

## ***bq76925EVM Evaluation Module***

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This user's guide for the bq76925EVM evaluation module can assist designers in their evaluation of the bq76925, Analog Front End for 3- to 6-Series Lithium-Ion Cells. This guide discusses setup and operation of the module and contains schematics, bill of materials, and printed-circuit board layout.

Before designing a battery management system with the bq76925, designers are advised to read the bq76925 data sheet ([SLUSAM9](#)).

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## 1 Overview

This section describes the features of the bq76925EVM and the equipment that is typically required to demonstrate and use the EVM.

### 1.1 Features

A summary of the features of the bq76925EVM follows.

- One bq76925 and one MSP430F2122 device with associated support circuitry
- Support for 3-to 6-series connected cells
  - Pluggable terminal block for cell connections, or
  - Onboard simulation of cells for operation from a power supply
- bq76925 circuit is jumper configurable for internal or external 3.3-V source
- MSP430 application circuit includes
  - JTAG connector
  - Reset and SOC buttons
  - Four, controllable LEDs
  - I2C interface to bq76925 and to USB-to-GPIO
  - Pack status connector
- Supports nominal 4.2-V to 26.4-V pack voltages, 30 V maximum
- 20-A continuous charge/discharge current rating
  - 0.001- $\Omega$  (equivalent) shunt resistor
  - High-current, stud-type connections for battery power and pack power
- Onboard thermistor for temperature measurement
- Transient voltage protection of PACK $\pm$  terminals
- Connector for USB-TO-GPIO Adapter
- Test points for monitoring of cell voltages and other important circuit nets

### 1.2 Kit Contents

The bq76925EVM includes the PWR008 printed-circuit board (PCB). Evaluation software is downloadable from the bq76925 product folder (<http://www.ti.com/product/BQ76925/toolssoftware>).

### 1.3 Equipment Requirements

The bq76925EVM includes one PCB containing a bq76925 application circuit. The following equipment and software are typically needed for operation. Some items depend on the usage case.

#### 1.3.1 bq76925 Evaluation Software

The bq76925 Evaluation Software is the Windows application that controls and interfaces with the bq76925. The installation file can be found on the product page for the bq76925 on the Texas Instruments Web site.

#### 1.3.2 USB-TO-GPIO Adapter

The USB-TO-GPIO Adapter is actually an EVM available from Texas Instruments. It is used to provide the I2C connection between the bq76925 and the PC.

### **CAUTION**

The USB-TO-GPIO Adapter original firmware is 1.0.10. Firmware version 2.0.19 or later must be installed using the USB-TO-GPIO Firmware Updater software available (free) on the TI Web site at <http://focus.ti.com/docs/toolsw/folders/print/usb2gpio-loader-sw.html>.

#### **1.3.3 Power Supply for Onboard Cell Simulator**

A resistor divider network is provided on the bq76925EVM to simulate cells. This allows basic evaluation of the bq76925 without the use of cells. In this case, a power supply connected between BATT+ and BATT– is required to power the resistor network. A 24-V power supply with a current capability of 100 mA is required to power the circuit .

#### **1.3.4 Power Supply for Simulation of Current**

A second power supply is used to simulate battery current. The bq76925 expects a sense resistor value of  $0.001 \Omega$  and 1 mV is equal to 1 A. A jumper (J5) allows the sense resistor to be disconnected from the current input of the bq76925 and be replaced with a millivolt source. A power supply that can accurately provide up to 100 mV can allow for simulated testing of up to 100 A without actually running this dangerously high current.

#### **1.3.5 Battery**

Lithium-ion, rechargeable-type cells can be used with this EVM. Typical cell voltage rating is 3.3 V to 3.7 V nominal and the pack consists of 3- to 6-series connected cells. Almost all Lithium-ion chemistries can be used with the bq76925.

### **WARNING**

**This EVM has no battery current control devices (MOSFETs) that can stop the flow of charge or discharge current in the event that a dangerous condition is induced through discharging or charging of a battery. Exercise extreme caution when using a battery with this EVM.**

#### **1.3.6 Power Supply to Charge Battery**

A power supply can be connected to the PACK± terminals to provide charge current if a battery is connected to the BATT± inputs.

### **WARNING**

**Use caution when mating batteries with a *charger* power supply. Some power supplies cannot tolerate current being fed into their output terminals. A battery connected to a power supply can easily cause this to happen. A properly sized blocking diode connected to the positive output voltage of the power supply can provide adequate protection against backfeed from the battery and into the power supply electronics.**

### 1.3.7 Electronic Load

An electronic load is often needed to sink current or power from the battery and through the EVM. A constant-current load provides a good means of evaluating the performance of the bq76925 when a battery is used. Equipment rating depends on the application. Typical criteria for electronic load selection are a voltage rating of up to 4.5 V/cell and up to 20-A discharge capability with 10-mA resolution.

### 1.3.8 Digital Multimeter

One or two digital multimeters (DMM) capable of voltage, current, and temperature measurement equal to or greater than the accuracy ratings of the bq76925 are needed for adequate evaluation. Numerous test clips on the PCB can accept a DMM.

### 1.3.9 Oscilloscope

An oscilloscope may be needed if evaluation of waveforms or timing measurements is required. Typical waveforms that a user may be interested in are the I2C signals (100 kHz), cell-balancing waveforms or capture of the activation time of the ALERT signal after an overcurrent event may be of interest. These signals can happen down to the 10s of microseconds time base.

## 2 Circuit Details and Configuration

This section highlights the important features of the EVM circuit, gives some operating instructions, and also provides a description of the connector pin assignments. Read through this section before using the EVM for the first time.

### CAUTION

Do not connect the battery, power supplies, or interface at this time. Wait until the next section.

### 2.1 Connections

Pin 1 on all multisignal-pin headers is indicated by a square solder pad.

#### 2.1.1 BATT+, BATT– (CN1, CN2)

These connections connect the battery terminals to the circuit.

The positive, current-carrying connection of the battery connects to the BATT+ terminal (CN1).

The negative, current-carrying connection of the battery connects to the BATT– terminal (CN2).

The BATT± connections are single, heavy-duty screw terminals that feature a 6-32 × 1/4-in.-long screw. This connector is rated to 30 A, maximum. Actual current is limited to a lower value (20 A) by other circuit board components.

#### 2.1.2 Cells (CN6)

The cell-sensing wires of the battery pack provide the connection for cell voltage measurement and resistive cell balancing. If the cell count is N, the number of cell wires is N+1.

**Table 1. Cell Voltage Connections**

Header Name	Terminal	Label	Purpose
CN6	1	Cell 6	Cell 6 positive terminal.
	2	Cell 5	Cell 5 positive terminal.
	3	Cell 4	Cell 4 positive terminal.
	4	Cell 3	Cell 3 positive terminal.
	5	Cell 2	Cell 2 positive terminal.
	6	Cell 1	Cell 1 positive terminal.
	7	Cell 0	Cell 1 negative terminal.

### 2.1.3 PACK+, PACK– (CN3, CN4)

The positive, current-carrying connection of the load or charger connects to the PACK+ terminal (CN3).

The negative, current-carrying connection of the load or charger connects to the PACK- terminal (CN4).

The PACK± connections are single, heavy-duty screw terminals that feature a 6-32 × 1/4-in. screw. This connector is rated to 30 A, maximum. Actual current is limited to a lower value (20 A) by other circuit board components.

### 2.1.4 USB Interface (CN8)

The USB interface connector (CN8) is for connection to the USB-TO-GPIO Adapter. The pin assignment is as follows:

**Table 2. USB Interface Connection**

Header Name	Terminal	Label	Purpose
CN8	1	–	V3P3 Monitor and Input
	2	–	ALERT Output
	3	–	None
	4	–	None
	5	–	+3.3V Output
	6	–	Ground
	7	–	None
	8	–	None
	9	–	I2C Clock (SCL)
	10	–	I2C Data (SDA)

### 2.1.5 JTAG Interface (CN7)

The JTAG Interface connector (CN7) is for connection to an MSP430 programmer, such as the MSP-FET430UIF. Use of this connector is not required for evaluation of the bq76925. This header is for those users who wish to write code for the MSP430F2122 resident on the EVM. The pin assignment is as follows:

**Table 3. JTAG Interface Connection**

Header Name	Terminal	Label	Purpose
CN7	1	1	TDI/TDO
	2	–	VCC-TOOL
	3	–	TDI/VPP
	4	–	VCC-TARGET
	5	–	TMS
	6	–	NONE
	7	–	TCK
	8	–	TEST/VPP
	9	–	GROUND
	10	–	NONE
	11	–	RESET
	12	–	NONE
	13	–	NONE
	14	–	NONE

### 2.1.6 Pack Status (CN5)

The Pack Status header is provided as a convenience for those users desiring to develop firmware for the MSP430. The default firmware does not use these pins. This connector can be used for GPIO or for an SPI interface. Total current sourcing from these pins must be limited such that the current rating of the 3.3-V source of the bq76925 circuit is not exceeded. Consult the data sheet for details.

**Table 4. Pack Status Connection**

Header Name	Terminal	Label	Purpose
CN5	1	GPIO1	GPIO, RXD, SOMI
	2	GPIO2	GPIO, TXD <sup>(1)</sup> , SIMO
	3	GPIO3	GPIO, SCLK
	4	GND	Ground

<sup>(1)</sup> Silkscreen on the board incorrectly reads RXD

## 2.2 Configuration Jumpers and Switches (J1 – J6, S2, S4)

Two- and three-terminal headers allow the user to configure the operation of the EVM by installing a shunt at the header. The description of each jumper header is shown in the following tables. Shunts are provided with the EVM in the default position.

**Table 5. J1, BAT Pin Circuit Configuration**

Header Name	Position	Purpose
J1	1 - 2	Zener diode and series diode in BAT pin circuit (default)
	2 - 3	Only series resistor in BAT pin circuit.

**Table 6. J2, VCTL Pin Circuit Configuration**

Header Name	Position	Purpose
J2	1 - 2	Internal V3P3 selected. Not recommended when SOC LEDs are being used.
	2 - 3	External V3P3 selected. (default)

**Table 7. J3, V3P3 Pin Circuit Configuration**

Header Name	Position	Purpose
J3	1 - 2	External V3P3 source in circuit (default).
	OFF	External V3P3 source in circuit

**Table 8. J4, V3P3 Pin Capacitor Circuit Configuration**

Header Name	Position	Purpose
J4	1 - 2	External V3P3 source in circuit 1- $\mu$ F + 4.7- $\mu$ F capacitance used (default).
	OFF	Internal V3P3 source in circuit and 1- $\mu$ F capacitance used

**Table 9. J5, SENSEP Pin Circuit Configuration**

Header Name	Position	Purpose
J5	1 - 2	SENSEP connected to sense resistor for normal operation (default).
	OFF	SENSEP disconnected from sense resistor. This is a test mode operation where a mV source is applied to J5:pin 1 for simulation of current.

**Table 10. J6, DVCC Pin Circuit Configuration**

Header Name	Position	Purpose
J6	1 - 2	Power to MSP430 during programming is from VCC-Tool. (default)
	2 - 3	Power to MSP430 during programming is from VCC-Target.

### 2.2.1 Cell Simulator DIP Switch (S4)

The eight-position DIP switch (S4) allows the user to simulate cell-voltage inputs to the bq76925 rather than supply actual cell voltages. See [Table 11](#) for details of the operation of the DIP switch.

#### CAUTION

Use silkscreen labeling and square pin 1 pad to determine orientation and operation of the eight-position DIP switch. Ignore numbers actually printed on the switch.

All S4 dip switches must be opened when using a battery with the EVM.

**Table 11. DIP Switch, S4**

Switch Name	Terminal	Label	Purpose
S4	1	Battery	Switch to connect power supply to resistor network. Closure activates LED D13.
	2	Cell 6	Applies simulated cell voltage to VC6.
	3	Cell 5	Applies simulated cell voltage to VC5.
	4	Cell 4	Applies simulated cell voltage to VC4.
	5	Cell 3	Applies simulated cell voltage to VC3.
	6	Cell 2	Applies simulated cell voltage to VC2.
	7	Cell 1	Applies simulated cell voltage to VC1.
	8	Cell 0	Applies simulated cell voltage to VC0.

### 2.2.2 Circuit Isolation DIP Switch (S2)

The eight-position DIP switch (S2) allows the user to isolate the MSP430 circuit from the bq76925 circuit. Circuit isolation may be needed to measure some performance characteristics of the bq76925 or during MSP430 programming.

#### CAUTION

Use silkscreen labeling and square pin 1 pad to determine orientation and operation of the eight-position DIP switch. Ignore numbers actually printed on the switch.

**Table 12. DIP Switch, S2**

Switch Name	Terminal	Label	Purpose
S2	1	V3P3	Controls application of V3P3 from bq76925 to MSP430
	2	Therm	Isolates the THERM circuit when opened.
	3	VCOUT	Isolates the VCOUT circuit when opened.
	4	VIOUT	Isolates the VIOUT circuit when opened.
	5	SDA	Isolates the SDA circuit when opened.
	6	SCL	Isolates the SCL circuit when opened.
	7	ALERT	Isolates the ALERT circuit when opened.
	8	VRef	Isolates the VREF circuit when opened.

### 2.3 Pushbuttons (S1, S3)

The two pushbuttons on the EVM are normally open, momentary-style buttons. The pushbutton labeled RESET (S1) is the reset button for the MSP430. Pressing this button restarts the MSP430.

The pushbutton labeled LEDs (S3) is intended to be a display control for the state of charge (SOC) display formed by the four LEDs (D8 –D11). Pressing this button triggers an input on the MSP430 that incrementally lights the four LEDs – despite what the actual SOC of the battery may be that is connected to the EVM. This is the default functionality defined by the firmware. The user can choose to use the pushbutton in another way by creating new firmware for the MSP430.

### 2.4 Test Points

Twenty-nine test loops are located on the EVM. [Table 13](#) names the circuit connected to each test point. The first 20 test points correspond one-to-one to the pin number on the bq76925.

**Table 13. Test Points**

Label	Ground Reference Test Point
TP1	VCTL
TP2	BAT
TP3	VC6
TP4	VC5
TP5	VC4
TP6	VC3
TP7	VC2
TP8	VC1
TP9	VC0
TP10	VSS
TP11	SENSEN
TP12	SENSEP
TP13	ALERT
TP14	VIOUT
TP15	VCOUT
TP16	VTB
TP17	VREF
TP18	SDA
TP19	SCL
TP20	V3P3
TP21	BATT+
TP22	PACK-
TP23	P2.5 ON MSP430
TP24	P3.7 ON MSP430
TP25	P3.5 ON MSP430
TP26	P3.4 ON MSP430
TP27	P3.0 ON MSP430
TP28	VSS
TP29	VSS

## 2.5 bq76925

The bq76925 application circuit provided allows for complete evaluation of the device performance with 3-, 4-, 5-, or 6-cell battery packs. Cell voltages, battery current, and temperature can be monitored. Monitoring is possible with the firmware that is preloaded into the MSP430 microcontroller and with the bq76925 Evaluation Software provided. Alternatively, the user can develop a custom system if desired.

## 2.6 MSP430F2122

The MSP430F2122 application circuit is provided to read the analog signals from the bq76925 and make them available for reading over the I2C bus by the bq76925 Evaluation Software. The MSP430 circuitry is designed to allow the user to create custom firmware if desired.

## 3 Quick-Start Demonstration

This section demonstrates the measurement system of the bq76925 using the onboard cell simulator.

To quickly get the bq76925EVM up and running, follow the instructions in this section. The following equipment and software are required:

- bq76925EVM Evaluation Module
- A 24-Vdc power supply

- Power supply capable of up to 100 mV and at least 100 mA of drive capability.
- PC with MS Windows operating system
- bq76925 Evaluation Software
- USB-TO-GPIO Adapter

### 3.1 Evaluation Software and USB-TO-GPIO Adapter

The bq76925 Evaluation Software and the USB-TO-GPIO Adapter must be installed and set up.

The USB-TO-GPIO Adapter is an EVM that is sold separately from the bq76925EVM. The firmware in it must be changed to work with the bq76925 because this EVM was developed for generic applications. Go to the TI Web site to download the firmware loader.

<http://focus.ti.com/docs/toolsw/folders/print/usb2gpio-loader-sw.html>

With the USB-TO-GPIO Adapter connected to the PC, follow the instructions included with the firmware loader software, and change the firmware version to 2.0.19. All necessary files are included with the USB-TO-GPIO Firmware Updater. The location of the firmware file (usb\_bms\_v2.0.19.bin) may be installed in a different directory location, so a Windows search may be needed to find its location.

#### CAUTION

If the firmware download fails, do not disconnect the USB-TO-GPIO Adapter. Try to load the firmware again until it is successful. Removing power after a failed download can permanently damage the USB-TO-GPIO Adapter.

The bq76925 Evaluation Software is free to download from the product page for the bq76925 on the TI Web site. Follow the installation instructions in the install package.

### 3.2 Configuration Switches and Jumpers

Before applying any power to the board, ensure that all of the jumpers and switches are set up correctly for this demonstration. A summary of all of the jumper and switch positions appears in [Table 14](#).

**Table 14. Circuit Configuration**

Header Name	Shunt or Switch Position	Notes
J1	1 – 2	Zener and blocking diode on BAT Pin
J2	2 – 3	External Pass Transistor enabled
J3	ON	External Pass Transistor enabled
J4	ON	5.7- $\mu$ F capacitance on V3P3 pin.
J5	ON	Normal mode
J6	1 – 2	VCC from Tool
S2	ON	All eight switches to the closed position.
S4	ON	All eight switches to the closed position.

### 3.3 Power to the bq76925EVM

Ensure that the configuration described in [Table 14](#) has been verified.

The bq76925EVM must be powered from a power supply for this demonstration. The power supply drives an onboard cell simulator as well as powers the bq76925 and MSP430 circuitry. No battery is required at this point.

Connect a 24-V power supply with current drive of at least 100 mA between the BATT+ and BATT-. Turn on the output of the power supply.

On application of power, the red LED, D13, illuminates.

A voltmeter can be used to verify that the 3.3-V output is working. Place the voltmeter between test points TP20 and TP10.

### 3.4 Connect USB-TO-GPIO Adapter

Connect the USB cable provided with the USB-TO-GPIO Adapter between the PC with the Evaluation Software installed on it and the USB-TO-GPIO Adapter.

The green LED near the USB connector illuminates to indicate that the USB-TO-GPIO Adapter is properly connected. Because of the marginal mechanical design of the case, the USB connection can sometimes become intermittent. The green LED is a good indication if a connection problem exists.

Connect the ribbon cable provided with the USB-TO-GPIO Adapter from it to header CN8 on the bq76925EVM. The red LED, D12, illuminates.

### 3.5 bq76925 Evaluation Software

#### 3.5.1 Open the Application

Having followed the instructions in the previous sections, open the bq76925 Evaluation Software.

The following screen appears (Figure 1). This main screen is often referred to as the *home* screen.

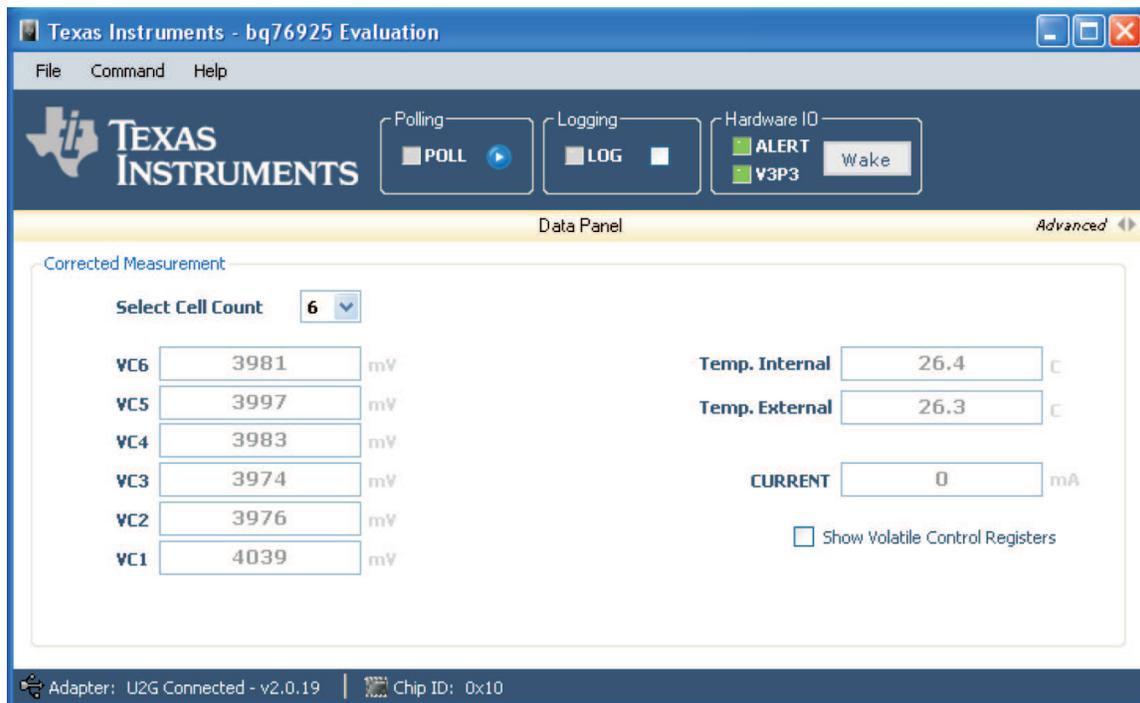


Figure 1. Home Screen of the Evaluation Software

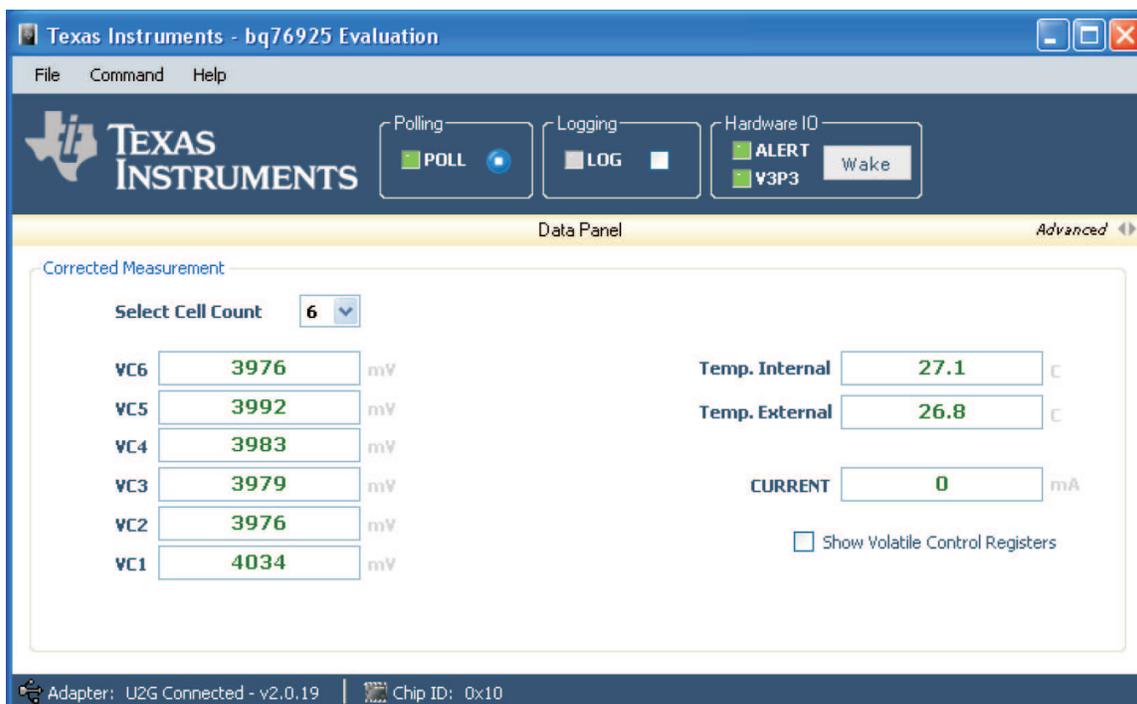
#### 3.5.2 Start Polling Data

Data from the bq76925 can be polled and displayed in the application. To start polling, click on the Poll button.



**Figure 2. Poll Button in the Evaluation Software.**

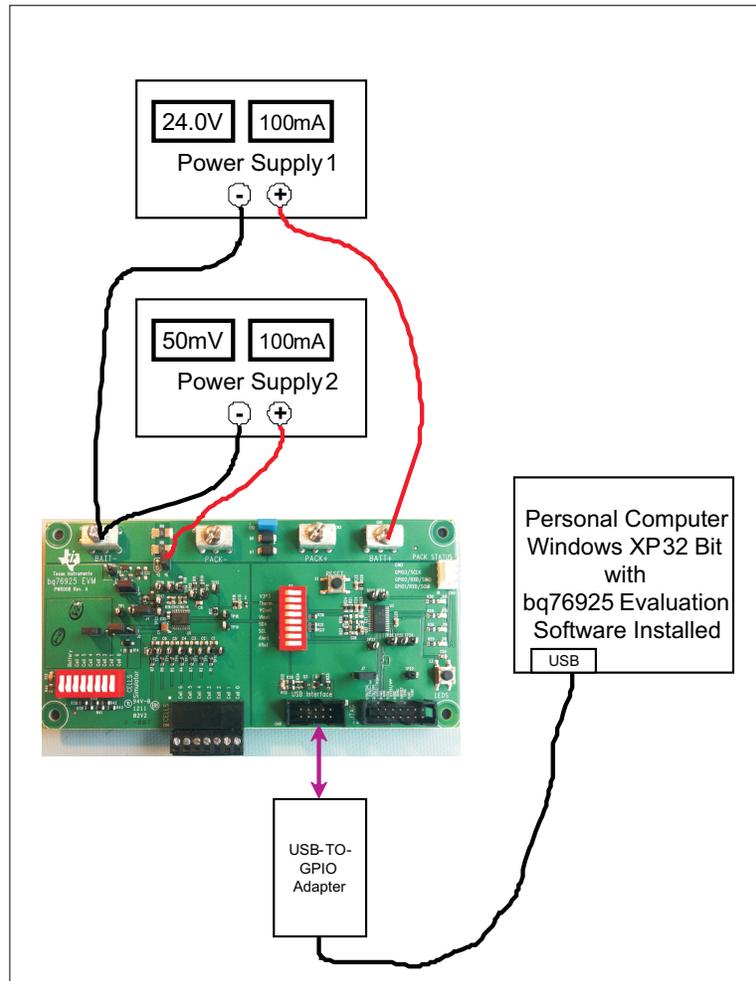
With polling active, the cell voltages and temperatures update on a periodic basis. The poll indicator light next to the word *POLL* flashes between green and orange for each poll cycle.



**Figure 3. Poll Button in the Evaluation Software**

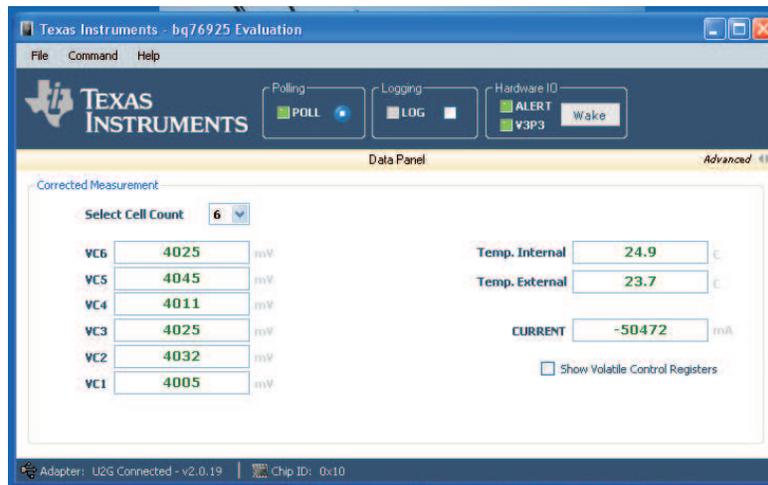
### 3.5.3 Add Second Power Supply to Simulate Current

One way to easily simulate battery current is to apply a millivolt source to the current-sense inputs of the bq76925. Tens of amperes can be simulated where each 10 mV is equal to 10 amperes.



**Figure 4. Demo With Two Power Supplies**

Remove the shunt from header J5. Use the second power supply to apply 50 mV between pin 1 of header J5 and the BATT- terminal. This simulates approximately  $-50\text{ A}$  or  $-50,000\text{ mA}$ , of discharge current.



**Figure 5. Voltage, Temperature, and Current Measurement in the Evaluation Software**

The drop-down box labeled *Select Cell Count* determines the number of cell voltage measurements that are displayed: 1 to 6. This function is independent of the cell count. For example, if the user only wanted to display 3 cells of a 6-cell pack, then the *Select Cell Count* box is changed to 3. This convenience feature avoids seeing a somewhat random number being displayed for unconnected cell inputs.

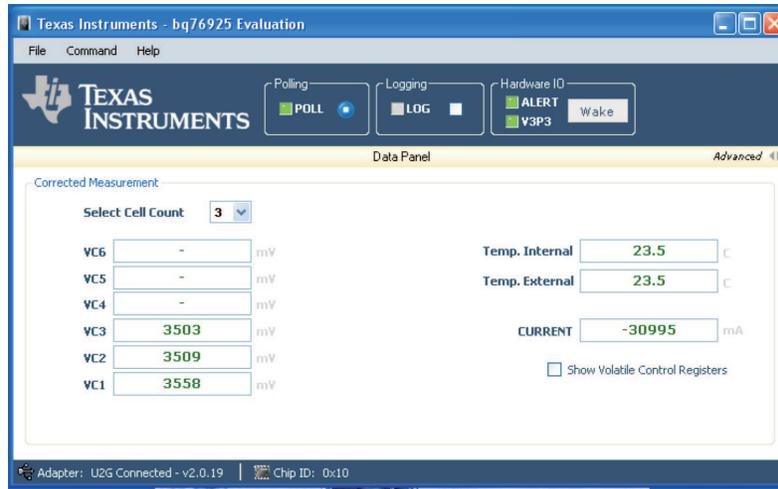


Figure 6. Select Cell Count Set to Three Cells

## 4 Control Register Demonstration

The Quick-Start demonstration from the previous section presents the fundamental measurement system of the bq76925. The method to access and modify the Control Registers using the Evaluation Software is presented in this section.

### 4.1 View Control Registers

#### 4.1.1 Introduction

Open the Evaluation Software, if not already open, and click the checkbox marked *Show Volatile Control Registers*.

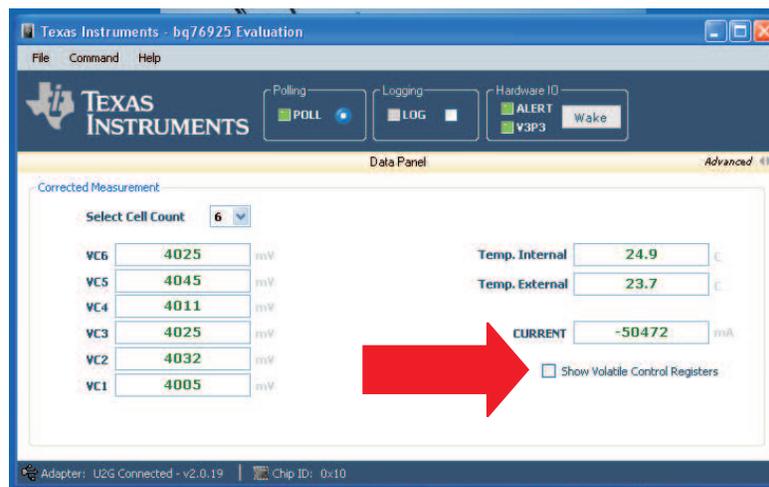


Figure 7. Volatile Control Registers Checkbox

This expands the home window to show the six registers.

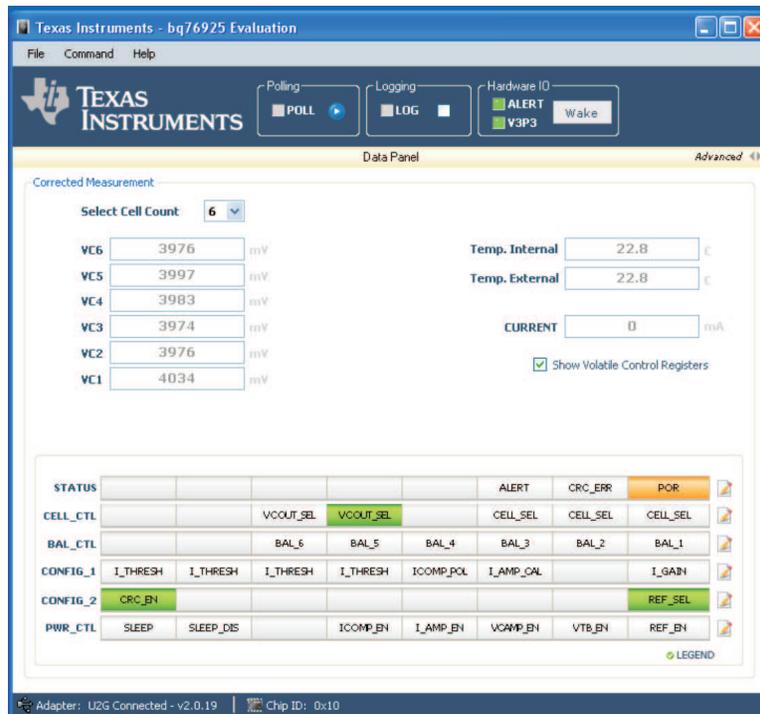


Figure 8. Volatile Control Registers Access

All of the bits that are assigned for reading and writing are shown. Bit positions that are unnamed are not used. These bits must always be left as zero.

A legend that can be clicked explains the bit colors. A zero value for a bit is displayed as a grey background. A one is shown as either a green background or as an orange background.

Clicking each bit toggles the bit value in real time. If a bit turns green, it is set to a 1. If a bit is white or grey, it is a zero. Each of the STATUS bits is displayed in orange when they are a value of 1.

If the SLEEP bit is a 1, it halts communications, so that the status of this bit is unable to be displayed. The SLEEP bit always appears to be OFF or MASKED.

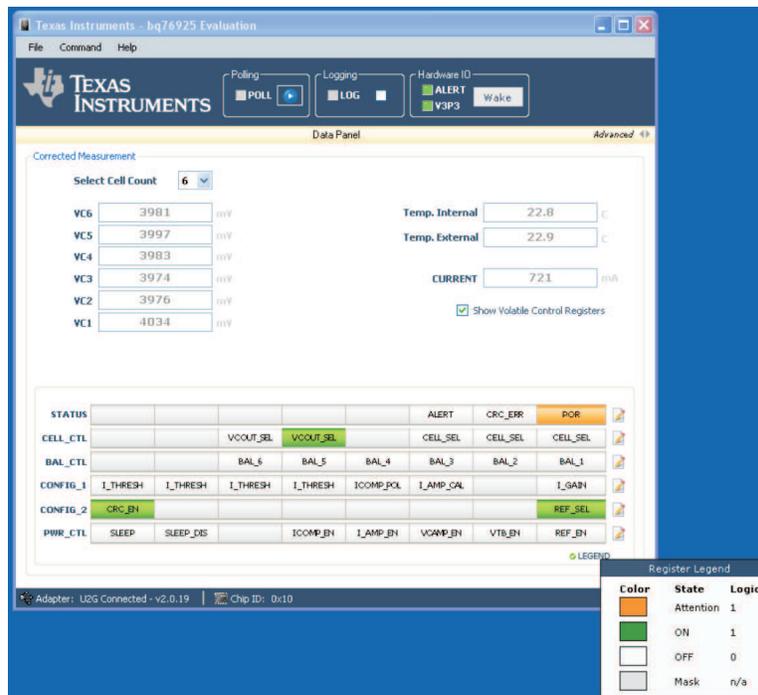


Figure 9. Volatile Control Registers Bit Legend

#### 4.1.2 Factory-Programmed Register Values

The Control Registers are programmed at the factory to have a default value. Table 15 shows these values.

Table 15. Default Register Values

Address	Register	Default Value
0x00	STATUS	0x01
0x01	CELL_CTL	0x10
0x02	BAL_CTL	0x00
0x03	CONFIG_1	0x00
0x04	CONFIG_2	0x81
0x05	PWR_CTL	0x00

#### 4.1.3 Register Values When Polling

When the Polling button is pressed, the PWR\_CTL register is forced to the value of 0x1F. This turns on all measurement systems as well as the current comparator. This is shown in the Control Register Display. Note that other bits are automatically updated (written) during polling but are not displayed (read). The update rate of the bits during polling is in the 10s of milliseconds and does not make sense to display.

### 4.2 Control Registers Introduction

The Control Registers of the bq76925 are used to configure and control the device. A summary of the read/write Control Registers follows. This user's guide, however, does not provide the necessary details on the operation and settings of these registers that are given in the bq76925 data sheet. For those details, see SLUSAM9.

Mousing over a bit in the Control Register section of the software displays a brief description of the bit.

#### 4.2.1 STATUS: 0x00

Bit 0 is the Power On Reset Flag (POR). It is set on a each power-up and wake up from sleep.

Bit 1 is the CRC Error Status Flag (CRC\_ERROR). It is updated on every I2C write packet.

Bit 2 is the Overcurrent Alert Status Flag (ALERT). This reflects the state of the overcurrent comparator.

#### 4.2.2 CELL\_CTL: 0x01

Bits 0-2 are the cell select bits (CELL\_SEL) that determine which cell voltage input (VC1 – VC6) is sent to the VCOOUT pin.

Bits 4-5 are the VCOOUT multiplexer selector bits (VCOOUT\_SEL). These bits determine the output of the VCOOUT pin: either VSS, VCn, Vref x 0.5, or Vref x 0.85.

#### 4.2.3 BAL\_CTL: 0x02

Bits 0-5 are for cell balance control (BAL\_1...BAL\_6).

#### 4.2.4 CONFIG\_1: 0x03

Bit 0 is the current amplifier gain select bit (I\_GAIN). The gain can be set to 4 or 8.

Bit 2 is the current amplifier calibration bit (I\_AMP\_CAL). It is used to select the current measurement: from SENSEN or SENSEP.

Bit 3 is the current comparator polarity select bit (I\_COMP\_POL). This determines the current direction used to trip the comparator: charge or discharge.

Bits 4 – 7 determine the current comparator threshold setting (I\_THRESH). Sixteen different mV levels are available.

#### 4.2.5 CONFIG\_2: 0x04

Bit 0 is used to set the reference voltage level (REF\_SEL). VREF has two different voltage levels.

Bit 7 is used to enable or disable the I2C CRC.

#### 4.2.6 POWER\_CTL: 0x05

Bit 0 is used to enable or disable the reference voltage (REF\_EN).

Bit 1 is used to enable or disable the thermistors bias voltage (VTB\_EN).

Bit 2 is used to enable or disable the cell voltage amplifier (VC\_AMP\_EN).

Bit 3 is used to enable or disable the current amplifier (I\_AMP\_EN).

Bit 4 is used to enable or disable the current comparator (ICOMP\_EN).

Bit 6 is used to disable the sleep mode (SLEEP\_DIS).

Bit 7 is used to enter sleep mode (SLEEP).

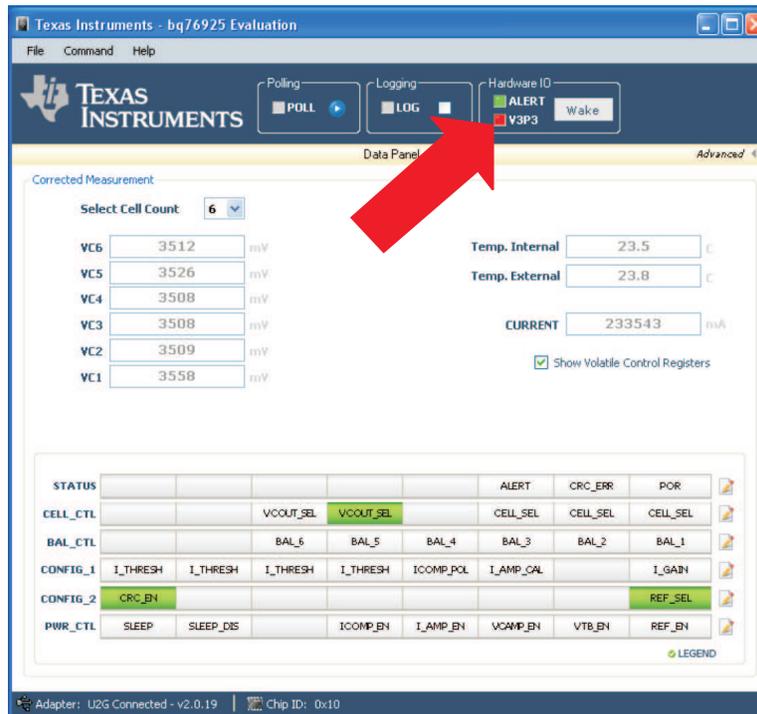
### 4.3 Modifying Control Registers

Control register bits that are writable can be modified by simply clicking on the bit that the user wishes to change. The modification is immediately communicated by the Evaluation Software to the bq76925.

### 4.4 Sleep Mode and Wake Up

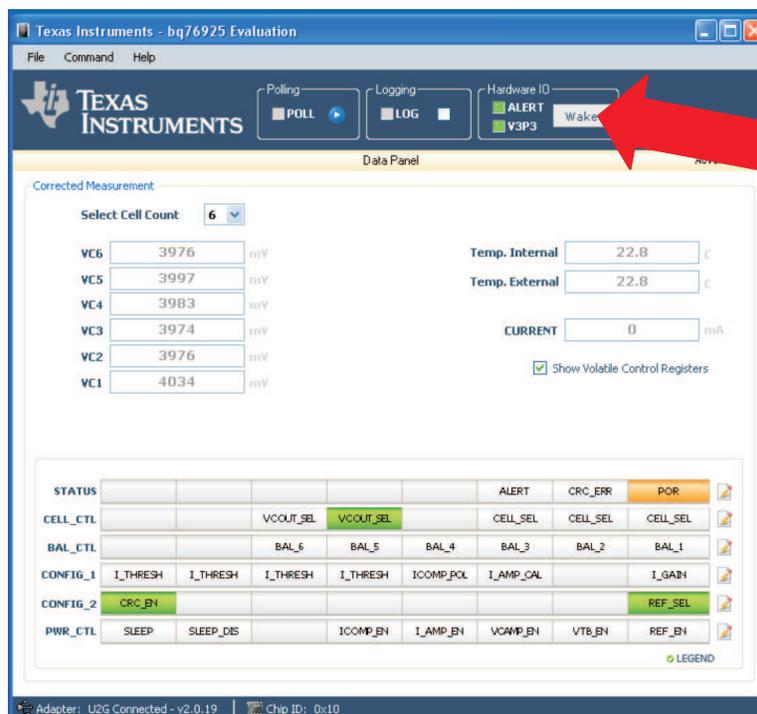
The bq76925 can be put into a low-power mode called Sleep. Bit 7 in the PWR\_CTL register is called SLEEP. When this bit is set to a 1, the part shuts down the V3P3 output and enters the low-power state. To enter sleep mode, simply click the SLEEP bit in the Control Registers display.

The bq76925 shuts down the 3.3-V level at the V3P3 pin. The Hardware IO section shows a red light next to V3P3 to indicate that the 3.3-V level is now zero. The Evaluation Software actually monitors the V3P3 output of the bq76925 via the USB-TO-GPIO Adapter input on pin 1.



**Figure 10. Sleep Mode Showing 3.3-V Status**

The method to wake the part from sleep is to apply a voltage, 3.3 V in the case of the bq76925EVM, to the ALERT pin. This is accomplished easily by clicking the Wake button in the Hardware IO Section.



**Figure 11. Wake Up From Sleep Mode**

## 5 Control Panel Demonstration

The Control Panel features of the bq76925 Evaluation Software are explained in this section. This is a deeper look in to the software operation and the functionality of the bq76925.

### 5.1 Access to the Control Panel

The Control Panel is purposefully hidden from view when the software is first opened. This approach eases the user into the complexity of the software. Access to the control panel is gained by clicking on the small toggle switch in the top right corner of the home screen labeled Advanced.

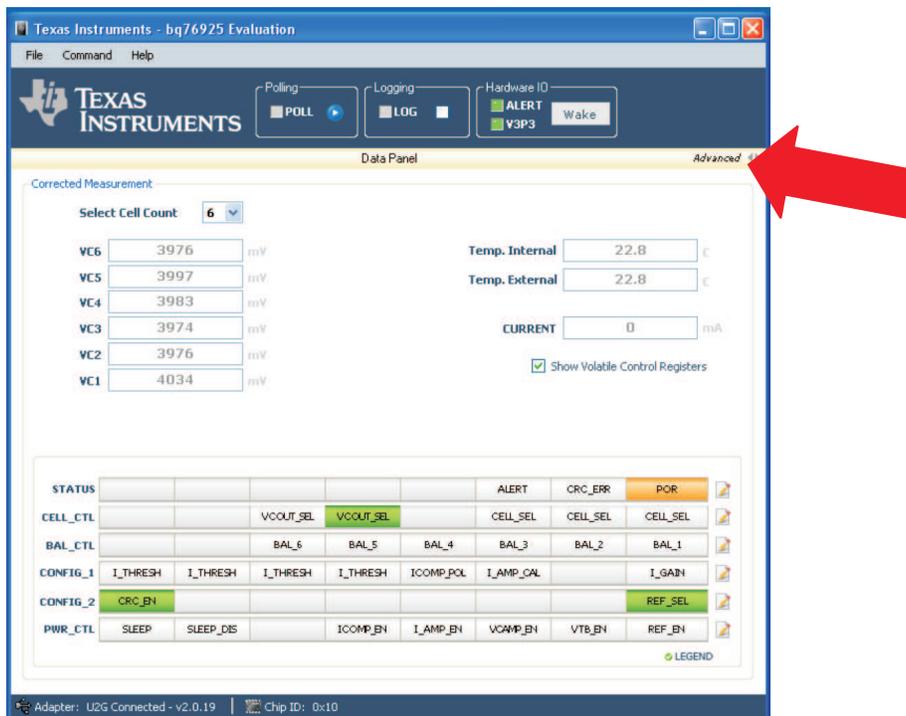


Figure 12. Open Control Panel

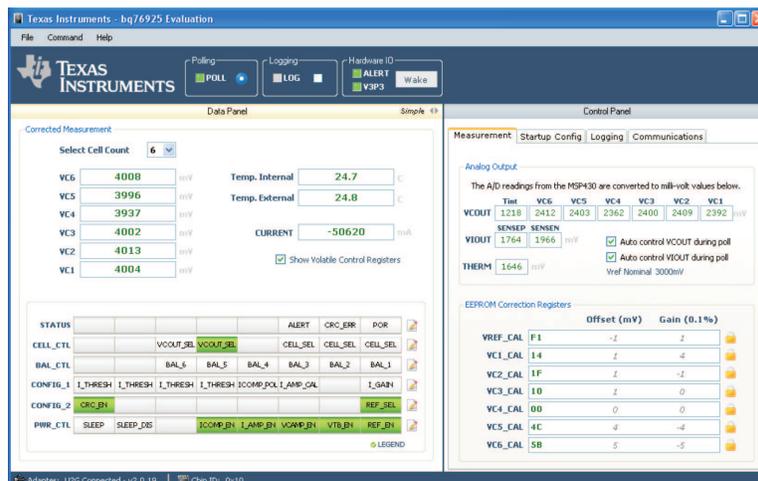


Figure 13. Control Panel Details

## 5.2 Measurement Tab

The measurement menu includes an Analog Output section and EEPROM Correction Registers section as shown in Figure 14.

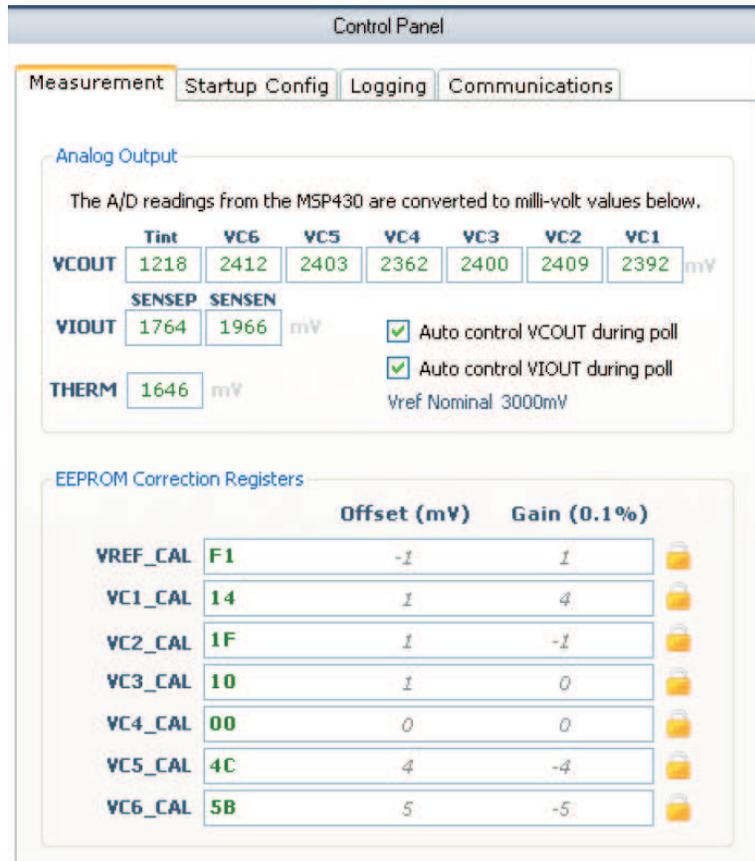


Figure 14. Measurement Tab in the Control Panel

## 5.3 Analog Output Section

The Analog Output Section consists primarily of a display of the analog outputs of the bq76925 circuit including VCOUT, VIOUT, VREF, and THERM.

The analog levels are measured by the onboard MSP430F2122 and then stored internally. The MSP430 updates all of the analog-to-digital converter (A/D) results on a 12- $\mu$ s interval. The bq76925 software writes to the control registers in the bq76925 to dictate how the measurement system operates. The sequence of events is as follows:

1. Set VCOUT to Read Internal Temperature.
2. Delay 40  $\mu$ s, get A/D Counts for Internal Temperature.
3. Set VCOUT to Read VC6.
4. Delay 40  $\mu$ s, get A/D Counts for VC6.
5. Set VCOUT to Read VC5.
6. Delay 40  $\mu$ s, get A/D Counts for VC5.
7. Set VCOUT to Read VC4.
8. Delay 40  $\mu$ s, get A/D Counts for VC4.
9. Set VCOUT to Read VC3.
10. Delay 40  $\mu$ s, get A/D Counts for VC3.

11. Set VCOOUT to Read VC2.
12. Delay 40  $\mu$ s, get A/D Counts for VC2.
13. Set VCOOUT to Read VC1.
14. Delay 40  $\mu$ s, get A/D Counts for VC1.
15. Set VIOOUT to read SENSEP (SENSEN for first 5 s of polling).
16. Delay 40  $\mu$ s, get A/D Counts for Current.
17. Get A/D Count for THERM.

## 5.4 VCOOUT Readings

VCOOUT is a multiplexed output, and up to seven measurement results can be displayed. These millivolt values are converted to Corrected Measurements on the home screen using the equations in [Table 16](#).

**Table 16. Formulas to Convert VCOOUT to either  $^{\circ}$ C or mV**

Display Name	Function	Formula to convert VCOOUT reading to Cell Voltage or Temperature	Units
Tint	Internal Temp.	$\left( \frac{1317 - \text{VCOOUT}}{4.018} \right)$	$^{\circ}$ C
VC6	Cell 6	$\left( \frac{\text{VC6} \times \text{GC}_{\text{VREF}} + \text{VC6\_OFFSET\_CORR} \times 0.001}{\text{G}_{\text{VCOOUT}}} \right) \times (1 + \text{VC6\_GAIN\_CORR} \times 0.001)$	mV
VC5	Cell 5	$\left( \frac{\text{VC5} \times \text{GC}_{\text{VREF}} + \text{VC5\_OFFSET\_CORR} \times 0.001}{\text{G}_{\text{VCOOUT}}} \right) \times (1 + \text{VC5\_GAIN\_CORR} \times 0.001)$	mV
VC4	Cell 4	$\left( \frac{\text{VC4} \times \text{GC}_{\text{VREF}} + \text{VC4\_OFFSET\_CORR} \times 0.001}{\text{G}_{\text{VCOOUT}}} \right) \times (1 + \text{VC4\_GAIN\_CORR} \times 0.001)$	mV
VC3	Cell 3	$\left( \frac{\text{VC3} \times \text{GC}_{\text{VREF}} + \text{VC3\_OFFSET\_CORR} \times 0.001}{\text{G}_{\text{VCOOUT}}} \right) \times (1 + \text{VC3\_GAIN\_CORR} \times 0.001)$	mV
VC2	Cell 2	$\left( \frac{\text{VC2} \times \text{GC}_{\text{VREF}} + \text{VC2\_OFFSET\_CORR} \times 0.001}{\text{G}_{\text{VCOOUT}}} \right) \times (1 + \text{VC2\_GAIN\_CORR} \times 0.001)$	mV
VC1	Cell 1	$\left( \frac{\text{VC1} \times \text{GC}_{\text{VREF}} + \text{VC1\_OFFSET\_CORR} \times 0.001}{\text{G}_{\text{VCOOUT}}} \right) \times (1 + \text{VC1\_GAIN\_CORR} \times 0.001)$	mV

In [Table 16](#),  $\text{GC}_{\text{VREF}}$  is defined as

$$\text{GC}_{\text{VREF}} = (1 + \text{VREF\_GAIN\_CORR} \times 0.001) + \frac{\text{VREF\_OFFSET\_CORR} \times 0.001}{\text{VREF}_{\text{NOMINAL}}} \quad (1)$$

And,  $\text{G}_{\text{VCOOUT}}$  must be set to 0.6 for the bq76925EVM.

The  $\text{VC}_n$  in [Table 16](#) is the millivolt reading shown in the measurement window.

## 5.5 VIOOUT Readings

The VIOOUT readings are shown in millivolts and labeled as SENSEP and SENSEN. The SENSEN readings are done with I\_AMP\_CAL set to zero and are only taken in the first 5 seconds of polling while the VIOOUT signal level stabilizes. After that time, SENSEN is not updated. The SENSEP readings are done with I\_AMP\_CAL set to one thereafter and are done continuously until polling is stopped.

This measurement technique results in an approximate 5-s delay before the current measurement stabilizes.

### 5.6 Auto Control

Two checkboxes are in the Analog Output Section: Auto Control V<sub>CO</sub>UT during poll and Auto Control V<sub>IO</sub>UT during poll, checked by default. The Auto Control V<sub>CO</sub>UT During Poll means that all six-cell voltage inputs are read during polling. The Auto Control V<sub>IO</sub>UT During Poll means that the current is read during polling. Note that these checkboxes do not turn the Voltage and Current Amplifier circuits on/off.

### 5.7 EEPROM Correction Registers

The EEPROM Correction Registers are the seven registers in the bq76925 that store the offset and gain values for the V<sub>Cn</sub> circuits and the V<sub>REF</sub> circuit. These values can be different for each device. See the data sheet for additional details.

Each gain value is derived from the top four bits (nibble) of the register value. This number is a signed 2's complement representation in the range of -8 to +7. The units are in mV.

Each offset value is derived from the bottom four bits (nibble) of the register value. This number is a signed 2's complement representation. The units are in 0.1%.

### 5.8 Startup Config Tab

The Startup Config tab is a convenience feature. It allows the user to set the way the bq76925 Evaluation Software initializes each time it is started or when the Find Target Command is issued.

This tab specifies the settings of the Control Registers 0x00 to 0x05 when the Enable checkbox is checked.

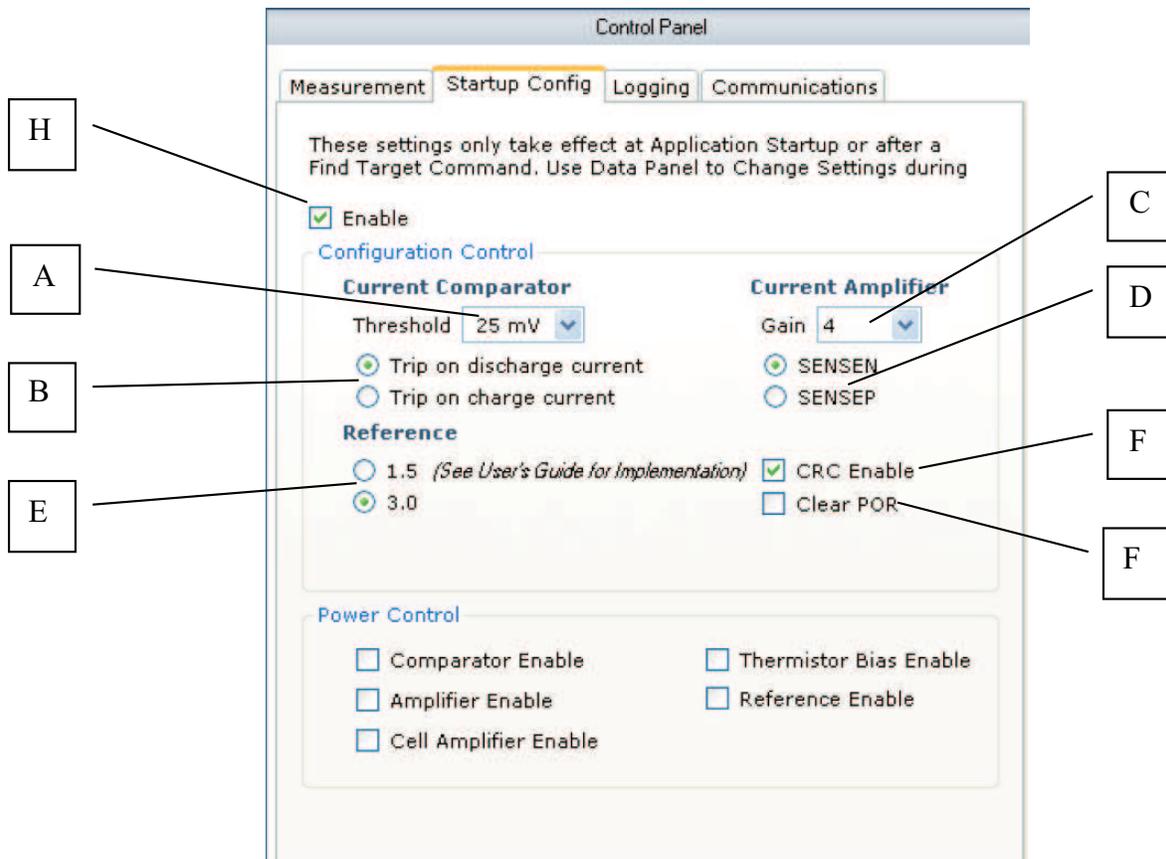


Figure 15. Startup Config Tab in the Control Panel

## 5.9 Configuration Control

The Configuration Control section displays some of the options that a user may want to have preselected each time the software starts. The features are listed by description rather than bit location and value (1 or 0). Again, this is a convenience feature, and usage of this tab is purely optional.

- A. A drop-down box for the Current Comparator threshold setting has values of 25, 50, 75, ... , 375, 400 mV. These are bits 4 to 7 in the CONFIG\_1 register.
- B. Two radio buttons allow the user to select the current polarity for the Current Comparator Threshold. This is bit 3 of the CONFIG\_1 register.
- C. A drop-down box for the Current Amplifier Gain is bit 0 of the CONFIG\_1 register.
- D. Two radio buttons allow the user to select the current measurement polarity for the Current Amplifier. This is bit 2 of the CONFIG\_1 register.
- E. Two radio buttons allow the user to select the voltage reference (VREF). This is bit 0 of the CONFIG\_2 register.
- F. The CRC Enable/Disable function has a checkbox. Check the box marked CRC Enable to turn on the CRC feature. This is bit 7 of the CONFIG\_2 register.
- G. The POR Enable/Disable function has a checkbox. Check the box marked POR Clear to turn on the POR clear feature. This is related to bit 0 of the CONFIG\_1 register.
- H. The Startup Config Functionality has a checkbox to enable/disable.

### 5.9.1 Configuration Control Example

As an example of how to use the Configuration Control, change the Current Comparator Threshold to 175 mV, and then press the F2 key to execute the Find Target Command. The I\_THRESH bits in the CONFIG\_1 register changes to [0110].

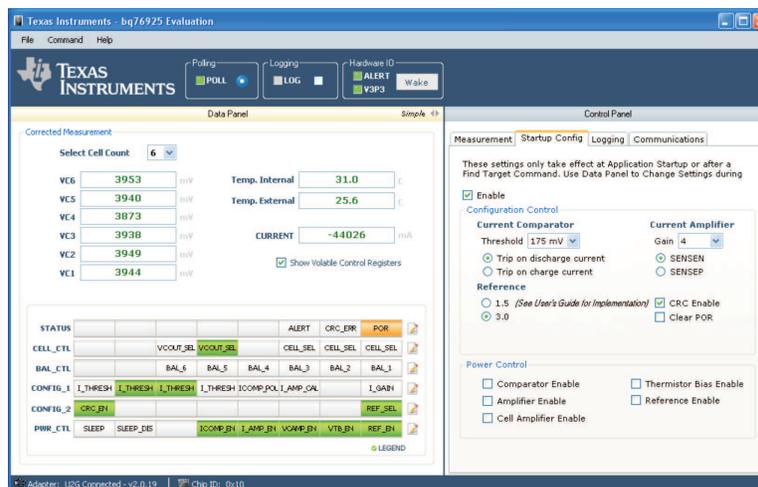


Figure 16. Change to the Current Comparator Threshold to 175 mV at Start-Up

## 5.10 Power Control

The Power Control section allows the user to have certain components of the measurement system enabled at the start of the software.

When checked, five checkboxes activate the corresponding components in the bq76925. The default setting is to have all of the components turned off.

These checkboxes correspond to bits 0 to 4 in the PWR\_CTL register.

### 5.11 Logging Tab

The logging tab is another convenience feature. It allows the user to record the I2C transactions that take place between the bq76925 software and the bq76925.

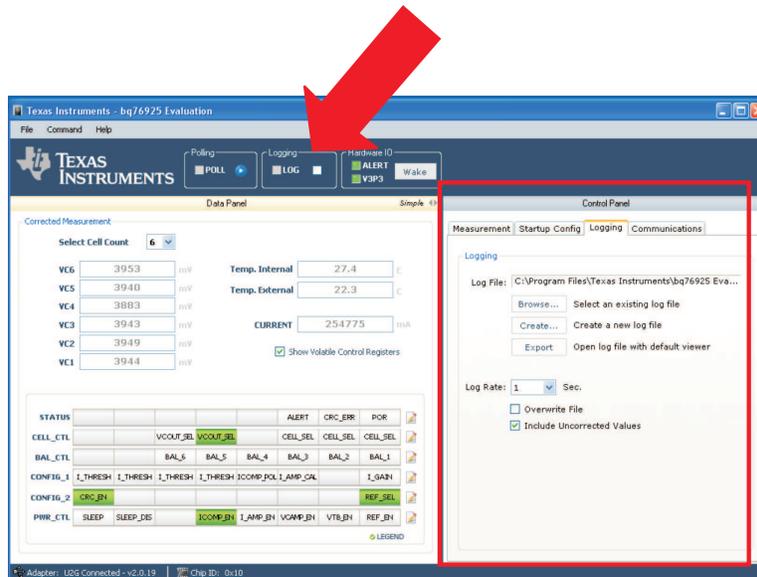


Figure 17. The Logging Tab

### 5.12 Log File

Three buttons specify the file to be used during logging.

1. The **Browse...** button opens a dialog box to let the user choose an existing log file to use to record the logged data.
2. The **Create...** button opens a dialog box to let the user create an existing log file to use to record the logged data.
3. The **Export...** button opens the file listed in the text box preceded by *Log File:* in the program assigned to open Common Separated Value (.csv) files on the computer.

### 5.13 Log File Options

The logging rate can be set by the drop-down box marked *Log Rate*. The logging rates are in seconds.

Two checkboxes offer options for how logging is done. The first checkbox labeled *Overwrite File* deletes any existing data in the specified log file (.csv) each time logging is started. The second checkbox labeled *Include Uncorrected Values* includes all of the uncorrected values for VCOU and VIOUT.

### 5.14 Enable/Disable Logging

Logging is enabled by clicking the checkbox on the home screen of the software marked *Logging*. Then, only after polling is started does the log file start to record samples of data. Logging is halted when polling is stopped.

Editing of the Logging Tab is disabled when logging is enabled.

### 5.15 Log File Example

Table 17 is an example of a log file recording. This file only includes the corrected data.

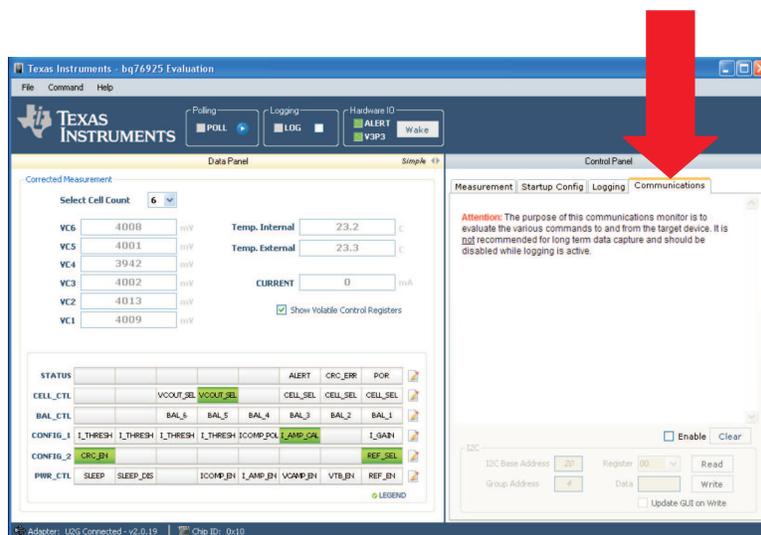
**Table 17. Example Log File**

TimeStamp	VC6	VC5	VC4	VC3	VC2	VC1	Int. Temperature	Ext. Temperature	Current
6/15/2011 9:52	3953	3935	3878	3943	3949	3944	27.4	26.8	-722
6/15/2011 9:52	3953	3940	3878	3938	3949	3940	27.4	26.7	-722
6/15/2011 9:52	3948	3940	3878	3938	3949	3944	27.4	26.3	-722
6/15/2011 9:52	3948	3940	3878	3938	3949	3944	27.4	26.7	-722
6/15/2011 9:52	3953	3940	3878	3938	3949	3940	27.4	26.7	-722
6/15/2011 9:52	3948	3940	3878	3938	3949	3944	27.4	26.1	-722
6/15/2011 9:52	3948	3940	3878	3943	3949	3935	27.4	26.9	-722
6/15/2011 9:52	3953	3940	3878	3943	3949	3940	27.4	26.8	-722
6/15/2011 9:52	3953	3940	3878	3938	3949	3944	28.2	26.8	-722
6/15/2011 9:52	3953	3940	3878	3938	3949	3944	27.4	26.9	-722
6/15/2011 9:52	3948	3940	3878	3938	3949	3940	27.4	26.7	-33922
6/15/2011 9:52	3943	3940	3878	3934	3949	3944	27.4	26.7	-47635
6/15/2011 9:52	3953	3940	3878	3938	3949	3944	27.4	26.8	-49800
6/15/2011 9:53	3948	3935	3878	3938	3949	3944	27.4	26.8	-49800
6/15/2011 9:53	3948	3940	3878	3943	3949	3944	27.4	26.8	-49800
6/15/2011 9:53	3953	3940	3878	3943	3949	3944	27.4	26.8	-50522
6/15/2011 9:53	3948	3940	3873	3938	3949	3940	27.4	26.9	-49800
6/15/2011 9:53	3953	3940	3878	3938	3949	3944	27.4	26.8	-49800
6/15/2011 9:53	3948	3940	3878	3938	3949	3944	27.4	26.8	-49800
6/15/2011 9:53	3948	3940	3878	3943	3949	3944	27.4	26.8	-50522

### 5.16 Communications Tab

The communications tab is another convenience feature of the bq76925 Evaluation Software. It gives the user insight into the communications happening between the Software, MSP430F2122, and the bq76925. It also allows the user to perform manual reads and writes of the control registers of the bq76925.

The software both writes and reads to the bq76925 and just reads from the MSP430F2122.



**Figure 18. Communications Tab**

## 5.17 Monitor Window

The Monitor window can be used to monitor all of the communication traffic on the I2C bus. It records the transaction history. The default condition of the monitor is to be off. Click on the checkbox below the window that is labeled *Enable* to enable the monitor.

The **Clear** button erases the contents of the monitor window, if clicked.

### CAUTION

Be aware of a warning that reads: "Attention. The purpose of this communications monitor is to evaluate the various commands to and from the target device. It is not recommended for long term data capture and should be disabled while logging is active." This restriction is computer dependent based on the amount of system memory. If left on for too long, the computer's system memory may get allocated to a point where the application performance can be severely affected.

*I2C\_W* is a write transaction from the software. *I2C\_R* is a read transaction issued by the software.

## 5.18 Transactions During a Connect to Device Command

The typical transaction history after a Connect to Device command appears as shown in [Table 18](#):

**Table 18. Example of a Device Connect Command**

Searching for I2C device...			
I2C_R:	20	1	49
Device found!			
Base Address: 0x20			
I2C_W:	21	10	1
I2C_R:	21	10	14
I2C_R:	20	1	49
I2C_W:	23	0	25
I2C_R:	23	0	30
I2C_R:	20	1	49
I2C_W:	24	81	7D
I2C_R:	24	81	68
I2C_R:	20	1	49
I2C_W:	25	0	D9
I2C_R:	25	0	CC
I2C_R:	20	1	49
I2C_R:	20	1	49
I2C_R:	21	10	14
I2C_R:	22	0	1A
I2C_R:	23	0	30
I2C_R:	24	81	68
I2C_R:	25	0	CC
I2C_R:	27	10	E8
I2C_R:	30	3F	5D
I2C_R:	31	10	BA
I2C_R:	32	10	C4
I2C_R:	33	30	0E
I2C_R:	34	4F	A2

**Table 18. Example of a Device Connect Command (continued)**

Searching for I2C device...			
I2C_R:	20	1	49
Device found!			
Base Address: 0x20			
I2C_R:	35	4E	8F
I2C_R:	36	4D	F8

First column is a comment. Second column is the combined device-address and register-address. Third column is the register value. Last column is the CRC.

### 5.19 I2C

The I2C section shows the I2C Base Address of the bq76925 and the group address. These are 0x20 and 0x04, respectively. The base address is the group address shifted to the left by three places.

The user can use this I2C section to read and write data to the bq76925.

### 5.20 I2C Register Read

To read a register, select the desired register to read using the drop-down box. Refer to the product data sheet to understand the meaning and usage of each register. Then click the **Read** button. The result is displayed in the Monitor window.

For example, a read of register 0x01, CELL\_CTL, appear as:

```
I2C_R:      22      00      1A.
```

The first number, 0x22, is the combined device address and the register number. The second number, 0x00, is the value of the register. The third number, 0x1A, is the CRC. If the CRC\_EN bit in the CONFIG\_2 register is not set, the CRC value 0x1A does not appear.

### 5.21 I2C Register Write

To write a register, select the desired register to write using the drop-down box. See the product data sheet to understand the meaning and usage of each register. Enter the value to be written in hexadecimal notation. Then click the **Write** button. The result is displayed in the Monitor window.

If the Update GUI on write checkbox is selected, then the change to the register is updated in the Volatile Control Registers section.

### 5.22 I2C Communications With MSP430F2122

The I2C device address of the MSP430F2122 was assigned as 0x40 so as to not interfere with the address structure of the bq76925.

The MSP430 reads the various analog outputs of the bq76925 and stores the results, in terms of counts, in registers in its memory. The MSP430 A/D converter has 10 bits of resolution. The software accesses these registers. The register map inside the MSP430 is shown in [Table 19](#).

**Table 19. Data From MSP430F2122**

Byte Number	Name	Description	Units
1	Status	Status of Alert pin. Bit zero indicates level of Alert pin: 1=High, 0=Low (Overcurrent).	None
2	Reserved	Reserved	None

**Table 19. Data From MSP430F2122 (continued)**

Byte Number	Name	Description	Units
3	Ext Thermistor, MSB	Thermistor voltage	Counts from 10-bit A/D converter
4	Ext Thermistor, LSB		
5	VCOUT, MSB	VCOUT voltage	
6	VCOUT, LSB		
7	VIOUT1, MSB	VIOUT1 voltage (current)	
8	VIOUT1, LSB		
9	VIOUT2, MSB	VIOUT2 voltage	
10	VIOUT2, LSB		
11	VREF, MSB	VREF voltage	
12	VREF, LSB		
13	1/2 x DVCC, MSB	DVCC voltage	
14	1/2 x DVCC, LSB		

To convert to mV, divide the 10-bit value by 1024 and multiply by the reference voltage (VREF) of 3000 mV.

### 5.23 Example of I2C Communications from MSP430F2122

The software continuously accesses the MSP430 registers during polling. An example of this appears in [Table 20](#).

**Table 20. Example of a Device Connect Command**

I2C_W:	25	1F	84												
I2C_R:	25	1F	91												
I2C_W:	21	16	13												
I2C_R:	40	0	0	2	30	1	9E	0	77	0	77	3	FF	2	2B
I2C_W:	21	15	1A												
I2C_R:	40	0	0	2	30	3	36	0	AC	0	AB	3	FE	2	2F
I2C_W:	21	14	1D												
I2C_R:	40	0	0	2	30	3	33	0	DB	0	DA	3	FF	2	2E
I2C_W:	21	13	8												
I2C_R:	40	0	0	2	30	3	26	1	5	0	FA	3	FE	2	30
I2C_W:	21	12	0F												
I2C_R:	40	0	0	2	30	3	32	1	22	1	21	3	FF	2	2F
I2C_W:	21	11	6												
I2C_R:	40	0	0	2	30	3	35	1	45	1	44	3	FF	2	2E
I2C_W:	21	10	1												
I2C_R:	40	0	0	2	30	3	2F	1	64	1	64	3	FE	2	30
I2C_W:	23	0	25												
I2C_R:	40	0	0	2	2F	3	30	1	81	1	81	3	FF	2	2F
I2C_W:	21	16	13												
I2C_R:	40	0	0	2	2F	1	9E	1	D6	1	D6	3	FF	2	2F
I2C_W:	21	15	1A												
I2C_R:	40	0	0	2	30	3	36	1	E9	1	E8	3	FF	2	2F
I2C_W:	21	14	1D												
I2C_R:	40	0	0	2	30	3	34	1	F9	1	F9	3	FF	2	2E
I2C_W:	21	13	8												
I2C_R:	40	0	0	2	30	3	26	2	6	2	7	3	FF	2	2F

**Table 20. Example of a Device Connect Command (continued)**

I2C_W:	21	12	0F												
I2C_R:	40	0	0	2	30	3	32	2	15	2	15	3	FF	2	2D
I2C_W:	21	11	6												
I2C_R:	40	0	0	2	30	3	35	2	21	2	21	3	FF	2	2F
I2C_W:	21	10	1												
I2C_R:	40	0	0	2	30	3	2F	2	2C	2	2C	3	FF	2	2E
I2C_W:	23	0	25												
I2C_R:	40	0	0	2	2F	3	2F	2	36	2	34	3	FE	2	30
I2C_W:	25	0	D9												
I2C_R:	25	0	CC												
I2C_W:	21	10	1												
I2C_R:	40	0	0	2	30	3	2F	2	2C	2	2C	3	FF	2	2E
I2C_W:	23	0	25												
I2C_R:	40	0	0	2	2F	3	2F	2	36	2	34	3	FE	2	30
I2C_W:	25	0	D9												
I2C_R:	25	0	CC												

In general, polling data involves writing to the Control Registers of the bq76925 to configure the outputs (VCO<sub>UT</sub>, VIO<sub>UT</sub> and VTB) and then reading the results from the MSP430.

## 6 3-, 4-, and 5-Cell Operation

This section includes instructions for setting up the bq76925EVM for operation with less than 6 cells. The discussion considers operation with the cell simulator only.

### 6.1 Introduction

The bq76925 is capable of working with cell packs that have 3-, 4-, 5-, or 6-series connected cells. There are some special considerations when operating with less than six series cells. For complete information, consult the bq76925 data sheet.

#### **CAUTION**

Configure the bq76925EVM for the appropriate cell count prior to applying power to the board.

### 6.2 Using Onboard Cell Simulator

The cell simulator can be set up for 3-, 4-, 5-, or 6-cell operation. The process simply involves placing a shorting wire across the proper pins on the CN6:CELLS connector.

### 6.3 Five-Cell Operation

The procedure for five-cell operation with the simulation circuit is as follows:

1. Ensure that the power to the board, at BATT+/-, is removed.
2. Close all switches on S4.
3. Apply a jumper wire from pin 1 to pin 2 on connector CN6. These are the inputs marked Cell 6 and Cell 5.
4. Set the power supply to a safe level for 5-cell operation. This is somewhere below 25 V.
5. Connect the power supply to BATT+ and BATT-.
6. Turn on the power supply.

7. Connect to the evaluation software.
8. Change the Select Cell Count drop-down box on the home screen to 5.

#### 6.4 Four-Cell Operation

The procedure for four-cell operation with the simulation circuit is as follows:

1. Ensure that the power to the board, at BATT+/-, is removed.
2. Close all switches on S4.
3. Apply a jumper wire from pin 1 to pin 2 on connector CN6. These are the inputs marked Cell 6 and Cell 5.
4. Apply a jumper wire from pin 2 to pin 3 on connector CN6. These are the inputs marked Cell 5 and Cell 4.
5. Set the power supply to a safe level for 4-cell operation. This is somewhere below 20 V.
6. Connect the power supply to BATT+ and BATT-.
7. Connect to the evaluation software.
8. Change the Select Cell Count drop-down box on the home screen to 4.

#### 6.5 Three-Cell Operation

The procedure for three-cell operation with the simulation circuit is as follows:

1. Ensure that the power to the board, at BATT+/-, is removed.
2. Close all switches on S4.
3. Apply a jumper wire from pin 1 to pin 2 on connector CN6. These are the inputs marked Cell 6 and Cell 5.
4. Apply a jumper wire from pin 2 to pin 3 on connector CN6. These are the inputs marked Cell 5 and Cell 4.
5. Apply a jumper wire from pin 3 to pin 4 on connector CN6. These are the inputs marked Cell 4 and Cell 3.
6. Set the power supply to a safe level for 4 cell operation. This would be somewhere below 15 V.
7. Connect the power supply to BATT+ and BATT-.
8. Connect to the evaluation software.
9. Change the Select Cell Count drop-down box on the home screen to 3.

### 7 Operation With Cells

This section discusses operating the bq76925EVM with a real cell pack.

#### 7.1 Preparing Circuit for Operation

##### **CAUTION**

Improper operation with real lithium-ion cells can cause permanent damage to the bq76925EVM.

## WARNING

**No battery current control devices (MOSFETs) are on this EVM that can stop the flow of charge or discharge current in the event that a dangerous condition is induced through discharging or charging of a battery. Exercise extreme caution when using a battery with this EVM.**

Disconnect all external electronics from the bq76925EVM prior to the connection of real cells. This includes power supplies, electronic load, USB-TO-GPIO Adapter or MSP-FET430UIF that may be connected.

### **7.2 Battery Connection Sequence**

The connection of a real battery pack to the bq76925EVM requires a certain connection sequence for safe operation.

The fundamental connection sequence is:

1. Ensure that all switches on S4 are open.
2. Connect BATT–.
3. Connect BATT+.
4. Connect CN6. The cell inputs have a specific assignment (1-1, 2-2, 3-3, etc) but no specific connection timing sequence is required.

Remove the CN6 mating connector from the board before wiring cell connections to the terminals.

### **7.3 Six-Cell Operation**

The procedure for six-cell operation with a cell pack is as follows:

1. Ensure that all switches on S4 are open.
2. Wire the seven-cell tap wires to the mating plug of CN6.
3. Connect BATT–.
4. Connect BATT+.
5. Connect CN6 to the EVM. The cell inputs can be connected in any order.
6. Connect to the evaluation software.
7. Change the Select Cell Count drop-down box on the home screen to 6.

### **7.4 Five-Cell Operation**

The procedure for five-cell operation with a cell pack is as follows:

1. Ensure that all switches on S4 are open.
2. Wire the six-cell tap wires to positions 2 through 7 on the mating plug of CN6.
3. Apply a jumper wire from pin 1 to pin 2 on mating plug of CN6. (These are the inputs marked Cell 6 and Cell 5.)
4. Connect BATT–.
5. Connect BATT+.
6. Connect CN6 to the EVM. The cell inputs can be connected in any order.
7. Connect to the evaluation software.
8. Change the Select Cell Count drop-down box on the home screen to 5.

### **7.5 Four-Cell Operation**

The procedure for four-cell operation with the simulation circuit is as follows:

1. Ensure that all switches on S4 are open.
2. Wire the five-cell tap wires to positions 3 through 7 on the mating plug of CN6.
3. Apply jumper wire from pin 1 to pin 2 on plug for CN6. These are inputs marked Cell 6 and Cell 5.
4. Apply jumper wire from pin 2 to pin 3 on plug for CN6. These are inputs marked Cell 5 and Cell 4.
5. Connect BATT–.
6. Connect BATT+.
7. Connect CN6 to the EVM. The cell inputs can be connected in any order.
8. Connect to the evaluation software.
9. Change the Select Cell Count drop-down box on the home screen to 4.

## 7.6 Three-Cell Operation

The procedure for three-cell operation with the simulation circuit is as follows:

1. Ensure that all switches on S4 are open.
2. Wire the four-cell tap wires to positions 4 through 7 on the mating plug of CN6.
3. Apply jumper wire from pin 1 to pin 2 on plug for CN6. These are inputs marked Cell 6 and Cell 5.
4. Apply jumper wire from pin 2 to pin 3 on plug for CN6. These are inputs marked Cell 5 and Cell 4.
5. Apply jumper wire from pin 3 to pin 4 on plug for CN6. These are inputs marked Cell 4 and Cell 3.
6. Connect BATT–.
7. Connect BATT+.
8. Connect CN6 to the EVM. The cell inputs can be connected in any order.
9. Connect to the Evaluation Software.
10. Change the Select Cell Count drop-down box on the home screen to 4.

## 7.7 Battery Removal Sequence

The removal of the battery from the bq76925EVM requires a certain sequence for safe operation.

The connection removal sequence is:

1. Remove USB-TO-GPIO connector at CN8.
2. Unplug CN6 (CELLS).
3. Remove BATT+ connection.
4. Remove BATT– connection.

## 8 Schematic and Bill of Materials

This section includes the schematic and the bill of materials for the bq76925EVM.

8.1 Schematics

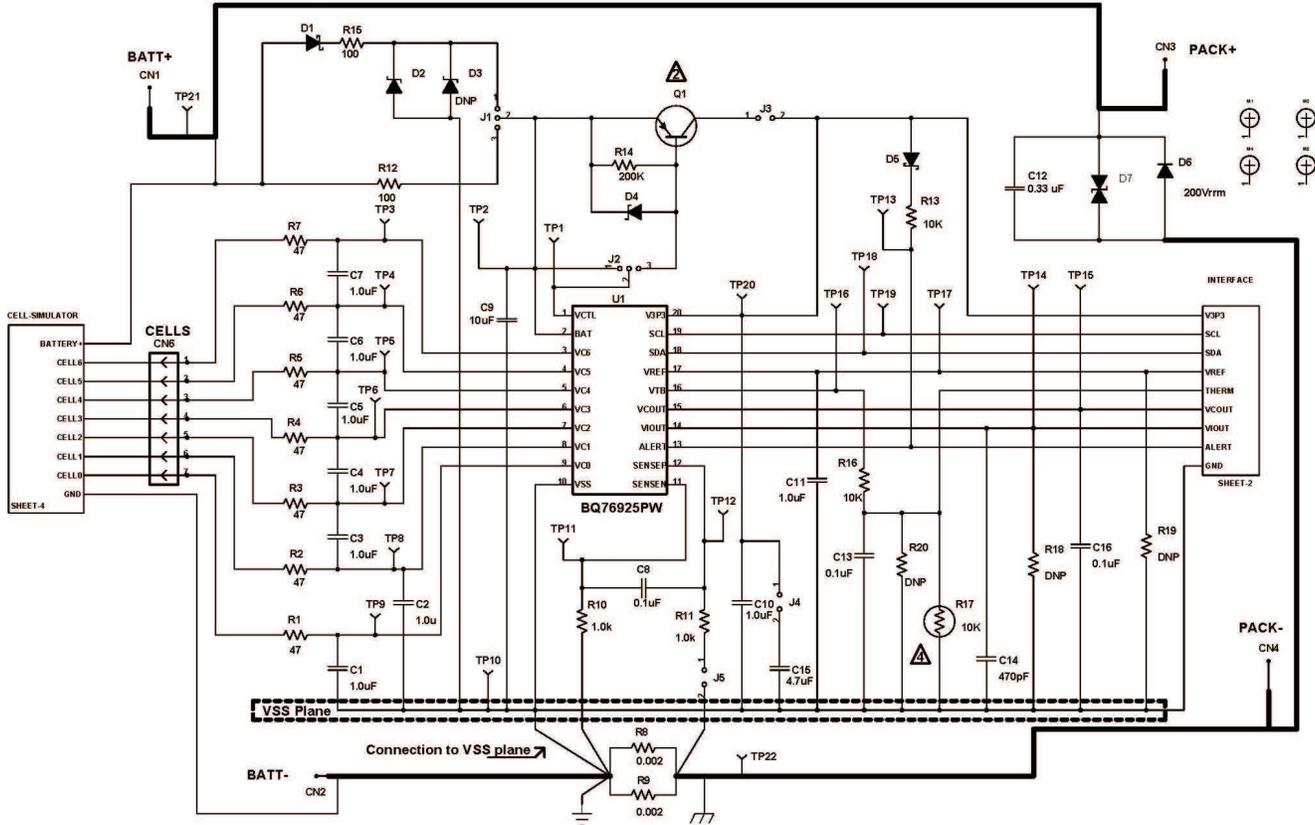


Figure 19. Schematic – Page 1 of 4

1. Only use LEDs with external V3P3 configuration. Firmware should sequentially flash each LED when S3 is pressed. Each flash should be 1 second long and separated by 1 second.
2. Q1 pass current limit is 30mA.

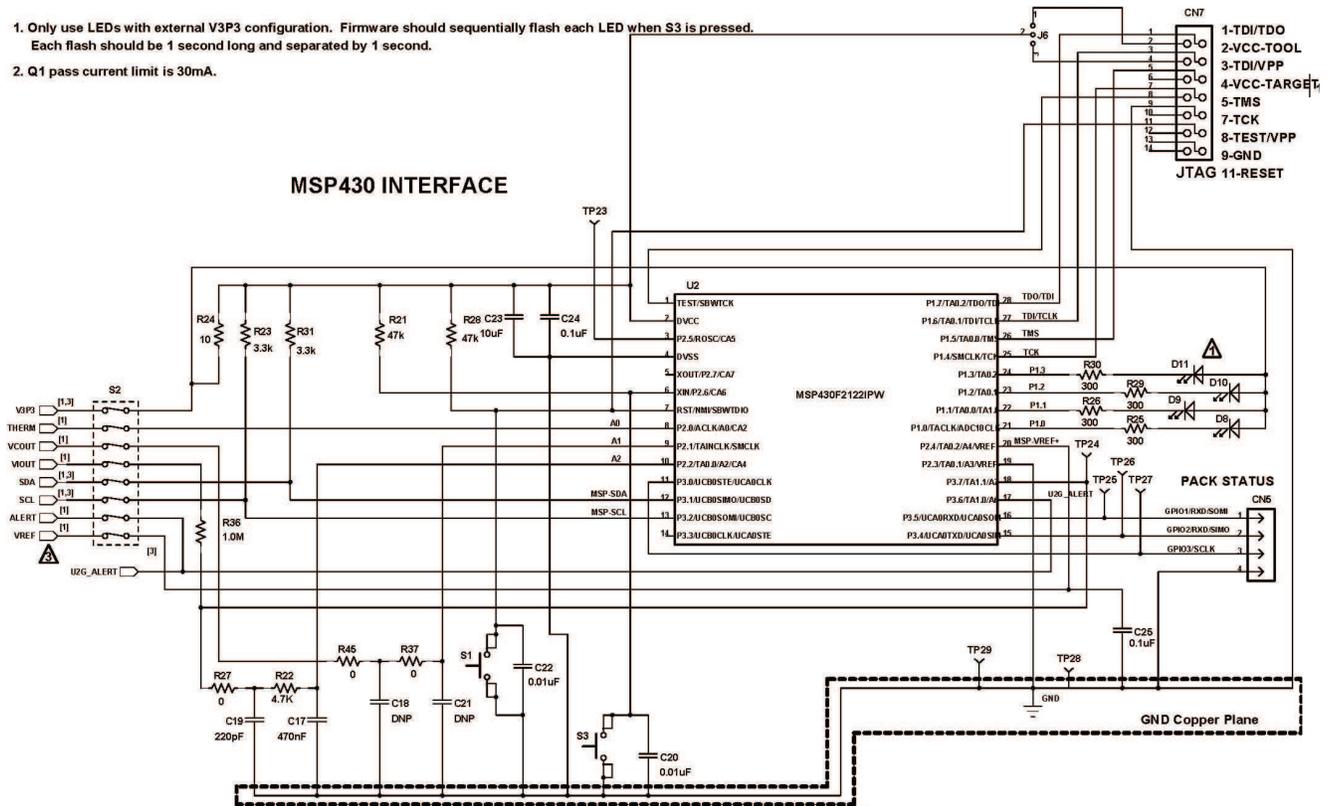


Figure 20. Schematic – Page 2 of 4

### INTERFACE TO USB-TO-GPIO ADAPTER AND GUI

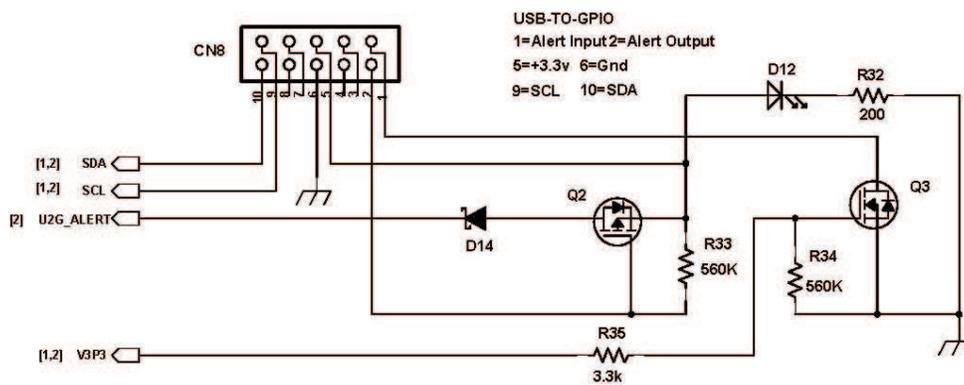


Figure 21. Schematic – Page 3 of 4

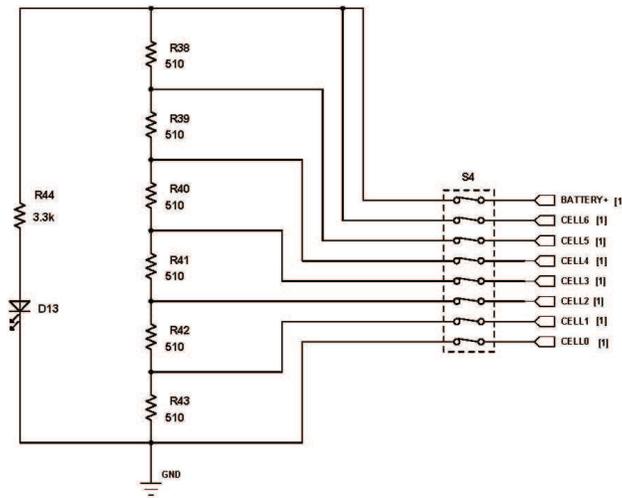


Figure 22. Schematic – Page 4 of 4

**8.2 Bill of Materials**

**Table 21. Bill of Materials**

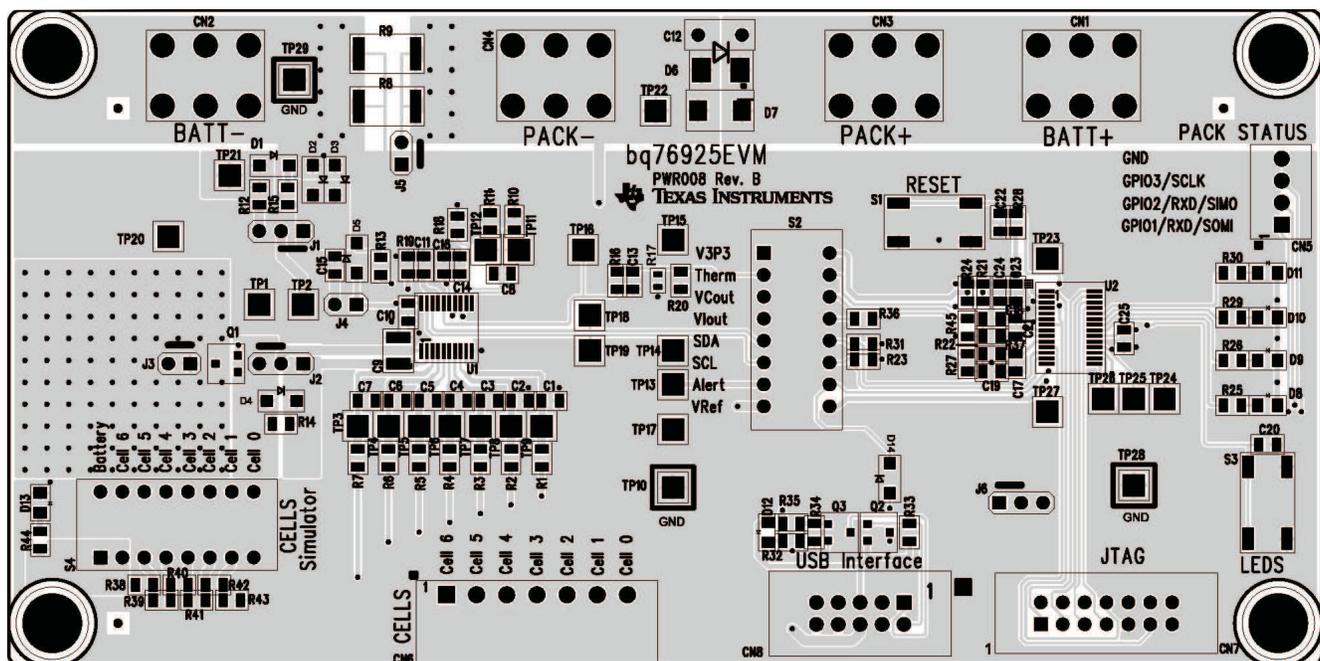
Count	RefDes	Value	Description	Size	Part Number	MFR
1	C9	10 µF	Capacitor, Ceramic, 50V, Y5V, -20%/+80%	1210	C3225Y5V1H106Z	TDK
1	C10	1.0 µF	Capacitor, Ceramic, Low Inductance, 16V, X7R, 10%	0805	Standard	Standard
1	C12	0.33 µF	Capacitor, Leaded, Metalized 40VAC, ±10%	3.0 x 7.2 mm	B32529C334K	Epcos
1	C14	470 pF	Capacitor, Ceramic, 50V, X7R, 10%	0805	Standard	Standard
1	C15	4.7 µF	Capacitor, Ceramic, 16V, X7R, 10%	0805	Standard	Standard
1	C17	470 nF	Capacitor, Ceramic, 50V, C0G, 5%	0805	Standard	Standard
1	C19	220 pF	Capacitor, Ceramic, 50V, X7R, 10%	0805	Standard	Standard
1	C23	10 µF	Capacitor, Ceramic, 10V, X7R, 10%	0805	Standard	Standard
8	C1-7 C11	1.0 µF	Capacitor, Ceramic, 25V, X7R, 10%	0805	Standard	Standard
0	C18 C21	DNP	Capacitor, Ceramic	0805	Standard	Standard
2	C20 C22	0.01 µF	Capacitor, Ceramic, 50V, X7R, 10%	0805	Standard	Standard
5	C8 C13 C16 C24-25	0.1 µF	Capacitor, Ceramic, 25V, X7R, 10%	0805	Standard	Standard
1	CN6		Header, RA 7p 300V 8A	9.2x28 mm	395021007	Molex
1	--		Plug for Header CN6		39500-0007	Molex
1	CN7		Header, 2x7 pin, 100mil spacing, Straight, 4 Wall	0.338 x 0.988 inch	N2514-6002-RB	3M
1	CN8		Connector, 10 pin Shrouded Vertical	0.388 x 0.400 inch	C-5103309-1	Tyco
1	CN5		Header, 4-pin Friction Lock, 100 mil spacing,	0.250 x 0.400 inch	22-11-2042	Molex
4	CN1-4		Terminal, PC Screw #6, 30A	0.310 x 0.507 inch	8199	Keystone
1	D2		Diode, Zener, 30V, 500mW	SOD-123	BZT52C30V-13-F	Diodes
0	D3	DNP	Diode, Zener	SOD-123	STD	Diodes
1	D4		Diode, Zener, 4.7V, 500mW	SOD-123	BZT52C4V7-13-F	On Semi
1	D6		Diode, UltraFast Rectifier, 1-A, 200-V	SMB	MURS120T3	On Semi
1	D7		Diode, Transient Voltage Suppressors 12A, 28V	0.155 x 0.180 inch	SMBJ28CA	Vishay-Liteon or Bourns
3	D1 D5 D14		Diode, Schottky, 0.5A, 40V	SOD-123	MBR0540T1G	Micro Commercial Co
6	D8-13		Diode, LED, Red, 100 mA	0805	SML-LXT0805SRW-TR	Lumen
3	J1-2 J6		Header, Male 3-pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN	Sullies
3	J3-5		Header, Male 2-pin, 100mil spacing,	0.100 inch x 2	PEC02SAAN	Sullies
6	--		Shunt, 100-mil, Black	0.100	929950-00	3M
1	Q1		Transistor, DNP Medium Power, 40V, 3A	SOT-23	ZXTP25040DFH	Exodus
1	Q2		MOSFETs, Pch, -50V, -0.13A, 10 Ω	SOT23	BSS84	Fairchild
1	Q3		MOSFETs, Nch, 50V, 0.22A, 3.5 Ω	SOT23	BSS138	Fairchild
1	R14	200K	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard

**Table 21. Bill of Materials (continued)**

Count	RefDes	Value	Description	Size	Part Number	MFR
1	R17	10K	Thermistor, NTC, 10 kΩ	0603	NCP18XH103F03RB	Murata
1	R22	4.7K	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
1	R24	10	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
1	R32	200	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
1	R36	1.0M	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
2	R10-11	1.0k	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
7	R1-7	47	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
2	R12 R15	100	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
2	R13 R16	10K	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
0	R18-20	DNP	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
2	R21 R28	47k	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
4	R23 R31 R35 R44	3.3k	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
3	R27 R37 R45	0	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
4	R30 R25-26 R29	300	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
2	R34 R33	560K	Resistor, Chip, 1/10W, 5%	0805	Standard	Standard
6	R38-43	510	Resistor, Chip, 1/8W, 5%	0805	Standard	Standard
2	R8-9	0.002	Res, Power Metal Strip, 1W, ±1%	2512	WSL-2512 2L000FEA	Vishay Dale
2	S1 S3		Switch, Micro Push Button 12V, 50mA	0.394 x 0.200 inch	FSM4JSMA	ITT
2	S2 S4		Switch, DIP, SPST, Raised rocker, 8-pos.	0.380 x 0.880 inch	76SB08ST	Grayhill
29	TP1-29		Test Point, Black, Thru Hole	0.125 x 0.125 inch	5011	Keystone
1	U1		IC, Host Controlled Analog Front End /Battery Protection and Gas Gage	TSSOP-20	BQ76925PW	TI
1	U2		IC, Mixed Signal Microcontroller	PW28	MSP430F2122IPW	TI
1	--		PCB, 6 In x 3 In x 0.062 In		PWR008	Any

## 9 Printed-Circuit Board

This section includes the plots of the printed-circuit board layers.


**Figure 23. Top Silkscreen Layer**

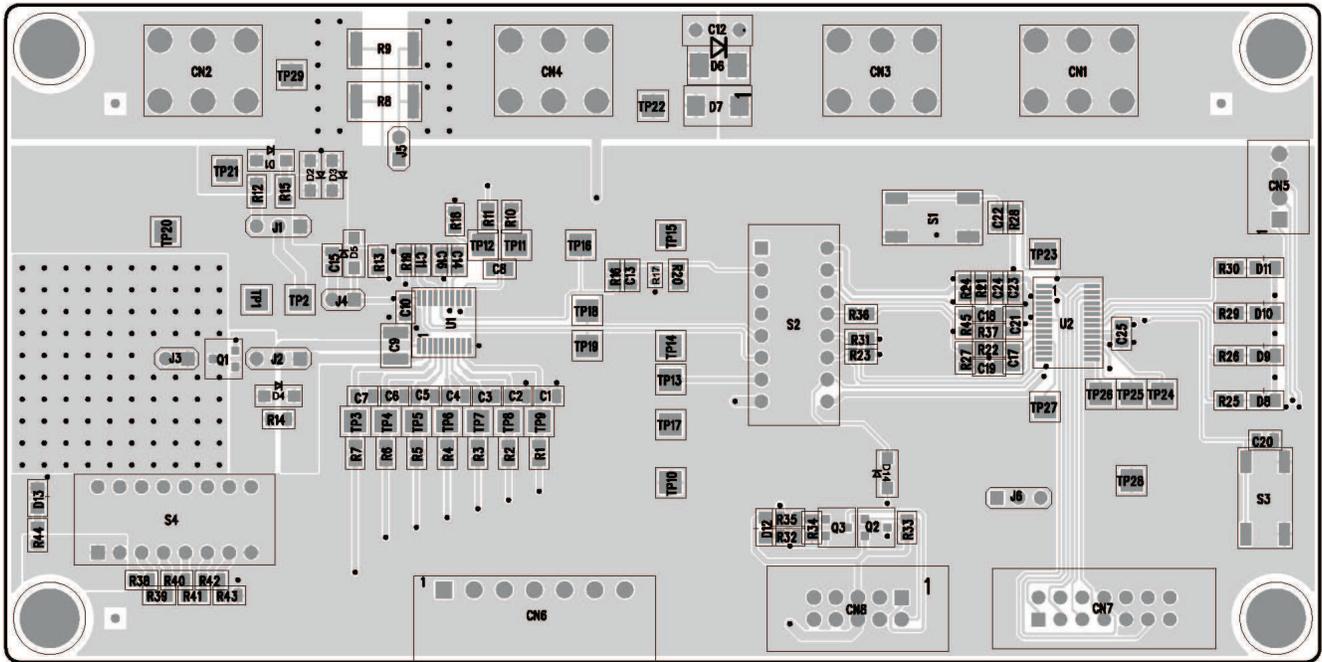


Figure 24. Top Copper Layer

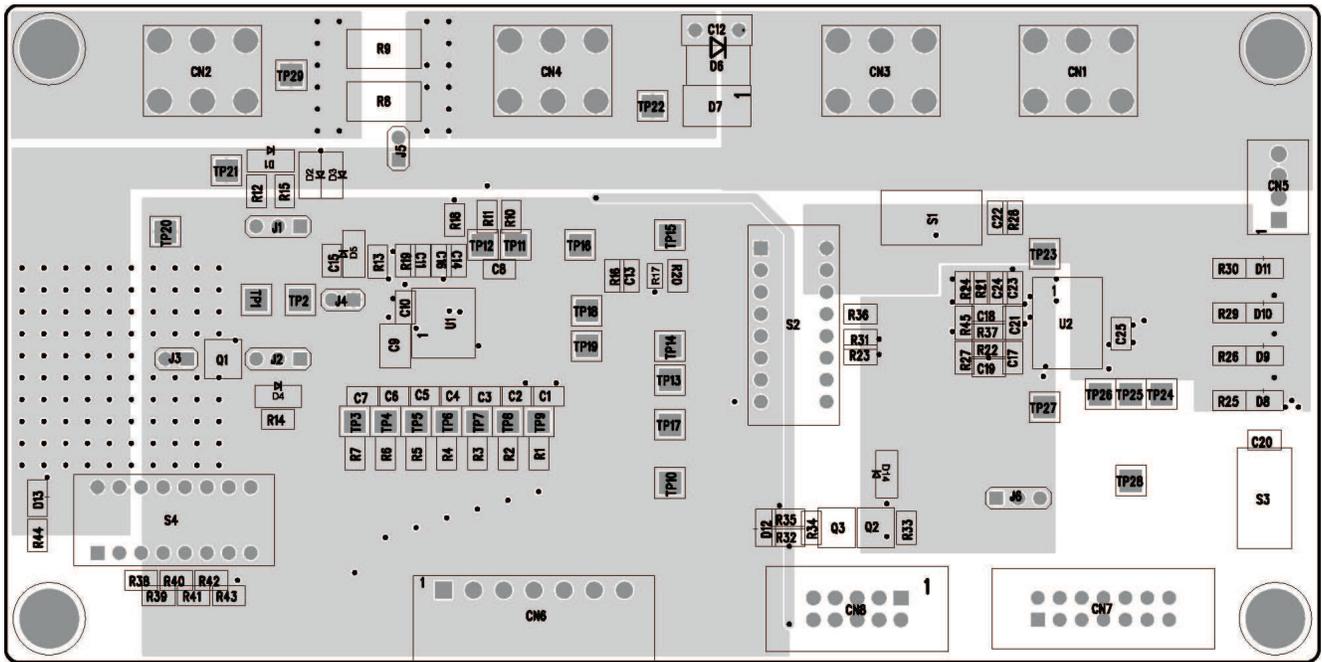


Figure 25. Inner Copper Layer

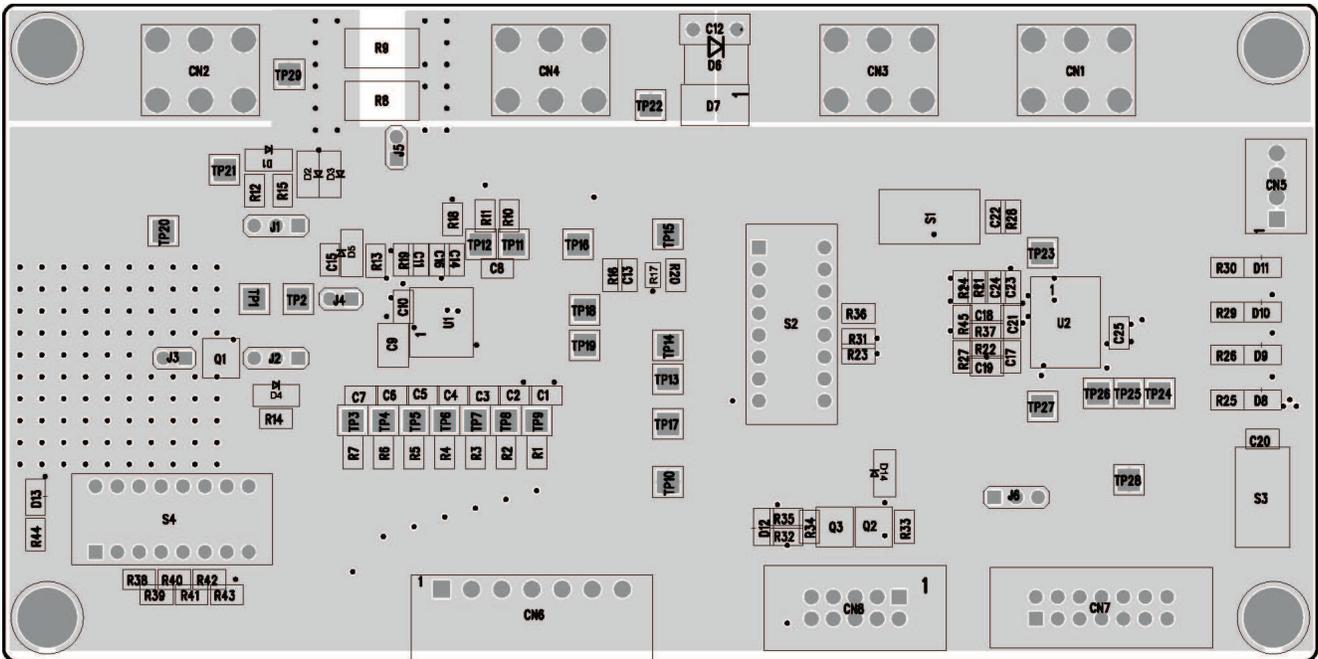


Figure 26. Inner Copper Layer

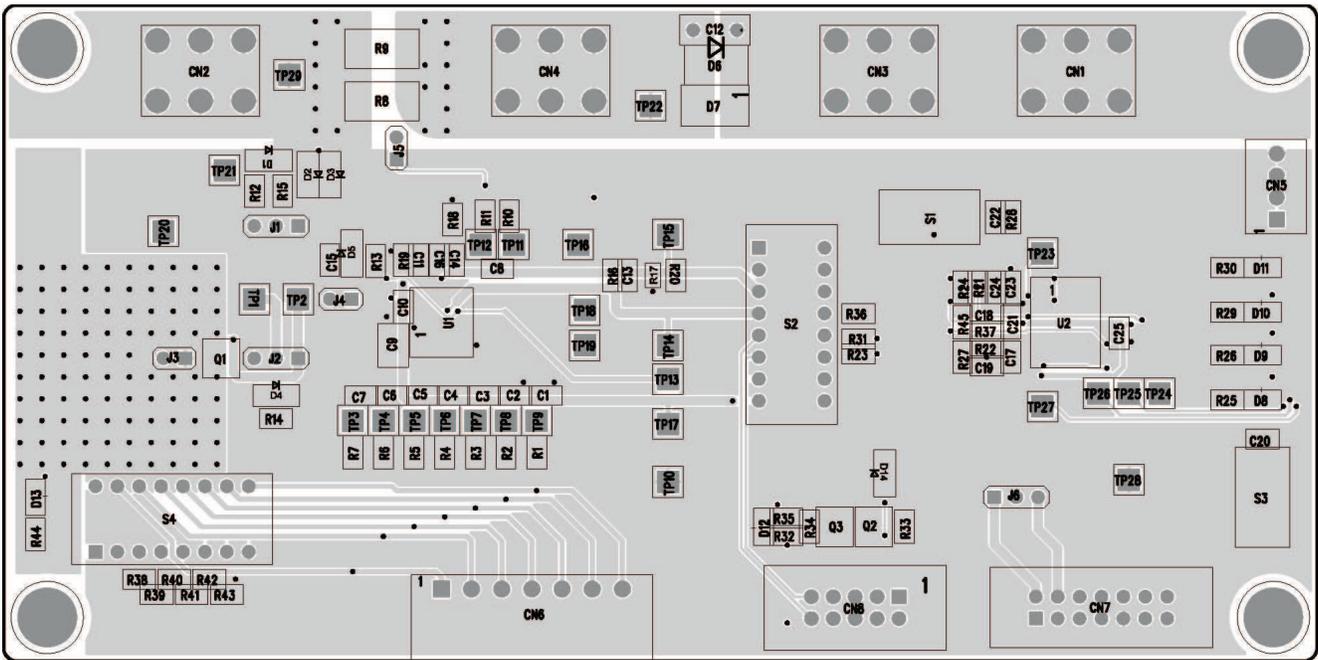


Figure 27. Bottom Copper Layer

SIZE	QTY	SYM	PLATED	TOL
38	15	+	YES	+/-0.0
37	10	X	YES	+/-0.0
40	4	□	YES	+/-0.0
47.24	7	◇	YES	+/-0.0
30	46	⊗	YES	+/-0.0
76	24	⊗	YES	+/-0.0
63	29	+ <sup>A</sup>	YES	+/-0.0
32	2	+ <sup>B</sup>	YES	+/-0.0
156	4	+ <sup>C</sup>	YES	+/-0.0
10	176	+ <sup>D</sup>	YES	+/-0.0

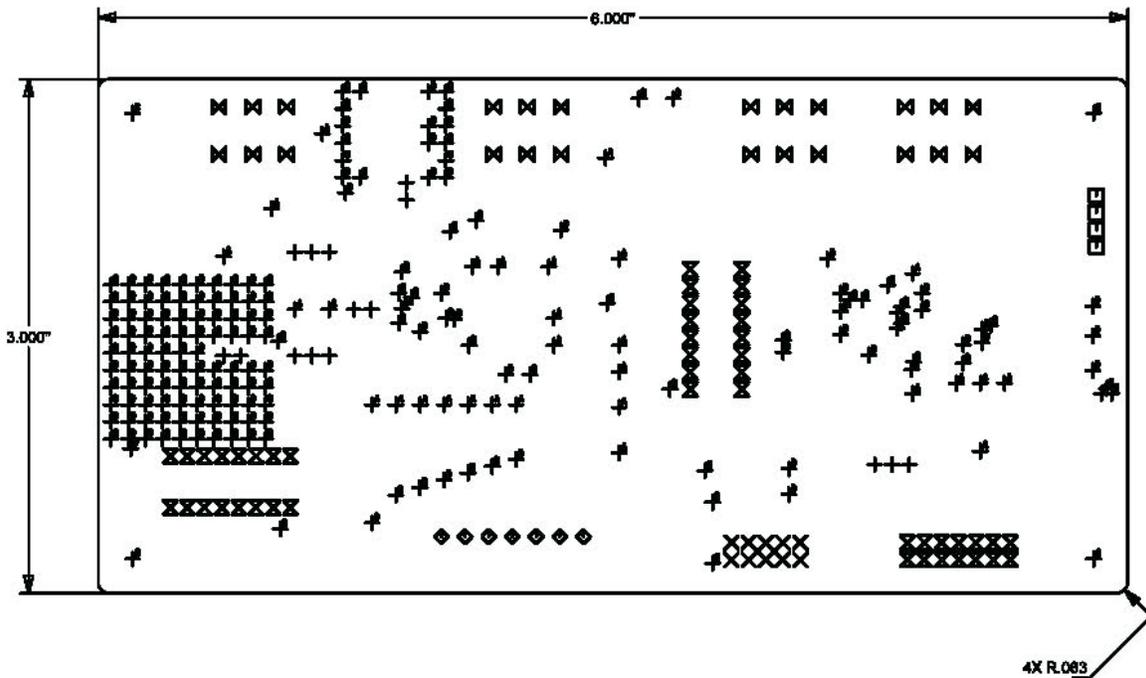


Figure 28. Drill Drawing

### Revision History

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

#### Changes from Original (July 2011) to A Revision

Page

- Added minor updates. Updated links to product folders and instructions for locating the new firmware after installing the USB-TO-GPIO software. .... 4

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**Evaluation Kits 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 shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.**

**NOTE:**

**EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.**

### 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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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。
3. 技術基準適合証明を取得後ご使用いただく。

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see [http://www.tij.co.jp/lstds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page)  
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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.

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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.

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