bq76PL455EVM and GUI User Guide

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Document History

Revision	Date	Comment
1.0	February 11, 2013	Initial Release
1.01	February 13, 2013	Updated block diagram, Figure 8 and Table of Figures
1.02	February 27, 2013	Further diagram update, minor text updates throughout document

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Overview

Scope

This document describes:

- The functionality of the bq76PL455EVM
- Setting up the bq76PL455EVM for use
- Installation of the bq76PL455 graphical user interface (GUI) on a personal computer (PC)
- Connecting and powering up the bq76PL455EVM
- Operating the bq76PL455EVM using the GUI
- Power down process

General Description

Texas Instruments' passive balancing bq76PL455EVM provides monitoring and balancing for a stack of up to 16 series connected lithium-ion battery cells. The bq76PL455EVM operates on stack voltages from 16V minimum to 80V maximum. In addition to 16 battery cell measurement channels, eight (8) additional analog channels are provided for either temperature or auxiliary signal sensing, and six (6) additional digital channels are provided. The digital channels can be optionally configured to generate faults when the level changes state, either high-to-low or low-to-high. The bq76PL455EVM typically delivers ±2 mV of channel voltage measurement accuracy over the 0 to 65°C operating temperature range (± 5 mV over -40°C to 105°C). The passive cell balancing current is set by onboard resistors to 56 mA for a 4.2V cell.

For battery stacks with more than 16 cells, up to six (6) bq76PL455EVMs can be stacked in series to support up to 96 cells. Communication with stacked bq76PLEVMs is via an isolated daisy chain differential bus capable of withstanding 500V. A stack of multiple bq76PL455EVMs can be woken from power down using a single wake command from the GUI. System faults are monitored and indicated in the GUI by simulated LED fault indicators.

A single or multiple stacked bq76PL455EVM(s) can be controlled using a PC-hosted GUI. Communication between the PC and the lowest in a stack of bq76PL455EVMs is via an FTDI USB to TTL (5V) serial interface cable. Communication between all other bq76PL455EVMs in the stack is via the isolated, daisy chain differential communication bus running at a speed of 8MHz. The PC GUI allows the bq76PL455EVMs to be configured to monitor cells, control balancing, and monitor details of any faults.

The bq76PL455EVM (shown in Figure 1 - bq76PL455EVM) demonstrates the performance of Texas Instrument's new highly integrated bq76PL455 16-cell, battery stack monitoring, passive balancing device. The bq76PL455 provides a highly accurate, reliable, and robust solution for battery management, integrating all of the following components:

- 14-bit Analog to Digital Converter (ADC)
- Precision voltage reference
- Precision, high-voltage Analog Front End (AFE)
- Universal asynchronous receiver/transceiver (UART) serial communication interface
- LDO voltage regulator
- Control logic for monitoring, balancing, and communication functions

Features

- 16-channel precision voltage cell monitoring and passive balancing
- 8-channel temperature or auxiliary signal monitoring
- 6-channel digital signal monitoring, with optional fault monitoring
- Isolated serial communications

- Stackable to support up to 96 cells

Electrical Characteristics

- Operating voltage range 16 to 80V
- Measures up to 16 cells from 1 to 5V
  - Absolute maximum cell open circuit voltage 5.5V
- High channel accuracy
  - ±2 mV 0 to 65°C typical
  - ±5 mV -40°C to 105°C typical
- Balancing current up to 56 mA at 4.2V
- Operating temperature -40°C to 105°C

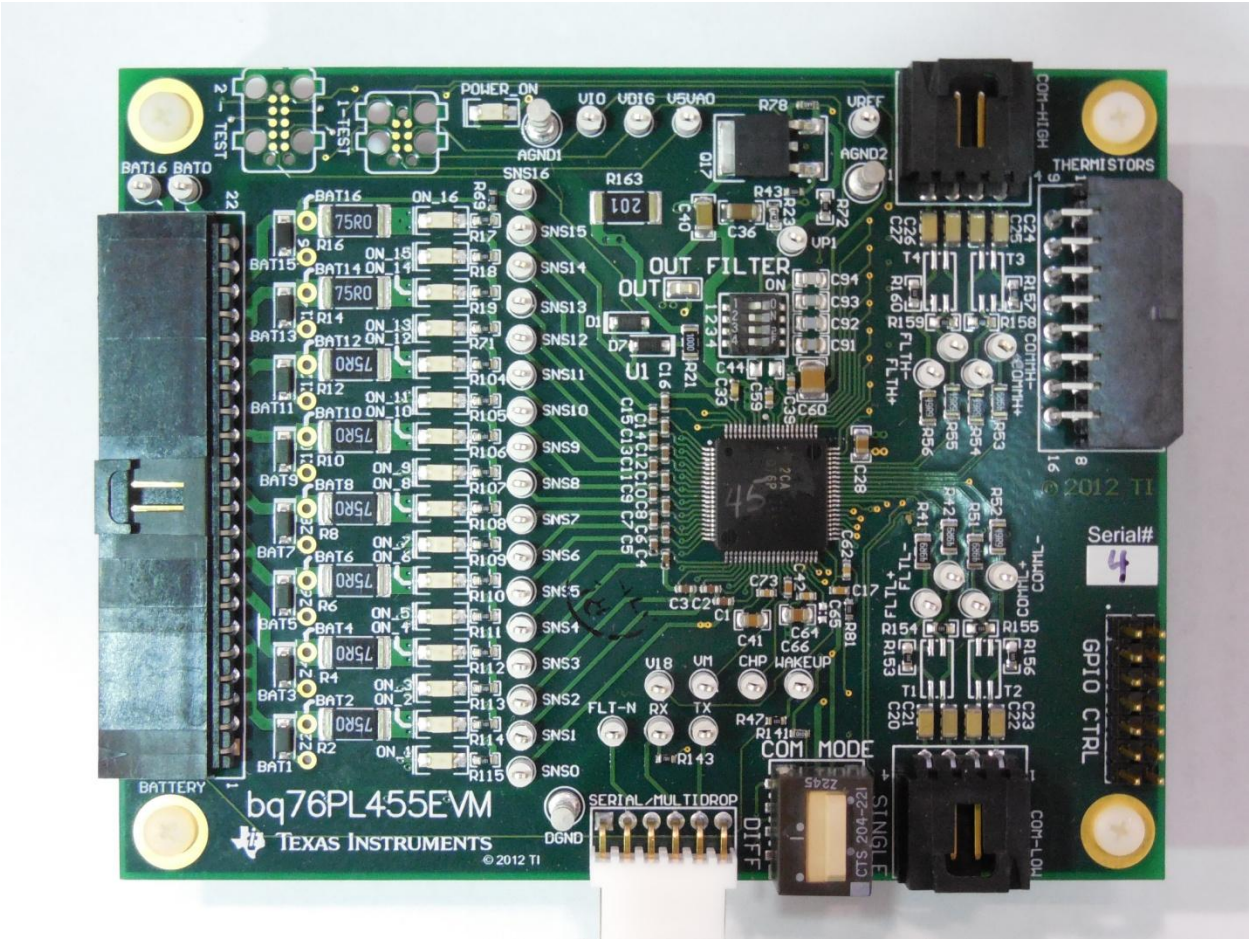

Figure 1 - bq76PL455EVM

Application

Texas Instrument's integrated passive balancing reference design is designed to monitor and balance battery cells to ensure safe and reliable operation. Energy storage systems can be severely impacted by improper management of the charge and discharge cycles of the employed battery cells. Over time, charge and discharge cycling causes individual variations in the voltage, charge capacity, and internal impedance of the battery pack cells leading to reduced effective capacity and lower efficiency.

If cells are mismatched by charge/discharge cycling, aging, or errors in manufacturing, they can be easily pushed beyond their rated operating voltage range by further charge/discharge cycles, causing permanent damage and compromising pack performance. Using the bq76PL455 monitoring and balancing system, the individual battery pack cells can be brought to the same voltage to optimize battery pack charge storage, lifetime, and application run time on a single charge.

The bq76PL455EVM implements the following functions:

- Cell voltage monitoring
- Cell UV and OV comparators
- Cell balancing
- Temperature/auxiliary signal monitoring
- Embedded control
- Fault monitoring
- Isolated differential daisy chain communications
- PC serial communications
- General Purpose I/O
- Power supply

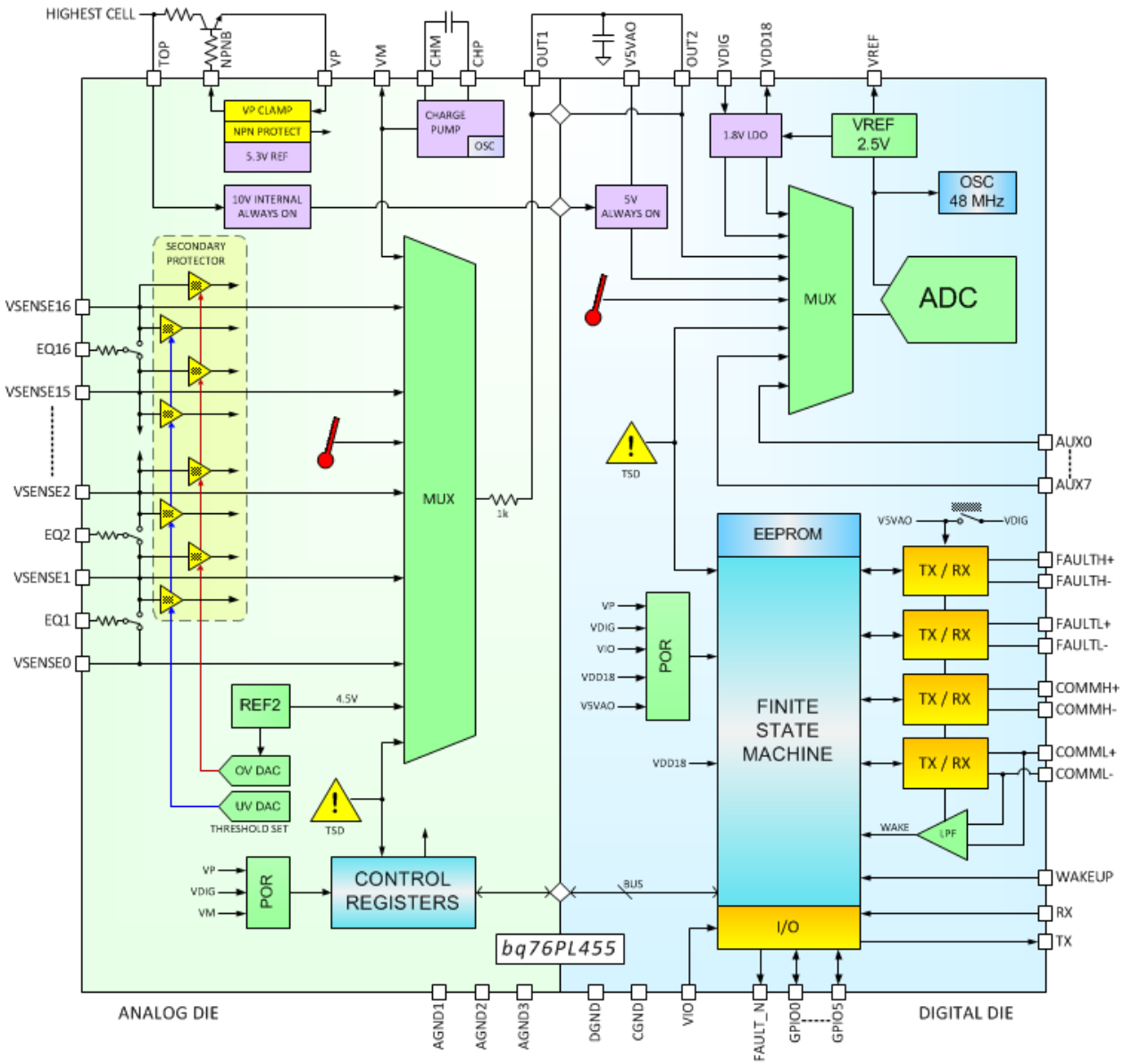

Figure 2 - bq76PL455 Functional Block Diagram

Cell Voltage Monitoring

Texas Instruments' bq76PL455 integrated balancing solution supports high-accuracy, high-speed cell voltage measurement. The whole measurement subsystem is designed for high-accuracy measurements while providing low-power operation. The cell monitoring block utilizes a high-voltage, high-accuracy AFE and a 14-bit ADC. The bq76PL455 is capable of monitoring up to 16 cells from a minimum stack voltage of 16V up to a maximum stack voltage of 80V. Each channel can measure cell voltage over an operating range of 1 to 5V.

The bq76PL455 can be programmed to sample any combination of its selected channels in descending order, with sampling times between 4.13 µs and 1000.08 µs. To reduce noise on measurements, the bq76PL455 can be set to oversample up to 32 times and respond back with the average sampled value from each channel during the oversampling. Using the PC GUI, the bq76PL455EVM can be set to continuously poll the programmed channels at various rates, depending on the oversampling period

selected. Cell under- and over-voltage limits can be set on the cell voltage measurements, causing fault register bits to be set. Active faults can be selectively programmed to trigger the bq76PL455 /FAULT output pin if a limit is exceeded.

Cell Under- and Over-Voltage Comparators

An independent bank of comparators with their own separate under- and over-voltage limits provides additional cell voltage monitoring and /FAULT line control.

Temperature and Auxiliary Signal Monitoring

Texas Instruments' bq76PL455 supports eight temperature/auxiliary channels. The bq76PL455EVM implements a connector for all of these channels, in order to allow the user to test remote temperature and auxiliary signal monitoring. Negative thermal coefficient (NTC) thermistors and/or external signals can be connected to the bq76PL455EVM's 8x2 pin right angle temperature sense THERMISTORS connector. Separate under- and over-voltage limits can be set for each of the 8 temperature/auxiliary channels. If these limits are reached, a fault will be flagged.

10K pull up resistors are fitted to support NTC use. Depending on the application and need, the user can choose their own thermistors, changing the 10K pull up resistors as required.

Cell Balancing

Based on the cell voltage data, the main system controller can determine when individual cells reach their maximum limit during charging. Without passive balancing, if an individual cell reaches its maximum voltage, then stack charging should stop to prevent overcharging and damaging that cell. However, that leaves other cells in the same series string less than 100% charged if all of the cells are not evenly matched and do not reach maximum charge at the same time. Premature termination of stack charging due to an individual cell reaching maximum voltage leaves the stack inefficiently charged to less than its theoretical maximum. With passive balancing, a switchable external shunt resistor across each cell is used to discharge cells and limit the voltage of individual cells already at maximum voltage to allow further charging of the battery pack and raising all the cells to their maximum state of charge. Passive balancing allows the battery stack to be charged to its true maximum potential.

Each of the 16 battery channels on the evaluation module incorporates an external N-channel MOSFET in series with a shunt 75Ω 1W resistor across the battery cell. A secondary load is also incorporated in the form of an LED which will light when the MOSFET is on and balancing is active. The 16 N-channel MOSFETs are controlled by 16 EQ lines from the bq76PL455 and allow each battery to be independently balanced as determined from the cell voltage measurements.

To balance an individual cell, the EQ line for the N-Channel MOSFET on the selected channel is driven high. Once it is turned on, current flows through the shunt resistor and LED circuit to dissipate excess charge. The standard bq76PL455EVM is supplied with 16 x 75Ω 1Watt (@ 25C° ambient) shunt resistors which will give 56 mA balancing current for a cell at 4.2V. The shunt resistor values can be made smaller or larger to suit application requirements. Minimum resistor value and maximum balancing current are limited only by the 1W (@ 25C°) power rating of the individual 2512 size balancing resistors and resulting PCB temperature when all 16 balancing resistors are on.

Embedded Controller

The bq76PL455 incorporates control logic to manage serial communications with the PC or main system controller to control the monitoring and balancing functions and to respond back to the PC or main system controller with requested data.

The bq76PL455 embedded controller uses both EEPROM and RAM to store control register values. EEPROM stores the control registers during power down and on waking. These EEPROM register values

are loaded into RAM where they are used during operation. The RAM value can be written to and modified by the main system controller or PC GUI in the case of the evaluation module.

New register settings written into RAM by the system controller can be written back to EEPROM on the bq76PL455 IC if required to be automatically loaded on the next power cycle. In the final product, the EEPROM is not required to be written frequently, and therefore, the bq76PL455 EEPROM is designed with limited endurance write cycles unsuited to the evaluation module environment.

Consequently, writing RAM register values back to EEPROM is disabled on the evaluation module and the user can store their own register configurations on the PC as .reg files. These can then be restored manually as required, such as after a power cycle. Alternatively, new configurations for the bq76PL455 can be written to RAM directly after any new power cycle using the user controls in the GUI.

Communications

Communication between the PC GUI and the first bq76PL455EVM is done via a USB to TTL Serial converter cable. This cable connects to the SERIAL/MULTIDROP connector on the bq76PL455EVM. Communication between all subsequent stacked bq76PL455EVMs is done over isolated, differential twisted pair, daisy chained communication lines connected between the COM-LOW and COM-HIGH connectors of neighboring bq76PL455EVMs. The communication rate between the PC and the first of potentially multiple stacked modules is adjustable to various baud rates from 125K to 1M, whereas the communication rate over the daisy chain link is fixed. The typical minimum bit period over the daisy chain link is 125ns (8MHz). Communication over the differential daisy chain link is transparent to the user via the GUI, as the conversion between the single-ended communications link and the differential communications link is handled in hardware by the bq76PL455.

Communication is mastered by the PC GUI using a command and response protocol which allows the GUI to configure and read back data from slave bq76PL455 evaluation modules. Under the command and response protocol, communication with the bq76PL455EVM(s) is always initiated by the GUI which issues a command frame. Command frames can be addressed to either an individual bq76PL455, sent as a broadcast to a pre-specified group of consecutively addressed bq76PL455 devices, or sent as a general broadcast to all bq76PL455 devices on the COM-LOW and COM-HIGH bus. Not all command types are currently supported by the GUI for demonstration.

The following six types of command frames are supported by the bq76PL455:

1. Write to a single bq76PL455 causing a returned response (i.e. essentially a “read” command).
2. Write to a single bq76PL455 with no response.
3. Write to a pre-defined group of bq76PL455 devices to generate a series of responses (device with highest address in group responds first).
4. Write to a pre-defined group of bq76PL455 devices without a response request.
5. Write to all connected bq76PL455 devices to generate a series of responses (device with the highest address responds first).
6. Write to all connected bq76PL455 devices with no responses generated.

The GUI currently uses command types 1, 2 and 6 from the afore-mentioned list during its operation.

On the bq76PL455EVM, high-voltage isolation is provided on all of the twisted pair differential communication links between each stacked evaluation module.

The serial bus allows Command data frames to be transmitted by the PC and to be received by all bq76PL455EVMs. Response frames, when requested, will be transmitted by any addressed bq76PL455EVM back to the PC.

Since response frames are only ever sent in response to command frames, a single physical pair of wires is used to communicate between any two neighboring bq76PL455 devices in a half duplex manner to

alternately send and receive data. The physical differential pair connections are implemented using capacitive-coupling and are designed to meet the needs of wired differential communications in automotive applications.

For battery systems with more than 16 cells where multiple bq76PL455EVMs are stacked, each evaluation module must have a unique address. Although the bq76PL455 IC allows addresses to be set either with the GPIO lines in hardware or via software, the evaluation module and GUI are by default auto-addressed by the GUI when the GUI starts. If more than one evaluation module is connected, bq76PL455EVMs will be auto-addressed with addresses from 0 to n-1, where n is the number of modules connected. The bq76PL455EVM connected to the PC will be address 0, the first daisy-chained evaluation module will be at address 1, the second daisy-chained evaluation module will be at address 2, and so on.

When polling and balancing, the GUI can communicate with multiple bq76PL455EVMs in a stacked configuration and log the data received from these evaluation modules to log files stored on the PC, but the GUI allows data from only a single bq76PL455EVM to be viewed in real time. To switch the real time view to another bq76PL455EVM, polling and balancing must be stopped, and the user must select a new evaluation module address from the Board Address pull-down menu on the *Setup* tab, then re-enable polling and/or balancing.

Fault

When a fault condition is detected, the bq76PL455 will communicate the fault back to the host PC on the /FAULT pin. Faults from evaluation modules higher in the daisy chain stack are communicated to the bottom (i.e. lowest address) evaluation module using the FAULT +/-differential signal pairs on the COM HI and COM LO connectors. In the case of the bottom bq76PL455, the single-ended active low /FAULT signal will be driven low whenever a fault is detected. Since a single virtual /FAULT line is shared by all bq76PL455 devices, in the final application the /FAULT line going low should trigger the system controller to start sending commands to discover which bq76PL455 detected the fault and understand the nature of that fault so it can take appropriate action.

Currently, the daisy-chained /FAULT signal terminates at the lowest evaluation module and the line status can be measured at pin 2 of the SERIAL/MULTIDROP connector. Additionally, a FLT-N test pin is also provided. The GUI automatically polls the fault registers of the bq76PL455 to show current status of all unmasked faults.

Wake and Power Down

The bq76PL455 has two power states, *On* and *Off*. The power down state is controlled by a hardware wake signal and a “wake up tone” on the differential twisted pair communications link between multiple evaluation modules. In single-ended mode, the bq76PL455 uses the WAKEUP signal (pin 49) as the wake input. When this pin on the bq76PL455 is driven high (using an inverted signal on the SERIAL/MULTIDROP connector), the bottom module in a daisy chain configuration will power on and generate a “wake up tone”. This tone will be sent to other modules via the differential communication bus. This in turn causes all modules in differential mode to also power on. To power down, the POWER_DOWN bit in the Device Control Register (address 11) is set by sending a Broadcast Command to the all bq76PL455 devices on the stack while the WAKEUP pin is low on the bottom module.

Power Supplies

The bq76PL455EVM is powered from the top of the cell stack being monitored and balanced, which may range from 16 to 80V. Although several options to post-regulate this high voltage supply down the bq76PL455’s integrated linear voltage regulator can be implemented, the bq76PL455EVM implements a simple drop down voltage divider. This provides the best low noise performance at the expense of higher

bq76PL455EVM current compared to an implementation in which a switching buck converter is used. A switching buck converter would optimize efficiency, but compromise noise performance.

The bq76PL455 linear voltage controller uses an external NPN power transistor to regulate a 5.3V output supply at VP1. The VP1 supply then drives the VDIG digital supply on the bq76PL455. A separate external VIO supply line into the bq76PL455 is provided by the PC host via pin 3 on the SERIAL/MULTIDROP connector. Although it is possible to externally supply the VDIG digital supply, it is not recommended to do so on the bq76PL455EVM.

The bq76PL455 also produces a regulated 1.8V supply for internal use and a 2.5V reference for use by the integrated 14-bit ADC.

Hardware

Switches

There are 2 DIP switch packages on the bq76PL455EVM. The DIP packages provide five levers, and these should be configured prior to application of bq76PL455EVM power. The switch package designations are:

- OUT FILTER switch package
- COM MODE switch package

WARNING: Changing switch lever positions with power connected to the evaluation module can cause damage to the bq76PL455EVM!

The operation of the switch packages are detailed in the following sub-sections.

OUT FILTER

This 4-position DIP switch is used to connect different capacitor values to OUT2, the output of the AFE before it enters the 14-bit ADC for conversion. This allows different single-pole low pass filters to be used in the signal path depending on the sampling speed of the ADC selected in the GUI.

NOTE: The current version of the GUI sets the default sample speed to 99.92uS. Please be sure to set the corresponding OUT FILTER selection switch to the proper setting to select the 4.7nF capacitor to match the GUI setting if it has been moved from the default setting.

Switch positions on the OUT FILTER selection switch package are marked with the numbers '1' through '4' on one side of the package, and marked with the word "ON" on the other side of the switch package.

The following table shows how to set switches for the various selectable sample rates. An 'x' means the indicated switch(es) should be set toward the "ON" side of the switch package.

OUT FILTER	99.92uS	60.04uS	40.10uS	30.02uS	24.98uS
Switch 1	x	x			
Switch 2	x		x	x	x
Switch 3	x		x		
Switch 4	x			x	

By setting the switch package switches as indicated above, the capacitor values associated with each sample rate are as follows:

- 99.92uS 4850pF
- 60.04uS 2700pF
- 40.10uS 1760pF

- 30.02uS 1590pF
- 24.98uS 1200pF - Not recommended (see note)

NOTE: Although selectable in the current version of the GUI, selection of sample rates faster than 24.98uS (19.94uS, 17.42uS, 14.90uS, 12.60uS, 10.08uS, 8.02uS, 5.96uS or 4.13uS) are not recommended at this time due to potential loss in accuracy at those sample rates. Recommended sample rates are 99.92uS, 60.04uS, 40.10uS, 30.02uS and in some cases 24.98uS.

COM MODE

This switch package has a single lever to control multiple connections. The purpose of the ganged switches controlled by the switch lever is to configure the low-side interface of the bq76PL455 between single-ended and differential modes. There are two labels, one on either side of the COM MODE switch: "SINGLE" and "DIFF". When the bq76PL455EVM is to be connected directly to a PC, then the COM MODE switch should be set so the lever is in the SINGLE mode position. On the other hand, if the bq76PL455EVM is to occupy the second or higher position in a stack of evaluation modules, then the COM MODE switch lever should be set to the DIFF mode position.

For Differential Mode, move the switch lever toward the DIFF label.
For Single-Ended Mode, move the switch lever toward the SINGLE label.

WARNING: Differential mode is the only allowed position when using the differential daisy-chain communication interface on stacked bq76PL455EVMs!

WARNING: Single-Ended mode is an un-isolated connection for PC communication and should not be used on stacked bq76PL455EVMs occupying positions 2 or higher in the stack!

Connectors

The following connections are provided on the bq76PL455EVM:

- 22-pin BATTERY connector
- 4-pin differential serial communications COM-LOW connector (to connect to lower bq76PL455EVM in daisy chain)
- 4-pin differential serial communications COM-HIGH connector (to connect to higher bq76PL455EVM in daisy chain)
- 6-pin single-ended SERIAL/MULTIDROP communications connector
- 16-pin (8x2) dual row THERMISTORS connector
- 14-pin (7x2) GPIO CTRL header

BATTERY Connector

The battery cell connections are made with a Molex connector as detailed in the table below. Cell voltage measurements and balancing currents are transmitted across these connections. Unused cell monitoring channels must be shorted to the top cell connection in the wiring harness.

The mating connector from Molex Connector Corporation is part number 50-57-9422.
Digikey Corporation: WM2920-ND.

The crimp pin for this mating connector from Molex Connector Corporation is part number 16-02-0088 or 16-02-0104.
Digikey Corporation: WM2564TR-ND or WM2564CT-ND or WM2564-ND.

The part number for the crimper to create custom cables using the above parts from Molex Connector Corporation is: 63811-8700.
Digikey Corporation: WM9017-ND.

NOTE: BAT 16S and BAT0S are the monitoring and balancing connections to the top and bottom of the stack. BAT 0 and BAT 16 are the top and bottom of the stack connections used to power the evaluation module.

Battery Connector Pin Assignments	
Connector Pin	**Pin Function**
1	BAT0
2	BAT16
3	BAT0
4	BAT0S
5	BAT1
6	BAT2
7	BAT3
8	BAT4
9	BAT5
10	BAT6
11	BAT7
12	BAT8
13	BAT9
14	BAT10
15	BAT11
16	BAT12
17	BAT13
18	BAT14
19	BAT15
20	BAT16S
21	BAT16
22	BAT0

NOTE: All signals with like names are connected together on the bq76PL455 PCB.

COM-LOW and COM-HIGH Connectors

The 4-pin COM-LOW and COM-HIGH connectors house the two isolated twisted pair differential communication signal pairs used to interconnect stacked bq76PL455EVMs. The two differential pairs at pins 1 to 4 of the lower module's COM-HIGH connector always connect to the two differential pairs at pins 4 to 1 of the next higher module's COM-LOW connector, respectively. For each twisted pair connection, the "xxL+" signal of one bq76PL455EVM is connected to the "xxH+" signal of the neighboring bq76PL455EVM, and the "xxL-" signal of one bq76PL455EVM is connected to the "xxH-" signal of the neighboring bq76PL455EVM. The two twisted pair signals are ISO-COMM +/- and ISO-FAULT +/-.

The tables below identify the pin assignments on the COM-LOW and COM-HIGH connectors. Pins 1 and 4 are marked on the silkscreen associated with the COM-LOW and COM-HIGH connectors on the bq76PL455EVM. Additionally, on both the COM-LOW and the COM-HIGH connector, pin 1 has a square pad on the bottom of the bq76PL455EVM.

COM-LOW Connector Pin Assignments	
Pin Number	Pin Function
1	ISO COMML-

2	ISO COMML+
3	ISO FAULTL-
4	ISO FAULTL+

COM-HIGH Connector Pin Assignments

Pin Number	Pin Function
1	ISO FAULTH+
2	ISO FAULTH-
3	ISO COMMH+
4	ISO COMMH-

NOTE: All signals ending in "H+" or "H-" connect with the next higher module, and all signals ending in "L+" or "L-" connect with the next lower module. In the event of no "next module", the pins should be left unconnected.

The mating connector from Molex Connector Corporation is part number 50-57-9404.
Digikey Corporation: WM2902-ND.

The crimp pin for this mating connector from Molex Connector Corporation is part number 16-02-0088 or 16-02-0104.
Digikey Corporation: WM2564TR-ND or WM2564CT-ND or WM2564-ND.

The part number for the crimper to create custom cables using the above parts from Molex Connector Corporation is: 63811-8700.
Digikey Corporation: WM9017-ND.

SERIAL/MULTIDROP Connector

The 6-pin SERIAL/MULTIDROP connector is used to connect the bq76PL455EVM to a PC running the GUI. Signals at the SERIAL/MULTIDROP connector are 5V TTL signals. Texas Instruments recommends the use of FTDI's USB to TTL Serial converter cable to allow connection with a PC's USB port. The recommended cable is available from FTDI (http://www.ftdichip.com), and the appropriate part number for the 1.8 meter cable is TTL-232R-5V.

The following table provides the SERIAL/MULTIDROP connector pin assignment.

NOTE: The /WAKE signal from the PC is inverted on the bq76PL455EVM before being directed to the bq76PL455.

Serial Connector Pin Assignments

Pin Number	Pin Function	Mating Cable Color
1	Ground	Black
2	/FAULT signal from bq76PL455	Brown
3	5V input from PC	Red
4	RX from PC to bq76PL455	Orange
5	TX from bq76PL455 to PC	Yellow
6	/WAKE signal from PC	Green

THERMISTORS Connector

There is provision for connecting up to eight thermistor signals via a 16-pin 8x2 right angle connector to the bq76PL455EVM. The bq76PL455EVM provides a 10K pull-up resistor to VP1, the on-board 5.3V regulated supply, for each AUX input channel. Each connector pin also has a 10 Ohm series resistor and a 0.1µF filter capacitor.

The THERMISTORS connector pin assignment is detailed in the following table.

Thermistor Connector Pin Assignments	
Pin Number	Pin Function
1	Ground (AGND1)
2	Ground (AGND1)
3	Ground (AGND1)
4	Ground (AGND1)
5	Ground (AGND1)
6	Ground (AGND1)
7	Ground (AGND1)
8	Ground (AGND1)
9	AUX0 (Thermistor 1)
10	AUX1 (Thermistor 2)
11	AUX2 (Thermistor 3)
12	AUX3 (Thermistor 4)
13	AUX4 (Thermistor 5)
14	AUX5 (Thermistor 6)
15	AUX6 (Thermistor 7)
16	AUX7 (Thermistor 8)

NOTE: Pins number assignments on the THERMISTORS connector is such that, when looking into the mouth of the connector, the bottom of row of the connector is numbered 1-8 from right to left, and the top row of the connector is numbered from 9-16 from right to left. Pin 1 on the connector has a square pad on the bottom of the PCB. Additionally, pins 1, 8, 9 and 16 are labeled with silkscreened numbers.

The mating connector from Molex Connector Corporation is part number 43025-1600.
Digikey Corporation: WM2490-ND.

The crimp pin for this mating connector from Molex Connector Corporation is part number 46235-5001 (or 46235-5002).
Digikey Corporation: WM2258TR-ND or WM2258CT-ND. (An alternate base number for different plating option is WM2259.)

The part number for the crimper to create custom cables using the above parts from Molex Connector Corporation is: 63819-2900.
Digikey Corporation: WM4747-ND.

GPIO CTRL Header

The bq76PL455 implements six General Purpose Input/Output (GPIO) signals. The bq76PL455EVM provides the user access to these GPIO pins (in addition to the VIO supply and DGND) at the 14-pin 7x2 unshrouded GPIO CNTRL header. The GPIO pins can be configured as input or output by writing to specific configuration registers in the bq76PL455. Additionally, the user can program configuration

registers to choose internal pull-up or pull-down resistors for any of the GPIO pins. Digital input signals can be read by reading the *General Purpose Input* register, and digital output values can be set by writing to the *General Purpose Output* register in the bq76PL455. These registers can be written and read using the *Register View* window from the GUI (see the appropriate *Setup* tab section elsewhere in this User Guide). The data sheet and can provide additional details.

When configured as inputs, the GPI can also be selectively programmed to generate fault signals when changing state either from digital high to low or from digital low to high. This configuration can be done on the Fault Mask tab in the GUI, and triggered faults can be viewed on the Faults tab.

The following table shows pin assignments for the GPIO CTRL header.

GPIO Header Pin Assignments	
Pin Number	**Pin Function**
1	GPIO0
2	Ground (DGND)
3	GPIO1
4	Ground (DGND)
5	GPIO2
6	Ground (DGND)
7	GPIO3
8	Ground (DGND)
9	GPIO4
10	Ground (DGND)
11	GPIO5
12	Ground (DGND)
13	VIO
14	Ground (DGND)

NOTE: The GPIO CTRL header is a 7x2 dual row unshrouded header. Pin 1 has a square pad on the underside of the PCB, and the silkscreen for the header indicates pin 1 with a small white dot. All even numbered pins are on one, and all odd numbered pins are on the other, row of the header.

Test Points

Following is a list of test points provided on the evaluation module:

Name	Description
BAT16	Positive terminal of cell 16
BAT0	Negative terminal of cell 1
SNS0-SNS16	Connected to Vsense0-16 on bq76PL455
VP1	Regulated 5.3V supply
VDIG	Digital 5V supply (connected to VP1)
V5VAO	5V output from bq76PL455
AGND1	Local analog ground
AGND2	Quiet analog ground
OUT2	AFE analog output from bq76PL455
VREF	2.500V precision reference output from bq76PL455
VIO	I/O supply (connected to VIO pin on the bq76PL455)
DGND	Local digital ground
VM	-5V charge pump output from bq76PL455
CHP	Charge pump flying capacitor connection
V1.8	1.8V output from bq76PL455

WAKEUP	The single-ended, active high wake pin to the bq76PL455
FLT-N	The single-ended, active low fault pin from the bq76PL455 (to the PC)
RX	The single-ended serial data receive pin on the bq76PL455 (data from PC)
TX	The single-ended serial data transmit pin on the bq76PL455 (data to the PC)
COMMH+	Half of the differential pair communicating data to and from the lower of two neighboring bq76PL455EVMs to the next higher bq76PL455EVM
COMMH-	Half of the differential pair communicating data to and from the lower of two neighboring bq76PL455EVMs to the next higher bq76PL455EVM
COMML+	Half of the differential pair communicating data to and from the higher of two neighboring bq76PL455EVMs to the next lower bq76PL455EVM
COMML-	Half of the differential pair communicating data to and from the higher of two neighboring bq76PL455EVMs to the next lower bq76PL455EVM
FAULTH+	Half of the differential pair receiving fault information from the next higher bq76PL455EVM
FAULTH-	Half of the differential pair receiving fault information from the next higher bq76PL455EVM
FAULTL+	Half of the differential pair transmitting fault information to the next lower bq76PL455EVM
FAULTL-	Half of the differential pair transmitting fault information to the next lower bq76PL455EVM

Getting Started with the bq76PL455EVM

The following sequence is recommended to use the bq76PL455 evaluation module:

1. Install the GUI on the PC.
2. Configure the bq76PL455EVM DIP switches.
3. Connect the bq76PL455EVM to the PC and battery stack.
4. Start the GUI and configure the bq76PL455 control registers. Start polling and balancing.
5. Stop polling, stop balancing and exit GUI.

These steps are detailed in the next sections.

Software Drivers

An FTDI FT232R USB to UART adapter driver is needed to connect to the passive balancing evaluation module to a PC. It can be downloaded at **www.ftdichip.com/Drivers/VCP.htm**, or it will be installed automatically as part of the cable install when installing the TTL-232R-5V from FTDI.

GUI

Included with the Texas Instruments passive balancing evaluation module is a PC GUI. The GUI is used to configure the evaluation module, read out and log all cell voltage data, control balancing, and manage faults.

The following are the primary parameters configurable in the GUI:

- Number of batteries/series cells in each module
- Min and max of cell voltage
- Over- and under-voltage limits
- Fault conditions

Recommended PC Requirements

- Windows XP system and above
- Intel Core2 Duo at 2 GHz
- 1 GB RAM

- 1024 x 768 display
- 4 MB hard drive space
- USB 2.0 port

Installation Instructions

Extract all files/folders in the provided .ZIP file. This will create a sub-folder on your system containing two files:

- *bq76PL455_GUI_Installer.msi*
- *setup.exe*

Run the *setup.exe* file included with the passive balancing evaluation module, making sure both of the afore-mentioned files are in the same directory. The *setup.exe* install utility will guide you through the installation process. After the software is installed, a shortcut called *bq76PL455_RevC_GUI* will be placed on the desktop. Additionally, the GUI and an Uninstall Utility will be accessible from the Windows Start Menu under:

Start -> Programs -> Texas Instruments -> bq76PL455-RevC GUI -> bq76PL455_RevC_GUI.exe

NOTE: If upgrading from a previous version of GUI, the previous version should be uninstalled prior to installation of the new version. This can be done easily by selecting the Uninstall utility from the same Start Menu location identified above.

Configuring a Single bq76PL455EVM

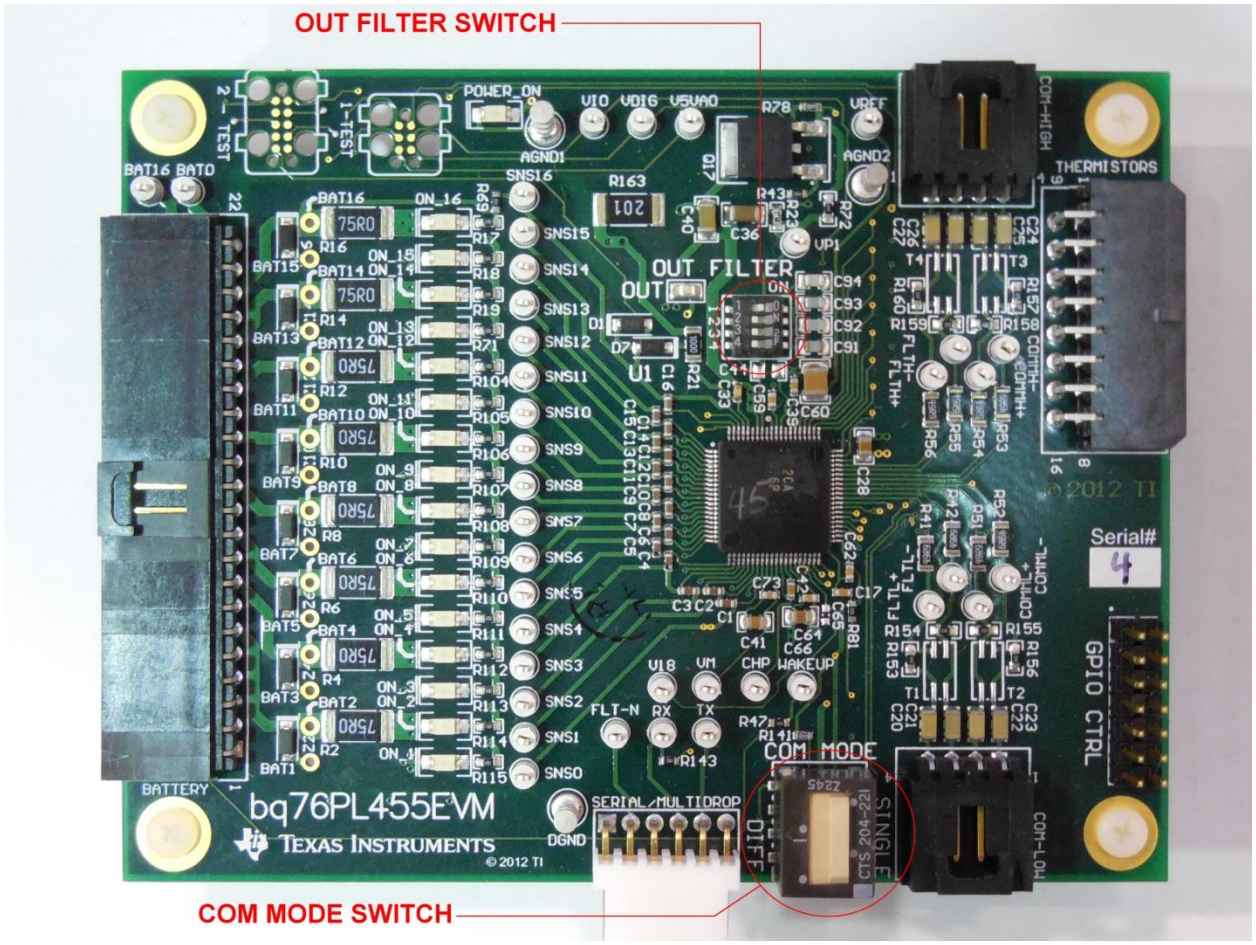

Figure 3 - Single bq76PL455EVM Switch Configuration

Figure 3 - Single bq76PL455EVM Switch Configuration shows an example of a single bq76PL455EVM configuration. Set the switches to the default positions or as follows:

1. Shown is the configuration for a sample period setting of 60.04 µs with 2.7 nF by setting switch 1 on the OUT FILTER switch package to "ON".
2. Select single-ended serial communication by setting the COM MODE switch toward the SINGLE silkscreen (i.e. away from the SERIAL/MULTIDROP connector as shown).
3. Connect the FTDI TTL-232R-5V USB to Serial cable to the SERIAL/MULTIDROP connector and the USB port on the PC.

NOTE: For additional isolation safety, a USB isolator can be used between the PC's USB port and the FTDI cable. The KX USB-150 Full Speed USB Isolator has been tested by Texas Instruments and it is available from Keterex (see www.keterex.com for more details).

Connecting and Powering the bq76PL455EVM

Connect the bq76PL455 evaluation module BATTERY connector to the battery stack or power supply and apply power. Alternatively, a user supplied load board (i.e. resistive ladder board) and power supply may be used to simulate cell connections.

NOTE: Although it is not strictly required due to the presence of on-module protection circuitry, when using a battery stack, it is recommended to first apply power from the top and bottom of the stack to BAT16 and BAT0 respectively in order to power the bq76PL455EVM, before applying

power from the intermediate stack cell connections to BAT0S, BAT1, BAT2 through to BAT15, and BAT16S. This can be achieved using a make-first, break-last type battery connector if hot plugging or using switches to sequence power application.

Start the GUI. This step is explained in greater detail in the Software section of this document.

Configuring Stacked bq76PL455EVMs

Instructions for configuring stacked bq76PL455EVMs are as follows:

1. Identify the bq76PL455EVM that will be connected to the bottom 16-cell module and the bq76PL455EVMs that will be stacked above it, connected to the higher 16-cell modules within the battery system. On the bottom bq76PL455EVM which will be connected to the PC, connect the bottom end of the twisted pair daisy chain cable to the COM-HIGH connector. Then, connect the other end of this twisted pair daisy chain cable to the COM-LOW connecter on the second bq76PL455EVM. Continue with this pattern for all subsequent bq76PL455EVMs in the daisy chain stack.
2. On the bottom bq76PL455EVM to be connected to the PC, set the COM MODE switch as shown in Figure 3 - Single bq76PL455EVM Switch Configuration (for single-ended mode). On all other stacked bq76PL455EVMs, set the lever on the COM MODE switch package in the opposite direction toward the DIFF label
3. Set OUT FILTER switches on all bq76PL455EVMs to the desired setting as outlined in the OUT FILTER section of this document or as shown in Figure 3 - Single bq76PL455EVM Switch Configuration.
4. Connect any desired temperature sensors to the THERMISTORS connector on any of the bq76PL455EVMs in the system.
5. Connect the lowest bq76PL455EVM SERIAL/MULTIDROP header to a PC USB port using an FTDI USB to TTL Serial (5V) cable.

Connecting and Powering Stacked bq76PL455EVMs

To power a stack of bq76PL455EVMs configured in the previous section, the following steps should be followed.

1. Connect the bottom evaluation module BATTERY connector to the lowest 16 cells of the battery stack and apply power.

   NOTE: When using a battery stack, it is recommended - although not strictly required - to first apply power from the top and bottom of the stack to BAT16 and BAT0 respectively in order to power the bq76PL455EVM, before applying power from the intermediate stack cell connections to BAT0S, BAT1, BAT2 through to BAT15 and BAT16S. This can be achieved using a make-first, break-last type battery connector if hot plugging or using switches to sequence power application.

2. Connect the next higher stacked evaluation module to the next higher set of 16 cells, e.g. cells 17-32, using the same relative powering sequence described in step 1. Then connect bq76PL455EVM 3 to cells 33-48, and so on.
3. Start the GUI (as described in the next section).

Software

Using the Software

To run the GUI, double-click the *bq76PL455_RevC_GUI* shortcut on the PC desktop. The user will be prompted to select the COM port number for the Serial to USB connection, as seen in Figure 4 - COM

selection window and Figure 5 - COM selection window options. In most cases, the highlighted COM port will be the appropriate COM port. If this is not the case due to a custom installation, the user can determine the appropriate COM port by checking the Ports section in Windows Device Manager.

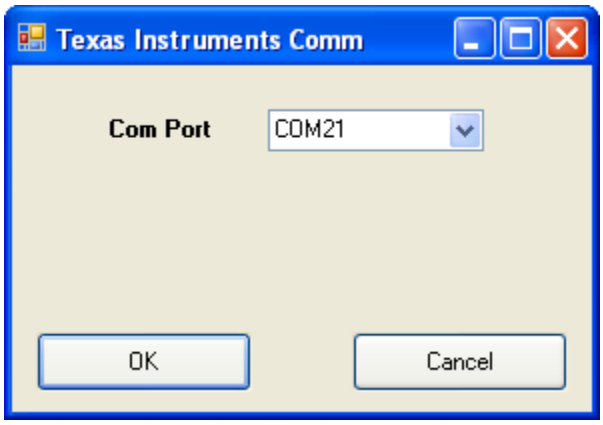

Figure 4 - COM selection window

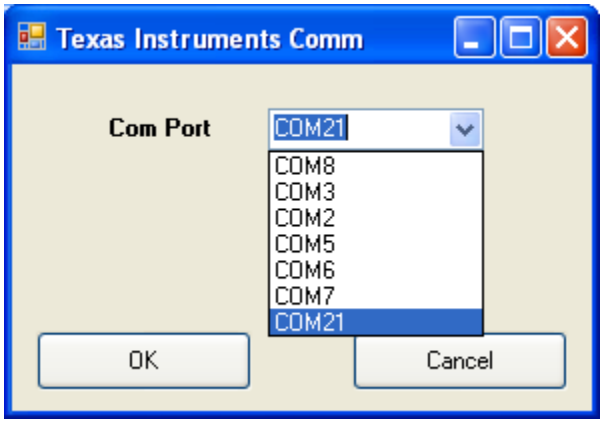

Figure 5 - COM selection window options

Once the correct COM port is selected, the GUI will attempt to find, communicate with, and auto-address all bq76PL455EVMs connected to this COM port. Once this process is complete, the user will be prompted to acknowledge the number of bq76PL455EVMs found. An example of this pop-up window for a system in which three bq76PL455EVMs are connected to the PC can be seen in Figure 6 - Auto-addressing.

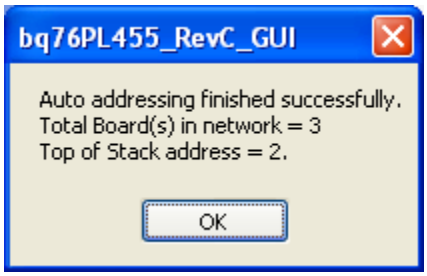

Figure 6 - Auto-addressing

Once the user acknowledges the number of bq76PL455EVMs found, the GUI will come up in its default state with the *Setup* tab displayed, as seen in Figure 7 - Initial View/Setup Tab. No polling data will be read from the passive balancing module until commands are sent to initialize and begin measurements. The default display shows the settings for Board 0, the lowest bq76PL455EVM in the stack.

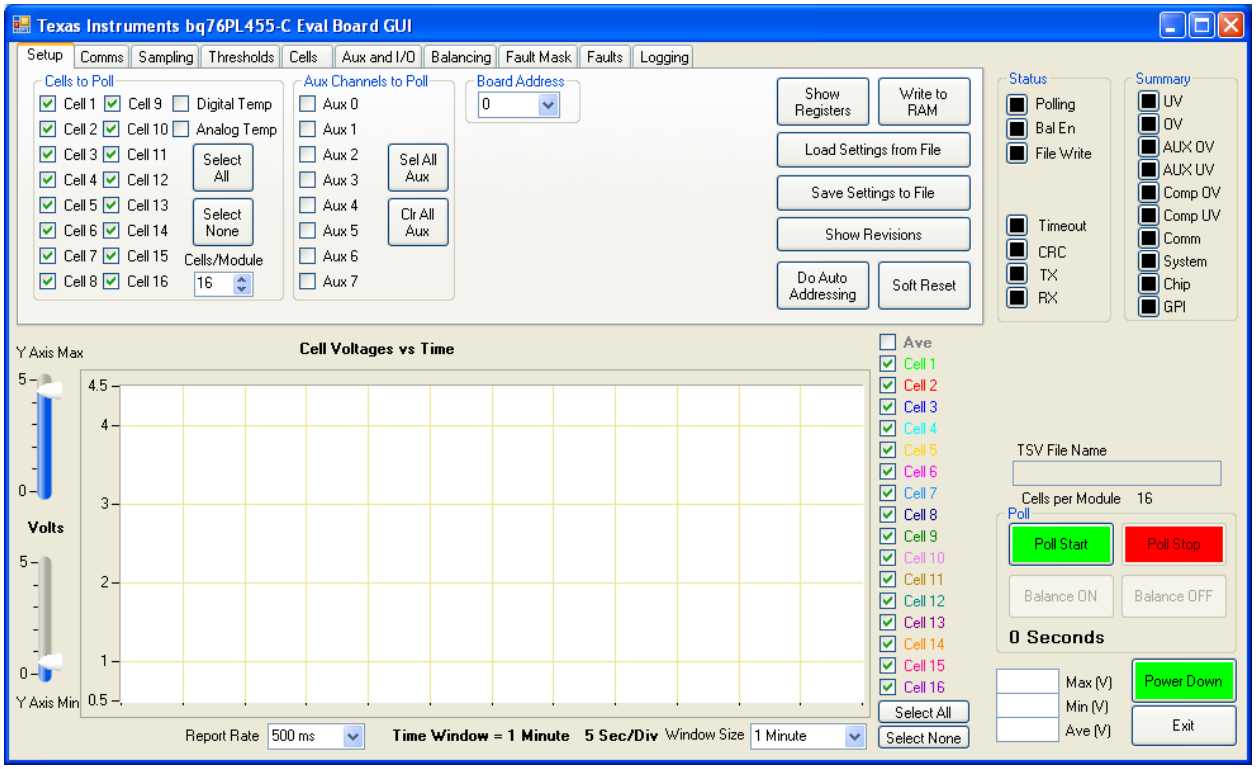

Figure 7 - Initial View/Setup Tab

Clicking across the different GUI tabs, including *Setup*, *Comms*, *Sampling, Thresholds*, *Cells, Aux and I/O, Balancing, Fault Mask, Faults, and Logging* at the top of the display window will produce different information displays related to these headings. It will be seen that the *Cell Voltages vs. Time*, *Status*, *Summary*, *Poll Start/Stop* buttons, *Balance ON/OFF* buttons, *Power Down*, and *Exit* buttons are common to all tabs.

The *Cell Voltages vs. Time* display can be set from one minute to 12 hours and the graph's voltage scale can be changed using the sliders to the left of the graph. To the right side of the graph, you can select to display individual cell data, all cell data, or none of the cell data. Additionally, an average of all selected cell data can be displayed. The selections made with the selection boxes to the right of the graph do not affect the channels which are sampled by the AFE in the bq76PL455, they only affect the channels which are displayed on the graph.

The *Status* indicators show the status of:

- Polling — Indicates when the bq76PL455 is actively polling selected cell channels
- Bal En — Indicates when bq76PL455 is actively balancing selected channels
- File Write — Indicates when the GUI is logging data to a file
- Timeout — Indicates the GUI timed out trying to communicate with a bq76PL455EVM
- CRC — Indicates a communications CRC error between the GUI and an EVM
- TX — Indicates the GUI is transmitting to evaluation bq76PL455EVM(s)
- RX — Indicates the GUI is receiving data from an evaluation bq76PL455EVM(s)

NOTE: The indicators for Polling, Balancing and File Write will turn green when the indicated activity is active. The Polling indicator has two states: on (green) and off (black). The File Write indicator, however, has three states: green (writing to file, polling active), red (not writing to file, polling active), and off/black (not writing to file, polling not active). The Balancing indicator also has three states: balancing on, no fault detected (green), balancing was requested but a fault prevented balancing (red) and off (black).

The Timeout and CRC fault indicators will indicate a fault has occurred by turning red. These indicators must be cleared manually once tripped, because they latch the indicated fault.

The TX and RX indicators will blink green whenever the indicated activity is active.

The *Summary* indicators indicate faults, including:

- UV — Indicates a cell voltage exceeds the under-voltage threshold
- OV — Indicates a cell voltage exceeds the over-voltage threshold
- AUX OV — Indicates an AUX input over-voltage threshold is exceeded
- AUX UV — Indicates an AUX input under-voltage threshold is exceeded
- Comp OV — Indicates a comparator over-voltage threshold is exceeded
- Comp UV — Indicates a comparator under-voltage threshold is exceeded
- Comm — Indicates a communication fault has occurred
- System — Indicates a general system fault is tripped (see data sheet for list)
- Chip — Indicates a fault captured in the Chip Fault register is tripped (see data sheet)
- GPI — Indicates a user-configured input fault condition has been triggered (on GPI pin)

Clicking any fault indicator clears all faults of the same type. For instance, clicking the UV fault button will clear all UV faults for any cell. To clear individual cell UV faults, the user should go to the Faults tab, Cell Faults, UV section and click on the desired cell under-voltage fault indicator. Any of the Summary Faults can be cleared while polling is active. If the fault persists, the fault indicator will reactivate.

The *TSV/File Name* field shows the file where data is being logged and is set on the *Logging* tab.

The *Poll Start* button is used to initiate polling. Polling is stopped using the *Poll Stop* button. Before polling is started, the user should set or verify the following parameters on the appropriate tab:

1. The number of Cells per Module and Channels to Poll on the *Setup* tab
2. The communications Baud Rate, the Comm Timeout period and Charge Pump settings on the *Comms* tab
3. The Initial Sample Delays, Sample Period, OverSample rate, Oversample Method and Aux Sample Period on the *Sampling* tab
4. The Cell Voltage OV and UV limits, Comparator OV and UV limits and Aux Voltage OV and UV limits on the *Thresholds* tab
5. The desired Fault Masks on the *Fault Masks* tab
6. Clear all faults on *Faults* tab (verifying proper clearing by issuing a Query All request, and clearing any latent faults)
7. The Log file name and location on the *Logging* tab

The *Balance ON* button is used to start balancing once the channels to be balanced have been selected on the *Balancing* tab and all faults have been cleared on the *Faults* tab.

NOTE: Cell balancing will not be allowed to start if any faults are active, unless those faults have been masked. Similarly, if a fault occurs during balancing, balancing will stop unless the fault has been masked. Most, but not all, faults can be masked on the Fault Mask tab.

The *Power Down* button will power down the bq76PL455EVM(s). Once powered down, the bq76PL455EVM can be powered back up by clicking the *Power Up* button, which appears in place of the *Power Down* button when the bq76PL455EVM is powered down.

Setup Tab

On the *Setup* tab, the user can set the number of cells in the module, which cell and aux channels are to be monitored, whether internal chip temperatures will be monitored, and the bq76PL455EVM address. The Board Address drop down menu will be populated with the addresses of all bq76PL455EVMs discovered during the GUI start-up.

If there was a problem with auto-addressing during GUI power up and not all connected bq76PL455EVMs were recognized, the search process can be re-initiated by clicking the *Do Auto Addressing* button once the connection problem has been rectified.

.

NOTE: Failure to select at least one channel before starting polling results in a GUI error message.

The user can save bq76PL455 RAM set up data using the *Save Settings to File* button which saves the data to a file on the PC. This data can later be restored to a bq76PL455EVM using the *Load Settings from File* button.

The *Show Registers* button produces a view, as shown in Figure 8 - Register View, of the user configurable registers which the GUI is writing to control bq76PL455 operation. This view allows the user to view and change values in the registers of the bq76PL455. These registers are described in detail in the bq76PL455 data sheet. Register values can be read and written from this Register View window, however values are only written to RAM and cannot be saved to EEPROM using the bq76PL455EVM GUI. If power is removed from the bq76PL455EVM(s), any changes will be lost. For this purpose, any changes may be saved to and restored from a file using the Export and Import buttons. When importing from a file, values are written to all registers as part of the import process. Some additional detail regarding the control buttons on this window is provided in the Register View Window section of this document.

NOTE: Since changes can be made using check boxes and radio buttons in the primary GUI window, registers shown in Register View can change while the Register View window is open. If making changes in the GUI while the Register View is open, the user is advised to click Read All upon returning to the Register View window.

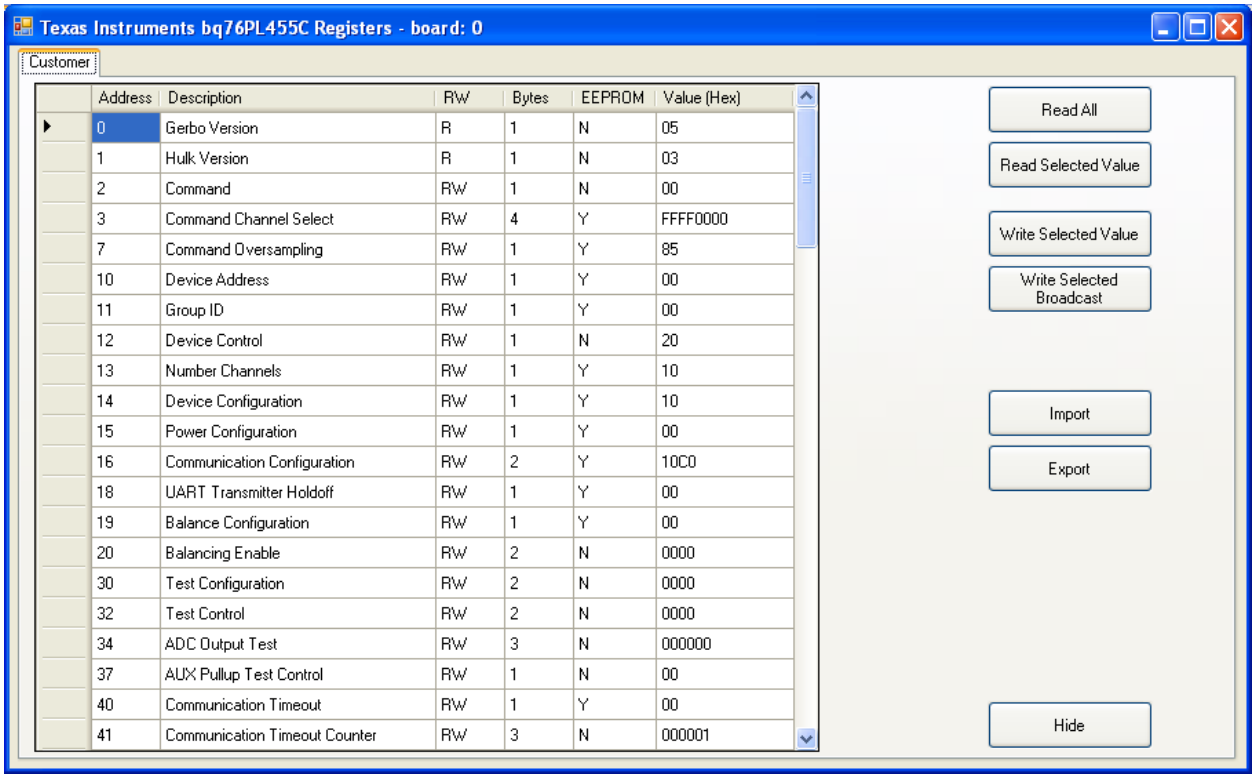

Figure 8 - Register View

The *Show Revisions* button displays the current version of the GUI.

The *Write to RAM* button writes all currently selected options from all tabs to the bq76PL455 registers in RAM. In most cases, the use of this button is superfluous, since most controls in the GUI are active controls and settings are saved immediately upon selection.

The *Soft Reset* button causes the SOFT_RESET bit in the Device Control register (register 12) to be set and initiates a reset of the digital control logic in the bq76PL455. Please refer to the bq76PL455 data sheet for the full description of the implications of this action. This action is not normally required or suggested, and it will result in the indication of Sys Reset and System faults on the *Faults* tab (since unexpected resets are considered faults). These faults will show as soon as the next request for Polling is made or the "Query All" button is clicked on the *Faults* tab.

NOTE: Failure to clear the Sys Reset and System faults after initiating a Soft Reset will prevent the ability to enable the balancing function.

Register View Window

The *Register View* window contains seven buttons: *Read All*, *Read Selected Value*, *Write Selected Value*, *Write Selected Broadcast*, *Import*, *Export* and *Hide*.

The *Read All* button will read all registers of the bq76PL455 on the currently selected bq76PL455EVM, and update the register values in the Register View window. The selected bq76PL455EVM address is displayed on the window title bar of the Register View window (see Figure 8 - Register View).

The user can also verify a properly written value or read only the value of an individual register by clicking on any column for a particular register and clicking the *Read Selected Value* button. The GUI will read the register from the bq76PL455 and update the Value column for the selected register with the data read. When a register is selected by the user, a small pointer will appear in the far left column next to the address of the selected register.

By clicking on the Value column for a selected register, the user has the ability to change this value. After doing so, the new value can be stored to the RAM copy of the register on the bq76PL455 by clicking the *Write Selected Register* button.

A register value can be written to all bq76PL455EVMs in a stack by selecting a register then clicking the *Write Selected Broadcast* button.

Once a device has been configured as desired, the *Export* button allows the register settings to be saved to a .reg file. The user will be prompted for a folder and file name to which to save the register information.

The *Import* button can be used to restore register values to values previously saved to .reg files using the *Export* button.

WARNING! The .reg files can also be viewed and modified external to the GUI with any text editor, but great care must be exercised when doing so, since register settings can put the IC into an undesirable state if mistakes are made in the .reg files and they are used to overwrite register values.

Comms Tab

The *Comms* tab view is shown in Figure 9 - Comms Tab. This tab view allows the user:

1. To set the baud rate at which the PC communicates with the bottom bq76PL455EVM in the stack (set to 250K by default)
2. Issue a communications reset in the event communications with the bq76PL455EVMs have been compromised
3. Set the communications timeout wait period (disabled by default)
4. Select the state of the internal charge pump (set to “on” by default)

NOTE: the communication rate over the differential communication bus connecting multiple stacked bq76PL455EVMs cannot be adjusted and is fixed. Only the rate for the single-ended link to the PC can be adjusted.

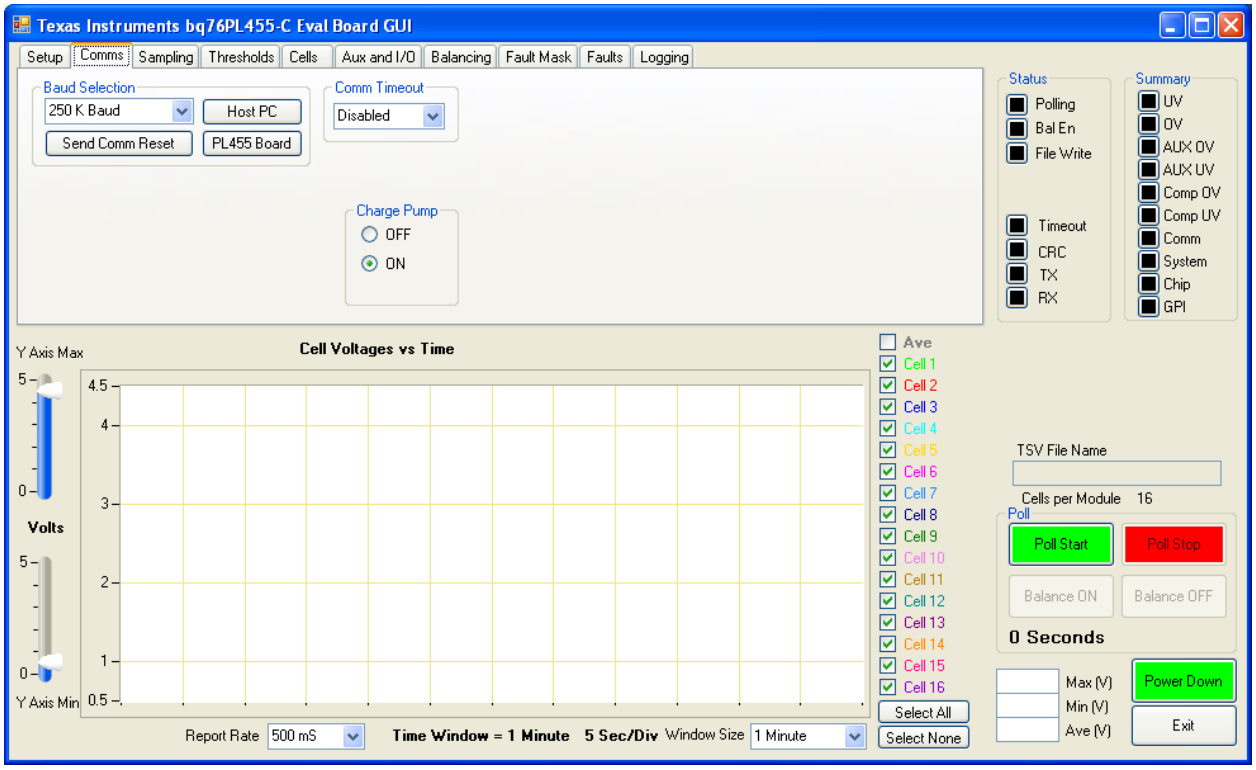

Figure 9 - Comms Tab

The Comm Timeout value can be Disabled or varied from 0.1 Seconds to 1 Hour. This value sets the period after which a COMM Timeout fault is generated by the bq76PL455 if it sees no bus activity. By default this value is disabled.

WARNING! It is important to note: during balancing, if the COMM Timeout is disabled and communication is lost with the GUI, balancing might continue draining cells below UV levels without tripping a UV error in the GUI. In a "real" system (as compared to a bench evaluation system) it is always advised to set a reasonable communications timeout value for safety reasons.

Sampling Tab

The *Sampling* tab view is shown in Figure 10 - Sampling Tab.

The *Sampling* tab allows the user to:

- Set the sample time for the cell voltage and internal temperature measurement channels.
- Set the oversampling rate. The oversampling rate can be set to 1, 2, 4, 8, 16, or 32 times.
- Set the oversampling method used during channel sampling.
- Set the additional initial sampling delay on the first channel sampled.

For additional details on the effect of these settings, the user should consult the bq76PL455 data sheet.

NOTE: *The AFE always samples the channels in reverse order so for a 16 cell module this would be channel 16 if all 16 channels are selected for measurement.*

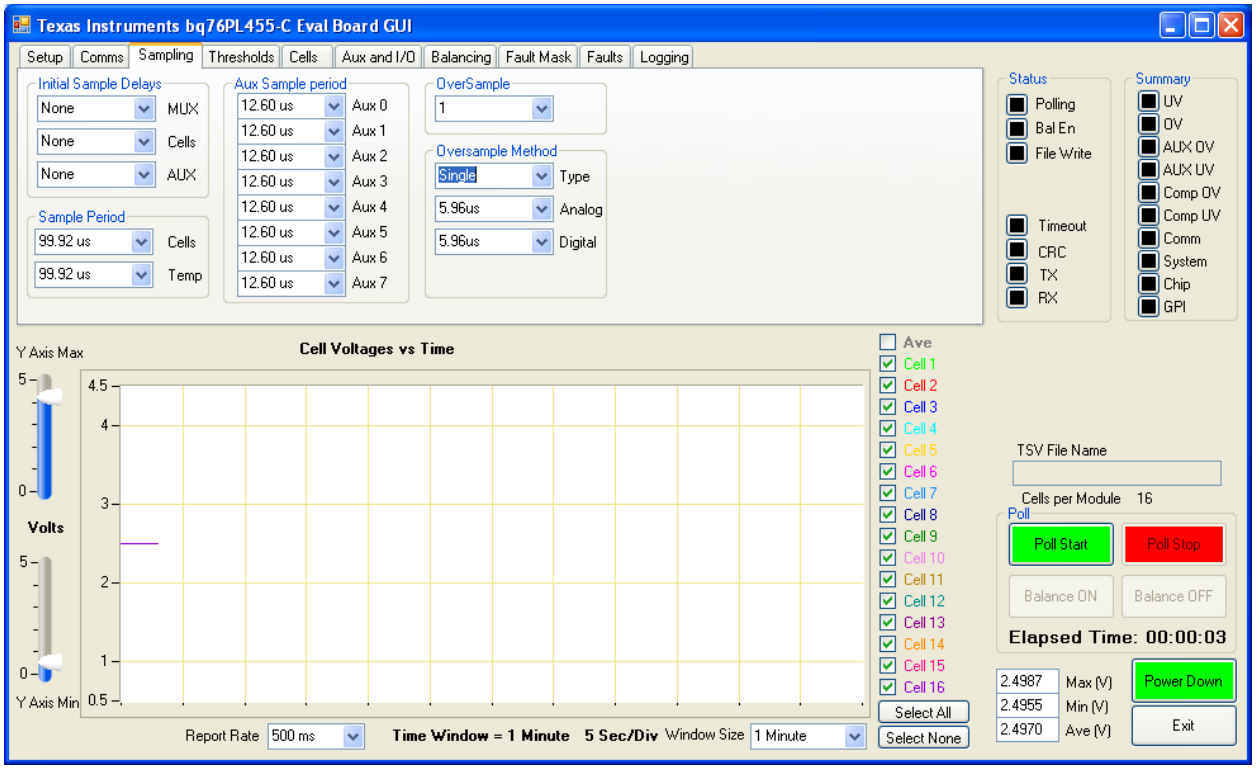

Figure 10 - Sampling Tab

Thresholds Tab

The *Thresholds* tab, shown in Figure 11 - Thresholds Tab, allows the user to:

1. Set the cell under-voltage and over-voltage fault triggering thresholds
2. Set the comparator under-voltage and over-voltage fault triggering thresholds
3. Set the auxiliary channel under-voltage and over-voltage fault triggering thresholds

The cell voltage thresholds can be varied between 0.0000V and 4.9997V.

The comparator over-voltage threshold can be varied between 2.000V and 5.175V.

The comparator under-voltage threshold can be varied between 0.700V and 3.875V.

The auxiliary channel under-voltage and over-voltage thresholds can be varied between 0.0000V and 4.9997V.

The thresholds are changed by typing appropriate values into the selected text boxes. Since the bq76PL455 has specific resolution restrictions for each of the settable thresholds, the GUI will automatically adjust the resolution of thresholds to the nearest available value to the number entered by the user. This adjusted value will be shown as soon as the input cell is deselected.

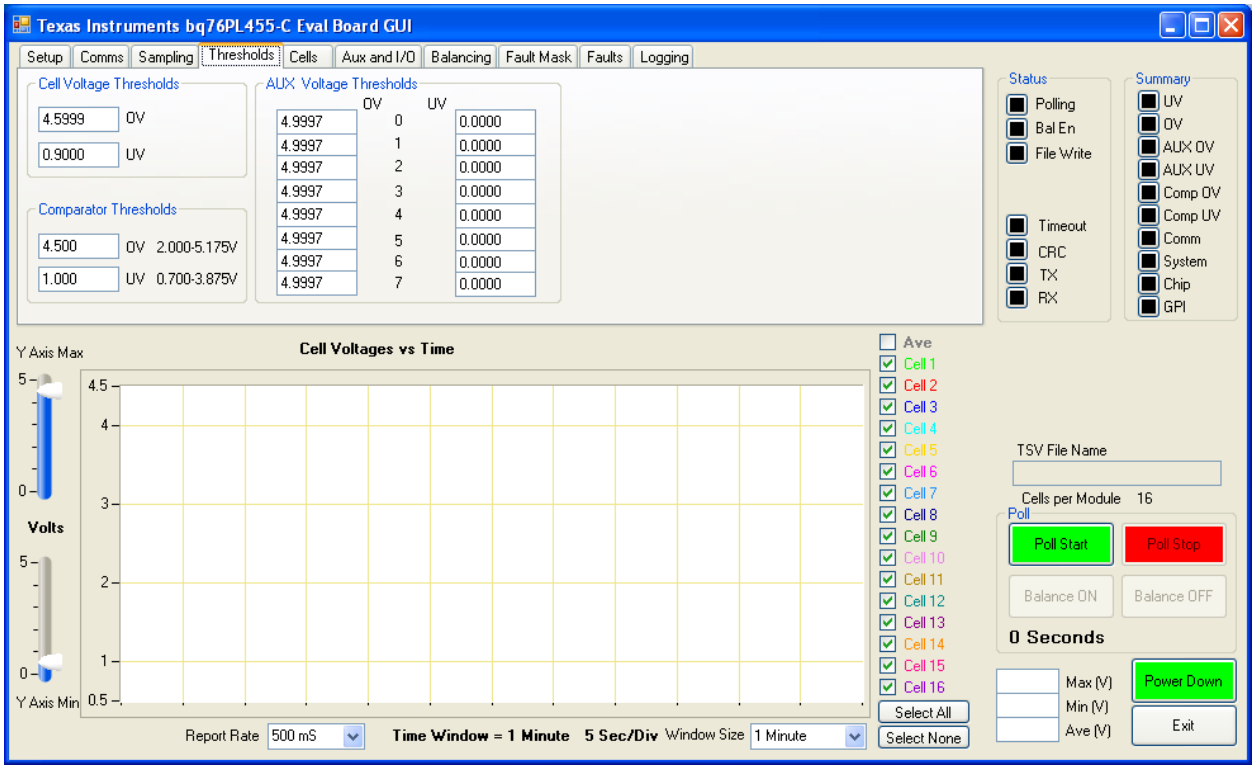

Figure 11 - Thresholds Tab

Cells Tab

In the *Cells* tab, a graphical representation of the voltage on each cell is displayed, as shown in Figure 12 - Cells Tab.

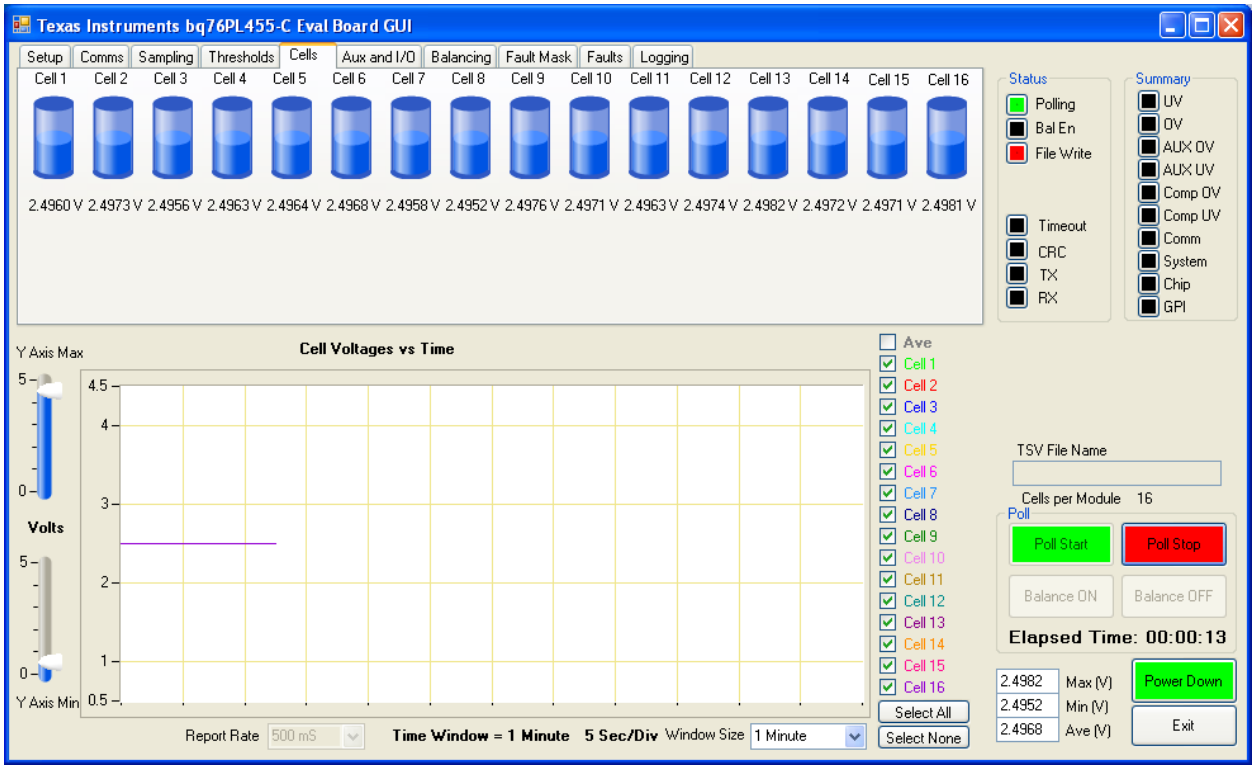

Figure 12 - Cells Tab

Aux and I/O Tab

The *Aux and I/O* tab, shown in Figure 13 - Aux and I/O Tab, allows the user to view the voltage on each Aux input channel. The voltage shown is updated when polling is active. When polling is inactive, the last value polled will be shown.

Only the specific Aux input channels selected on the *Setup* tab will have their values actively updated on the *Aux* tab when polling is active. The value for any unselected Aux input channel will be displayed as zero when polling is active.

Additionally, the GPIO configuration options and states are indicated on this tab. Four separate configuration groups are provided:

1. GPIO Input Enable – Allows GPIO channels to be configured as inputs
2. GPIO Pull-up Enable – Allows for an internal pull-up to be enabled
3. GPIO Pull-down Enable – Allows for and internal pull-down to be enabled
4. GPIO Output State – Indicates whether a GPIO pin output driver is on when configured as an output

WARNING: The bq76PL455 does not prevent the user from enabling both the internal pull-up and pull-down resistors simultaneously, so the user should exercise caution when selecting these options.

NOTE: Additional configuration is possible for GPIO pins configured as inputs. This additional configuration allows for the input to trigger a fault when changing state. This configuration is made on the Fault Mask tab.

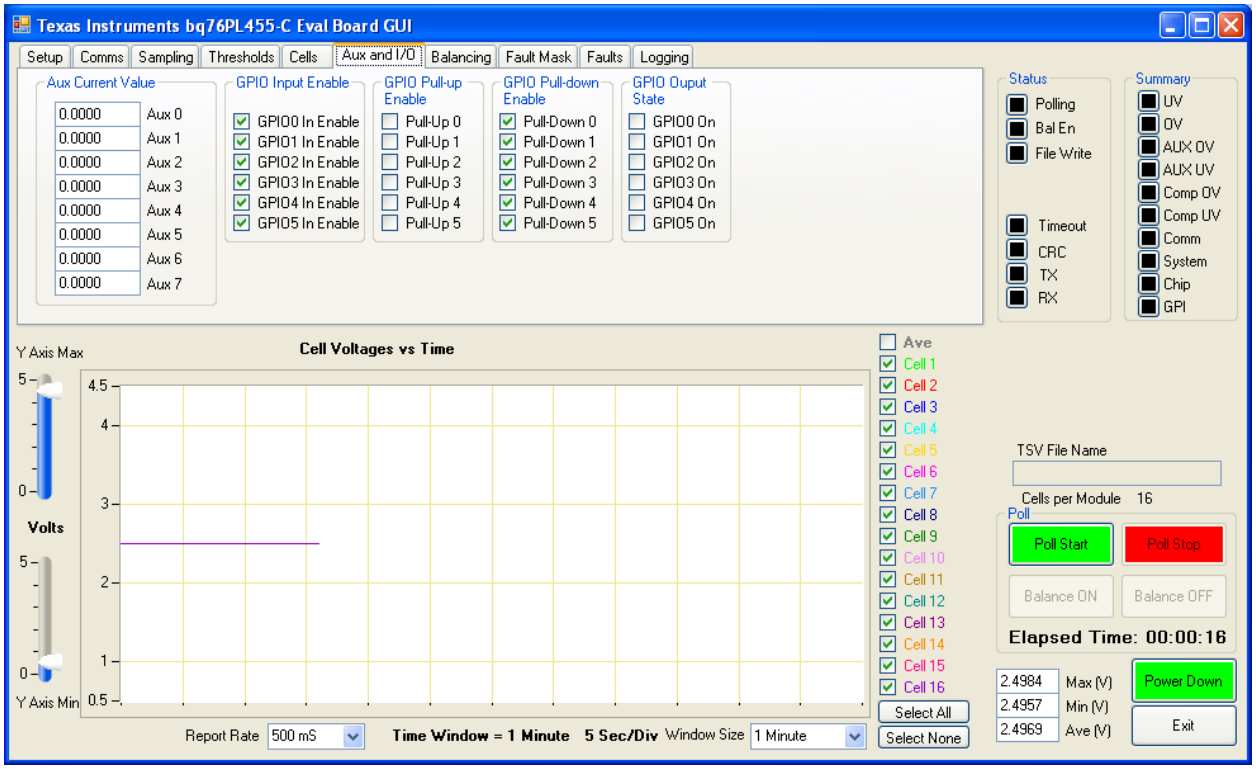

Figure 13 - Aux and I/O Tab

Balancing Tab

The *Balancing* tab, shown in ***NOTE: The example screen capture was taken with a resistor ladder consisting of alternating resistor values connected to the cell sense lines, so the effect is somewhat different from what you would expect to see when battery cells are connected to the sense lines.***

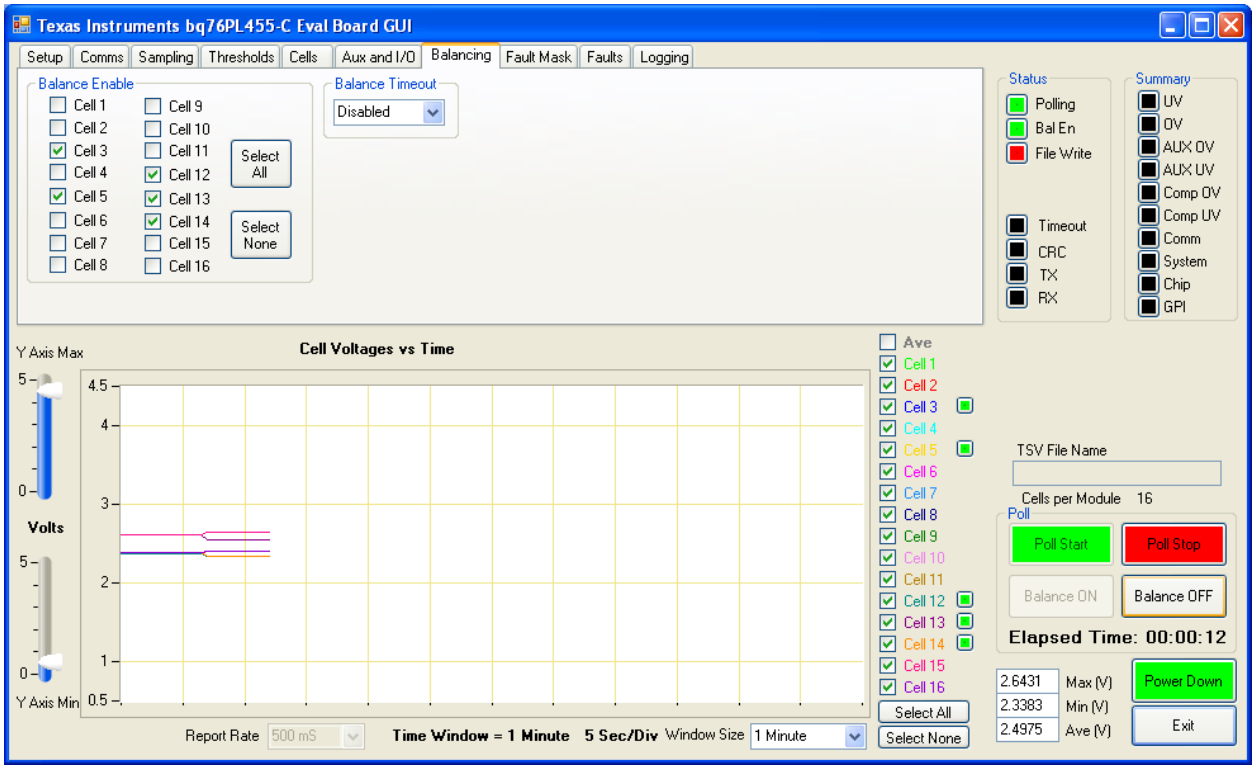

Figure 14 - Balancing Tab, allows the user to select the cells which will be balanced when the *Start Balancing* button is clicked and polling is active. In the specific example, balancing for cells 3, 5, 12, 13 and 14 is both enabled and turned on with polling active.

A small indicator appears to the right of the voltage/time grid, next to the appropriate cell, for each cell selected on the *Balancing* tab. This virtual LED indicator will be black when balancing is off, green when balancing of a cell is on without faults and red if balancing is on and a fault has occurred.

NOTE: The example screen capture was taken with a resistor ladder consisting of alternating resistor values connected to the cell sense lines, so the effect is somewhat different from what you would expect to see when battery cells are connected to the sense lines.

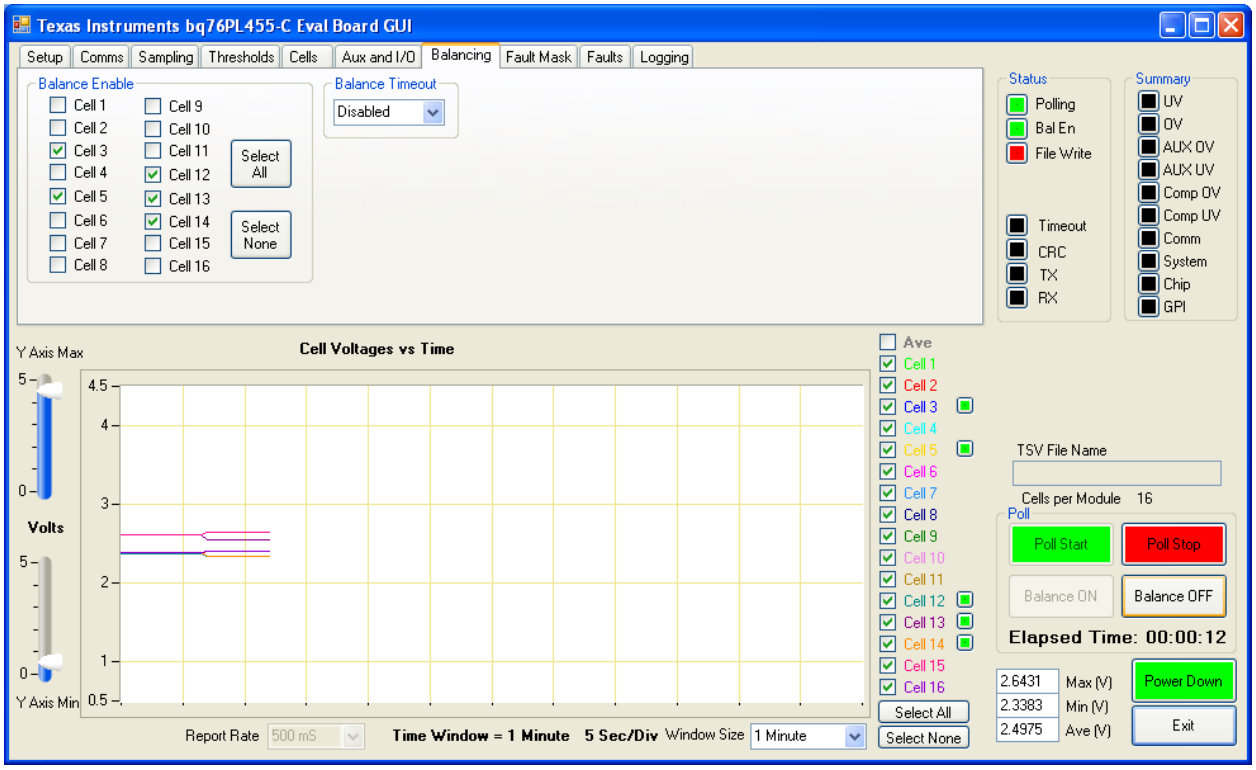

Figure 14 - Balancing Tab

Fault Mask Tab

The *Fault Mask* tab, shown in Figure 15 - Fault Mask Tab, allows the user to turn off and mask faults from various events and select which faults will trigger the active low FAULT* pin on the bq76PL455. Faults are grouped by type and correspond to their register locations. Further details regarding the faults and their meanings can be found in the bq76PL455 data sheet.

NOTE: Any triggered fault, if left unmasked, will prevent the ability to enable balancing.

The *Fault Mask* tab also allows the user to configure the General Purpose Input (GPI) pins to be to trigger faults when they change state. This configuration is done in the "GPI Faults (check to enable)" group box in the upper right portion of the *Fault Mask* tab.

The sample screen shot shows GPI0 and GPI1 configured such that a fault will be triggered when the inputs change from Hi to Lo (and the screen shot shows that such a transition has occurred because the GPI fault indicator is red). In this case, since the GPI_FAULT_OUT box is checked in the "Fault Output Control (check to enable)" group box, the user should also expect the active low FAULT* output pin of the bq76PL455 to be low, indicating an active fault.

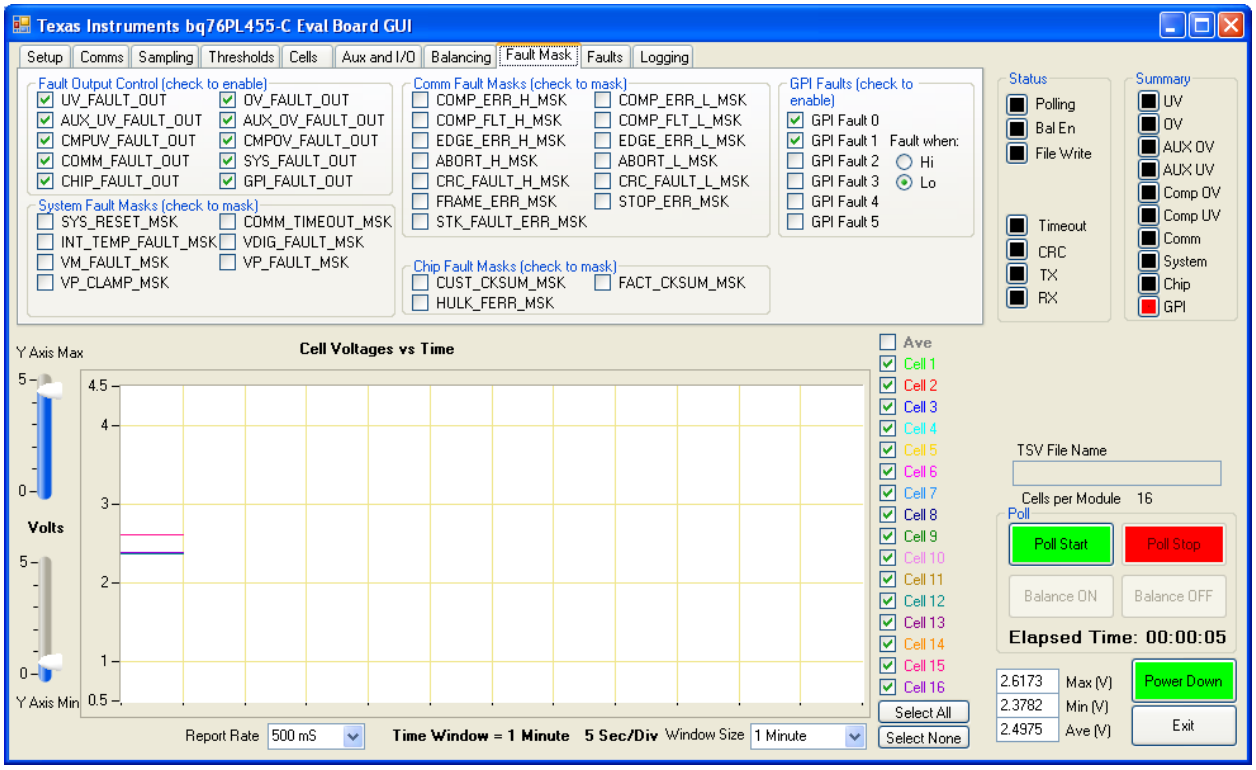

Figure 15 - Fault Mask Tab

Faults Tab

The *Faults* tab, shown in Figure 16 - Faults Tab, provides a more in-depth break down of the cause of any faults shown in the Summary box in the upper right-hand corner of the GUI. In the example figure, the data, acquired using a resistor ladder connected to a power supply so half the Vsense inputs are set to a slightly lower voltage than the other Vsense inputs, shows under-voltage faults for alternating cells. Additionally, GPI faults for GPI0 and GPI1 are shown as active faults.

Clicking any fault indicator (i.e. the ones lit in red) clears the fault. This includes:

- All System Fault sources including Comm Timeout and Sys Reset
- All Chip Fault sources
- All individual cell over- and under-voltage faults
- All individual comparator over- and under-voltage faults
- All AUX input over- and under-voltage faults
- All individual GPI Fault sources

Clicking on any lit fault indicator in the Fault Summary box in the upper right-hand corner of the GUI will clear all individual faults within that category of faults. For instance, in the example shown, clicking on *UV* in the Fault Summary box would clear all *UV* faults in the *Cell Faults* box on the *Faults* tab.

If a summary or individual fault indicator is cleared and the fault persists in the hardware, the fault indicator will show the fault again the next time it is polled. A manual poll of all fault conditions can be performed by clicking on the “Query All” button.

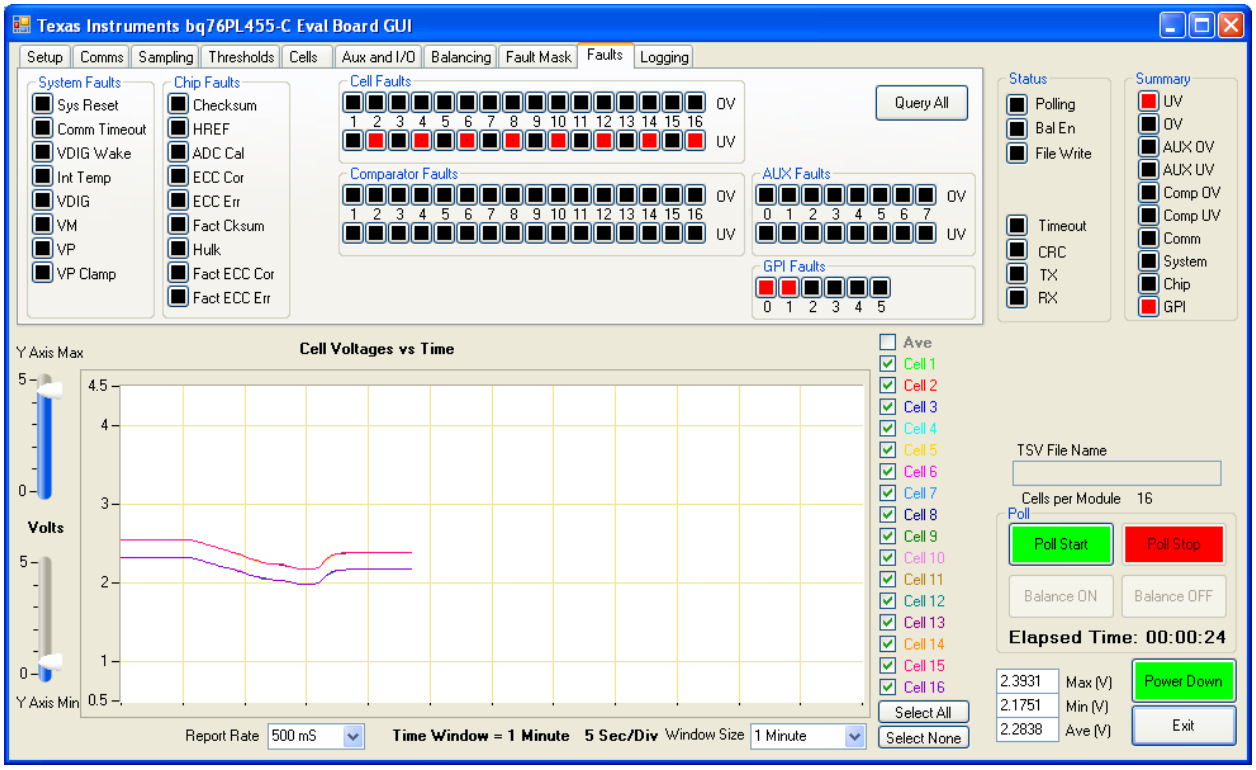

Figure 16 - Faults Tab

Logging Tab

All the cell voltage data and configuration settings can be saved as a .tsv (Tab Separated Value) file locally on the user's PC. Under the *Logging* tab, shown in Figure 17 - Logging Tab, Auto File Name and Figure 18 - Logging Tab, User Specified File Name, the user can turn on logging, control the file name, and set the location where the log data file is saved.

The *Enable File Write* tick box controls whether logging is enabled and the *Auto File Name* tick box controls whether a file name is automatically generated or whether the user must specify a name. To specify a file name and location the user must click the *Specify TSV* file button and enter the log file path and name. Notes can be added in the notes dialog box and will appear in the log file.

If *Auto File Name* is left un-ticked, the GUI will append new data to the same file name specified by the user each time polling is started. Selecting *Auto File Name* and *Enable File Write* will, by default, cause the GUI to generate log files on the desktop with file names in the format *TI_yymmdd_hhmmss.tsv* where the automatically generated digits are based on the date (year, month, day) and time (hour, minute, second). A specific example would be TI_130115_151635.tsv, in which the date and time are 2013, January 15, and 1500 hours, 16 minutes, and 35 seconds.

***TIP**: Un-ticking the Auto File Name box, entering a file name and location, and then ticking the Auto File Name box, prompts the GUI to start auto-generating file names in the selected path. If the GUI is shut down cleanly at the end of the session, it will remember to store in that location next time as well, avoiding a desktop littered with log files!*

The *Log All Boards* tick box controls whether only the data from the currently viewed bq76PL455EVM address or the data from all bq76PL455EVMs in the system will be logged to the appropriately specified log file(s). If the Log All Boards tick box is selected, the log file name will be appended with _00, _01, _02,

etc. This appended extension to the specified file name is the address of the bq76PL455EVM from which the data were collected.

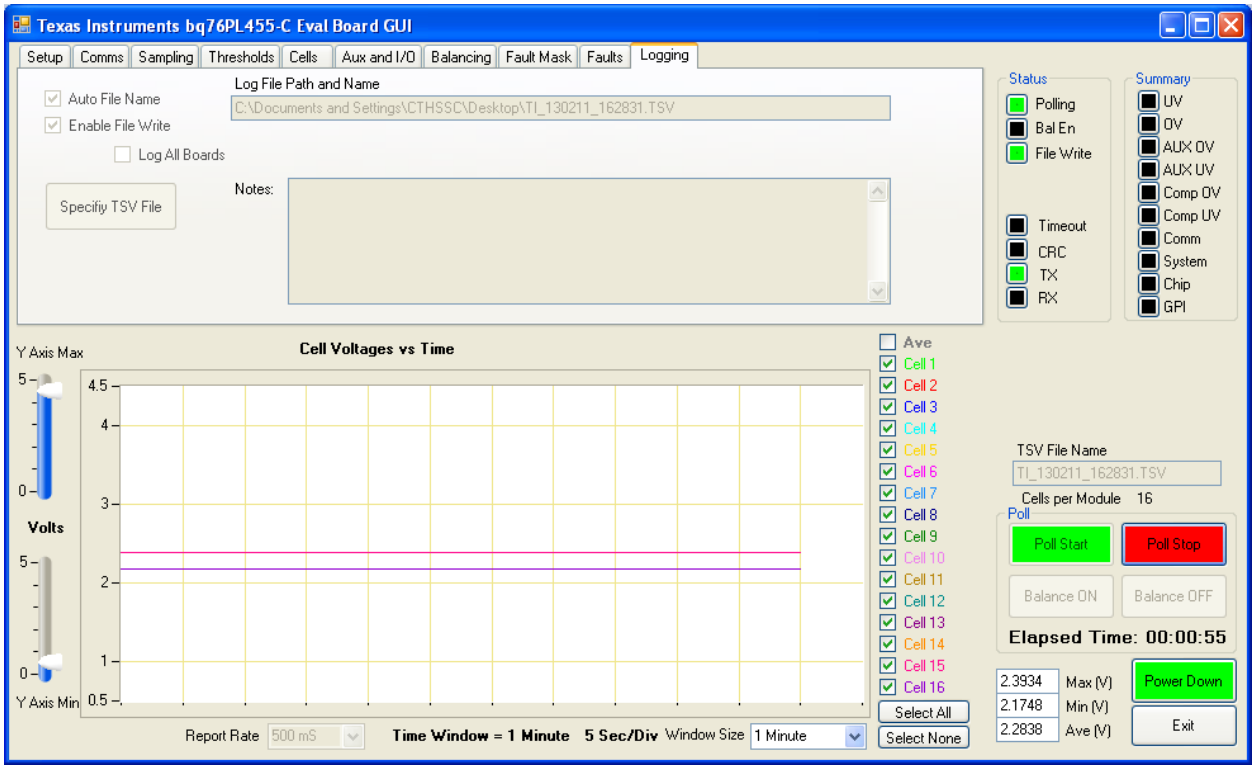

Figure 17 - Logging Tab, Auto File Name

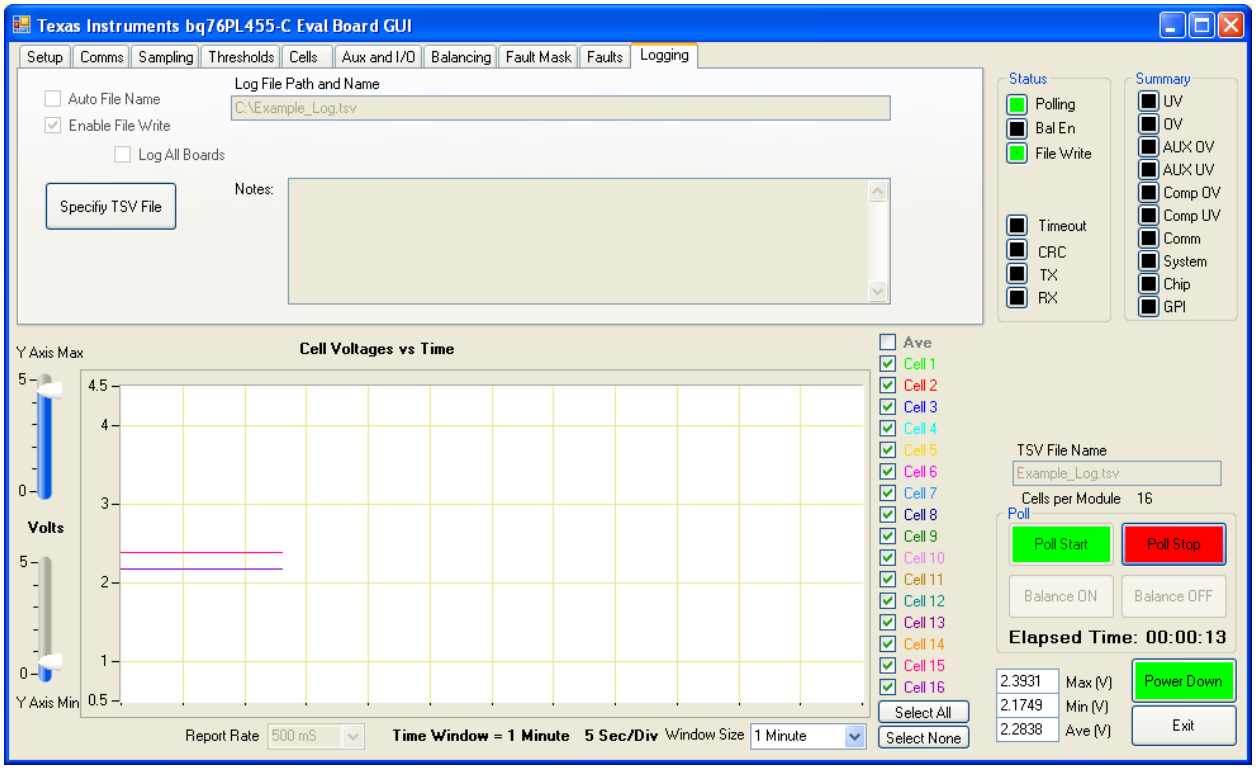

Figure 18 - Logging Tab, User Specified File Name

Stopping and Starting Polling and Balancing

Once the hardware is set up and the GUI settings have been defined, the user can begin polling cell voltage data, auxiliary input data, and enabling/disabling balancing.

Near the lower right-hand corner of the GUI in the "Poll" group box, the user will find the *Poll Start* button highlighted in green. When clicked, the GUI will begin polling cell voltage and auxiliary input data. The polling rate can be set using the *Report Rate* drop down menu found below the graph. The user can define a polling rate of 200 ms to 5 seconds. The data will be saved in a .tsv file defined by the user in the *Logging* tab. The cell voltage data will be displayed in real time across the *Cell Voltages vs. Time* graph, as seen in Figure 12 - Cells Tab. The user can change the time scale using the Window Size drop down menu, and define the time scale from 1 minute to 12 hours. The voltage scale can be changed using the sliders to the left of the graph.

The *Balance ON* and *Balance OFF* buttons will start and stop balancing, respectively. The Balance ON and Balance OFF buttons will not be enabled unless at least one cell has been selected on the *Balancing* tab. Also, the Balance ON button will not be enabled if the bq76PL455 is already balancing, and the Balance OFF button will not be enabled if the bq76PL455 is not already balancing.

If there were no faults during the activation of the balancing function, the green balancing status LED (*Bal En*) near the upper right hand corner of the GUI screen and cell balancing indicators next to selected cell(s) will turn green. If, on the other hand, a fault occurred during balance enabling, the balancing status LED (Bal En) will turn red, and all balancing will be disabled. For safety, all faults will need to be cleared before balancing can be re-started.

As shown in the Cell 10 example in Figure 19 - Cell 10 Balancing Example, when balancing is enabled the voltage of the balanced cell in the Cell Voltage vs. Time view will drop. It can also be seen that during balancing, the measurement of the adjacent Cells 9 and 11 is also affected as these share common

sense lines in the battery cable. It is important to understand that measurement accuracy is affected by the balancing process and is due to the presence of the balancing current flowing in the measurement sense lines which have non-zero resistance.

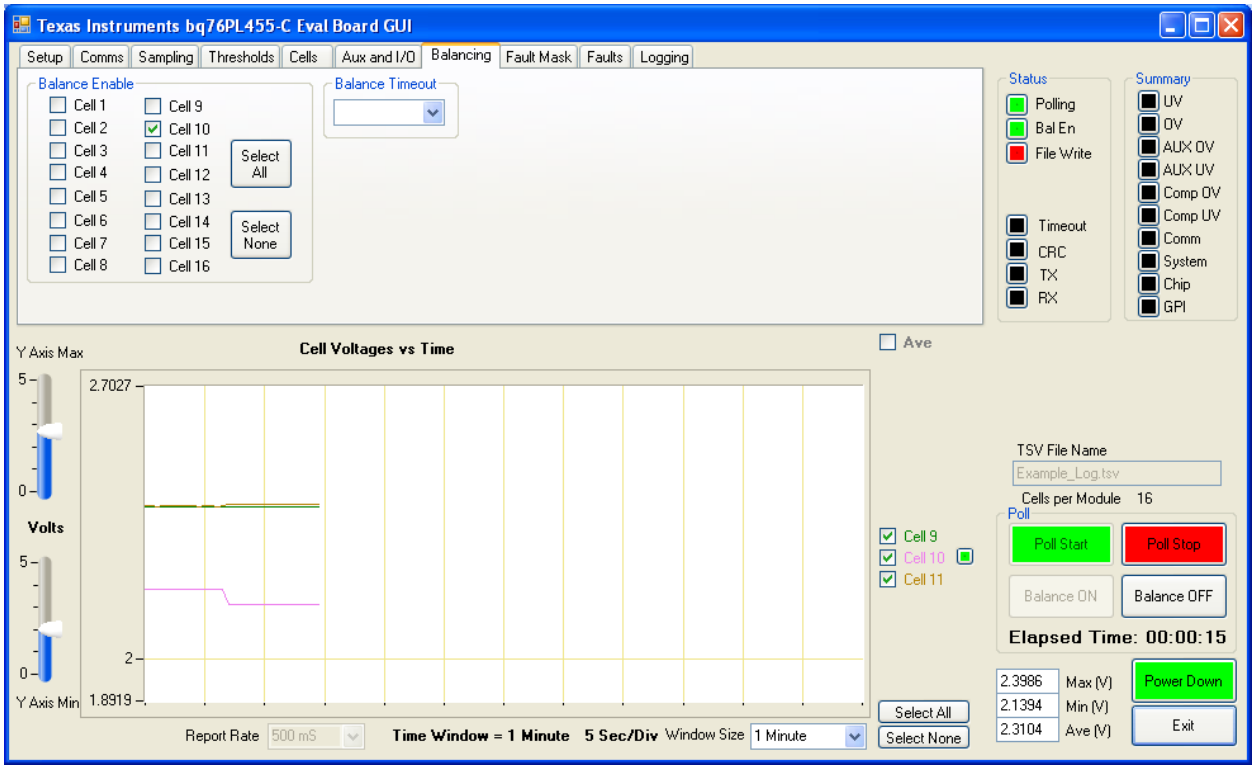

Figure 19 - Cell 10 Balancing Example

Shutting Down

To shut down, first click on the *Balance Off* button then click on the *Poll Stop* button. The GUI will now be in idle state. To exit the GUI, either click the *Exit* button in the lower right-hand corner of the GUI or click on the 'X' Window close box.

Remove the battery connections in reverse order to the sequence used during power up. (eg. remove BAT16S, BAT15 down through BAT1, BAT0S, and then BAT16 and BAT0).

Appendix A

Log File Information

Each log file produced by the GUI contains information for a single evaluation module in the stack of bq76PL455EVMs connected to the host controller PC. This Appendix section provides detail and sample data for a log file produced by the GUI.

A log file produced by the GUI will be in .tsv (Tab Separated Value) format. The name for this file may be chosen by the user, or it can be automatically generated by the GUI. If the name is set by the user, the user should provide a full path and name for the file. If the GUI automatically generates the file name, the format of the name will be *NB_yymmdd_hhmmss.tsv* and the file will be stored in the default directory specified by the user upon initial GUI installation. For the GUI-generated file name, the dynamic portions of the name (in order of appearance in the file name template above) have the following meanings:

- yy: last two digits of year in which file was generated
- mm: two-digit month in which file was generated
- dd: two-digit day of month on which file was generated
- hh: hour, in 24-hour format, at which logging began
- mm: minute at which logging began
- ss: second at which logging began

To summarize, each log file contains the Board Address (ID) of the bq76PL455EVM from which the data were collected, specific user *Notes* as entered by the user in the available GUI field, the addresses and contents of a subset of the bq76PL455 registers at the time data were collected, and the time-stamped data collected during a device polling session.

Each line entry of data collected from a selected bq76PL455EVM is date and time-stamped and contains data for all selected voltage and AUX channels. Reference should be made to the bq76PL455 data sheet for an explanation of the meanings of the register data.

Sample bq76PL455 Log File

The following log file is a partial file example. The data section was shortened to save space and the tabs which would normally appear in the file between each value have been substituted with commas for easier readability. Enough of each section of the file was kept in this example to provide an explanation of the file's content.

Comments regarding the file are in maroon italicized type to distinguish these from actual file content. The file content is shown in its native text (TSV) format. The content of this file can be imported by spreadsheet software, such as Microsoft Excel, for easy viewing. Values in the sample below are not meant to be representative of recommended values and are provided as sample data only to demonstrate file structure.

GUI Version: *X.X.X.XX* *The version of the GUI which generated this file*
Board Address: 3 *Data in this file is from bq76PL455EVM 3*
Notes: *Any user-entered notes from the GUI would appear here*

Address Register Name Value (Hex) *Column names (useful in spreadsheet view)*
2 Command 00
3 Command Channel Select 0FFF0000

Note: For multiple byte values, the start address refers to the address of the LSB of the value shown. For example, a 4-byte hex value of 89ABCD12 shown for address 3 would mean address 3 = 12h, address 4 =CDh, address 5 = ABh, and address 6 = 89h

7	Command Oversampling	85		
10	Device Address	00		
11	Group ID	00		
12	Device Control	20		
13	Number Channels	10		
14	Device Configuration	10		
15	Power Configuration	00		
16	Communication Configuration	10C0		
18	UART Transmitter Holdoff	00		
19	Balance Configuration	00		
20	Balancing Enable	0000		
30	Test Configuration	0000		
32	Test Control	0000		
34	ADC Output Test	000000		
37	AUX Pullup Test Control	00		
40	Communication Timeout	00		
41	Communication Timeout Counter	000001		
50	Auto-Monitor Period	00		
51	Auto-Monitor Channel Select	00000000		
55	Auto-Monitor Oversampling	00		
60	ADC Mux Change Delay	00		
61	Initial Sampling Delay	00		
62	Voltage & Internal Temp Sampling Period	99		
63	AUX Sampling Period	44444444		
67	Test Sampling Periods	F999		
81	System Status	02		
82	Fault Summary	0000		
84	Cell Under-Voltage Fault	0000		
86	Cell Over-Voltage Fault	0000		
88	Auxiliary Under/Over-Threshold Fault	0000		
90	Comparator Under-Voltage Fault	0000		
92	Comparator Over-Voltage Fault	0000		
94	Communication Fault	0000		
96	System Fault	00		
97	Chip Fault	0000		
99	GPI Fault	00		
104	Communication Fault Masks	0000		
106	System Fault Masks	10		
107	Chip Fault Masks	0000		
110	Fault Output Control	FFC0		
120	General Purpose IO Direction	00		
121	General Purpose Output	00		
122	General Purpose Pullup	00		
123	General Purpose Pulldown	3F		
125	General Purpose Fault Input	00		
140	Comparator Under-Voltage Threshold	18		
141	Comparator Over-Voltage Threshold	C8		
142	Cell Under-Voltage Threshold	2E14		
144	Cell Over-Voltage Threshold	EB84		
146	AUX0 Under-Voltage Threshold	0000		
148	AUX0 Over-Voltage Threshold	FFFC		
150	AUX1 Under-Voltage Threshold	0000		
152	AUX1 Over-Voltage Threshold	FFFC		
154	AUX2 Under-Voltage Threshold	0000		

156	AUX2 Over-Voltage Threshold	FFFC
158	AUX3 Under-Voltage Threshold	0000
160	AUX3 Over-Voltage Threshold	FFFC
162	AUX4 Under-Voltage Threshold	0000
164	AUX4 Over-Voltage Threshold	FFFC
166	AUX5 Under-Voltage Threshold	0000
168	AUX5 Over-Voltage Threshold	FFFC
170	AUX6 Under-Voltage Threshold	0000
172	AUX6 Over-Voltage Threshold	FFFC
174	AUX7 Under-Voltage Threshold	0000
176	AUX7 Over-Voltage Threshold	FFFC
200	Customer Scratchpad	0000000000000000
210	Customer Cell Offset	00
211	Customer Gain Offset	00
212	Customer AUX0 Offset	0000
214	Customer AUX1 Offset	0000
216	Customer AUX2 Offset	0000
218	Customer AUX3 Offset	0000
220	Customer AUX4 Offset	0000
222	Customer AUX5 Offset	0000
224	Customer AUX6 Offset	0000
226	Customer AUX7 Offset	0000
240	Customer Checksum	ED373408
250	EEPROM Burn Count	00

Board Address: 3 *Module address shown again for easier viewing directly before logged data*

Time, Elapsed Time (Sec), BalanceEnable, Error Message, Cell_1, Cell_2, Cell_3, Cell_4, Cell_5, Cell_6, Cell_7, Cell_8, Cell_9, Cell_10, Cell_11, Cell_12, Cell_13, Cell_14, Cell_15, Cell_16, AUX_1, AUX_2, AUX_3, AUX_4, AUX_5, AUX_6, AUX_7, AUX_8, Int Dig Temp, Int Anlg Temp

The above column names are useful when data is viewed with spreadsheet software; spaces were added after each comma/tab to aid readability of the data. These spaces will not be present in the actual log file and all commas would be tabs in the .tsv file. The "BalanceEnable" column will only contain data when balancing is enabled and turned on. The data in such a case will be the value of the Balancing Enable register at addresses 20 and 21 (see the bq76PL455 data sheet for additional information regarding this register). The same comment applies to the four data samples below. In the case of a fault, the Error Message column will contain information indicating the possible source of the fault.

8/31/2011 5:26:39 PM, 0.199000, , , 3.112211, 3.349493, 3.548345, 3.794567, 3.023567, 3.219912, 3.504123, 3.697098, 3.890456, 3.099765, 3.333789, 3.554325, 3.745012, 3.991543, 4.176456, 3.454876, 1.188246, 1.439135, 1.934864, 1.856086, 1.881975, 1.814135, 1.715864, 1.302648, 0

Internal temperature is not being logged in this example. "3814" in the intervals at 0.400000 seconds and 0.601000 seconds indicate that cells 3, 5, 12, 13 and 14 were being actively balanced. "3814" is a hexadecimal representation of the binary value 0011 1000 0001 0100. Each '1' bit represents a cell being balanced, each '0' bit represents a cell not being balanced. (Refer to the description of the Balancing Enable register in the bq76PL455 data sheet for additional information.)

8/31/2011 5:26:39 PM, 0.400000, 3814, , 3.116230, 3.347999, 3.550401, 3.795432, 3.022998, 3.222023, 3.502967, 3.698901, 3.891953, 3.098876, 3.333893, 3.553979, 3.748014, 3.988978, 4.177001, 3.454023, 1.423829, 1.089947, 1.666958, 1.632123, 1.645456, 1.600789, 1.503890, 1.269901, 0

8/31/2011 5:26:39 PM, 0.601000, 3814, , 3.116233, 3.347970, 3.550395, 3.795398, 3.022945, 3.221096, 3.503012, 3.698845, 3.892021, 3.099121, 3.334031, 3.553989, 3.748012, 3.990021, 4.174011, 3.454012, 1.929034,1.857302, 1.493123, 1.479234, 1.510345, 1.471456, 1.399567, 1.267678, 0

8/31/2011 5:26:40 PM, 0.802000, , ,3.112221, 3.350678, 3.549369, 3.795402, 3.024783, 3.218998, 3.504001, 3.699001, 3.892025, 3.100002, 3.333794, 3.556005, 3.747987, 3.991100, 4.176022, 3.452017, 1.571526, 1.687453, 1.393345, 1.390234, 1.427456, 1.394432, 1.343345, 1.268543, 0

NOTE: When logging data for all bq76PL455EVMs, the specified target file name for the collected data will be appended with an underscore and the bq76PL455EVM address of the evaluation module from which the data were collected.

NOTE: From time to time, log file formats and other GUI features are adjusted slightly to add new features. Although every effort will be made to update this document appropriately when such changes are made, there may be some mismatch between this document and the version of GUI the user is using.