EM1401EVM

User's Guide

Texas Instruments

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EM1401EVM User's Guide

Topic Page

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1 General Description

The Texas Instruments EM1401EVM Battery Management System (BMS) is an evaluation board of the Active Balance chipset for use in large format Lithium-ion batteries that provides monitoring, balancing, and communications. With precise and robust active balancing, the Active Balance BMS is capable of bi-direction power transfer at each cell. Each EM1401EVM can manage 6 to 14 cells (60V max) for Li-ion battery applications. The EM1401EVM modules can be stacked up to 1300V. The system provides fast cell balancing, diagnostics, and module to controller communication. Independent protection circuitry is also provided.

The EM1401EVM is equipped with precision measurement and synchronous communication to enable a master controller to perform State of Charge (SOC) and State of Health (SOH) estimation. Highly accurate cell voltages and a fast sampling time for the entire battery pack allows more efficient operation of battery modules and more accurate SOC / SOH calculations. The user will be able to extend the available capacity of the battery and will benefit from longer pack lifetimes versus passive or dissipative balancing systems.

The EM1401EVM is equipped with smart diagnostic systems. These systems monitor fault events such as under-voltage, over-voltage, and over-temperature. The system is also capable of pack temperature and cell temperature sensing. The fault flagging systems help protect the battery module and alert the user of potential problems.

2 Key Features

- Active Bi-Directional Cell Balancing
- Multi-Cell Charge/Discharge Capability
- Isolated Communications (5kV)
- Flexible Architecture for 6 to 14 cells
- CAN Bus Interface
- High Accuracy Cell Voltage Measurement
- Diagnostics

3 Key Electrical Parameters

- Maximum Battery Pack Voltage: 1300 V
- Maximum Operating Voltage: 59 V
- Minimum Operating Voltage: 20 V
- Maximum Cell Open Circuit Voltage: 5 V
- Ambient Temperature: –40°C to 85 °C
- Nominal Operating Temperature: –20 °C to 60°C
- Cell Balancing Current: up to ±5 A

3.1 Functional Block Diagram

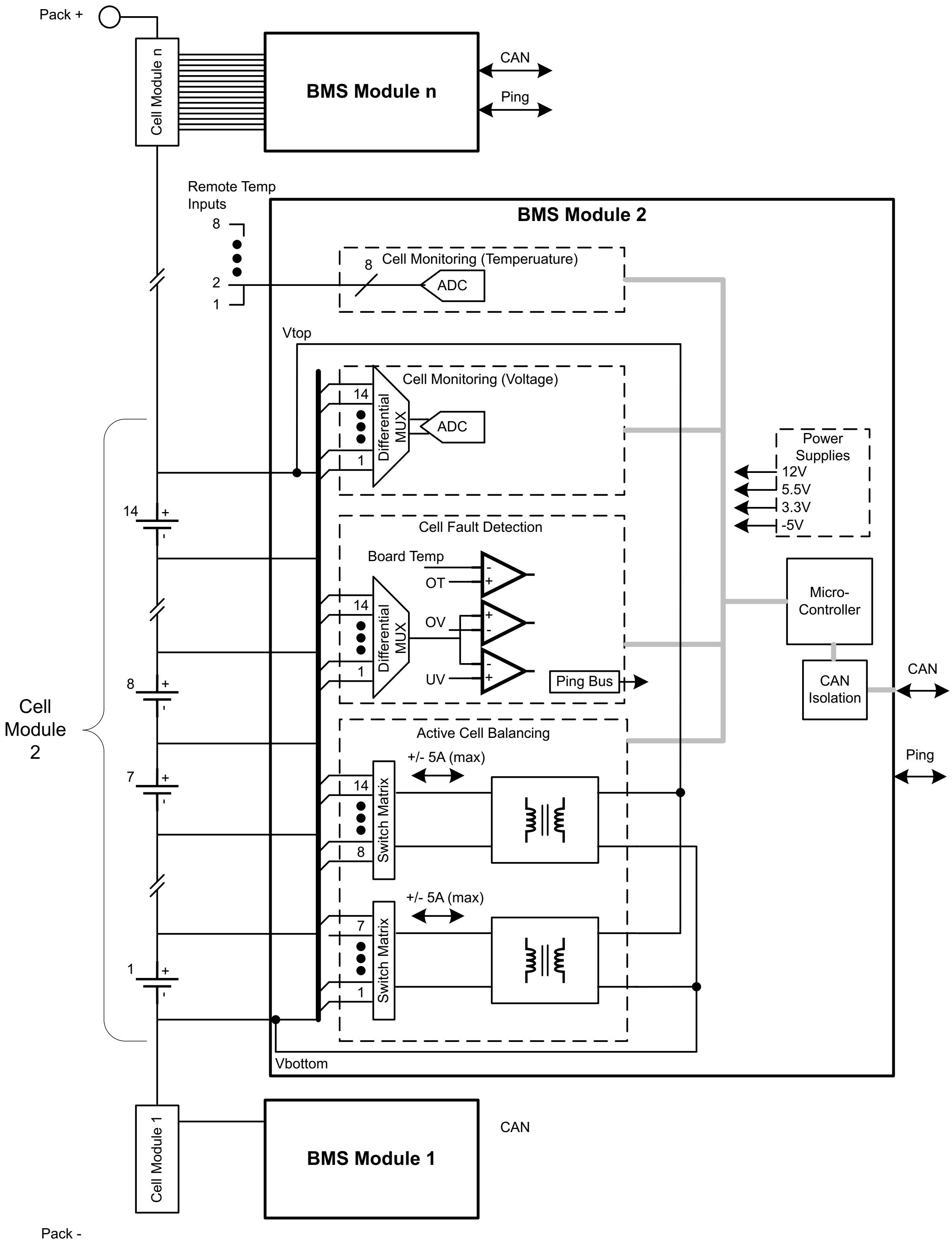

Figure 1. EM1401 Functional Block Diagram

4 Theory of Operation

The BMS system is designed to prolong the useful life of Lithium-ion cells in battery packs through active balancing. The battery pack is broken into a series of modules, each of which contains 6 to 14 cells. This system will monitor voltages of individual battery cells and transfer charge from the module stack to an under-charged cell or take charge from an over-charged cell and transfer it to the module stack. The BMS allows battery powered electric machines to use smaller battery packs and use fewer charging cycles to perform the same amount of work. It also improves the overall lifetime of Li-ion battery packs by preventing under- and over-voltage damage from occurring.

The BMS system has three main sub-systems, as shown in Figure 1:

- Cell Voltage Monitoring Circuitry
- Cell Fault Detection
- Active Cell Balancing Engine

The cell-monitoring architecture is based on the EMB1432 (AFE), EMB1433 (battery pack protection) and LM3S5R31 ARM Cortex M3 microcontroller. The EMB1428 is designed to control access to up to 7 cells of a typical 14 cell battery module; the full 14 cell module utilizes two EMB1428 and one or two EMB1499 ICs. The EM1401EVM is designed with two EMB1499 ICs to allow simultaneous charge/discharge of up to two cells (one in each group of upper and lower 7 cells).

When the BMS starts up, a CAN bus command begins monitoring. In this mode, the monitor circuit measures and stores the current voltages of each cell. The values can be requested via the CAN bus. A basic flowchart showing the EM1401EVM startup activities can be seen in Figure 2.

When a CAN bus command to begin active balancing is received, all cell voltage values are monitored and cell balancing commences based on identifying the cell with the largest difference from the average voltage value across all the cells. If the difference is less than the configured threshold, Vdiff (±2mV for example), the BMS will be operated just as in the initial startup mode with only the monitoring function enabled. When individual cell voltage values are found to be outside of the Vdiff threshold the cell balancing engine will be enabled to either charge the lowest cell at up to 5A from the module, or discharge the highest cell at up to 5A into the module.

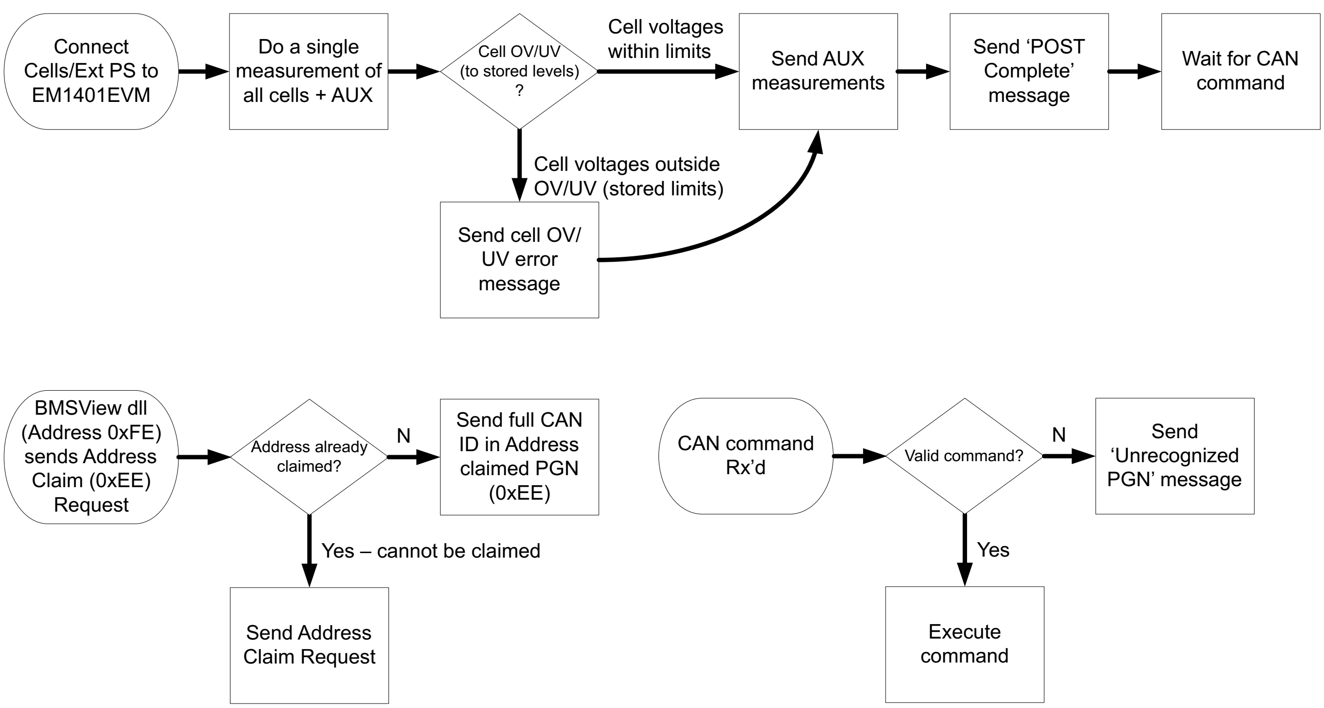

Figure 2. EM1401EVM Software Startup Flowchart

4.1 Single Board

As a single board the BMS can actively balance 6 - 14 cells up to 60V of total voltage. Communication to the BMS is handled by the CAN bus.

4.2 Stacked Systems

The BMS boards may be stacked up to 1300V. Communication for all BMS modules stacked in the pack is handled by the same CAN bus. When connecting the CAN Bus, the top and bottom CAN nodes on the bus must be terminated. The user should take note of the Board ID and position in the stack to configure the pack through the provided BMSView PC GUI.

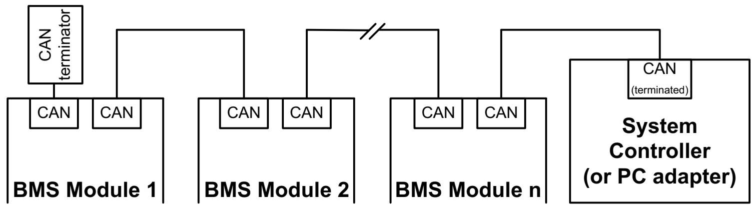

Figure 3. CAN Bus Termination

4.3 Automatic Cell Balancing (ACB) Algorithm Description

4.3.1 Balance to Average

In the EM1401EVM, the cell balancing currents flow from cell to module and module to cell. The cell that is furthest from the average voltage for the module should be charged or discharged until that cell is within a threshold of the average or until another cell in the module is further from the average.

4.3.2 Simultaneous Balancing Of Upper and Lower Banks

A feature of the EM1401EVM is that the module is divided into upper and lower banks. Each bank has independent balancing circuits that operate simultaneously, even if the minimum and maximum voltage cells for the module are in one bank. For each bank, every cell is compared to the average, and the cell furthest from the average is charged or discharged to move it closer to the average. Both the upper and lower banks of each module can be balanced simultaneously and independently using these simple criteria. When each bank reaches the target voltage threshold it will automatically switch to an idle state, where the cells are still monitored, and charge/discharge will not occur until the minimum or maximum cell voltage within the bank surpasses the provided threshold.

4.3.3 ACB Balance Cycle

Figure 4 shows the basic overview of the ACB Balance Cycle which consists of the following functions occurring in the order outlined below. The user parameters are provided in the GUI (see Figure 26) or via CAN commands (see HLP_CAN_NSC.pdf document).

1. All cells sampled, at the user specified level of oversampling (32 by default).
2. Average cell voltage (Vavg) calculated, and all cell samples compared to Vavg to determine the cell within each half-stack (cells 0-7 and cells 8-14) furthest from Vavg which will require charge or discharge.
3. Cell charge or discharge applied within each half-stack for a duration specified by the user.
4. Cell charge or discharge removed and a relaxation period applied for a duration specified by the user. The applied relaxation time will be reduced by the system firmware to accommodate the time taken by the system to take the cell samples at the beginning of the ACB Balance Cycle (~73ms when set for 32 oversamples, ~2ms when set for 1 oversample). As a result, the entire period from start of cell charge/discharge applied and the next cycle of cell charge/discharge applied will be the sum of the user specified charge/discharge duration and the user specified relaxation duration.

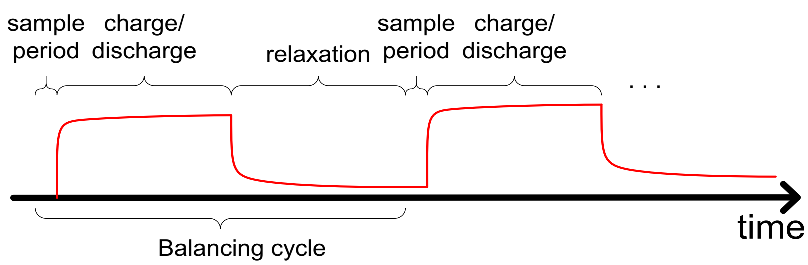

Figure 4. ACB Balance Cycle

4.3.4 Hysteretic Balancing

Efficiency is a critical factor in cell balancing, so it is important to prevent the balancing algorithm from charging and discharging the same cell in response to noise in the AFE readings (toggling). To prevent toggling, a hysteresis threshold can be used in the balancing algorithm. With hysteresis the balancing threshold is smaller in the forward direction than the reverse directions, making it harder for the algorithm to reverse course and discharge a cell that was just charged (or vice versa). When a voltage difference large enough to reverse the direction does occur, the thresholds are adjusted so that the new forward direction is smaller than the new reverse direction.

The forward and hysteresis thresholds can be adjusted based on noise levels in the system.

An example of its usage is described below.

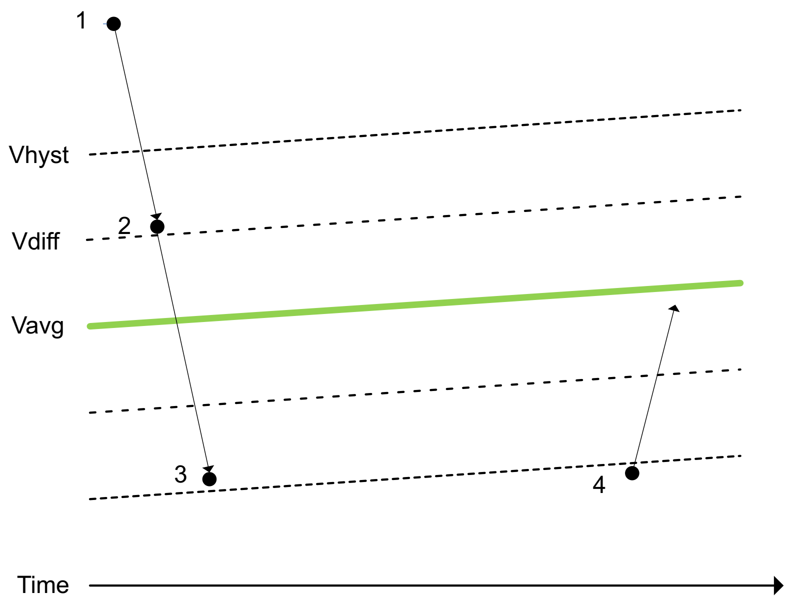

Figure 5. Vdiff, Vhyst Description

1. Cell is highest (only one cell is shown for this example) deviant from Vavg, so is selected for discharge.
2. Cell is still highest, and still has a deviation from Vavg that is higher than Vdiff. Cell is selected for discharge again.
3. Cell is still highest deviant from Vavg, but would require charging (opposite direction from previous event) to be brought into Vdiff region. The cell has not exceeded Vhyst deviation from Vavg. The cell is NOT selected for either charge or discharge.
4. After some time (or other cells being balanced) cell is now greater than the Vhyst deviation from Vavg. Cell is selected to be charged.

5 Hardware Setup

5.1 Connectors

5.1.1 Battery Connector

The battery cell connections are made from connector BATTERY_16. Cell voltage measurements and balancing currents use these connections. Short unused channels to top cell connection in wiring harness to support less than 14-cells.

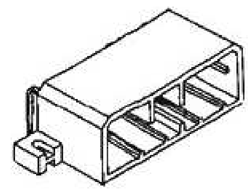

Figure 6. Tyco Electronics 175785-1 (Reference Image Only)

5.1.1.1 Connector Information

Table 1.

Designator	Manufacturer	Part Number	Mating Connector
BATTERY_16	Tyco Electronics	Manufacturer: 175785-1 Digi-Key: 175785-1-ND	Manufacturer: 174952-1 Digi-Key: 1-174952-1-ND Contacts: Manufacturer: 175027-6 (16 -20AWG) Digi-Key: 175027-6-ND

5.1.1.2 Pin Description

Table 2.

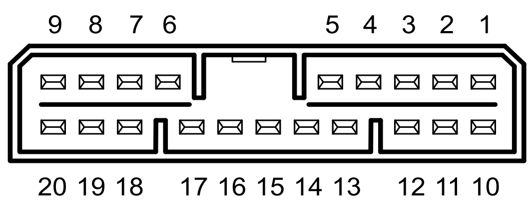

Figure 7.

Pin	Name	Comments
1	BAT0	Negative terminal of BAT1. Local ground for module.
2	BAT12	Positive terminal of BAT12/negative terminal of BAT13.
3	BAT11	Positive terminal of BAT11/negative terminal of BAT12.
4	BAT10	Positive terminal of BAT10/negative terminal of BAT11.
5	BAT9	Positive terminal of BAT9/negative terminal of BAT10.
6	BAT4	Positive terminal of BAT4/negative terminal of BAT5.
7	BAT3	Positive terminal of BAT3/negative terminal of BAT4.
8	BAT2	Positive terminal of BAT2/negative terminal of BAT3.
9	BAT14	Positive terminal of BAT14/negative terminal of BAT15.
10	BAT13	Positive terminal of BAT13/negative terminal of BAT14.

Table 2. (continued)

11	BAT14	Positive terminal of BAT14/negative terminal of BAT15.
12	NC	Not connected
13	NC	Not connected
14	BAT8	Positive terminal of BAT8/negative terminal of BAT9.
15	BAT7	Positive terminal of BAT7/negative terminal of BAT8.
16	BAT6	Positive terminal of BAT6/negative terminal of BAT7.
17	BAT5	Positive terminal of BAT5/negative terminal of BAT6.
18	NC	Not connected
19	BAT0	Negative terminal of BAT1. Local ground for module.
20	BAT1	Positive terminal of BAT1/negative terminal of BAT2.

5.1.2 CAN bus

The CAN bus connections are made from connector CAN BUS. The cable can be a standard CAT5 Ethernet cable with RJ45 connectors. There are receptacles for 2 cables to allow daisy-chain connection to adjacent BMS boards.

Figure 8. CANbus RJ45 (Reference Image Only)

5.1.2.1 Connector Information

Table 3.

Designator	Manufacturer	Part Number	Mating Connector
CAN BUS	EDAC	Manufacturer: A00-216-262-450	3.28' (1m) shielded cable Digi-Key: AE9971-ND

5.1.3 Thermistor Inputs

There are 8 thermistor connections. The board provides a 20kΩ pullup to 3.3V.

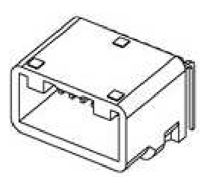

Figure 9. Thermistor Connector (Reference Image Only)

5.1.3.1 Connector Information

Table 4.

Designator	Manufacturer	Part Number	Mating Connector
TEMP_SENSE	Tyco Electronics	Manufacturer: 1318382-2	Manufacturer: 1717109-2 Digi-Key: 1717109-2-ND Contacts: Manufacturer: 175027-6 (16 -20AWG) Digi-Key: 175027-6-ND

5.1.3.2 Pin Description

Table 5.

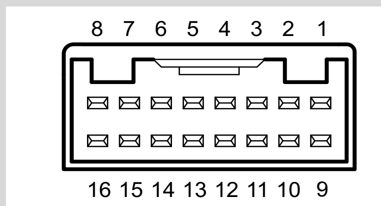

Figure 10.

Pin	Name	Comments
1	TS_0	Thermistor 1 connection (on-board 20kΩ pullup to 3.3V)
2	TS_1	Thermistor 2 connection (on-board 20kΩ pullup to 3.3V)
3	TS_2	Thermistor 3 connection (on-board 20kΩ pullup to 3.3V)
4	TS_3	Thermistor 4 connection (on-board 20kΩ pullup to 3.3V)
5	TS_4	Thermistor 5 connection (on-board 20kΩ pullup to 3.3V)
6	TS_5	Thermistor 6 connection (on-board 20kΩ pullup to 3.3V)
7	TS_6	Thermistor 7 connection (on-board 20kΩ pullup to 3.3V)
8	TS_7	Thermistor 8 connection (on-board 20kΩ pullup to 3.3V)
9	GND	Ground
10	GND	Ground
11	GND	Ground
12	GND	Ground
13	GND	Ground
14	GND	Ground
15	GND	Ground
16	GND	Ground

5.1.4 External Power Supply

This connector provides the capability to power all on-board house-keeping power supplies from an external supply.

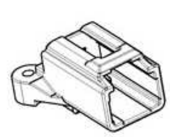

Figure 11. External Power Supply Connector (Reference Image Only)

5.1.4.1 Connector Information

Table 6. Connector Information

Designator	Manufacturer	Part Number	Mating Connector
P2	Tyco Electronics	Manufacturer: 1452625-1	Manufacturer: 1452598-1 Contacts: Manufacturer: 1393367-1 (22-24AWG)

5.1.4.2 Pin Description

Table 7.

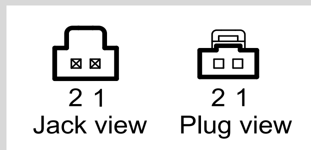

Figure 12.

Pin	Name	Comments
1	14 to 70 V	Positive external power supply input (isolated from all other BMS modules)
2	GND	GND external power supply input

5.1.5 Ping Bus

There are 2 Ping Bus connectors, PING_IN which connects to the board above (or no connect at top of pack), and PING_OUT which connects to the board below (or to the pack controller at the bottom of the pack).

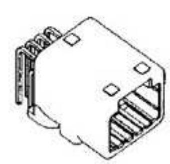

Figure 13. PING_IN or PING_OUT Connector (Reference Image Only)

5.1.5.1 Connector Information – PING_IN

Table 8. Connector Information, PING_IN

Designator	Manufacturer	Part Number	Mating Connector
PING_IN	Tyco Electronics	Manufacturer: 1565749-1 Digi-Key: 1565749-1-ND	Manufacturer: 1473672-1 Digi-Key: 1473672-1-ND Contacts: Manufacturer: 1318143-1 (24AWG) Digi-Key: 1318143-1-ND

5.1.5.2 Pin Description - PING_IN

Table 9.

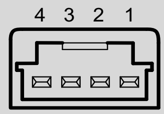

Figure 14.

Pin	Name	Comments
1	PING_IO_HS	IO input from upper adjacent BMS module. Connects to PING_IO_LS of upper adjacent BMS module. If top BMS module, leave floating.
2	DIN_LS	“Heart” pulse fault monitor input from upper adjacent BMS module. Connects to DOUT_LS of upper adjacent BMS module. If top BMS module, leave floating.
3	TOP_DRV	Connect to 3V3 (pin 4 below) if top of the stack module or if the 1 wire fault communication channel is unused. For all the other modules, leave TOP_DRV not connected (on-board pull-down to DGND).
4	3V3	3.3V

5.1.5.3 Connector Information – PING_OUT

Table 10. Connector Information, PING_OUT

Designator	Manufacturer	Part Number	Mating Connector
PING_OUT	Tyco Electronics	Manufacturer: 1376350-1 Digi-Key: 1376350-1-ND	Manufacturer: 1376352-2 Digi-Key: 1376352-2-ND Contacts: Manufacturer: 1318143-1 (24AWG) Digi-Key: 1318143-1-ND

5.1.5.4 Pin Description - PING_OUT

Table 11.

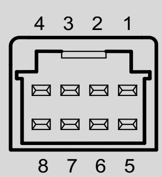

Figure 15.

Pin	Name	Comments
1	GND	
2	NC	No connect
3	DOUT_LS	“Heart” pulse fault monitor output to lower adjacent BMS module. Connects to DIN_LS of lower adjacent BMS module. If bottom BMS module – no connect.
4	PING IO LS	IO output to lower adjacent BMS module. Connects to PING_IO_HS of lower adjacent BMS module. If bottom BMS module – no connect.
5	PING LS OUT	If bottom BMS module, digital output to system controller. Communicates fault information over a single wire. All other BMS modules - no connect.
6	PING LS IN	If bottom BMS module, digital input from system controller. A single high pulse initiates a fault status communication on the PING_LS_OUT pin. All other BMS modules - no connect.
7	nFAULT	If bottom BMS module, “Heart beat” pulse digital output to system controller. All other BMS modules - no connect.

Table 11. (continued)

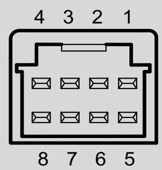

Figure 15.

Pin	Name	Comments
8	NC	No connect

5.2 Connection Sequence

1. Connect CAN bus
2. Connect battery cell harnesses to EM1401EVM
3. Connect all inputs (Ping bus, thermistor, if used)

Immediately upon connecting the battery cells, the BMS will flash the red LED a number of times corresponding to the board ID, followed by holding the red LED lit for 2 seconds then repeat.

5.3 Single Board Setup

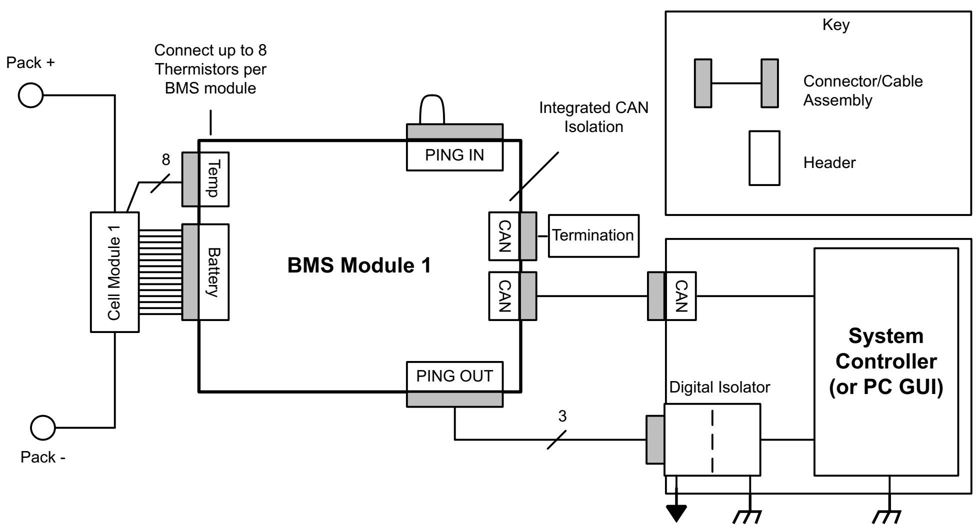

Figure 16. Single Module Connection Overview

5.4 System Connection Diagram

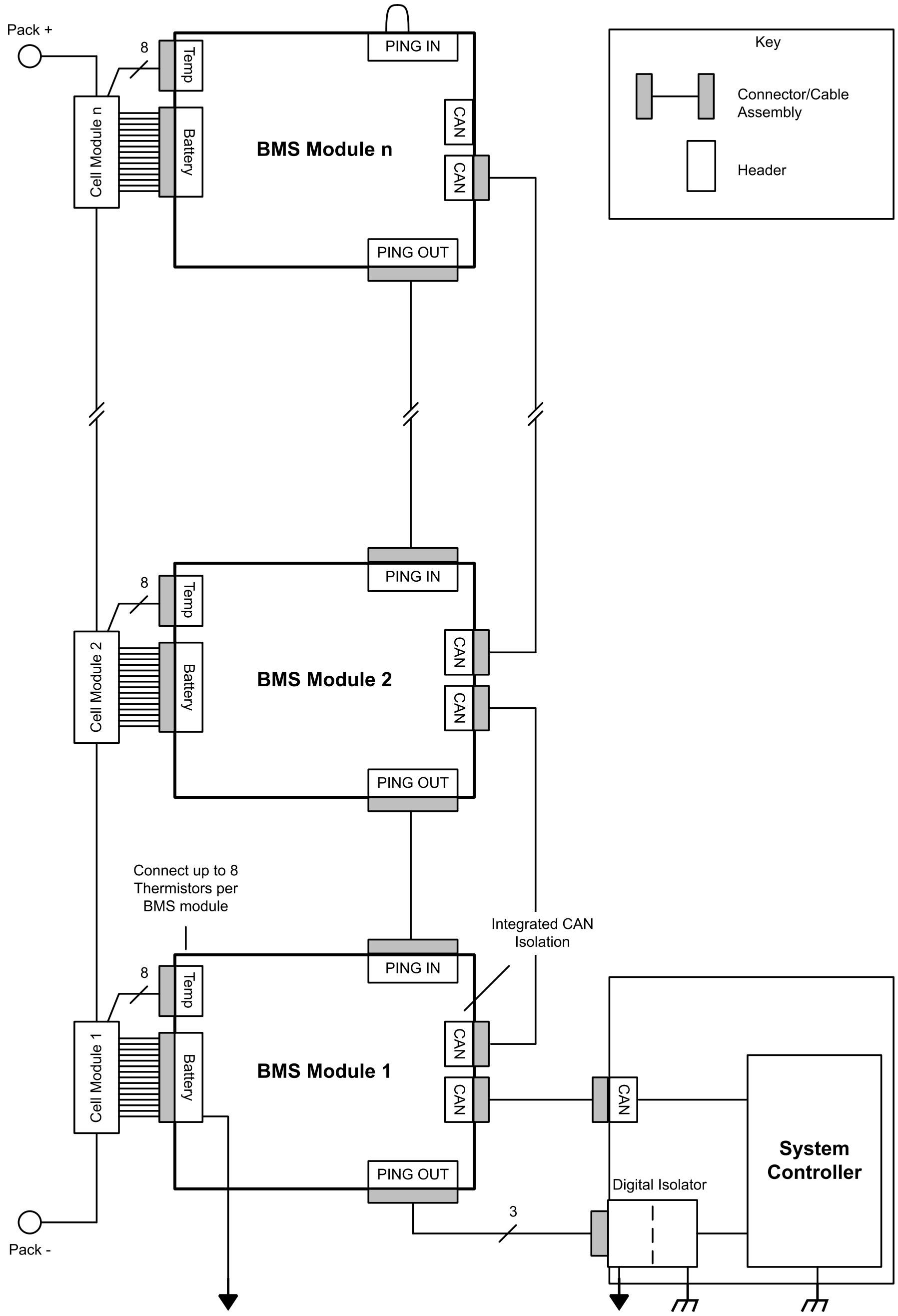

Figure 17. System Interconnection Diagram

6 Software

A PC GUI has been developed to demonstrate the EM1401EVM, BMSView v2.2.2. The BMSView PC GUI software requires the use of the VS-Com model 420 USB CAN adapter (http://www.vscom.de/420.htm). Driver Installation instruction for the VS-Com 420 USB CAN adapter are provided below.

6.1 USB CAN Drivers

The following tools are used to connect to the BMS:

- VS-Com USB CAN adapter
  - Downloadable from:
    - http://www.vscom.de/420_download.htm

6.1.1 Installation Instructions

Use the USB driver from the directory "USB-CAN\Driver" on the product CD or download it from the company website listed above. If you've done this, you could plug in the adapter in an USB port of your choice. When you will be asked for the driver, you must choose the location of the driver files. The device will be registered and you can use the COM port (see Figure 18 - Device Manager).

Figure 18. Device Manager

To set the baudrate required for operation at 500Kbps you must call the script "regmodify.vbs" with the desired COM port at the Windows command prompt, in the path of the driver files (USB-CAN\Driver) like this:

"cscript regmodify.vbs COM15"

Please disconnect the device from the system after this step.The CAN adapter is now ready to be used by the BMS system and the PC GUI software.

The VS-Com CAN-USB adapter has a DB9 connector. The user is required to create an adapter cable to connect to the RJ45 connector on the EM1401EVM. The schematic for the adapter is provided in Appendix D.

The user can choose to provided termination to the CAN bus in the adapter or on the EM1401EVM board by populating R26 and R283 with 60Ω 0603 resistors. Power to the isolated portion of the CAN bus on each BMS module will need to be provided from an external DC-DC supply. The user can choose to use the power provided by the USB CAN adapter itself, which will be sourced from the PC USB port. As the PC USB port is limited in the amount of current that can be sourced, it is recommended to use this source only if connecting to 3 or less BMS modules attached to the same CAN bus. Each BMS module consumes ~40mA. The external DC-DC supply will need to provide 5V and sufficient current to supply the number of BMS modules in the pack. The external DC-DC supply is connected to the +5V_CAN header located beside the CAN connectors on the BMS board. Only one BMS module in the entire pack will need to be connected to the external DC-DC supply, as the +5V_CAN net is included in the connected signals on the RJ45 connector.

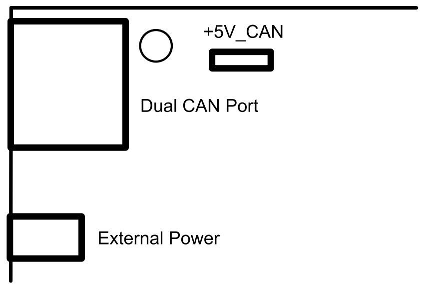

Figure 19. Location of +5V_CAN Header

6.1.2 PC Hardware System Requirements

There are known factors which will affect the GUI performance based on PC hardware and EM1401EVM configurations if plotting dynamically:

1. Data sampling rate
2. Number of EM1401EVM boards transmitting data
3. Duration of the plotting session (that is, total data points collected)

The following are recommended system requirements for running the BMSView software for a pair of identified use models:

1. Assuming the use of two EM1401EVM boards and performing Module-to-Module charge transfer while sampling data every 0.100 seconds and plotting dynamically.
   - Windows XP system:
     – Intel Core2 Duo @ 2GHz
     – 1 GB RAM
     – 1024x768 display
       - (Minimum requirement for program installation. Additional space required on C:\ drive for data log file).
     – 50MB HD Space (plus 20MB for installer file)
       - (Minimum requirement for program installation. Additional space required on C:\ drive for data log file).
     – USB 2.0 port (for VSCom™ VSCAN USB-CAN module)
2. Assuming the use of five EM1401EVM boards and performing Module-to-Module charge transfer between two boards and sampling data from all boards every 1.000 seconds and plotting dynamically:
   - Windows XP system:
     – Intel Core i5 @ 2.4GHz
     – 3 GB RAM
     – 1024x768 display
       - (A lower resolution display can be used, but the BMSView tool will utilize scroll bars for certain sections).

– 50MB HD Space (plus 20MB for installer file)
  - (Minimum requirement for program installation. Additional space required on C:\ drive for data log file).

– USB 2.0 port (for VSCom™ VSCAN USB-CAN module)

If the PC hardware configuration is not sufficient to meet the demands of the GUI for plotting dynamic data, the following may occur:

- Delays in the capture of data, which will appear as latency between events on the hardware and the plotting in the GUI.
- Eventual crash of the GUI

Workarounds if the above problems occur:

1. Do not plot data dynamically if not required. The BMSView tool stores all the data collected, and will display all the data if the user chooses to plot at a later time. Do not plot dynamically if there is no one watching the data.
2. Clear the data from the plots if there is no longer a need to view past events. Data for the entire BMSView session is still stored in the log file.
3. Consider reducing the sampling data rate if dynamic plotting is necessary.

6.1.3 Use of Software

After installing the software, a new folder will be created in the Windows start menu called BMSView. In that folder there are 3 links: BMSView, can2csv and Uninstall BMSView.

BMSView	The graphical user interface (GUI) for interfacing to the BMS from the PC.
can2csv	An app that reads the log file output and filters out the AFE channel measurement data to a comma-delimited csv file format. This file can be opened in Microsoft Excel for further analysis.
Uninstall BMSView	Uninstalls the BMSView application and deletes the application folder.

Upon running BMSView, the first response will be a request for the COM port the CAN adapter is using. Enter the COM port number as "COM" followed by the port number.

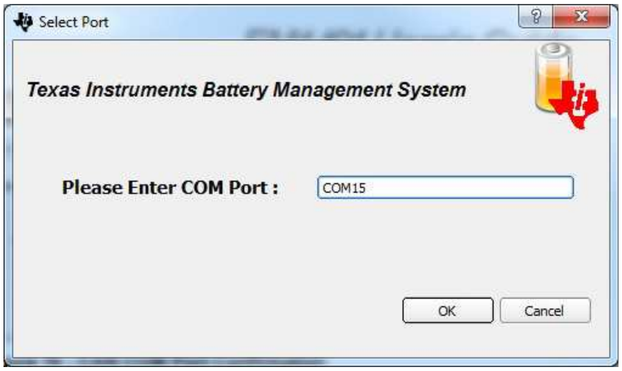

Figure 20. CAN COM Port Confirmation

Next, the GUI will search the CAN bus for EM1401EVM boards and then display a module map. The GUI will attempt to read the stack location assigned to each BMS. If the stack location has never been assigned before, then the stack location will be displayed as '255'. **The BMS modules MUST be assigned a stack location number of 1 to n, where n = the total number of BMS modules in the pack.** The user will need to confirm and write the stack location at least once after initial startup of the system. The number of cells for each module is also entered here. "Write Setting To Board" sends the values of stack location and number of cells to each BMS over the CAN bus to be written into the onboard non-volatile memory. Click "OK" once the settings have been written and confirmed.

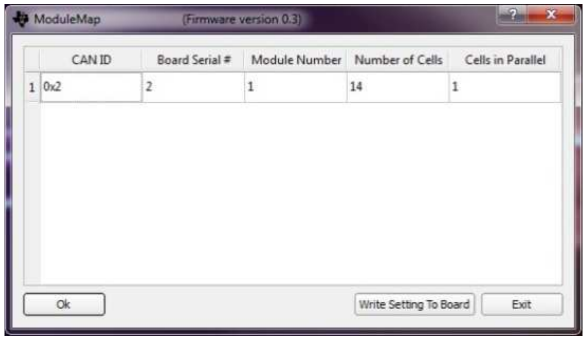

Figure 21. Module Map Confirmation

The GUI will now come up in its default state. Nothing will be read from the BMS until a command is sent.

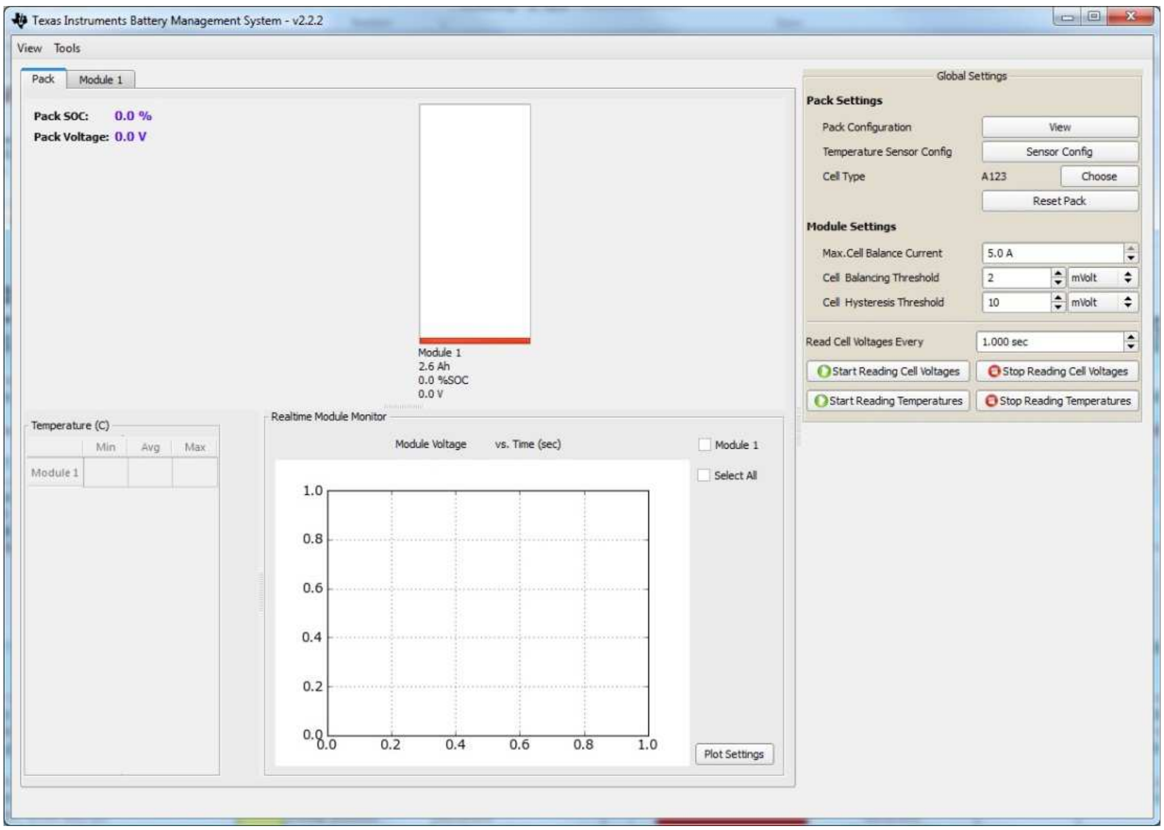

Figure 22. GUI Initial View

6.1.3.1 Global Settings

The global settings area displays all of the parameters and commands that are global in nature, ie. the same for all cells and modules in the entire pack.

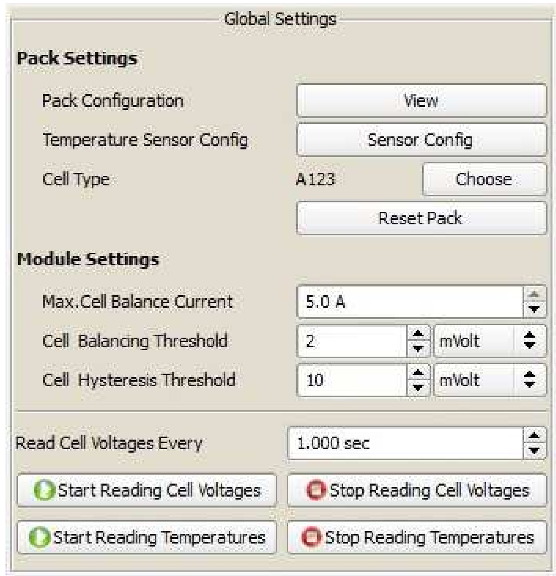

Figure 23. Global Settings

The following parameters can be set (see Figure 23):

Pack configuration - the module map can be reconfigured. The module number (stack position) and number of cells can be edited. This is usually done at GUI startup.

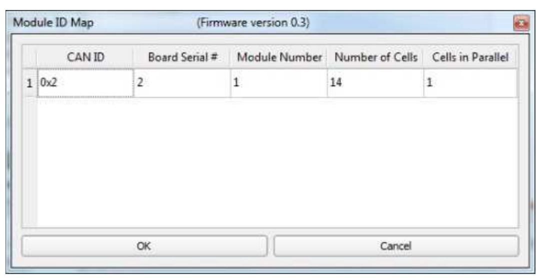

Figure 24. Module Map Configuration from within GUI

Temperature sensor configuration - the parameters of the thermistors that are attached to the board can be set. The thermistor R (resistance) and Beta value are required.

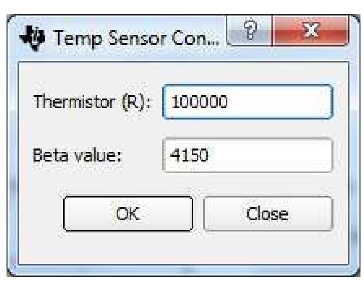

Figure 25. Temperature Sensor Configuration

Cell type - the cell characteristics can be configured in the view shown in Figure 26. The parameters below can be set, which affect the automatic cell balancing algorithm and safety limits. The cell information is stored in a local directory (for Windows XP: c:\documents and settings\<user>\Application Data\Texas_Instruments\BMSView\cellinfo.txt. For Windows 7: c:\Users\<user>\AppData\Roaming\Texas_Instruments\BMSView\cellinfo.txt). When the GUI starts the board will be read and the parameters compared to the local file to complete the name. If the read parameters do not match any entries saved in the local file, the cell name "UNKNOWN" will be shown. In this case the parameters will need to be saved to the local file. To add a new cell type, press "Add Cell Type", enter the parameters, then "Save To File". The user can then choose the cell type in the "Choose Cell Type" list and press "Write To All Boards" to write the cell configuration to all of the BMS modules.

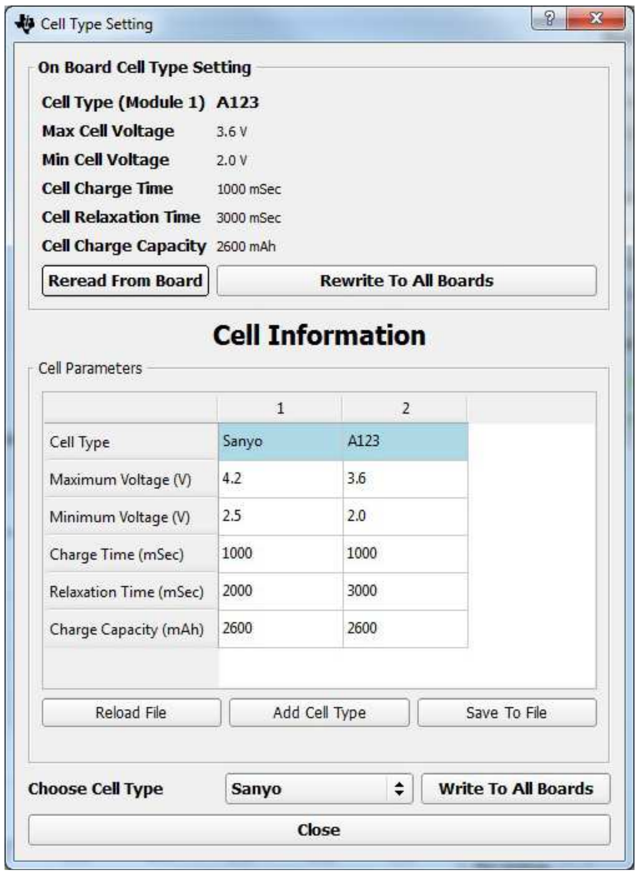

Figure 26. Cell type Configuration

Name - the user can assign any useful name to the cell configuration.

Max cell voltage - the voltage above which charging will not be allowed.

Min cell voltage - the voltage below which discharging will not be allowed.

Cell charge time - the duration of the charge/discharge portion of the balancing cycle.

Cell relaxation time - the duration of the relaxation portion of the balancing cycle.

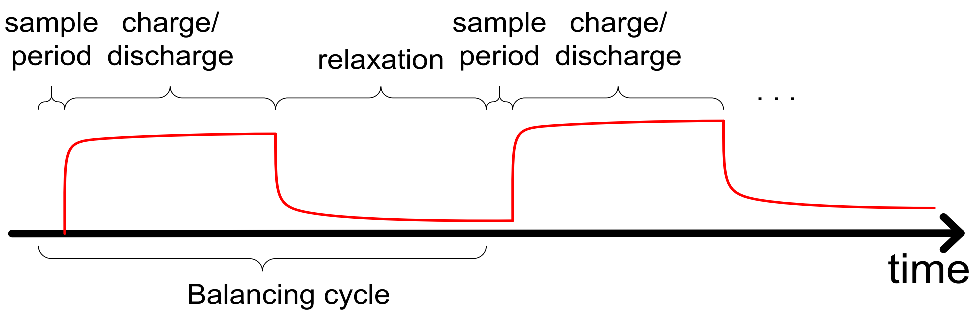

Figure 27. Parameters in the Balancing Cycle (Charge Shown)

Cell charge capacity - the total capacity in mAh of the cell

Max cell balance current - Sets the max current allowed during automatic cell balancing. Valid setting is 2.0 to 5.0 Amps. This parameter is sent to the board as part of the enable active balancing command.

Cell balancing threshold - the absolute voltage difference in millivolts from average [of all cells] above which balancing is enabled. This parameter is sent to the board as part of the enable active balancing command. ±2mV by default.

Cell hysteresis threshold - the absolute voltage difference in millivolts from average [of all cells] above which balancing in the opposite direction of the previous operation is enabled. This parameter is sent to the board as part of the enable active balancing command. ±10mV by default.

The following commands are supported from the global view (shown in Figure 23):

Reset Pack – This will send a reset command to all BMS modules in the pack. The BMS boards will do a soft reset. After reset the GUI will also reset it's display and will be ready for new commands to be executed.

Start Reading Cell Voltages - The GUI will issue the commands to the BMS necessary to start measuring all of the cells and the data will be sent via the CAN bus to be read by the GUI. The data rate to output all 14 cell measurements is set in field called “Cell Voltages Every:”. The minimum value supported is 100ms.

Stop Reading Cell Voltages - The BMS will stop reporting cell measurements to the CAN bus.

Start Reading Temperatures - The GUI will issue the commands to the BMS necessary to start measuring the 8 thermistors and the data will be sent via the CAN bus to be read by the GUI. The data rate is pre-configured to output all 8 thermistor temperatures at a 10 second interval. Before running this command, the Sensor Config should be set to the parameters of the thermistors that are attached to the board.

Stop Reading Temperatures - The BMS will stop reporting cell measurements to the CAN bus.

6.1.3.2 Module Commands

The module settings area displays all of the parameters and commands that are related only to the module level, i.e. cell balancing.

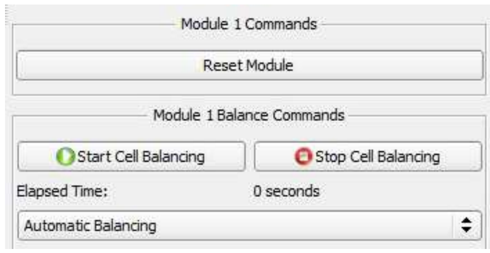

Figure 28. Module Commands - Automatic Cell Balancing

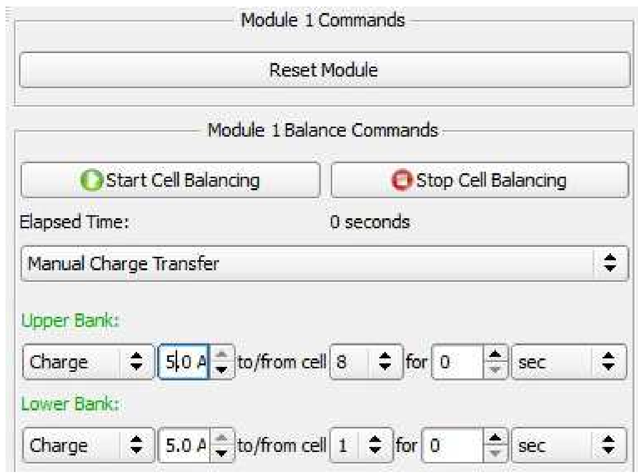

Figure 29. Module Commands - Manual Cell Charge Transfer

The following commands are supported from the module view:

Start Balancing - The cell balancing method selected in the drop down list (automatic balancing and manual charge transfer) will be enabled.

Stop Balancing - The BMS will stop cell balancing.

6.1.3.3 Automatic Cell Balancing

This mode will enable the hysteretic automatic cell balancing algorithm described in previous sections.

6.1.3.4 Cell Balancing Manual Charge Transfer

The user can select the charge/discharge current (1.0 - 5.0 Amps supported) and duration in seconds, minutes or hours for one cell in each half stack of 7 cells (see Figure 29). If only one cell in the entire module is to be selected for charge/discharge, set the desired parameters for that cell within its half-stack (upper or lower) and set the charge current or duration to 0 for the opposite half-stack. Once the parameters are set, press **Start Balancing** to send the balancing command to the BMS.

6.1.3.5 Notification Window

The EM1401EVM will periodically send information or error notifications which will be displayed in the notification window, shown in Figure 30. Explanation of the error codes is provided in Section 9 .

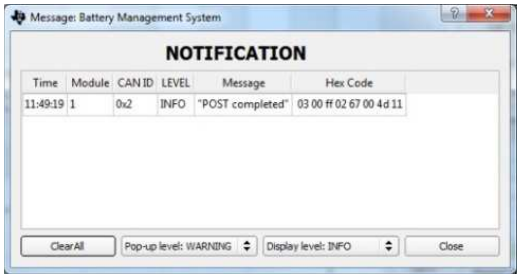

Figure 30. Notification Window

6.1.3.6 Plot Settings

The plot settings can also be configured.

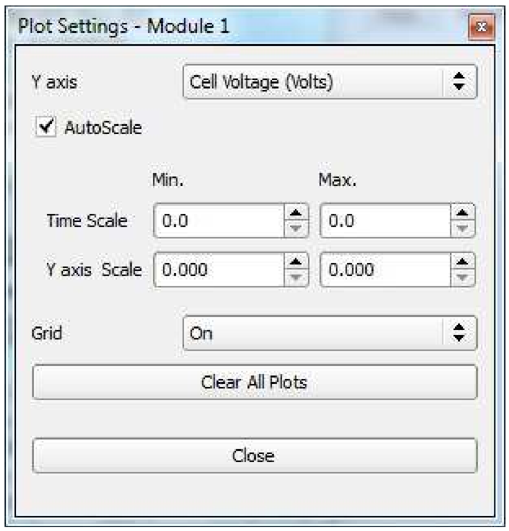

Figure 31. Plot Settings

The following parameters can be configured:

AutoScale	Setting this will configure the plot window to show all available data.
Time Scale	The min and max values can be set for the beginning and end sample count to zoom the plot to.
Y Axis Scale	The min and max values can be set for the beginning and end Y axis level (voltage) to zoom the plot to.
Grid	Enables the visible grid in the plot window.
Clear All Plots	This will clear all plot windows (pack and modules).

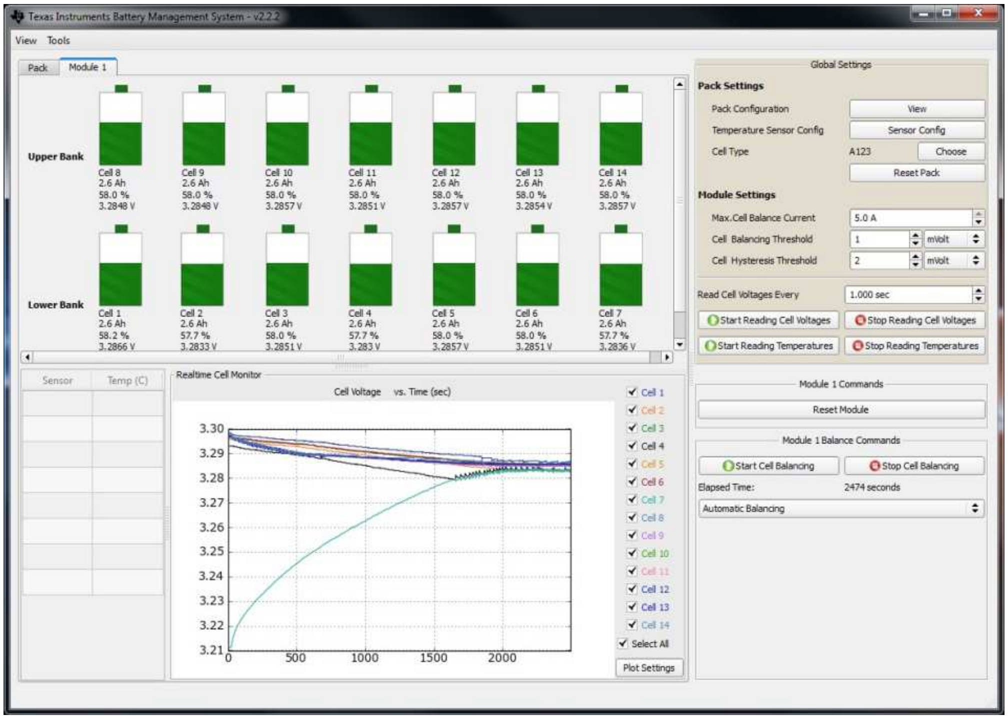

Figure 32. Module View in Operation

7 Appendix A

7.1 Enclosure Requirements

The BMS board must be in a sealed enclosure to prevent contamination and ensure life of the board. Requirements for the enclosure include:

- IP67 rated
- Maximum enclosure ambient temperature not to exceed 850C
- Metal or shielded enclosure for EMI protection
- Automotive grade connectors
- Secure mounting, no shock greater than 30 Grms in any direction

8 Appendix B

8.1 Physical Specifications

8.1.1 Board Dimensions

Board dimensions: 7" x 6.1"

Board height:

- Top - Tallest component (CAN BUS) is 1.4" (35. 0mm) above PCB.
- Bottom - Tallest component (L1) is 0.150" (3.8mm) above PCB.

8.1.2 Board Mounting

The mounting holes are shown in Figure 33 - Board Dimensions

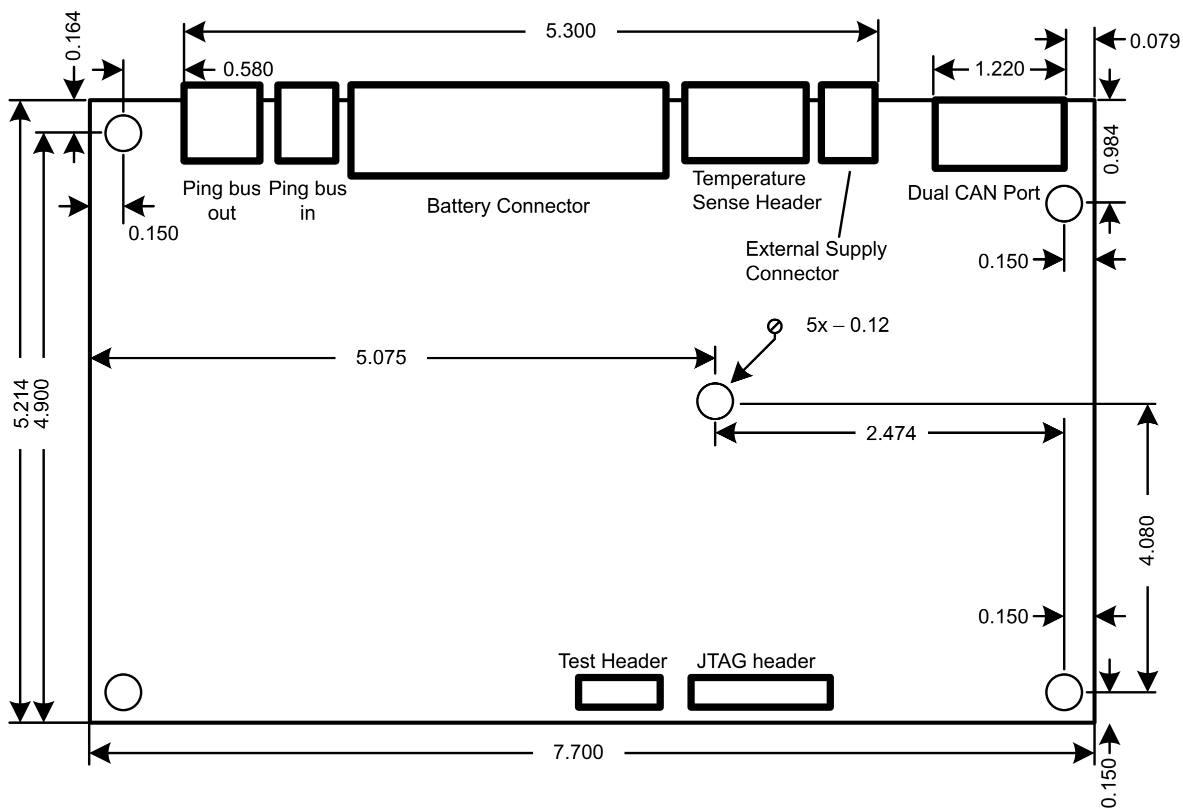

Figure 33. Board Dimensions

9 Appendix C

9.1 Notification Messages

There are 3 basic Notification Message types sent from the BMS (starting from firmware revision 2.x). The first data byte of the DB PGN (refer to the BMS CAN Higher Level Protocol documentation) provides a description of what the rest of the data in the message will be referring to.

Table 12. Notification Message Type and Level

Byte 0	
Bits [4:7]	Bits [0:3]
Message Type	Message Level

Message Type – There are 3 types of message formats:

0. Legacy – Older message format, no longer used in 2.x firmware.
1. Fixed Message Type
2. Debug Message Type

Message Level - The importance level of the error:

0. DEBUG message
1. INFORM message
2. WARN message
3. CRITICAL message
4. FATAL message

9.1.1 Fixed Message Type

The Fixed Message Type is the most common message type used for notification in the BMS.

Table 13. Fixed Message Data Fields

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Fixed Message Code	Task State	Power Status	Power Mode	N/A	Firmware Build 0.xx	Firmware Build x.00

Fixed Message Code – A fixed message (hex) for common system notifications from the BMS.

Hex	Dec	Name	Description
0x00	0	debugCode	Generic Debug
0x01	1	criticalError	Critical fault
0x02	2	queueOverflow	CAN callback queue overflow
0x03	3	topLigerFault	Top half-stack cell balancing fault
0x04	4	bottomLigerFault	Bottom half-stack cell balancing fault
0x05	5	cellBalancingStopped	Cell balancing stopped
0x06	6	invalidParameter	Invalid parameter
0x07	7	invalidFlashMap	Invalid Flash map version
0x08	8	invalidFlashWrite	Flash write of this value not allowed
0x09	9	overVoltageCell1	Cell 1 over recommended max voltage
0x0A	10	overVoltageCell2	Cell 2 over recommended max voltage
0x0B	11	overVoltageCell3	Cell 3 over recommended max voltage
0x0C	12	overVoltageCell4	Cell 4 over recommended max voltage
0x0D	13	overVoltageCell5	Cell 5 over recommended max voltage

(continued)

Hex	Dec	Name	Description
0x0E	14	overVoltageCell6	Cell 6 over recommended max voltage
0x0F	15	overVoltageCell7	Cell 7 over recommended max voltage
0x10	16	overVoltageCell8	Cell 8 over recommended max voltage
0x11	17	overVoltageCell9	Cell 9 over recommended max voltage
0x12	18	overVoltageCell10	Cell 10 over recommended max voltage
0x13	19	overVoltageCell11	Cell 11 over recommended max voltage
0x14	20	overVoltageCell12	Cell 12 over recommended max voltage
0x15	21	overVoltageCell13	Cell 13 over recommended max voltage
0x16	22	overVoltageCell14	Cell 14 over recommended max voltage
0x17	23	overVoltageCell15	Cell 15 over recommended max voltage
0x18	24	overVoltageCell16	Cell 16 over recommended max voltage
0x19	25	minCellAtMaxVoltage	Min cell is at max recommended voltage
0x1A	26	underVoltageCell1	Cell 1 under recommended min voltage
0x1B	27	underVoltageCell2	Cell 2 under recommended min voltage
0x1C	28	underVoltageCell3	Cell 3 under recommended min voltage
0x1D	29	underVoltageCell4	Cell 4 under recommended min voltage
0x1E	30	underVoltageCell5	Cell 5 under recommended min voltage
0x1F	31	underVoltageCell6	Cell 6 under recommended min voltage
0x20	32	underVoltageCell7	Cell 7 under recommended min voltage
0x21	33	underVoltageCell8	Cell 8 under recommended min voltage
0x22	34	underVoltageCell9	Cell 9 under recommended min voltage
0x23	35	underVoltageCell10	Cell 10 under recommended min voltage
0x24	36	underVoltageCell11	Cell 11 under recommended min voltage
0x25	37	underVoltageCell12	Cell 12 under recommended min voltage
0x26	38	underVoltageCell13	Cell 13 under recommended min voltage
0x27	39	underVoltageCell14	Cell 14 under recommended min voltage
0x28	40	underVoltageCell15	Cell 15 under recommended min voltage
0x29	41	underVoltageCell16	Cell 16 under recommended min voltage
0x2A	42	maxCellAtMinVoltage	Max cell is at min recommended voltage
0x2B	43	overTemp1	Temp channel 1 over max recommended temp
0x2C	44	overTemp2	Temp channel 2 over max recommended temp
0x2D	45	overTemp3	Temp channel 3 over max recommended temp
0x2E	46	overTemp4	Temp channel 4 over max recommended temp
0x2F	47	overTemp5	Temp channel 5 over max recommended temp
0x30	48	overTemp6	Temp channel 6 over max recommended temp
0x31	49	overTemp7	Temp channel 7 over max recommended temp
0x32	50	overTemp8	Temp channel 8 over max recommended temp
0x33	51	underTemp1	Temp channel 1 under min recommended temp
0x34	52	underTemp2	Temp channel 2 under min recommended temp
0x35	53	underTemp3	Temp channel 3 under min recommended temp
0x36	54	underTemp4	Temp channel 4 under min recommended temp
0x37	55	underTemp5	Temp channel 5 under min recommended temp
0x38	56	underTemp6	Temp channel 6 under min recommended temp
0x39	57	underTemp7	Temp channel 7 under min recommended temp
0x3A	58	underTemp8	Temp channel 8 under min recommended temp
0x3B	59	thermistor1NotAttached	Temp channel 1 no thermistor
0x3C	60	thermistor2NotAttached	Temp channel 2 no thermistor

(continued)

Hex	Dec	Name	Description
0x3D	61	thermistor3NotAttached	Temp channel 3 no thermistor
0x3E	62	thermistor4NotAttached	Temp channel 4 no thermistor
0x3F	63	thermistor5NotAttached	Temp channel 5 no thermistor
0x40	64	thermistor6NotAttached	Temp channel 6 no thermistor
0x41	65	thermistor7NotAttached	Temp channel 7 no thermistor
0x42	66	thermistor8NotAttached	Temp channel 8 no thermistor
0x43	67	moduleBalanced	Module balanced
0x44	68	bottomStackBalanced	Bottom half-stack balanced
0x45	69	topStackBalanced	Top half-stack balanced
0x46	70	powerModeChangedLimp	Operating mode changed to LIMP
0x47	71	powerModeChangedIdle	Operating mode changed to IDLE
0x48	72	powerModeChangedIdleNoAFE	Operating mode changed to IDLE_NOAFE
0x49	73	powerModeChangedRun	Operating mode changed to RUN
0x4A	74	powerModeChangedShutdown	Operating mode changed to SHUTDOWN
0x4B	75	powerModeChangedLowPower	Operating mode changed to LOWPOWER
0x4C	76	powerModeChangedTest	Operating mode changed to TEST
0x4D	77	postCompleted	POST completed
0x4E	78	featureNotImplemented	This feature has not been implemented
0x4F	79	commandReadbackFailure	Command read back failed
0x50	80	bottomLigerStopped	Bottom half-stack stopped
0x51	81	topLigerStopped	Top half-stack stopped
0x52	82	extiFault	Ext Interrupt channel 5-15 not defined
0x53	83	bottomStackBalance	Bottom half-stack balancing started
0x54	84	topStackBalance	Top half-stack balancing started
0x55	85	MMBPitcherStarted	MMB Pitcher started
0x56	86	MMBCatcherStarted	MMB Catcher started
0x57	87	MMBTransferStopped	MMB transfer stopped
0x58	88	MMBTransferComplete	MMB transfer finished

Task State

0. AFE
1. Bottom Liger
2. Top Liger
3. Module Balancing
4. Temp Sense
5. Manual Cell Transfer

Power Status – A bit set high indicates that supply rail is on.

0. 5.5V supply rail
1. 5VD supply rail
2. 5V1 supply rail
3. -5V supply rail
4. 12V supply rail
5. 3V3 supply rail

Power Status – A bit set high indicates that supply rail is on.

0. 5.5V
1. 5VD supply rail
2. 5V1 supply rail
3. –5V supply rail
4. 12V supply rail

3V3 supply rail

Power Mode – Indicates the global power mode the firmware is currently set to operate in

1. SHUTDOWN – All activity suspended (not currently supported in rev A4 hardware).
2. IDLE – Minimal power mode with AFE still allowed to operate, all other sub-systems disabled.
3. IDLE_NOAFE – Not used
4. RUN – All sub-systems active.
5. TESTMODE – All supply rails enabled (for test purpose only).

.

9.1.2 Debug Message Type

The Debug Message Type is used for debug purposes only and will be seen only very rarely.

Table 14. Debug Message Data Fields

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Module	Debug Message Data			N/A	N/A	N/A

Module – The specific software module generating the error:

1. Flash Module
2. Command Line Interface (not used)
3. CAN Module
4. CAN Message Parser
5. DMA Module
6. SPI Driver
7. ACB DC-DC module
8. Analog Front End (AFE) Module
9. Module Balancing Module
10. Power Module
11. Temp Sense Module
12. J1939 Address Enumeration Module
13. Time Sync Module
14. Module Balance Command Parser
15. Automatic Cell Balance (ACB) Module

Debug Message Data – A reference to a particular line of code in the firmware or other specialized purpose.

Appendix D

CAN DB9 Adapter Schematic

Figure 34 shows the schematic for the VSCom USB-CAN DB9 to RJ45 adapter. The white wire is optional. The white wire should only be used when the user wants to have the VSCom USB-CAN adapter provide power to the CAN bus. It is not recommended when there are 4 or more EM1401EVM boards attached to the CAN bus. In this case, an external 5V power supply should be provided in the system.

Blue: –CAN_H

Orange: – CAN_L

Black: – GND

White: – 5V (optional)

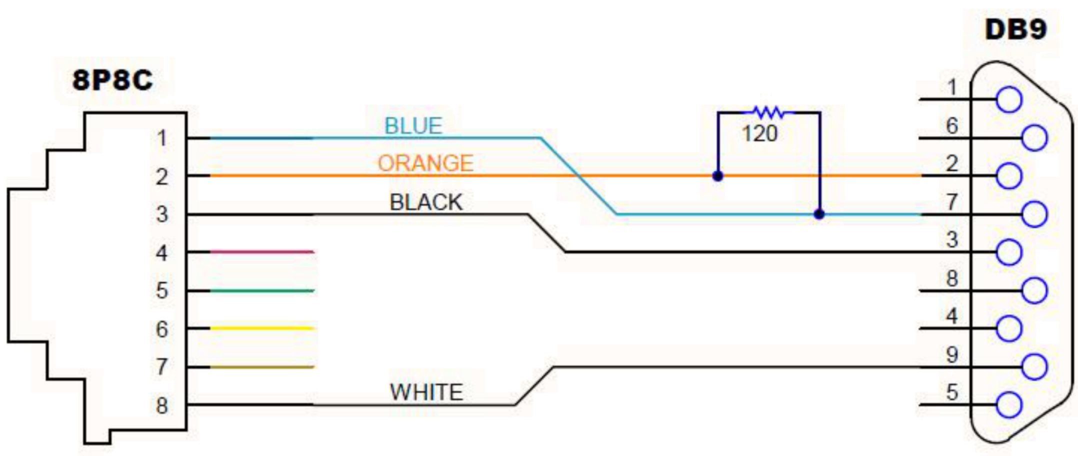

Figure 34. VSCom USB-CAN DB9 to RJ45 Adapter Schematic

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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 could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

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 its own expense.

FCC Interference Statement for Class B EVM devices

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.

Industry Canada Compliance (English)

For EVMs Annotated as IC – INDUSTRY CANADA Compliant:

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs Including Radio Transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

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.

Canada Industry Canada Compliance (French)

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

Important Notice for Users of EVMs Considered “Radio Frequency Products” in Japan

EVMs entering Japan are NOT certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If user uses EVMs in Japan, user is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

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.

http://www.tij.co.jp

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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
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