

Cells should be connected in sequence from lowest to highest voltage as described in the following steps:

1. Connect the lowest cell negative terminal to the EVM BATTERY– terminal. Connect it also to the EVM 1N terminal if R2 was removed.
2. Connect the lowest cell positive terminal to the EVM 1P terminal
3. Connect the second lowest cell positive terminal to the 2P terminal
4. Connect the next lowest cell positive terminal to the 3P terminal
5. Continue connecting each higher cell in sequence. When all other connections have been made, connect the most positive cell to the EVM BATTERY+ terminal, then to the 10P terminal if R1 was removed.
6. When removing cells, disconnect in the reverse order.

4.3 Pack Connections

A load or charger is connected to the pack terminals using the terminal blocks provided. It is recommended that the load or charger be connected with the current switched off to prevent arcing or transients during connection of the wires to the terminal blocks.

Although designed for 30A operation, the board may not dissipate enough power to operate without exceeding the ratings. The user should monitor the temperature of the board and components during evaluation and provide cooling air and/or heatsinks as required for operation. The thermal sensor on the board may not respond to protect the FETs from damaging temperatures due to its location and possible thermal gradients on the board.

CAUTION

The bq77PL900 circuit module may be damaged by over temperature. To avoid damage, monitor the temperature during evaluation and provide cooling as needed for your system environment.

WARNING

The bq77PL900 circuit module may become hot during operation due to dissipation of heat. Avoid contact with the board. Follow all applicable safety procedures applicable to your laboratory.

4.4 Thermal Sensor

The thermal protection on the bq77PL900EVM circuit module is set to provide a trip threshold of 60°C with nominal values. Component tolerances and substitute values may alter this trip point. The thermistor in particular will impact the linearity and limit of the temperature sensor. The thermistor could be moved off board for sensing cell temperature, or closer to the FETs or a heatsink or other system component for evaluation. To adjust the value of the trip point, change the value of R22. The linearization resistor R29 will have a lesser effect.

4.5 Basic Operation

The following steps are suggested for basic operation for a board configured for 10 cells with the default safety configuration in EEPROM.

1. Connect cells or cell simulation resistors and a power supply to the battery side of the board. Set the bench supply (if used) to approximately 20V.
2. Connect a disabled load to the pack terminals.
3. Wake up the part by momentarily connecting a charge voltage > 7.5V to the pack terminals. If the load is disconnected, the user can momentarily short the BATTERY+ to PACK+ with a resistor.
4. Monitor the XALERT, 3.3V or 5V outputs to observe the operation of the device as desired.
5. Increase the load to >10A to observe XALERT goes low due to overcurrent or under voltage if the power supply current limits.
6. Remove the load and attach a charger to allow the device to recover.
7. If using a power supply, reduce the voltage of the cells to observe the device shuts off at ~14V.

5 Software Installation

This section describes how to install the software for the bq77PL900EVM-001, and how to connect the PC interface board of the EVM.

5.1 System Requirements

The bq77PL900EVSW requires Windows 2000, Windows XP, or newer operating system version. You must have administrative rights on the computer.

5.2 Communication Adapter

A communication adapter supported by the software is required. The EV2400 is the newer communication adapter. See http://www.ti.com/tool/EV2400. The EV2400 uses human interface device drivers included with the operating system and driver installation is not required. The bq77PL900EVM Software does require the Support components to enable specific TI software (bqEVSW) to work with EV2400 available in the EV2400 tool folder.

The EV2300 is an older interface which requires drivers. If your use the EV2300 and it works with your system changing to the EV2400 is not required. EV2300 drivers may not be available for all systems. See http://www.ti.com/tool/EV2300 for 32 bit drivers. For more information on the EV2300 and drivers search at http://e2e.ti.com/.

The bq77PL900EVSW does not support other communication adapters.

5.3 Install The bq77PL900EVM Software

Find the latest software version in the bq77PL900EVM-001 tool folder http://www.ti.com/tool/bq77PL900EVM-001. Check periodically for software updates. Use the following steps to install the bq77PL900 Evaluation Software:

1. Copy the archive file to a directory of your choice.
2. Extract the archive containing the installation package into the temporary directory. Be sure to preserve folder names.
3. In the temporary folder, double-click on setup.exe and follow the installer instructions to complete the bq77PL900 EVSW installation.

4. If using the EV2400 install the support components. In some cases the support components will need updated to communicate, installing a newer EVSW such as bq30z554-R1 bqEasy Software will provide the update.

5. If using the EV2300 and the computer was previously used with the EV2300, driver installation should not be needed. If using the EV2300 on a new computer install drivers for the EV2300. Use the drivers from the EV2300 tool folder disregarding the drivers included with the bq77PL900EVSW.

6   Troubleshooting Unexpected Dialog Boxes

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

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

7   Software Operation

This section describes operation of the software.

Software is started from the sequence Start > All Programs > Texas Instruments > bq77PL900 Evaluation Software.

The software window has 2 sections, a tab section and a status section. The left side of the window displays one of 3 tabs selected by clicking on the tab name and described in the following sections. The right section of the window provides visual indicators of the status register which is polled periodically by the software. The connection status of the I2C is shown above the status section.

7.1 Registers Tab

After the software starts, the registers tab is displayed. The registers tab can be used to read all registers and write selected registers. The scanning check box in the right bottom corner controls continuous scanning of the registers. Register scanning is independent of the status section scanning. When the scanning box is not checked, the values are not automatically read when the tab is selected. Select the "Read All" button to update the register status when scanning is off. Random patterns should not be written to the registers, refer to the data sheet for register bit definitions.

Figure 3. Registers Tab Window

7.2 Control Tab

The Control tab is shown in Figure 4. This tab allows the user to adjust control of the features of the part. In stand-alone mode, the features are not applicable and are grayed out. When host mode is selected, the user can make adjustments to demonstrate controls that would be performed by the host in a system implementation. Refer to the data sheet for detailed bit definitions.

The OUTPUT CONTROL section is used primarily to turn on and off FETs and clear errors. The STATE CONTROL section is used to select Host mode, the amplifier gains and shutdown. The FUNCTION CONTROL section contains the Thermistor Power control, but also along with the CELL SEL section allows demonstration of the voltage and current monitor outputs and selections. These would normally be used in a host controlled system to monitor the battery operation and allow calibration of the host measurement system. Refer to the data sheet for more information on the features to support system calibration.

The CELL BALANCE section allows control of individual cell-balancing bits, and should not be randomly written. In host mode the user has control of cell balancing. Cell balancing should be enabled using an algorithm to protect the cell sense IC pins from over voltage induced by the cell balancing function. This is summarized by:

- No adjacent cell balancing
- No every-other-cell balancing.

See the application note *Cell Balancing With the bq77PL900*, SLUA463 for more information on cell balancing.
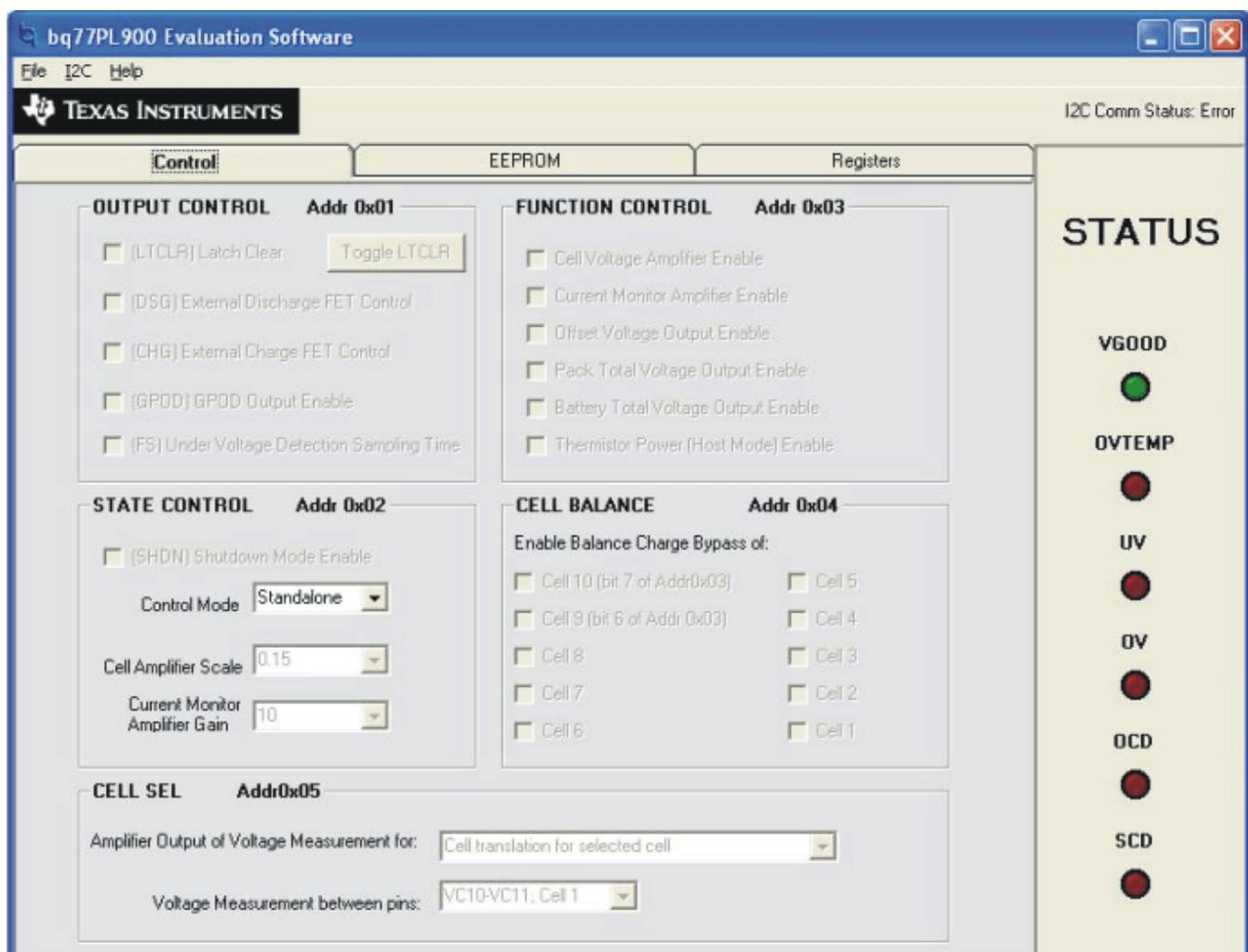

Figure 4. Control Tab Window

7.3 EEPROM Tab

> **CAUTION**
>
> The EV2300 provides 5V for the EEPROM signal when programming. If the board is configured for VLOG = 3.3V during programming, damaging voltages may be imposed on VREG2 and the I2C lines. Disconnect any sensitive host and set VLOG = 5V before programming with the EV2300.

The EEPROM tab is used to change the settings of the protection features of the device. The values are read from the part and the window updated when the tab is selected. Changes can be made using the selection and checkboxes. The Preview button will display the present EEPROM selections in a register format. The preview window must be closed before other operations can take place. Changes will be written to the EEPROM when the Program EEPROM button is selected. Note that the EEPROM can only be written when the voltage to the part is sufficient.

With the EEPROM tab selected, the File menu will have options to save or open EEPROM data. The save option will allow a file to be created from the current settings even if they have not been programmed to the device. The open option will allow a file to be read and replace the values in the window. These values loaded from the file are not written to the EEPROM until the "Program EEPROM" button is selected. Selecting either the Control or Registers tab before programming will cause the settings to be lost. The settings in the device will be read again when the EEPROM tab is selected again. Selections can be made and saved to a file without having a device connected.
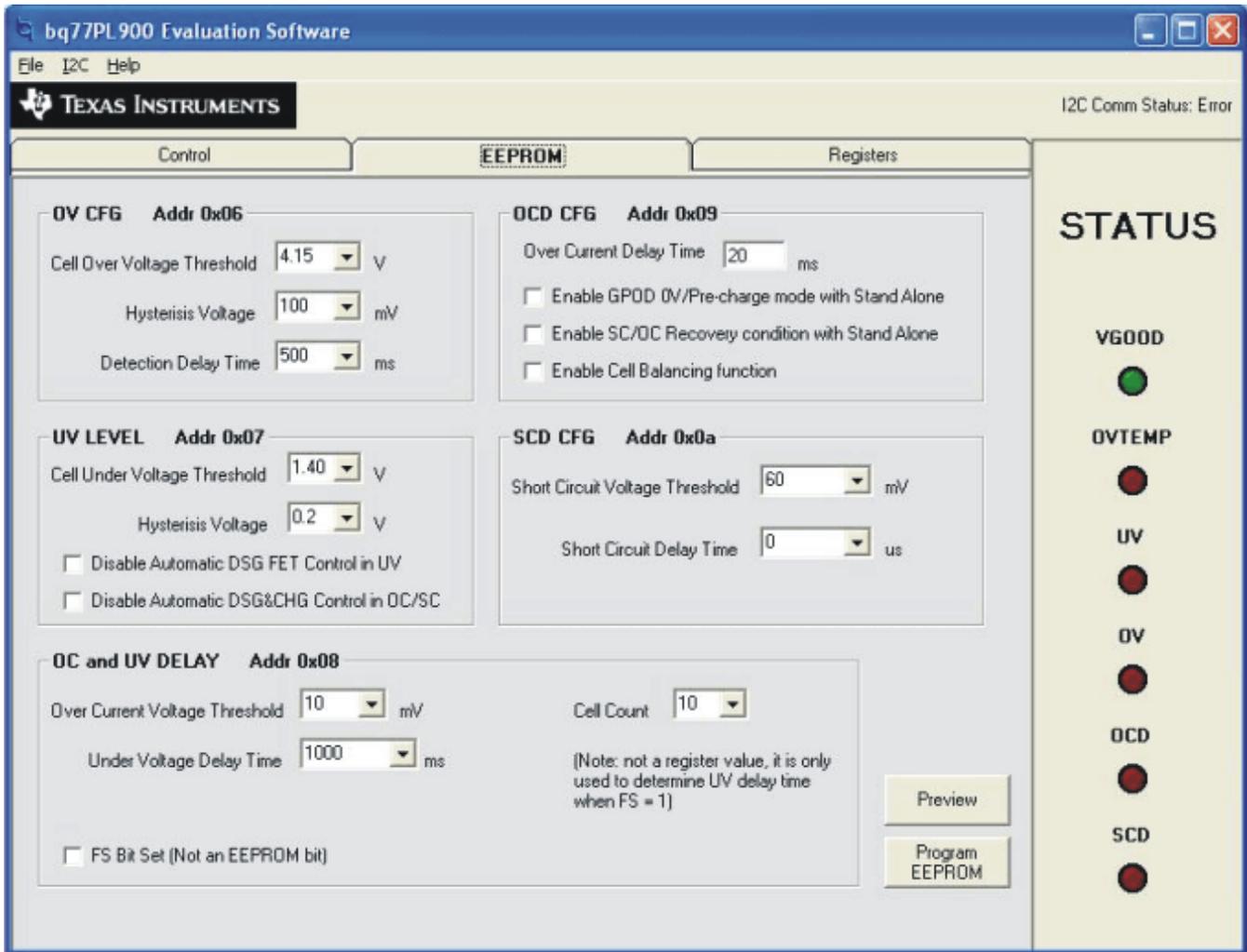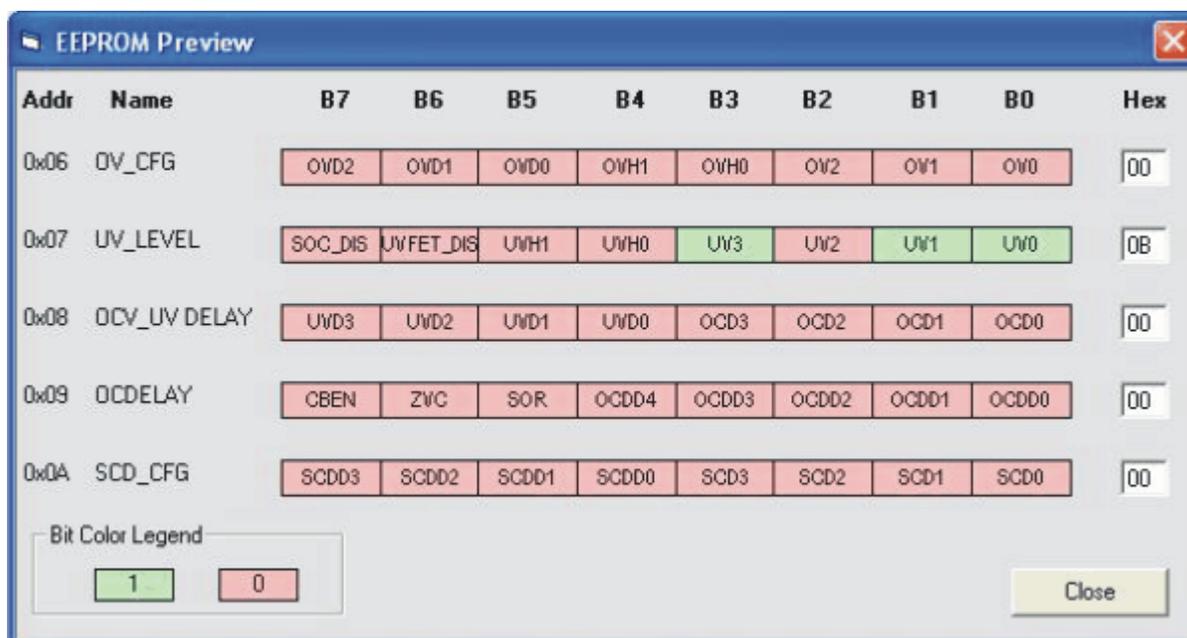
Figure 5. EEPROM Tab Window

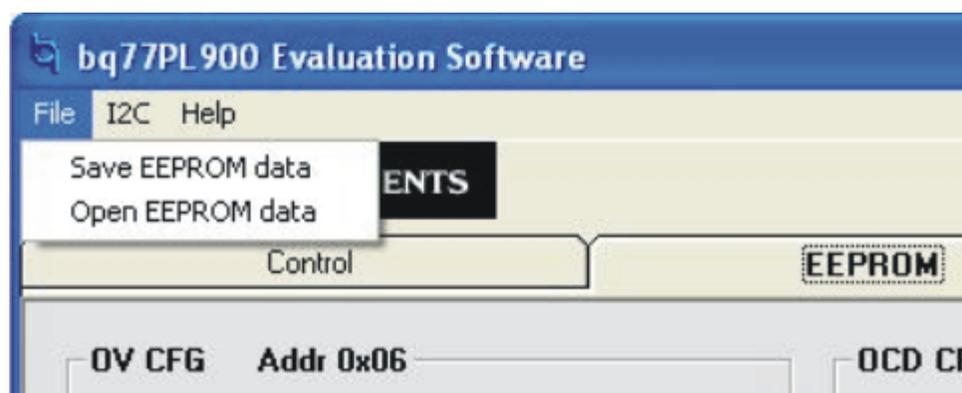**Figure 6. EEPROM Preview Window**

Figure 7. EEPROM File Options

7.4 Basic Operation With Software

The following steps are suggested for basic operation in host mode for a board configured for 10 cells with the default safety configuration in EEPROM.

1. Connect cells or cell simulation resistors and a power supply to the battery side of the board. Set the bench supply (if used) to approximately 20V.
2. Install the software.
3. Connect the EV2300 to the computer with the USB cable.
4. Connect the communication cable from the EV2300 I^{2}C port to the circuit module J12.
5. Start the software.
6. Connect a disabled load to the pack terminals.
7. Wake up the part by momentarily connecting a charge voltage >7.5V to the pack terminals. If the load is disconnected, the user can momentarily short the BATTERY+ to PACK+ with a low value resistor. The device will wake up in standalone mode.
8. Select the control tab in the software window.

9. In the control tab, select 'host' the STATE CONTROL Control Mode box. The features in the window should become clearly visible.

10. Observe using a voltmeter or other method that the pack has no output voltage.

11. In the OUTPUT CONTROL section, select the check boxes for CHG and DSG FETs.

12. Observe using a voltmeter or other method that the pack has an output voltage.

13. Decrease the power supply voltage to approximately 10V. Observe that the UV indicator comes on and the output voltage goes away.

14. Increase the power supply voltage to 20V. Observe that the UV indicator remains on and the output voltage remains off.

15. Click on the Toggle LTCLR button in the OUTPUT CONTROL section. Observe the UV indicator goes out and the output voltage comes on again.

8 References:

1. Texas Instruments, *bq77PL900, Five to Ten Series Cell Lithium-Ion or Lithium-Polymer Battery Protector and Analog Front End Data Sheet*
2. Texas Instruments, *Cell Balancing With the bq77PL900 Application Report*
3. Texas Instruments, *EV2400 Evaluation Module Interface Board User's Guide*
4. Texas Instruments, *EV2300 Evaluation Module Interface Board User's Guide*

9 bq77PL900 Circuit Module Physical Construction

This section contains the pcb layout, bill of materials and schematic of the bq77PL900EVM circuit module.

9.1 Board Layout

The bq77PL900EVM circuit module is a 4.5-inch × 3.25-inch 2-layer circuit card assembly. It is designed for easy connection with cell connections on the left side and load connection on the right using standard wires to the terminal blocks. Dual FETs are used to reduce resistance for a design-specified 30A current flow. Wide trace areas are used to reduce voltage drops and provide surface area for heat dissipation without a heatsink. This layout and construction allows easy understanding of the connections for evaluation, but results in a large board. The main solution components are outlined on the silkscreen layer.

See additional information in the configuration and operation sections of this document. Figure 8 to Figure 13 show the board layout.
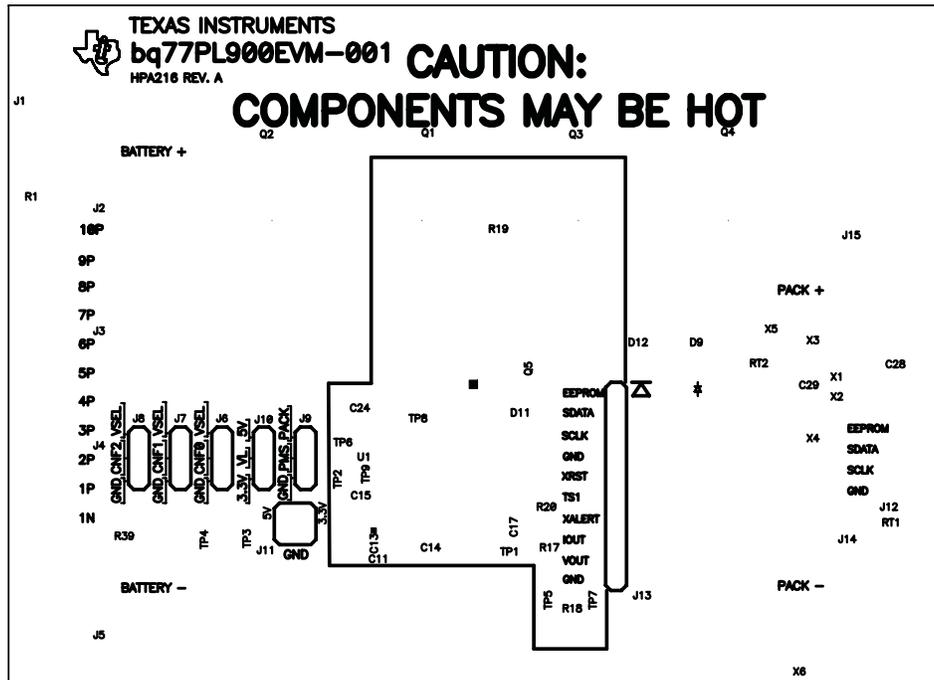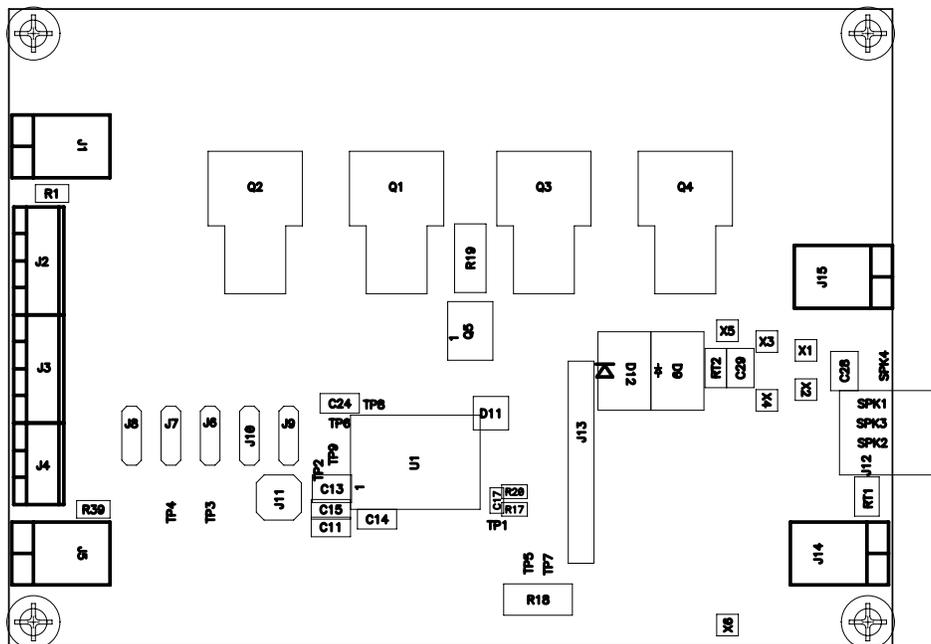

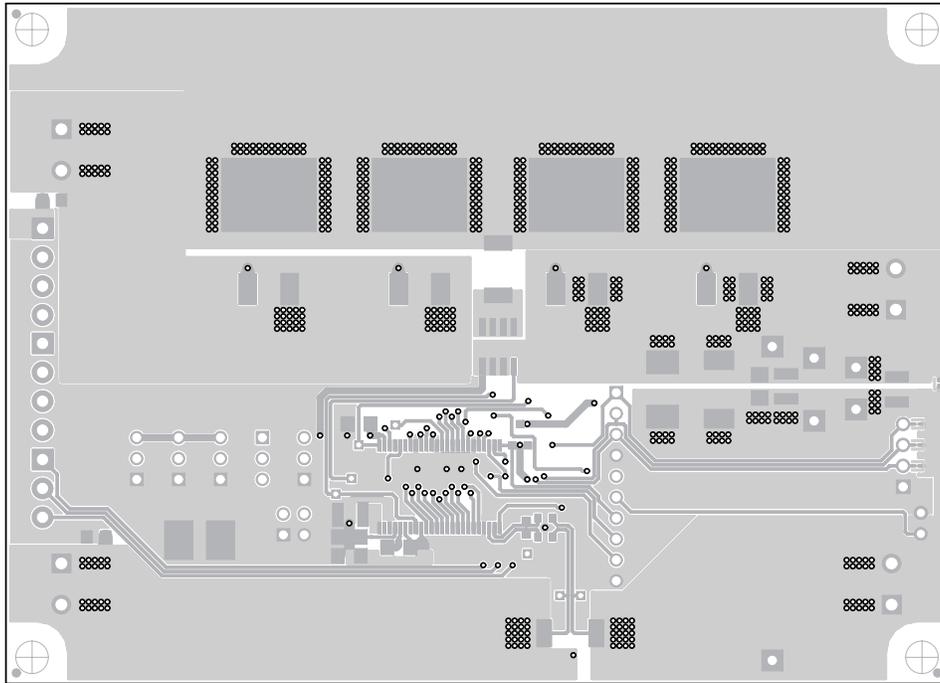**Figure 8. Top Silk Screen**

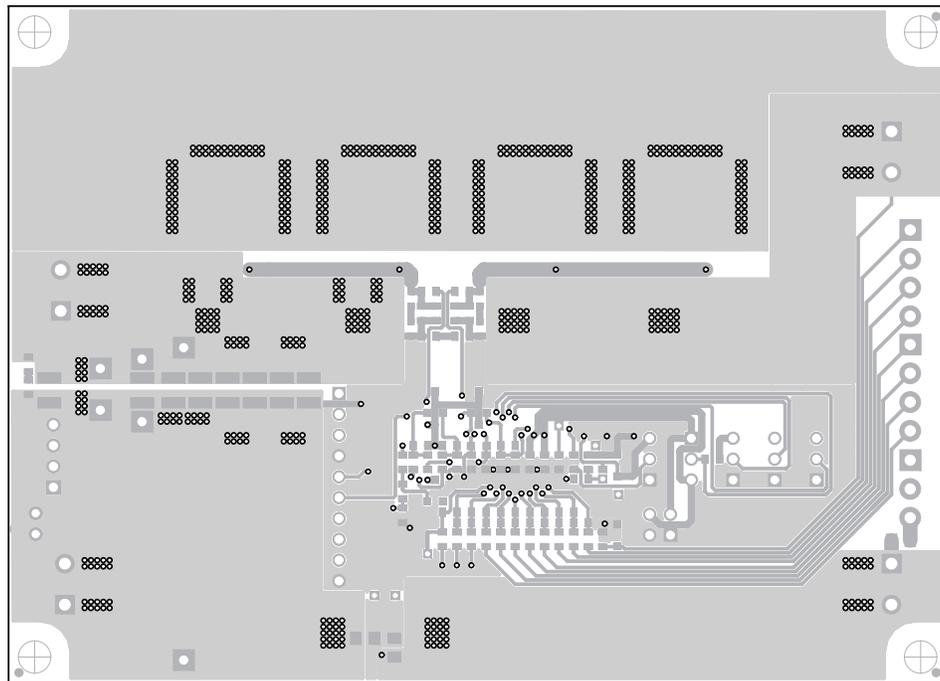

Figure 9. Top Assembly

Figure 10. Top Layer

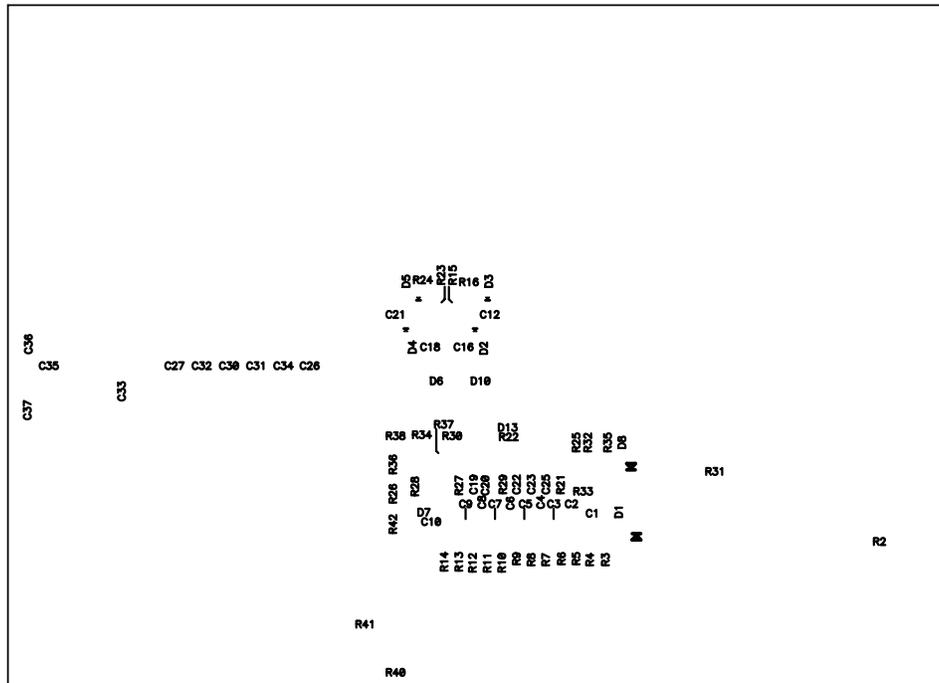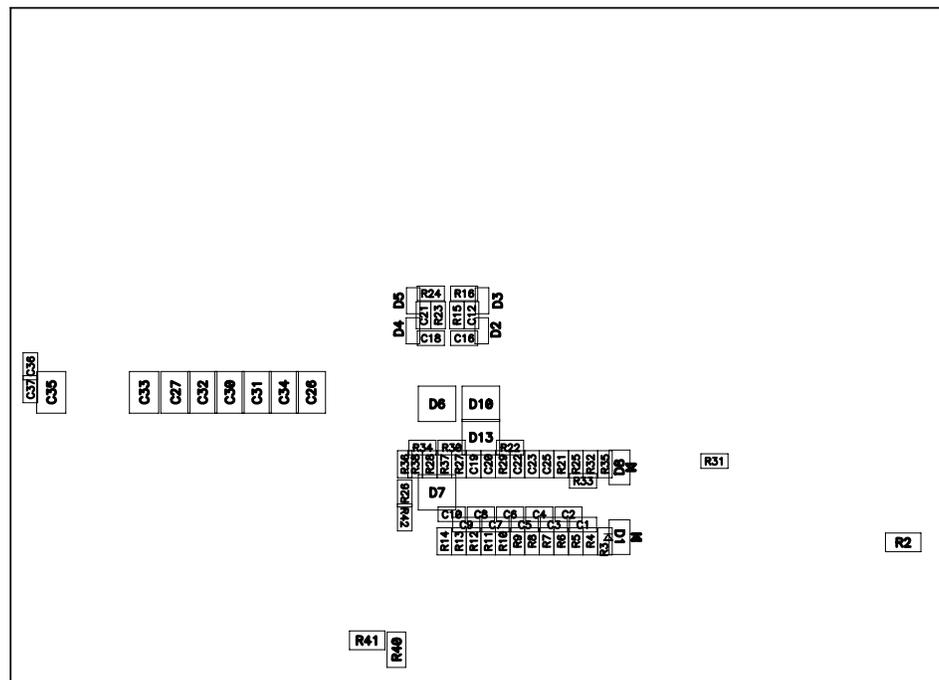**Figure 11. Bottom Layer**

Figure 12. Bottom Silk Screen

Figure 13. Bottom Assembly

9.2 Bill of Materials

The bill of materials for the circuit module is shown in Table 10. Substitute parts may be used in the manufacturing of the assembly.

Table 10. Bill of Materials

RefDes	Value	Description	Size	Part Number	MFR
C1–C10, C16–C20, C36, C37	0.1 µF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
C11, C24	2.2 µF	Capacitor, Ceramic, 50V, Y5V, 20%	1206	STD	Std
C12, C21	4.7 nF	Capacitor, Ceramic, 50V, X7R, 20%	0603	Std	Std
C13	4.7 µF	Capacitor, Ceramic, 50V, Y5V, 20%	1210	Std	Std
C14, C15	1 µF	Capacitor, Ceramic, 50V, X7R, 10%	1206	Std	Std
C22	10 nF	Capacitor, Ceramic, 16V, X7R, 20%	0603	Std	Std
C23, C25	2.2 µF	Capacitor, Ceramic, 16V, X7R, 20%	0603	Std	Std
C26–C35	2.2 µF	Capacitor, Ceramic, 100V, X7R	1210	GRM32ER72A225K	Murata
D1, D8		Diode, Switching, 90V, 225 mA Ifm, High speed	SOD-323	1SS355	Rohm
D10, D11, D13		Diode, TVS Bidirectional , 17 A, 300V	SOT23	SM05T1	ON Semiconductor
D12		Diode, Schottky 3-A 100-V	SMC	MBRS3100T3	On Semi
D2–D5		Diode, Zener, 300mW, 16V	SOD-523	BZX585-C16	Philips
D6, D7		Diode, Dual, Zener, 5.6V, 300mW	SOT23	AZ23C5V6	Vishay-Telefunken
D9		Diode, SMT TVS Unidirectional	DO-214AB	1.5SMCxxx	TSC
J1, J5, J14, J15		Header, Side Entry 2-pin, 5 mm spacing	0.441 × 0.200 inch	1711026	Phoenix Contact
J11		Header, 2x2-pin, 100 mil spacing (36-pin strip)	0.20 × 0.20 inch	PTC36DAAN	Sullins
J12		Header, Friction Lock Ass'y, 4-pin Right Angle,	0.400 × 0.500 inch	22-05-3041	Molex
J13		Header, Male 10-pin, 100mil spacing, (36-pin strip)	0.100 inch × 10	PTC36SAAN	Sullins
J2, J3		Terminal Block, 4-pin, 6-A, 3,5 mm	0.55 × 0.25 inch	ED555/4DS	OST
J4		Terminal Block, 3-pin, 6-A, 3,5 mm	0.41 × 0.25 inch	ED555/3DS	OST
J6–J10		Header, Male 3-pin, 100mil spacing, (36-pin strip)	0.100 inch x 3	PTC36SAAN	Sullins
Q1–Q4		MOSFET, P-ch, –80V, –110A	DDPAK	SUM110P08-11L	Vishay
Q5		Trans, P-Chan 60V 3A	SO-8	NDS9407	Fairchild
R1, R2, R39	0	Resistor, Chip, 1/10W, 5%	0805	Std	Std
R15, R23, R30, R34	1MΩ	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R16, R21, R24	1KΩ	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R17, R20	200Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R18	0.001Ω, 1W ±275ppm	Resistor, Chip, 1W, 1%	2512	WSL25121L000FEA	Vishay
R19	1.78kΩ	Resistor, Chip, 1W, 1%	2512	Std	STD
R22	6.98kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R25, R31, R35	100kΩ	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R26–R28, R36–R38	100Ω	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R29	61.9kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R3, R42	10kΩ	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R32	390kΩ	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R33	820kΩ	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R4–R14	510Ω	Resistor, Chip, 1/16W, 5%	0603	Std	Std
R40, R41		Resistor, Chip, 1/10W, 5%	0805	Std	Std
RT1**	10kΩ	Thermistor, TH, ±1%	0.095 × 0.150 inch	103AT-2	Semitec
RT2		Varistor	1206	VxxMLx1206N	Littelfuse
SPK1–SPK4		Spark Gap, 0.010 inch space	0.050 × 0.070 inch	Spark Gap	mfg
TP1, TP2, TP5–TP9		Test Point, 0.020 Hole	0.043 inch	STD	STD
TP3, TP4		Test Point, SM, 0.150 × 0.090	0.185 × 0.135 inch	5016	Keystone
U1		IC, 5-10 Series Cell L-Ion or L-Polymer Battery Protection and AFE	SSOP-48	BQ77PL900DL	TI
X1– X6		Through Hole, O.040 Dia		STD	STD
—		PCB		HPA216	Any
		Shunt, 100-mil black		929950-00	3m

Figure 14. Schematic Diagram
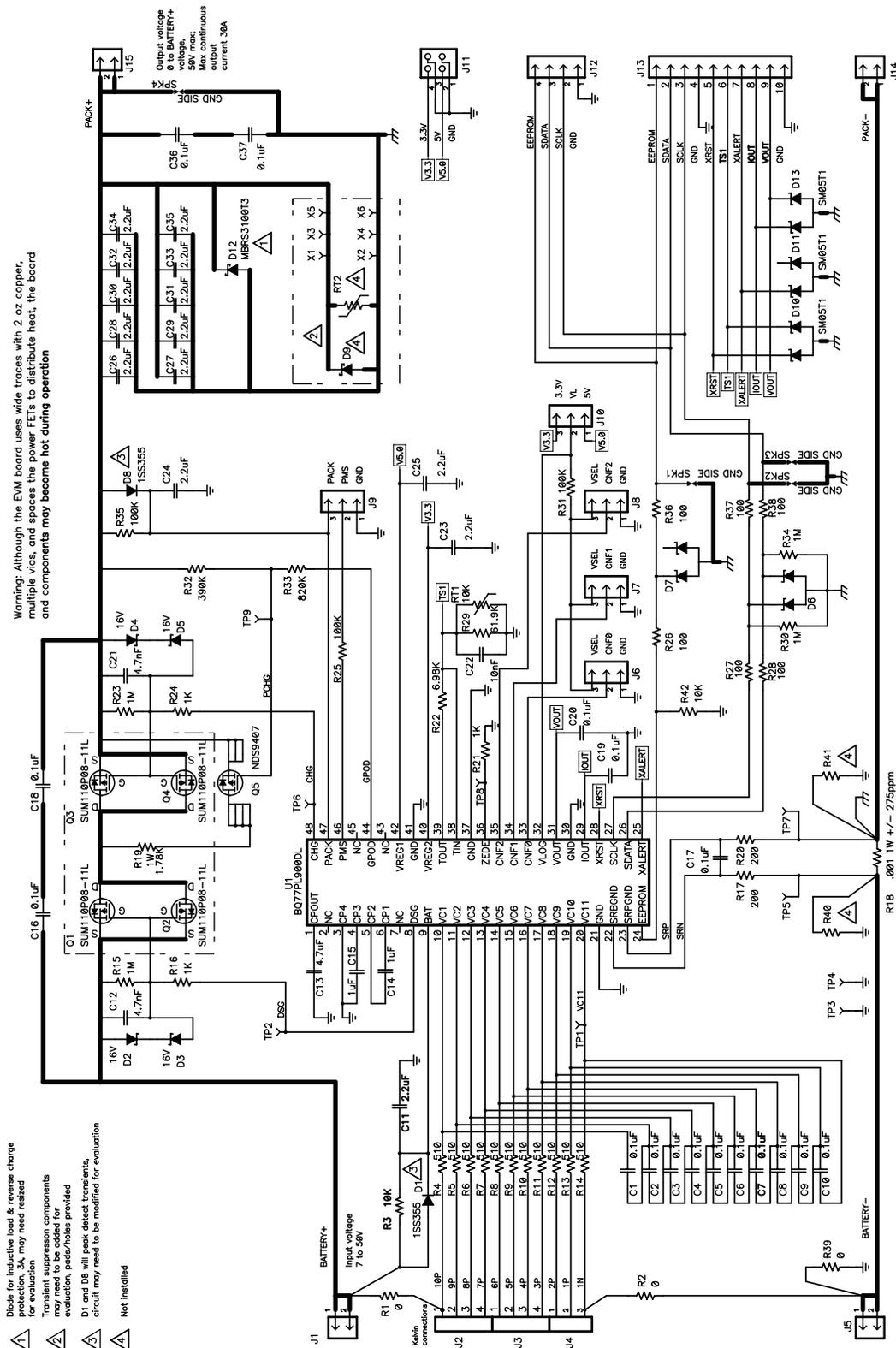
9.3 *bq77PL900 Circuit Module Performance Specification Summary*

This section summarizes the performance specifications of the bq6400 circuit module.

Typical voltage will depend on the number of cells configured. Typical current will depend on the application. Board cooling may be required for continuous operation at or below maximum current.

Table 11. Performance Specification Summary

Specification	Min	Typ	Max	Unit
Input voltage PACK+ to PACK–	7.5	–	50	V
Continuous charge and discharge current	0	–	30	A

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from A Revision (October 2013) to B Revision **Page**

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   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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なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

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西新宿三井ビル

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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.

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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.