TECHNICAL GUIDE

Altair Embed® 2025.2

Battery Management Applications with Altair Embed/Digital Power Designer

Altair Embed Applications - Battery Management Systems

Battery Management Systems (BMS)

This document describes the application examples in the Altair Embed Digital Power Designer. The examples are found under the Applications section of DPD. Currently there are applications for the Texas Instruments bq76PL455A-Q1 and the Infineon TLE9012 BMS evaluation boards.

The TI bq76PL455EVM BMS Demonstration

Hardware Description

This section describes the Altair Embed® / Texas Instruments™ (TI) battery management system (BMS) demo kit necessary to develop firmware for a complete, production-ready battery monitoring system. To learn more about battery monitoring development with Embed:

- Watch a short Battery Monitoring Development with Embed video on YouTube
- Read the Battery Monitoring Systems blog on the Altair website

Altair Embed/TI BMS demo kit

The required material for the Altair Embed / TI battery management system (BMS) demo kit is as follows:

- Texas Instruments (TI) bq76PL455EVM evaluation module (EVM)[1]
- Battery board for up to 16 cells.[1]
- Texas Instruments Microcontroller Docking station with TI TMS320F28379 control card.[2]
- Necessary cables for connections.
- 18650 battery cells.[3]

1. Multiple bq76PL455EVMs and battery boards are required when there are more than 16 cells in the system. The TI bq76PL455EVM evaluation module and the Altair Embed GUI supports up to 6 series connected modules which are linked in a chain by the isolated serial communication interface and cables. However, the bq76PL455EVMq1 integrated circuit supports up to 16 connected in series.
2. Requires hardware modifications to connect the serial interface and the ADC connector as a minimum requirement.
3. The battery board accepts 18650 cells and these cells are purchased optionally.

The TI battery management system bq76PL455EVM evaluation module consists of the evaluation board as shown in figure 1, along with the battery cell connection cable for up to 16 series cells and a 6-pin serial connector cable from FTDI™ (part number TTL-232R-5V).

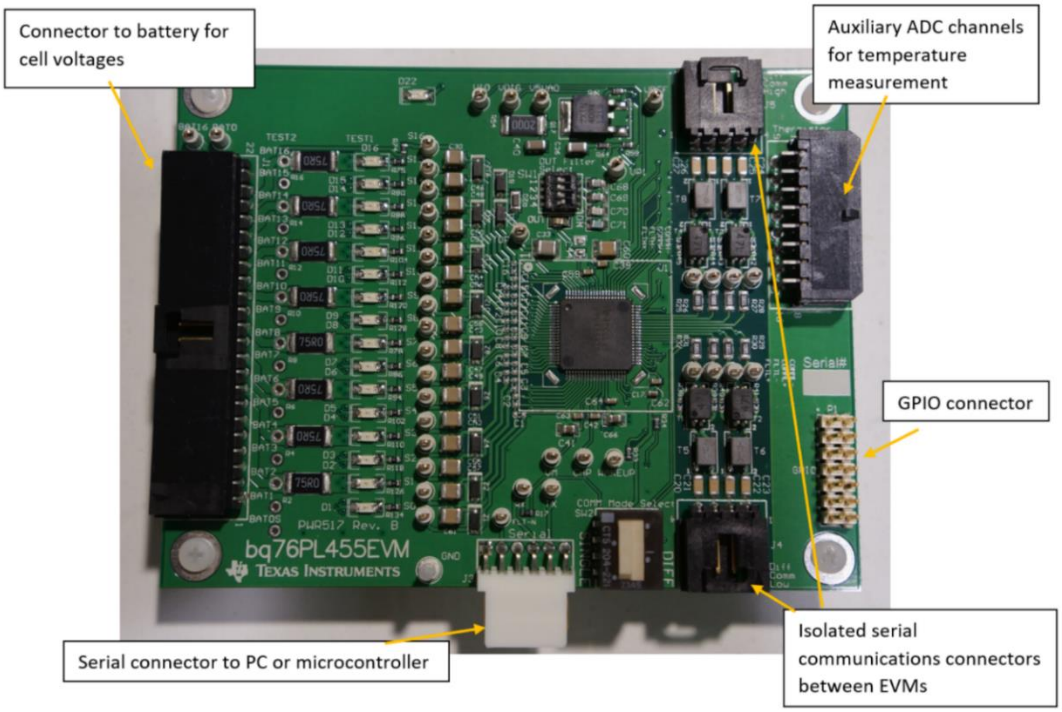


Figure 1: Texas Instruments bq76PL455EVM evaluation board.

Battery Board

The B18650-16 battery board is used in this demonstration and is shown in figure 2.

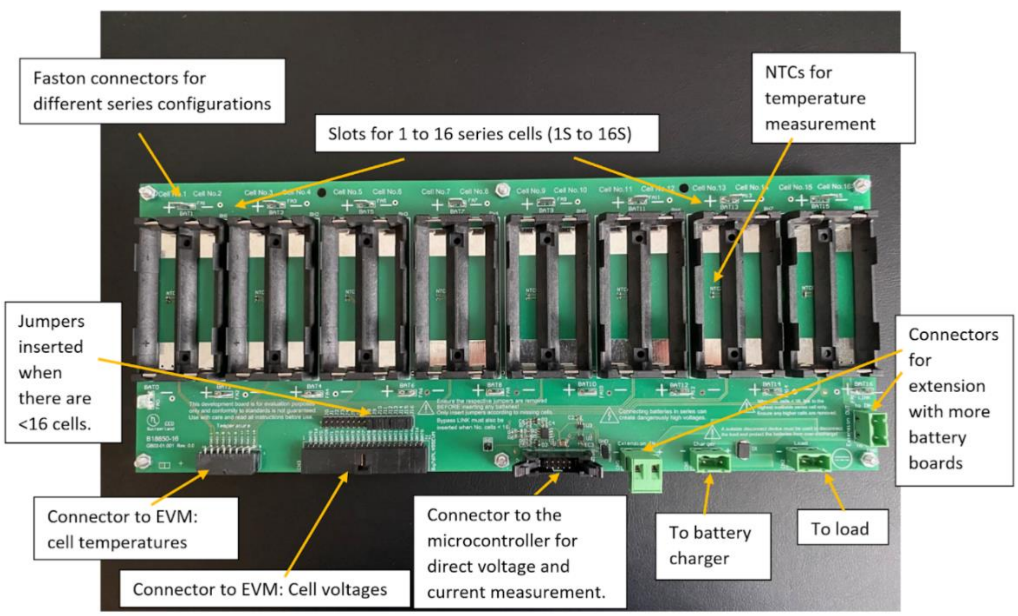


Figure 2: Battery board developed to evaluate the bq76PL455EVM together with [Altair Embed](#).

- The battery board consists of slots for up to sixteen 18650 cells (a shorting link is provided if less cells are installed)
- Eight NTC thermistors for temperature measurement of odd-numbered cells or the ambient temperature

- Two current sensors for the battery current (charging and discharging)
- A voltage sensor operational amplifier
- Connectors for a charger and load
- Connectors for expansion so that battery boards can be configured in a series or parallel connection with a maximum of 6 battery boards.

For voltage and current measurement, the board should be supplied with +5V at the CN7 10-pole connector (normally from the TI docking station).

Connecting battery cells in series can create dangerously high voltages. Six series-connected battery boards, each with 16 mounted cells will create a battery voltage greater than 400V! It is the responsibility of the user to ensure the required safety precautions are applied at ALL times during the development phase and during the use of the BMS demo kit.

- A shorting link is described in figure 3 and inserted if the number of cells used is less than sixteen. This must be connected if the batteries are to be charged and discharged while inserted in the battery board slots. It is inserted from the BAT16 connection point to the connection point of the highest inserted cell.
- Note that during the development phase of the BMS firmware, the battery boards do not need to be connected in series and can be referenced to a common ground at the negative pole of each board. In this way, the firmware can proceed for multiple boards at relatively safer voltages, though care must still be taken when working with any battery voltage.
- Jumpers are provided to short out connections where battery cells are unpopulated as required by the bq76PL455q1 integrated circuit. Take care to remove any jumpers BEFORE inserting a battery cell in that position.
- Before use, follow all instructions in this section of the user guide and any instructions on the battery board itself.

Cables for the TI BMS Kit

The required cabling for the interconnection of the demo boards and the PC running the Embed GUI are given in figure 3.

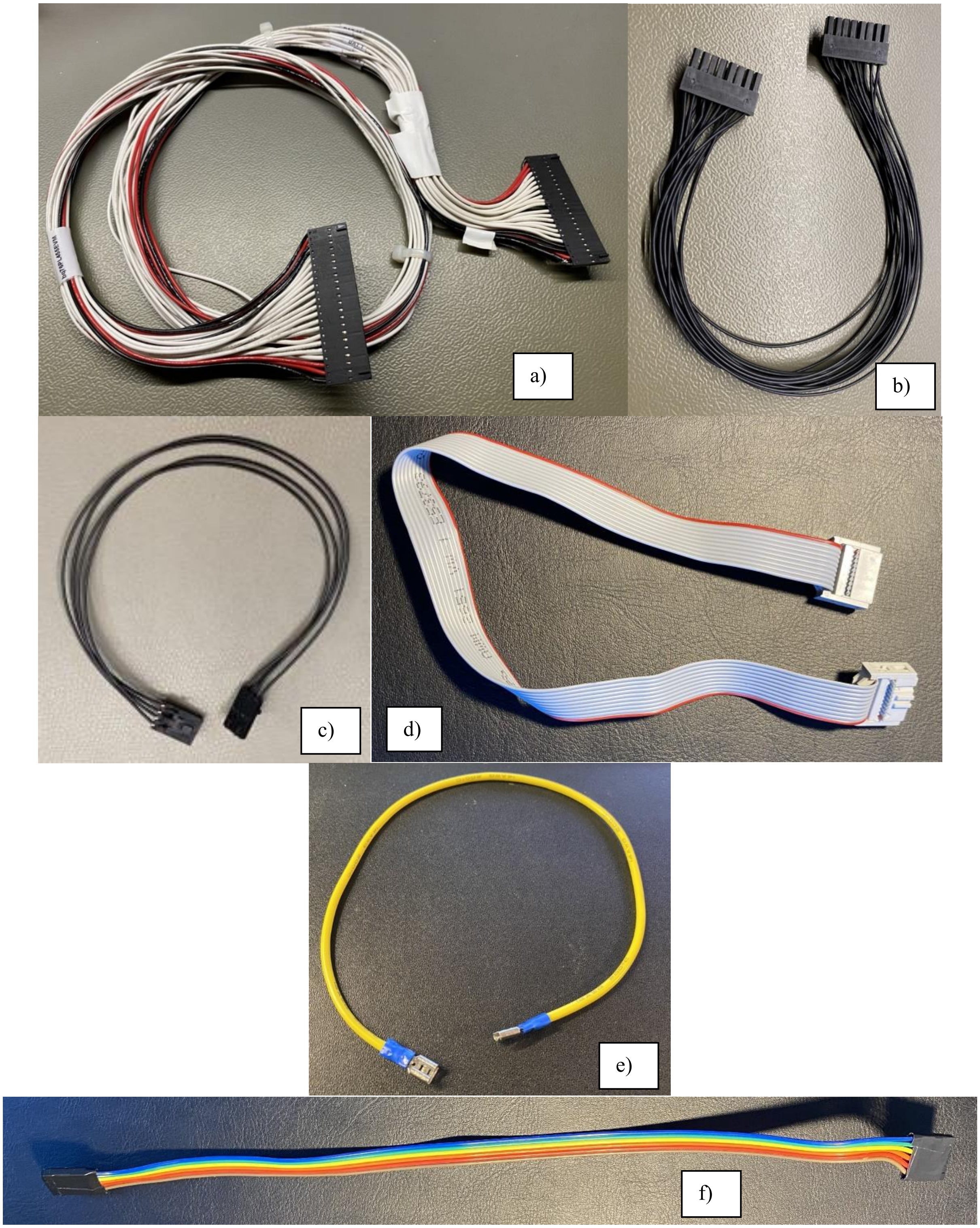


Figure 3: Necessary cabling for interconnections:

a) Battery cell connections – this cable is supplied with the bq76PL455EVM. It may be crimped with a connector for the battery board or soldered directly to the battery board.

b) Temperature sensor cable
c) isoUART cable for interconnection of more than one bq76PL455EVM board
d) 10-pole cable for connection of the battery board to the docking station for the ADC.
e) Shorting link used when less than 16 cells are mounted on the battery board
f) Serial connection from the TI docking station to the bq76PL455EVM.

A USB – to – serial UART converter cable is also supplied with the bq75PL455EVM evaluation module and this is required for the setups in figures 8 and 9.

The battery board is connected to the bq76PL455EVM using the supplied cables as shown in figure 4. This configuration uses a direct connection to the Embed TI BMS GUI running on the PC.

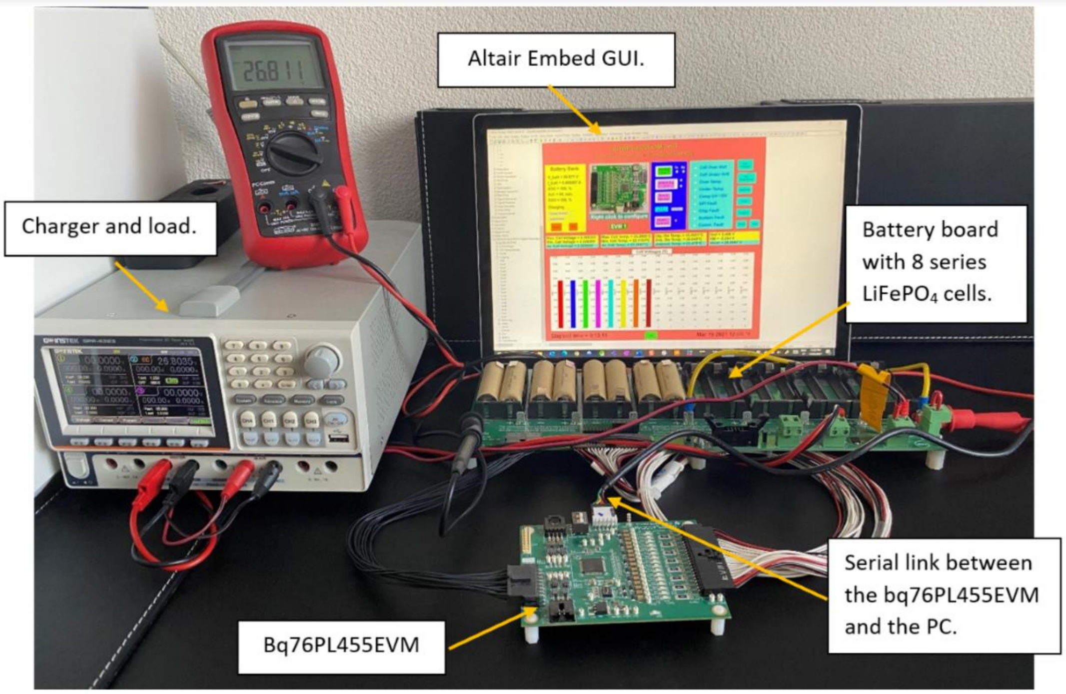


Figure 4: BMS setup with 8 series cells connected to a charger/load. The serial communication interface of the bq76PL455EVM is connected directly to the PC running the [Embed](#) GUI.

The battery board can also be connected to the bq76PL455EVM and a TI microcontroller using the supplied cables and a TI docking station as shown in figure 5. In this case, the bq76PL455EVM communicates with the microcontroller and it is the microcontroller that communicates with the Embed GUI over the JTAG interface.

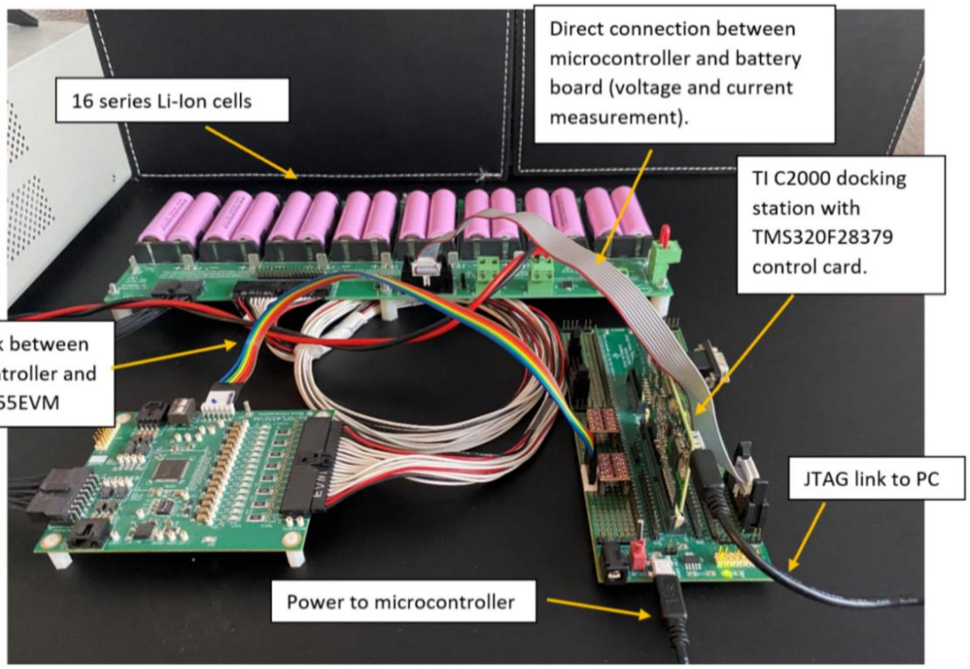


Figure 5: BMS setup with a Texas Instruments TMS320F28379 microcontroller interfaced directly to the EVM.

Multiple battery boards can be connected in series using multiple EVMs and up to six bq76PL455EVMs can be connected in this way as shown in figure 6.

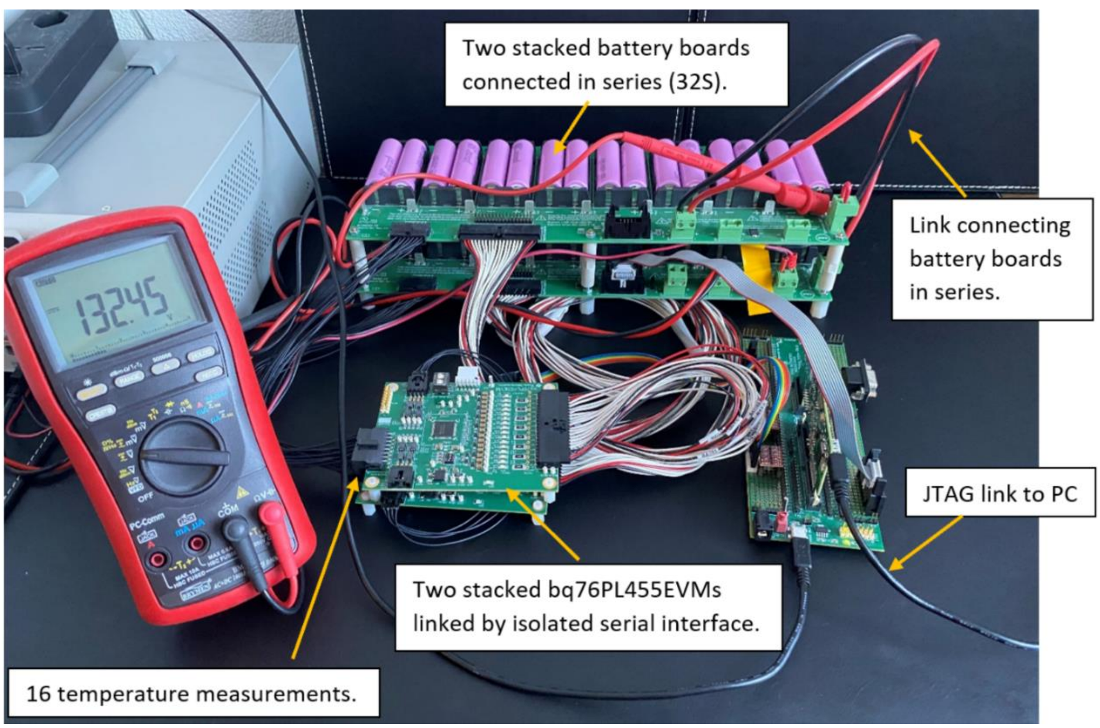


Figure 6: BMS setup with stacked EVMs and battery boards for higher battery voltages (in this case with a nominal battery voltage of 134.4V).

CAN communication can also be achieved as shown in figure 7.

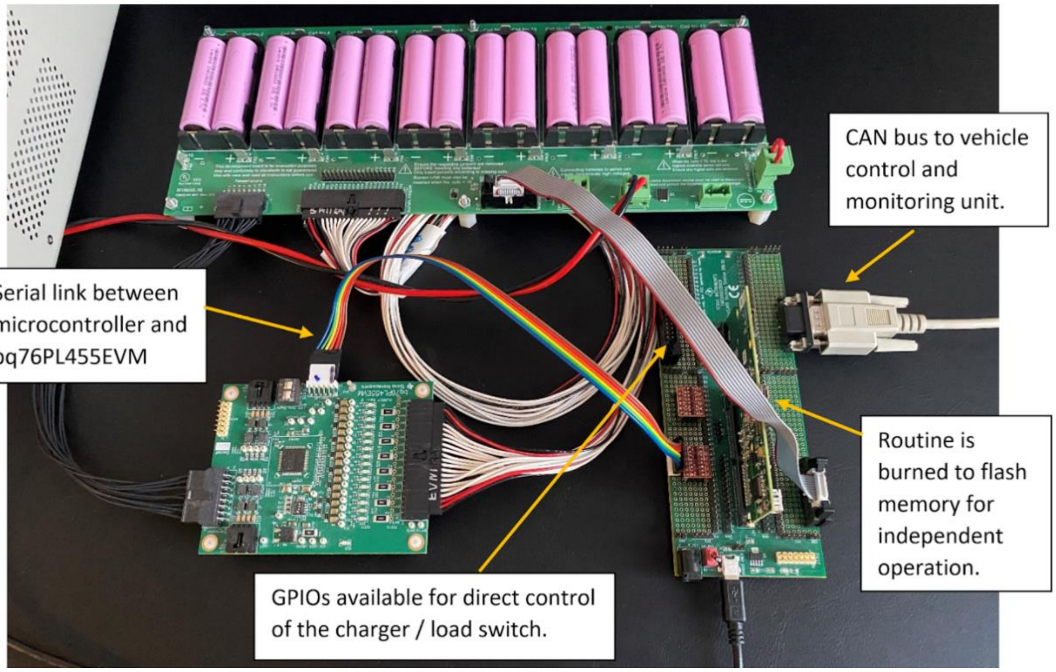


Figure 7: Independent operation of the BMS system with CAN bus communication with the vehicle control unit (VCU), and BMS firmware ready for application with in-vehicle operation.

BMS Set-ups

There are three basic set-ups for the TI BMS demonstration. The set-ups in figures 8 and 9 use the real-time serial blocks of Altair Embed in the diagrams. Figure 9 varies from figure 8 in that the Altair Embed BMS GUI is concurrently connected to a microcontroller through the JTAG interface. The battery voltage and current is now measured by the microcontroller and the SOC and autonomy calculations on the battery bank are performed within the microcontroller. In the set-up in figure 10, the microcontroller performs all the BMS operations of communicating with the bq76PL455EVM. In this case the target embedded UART serial blocks are used in the corresponding code-gen diagram. Figure 8 below shows the configuration for three bq76PL455EVMs and three battery boards connected directly to the Altair Embed GUI with communication of the serial line.

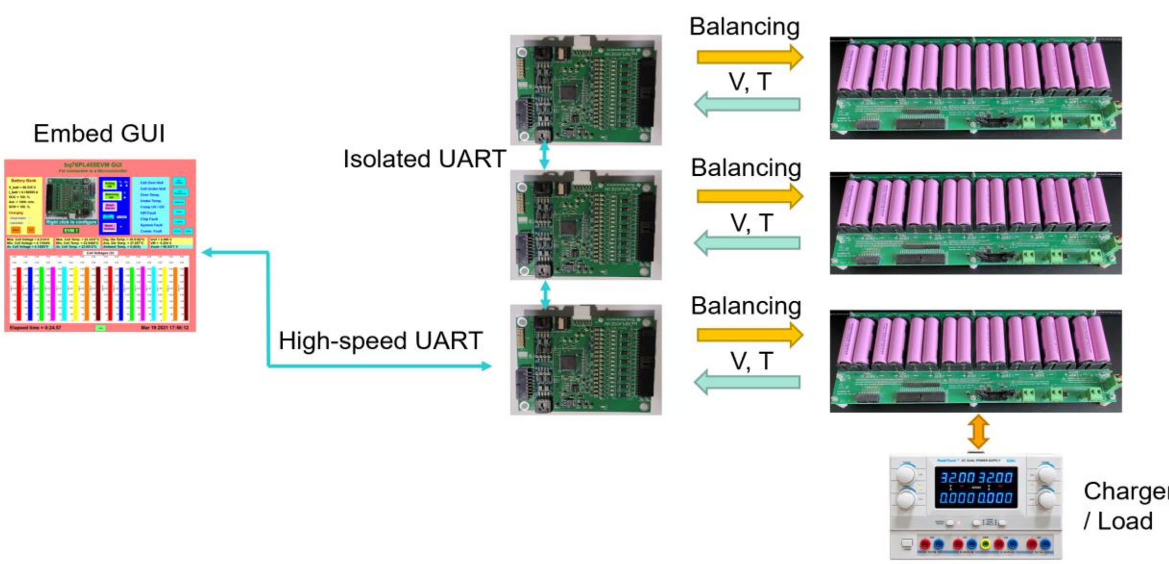


Figure 8: Schematic representation of the direct connection of the bq76PL455EVMs to the PC.

Figure 9 below shows the configuration for three bq76PL455EVMs and three battery boards connected directly to the Altair Embed GUI with communication of the serial line and the microcontroller communicates with the Altair Embed GUI over the JTAG communication interface.

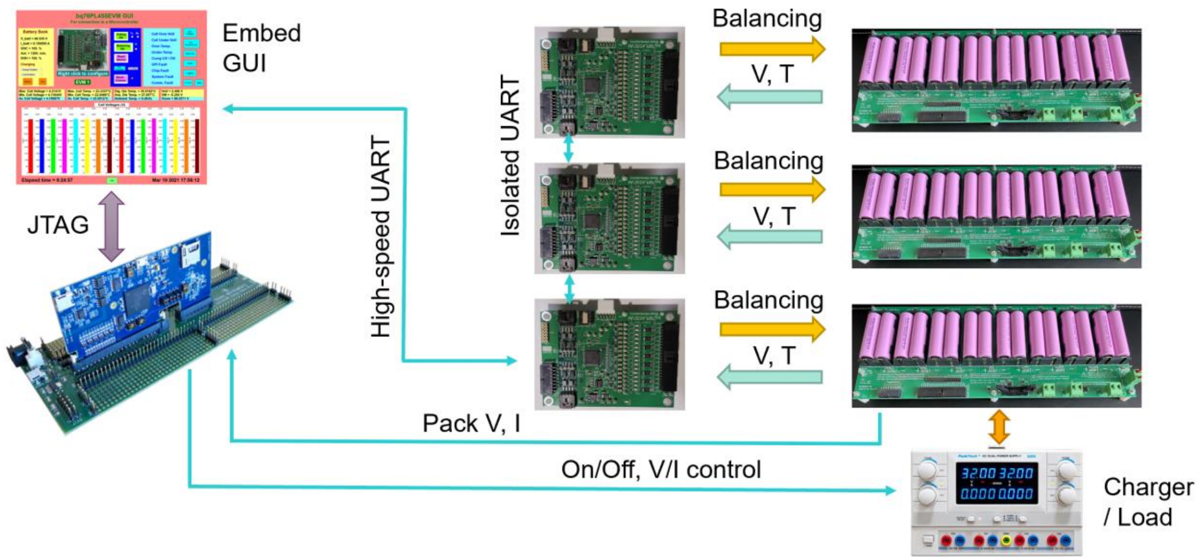


Figure 9: Schematic representation of the direct connection of three bq76PL455EVMs to the PC and with a concurrent connection to the microcontroller over the JTAG interface for the battery board measurements and charger/load control.

Figure 10 below shows the configuration for three bq76PL455EVMs and three battery boards connected directly to the microcontroller over the serial line and the microcontroller communicates with the Altair Embed GUI over the JTAG communication interface.

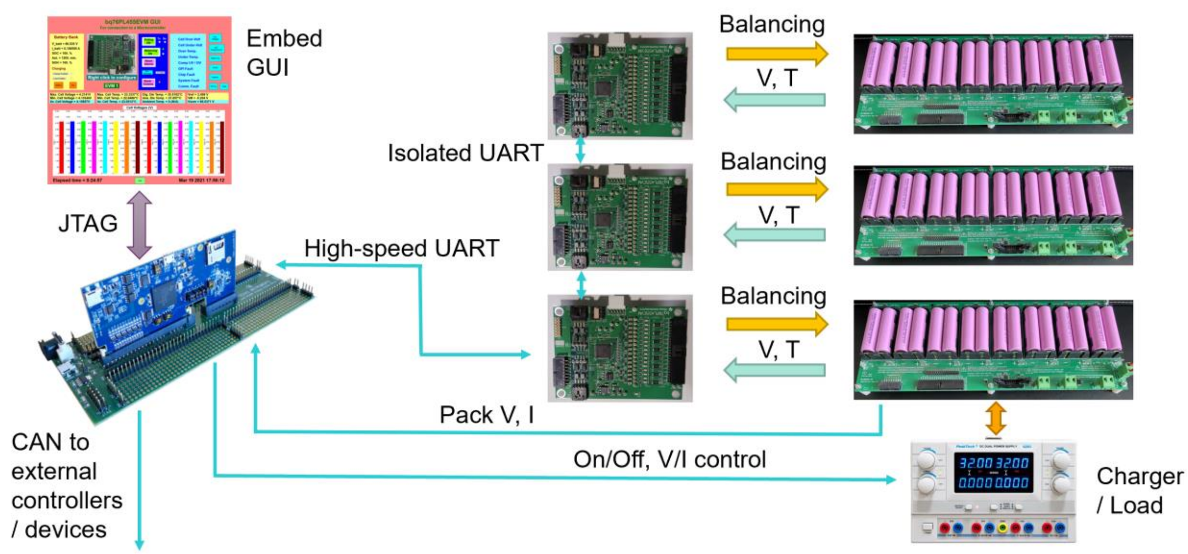


Figure 10: Schematic representation of the connection of the bq76PL455EVMs to the PC via a microcontroller. The serial link is connected to the microcontroller board. The Embed GUI communicates with the microcontroller over the JTAG link.

Altair Embed TI BMS Diagrams

The Altair Embed BMS diagrams can be found under:
Examples → Digital Power → Applications → Battery Monitoring Systems → TI.
The Embed diagrams for the TI BMS demonstration consist of the following:

1. The Embed TI BMS GUI for the direct connection of the PC to the bq76PL455EVM and with the battery bank charging and discharging running as a PC simulation.
2. The Embed TI BMS GUI for the direct connection of the PC to the bq76PL455EVM and with the battery bank charging and discharging being monitored by the microcontroller, measuring the battery voltage and current.
3. The code-gen diagram of the bq76PL455EVM routine found in the previous diagrams but with real-time serial blocks replaced by the microcontroller specific UART serial blocks. This diagram can be compiled for the target microcontroller and used in the fourth Embed diagram.
4. The Embed TI BMS GUI for the connection of the PC to the microcontroller only. The microcontroller communicates with the bq76PL455EVM, while the microcontroller concurrently communicates over the JTAG interface with the Embed GUI running on the PC. This diagram contains the target interface block which links to the .out file compiled using the diagram in point 3 above.

These diagrams can be used and applied independently in the configuration desired by the user. The diagram in 1, is the simplest to perform debugging of the system. The diagram in 4. Is the closest to the final desired result for an independently operating BMS system.

Altair Embed TI BMS Graphical User Interface

The Altair Embed TI BMS GUI is given below for the direct connection of the PC to the BMS hardware (bq76PL455EVM).

To activate the communication with the bq76PL455EVM, one must start a simulation using the Go toolbar item  or by pressing (F5).

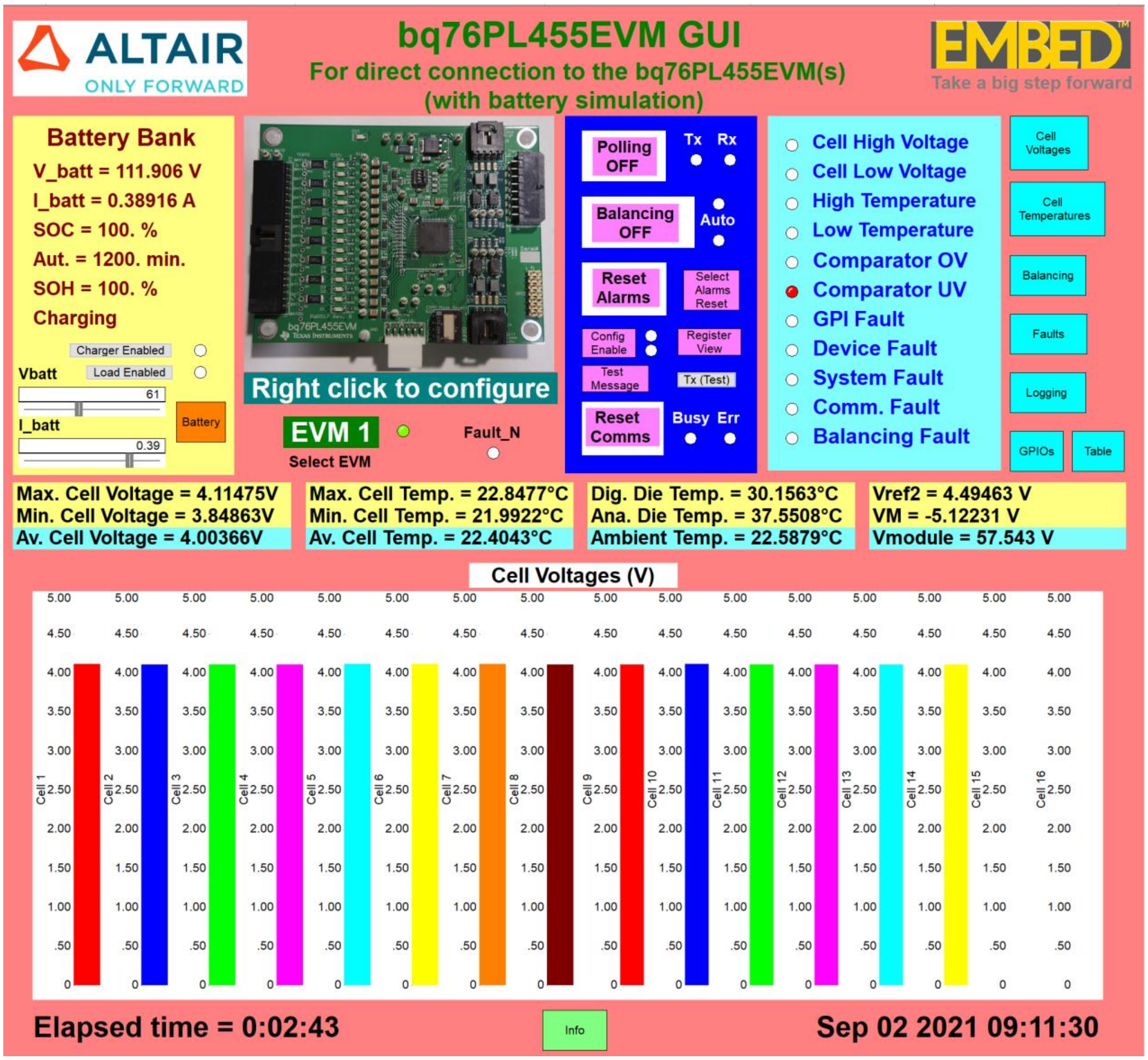
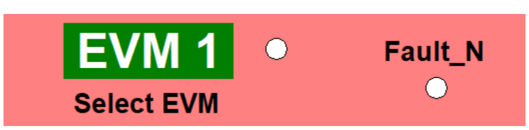


Figure 11: Altair Embed TI BMS GUI.

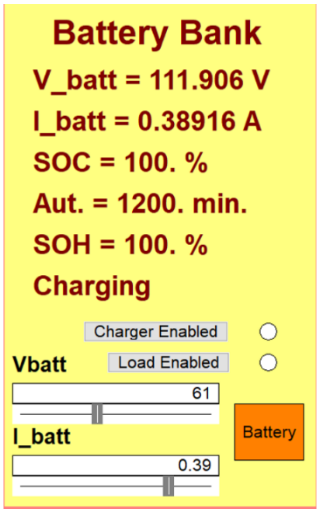
The various sections of the Embed GUI are described in the following sections.

Right clicking on the bq76PL455EVM image will bring up the configuration dialogs. These are described in detail in a later section of this document. Below the bq76PL455EVM image in the GUI is the EVM selection section.



Clicking on 

will change the selected bq76PL455EVM and all the measurements on the main GUI page relative to the bq76PL455EVM will be referred to that EVM. The Fault_N indication is the Fault signal that is transmitted independently on the differential line (refer to the TI documentation).



<u>Battery bank section</u>

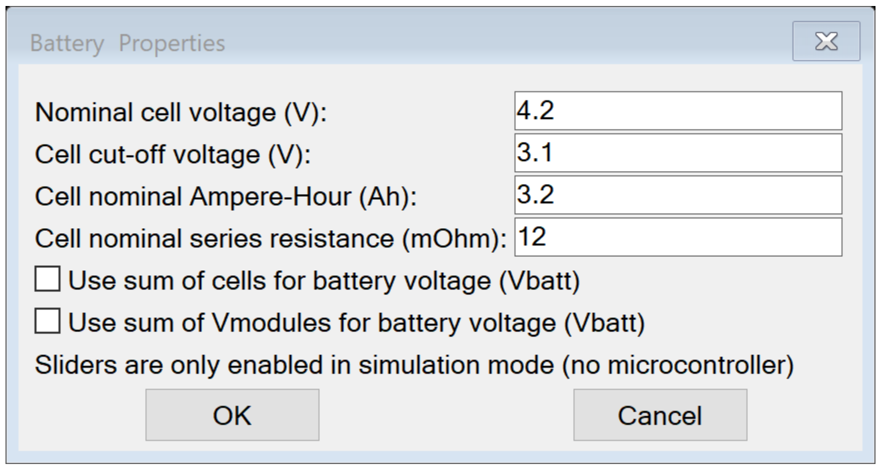
The battery bank section of the GUI gives the values of the battery bank voltage and current. Where, more battery boards are connected in series, the battery bank voltage is the total voltage.

The battery voltages and currents may be controlled by the sliders or they may be the measured values, depending upon the configuration as described below.

The charging / discharging status, the internally calculated state-of-charge (SOC), autonomy time of the battery in minutes and an estimation of the state-of-health (SOH) of the battery are also given.

Right clicking on the 

block in this yellow battery bank section of the GUI will bring up the following dialog:



The battery properties dialog set up the battery parameters.

Nominal cell voltage (V):

Enter the nominal voltage of each cell (when charged).

Cell cut-off voltage (V):

Enter the normal voltage at which the load would be removed on discharge, where the battery cells are considered to have the minimum amount of capacity remaining.

Cell nominal ampere-hour (Ah):

Enter the nominal ampere-hour rating of each cell. This is use for capacity estimation and discharge autonomy time estimation.

Cell nominal series resistance (mOhm):

Enter the nominal cell resistance of a cell in milli-ohms.

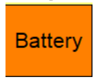
Use sum of cells for battery voltage:

If selected, the battery voltage displayed will be the sum of cells for all cells in the system, including multiple battery boards.

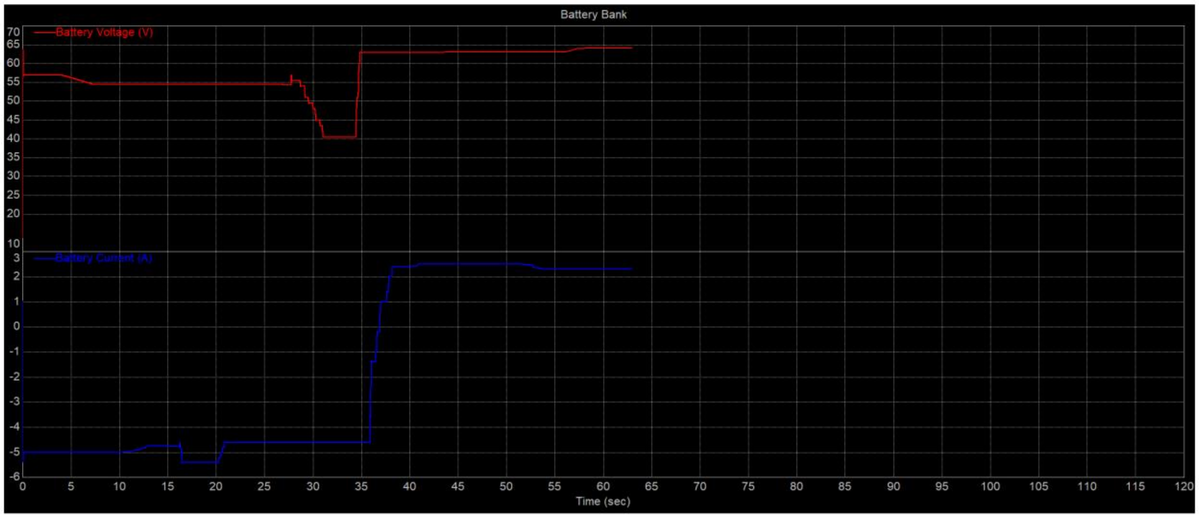
Use sum of Vmodules for battery voltage:

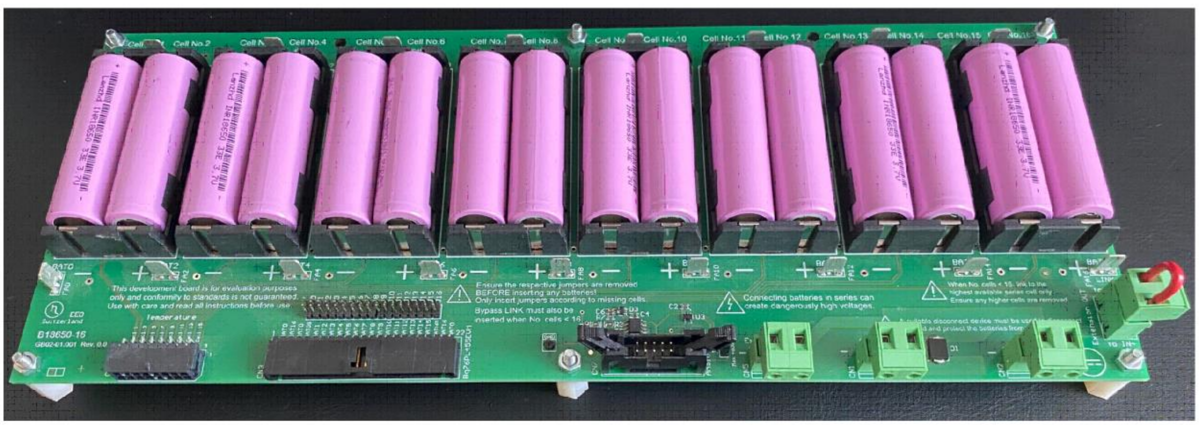
If selected, the battery voltage displayed will be the sum of module voltages for all connected battery boards and bq76PL455EVMs in the system, including multiple battery boards.

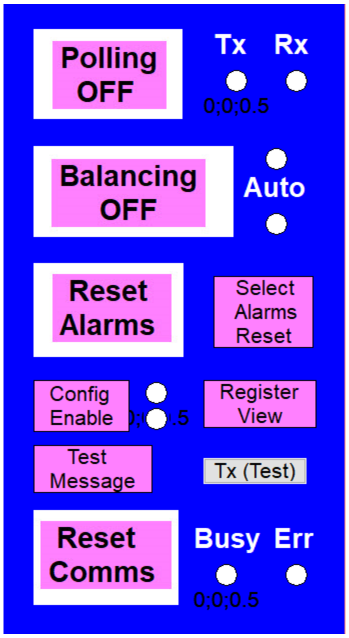
If neither of the above two selections are enabled, the battery voltage and current will be simulated values controlled by the sliders. If the Embed GUI is connected to a microcontroller as in figures 9 or 10 above, the current and voltage will be that measured by the microcontroller using the sensors on the lowest-addressed battery board. Otherwise, in the case of the configuration in figure 8, the current will be taken from the slider.

By double left clicking on the 

block, the following visualization occurs, where the battery bank voltage and current is plotted over time.





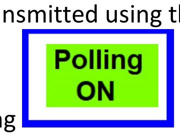


<u>Control section</u>

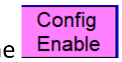
The control section provides the ability to control the polling of the measurements and faults, to enable or disable the balancing, to set what is configured and to reset the alarms (or faults) and the communication routine.

The transmit / receive activation can be viewed along with the configuration status and registers.

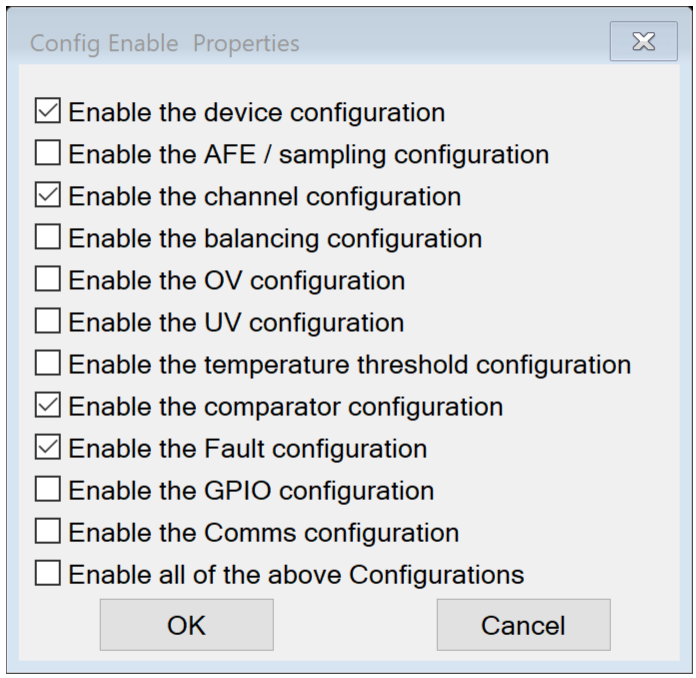
A test message can be configured and transmitted using the Tx (Test) tab.

Polling is enabled by clicking on the Polling 

tab. When enabled, the measurements, faults and any other items (such as GPIO status) which is enabled for polling, will be transmitted at the selected polling rate.

Right clicking on the 

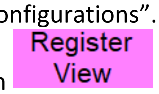
block will bring up the following dialog:



Each individual configuration selection can be enabled or disabled using this dialog. When re-starting a simulation of the Embed BMS diagram, it may be desirable to disable the configuration since the hardware will have been configured from the last simulation if power was not switched off to the bq76PL455EVM. Also, various configuration selections can be enabled or disabled for testing purposes.

On initial start-up, if there are no special configurations required, only the Device configuration, AFE/sampling configuration and channel configurations are essential.

The complete configuration can be enabled by selecting the “Enable all of the above Configurations”.

The configuration registers, along with the active registers can be viewed by clicking on 

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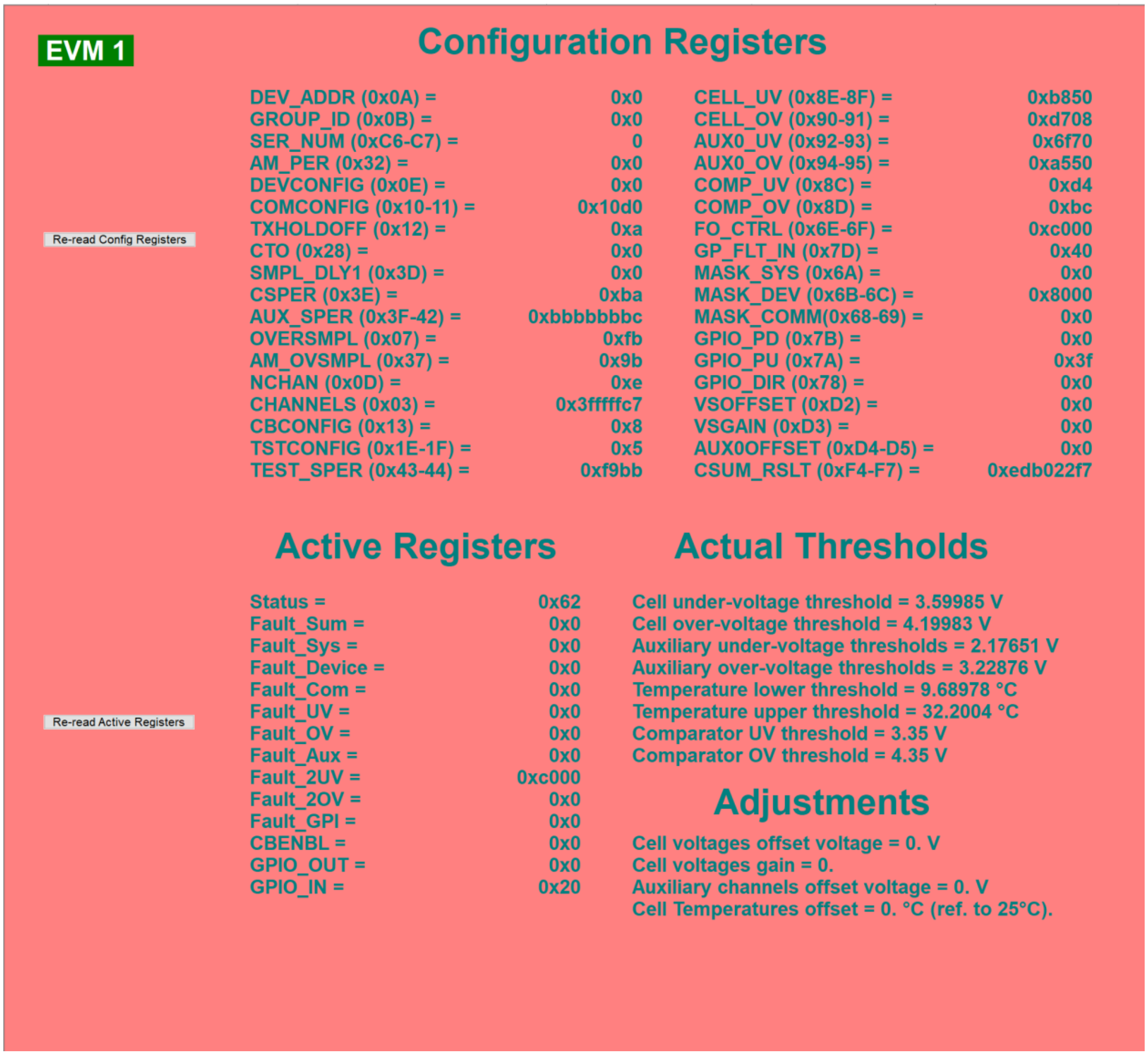
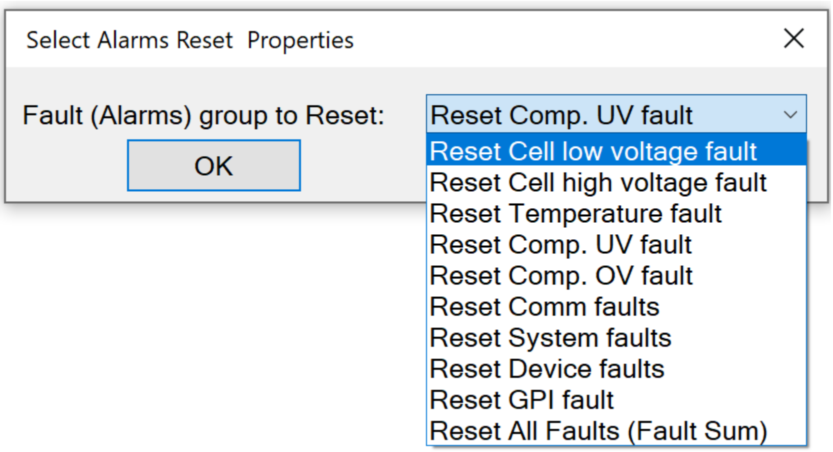


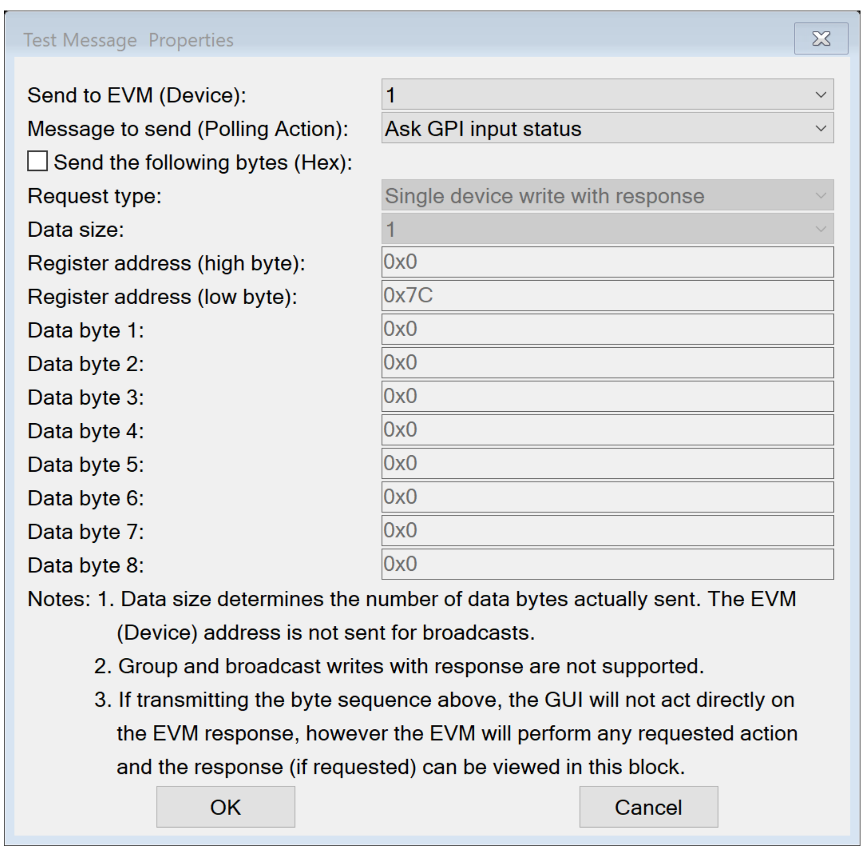
The main configuration registers can be viewed for each enabled bq76PL455EVM along with the current active registers. The actual values of the thresholds in the selected units are re-calculated from the received register values and displayed. The registers can be re-read at any time by clicking on the tabs to the left.

Right clicking on the Select Alarms Reset block will bring up the following dialog:



After selecting the faults to be reset, the reset message will be transmitted when clicking on the Reset Alarms icon. Note that polling may be needed to be enabled in order to re-read the fault status after a reset action.

Right clicking on the Test Message block will bring up the following dialog:

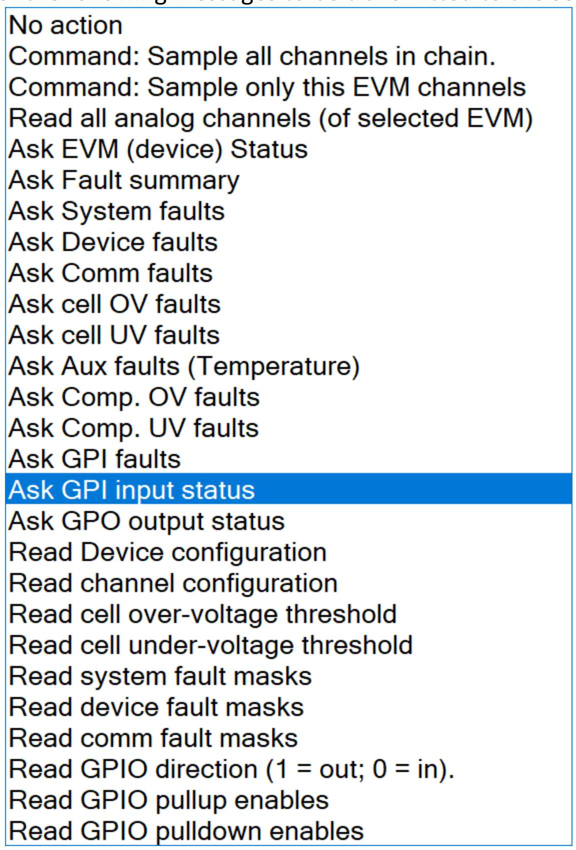


Send to EVM (Device):

Select the EVM from 1 to 6 (where present) which will receive the test message.

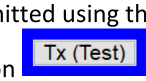
Message to send (Polling Action):

Select any one of the following messages to be transmitted to the selected EVM:



Send the following bytes (Hex):

Alternatively, a message can be transmitted using the specified byte fields.

The selected test message is transmitted when clicking on 

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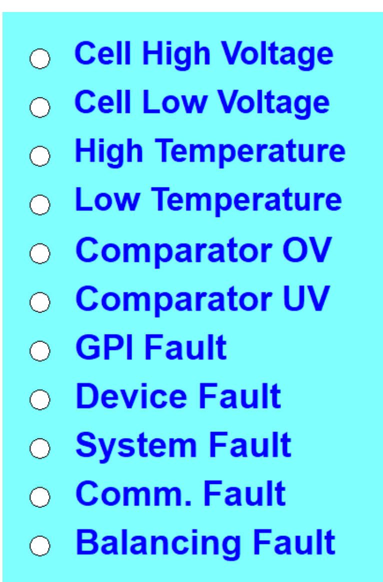
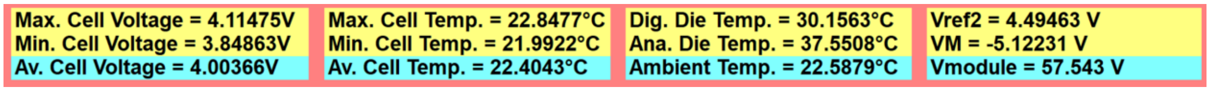


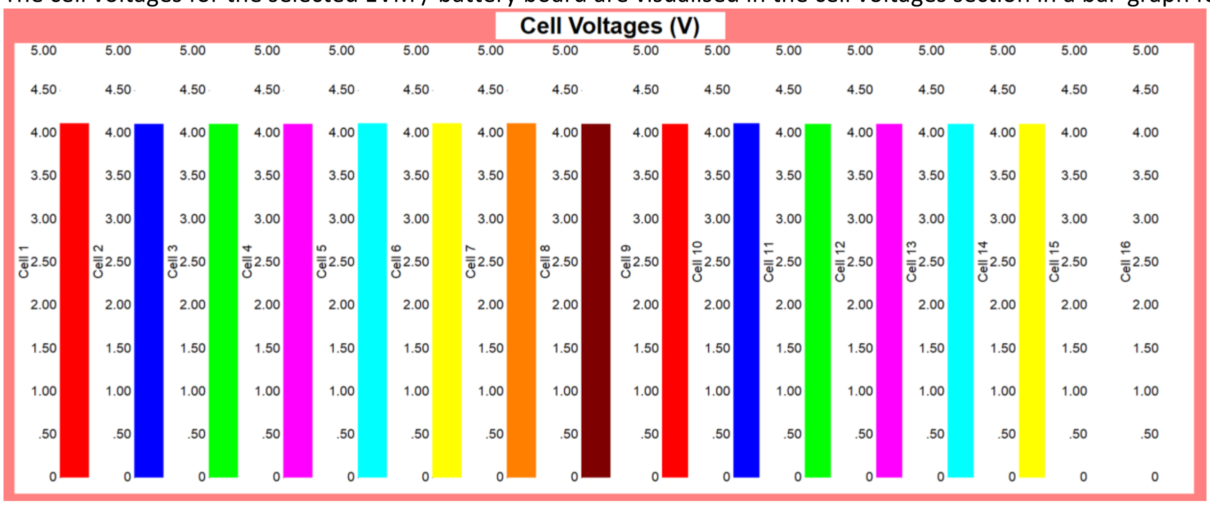
Summary Faults

The summary faults section visualizes the current status of all the summary faults. Note that the balancing fault condition is generated within the balancing routine in the Embed diagram.

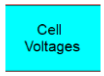
The calculated maximum and minimum and average cell voltages and temperatures can be viewed in the auxiliary measurements section. Along with these values, the selected internal chip temperatures and reference voltages will be visualized if selected. The ambient temperature will also be shown if enabled.



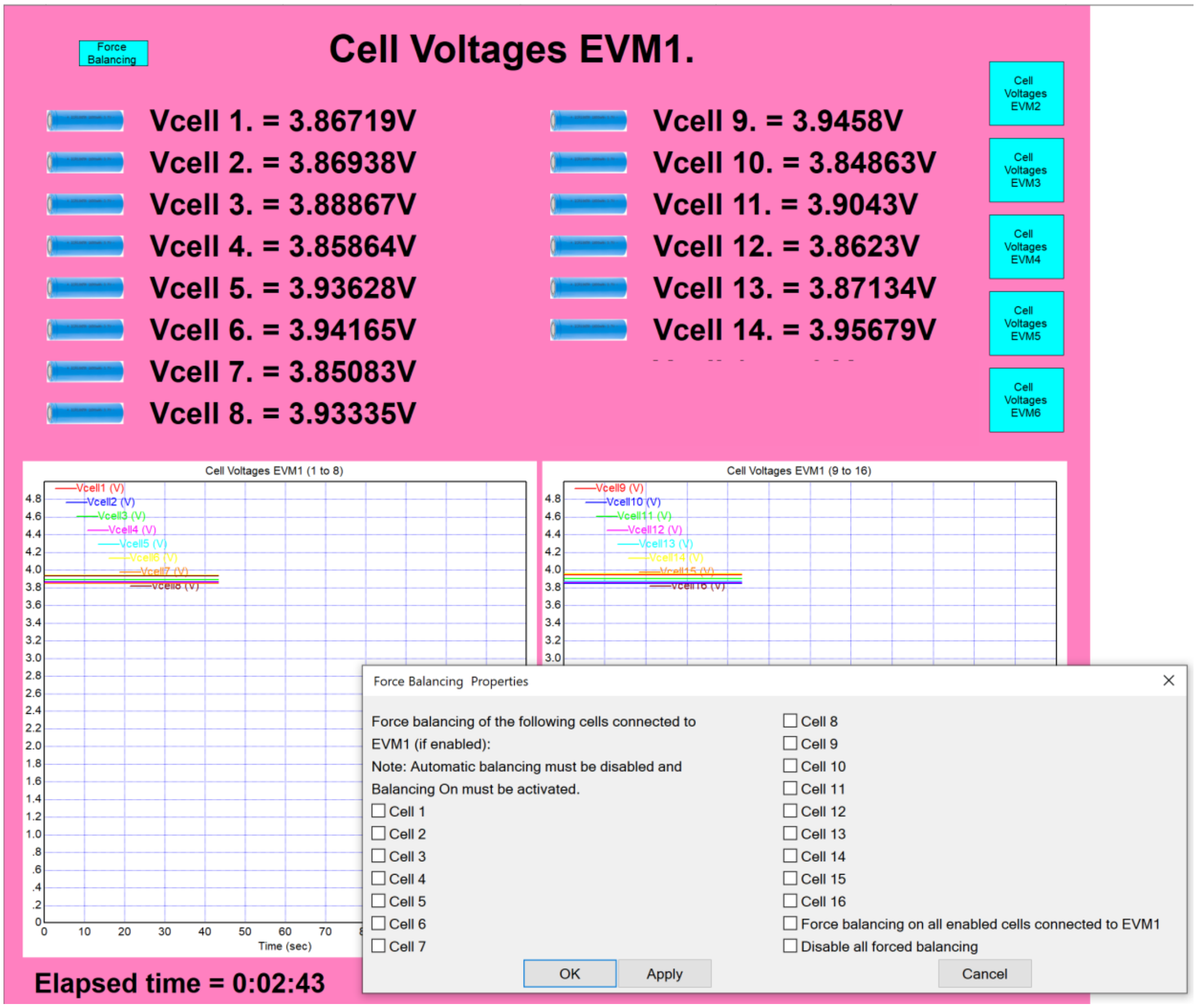
The cell voltages for the selected EVM / battery board are visualised in the cell voltages section in a bar-graph format.



<u>Visualization Tabs</u>

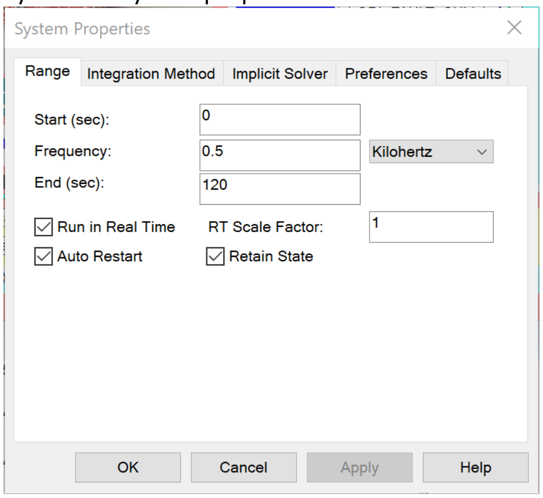
When right clicking of the cell voltages 

block on the main GUI page, the following window will appear within Embed. The currently activated cell voltages will be shown and plotted over time.



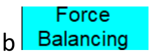
Note that the time duration of all plots can be simply varied during the simulation by going to:

System → System properties...

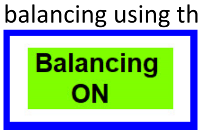


The plotting time can be varied by changing the End time in the dialog.
In normal operation, the BMS system and GUI will continue running unless stopped by the user. However, the plots will refresh at the given End time and in this way, one can select the desired plot length. The plots can also be zoomed in and out at any time.

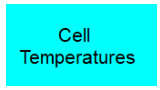
There are 5 more tabs (compound blocks) to the right where an identical view is shown for up to six bq76PL455EVMs and battery boards.

To the top-left, a Force balancing tab 

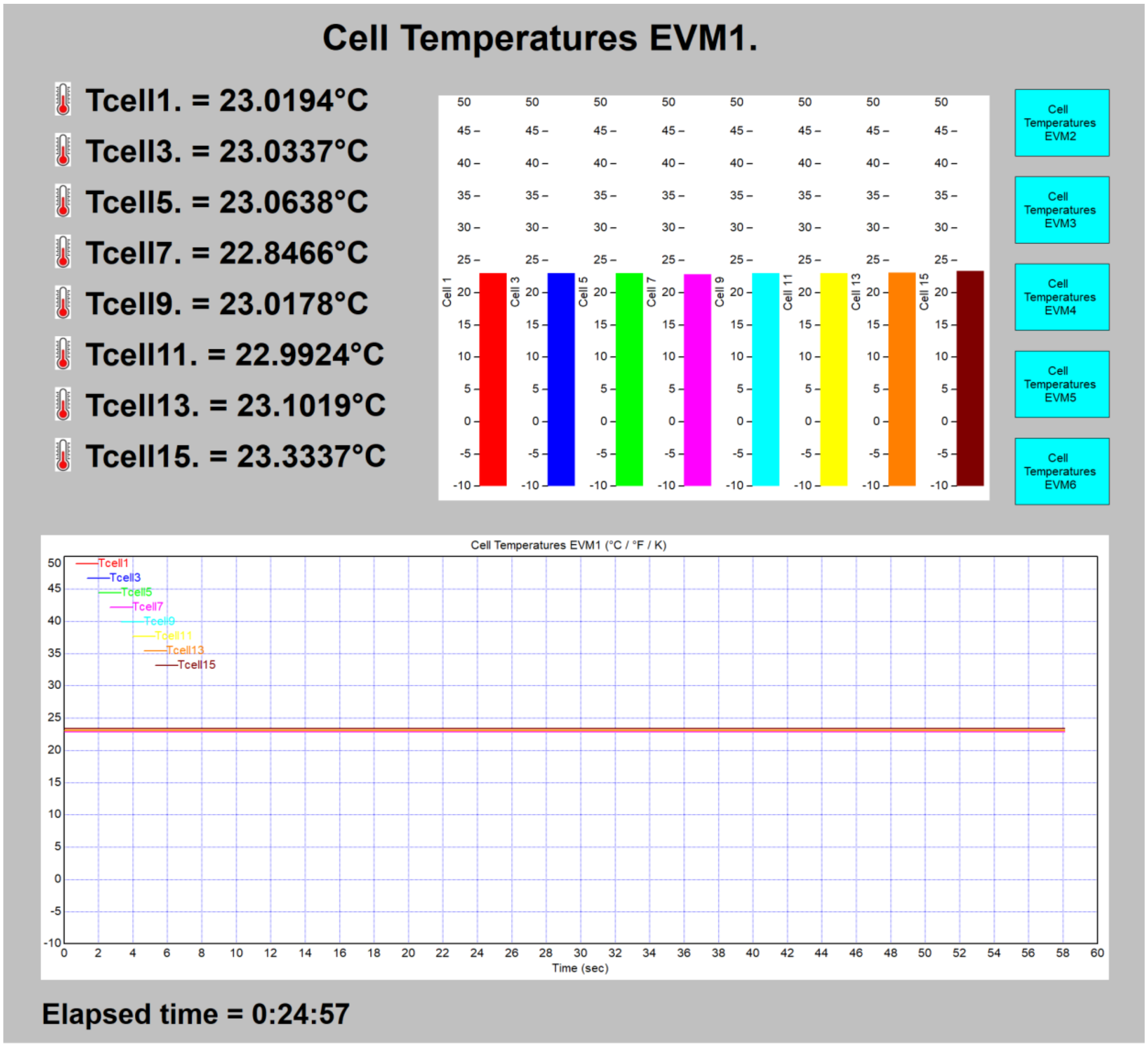
is present and clicking on this opens a dialog where the cells balancing can be forced on or off for the selected cells. Note that for manual balancing using this dialog, the automatic balancing must be disabled and the balancing must be enabled

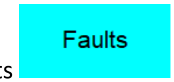


in the control section of the GUI.

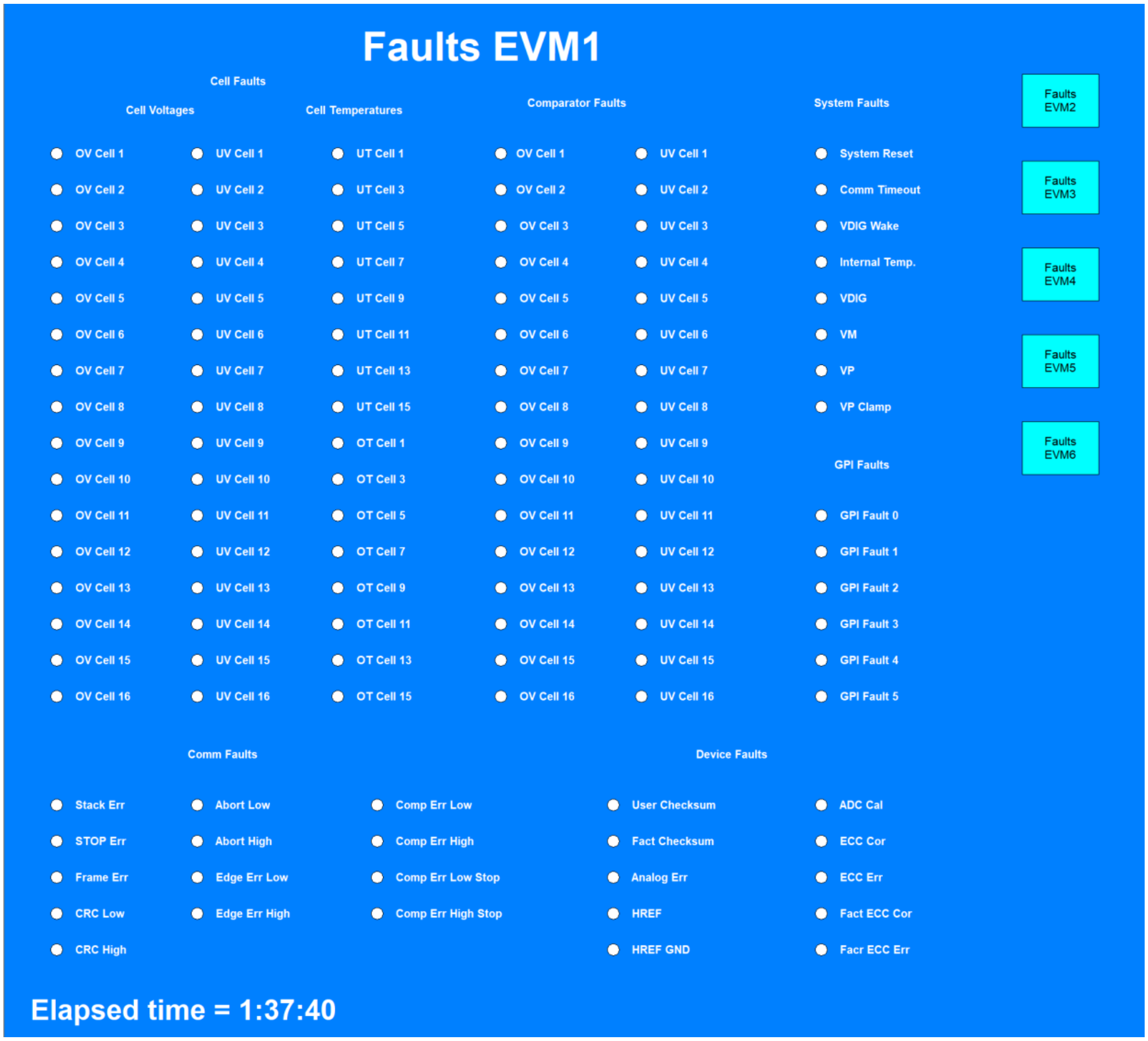
When right clicking of the cell temperatures 

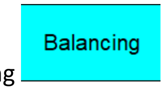
block on the main GUI page, the following window will appear within Embed similarly to that of the cell voltages window. Here the currently activated cell temperatures will be shown and plotted over time for all activated bq76PL455EVMs.



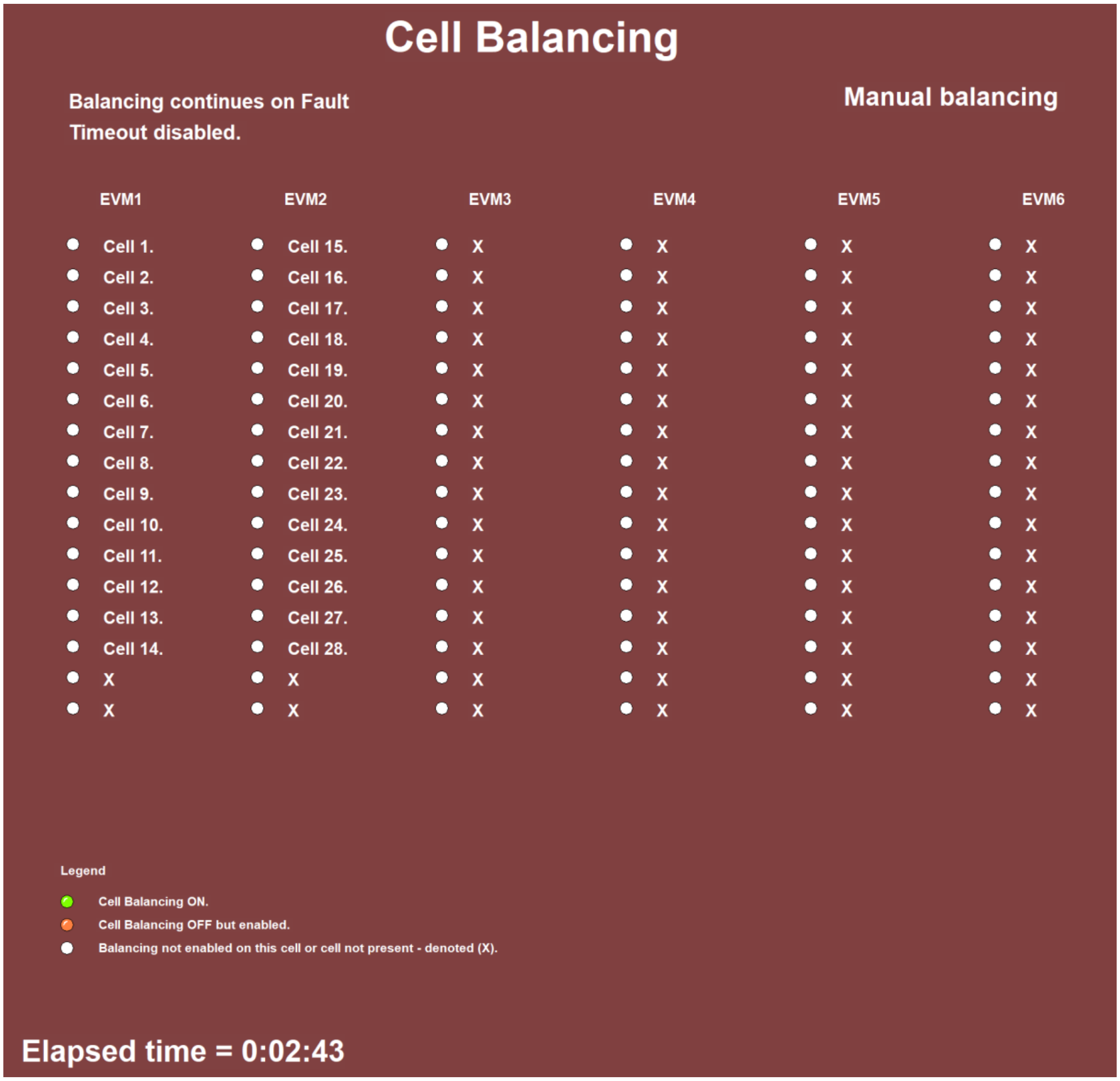
All faults of all enabled EVMs can be visualized by clicking on the Faults 

tab.



The balancing status of all enabled EVMs can be visualized by clicking on the balancing 

tab. The status will be shown for both manual or automatic balancing.



The cell voltages and temperatures can be visualized in table format by clicking on the Table tab.

Cell Voltages (V)

EVM / Cell	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1.	3.86719	3.86938	3.88867	3.85864	3.93628	3.94165	3.85083	3.93335	3.9458	3.84863	3.9043	3.8623	3.87134	3.95679	0	0
2.	4.11377	4.10986	4.11035	4.11182	4.11401	4.11353	4.11499	4.11182	4.11133	4.11328	4.10889	4.11255	4.10962	4.11255	0	0
3.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Av. Cell Voltage = 4.00366V

Cell Temperatures (°C)

EVM / Cell	1.	3.	5.	7.	9.	11.	13.	15.
1.	22.199219	22.167969	22.214844	21.992188	22.146484	22.113281	22.097656	0
2.	22.845703	22.748047	22.726563	22.550781	22.746094	22.675781	22.427734	0
3.	0	0	0	0	0	0	0	0
4.	0	0	0	0	0	0	0	0
5.	0	0	0	0	0	0	0	0
6.	0	0	0	0	0	0	0	0

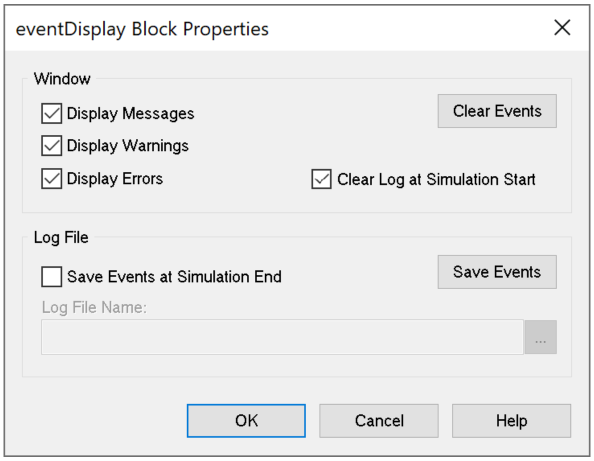
Ambient Temp. = 22.5879°C

The current logging status can be visualized by clicking on the logging **Logging** tab.

bq76PL455EVM Events

Date	Time	Source	Event
2/09/2021	9:07:28 AM	System	Stop polling
2/09/2021	9:07:28 AM	System	Balancing Disabled
2/09/2021	9:07:39 AM	Configuration	GPIOs configured.
2/09/2021	9:07:54 AM	Configuration	Device parameters configured.
2/09/2021	9:07:57 AM	Configuration	Sampling parameters / AFE configured.
2/09/2021	9:07:59 AM	Configuration	Channels configured.
2/09/2021	9:08:00 AM	Configuration	Cell over-voltage thresholds configured.
2/09/2021	9:08:00 AM	Configuration	Balancing parameters configured.
2/09/2021	9:08:01 AM	Configuration	Cell under-voltage thresholds configured.
2/09/2021	9:08:02 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:08:09 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:08:16 AM	Alarm Status	Polling not activated.
2/09/2021	9:08:17 AM	Configuration	Comparator over and under-voltage thresholds configured.
2/09/2021	9:08:19 AM	Configuration	Fault masks configured.
2/09/2021	9:08:21 AM	Configuration	Communication parameters configured.
2/09/2021	9:08:31 AM	System	Start polling
2/09/2021	9:08:45 AM	System	Stop polling
2/09/2021	9:09:01 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:09:49 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:10:28 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:10:28 AM	System	Stop polling
2/09/2021	9:10:28 AM	System	Balancing Disabled
2/09/2021	9:10:31 AM	Configuration	EVMs addressed. EVM1 address = 0.
2/09/2021	9:10:36 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:10:37 AM	Configuration	Fault masks configured.
2/09/2021	9:10:37 AM	Configuration	GPIOs configured.
2/09/2021	9:10:42 AM	Configuration	Device parameters configured.
2/09/2021	9:10:45 AM	Configuration	Sampling parameters / AFE configured.
2/09/2021	9:10:46 AM	Configuration	Channels configured.
2/09/2021	9:10:46 AM	Configuration	Cell over-voltage thresholds configured.
2/09/2021	9:10:46 AM	Configuration	Balancing Config Error.
2/09/2021	9:10:47 AM	Configuration	Cell under-voltage thresholds configured.
2/09/2021	9:10:47 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:10:53 AM	Configuration	Comparator over and under-voltage thresholds configured.
2/09/2021	9:10:55 AM	Configuration	Fault masks configured.
2/09/2021	9:10:59 AM	Configuration	Communication parameters configured.
2/09/2021	9:11:06 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:11:28 AM	Configuration	Balancing parameters configured.

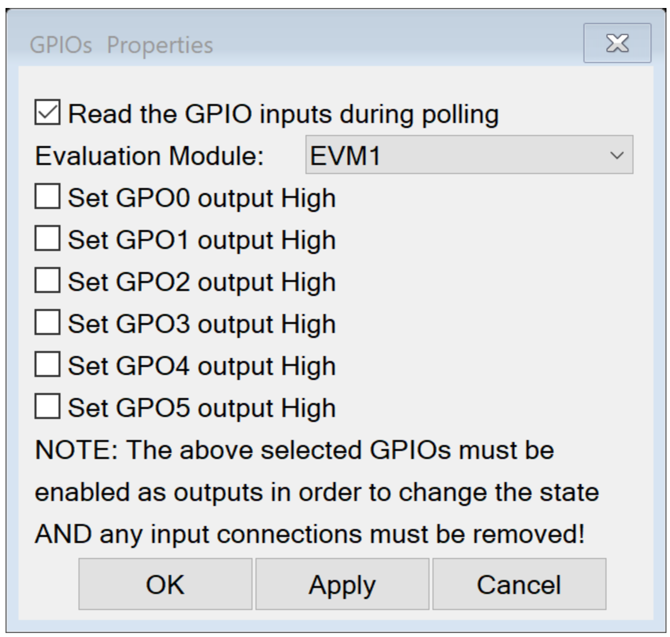
Elapsed time = 0:02:43



By right clicking on the logging window, the following dialog will appear and events can be cleared or saved to a file of choice.

When right clicking on the 

block, the following dialog will appear.



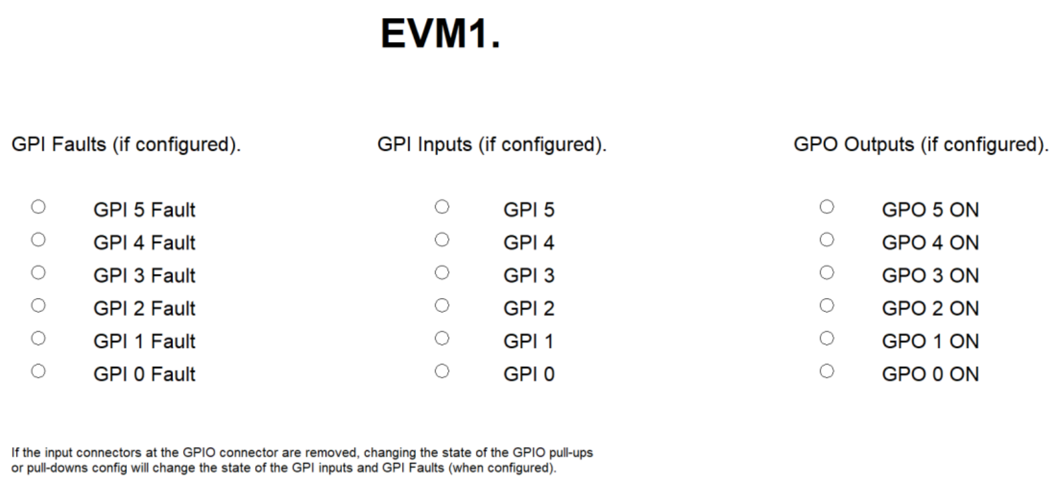
Read the GPIO inputs during polling:

If selected, the GPIO input status will be enquired at every polling interval and the GUI updated.

Set GPOx to high:

If enabled as outputs, the GPO output status can be set with this dialog. ENSURE that the address programming jumpers have been removed BEFORE enabling the GPIOs as outputs.

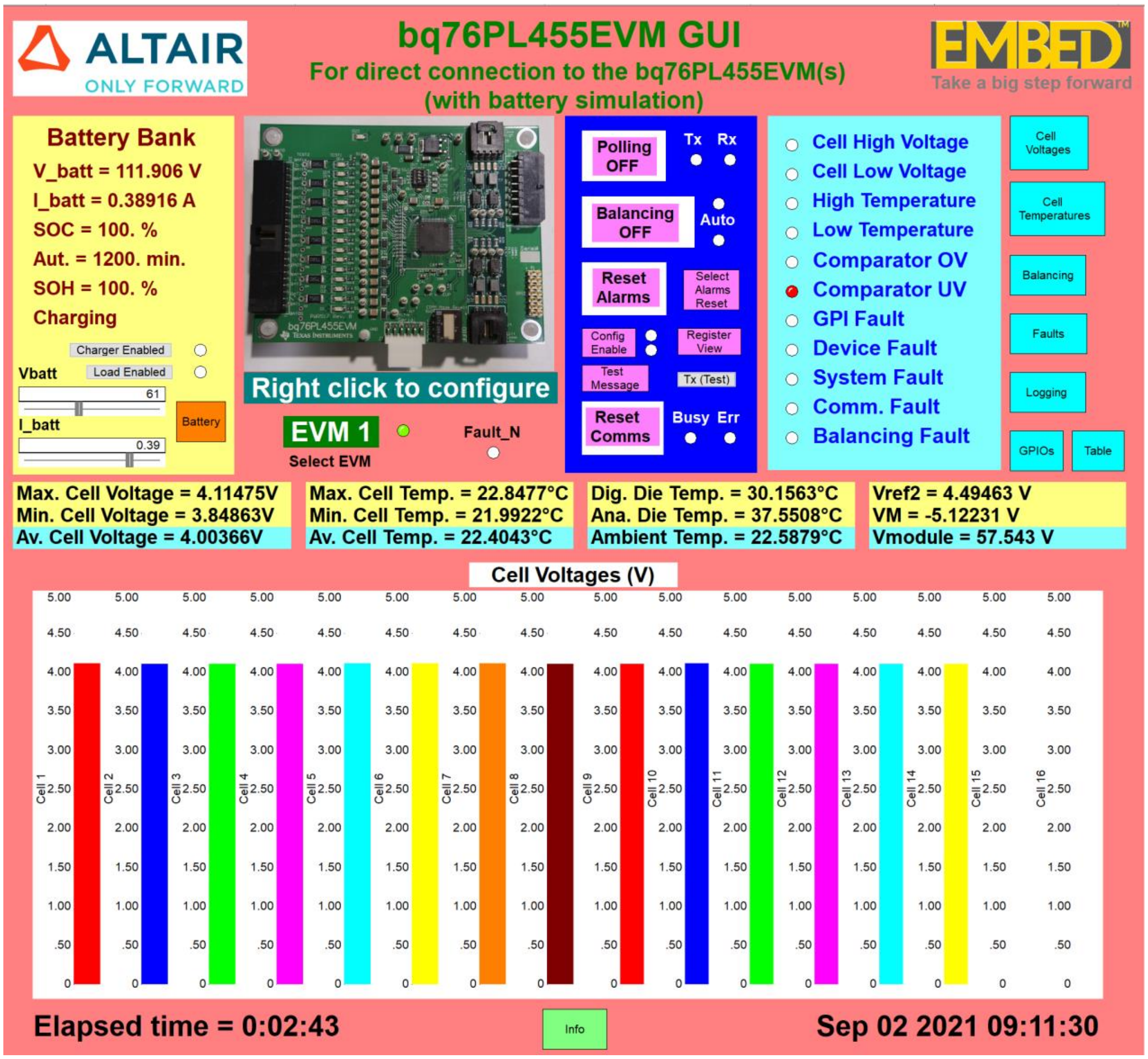
When double-left clicking on this block, the following visualisation will appear in Embed:



where the current GPIO status (and GPIO faults) can be directly visualized.

Configuring the Altair Embed TI BMS System

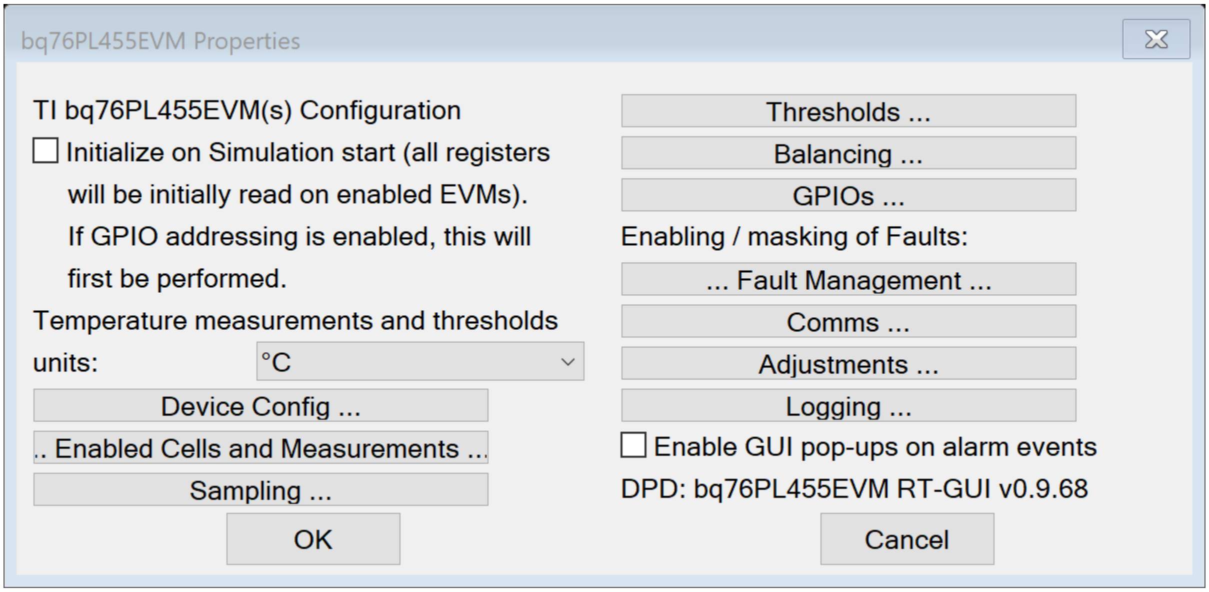
This section of this document replaces the sections 6 and 7 of the Texas Instruments (TI) document “bq76PL455EVM and GUI User Guide”, SLUUBA7A when using the Altair Embed TI BMS GUI since the procedure here varies when using the Altair Embed TI BMS GUI. For further information to this set-up procedure and the bq76PL455EVM, refer to the relevant TI documentation.
The Altair Embed TI BMS GUI is given below:



Before starting a simulation run, the BMS hardware should be connected and the USB-to-serial converter and/or the USB-to-JTAG converter connected to the PC. The BMS hardware registers of the bq76PL455q1 integrated circuit (IC) now need to be configured for the current hardware configuration. When starting and stopping the Embed simulation, if the BMS hardware itself is not switched off, or the PC interface is not removed, then it is not necessary to reconfigure the hardware on every simulation run.

By right clicking on the bq76PL455EVM image, the following configuration dialogs will appear.

Main Dialog



Initialize on simulation start:

This should be selected when connecting to the bq76PL455EVM(s) for the first time after powering up. Afterwards, when stopping and starting the Embed GUI, it is not necessary to perform the initialization every time.

Temperature measurements and thresholds units:

Select the desired units of the temperature measurements in either:

1. °C
2. °F
3. K.

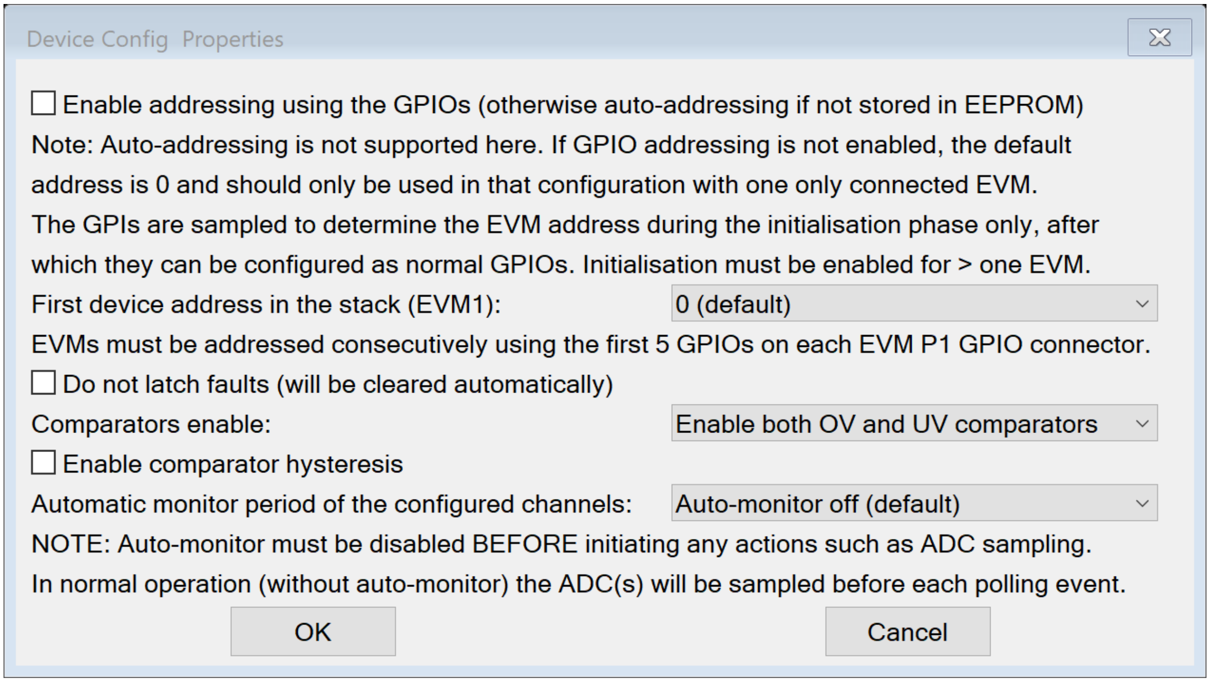
These units will be used throughout the Embed BMS GUI for the temperature measurements, temperature settings and thresholds.

The various configuration settings are groups into the nested Tabs and are described in the following sections.

Enable GUI pop-ups on alarm events:

When selected, pop-ups will appear on the occurrence of alarms in the system. Otherwise, only critical pop-ups will be enabled.

<u>Device Configuration</u>



Enable Auto-addressing using GPIOs:

If selected, the EVM address can be read at the GPIO inputs. This is necessary when more than one EVM is connected and must have a unique address. Initialization must also be enabled to initialize the EVM address(es). Auto-addressing can be achieved by developing an Embed block to insert into the diagram. Note that the GPIO inputs will be required for this addressing during initialization but can be reconfigured after the initialization as the address will be retained. In this case, the initialization should be disabled after the first simulation run of the Embed diagram.

First device address in the stack (EVM1):

Here, one can select the address of the first EVM. It can be selected as address 0 or 1. All other EVMs must have consecutive addresses after this first address as set at the GPIO inputs.

Do not latch faults:

If selected, all faults will be cleared automatically when the fault condition is no longer active.

Comparators enable:

The overvoltage and undervoltage comparators can be both enabled, both disabled or only the overvoltage comparators enabled.

Enable comparator hysteresis:

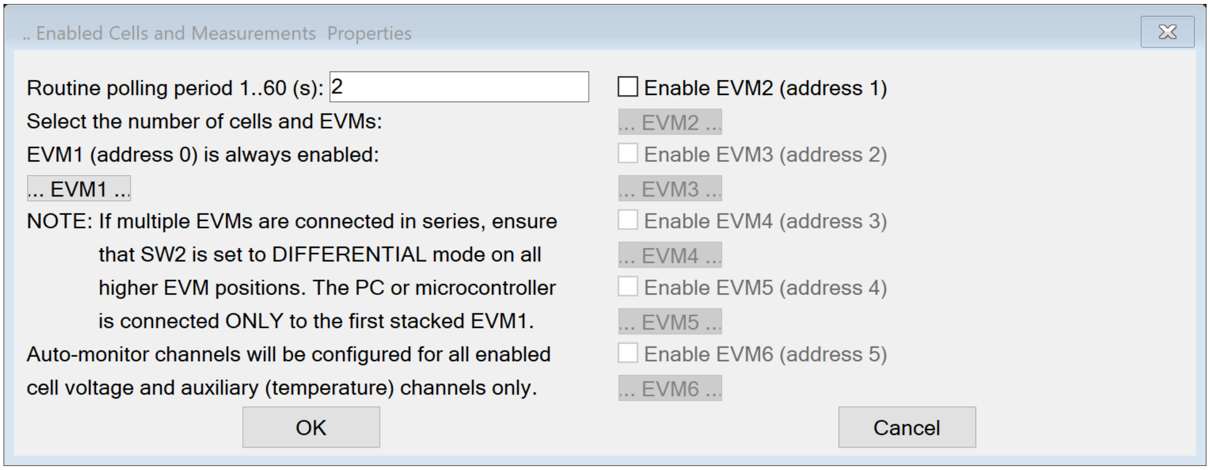
If selected, the comparator hysteresis will be enabled.

Automatic monitor period of the configured channels:

The automatic monitor period can be set here. The auto-monitor is enabled for a period > 0. Note that the auto-monitor sampling settings vary from the normal settings and the auto-monitor channels will be set-up for all normally enabled voltage and temperature channels.

<u>Enabling Cell and device Measurements</u>

The number of cells in each EVM and the desired cell and device measurements can be selected here for one to six bq76PL455EVMs.

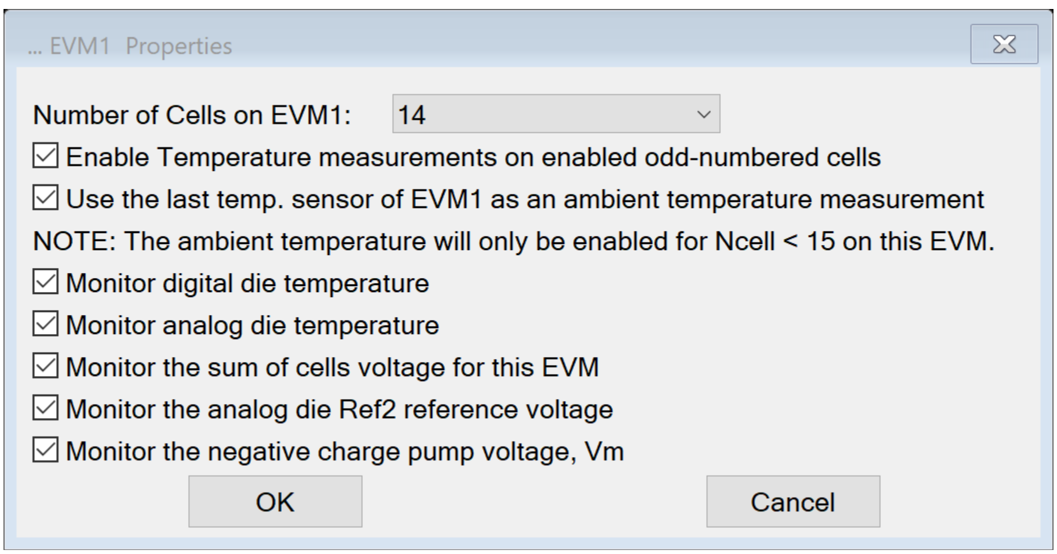


Routine polling period 1 … 60 (s):

Enter the value in seconds for the period between polling of the cell and device measurements.

Enable the number of connected EVMs from 1 to 6.

Each EVM tab contains the following dialog:



Number of cells on EVMx:

Select the number of series cells on the corresponding EVM from 6 to 16 cells. Each EVM can have a different number of cells enabled.

Enable temperature measurements on enabled odd-numbered cells:

When selected, the temperature measurements on all odd-numbered enabled cells (maximum of 8 per EVM) will be enabled. The battery board has a NTC sensor under each odd-numbered cell.

Use the last temperature sensor of EVMx as the ambient temperature sensor:

The last temperature sensor of one EVM (or battery board) can be selected as the ambient temperature. Note that this will only be enabled if the cell is not populated at this position.

Monitor digital die temperature:

The internal chip temperature of the digital die will be monitored if enabled.

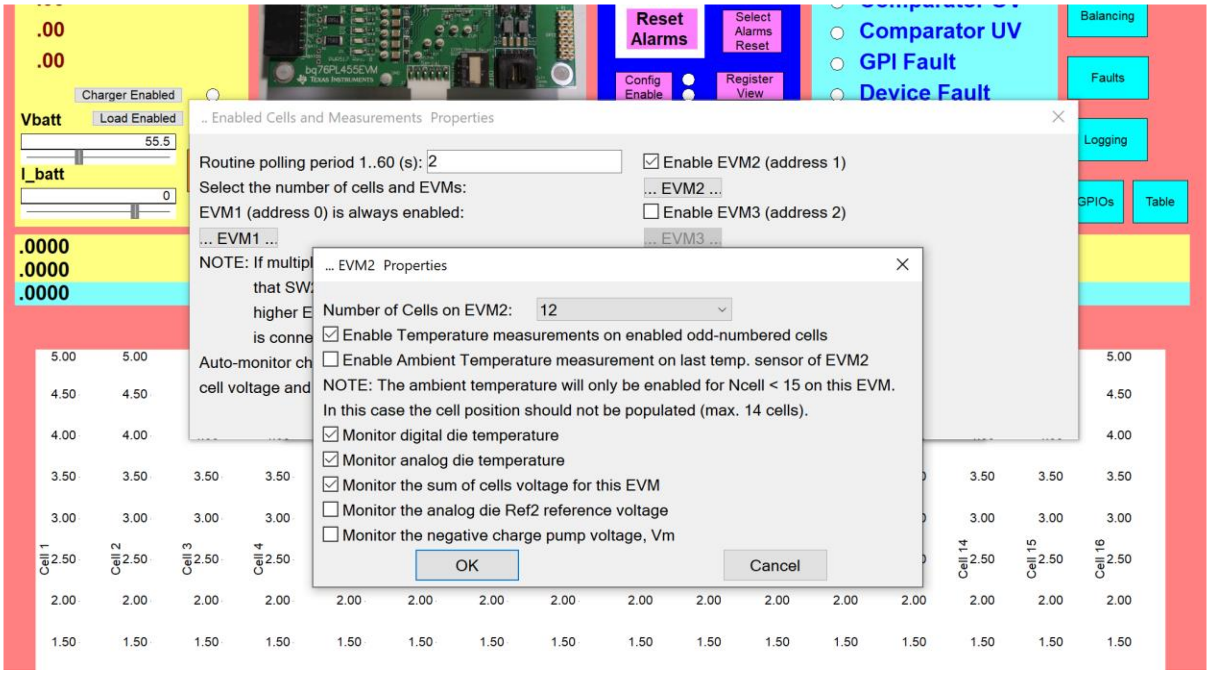
Monitor analog die temperature:
The internal chip temperature of the analog die will be monitored if enabled.

Monitor the sum of cells voltage:
If enabled, the total cell voltage from the most positive to the most negative points, connected to the EVM (sum of cells) will be measured and transmitted together with the other selected measurements.

Monitor the analog die Ref2 reference voltage:
The analog die Ref2 reference voltage (4.5V) will be monitored if enabled.

Monitor the negative charge pump voltage, Vm:
The negative charge pump voltage, Vm (approximately -5.2V) will be monitored if enabled.

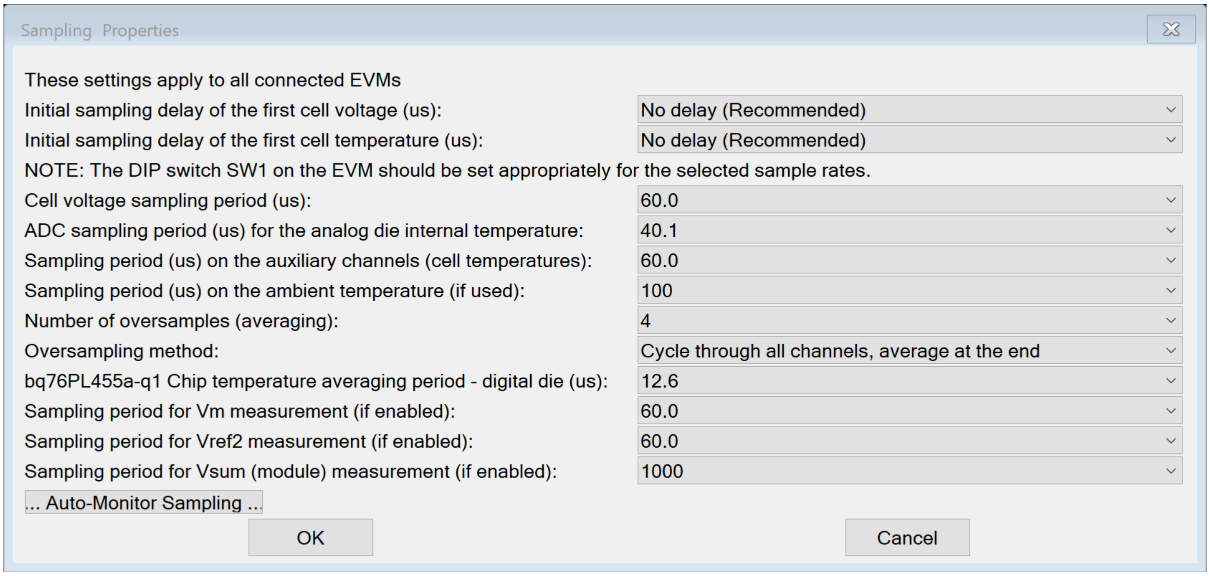
Similarly, any other connected EVM boards can be configured using this dialog:



The other EVMs can be configured with any number from 6 to 16 cells and the configuration may vary between the connected EVM boards.

Sampling Configuration

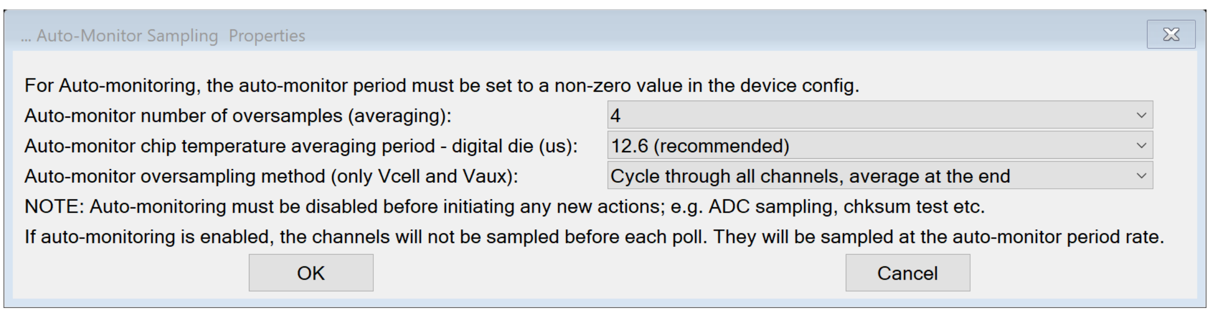
The ADC sampling can be configured in the following dialog.



The various sampling delays of the various measurements can be set in this configuration dialog. The recommended setting and / or the default settings are generally noted.

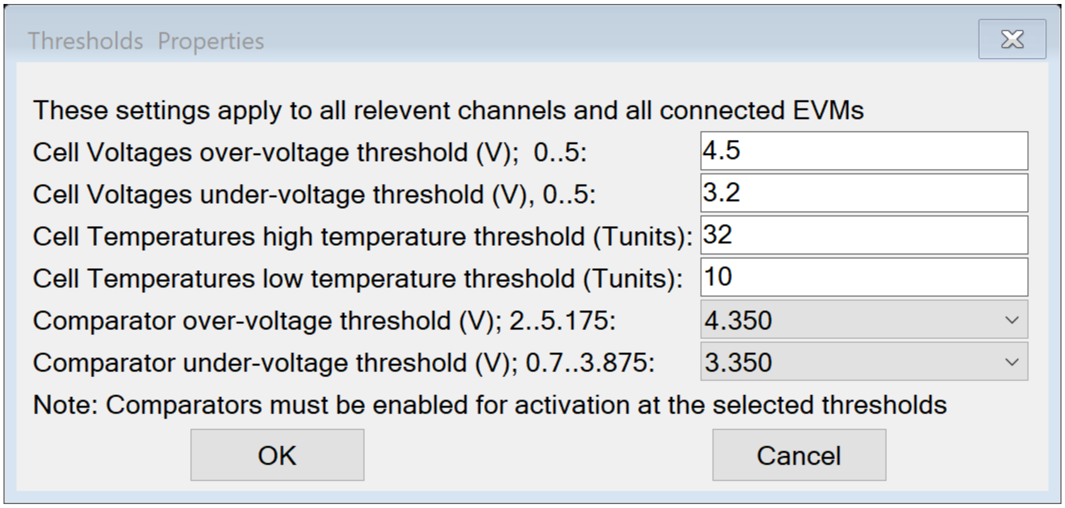
The oversampling can also be configured in this dialog.

The auto-monitor sampling can be configured similarly and separately to the above in the following dialog which appears after clicking on the Auto-monitor sampling Tab.



Thresholds Configuration

The desired thresholds can be set in this dialog. The given thresholds will be set identically for all configured channels and all enabled EVMs.



Cell voltages over-voltage threshold 0…5V:
: Enter the desired value of the cell over-voltage threshold in volts.

Cell voltages under-voltage threshold 0…5V:
: Enter the desired value of the cell under-voltage threshold in volts.

Cell temperatures high temperature threshold (Tunits):
: Enter the desired value of the cell high temperature threshold in the GUI selected temperature units.

Cell temperatures low temperature threshold (Tunits):
: Enter the desired value of the cell low temperature threshold in the GUI selected temperature units.

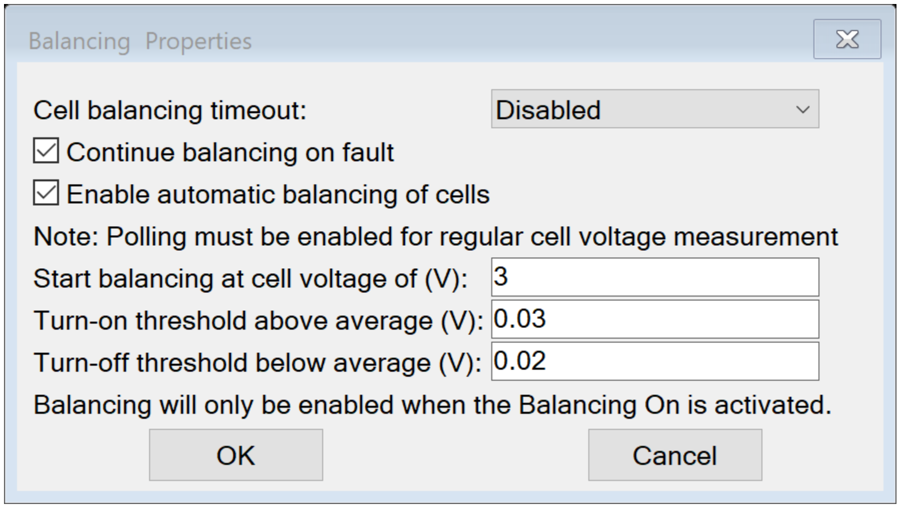
Comparator over-voltage threshold 2…5.175V:
: Select the desired value of the auxiliary cell voltage comparator over-voltage threshold in increments of 25mV.

Comparator under-voltage threshold 2…5.175V:
: Select the desired value of the auxiliary cell voltage comparator under-voltage threshold in increments of 25mV.

Note that the auxiliary comparators can be enabled or disabled in the main dialog configuration.

<u>Balancing Configuration</u>

The balancing can be configured on the following dialog after clicking on the balancing tab in the main dialog. The first two selections are determined in the bq76PL455EVM and set-up the CBCONFIG register. The remaining selections are configurations of the automatic balancing subroutine block within the Embed GUI diagram.



Cell balancing timeout:
: Select the desired timeout of the cell balancing.

Continue balancing on fault:
: Select this to continue the balancing even in the case of a fault.

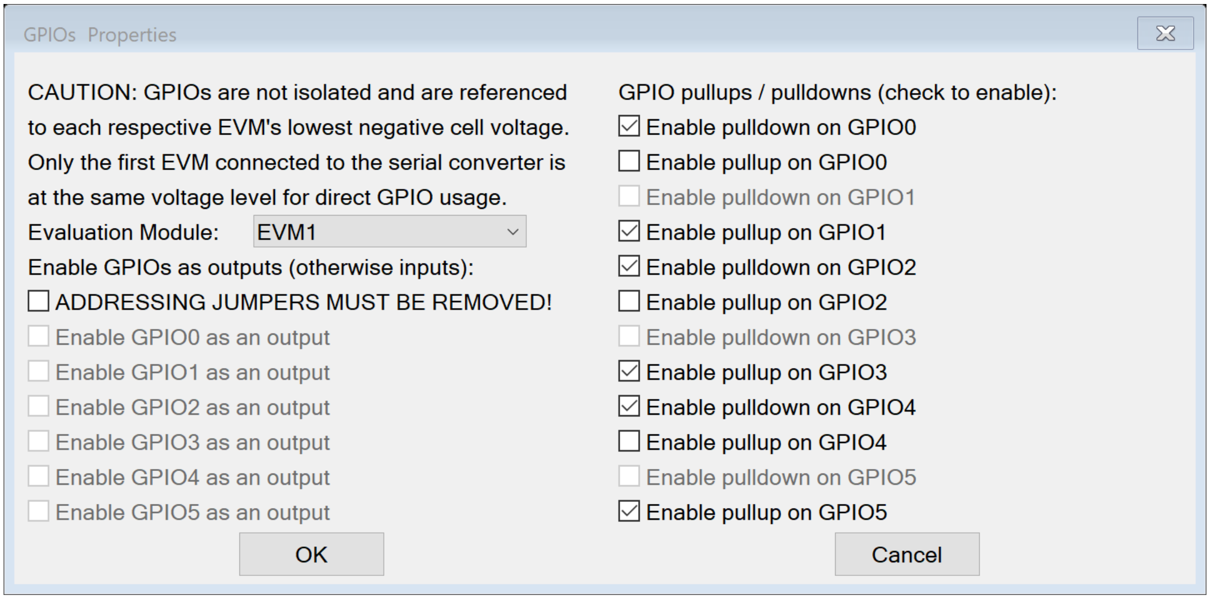
Start balancing at a cell voltage of:
: Enter the desired cell voltage, above which the automatic balancing should be enabled. If the cell voltage is lower than this value, the automatic balancing will not be active (the cell is discharged or is heavily charging).

Turn-on threshold above average:
: Enter the value in volts of the voltage above the average cell voltage at which the cell balancing should turn on.

Turn-off threshold below average:
: Enter the value in volts of the voltage below the average cell voltage at which the cell balancing should turn off.

GPIO Configuration

The GPIOs can be configured when clicking on the GPIO tab in the main dialog.



Evaluation module:

Select the evaluation module to which the configuration settings are to apply (other EVMs can be configured consecutively).

Enable GPIOs as outputs:

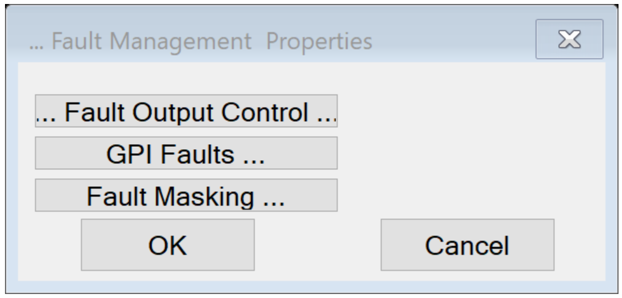
The individual GPIOs can be set as outputs. ENSURE to remove any addressing jumpers at the GPIOs before enabling this option.

GPIO pullups / pulldowns (check to enable):

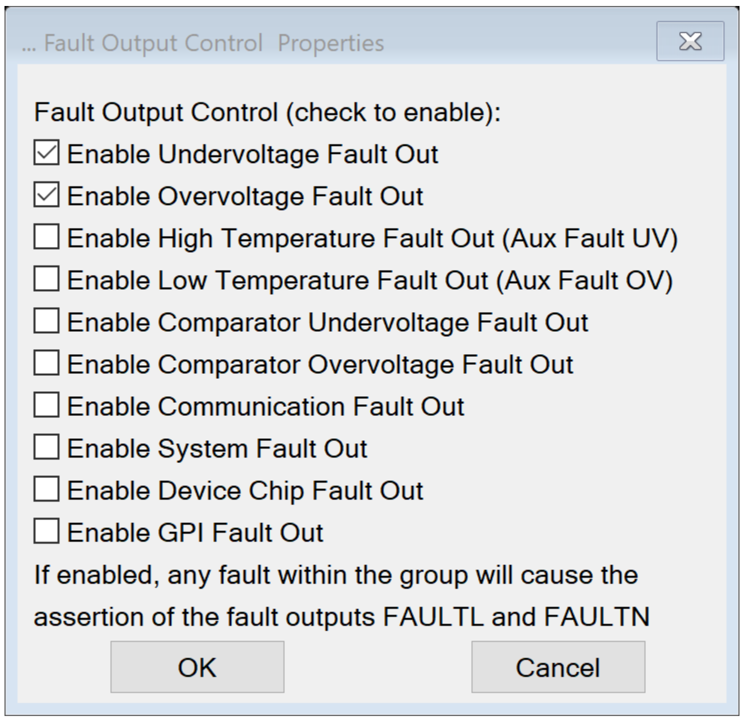
The GPIO pull-ups or pull-downs can be enabled in this section. Although the bq76PL455EVM will allow both the pull-up and pull-down to be enabled on a GPIO (not desired), this dialog will not allow both to be enabled and the pull-up is dominant.

<u>Fault Management Configuration</u>

Three groups of faults can be selected in the fault management configuration dialog:

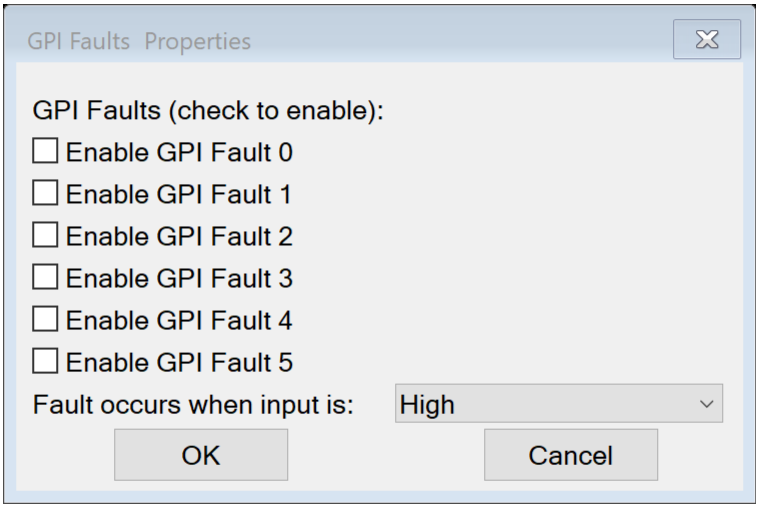


Clicking on either Tab will open the following sub-dialogs:
The fault output control sub-dialog is as follows:

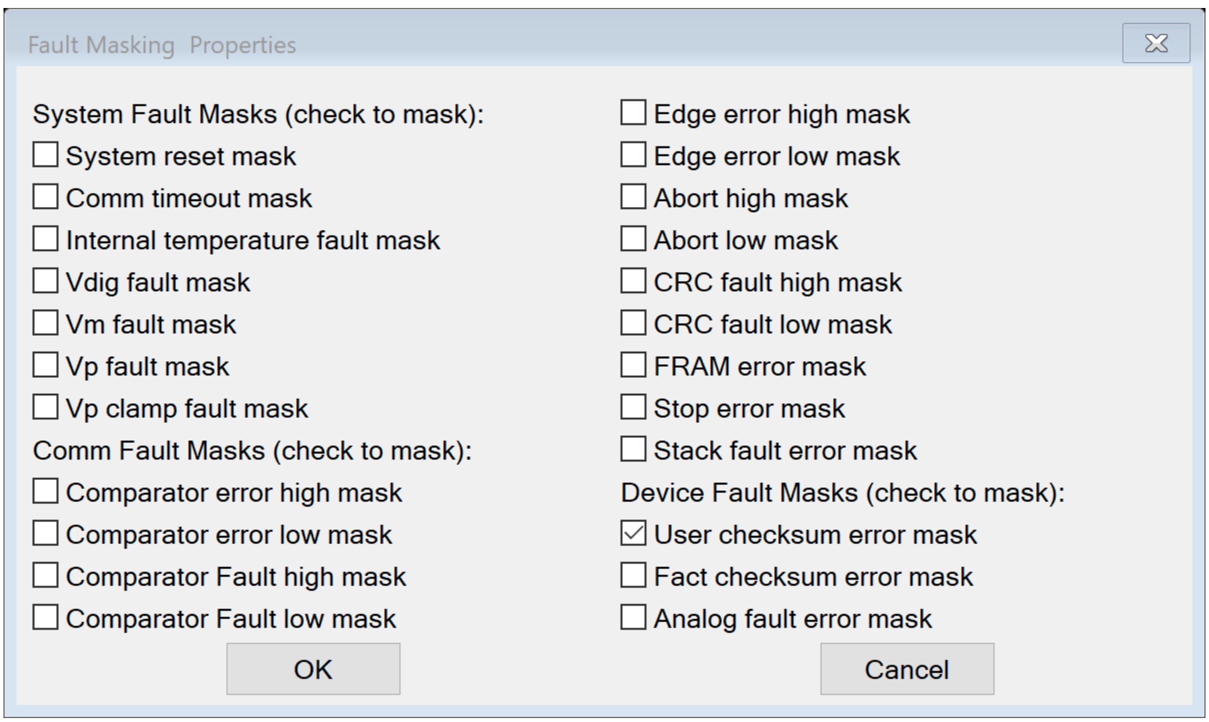


In this dialog, the faults which are to be included in the FAULTL and FAULTN lines can be selected.

The GPI Faults sub-dialog is as follows:

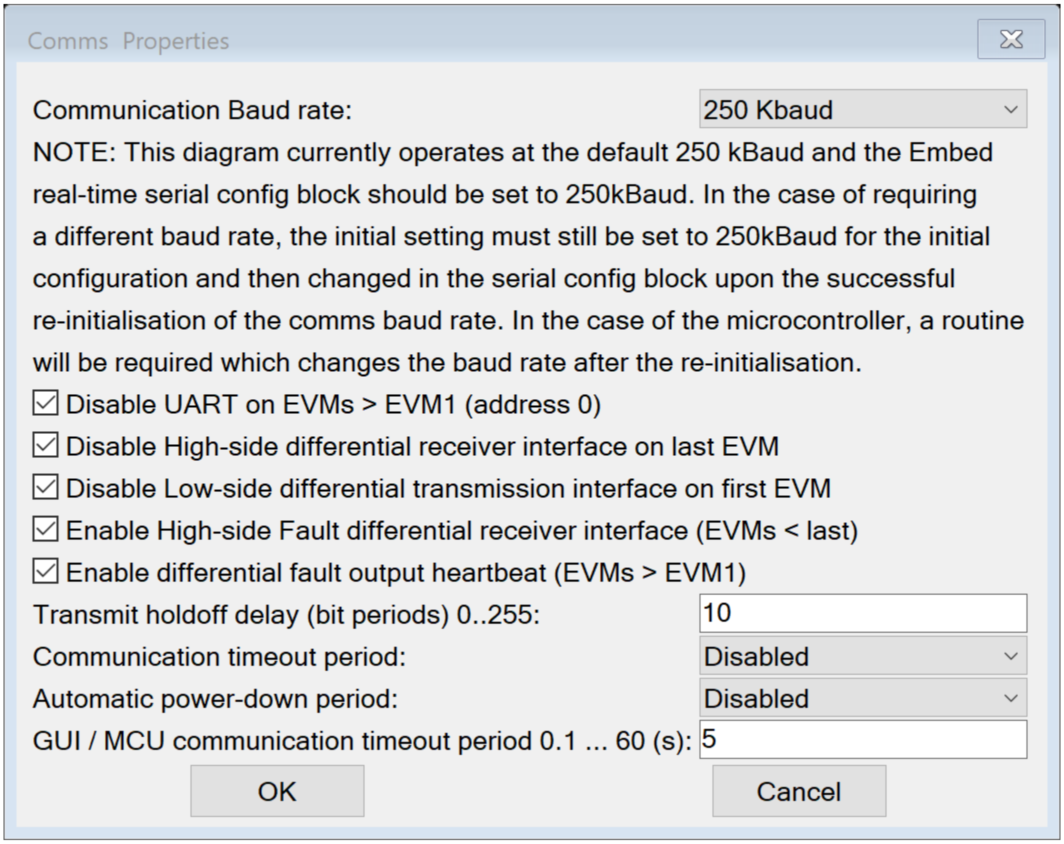


In this dialog, the individual GPIs can be enabled to activate a fault (on a low or high state selectable).
The system fault masks sub-dialog is as follows:



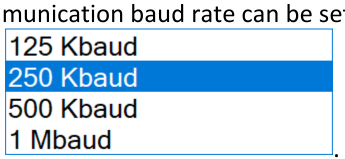
Selected faults can be masked in this dialog.

<u>Communication Configuration</u>
The dialog is given as follows:

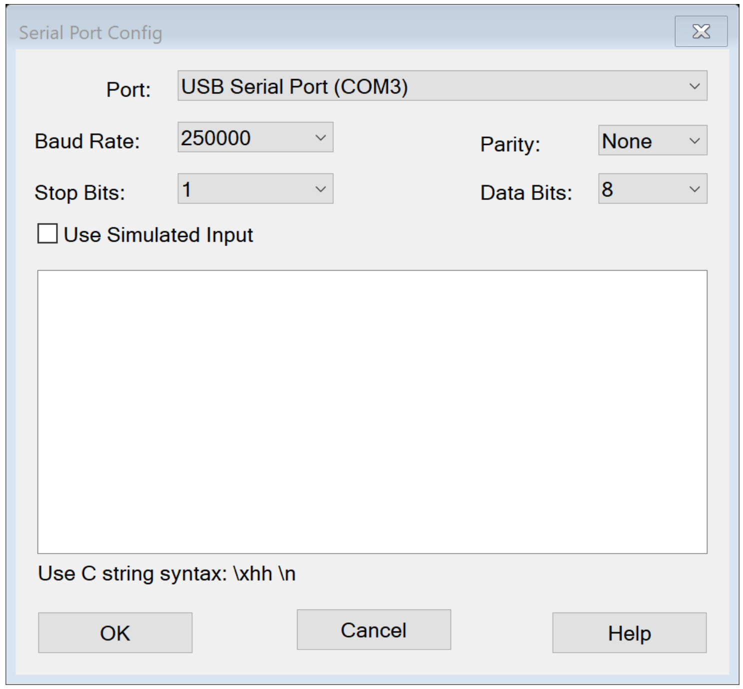


Communication Baud rate:

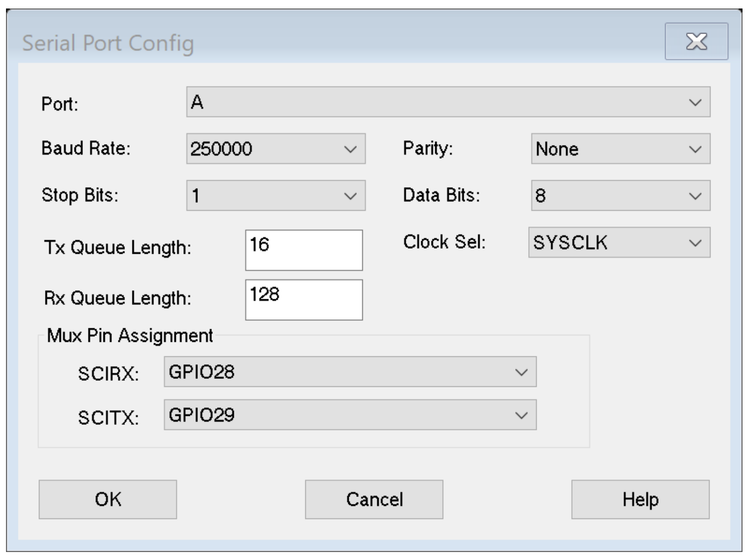
The communication baud rate can be set on the bq76PL455EVM to any of the following rates:



The default is 250kbaud and it is recommended to use this baud rate. In order to change the baud rate, the baud rate must first be set to 250kbaud and the configuration message sent. It will then be necessary to change the communication parameters in the Embed menu under: Blocks → Real time → Serial Config. As shown in the following:



Where the new baud rate can be selected. If a microcontroller is used, the microcontroller should be re-programmed with the new baud-rate setting under: Embed → Delfino → Serial UART → Serial UART Config…



Otherwise, a dedicated routine can be developed for the microcontroller, which automatically changes the baud rate to the desired new baud rate upon initialisation of the bq76PL455EVMs present in the system. This activity is left as an exercise for the user, if desired, and is not necessary for the complete and normal functioning of the BMS system and demonstration.

Disable UART on EVMs > EVM1 (address 0):

This option disables the non-isolated UART input on EVMs above address 0. Normally, only the first EVM can be connected to the PC / microcontroller since in a normal series configuration of the battery cells and modules, only the first EVM will be referenced to the controller / PC ground.

Disable high-side differential receiver on last EVM:

This option disables the differential high-side receiver on the last EVM in the chain. Since it is the last EVM, there will be no further EVMs to receive data and the receiver can be disabled to reduce the risk of noise on the differential communication line.

Disable low-side differential transmission interface on first EVM:

Similarly, this option disables the differential low-side transmitter on the first EVM since the normal UART communication would be used on this EVM.

Enable high-side fault differential receiver interface (EVMs < last):

This option will enable the fault line differential receiver interface for all EVMs in the system which have a lower address to the last address.

Enable differential fault output heartbeat (EVMs > EVM1):

This option will enable a regular heartbeat pulse to be sent on the differential isoUART line.

Transmit holdoff delay (bit periods) 0…255:

The holdoff delay can be set by the number of bit periods.

Communication timeout period:

Programmable internal communication timeout period of the EVMs (hardware timeout).

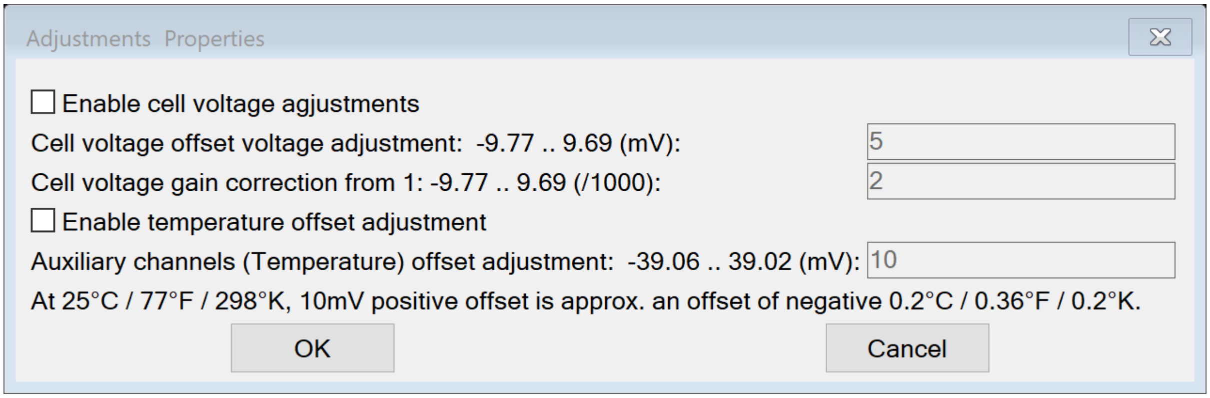
Automatic power-down period:

This option sets the automatic power down period of the bq76PL455qi IC. Power down is not currently supporting in the Embed diagrams though a simple routine (compound block) can be added to the diagrams by the user if desired.

GUI / MCU communication timeout period 0.1 … 60 (s):

This is a parameter used within the GUI control diagram, whether it resides on the PC or on a connected microcontroller. A timeout pop-up message will appear if no response is received to a transmitted message within the given timeout period.

<u>Adjustments Configuration</u>
The dialog is given as follows:



Enable cell voltage adjustments:

Select to enable the transmission of the cell voltage offset and gain adjustments.

Cell voltage offset adjustment:

The cell voltages can have an offset from -9.77mV to 9.69mV directly applied to the measurements stored in the bq76PL455EVM before transmitting to the GUI.

Cell voltage gain adjustment:

The cell voltages can have a gain adjustment from -0.00977 to 0.00969 directly applied to the measurements stored in the bq76PL455EVM before transmitting to the GUI.

Enable temperature offset adjustment:

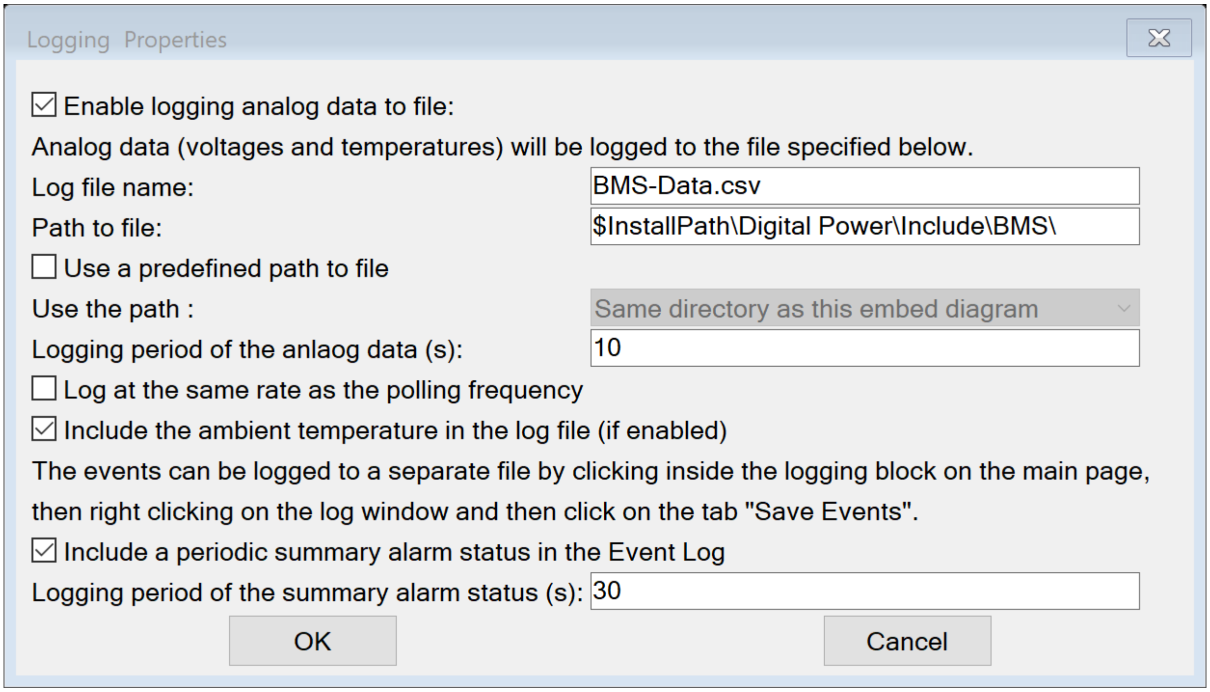
Select to enable the transmission of the cell temperature (auxiliary) offset adjustments.

Auxiliary channels (temperature) offset adjustment:

The auxiliary channels can have an offset adjustment from -39.06mV to 39.02mV directly applied to the auxiliary measurements stored in the bq76PL455EVM before transmitting to them to the GUI. An offset of 10mV at 25°C will correspond to approximately a 0.2°C offset in the temperature measurement using the battery board NTCs.

Logging Configuration

The BMS data can be logged to a defined file in a defined location.



Enable logging analog data to file:

Analog data (cell voltages and temperatures) can be logged to a file when enabled.
Enter the file name and path of the file.

Logging period of the analog data:

The period at which the selected analog data is logged can be entered.

Include the ambient temperature in the log file:

Enable this if the ambient temperature is to be included in the log file.

Include a periodic summary alarm status in the event log:

Enable this to include summary of the alarm / fault status in the event log found on the main page in the logging block.

Logging period of the summary alarm status:

The period at which the summary alarm status is logged in the event log can be entered.

Contents – Applications

The Infineon TLE9012 / TLE9015 BMS Demonstration

Hardware Description

This section describes the Altair Embed® / Infineon™ battery management system (BMS) demo kit necessary to develop firmware for a complete, production-ready battery monitoring system using this hardware setup.

Altair Embed / Infineon BMS demo kit

The required material for the Altair Embed / Infineon battery management system (BMS) demo kit is as follows:

- Infineon TLE9012**AQU[1]** evaluation kit.[1]
- Battery board for up to 12 cells.[2]
- Texas Instruments Microcontroller Docking station with TI TMS320F28379 control card.[3]
- Necessary cables for connections.
- 18650 battery cells.[4]

1. This work was performed with the TLE9012AQU device which is to be superseded by the TLE9012DQU device with similar functionality. Refer to the Infineon datasheets for differences between the devices if the TLE9012DQU device is to be adapted to this GUI and code-generation software.
2. Multiple TLE9012 boards and battery boards are required when there are more than 12 cells in the system. The Infineon TLE9012 evaluation kit and the Altair Embed GUI supports up to 6 series connected boards which are normally linked in a chain by the isolated serial communication interface board, TLE9015 and the provided cables. However, the Infineon TLE9012 integrated circuit supports many more TLE9012 chips connected in series.
3. Requires hardware modifications to connect the serial interface and the ADC connector as a minimum requirement.
4. The battery board accepts 18650 cells and these cells are purchased optionally.

The Infineon battery management system evaluation kit consists of the evaluation board TLE9012 as shown in figure 12, along with the differential isolated transceiver communications board TLE9015 and connection cables.

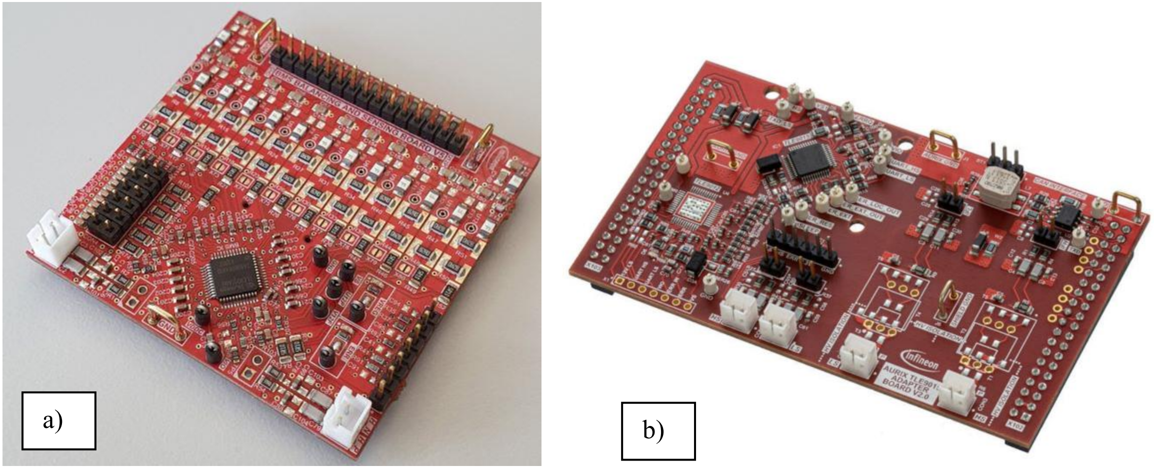


Figure 12: Infineon TLE9012 (a) evaluation board and the optional Infineon TLE9015 (b) isolated communications differential transceiver board.

For more information on the Infineon BMS evaluation kit, refer to the relevant Infineon application note and the Infineon TLE9012 and TLE9015 datasheets.

Battery Board

The B18650-16 battery board is used in this demonstration and is shown in figure 13.

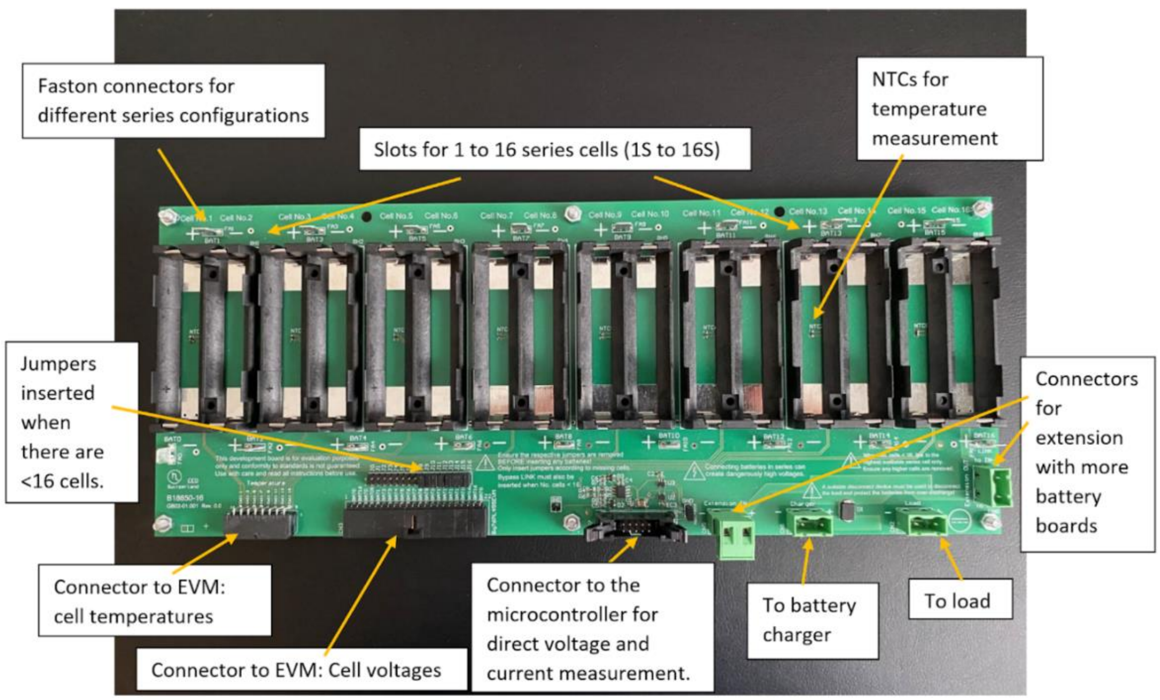


Figure 13: Battery board developed to evaluate various BMS systems together with [Altair Embed](). The board can be directly connected to the TLE9012 board.

- The battery board consists of slots for up to sixteen 18650 cells (a shorting link is provided when less cells are installed as is the case for the Infineon BMS hardware with a maximum of 12 cells for each TLE9012 board)

- Eight NTC thermistors for temperature measurement of odd-numbered cells or the ambient temperature (up to 5 temperatures can be measured using one TLE9012 board)
- Two current sensors for the battery current (charging and discharging)
- A voltage sensor operational amplifier
- Connectors for a charger and load
- Connectors for expansion so that battery boards can be configured in a series or parallel connection with a maximum of 6 battery boards.

  For voltage and current measurement, the board should be supplied with +5V at the CN7 10-pole connector (normally from the TI docking station as used in this demonstration).

Connecting battery cells in series can create dangerously high voltages. Six series-connected battery boards, each with 16 mounted cells will create a battery voltage greater than 400V! It is the responsibility of the user to ensure the required safety precautions are applied at ALL times during the development phase and during the use of the BMS demo kit.

- A shorting link is described in figure 14 and inserted if the number of cells used is less than sixteen. The maximum number of cells for the Infineon BMS hardware is twelve. This must be connected if the batteries are to be charged and discharged while inserted in the battery board slots. It is inserted from the BAT16 connection point to the connection point of the highest inserted cell.
- Note that during the development phase of the BMS firmware, the battery boards do not need to be connected in series and can be referenced to a common ground at the negative pole of each board. In this way, the firmware can proceed for multiple boards at relatively safer voltages, though care must still be taken when working with any battery voltage.
- Jumpers are provided to short out connections where battery cells are unpopulated though there is no specific requirement from Infineon that this is the case. Take care to remove any jumpers BEFORE inserting a battery cell in that position.
- Before use, follow all instructions in this section of the user guide and any instructions on the battery board itself.

Cables for the Infineon BMS Kit

The required cabling for the interconnection of the demo boards and the PC running the Embed GUI are given in figure 14.

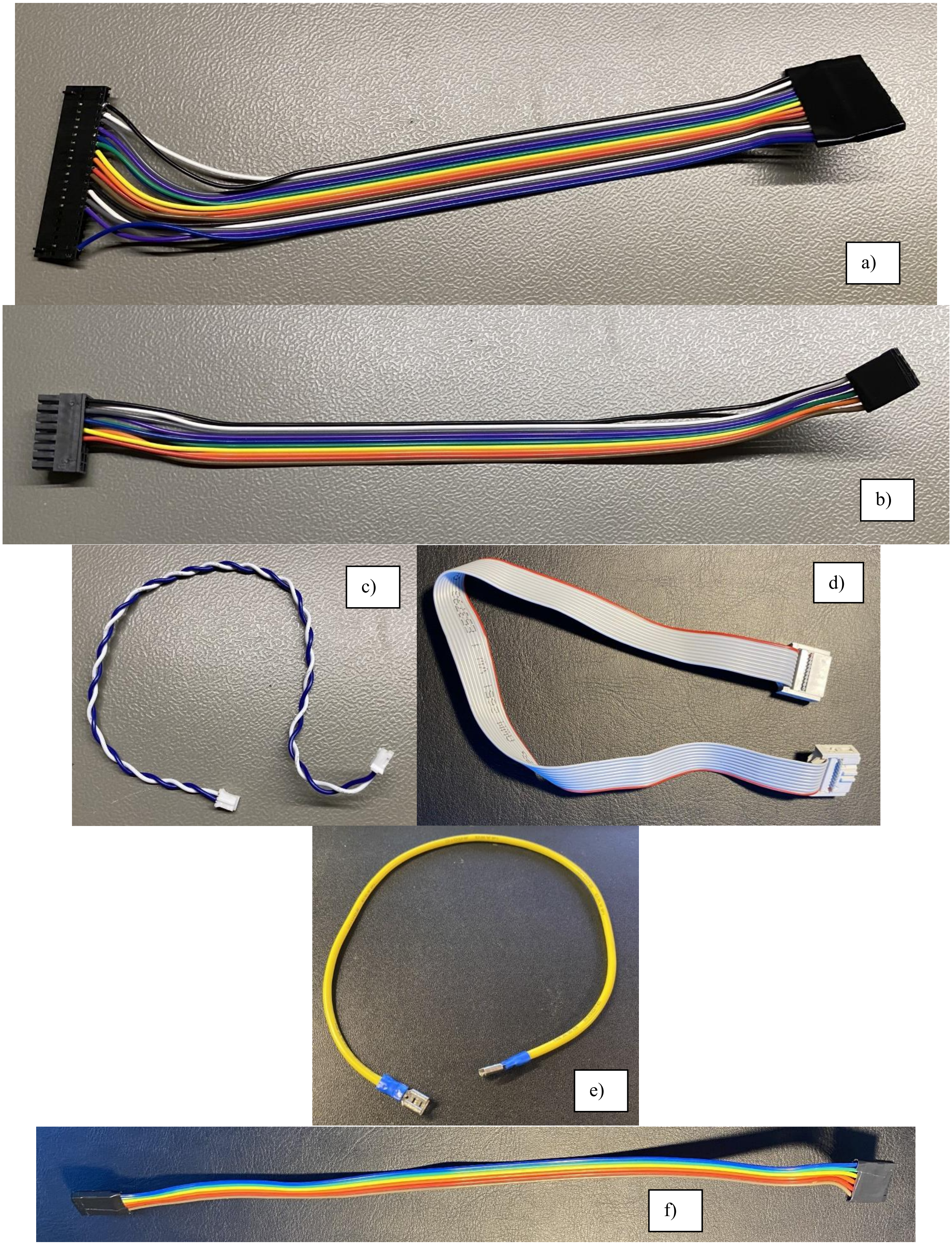

a)
b)
c)
d)
e)
f)

Figure 14: Necessary cabling for interconnections for the Infineon BMS setup:

a) *Battery cell connections – this cable is crimped with the required connector for the battery board cell connector and at the other end for the TLE9012 header input. It may be crimped with the connector for the battery board or soldered directly to the battery board itself (unpluggable then only at the BMS board side).*
b) *Temperature thermister cable, crimped for 5 temperature measurements.*
c) *Isolated communication cable for interconnection of more than one TLE9012 board as supplied with the Infineon BMS kit*
d) *10-pole cable for connection of the battery board to the docking station for the ADC measurements.*
e) *Shorting link used when less than 16 cells are mounted on the battery board*
f) *Serial connection from the TI docking station to the TLE9012 board or the TLE9015 board*

The TLE9012 board is connected to the TI docking station using the specified cables as shown in figures 15, 16 and 17. These configurations use the JTAG connection to the Embed Infineon BMS GUI running on the PC.

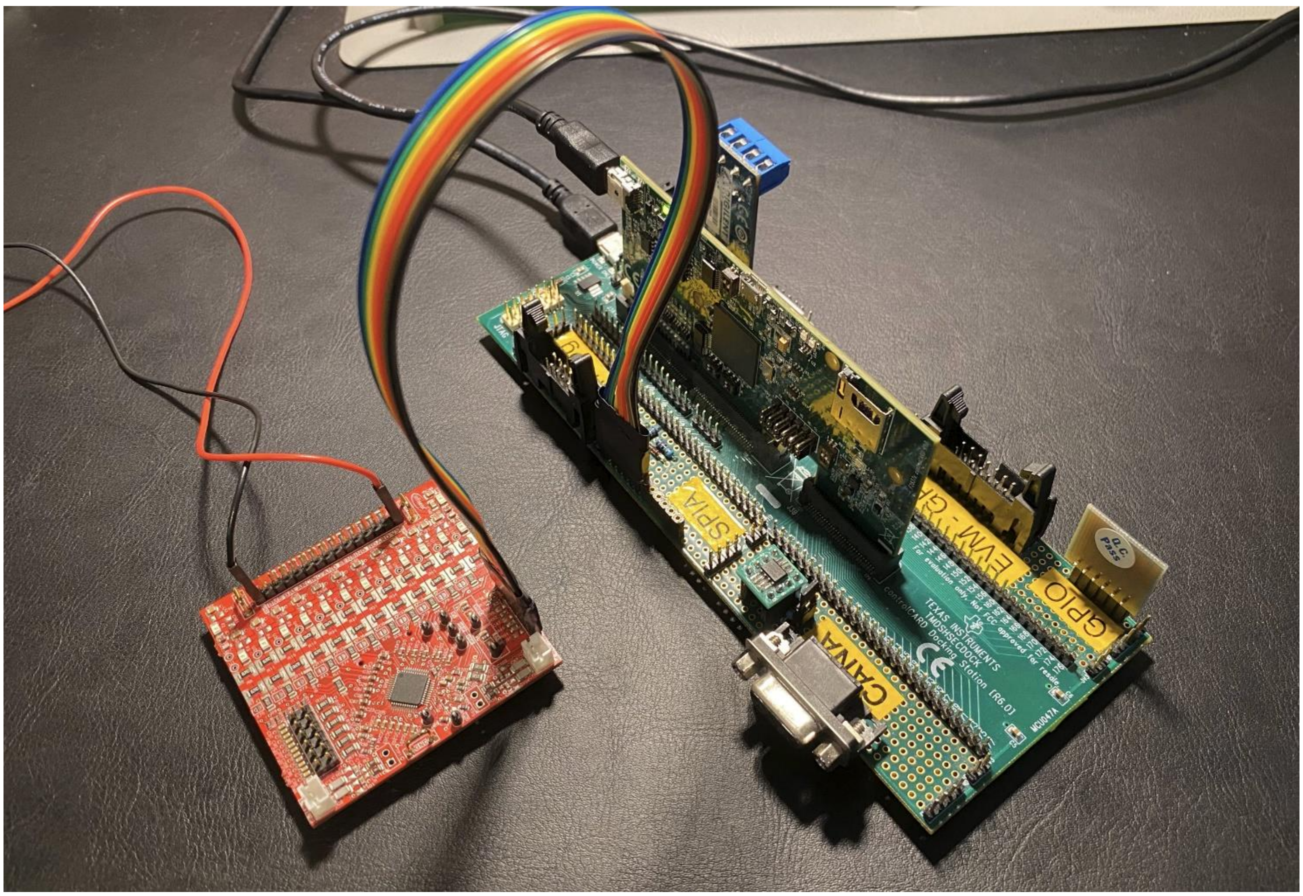


Figure 15: BMS setup using only the microcontroller connected to the TLE9012 board and using the on-board resistor network for the cell voltage measurements. In this case, the open-load faults need to be disabled. The TI docking station is modified for the interface to the TLE9012 BMS board. It also has the facility for CAN bus communication and MODbus communication.

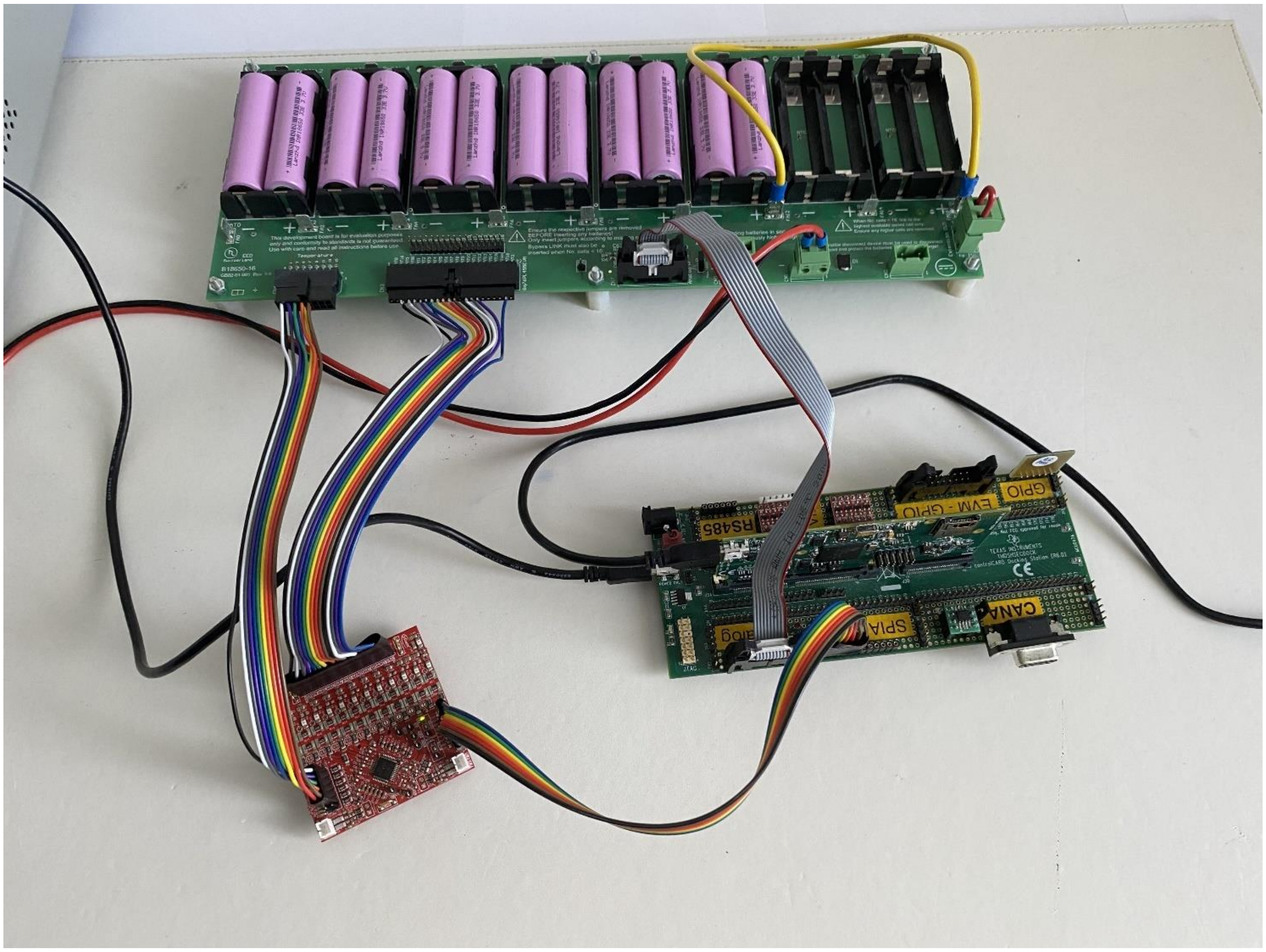


Figure 16: BMS setup with 12 series cells connected to a charger/load. The high-speed serial interface (normal UART) of the TLE9012 is connected to the microcontroller and the JTAG communication interface is connected from the microcontroller to the PC running the [Embed](#) Infineon BMS GUI.

The TLE9012 board can also be connected to the battery board for true cell voltage measurement and cell balancing during charging. The TI microcontroller is inserted in the TI docking station as shown in figure 16. In this case, the TLE9012 communicates with the microcontroller over the high-speed UART interface and the microcontroller communicates with the Embed GUI over the JTAG interface.

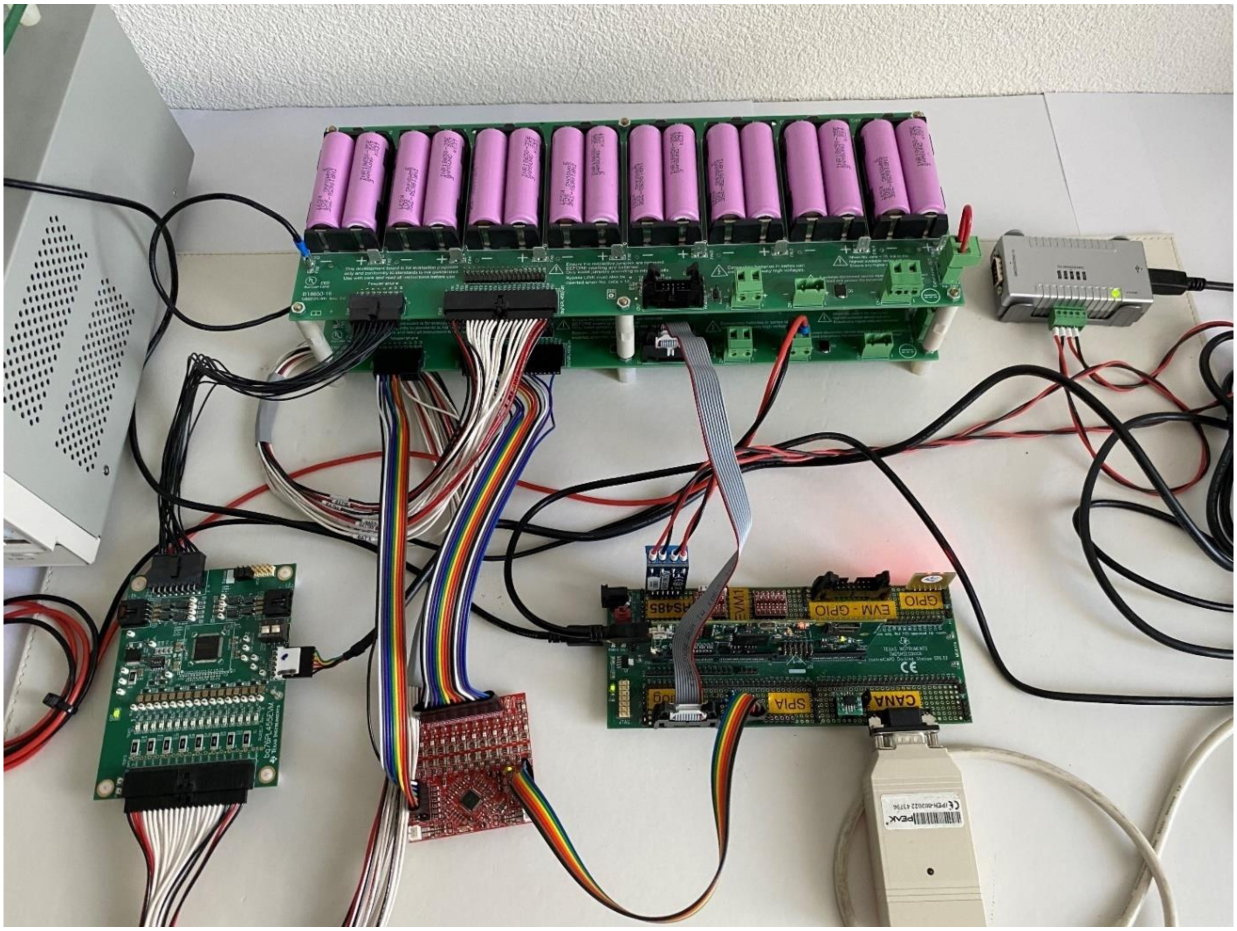


Figure 17: An example of a BMS setup using two battery boards and a mixed system of the TI bq76PL455EVM and the Infineon TLE9012AQU board connected to a single microcontroller for evaluation purposes.

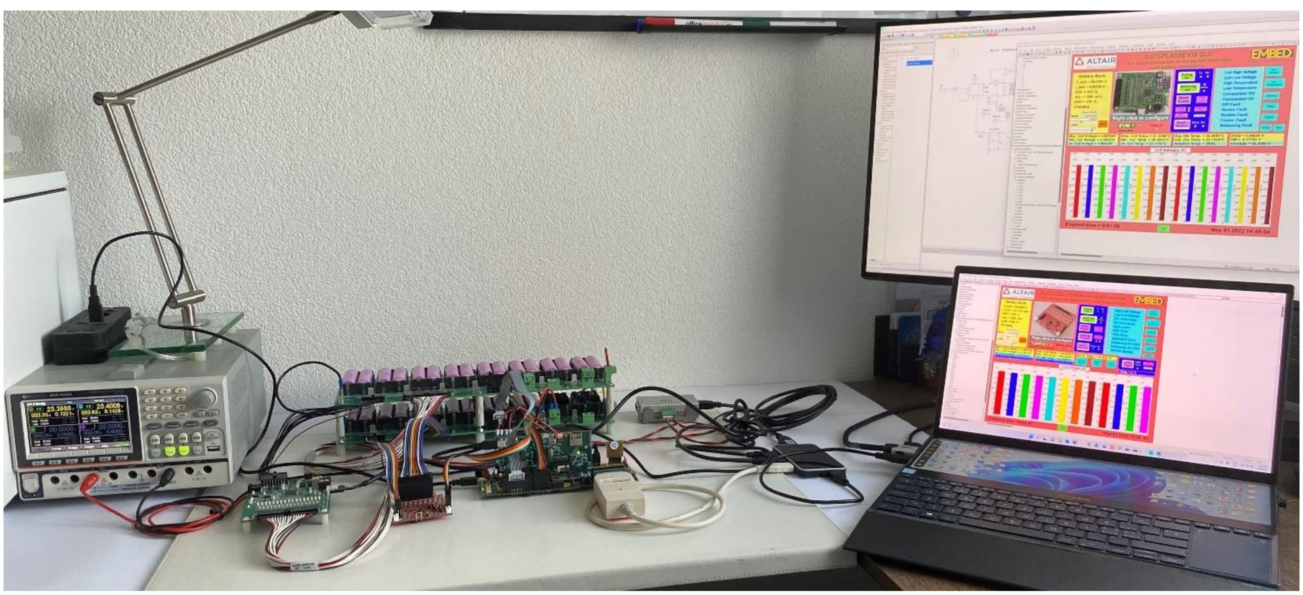


Figure 18: The full BMS setup using two battery boards with the mixed system of the TI bq76PL455EVM and the Infineon TLE9012AQU BMS boards connected to a single microcontroller while running two separate instances of Embed with both GUIs monitoring the system simultaneously. CAN bus and MOD bus interfaces are also connected.

Altair Embed Infineon BMS Diagrams

The Altair Embed BMS diagrams can be found under:
Examples → Digital Power → Applications → Battery Monitoring Systems → Infineon.
The Embed diagrams for the Infineon BMS demonstration consist of the following:

1. The simulation, test and code-gen diagram of the TLE9012 routine with the microcontroller specific UART serial blocks. This diagram can be simulated using installed test data and can be compiled for the target microcontroller by selecting the internal block. The compiled .out file can be used with the target interface diagram in point 2 below.
2. The Embed Infineon BMS GUI for the connection of the PC to the microcontroller. The microcontroller communicates with the TLE9012, while the microcontroller concurrently communicates over the JTAG interface with the Embed GUI running on the PC. This diagram contains the target interface block which links to the .out file compiled using the diagram in point 1 above.

These diagrams can be used and applied independently in the configuration desired by the user. The diagrams can be connected to the BMS hardware either directly using the TLE9012 board or by using the TLE9015 transceiver together with the TLE9012 board. The TLE9012 board can be connected using the resistor network or can be connected to the battery board using the cables detailed in figure 14 (in this case the shorting links on the TLE9012 board connecting the resistor network should be de-soldered).

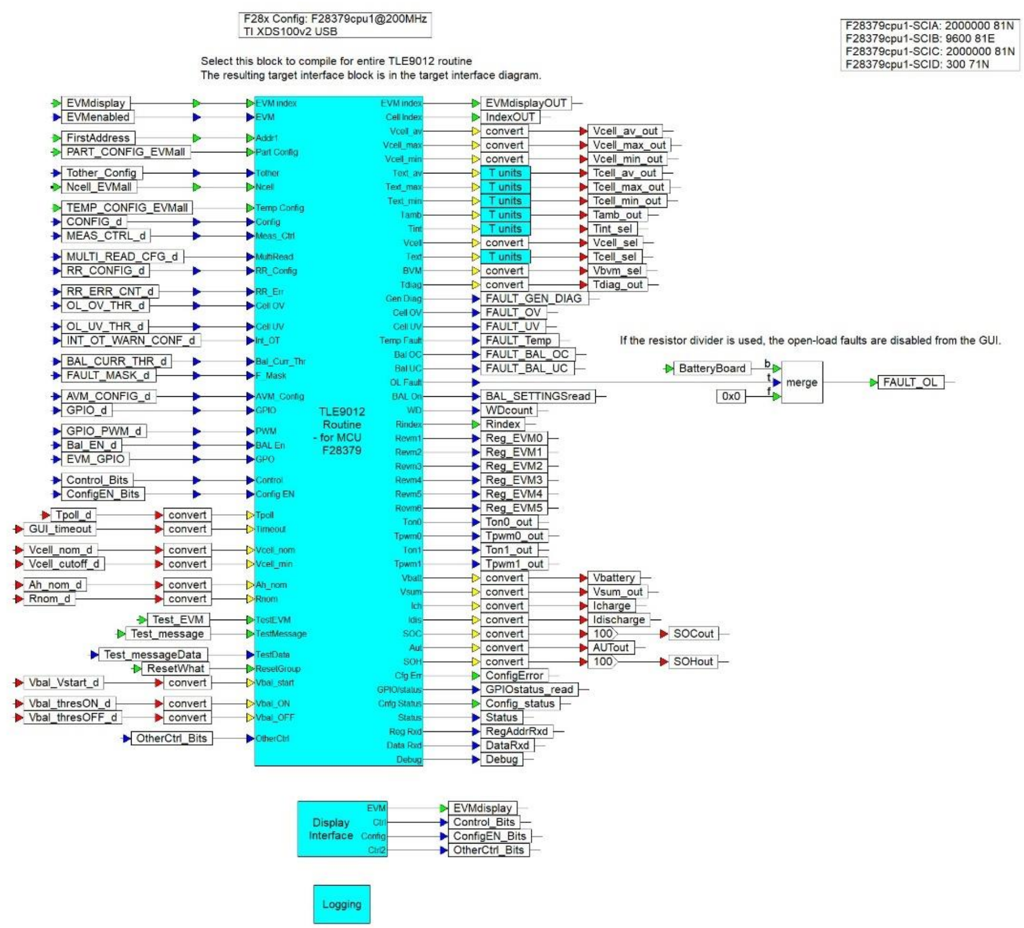


Figure 19: The code-generable block found internally in the code-gen diagram.

In the code-generable diagram, the internal block “TLE9012 Routine – for MCU F28379” should be selected and compiled for the target using the Code gen under the Embed Tools menu.

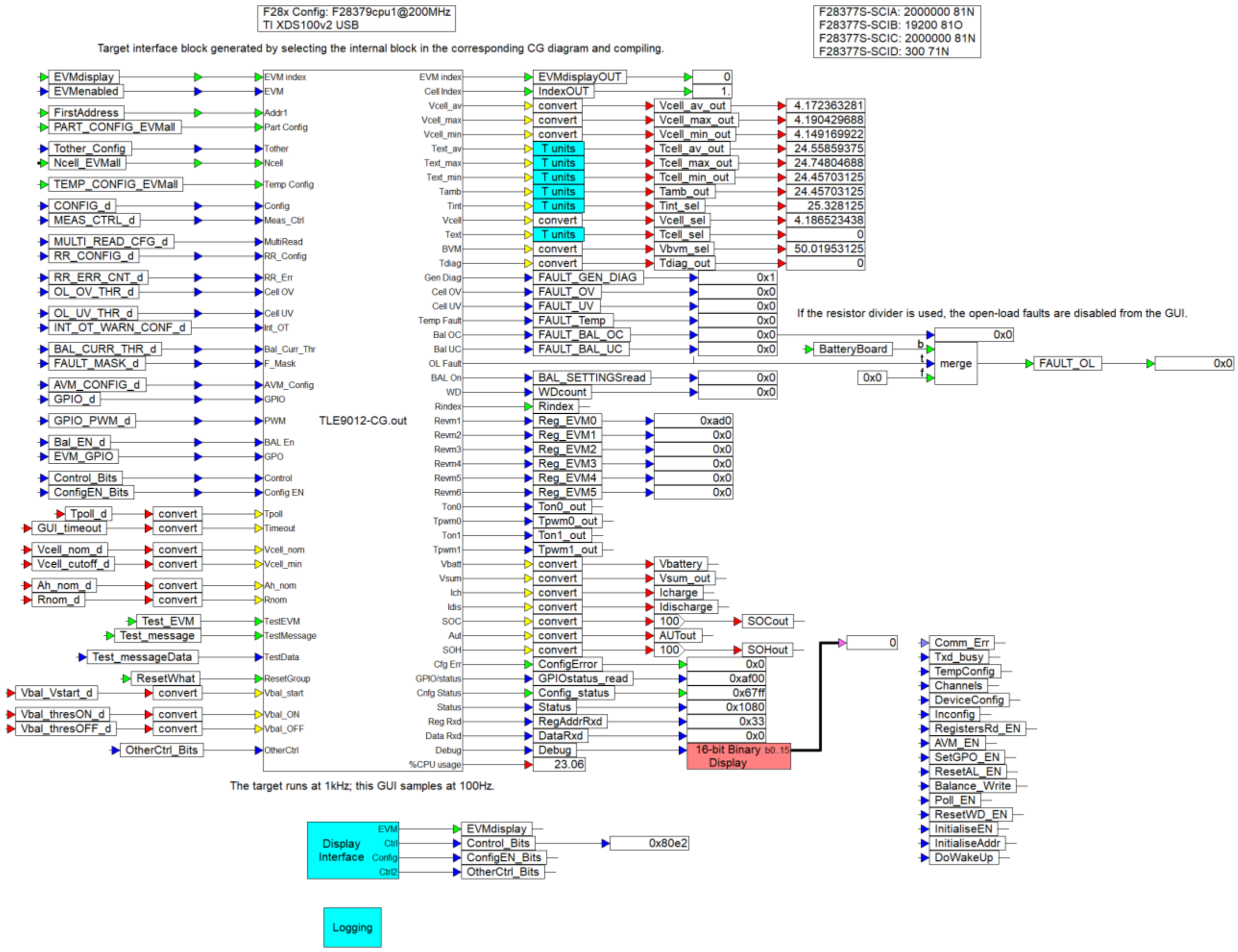
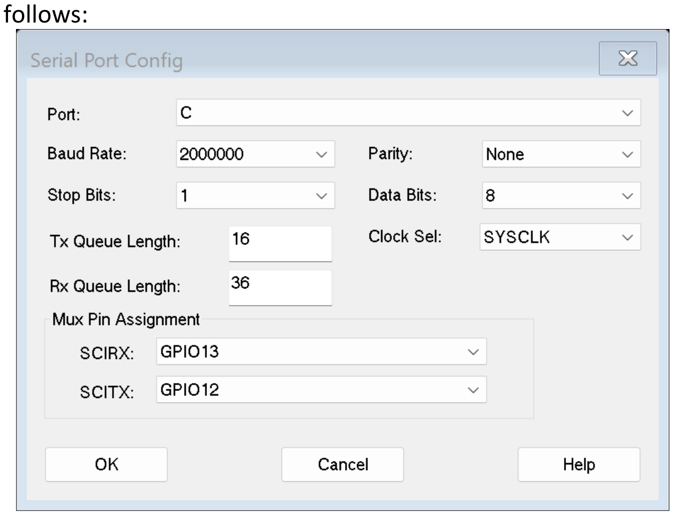


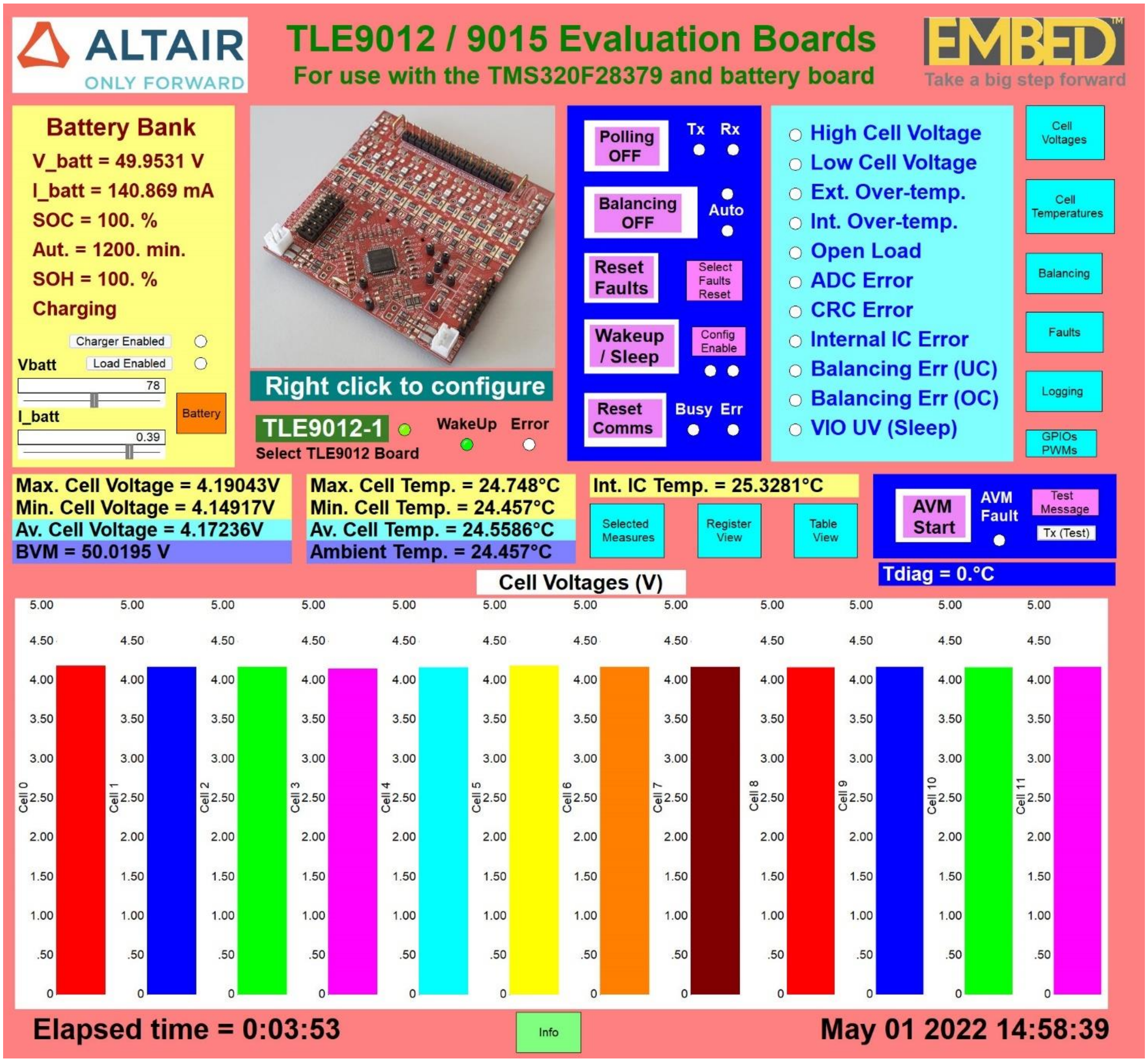
Figure 20: The code-generable block in the code-gen diagram is replaced by the target interface block in the target interface GUI diagram.

This Infineon BMS example diagram uses the SCI port C on the TMS320F28379 microcontroller for the UART connection and the UART configuration settings are as follows:



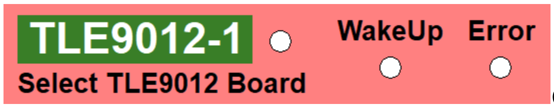
Altair Embed Infineon BMS Graphical User Interface

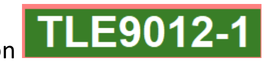
The Altair Embed Infineon BMS GUI is given below for the connection of the PC to the BMS hardware (TLE9012). To activate the communication with the TLE9012AQU chip, one must start a simulation using the Go toolbar item  or by pressing (F5).



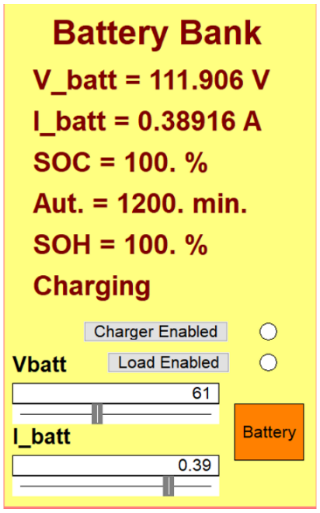
The various sections of the Embed GUI are described in the following sections.

Right clicking on the bq76PL455EVM image will bring up the configuration dialogs. These are described in detail in a later section of this document. Below the bq76PL455EVM image in the GUI is the EVM selection section.



Clicking on 

will change the selected TLE9012 and all the measurements on the main GUI page relative to the TLE9012 board will be referred to that demo board. If the board is present and active, the green indicator next to the TLE9012 board number will be lit. The wakeup green indicator shows the current wakeup status of the TLE9012 chip. The Error indication is the Fault signal that is transmitted independently on the differential line (refer to the Infineon documentation).



<u>Battery bank section</u>

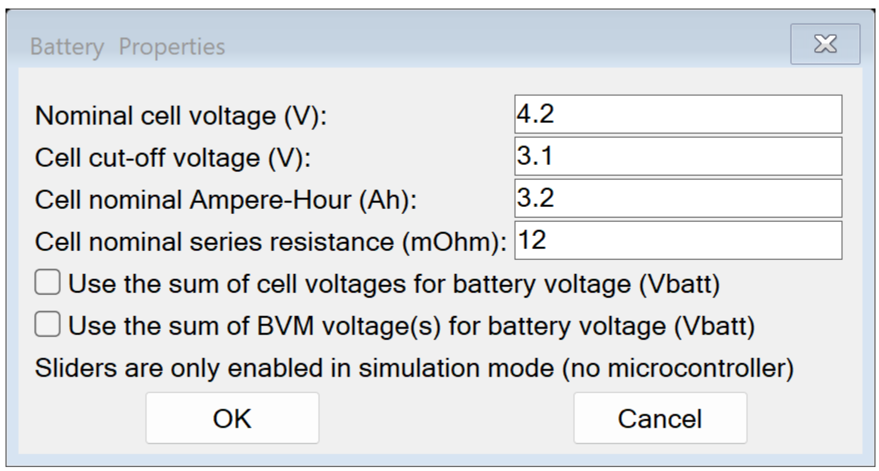
The battery bank section of the GUI gives the values of the battery bank voltage and current. Where, more battery boards are connected in series, the battery bank voltage is the total voltage.

The battery voltages and currents may be controlled by the sliders or they may be the measured values, depending upon the configuration as described below.

The charging / discharging status, the internally calculated state-of-charge (SOC), autonomy time of the battery in minutes and an estimation of the state-of-health (SOH) of the battery are also given.

Right clicking on the 

block in this yellow battery bank section of the GUI will bring up the following dialog:



The battery properties dialog set up the battery parameters.

Nominal cell voltage (V):

Enter the nominal voltage of each cell (when charged).

Cell cut-off voltage (V):

Enter the normal voltage at which the load would be removed on discharge, where the battery cells are considered to have the minimum amount of capacity remaining.

Cell nominal ampere-hour (Ah):

Enter the nominal ampere-hour rating of each cell. This is use for capacity estimation and discharge autonomy time estimation.

Cell nominal series resistance (mOhm):

Enter the nominal cell resistance of a cell in milli-ohms.

Use sum of cells for battery voltage:

If selected, the battery voltage displayed will be the sum of cells for all cells in the system, including multiple battery boards.

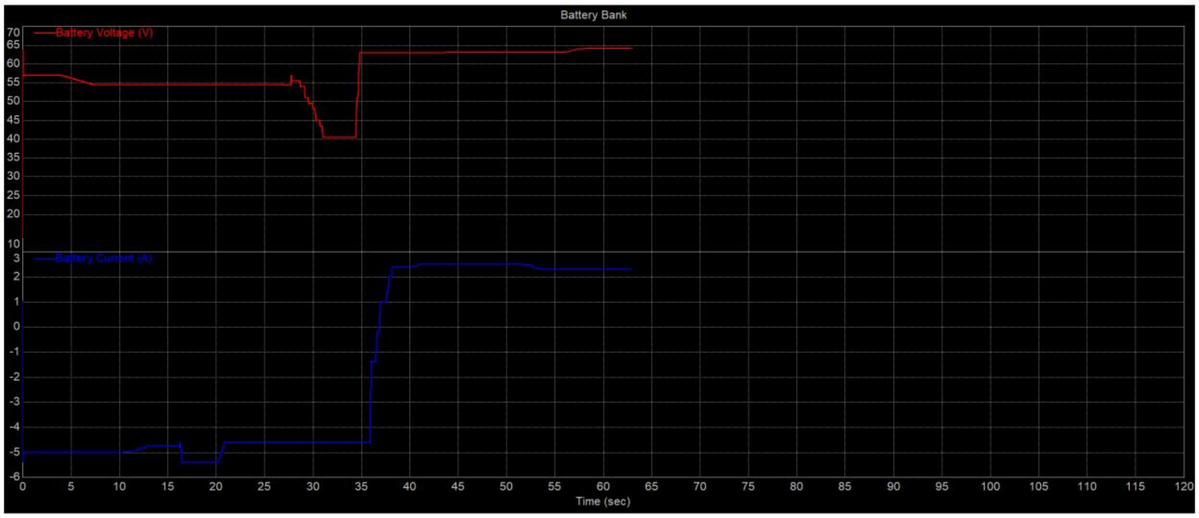
Use sum of BVM voltage(s) for the battery voltage (Vbatt):

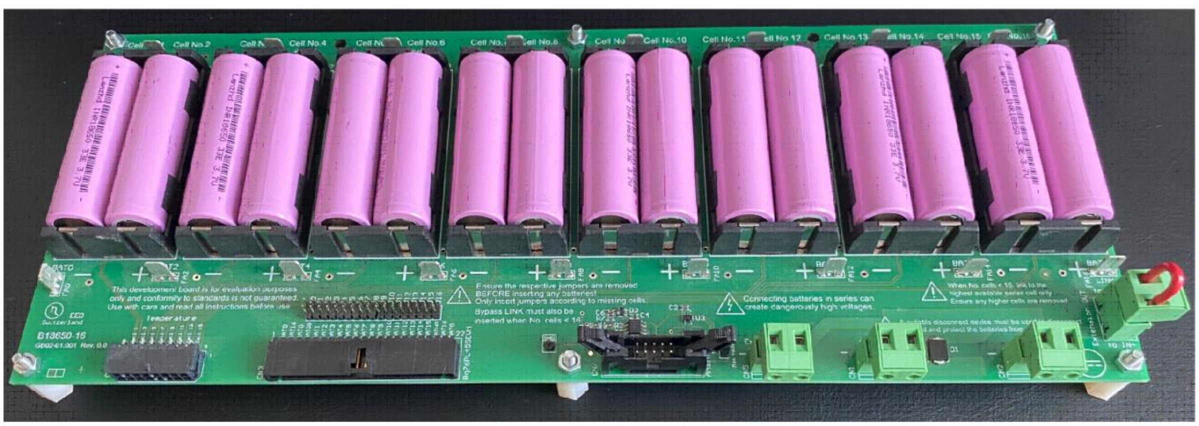
If selected, the battery voltage displayed will be the sum of module voltages for all connected battery boards and TLE9012s in the system, including multiple battery boards.

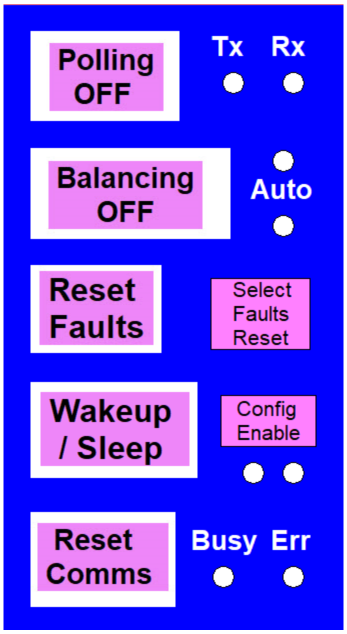
If neither of the above two selections are enabled, the battery voltage and current will be simulated values controlled by the sliders. If the Embed GUI is connected to a microcontroller and the battery board as in figures 16 or 17, the current and voltage will be that measured by the microcontroller using the sensors on the lowest-addressed battery board. Otherwise, in the case of the configuration in figure 15, the current will be taken from the slider.

By double left clicking on the 

block, the following visualization occurs, where the battery bank voltage and current is plotted over time.

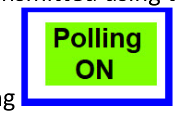




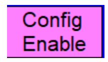


Control section

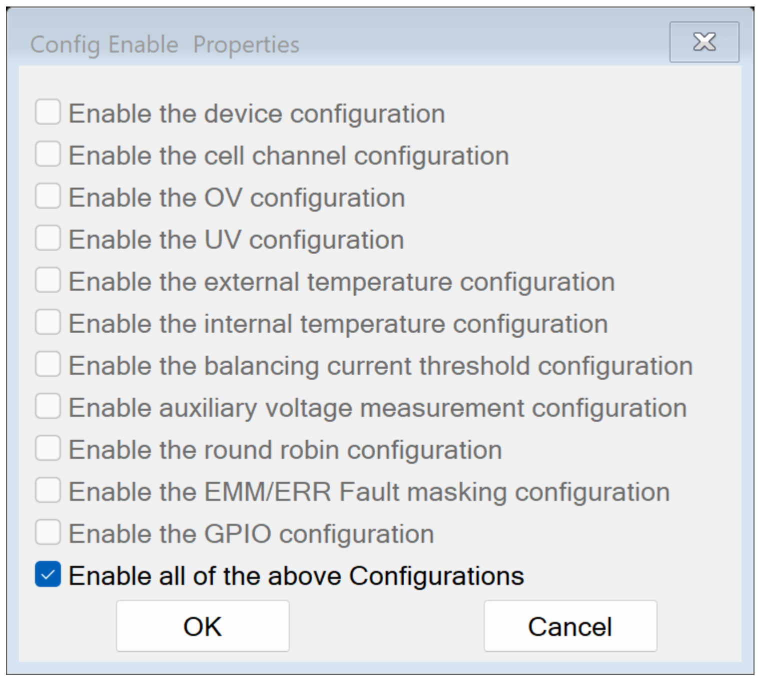
The control section provides the ability to control the polling of the measurements and faults, to enable or disable the balancing, to set what is configured and to reset the alarms (or faults) and the communication routine.
The transmit / receive activation can be viewed along with the configuration status and registers.
A test message can be configured and transmitted using the Tx (Test) tab.

Polling is enabled by clicking on the Polling 

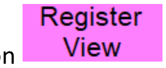
tab. When enabled, the measurements, faults and any other items (such as GPIO status) which is enabled for polling, will be transmitted at the selected polling rate.

Right clicking on the 

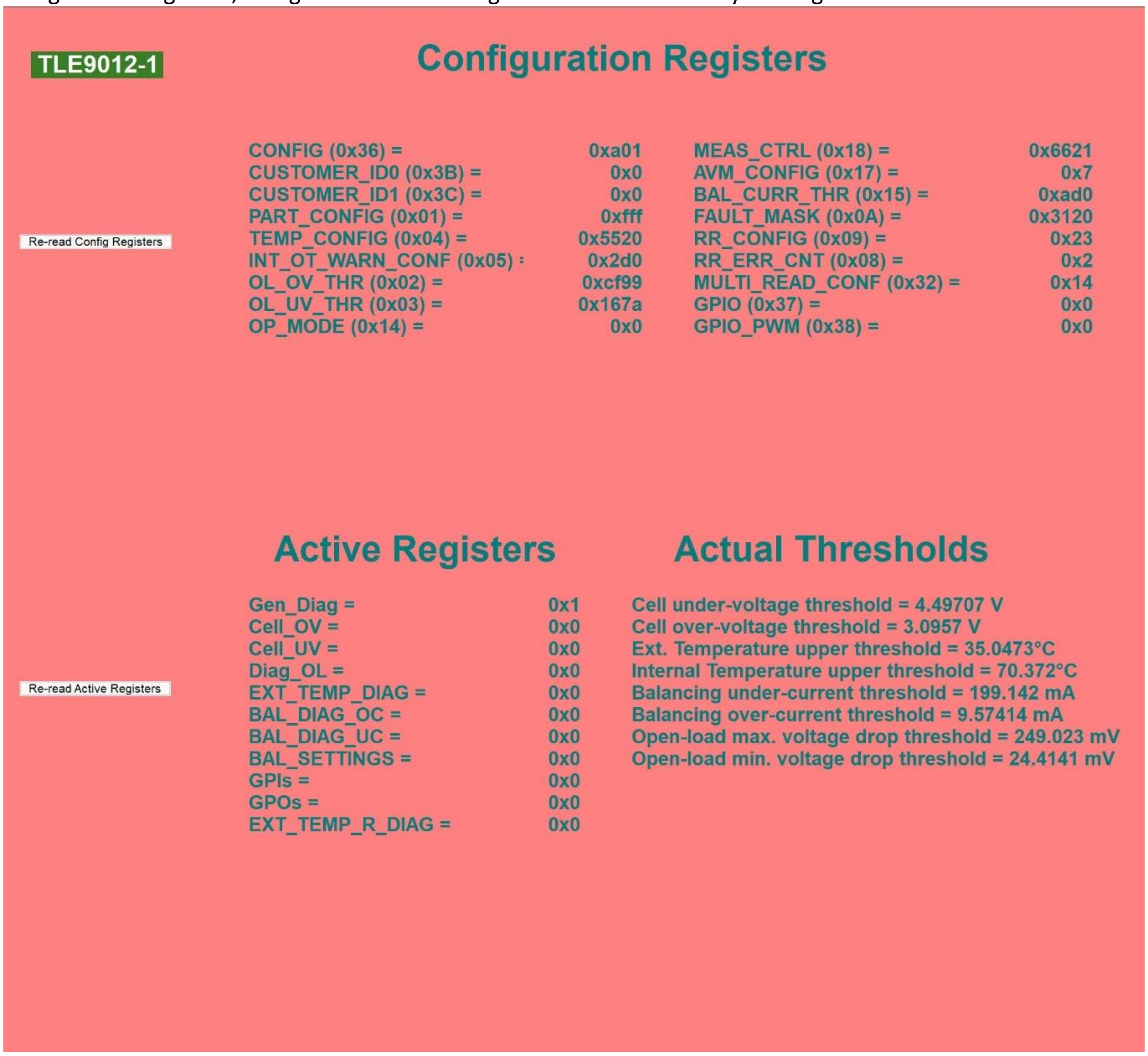
block will bring up the following dialog:



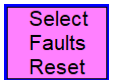
Each individual configuration selection can be enabled or disabled using this dialog. When re-starting a simulation of the Embed BMS diagram, it may be desirable to disable the configuration since the hardware will have been configured from the last simulation if power was not switched off to the TLE9012 board. Also, various configuration selections can be enabled or disabled for testing purposes.
On initial start-up, if there are no special configurations required, only the Device configuration and cell channel configurations are essential.
The complete configuration can be enabled by selecting the “Enable all of the above Configurations”. This process is reasonably fast when directly connected to the target microcontroller.

The configuration registers, along with the active registers can be viewed by clicking on 

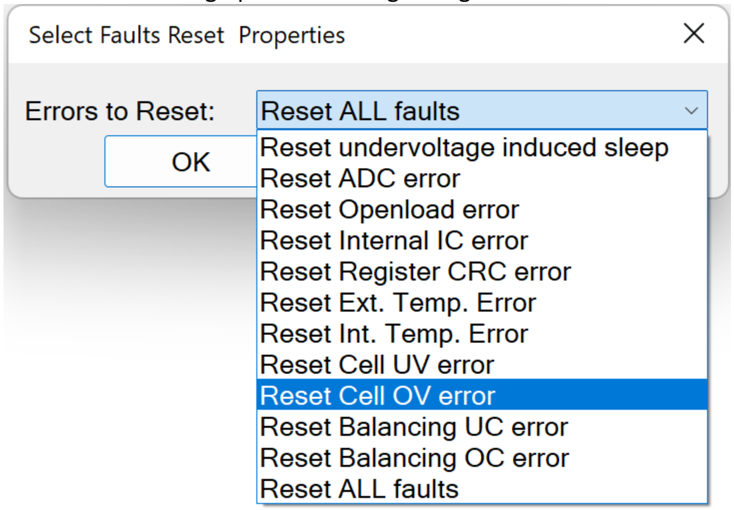
.



The main configuration registers can be viewed for each enabled TLE9012 along with the current active registers. The actual values of the thresholds in the selected units are re-calculated from the received register values and displayed. The registers can be re-read at any time by clicking on the tabs to the left.

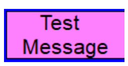
Right clicking on the 

block will bring up the following dialog:

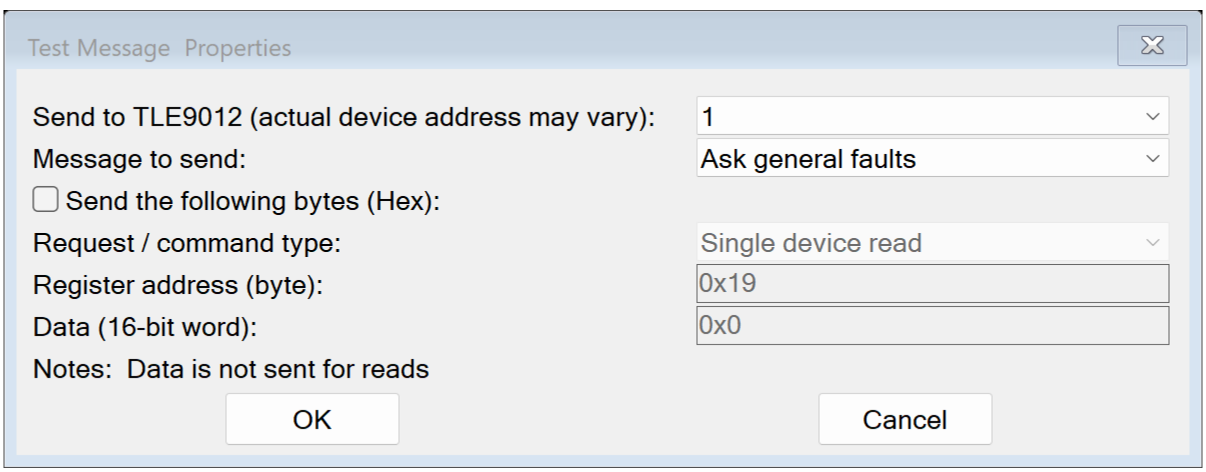


After selecting the faults to be reset, the reset message will be transmitted when clicking on the 

icon. Note that polling may be needed to be enabled in order to re-read the fault status after a reset action.

Right clicking on the 

block will bring up the following dialog:

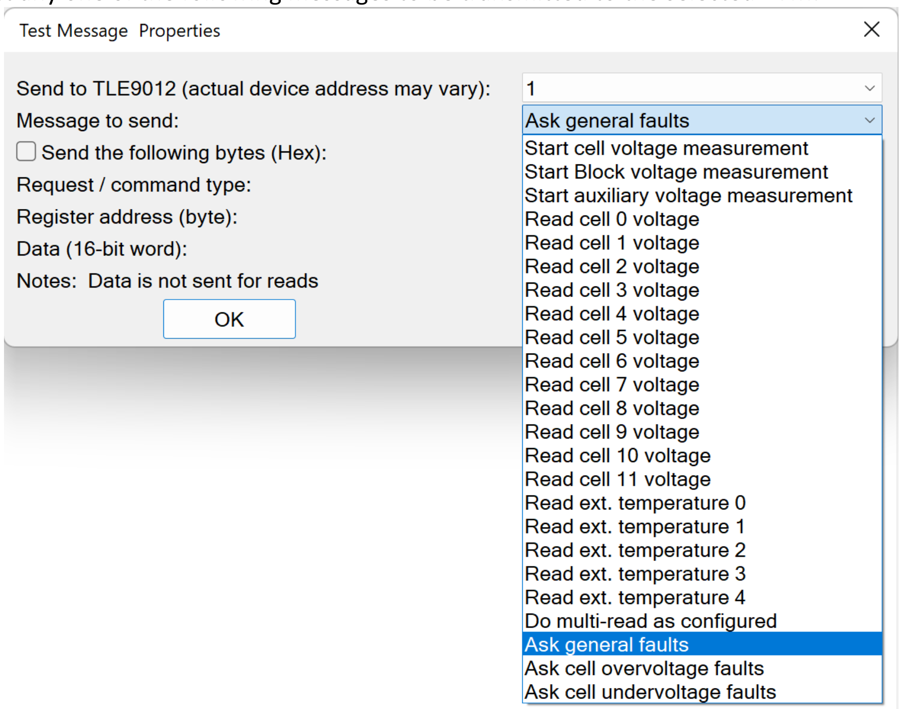


Send to TLE9012 (actual device address may vary):

Select the TLE9012 from the first to the sixth connected TLE9012 board (where present) which will receive the test message.

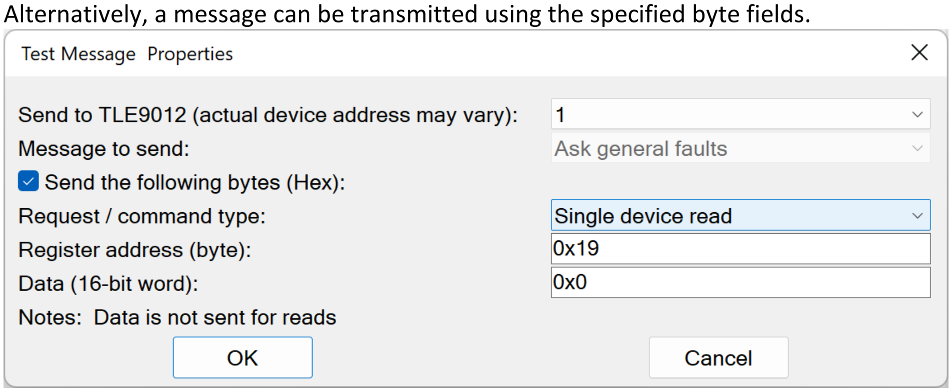
Message to send (Polling Action):

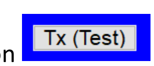
Select any one of the following messages to be transmitted to the selected EVM:



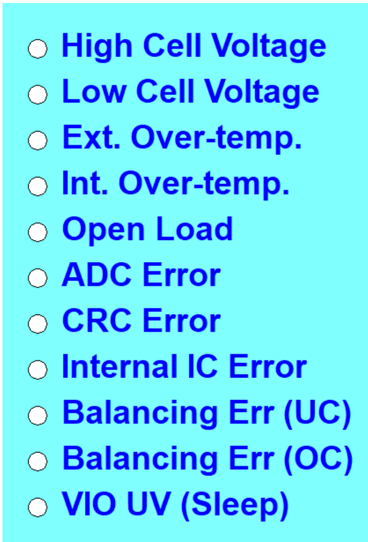
Send the following bytes (Hex):

Alternatively, a message can be transmitted using the specified byte fields.



The selected test message is transmitted when clicking on 

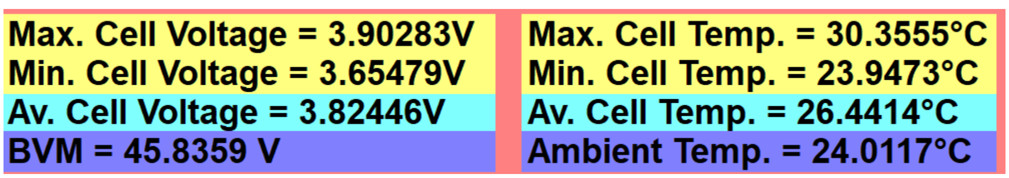
.



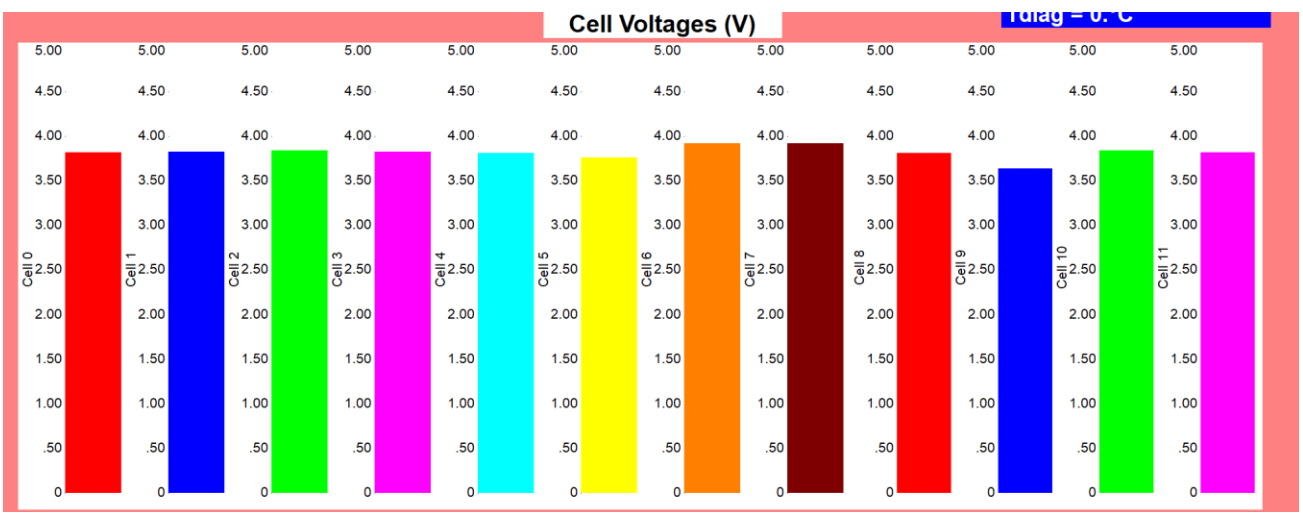
<u>Summary Faults</u>

The summary faults section visualizes the current status of all the summary faults. Note that the balancing fault condition is generated within the balancing routine in the Embed diagram.

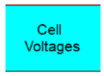
The calculated maximum and minimum and average cell voltages and temperatures can be viewed in the auxiliary measurements section. Along with these values, the selected internal chip temperatures and the module battery voltage (BVM) will be visualized if selected. The ambient temperature will also be shown if enabled.



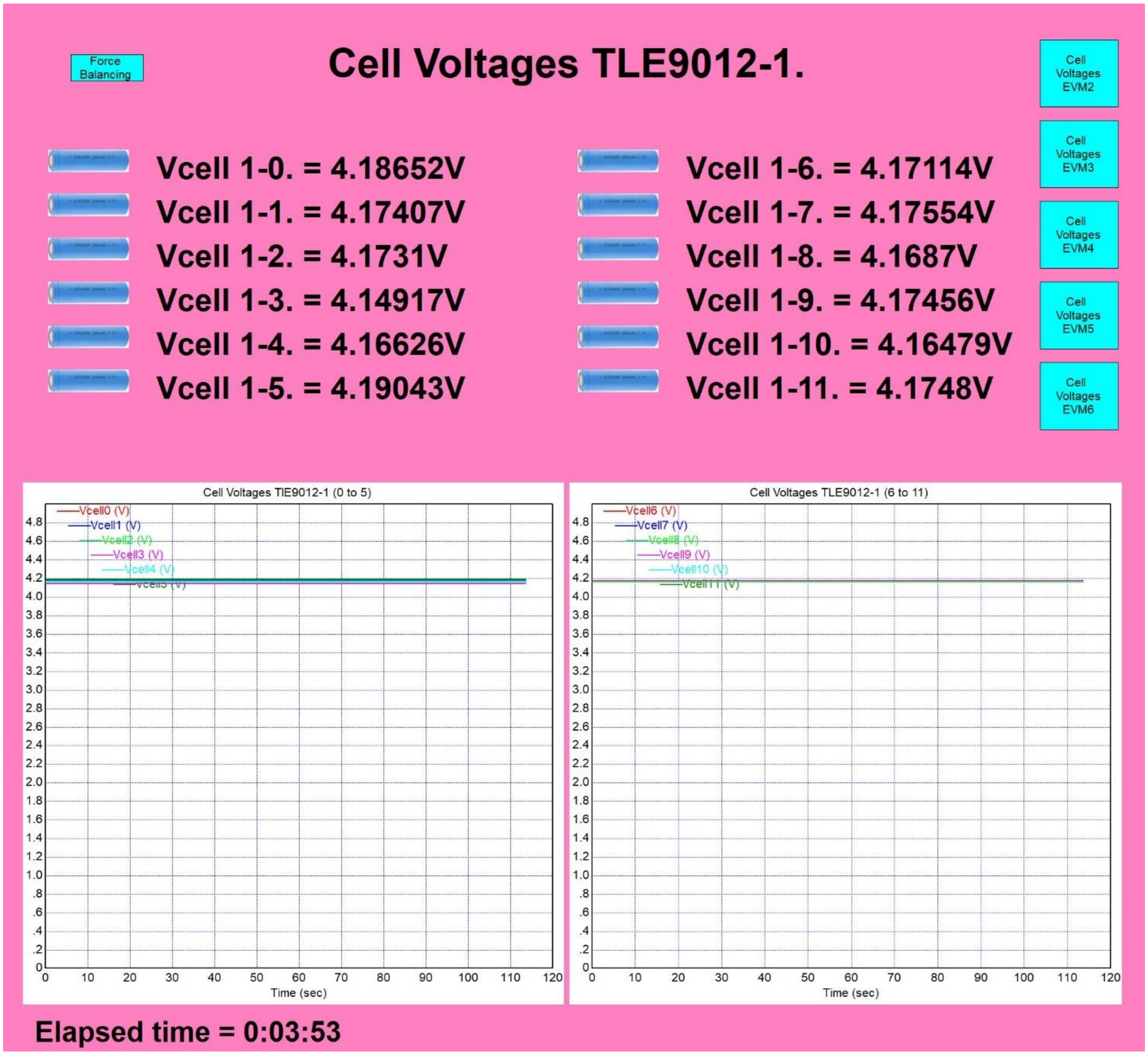
The cell voltages for the selected BMS / battery board are visualized in the cell voltages section in a bar-graph format.



<u>Visualization Tabs</u>

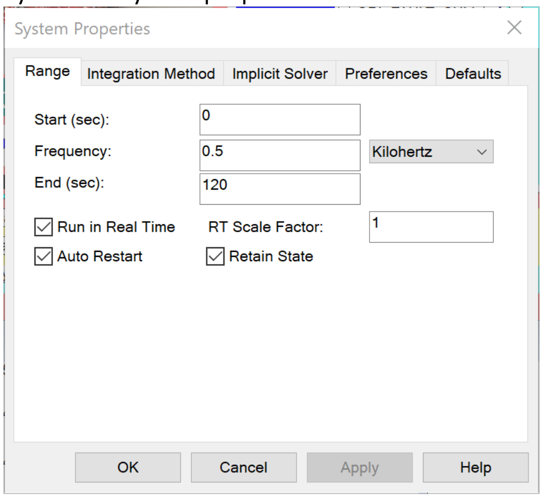
When right clicking of the cell voltages 

block on the main GUI page, the following window will appear within Embed. The currently activated cell voltages will be shown and also plotted over time.



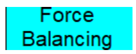
Note that the time duration of all plots can be simply varied during the simulation by going to:

System → System properties…

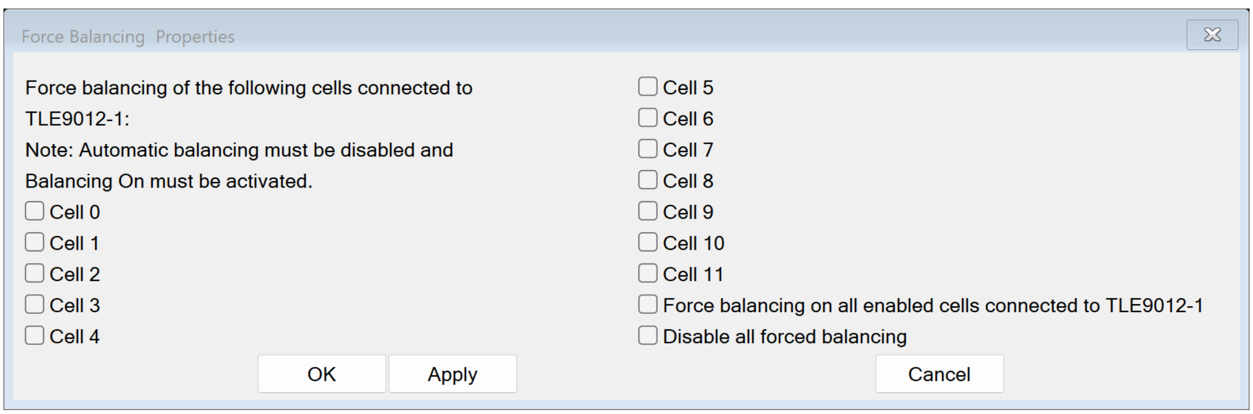


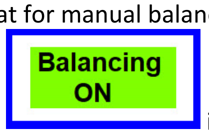
The plotting time can be varied by changing the End time in the dialog (the diagram may need to be removed from the display mode visualization).
In normal operation, the BMS system and GUI will continue running unless stopped by the user. However, the plots will refresh at the given End time and in this way, one can select the desired plot length. The plots can also be zoomed in and out at any time.

There are 5 more tabs (compound blocks) to the right where an identical view is shown for up to six TLE9012 boards and battery boards.

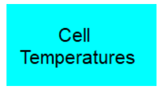
To the top-left, a Force balancing tab 

is present and right clicking on this opens a dialog where the cells balancing can be manually forced on or off for the selected cells.

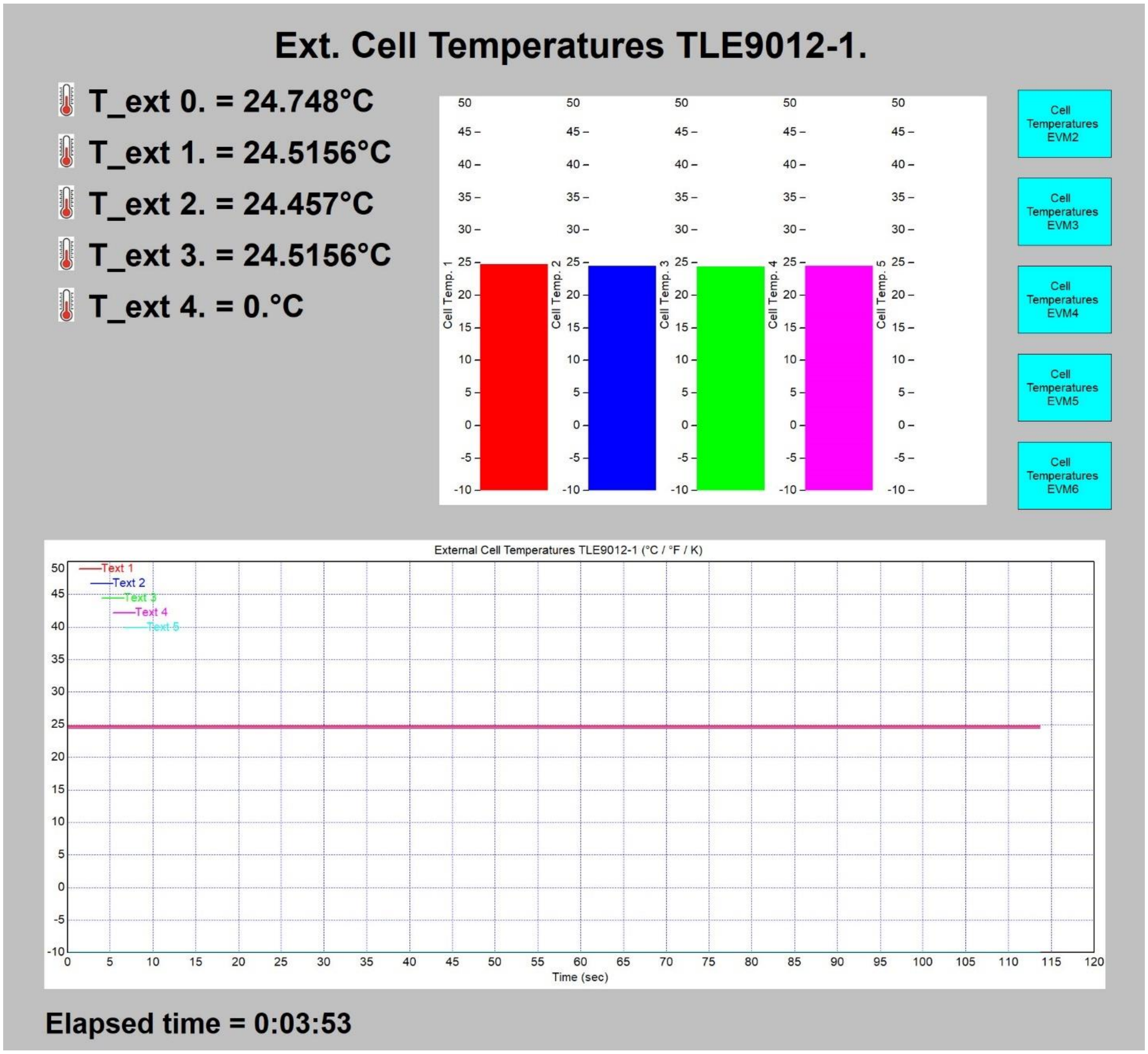


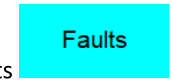
Note that for manual balancing using this dialog, the automatic balancing must be disabled and the balancing must be enabled 

in the control section of the GUI.

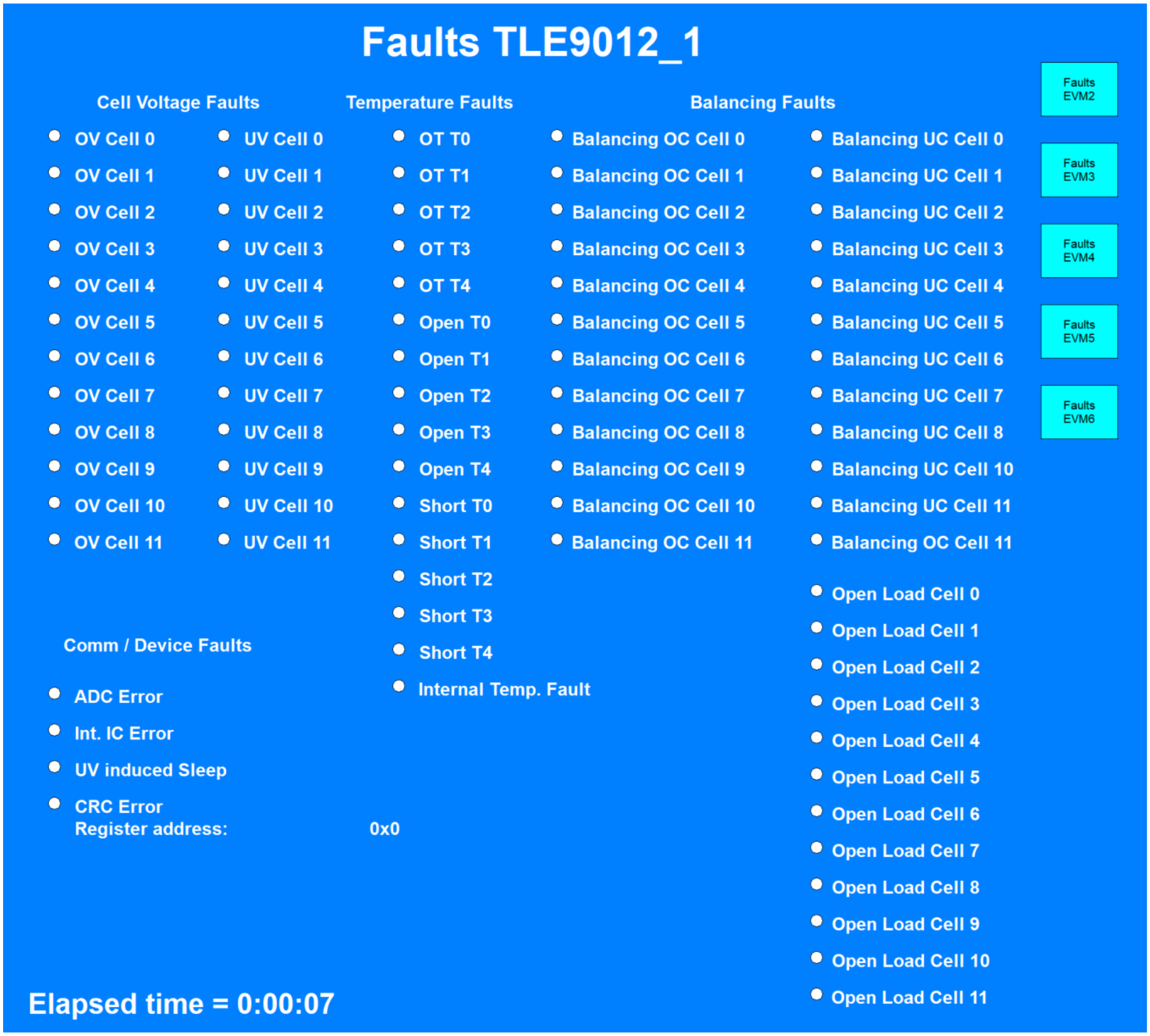
When right clicking of the cell temperatures 

block on the main GUI page, the following window will appear within Embed, similarly to that of the cell voltages window. Here the currently activated cell temperatures will be shown and plotted over time for all activated TLE9012 boards.

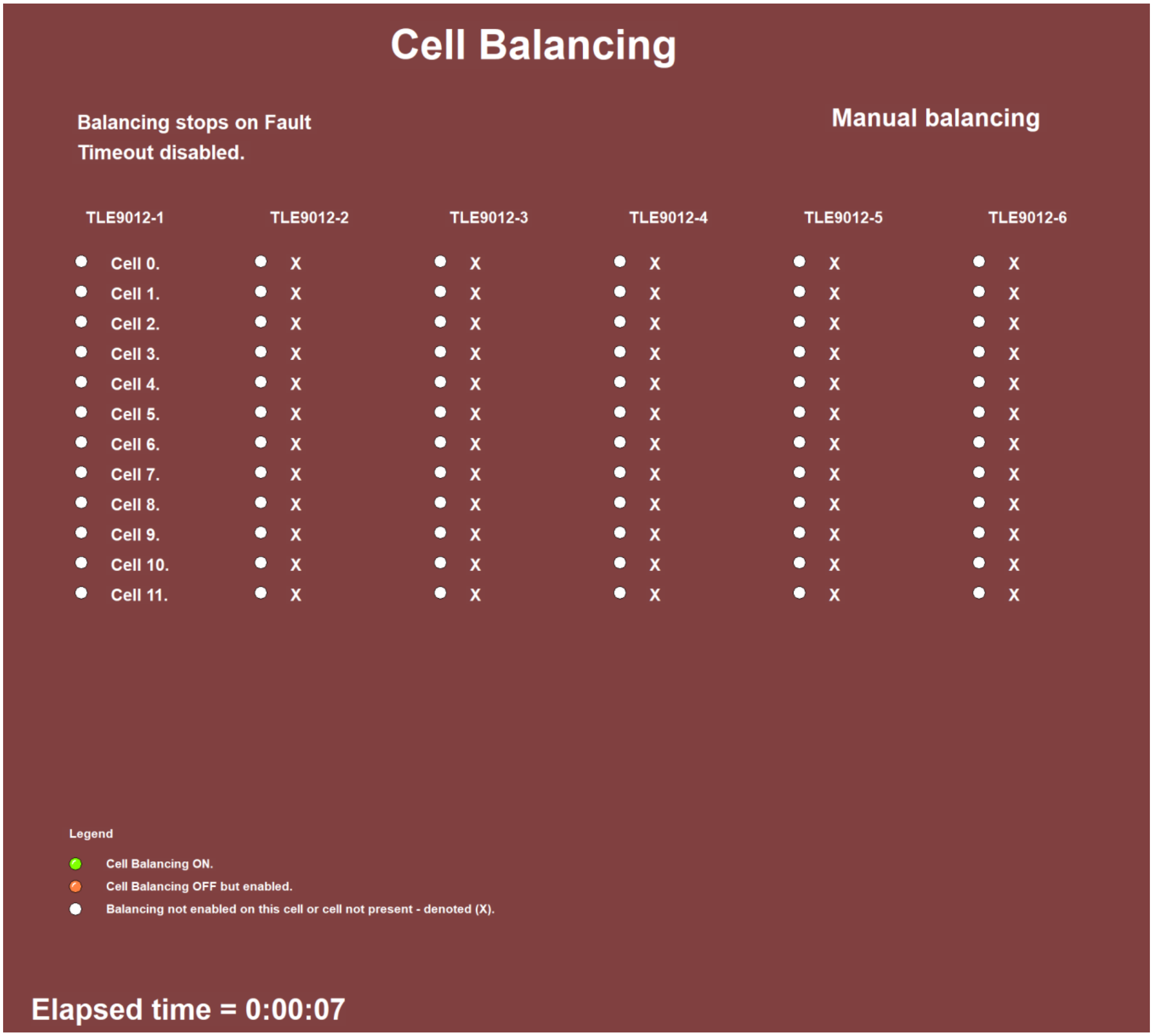


All faults of all enabled TLE9012s can be visualized by clicking on the Faults 

tab.



The balancing status of all enabled EVMs can be visualized by clicking on the balancing Balancing tab. The status will be shown for both manual or automatic balancing.



The cell voltages and temperatures can be visualized in table format by clicking on the Table tab.

The current logging status can be visualized by clicking on the logging Logging tab.

Cell Voltages (V)

TLE9012 / Cell	0	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.	3.8208	3.823	3.8418	3.823	3.81079	3.76392	3.92285	3.91895	3.81177	3.64087	3.83887	3.81787
2.	0	0	0	0	0	0	0	0	0	0	0	0
3.	0	0	0	0	0	0	0	0	0	0	0	0
4.	0	0	0	0	0	0	0	0	0	0	0	0
5.	0	0	0	0	0	0	0	0	0	0	0	0
6.	0	0	0	0	0	0	0	0	0	0	0	0

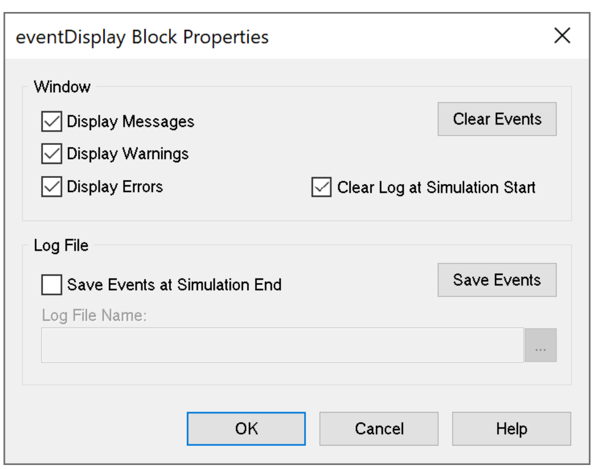
Av. Cell Voltage = 3.82446V

Cell Temperatures (°C)

TLE9012 / Cell	0	1.	2.	3.	4.
1.	24.328125	24.349609	24.46875	21.96875	22.029297
2.	0	0	0	0	0
3.	0	0	0	0	0
4.	0	0	0	0	0
5.	0	0	0	0	0
6.	0	0	0	0	0

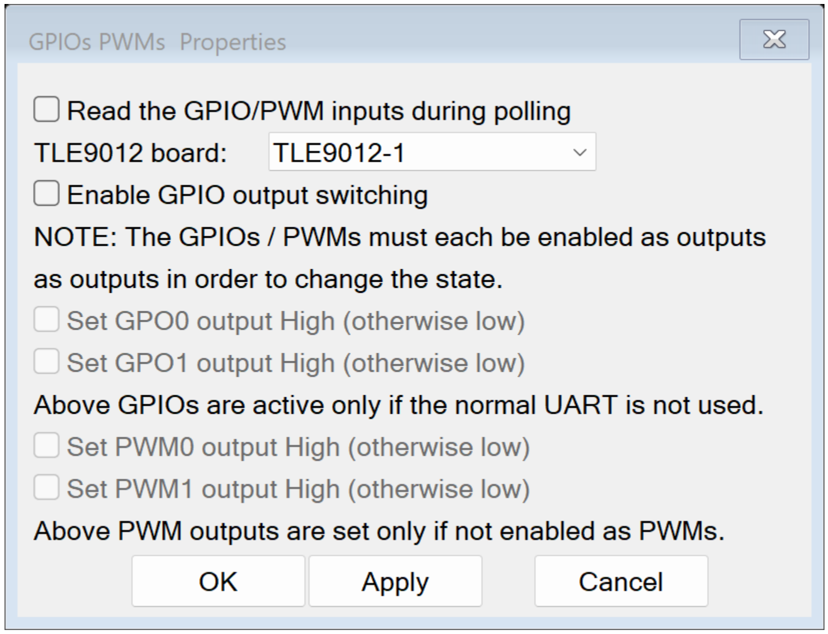
Ambient Temp. = 24.0117°C

Date	Time	Source	Event
2/09/2021	9:07:28 AM	System	Stop polling
2/09/2021	9:07:28 AM	System	Balancing Disabled
2/09/2021	9:07:39 AM	Configuration	GPIOs configured.
2/09/2021	9:07:54 AM	Configuration	Device parameters configured.
2/09/2021	9:07:57 AM	Configuration	Sampling parameters / AFE configured.
2/09/2021	9:07:59 AM	Configuration	Channels configured.
2/09/2021	9:08:00 AM	Configuration	Cell over-voltage thresholds configured.
2/09/2021	9:08:00 AM	Configuration	Balancing parameters configured.
2/09/2021	9:08:01 AM	Configuration	Cell under-voltage thresholds configured.
2/09/2021	9:08:02 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:08:09 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:08:16 AM	Alarm Status	Polling not activated.
2/09/2021	9:08:17 AM	Configuration	Comparator over and under-voltage thresholds configured.
2/09/2021	9:08:19 AM	Configuration	Fault masks configured.
2/09/2021	9:08:21 AM	Configuration	Communication parameters configured.
2/09/2021	9:08:31 AM	System	Start polling
2/09/2021	9:08:45 AM	System	Stop polling
2/09/2021	9:09:01 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:09:49 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:10:28 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:10:28 AM	System	Stop polling
2/09/2021	9:10:28 AM	System	Balancing Disabled
2/09/2021	9:10:31 AM	Configuration	EVMs addressed. EVM1 address = 0.
2/09/2021	9:10:36 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:10:37 AM	Configuration	Fault masks configured.
2/09/2021	9:10:37 AM	Configuration	GPIOs configured.
2/09/2021	9:10:42 AM	Configuration	Device parameters configured.
2/09/2021	9:10:45 AM	Configuration	Sampling parameters / AFE configured.
2/09/2021	9:10:46 AM	Configuration	Channels configured.
2/09/2021	9:10:46 AM	Configuration	Cell over-voltage thresholds configured.
2/09/2021	9:10:46 AM	Configuration	Balancing Config Error.
2/09/2021	9:10:47 AM	Configuration	Cell under-voltage thresholds configured.
2/09/2021	9:10:47 AM	Configuration	Temperature thresholds configured.
2/09/2021	9:10:53 AM	Configuration	Comparator over and under-voltage thresholds configured.
2/09/2021	9:10:55 AM	Configuration	Fault masks configured.
2/09/2021	9:10:59 AM	Configuration	Communication parameters configured.
2/09/2021	9:11:06 AM	Alarm Status	Comparator Undervoltage,
2/09/2021	9:11:28 AM	Configuration	Balancing parameters configured.



By right clicking on the logging window, the following dialog will appear and events can be cleared or saved to a file of choice.

When right clicking on the GPIOs PWMs block, the following dialog will appear.



Read the GPIO / PWM inputs during polling:

If selected, the GPIO input status will be enquired at every polling interval and the GUI updated.

TLE9012 board:

Select the TLE9012 board to which the GPIO / PWM settings will apply.

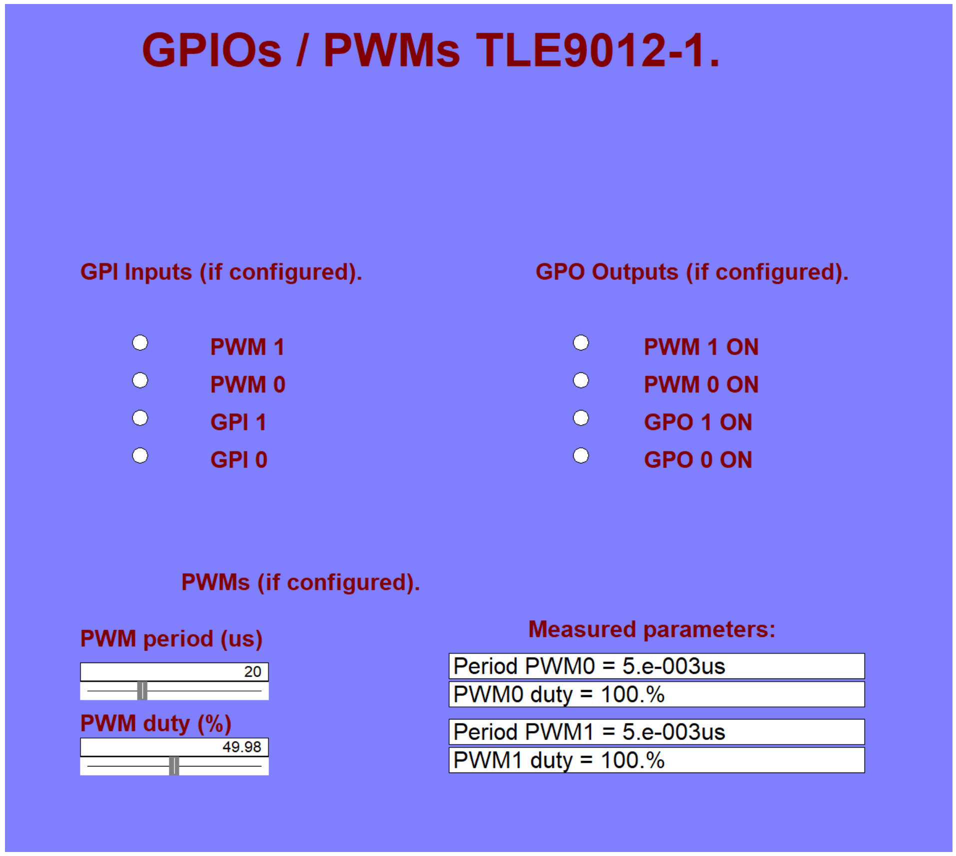
Set GPOx output high:

If enabled as outputs, the GPO output status can be set with this dialog. Note that the first two GPIOs are only available if the local UART is not in use.

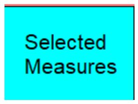
Set PWMx output high:

If enabled as GPO outputs, the GPO output status can be set with these selections.

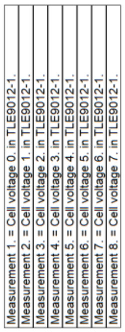
When double-left clicking on this block, the following visualization will appear in Embed:

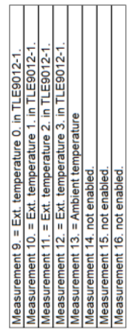


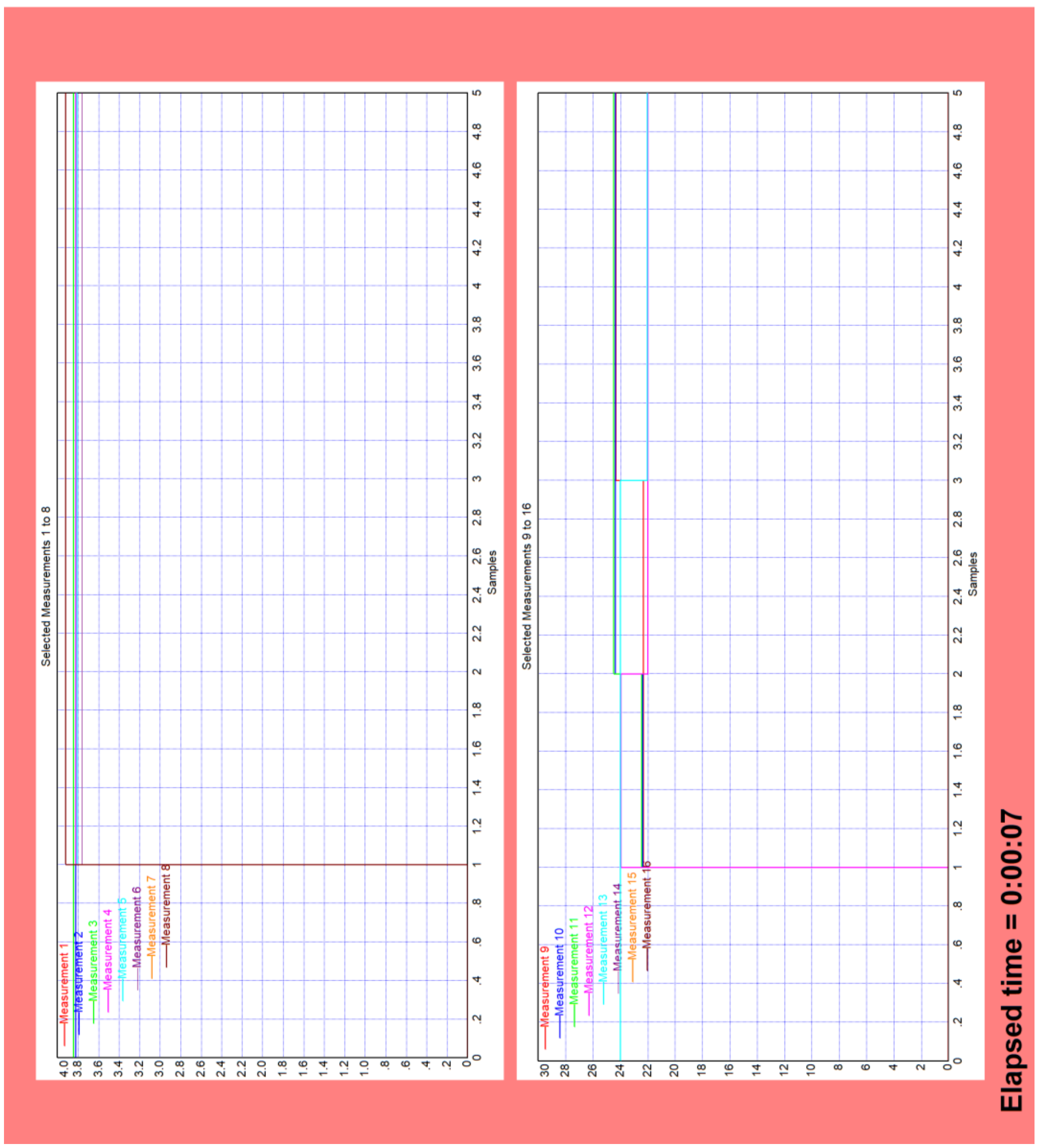
where the current GPIO and PWM status including duty cycle and period can be directly visualized.

Two additional plots are available to select measurements grouping them together as desired and can be viewed by double-left clicking on 

.

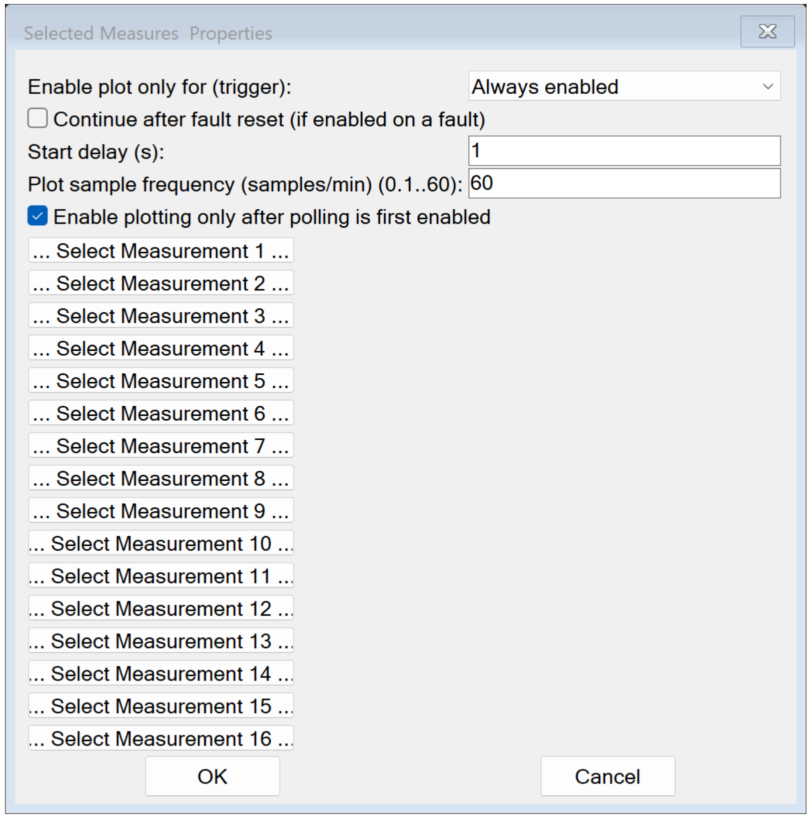




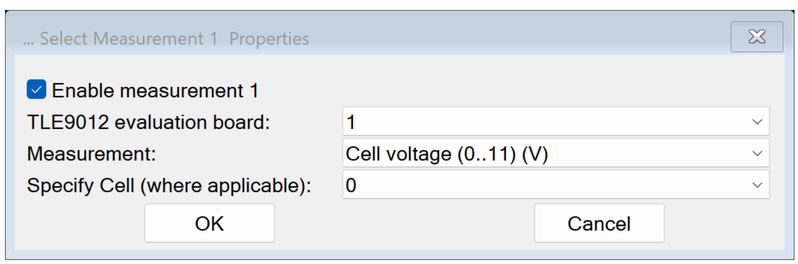


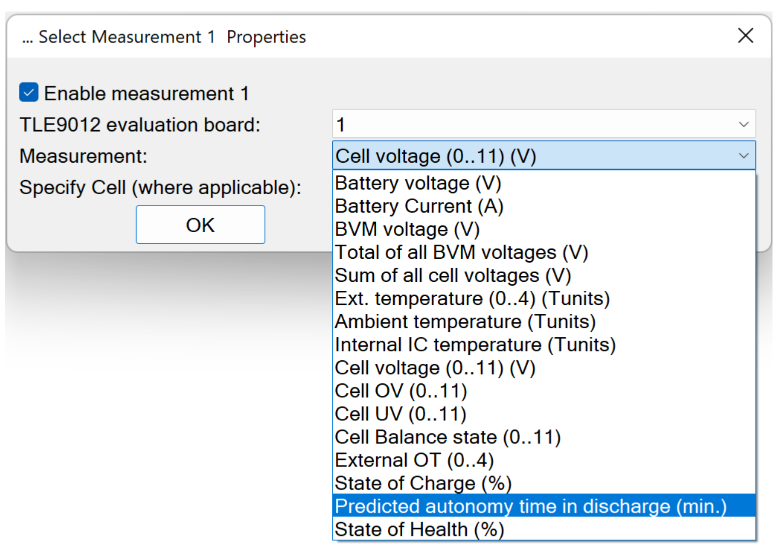
The currently selected measurements are shown to the right of the plots.

The measurements can be selected in the dialog of this block:



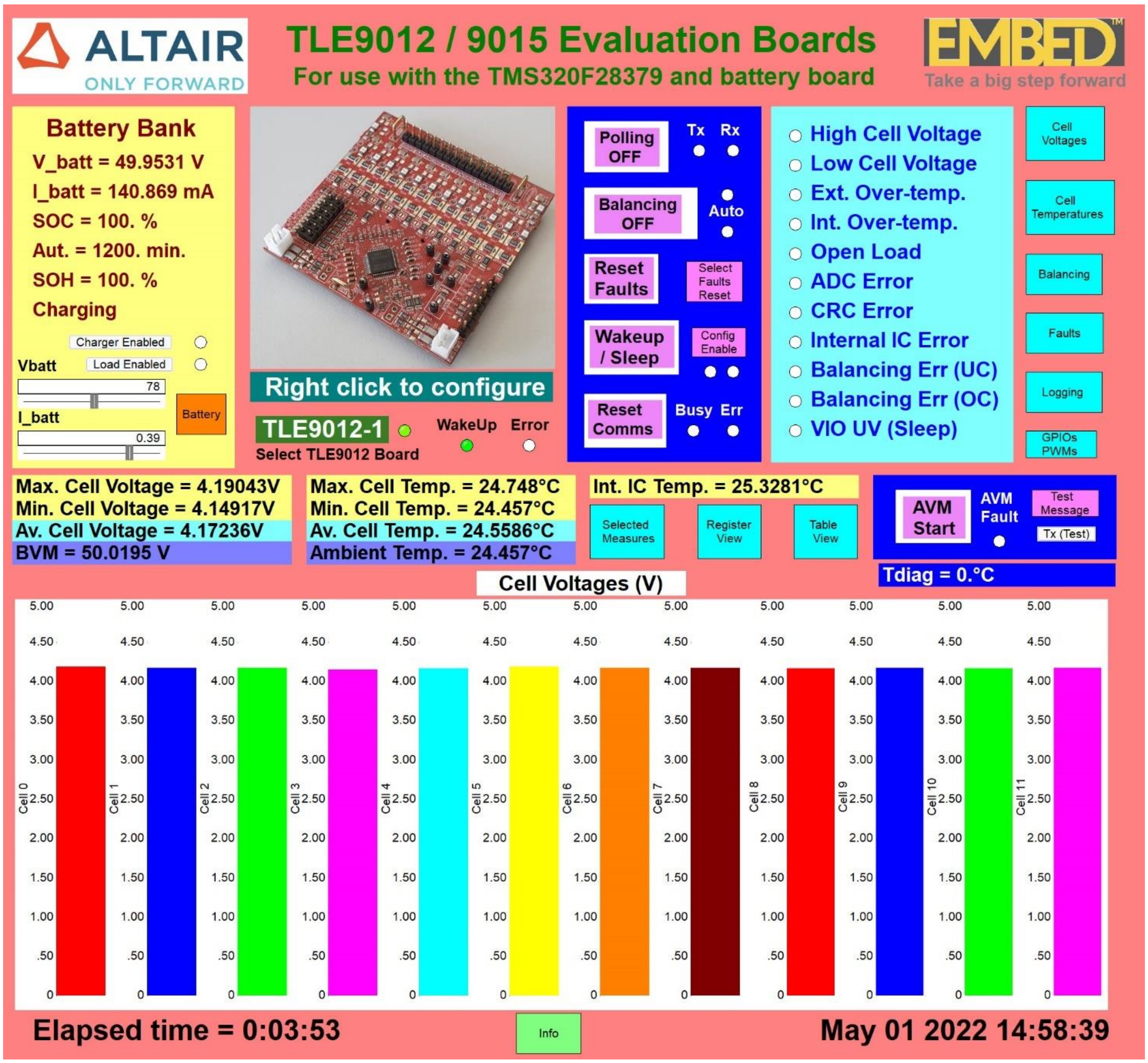
There are 16 available channels for the two plots. Each channel can be selected individually as:





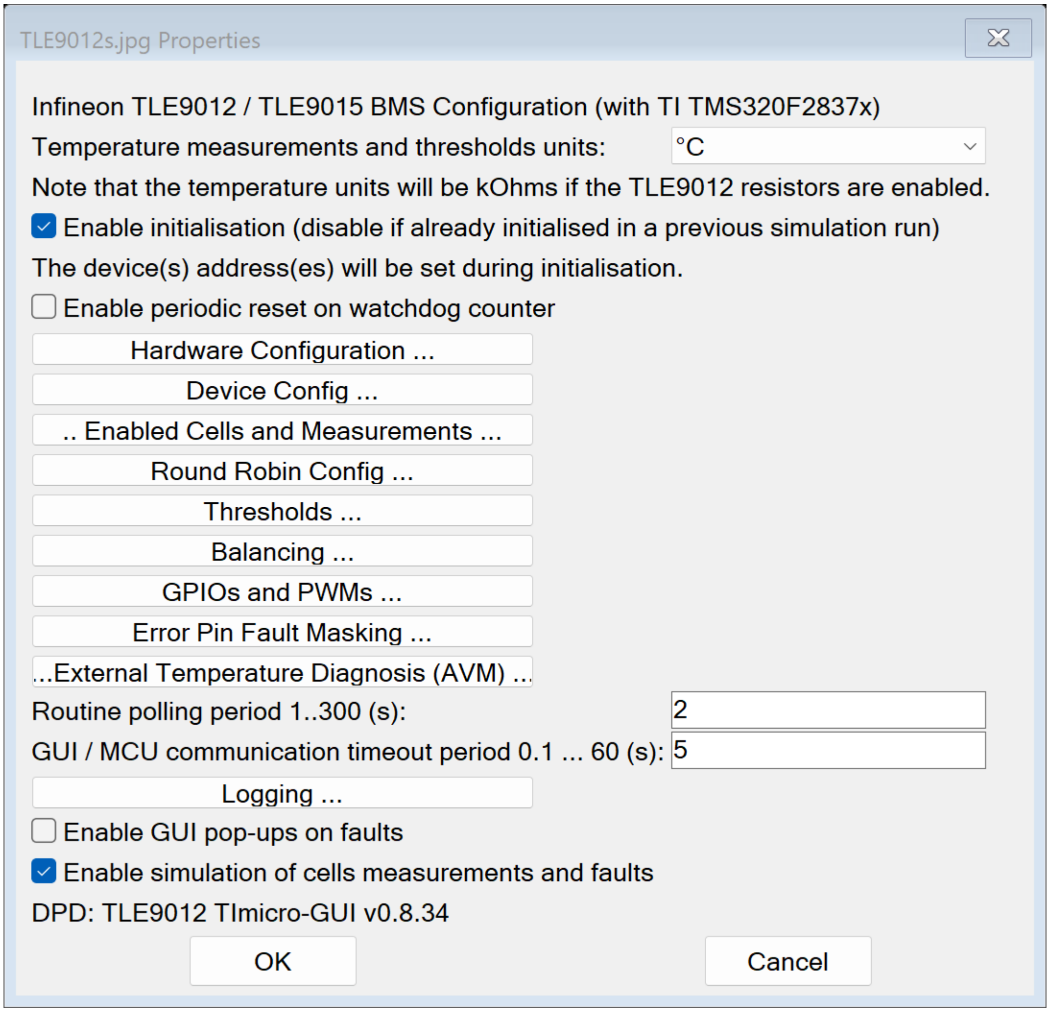
Configuring the Altair Embed Infineon BMS System

This section describes the configuration of the Infineon TLE9012 / TLE9015 BMS system using the Altair Embed Infineon BMS GUI. For further information to this configuration procedure and the TLE9012 board, refer to the relevant Infineon documentation.
The Altair Embed Infineon BMS GUI is given below:



Before starting a simulation run, the BMS hardware should be connected and the USB-to-JTAG converter connected to the PC (mounted on the microcontroller control card). The BMS hardware registers of the TLE9012 integrated circuit (chip) now need to be configured for the current hardware configuration. When starting and stopping the Embed simulation, if the BMS hardware itself is not switched off, or the PC interface is not removed, then it is not necessary to reconfigure the hardware on every simulation run.
By right clicking on the TLE9012 image in the GUI, the following configuration dialogs will appear.

Main Dialog



Temperature measurements and thresholds units:

Select the desired units of the temperature measurements in either:

1. °C
2. °F
3. K.

These units will be used throughout the Embed BMS GUI for the temperature measurements, temperature settings and thresholds.

Enable Initialization (disable if already initialized on a previous simulation run):

This should be selected when connecting to the TLE9012(s) for the first time after powering up. Afterwards, when stopping and starting the Embed GUI, it is not necessary to perform the initialization every time.

Enable periodic reset of watchdog counter:

The device will return to sleep mode if the watchdog counter is not reset at regular periods. Enabling this option will send a reset of the watchdog counter at regular periods to keep the device awake.

The various configuration settings are grouped into the nested Tabs and are described in the following sections.

Routine polling period 1..300 (s):

Enter the period between polls for the battery voltages, temperatures and faults.

GUI / MCU communication timeout period 0.1..60 (s):

Enter the period before the communication times out if no response is received form the addressed TLE9012 device.

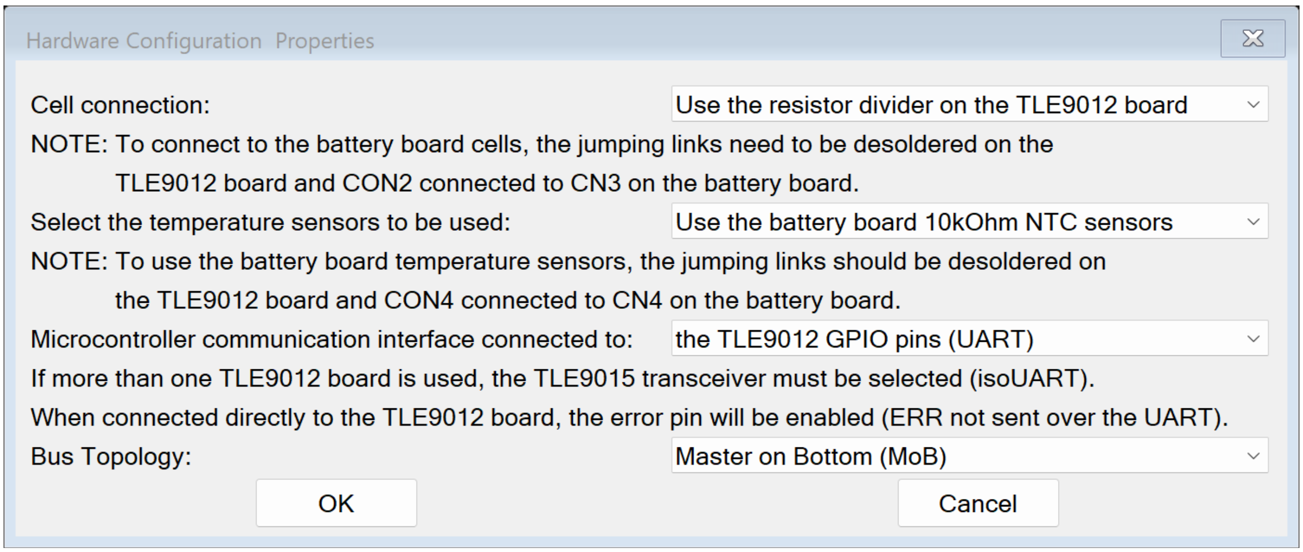
Enable GUI pop-ups on faults:

When selected, pop-ups will appear on the occurrence of faults in the system. Otherwise, only critical pop-ups will be enabled.

Enable simulation of cells measurements and faults:

If selected, this diagram can be run in simulation to test the GUI functioning in a demonstration mode.

<u>Hardware Configuration</u>



Cell connection:

The connection of the cells can be one of the following:

- Use the resistor divider network on the TLE9012 board
- Connected to the battery cells of the battery board

If the battery board is not available, much of the code development and verification can be performed by using the resistive divider network on the Infineon TLE9012 BMS board. The board can be connected to a power supply as shown in figure 15 and the cell voltages will be measured as the voltage across each resistor of the resistive divider network. In this case, balancing cannot be performed and open-load error messages will occur. With this selection, the open-load errors are disabled from the GUI display and the balancing is disabled.
If connecting the TLE9012 BMS board to the battery board, the shorting links to the resistor network should be de-soldered as shown in figure 21. Otherwise, they will discharge the cells and the balancing will also be less effective.

Select the temperature sensors to be used:

- Use the TLE9012 demo board 5.1kΩ resistors
- Use the battery board 10kΩ NTC sensors

The TLE9012 BMS board has on-board 5.1kΩ resistors connected to the auxiliary connector pins for temperature measurement. If this option is selected, the temperature measurements will be configured to measure the resistance rather than a temperature.

If the second option is selected, the auxiliary measurements will be temperature measurements according to the NTC characteristic on the battery board. Note that likewise to the cell voltage selection, the shorting links on the TLE9012 BMS board will need to be de-soldered as shown in figure 21.

Microcontroller communication interface connected to:

The available selections here are:.

- the TLE9012 GPIO pins (UART)
- the TLE9015 transceiver (isoUART)

If the GPIO pins are used, the communication can be connected directly to the TLE9012 BMS board. Otherwise, with the second option, the TLE9015 transceiver board is used for the isoUART connection.

NOTE that if using the first normal UART option, multiple battery boards cannot be connected in series and this option is intended for systems with 12 or fewer cells. This connection is not isolated and boards cannot be stringed together since each board reference voltage will be offset by the battery voltage of the previous boards.

If the normal UART is selected, the first two GPIO pins will not be available and the configuration will reflect this since they are occupied for the communication interface.

Bus Topology:

The selections here are as follows:

- Master on Bottom (MoB)
- Master on Top (MoT)
- Ring Topology

These selections set the topology of the communication connections between TLE9012 BMS boards and the TLE9015 board if used. For further information, refer to the Infineon documentation.

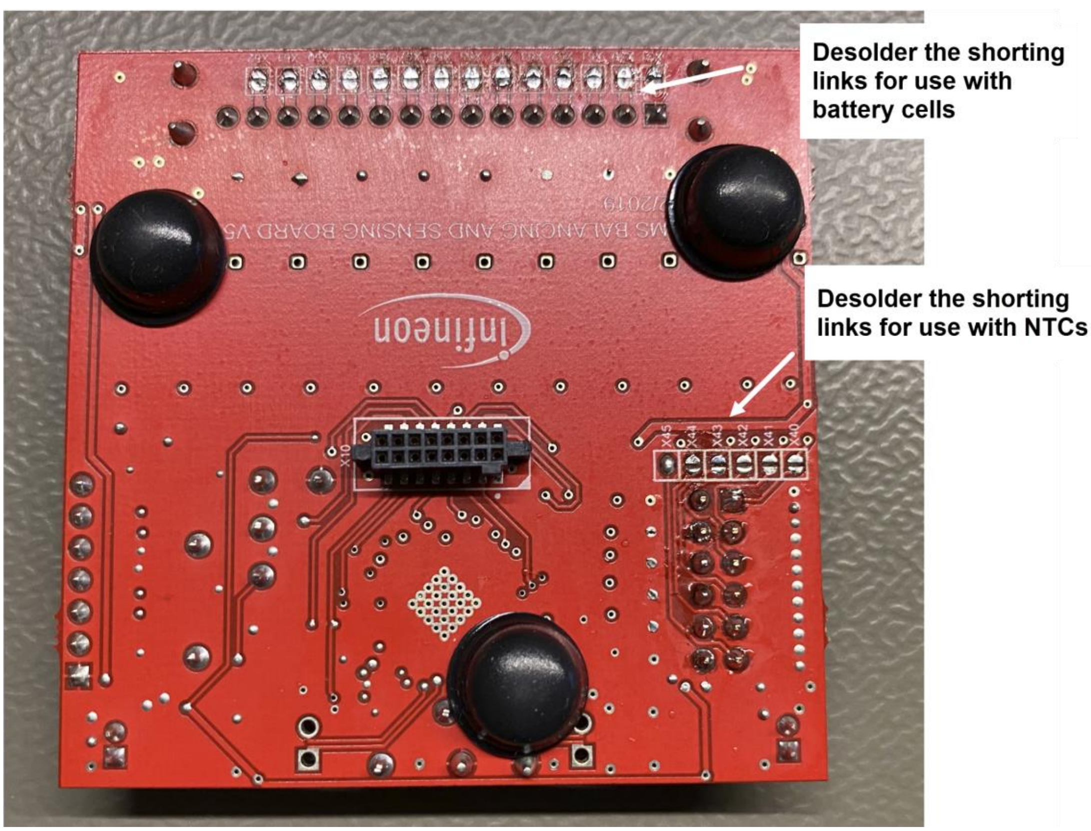
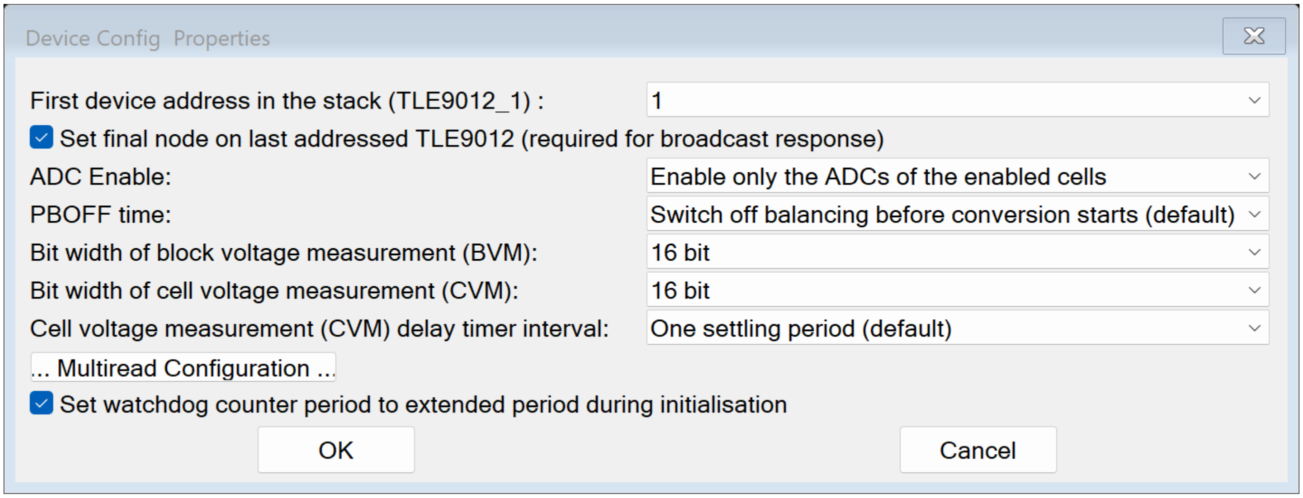


Figure 21 The underside of the TLE9012 BMS board showing the shorting links which need to be de-soldered for use with the battery board.

Device Configuration



First device address in the stack (TLE9012_1):

The address of the first device can be set from 1 to 10 but will normally be 1.

Set final node on last addressed TLE9012 (required for broadcast response):

This should be enabled in order to set the last TLE9012 device in the string to the final node and allow broadcasts.

ADC Enable:

The ADCs of only the enabled or populated cells can be enabled or all of the ADCs enabled, regardless of the number of cells.

PBOFF time:

The balancing can be temporarily switched off during the BVM and CVM measurements (default) or it can be set to remain unchanged.

Bit width of block voltage measurement (BVM):

Set the resolution of the BVM measurement from 10 to 16bit. The lower resolution will mean a faster measurement time.

Bit width of cell voltage measurement (CVM):

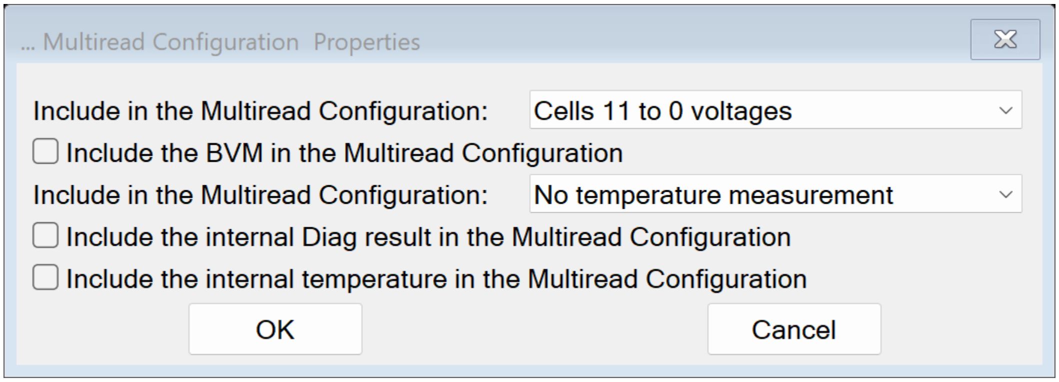
Set the resolution of the cell voltage measurements from 10 to 16bit. The lower resolution will mean a faster measurement time.

Cell voltage measurement (CVM) delay timer interval:

Set the number of settling periods for the cell voltage measurement

Multiread Configuration

A multiread command can be transmitted to the TLE9012 devices. The following configuration dialog configures the measurements to be included in the multiread.



Include in the multiread configuration:

The measurement of the cell voltages, depending upon those present, can be selected to be included in the multiread.

Include the BVM measurement in the multiread configuration:

The block voltage measurement can be included.

Include in the multiread configuration:

Select the external temperature measurements to be included.

Include the internal Diag result in the multiread configuration:

Include the internal diagnosis result in the multiread.

Include in the internal temperature in the multiread configuration:

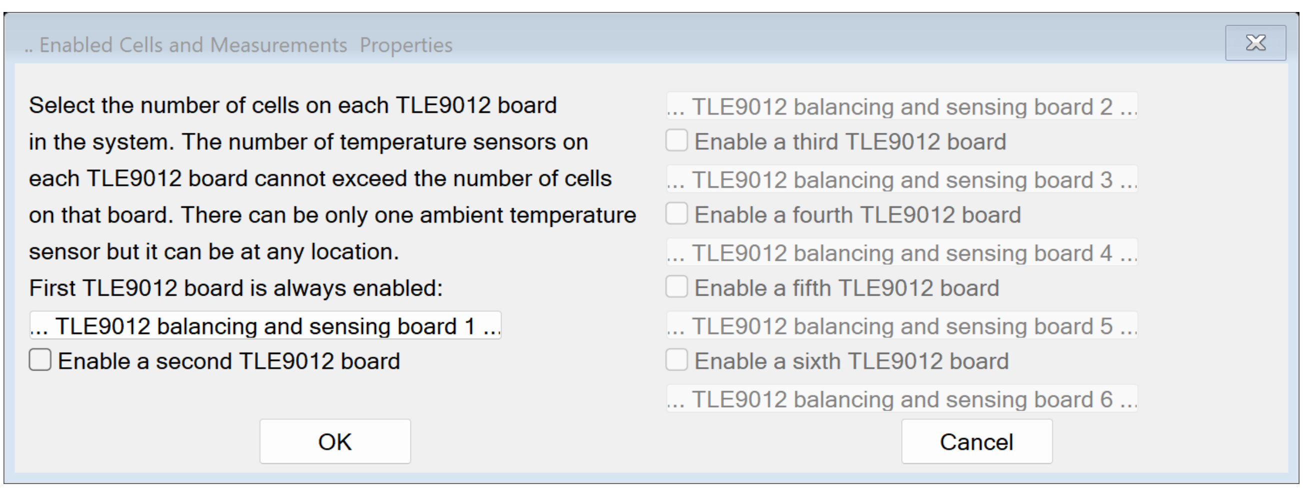
Include the internal chip temperature measurement.

Set watchdog counter period to extended period during initialization:

This option is recommended, especially during debugging since it will significantly increase the duration of the device remaining in wakeup mode before returning to sleep without resetting the watchdog cpounter.

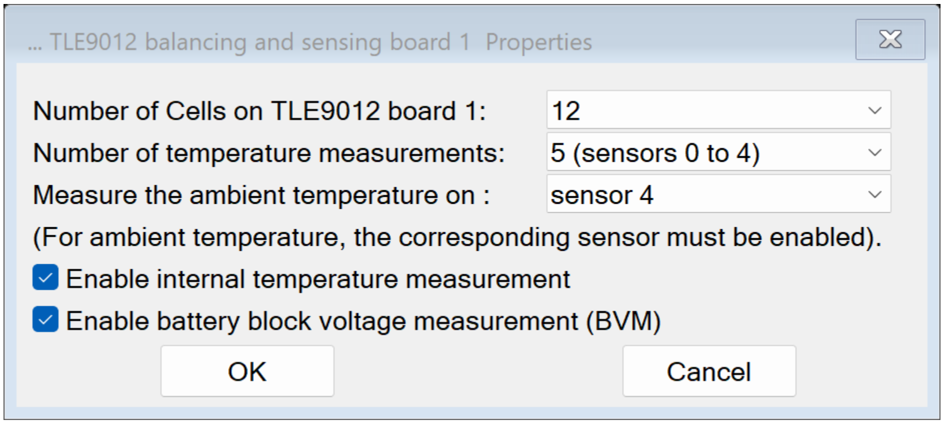
Enabling Cell and device Measurements

The number of cells in each TLE9012 board and the desired cell and device measurements can be selected here for one to six TLE9012 boards.



Enable the number of connected TLE9012 boards from 1 to 6.

Each TLE9012 balancing and sensing board tab contains the following dialog:



Number of cells on TLE9012 board x:

Select the number of series cells on the corresponding TLE9012 from 3 to 12 cells. Each TLE9012 board can have a different number of cells enabled.

Number of temperature measurements:

The number of temperature measurements can be configured here (maximum of 5 for each TLE9012 board). The TLE9012 board has on-board test resistors for this measurement. The battery board has a NTC sensor under each odd-numbered cell. The selection of the NTC sensors is done in the hardware configuration menu.

Measure the ambient temperature on:

Select the channel where the ambient temperature is to be measured (or battery board) can be selected as the ambient temperature. Note that this will only be enabled if the cell is not populated at this position.

Enable internal temperature measurement:

The internal chip temperature of the digital die will be monitored and reported by the GUI if enabled here.

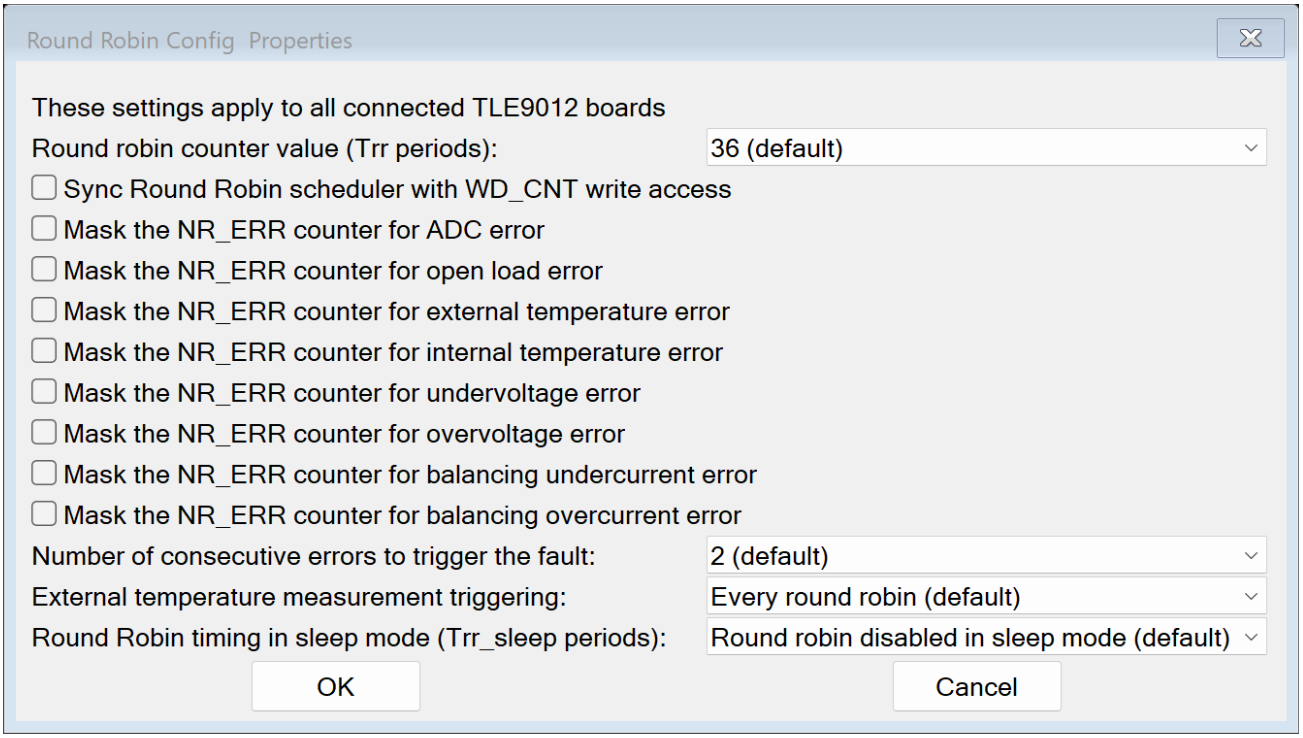
Enable battery block voltage measurement (BVM):

The battery block voltage measurement (total battery voltage of each TLE9012 board) will be performed and reported to the GUI if enabled here.

The other TLE9012 boards can be configured with any number from 3 to 12 cells and the configuration may vary between the connected TLE9012 boards.

Round Robin Configuration

The round robin scheduling scheme can be configured in the following dialog. This feature triggers internal diagnostics to check for internal device faults.



Round robin counter value (Trr periods):

Set the period of the round robin diagnostic timer from 1 to 128 periods (default is 36 periods). Refer to the datasheet sheet for the value of the timer period, Trr.

Sync round robin scheduler with WD_CNT access

Enable the sync the scheduler with watchdog writes

Mask the NR_ERR counter for various faults (errors):

The selected masks of the internal errors

Number of consecutive errors to trigger the fault:

The number of consecutive errors that must occur before the fault is triggered can be configured from 1 to 7.

External temperature measurement triggering:

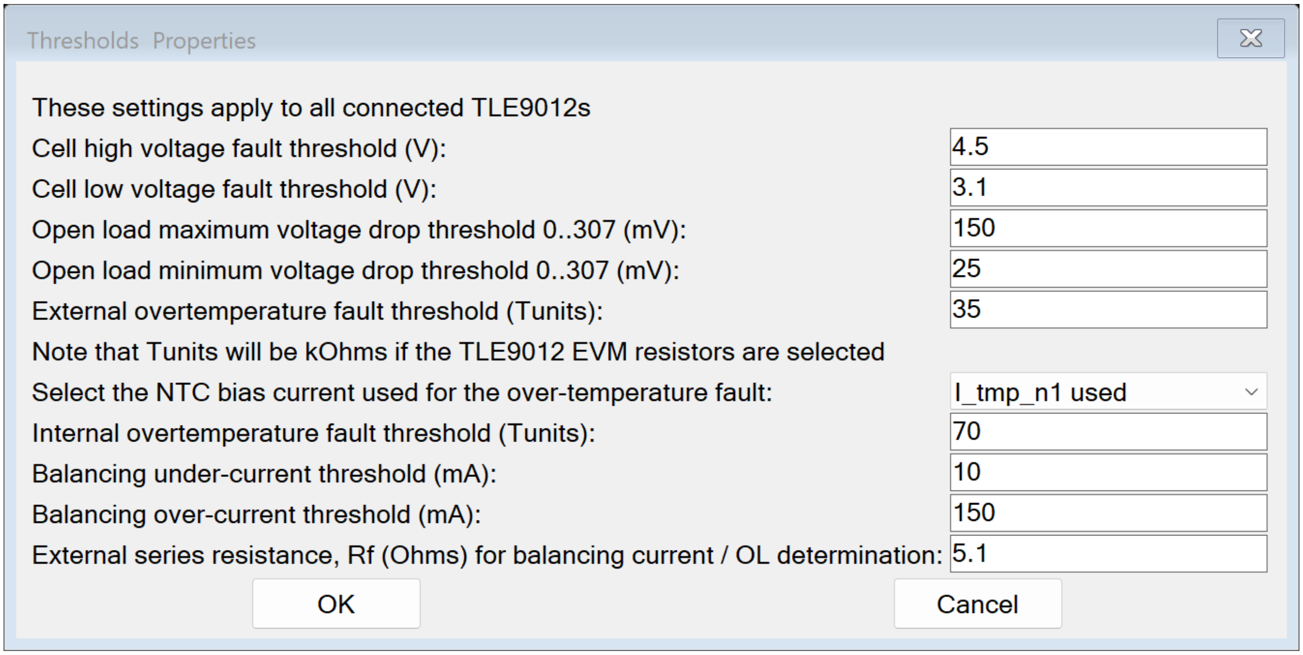
The external temperature measurements are triggered by the round robin scheduler and can be triggered from every round robin trigger to every eighth round robin trigger event.

Round robin timing in sleep mode:

The round robin period during sleep mode can be configured here from 1 to 1023 or disabled.

Thresholds Configuration

The desired thresholds can be set in this dialog. The given thresholds will be set identically for all configured channels and all enabled TLE9012 boards.



Cell high voltage fault threshold (V):
: Enter the desired value of the cell over-voltage threshold in volts.

Cell low voltage fault threshold (V):
: Enter the desired value of the cell under-voltage threshold in volts.

Open load maximum voltage drop threshold (mV):
: Enter the value of the maximum voltage drop to determine the open load fault.

Open load minimum voltage drop threshold (mV):
: Enter the value of the minimum voltage drop to determine the open load fault.

External overtemperature fault threshold (Tunits):
: Enter the desired value of the cell high temperature threshold in the GUI selected temperature units. Note that if the on-board 5.1kΩ resistors are used, this will be in kΩ.

Select the NTC bias current used for the over-temperature fault:
: Select the NTC bias current setting for the over-temperature fault determination. This setting is applicable to the over-temperature fault only. The bias current for the temperature measurement will be automatically determined by the TLE9012 device for the best setting.

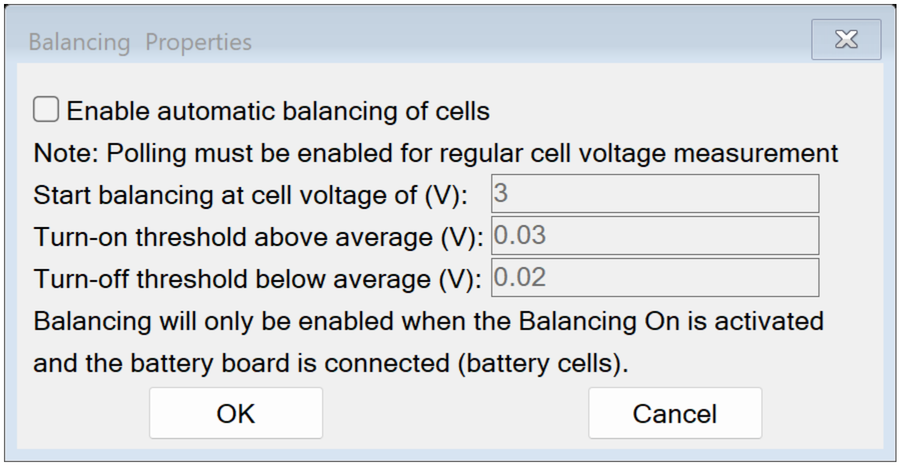
Balancing undercurrent threshold (mA):
: The balancing overcurrent setting can be given milli-Amperes. This value will be dependent upon the value of the series resistance given below, since the measurement performed is the voltage drop across this series resistance.

Balancing overcurrent threshold (mA):
: The balancing undercurrent setting can be given milli-Amperes similarly to the overcurrent setting.

External series resistance, Rf (Ohms) for the balancing current / OL determination:
: There is a series resistance required for the balancing current fault thresholds and open-load thresholds as described in the TLE9012 datasheet. On the TLE9012 evaluation board, this value is 5.1Ω.

Balancing Configuration

The balancing can be configured on the following dialog after clicking on the balancing tab in the main dialog. These selections are configurations of the automatic balancing subroutine block within the Embed GUI diagram.



Enable automatic balancing of cells:

Select this to enable automatic cell balancing.

Start balancing at a cell voltage of:

Enter the desired cell voltage, above which the automatic balancing should be enabled. If the cell voltage is lower than this value, the automatic balancing will not be active (the cell is discharged or is heavily charging).

Turn-on threshold above average:

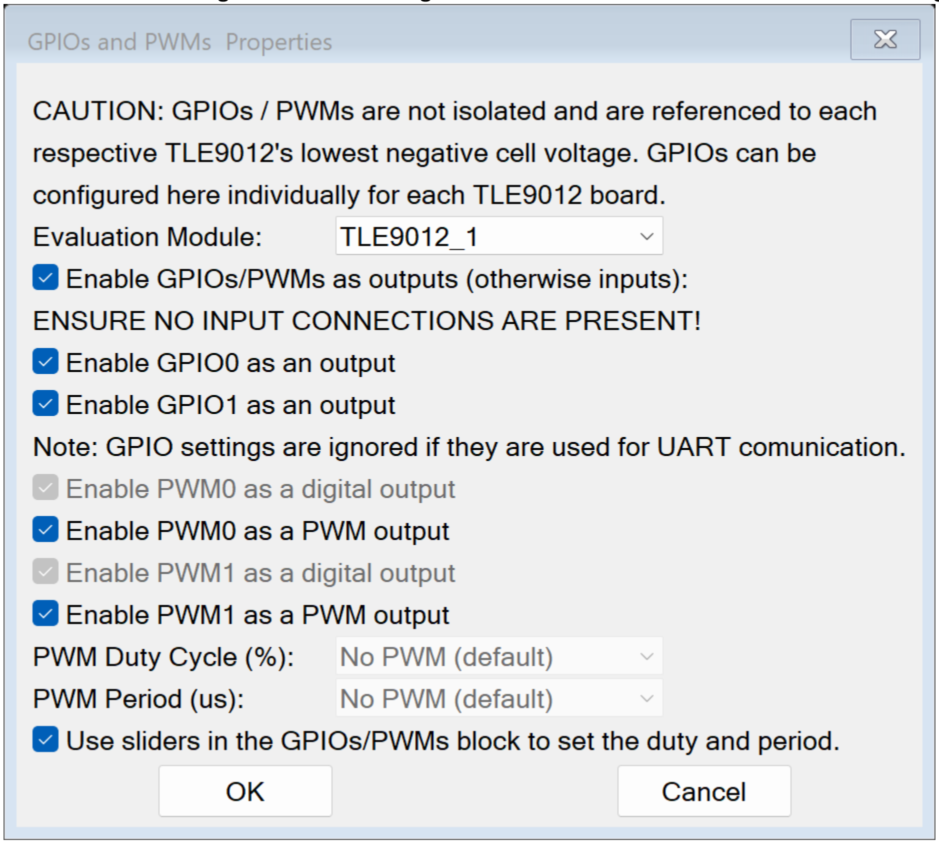
Enter the value in volts of the voltage above the average cell voltage at which the cell balancing should turn on.

Turn-off threshold below average:

Enter the value in volts of the voltage below the average cell voltage at which the cell balancing should turn off.

GPIOs and PWMs Configuration

The GPIOs and/or PWMs can be configured when clicking on the GPIOs and PWMs tab in the main dialog.



Evaluation module:

Select the TLE9012 BMS board to which the configuration settings are to apply (other boards can be configured consecutively).

Enable GPIOx as outputs:

The individual GPIOs can be set as outputs. ENSURE to remove any input connections to the GPIOs before enabling this option. These two GPIOs are not available if the local UART communication connection is used (only available with the isoUART in use).

Enable PWMx as outputs:

The individual PWMs can be enabled and set as either normal inputs / outputs or PWM outputs.

PWM duty cycle (%):

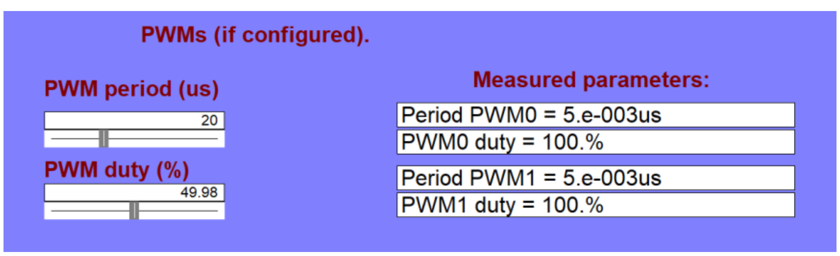
The duty cycle of the PWM output (if enabled) can be selected here.

PWM period (us):

The period of the PWM output in micro-seconds (if enabled) can be selected here.

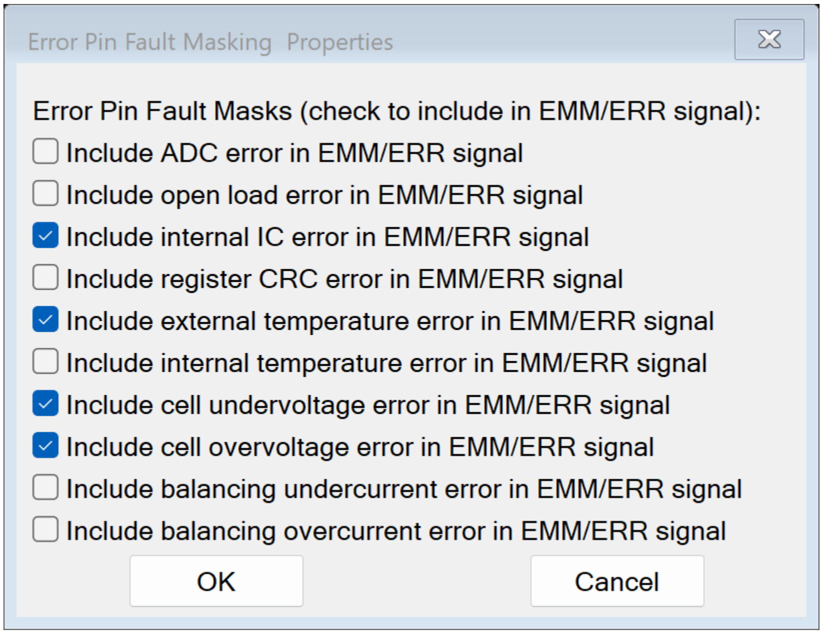
Use sliders in the GPIOs/PWMs block to set the duty cycle and period:

Select this option if it is desired to change the period and duty cycle of the PWM outputs with the sliders that can be found inside the GPIOs / PWMs tab in the main GUI menu.



Fault Management Configuration

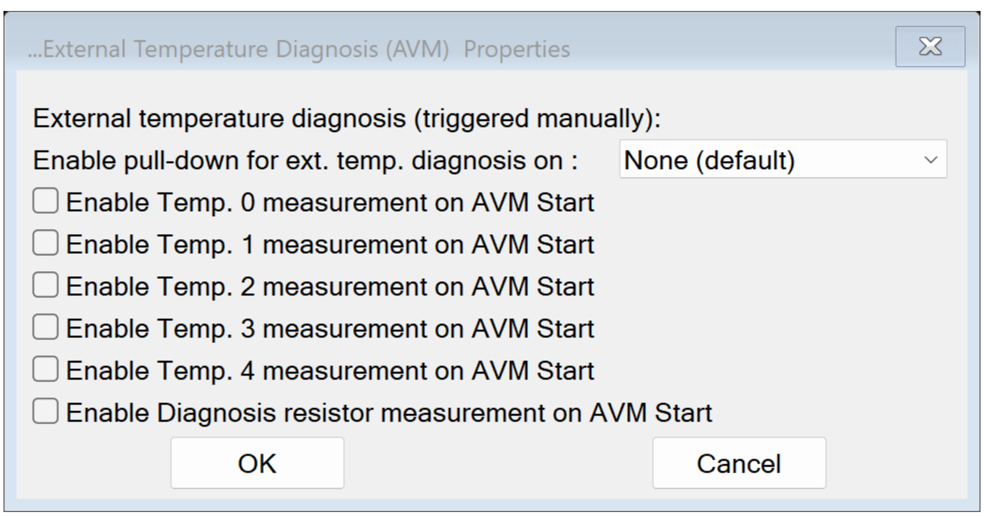
The error pin configuration can be performed in the following dialog:



In this dialog, the faults which are to be included in the independent ERROR pin can be selected.
The faults are normally masked from the error pin and can be individually included by using the dialog.
The error pin condition is signaled by the Error light on the main GUI.

External Temperature Diagnosis (AVM) Configuration

The 13th ADC channel of the TLE9012 device can be used to perform an auxiliary voltage measurement for diagnosis purposes. The auxiliary voltage measurement configuration dialog is shown in the following:



Enable pull-down for external temperature diagnosis:

A pull-down resistor can be enabled on any one (or none) of the temperature measurement channels.

Enable Temp. x measurement on AVM start:

The individual temperature measurements can be enabled during the AVM measurement.

Enable diagnosis resistor measurement on AVM start:

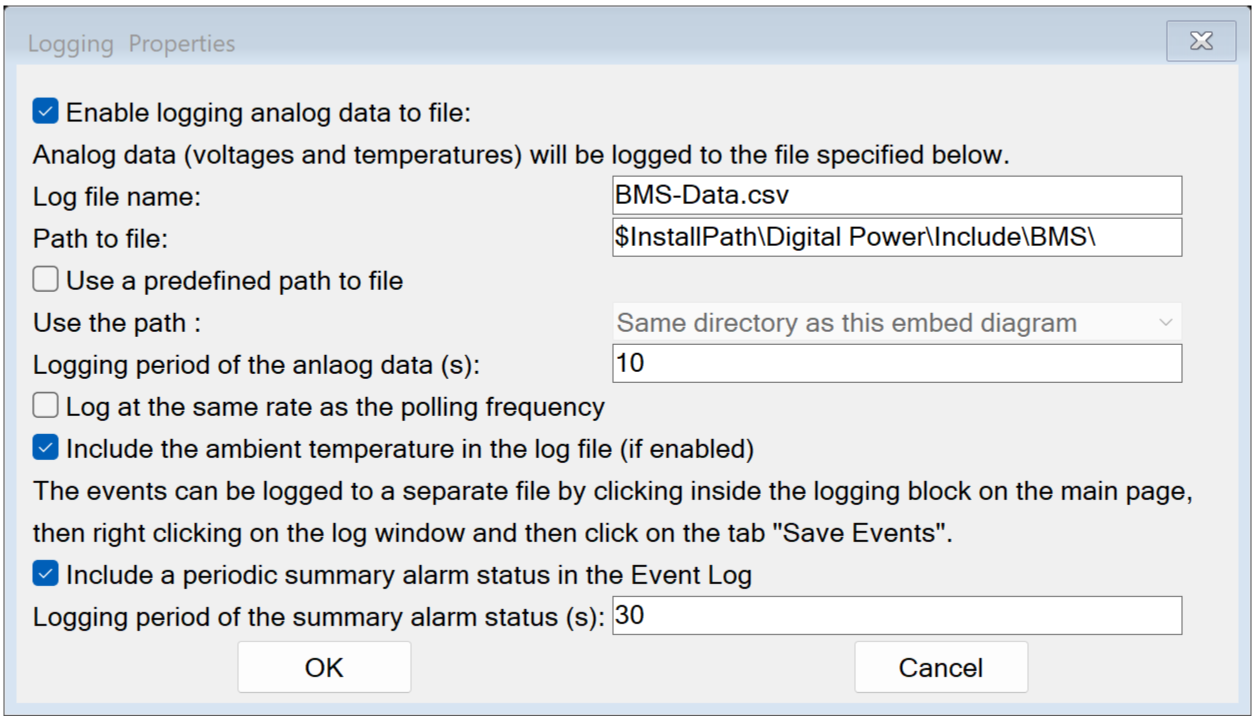
The pull-down resistor measurement can be enabled when the AVM measurement is triggered.

The AVM can be performed manually by using the 

tab in the main GUI. A fault on this diagnosis is signaled by the light "AVM Fault" turning red next to the AVM start tab.

Logging Configuration

The Infineon BMS data can be logged to a defined file in a defined location.



Enable logging analog data to file:

Analog data (cell voltages and temperatures) can be logged to a file when enabled.
Enter the file name and path of the file.

Logging period of the analog data:

The period at which the selected analog data is logged can be entered.

Include the ambient temperature in the log file:

Enable this if the ambient temperature is to be included in the log file.

Include a periodic summary alarm status in the event log:

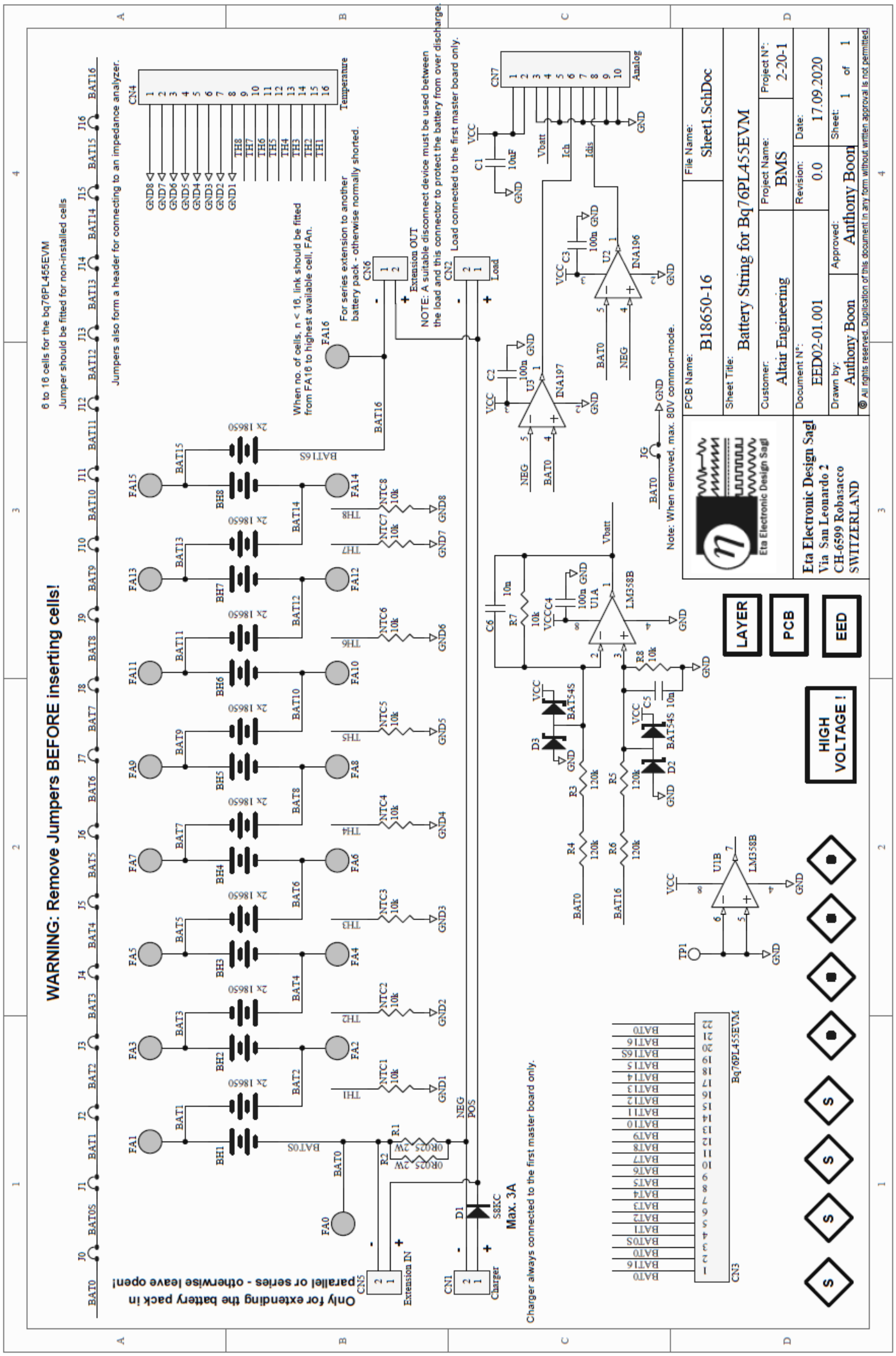
Enable this to include summary of the alarm / fault status in the event log found on the main page in the logging block.

Logging period of the summary alarm status:

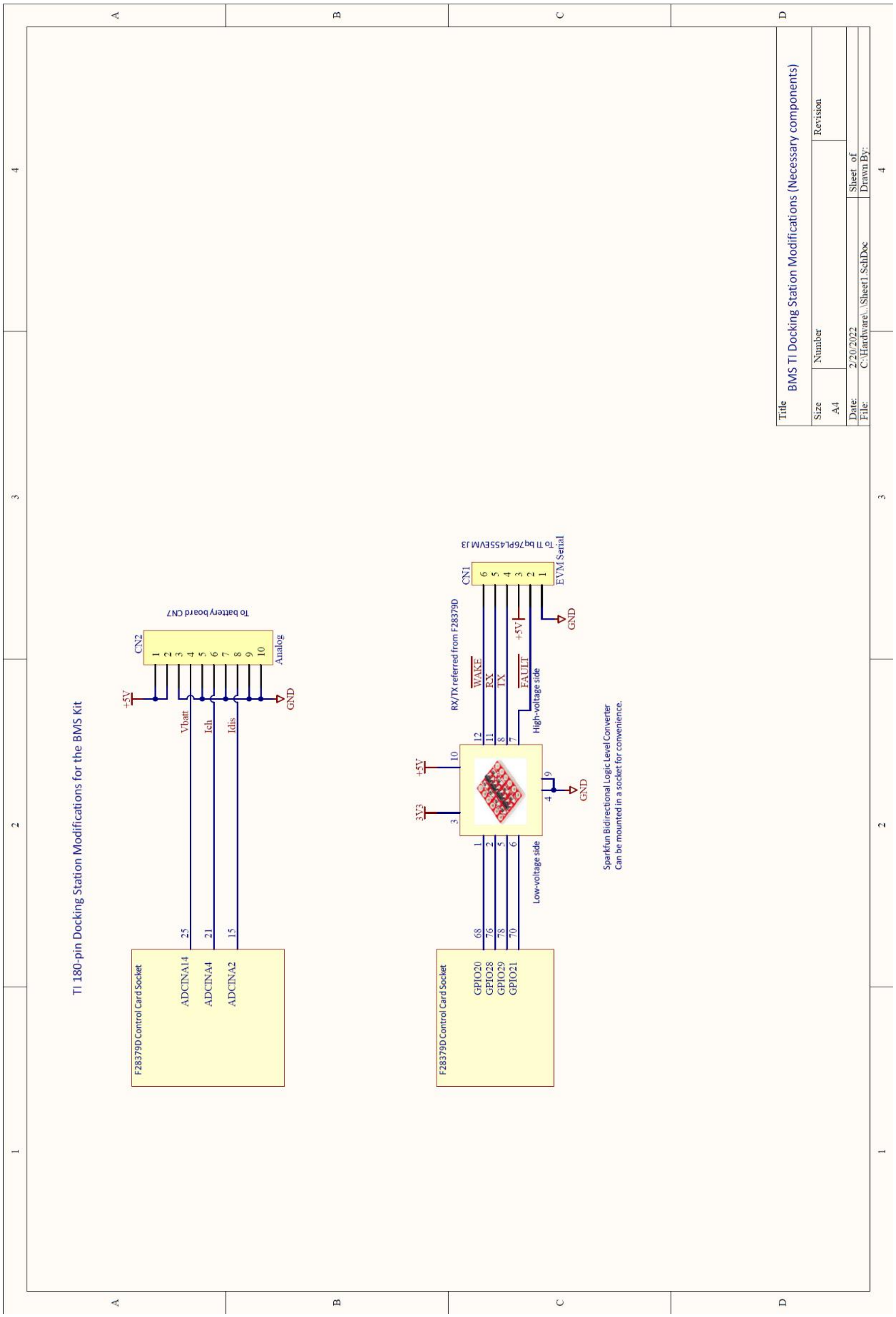
The period at which the summary alarm status is logged in the event log can be entered.

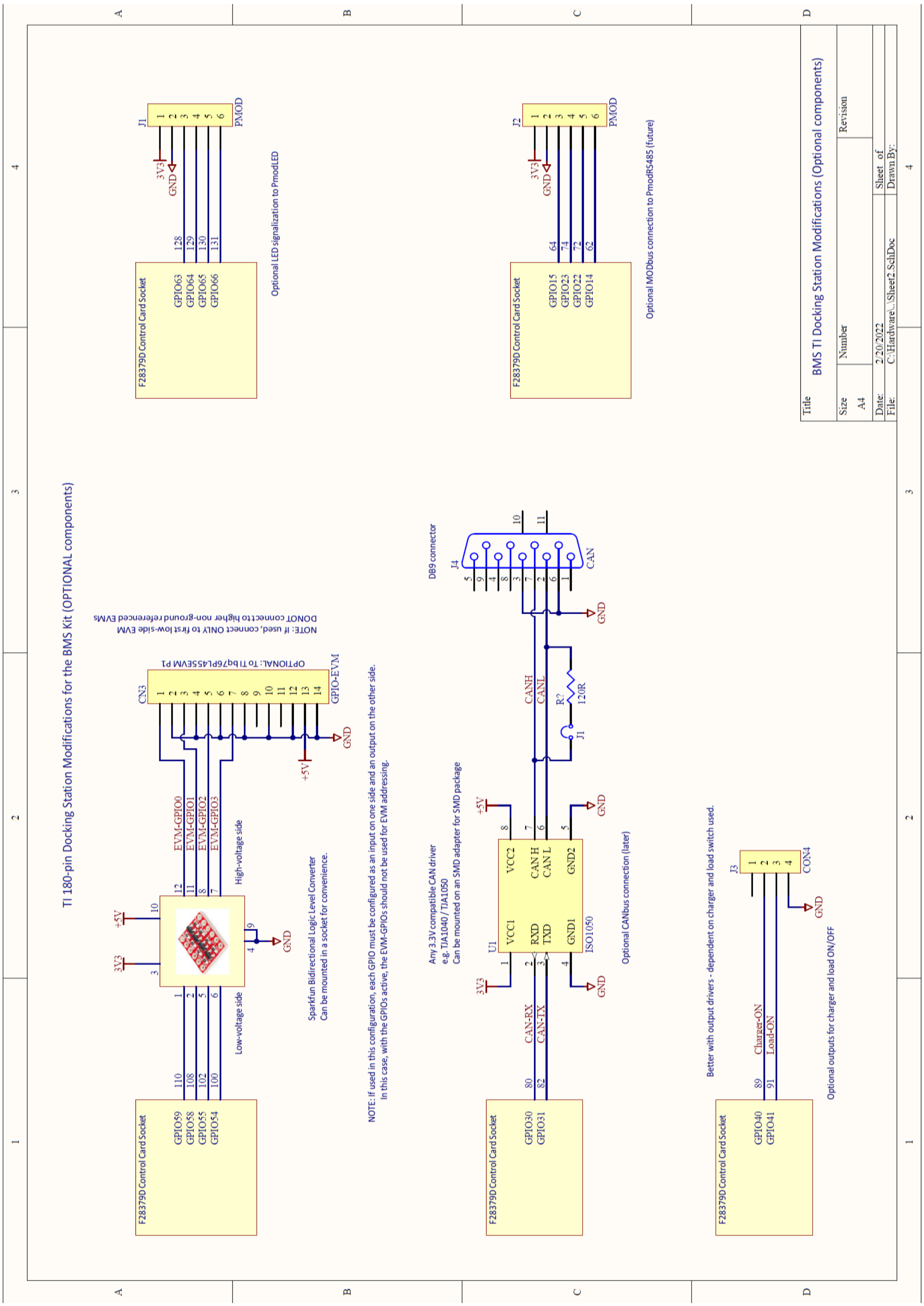
Contents – Applications

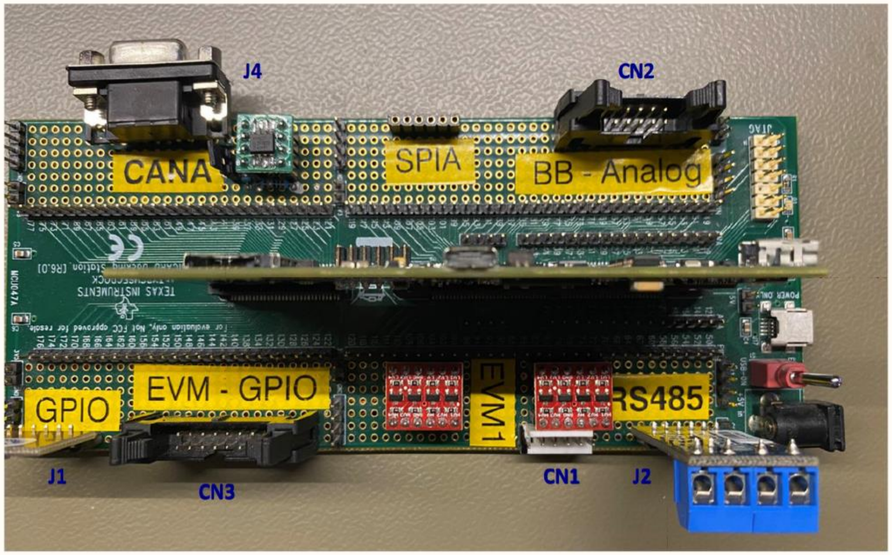
Appendix A: B18650-16 Battery Board Schematic

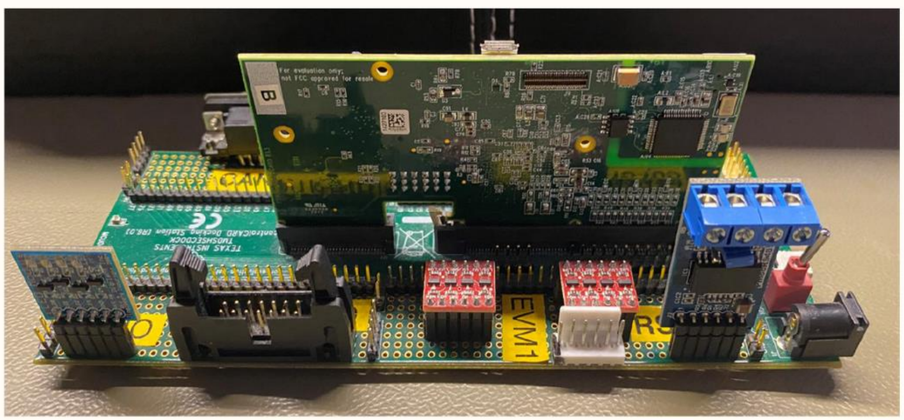


Appendix B: TI Docking station schematic of modifications




TI 180-pin Docking Station Modifications for the BMS Kit (OPTIONAL components)
Optional LED signalization to PmodLED
Optional MODbus connection to PmodRS485 (future)
OPTIONAL: To TI bq79PL455EVM P1
NOTE: If used, connect ONLY to first low-side EVM
DONOT connect to higher non-ground referenced EVMs
Sparkfun Bidirectional Logic Level Converter
Can be mounted in a socket for convenience.
NOTE: If used in this configuration, each GPIO must be configured as an input on one side and an output on the other side.
In this case, with the GPIOs active, the EVM-GPIOs should not be used for EVM addressing.
Any 3.3V compatible CAN driver
e.g. TJA1040 / TJA1050
Can be mounted on an SMD adapter for SMD package
Optional CANbus connection (later)
DB9 connector
Better with output drivers - dependent on charger and load switch used.
Optional outputs for charger and load ON/OFF
F28379D Control Card Socket
BMS TI Docking Station Modifications (Optional components)
Title
Size
A4
Number
Revision
Date: 2/20/2022
File: C:\Hardware\..\Sheet2.SchDoc
Sheet of
Drawn By:



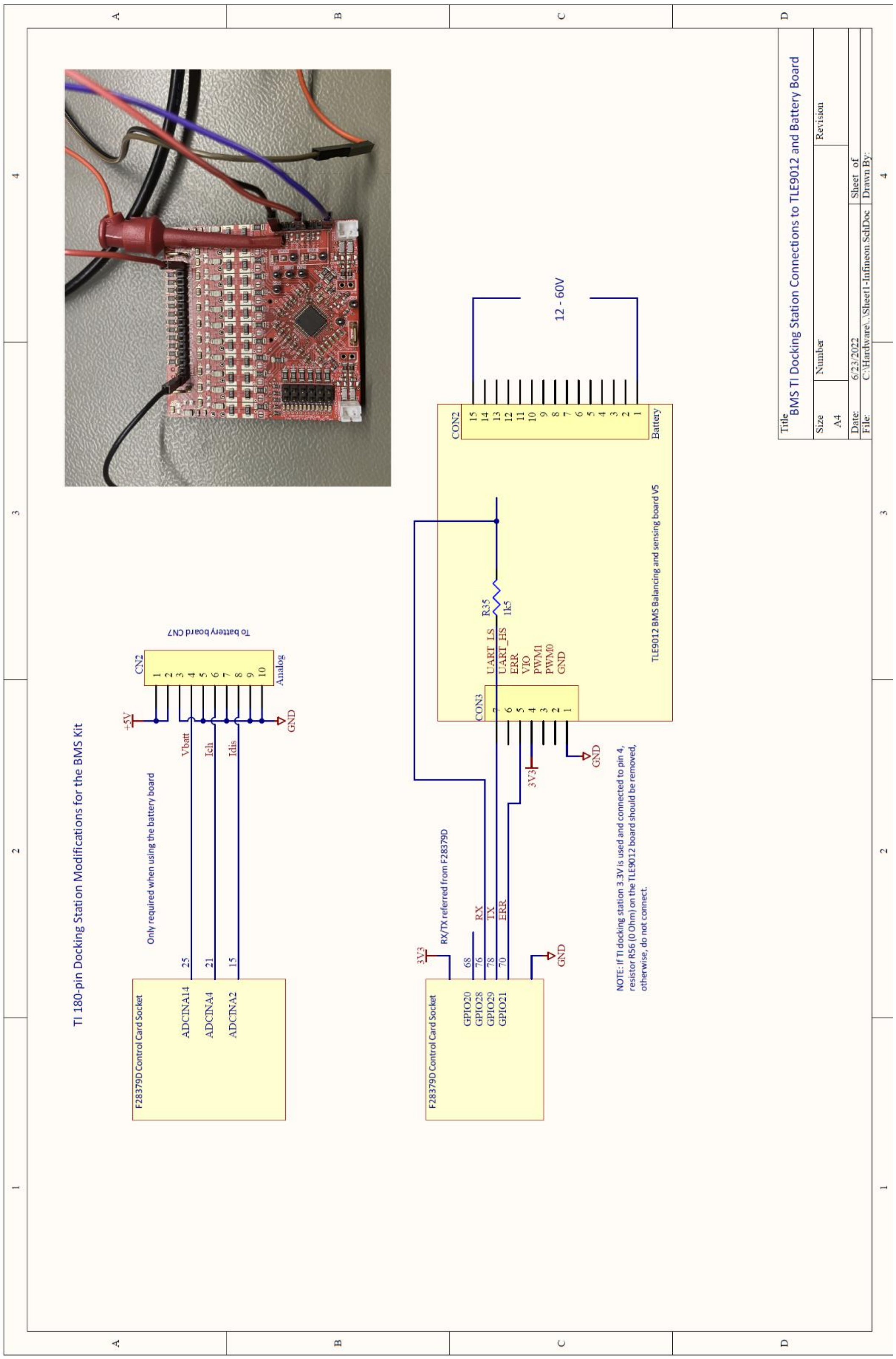


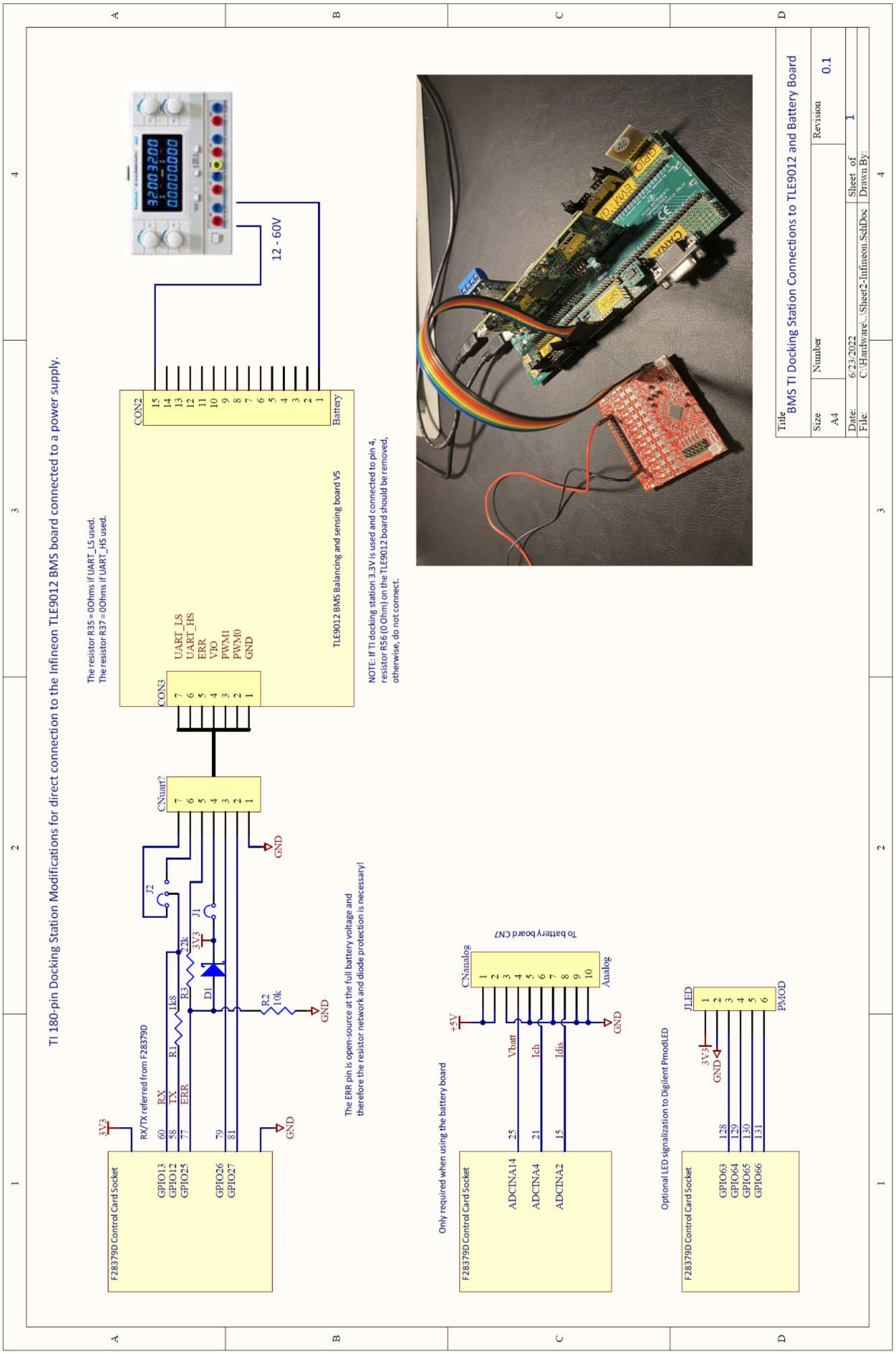
Note: SPIA connector shown here is not used.

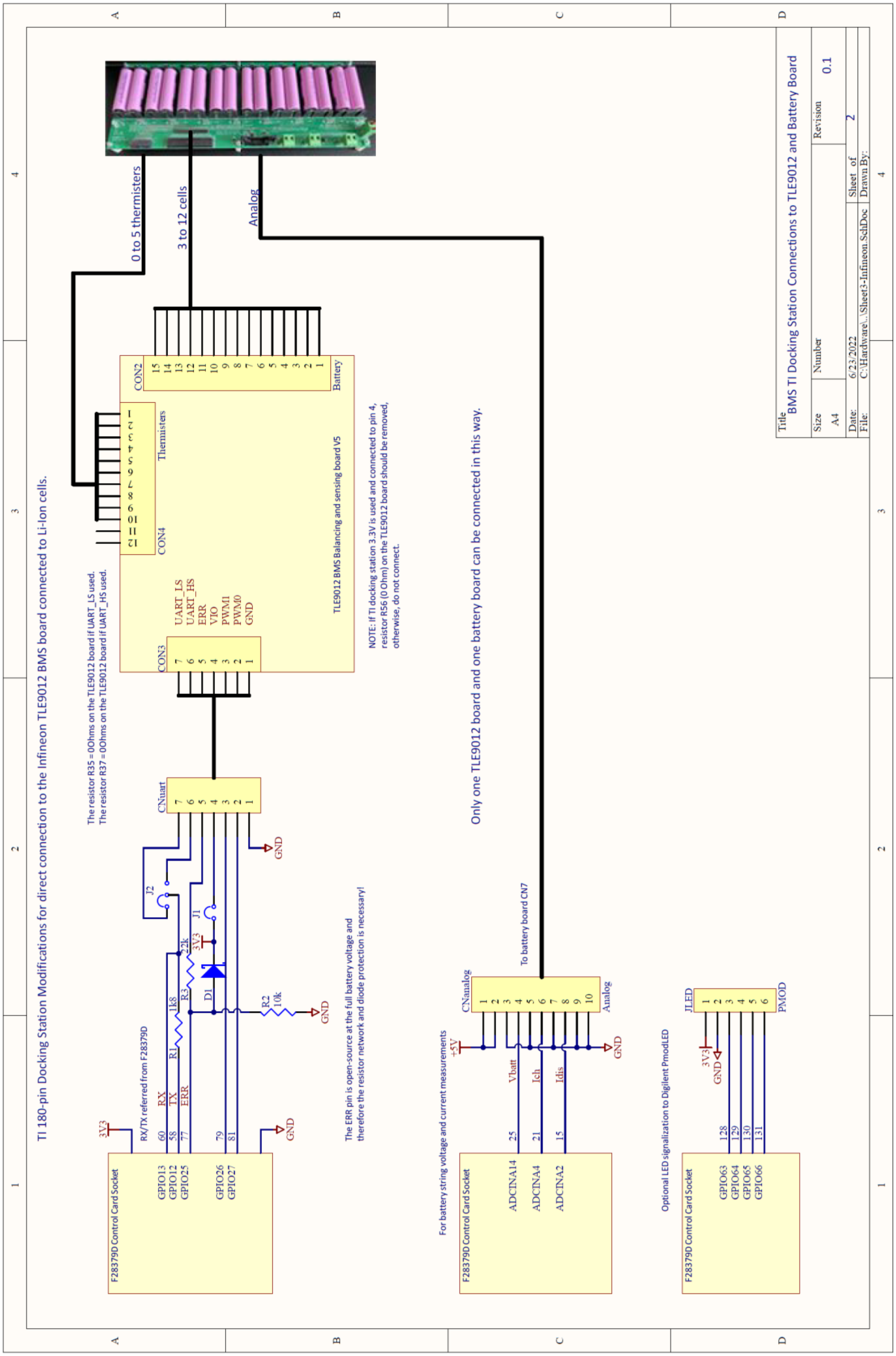
For the connector J3, the GPIO output pins have been directly used but this will depend upon the interface hardware of the charger and load switch.

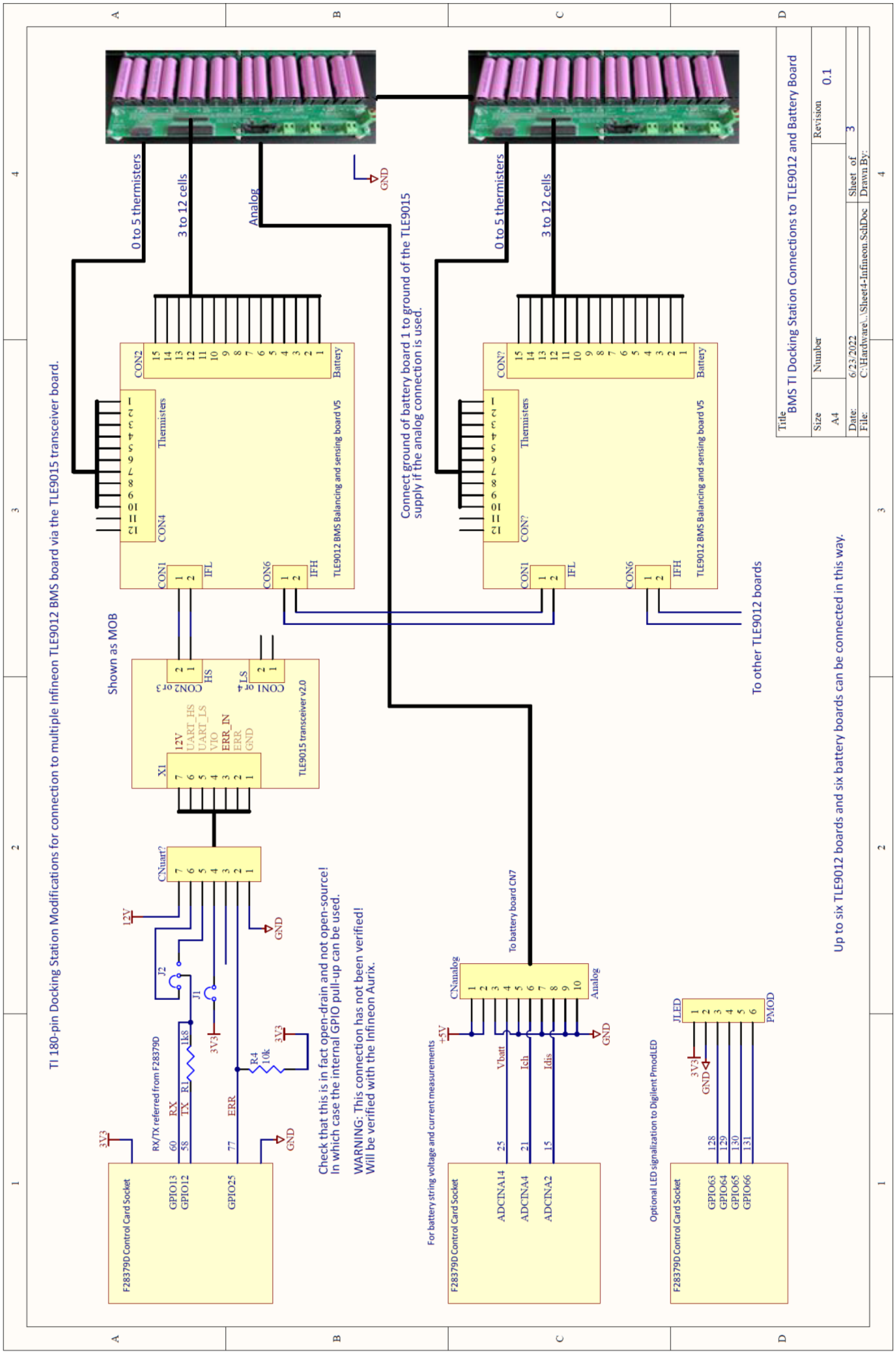
Title	BMS TI Docking Station Modifications (Completed board)		
Size A4	Number		Revision
Date:	2/20/2022	Sheet of	
File:	C:\Hardware\..\Sheet3.SchDoc	Drawn By:	

Appendix C: Infineon Docking station schematic of modifications




TI 180-pin Docking Station Modifications for direct connection to the Infineon TLE9012 BMS board connected to a power supply.
The resistor R35 = 0Ohms if UART_LS used.
The resistor R37 = 0Ohms if UART_HS used.
12 - 60V
CON2
Battery
CON3
UART_LS
UART_HS
ERR
VIO
PWM1
PWM0
GND
TLE9012 BMS Balancing and sensing board V5
NOTE: If TI docking station 3.3V is used and connected to pin 4, resistor R56 (0 Ohm) on the TLE9012 board should be removed, otherwise, do not connect.
CNuart?
F28379D Control Card Socket
GPIO13
GPIO12
GPIO25
GPIO26
GPIO27
RX/TX referred from F28379D
RX
TX
ERR
3V3
GND
J1
J2
R1
1k8
R3
2k2
D1
R2
10k
The ERR pin is open-source at the full battery voltage and therefore the resistor network and diode protection is necessary!
Only required when using the battery board
ADCINA14
ADCINA4
ADCINA2
Vbatt
Ich
Idis
+5V
CNanalog
Analog
To battery board CN7
Optional LED signalization to Digilent PmodLED
GPIO63
GPIO64
GPIO65
GPIO66
JLED
PMOD
Title
BMS TI Docking Station Connections to TLE9012 and Battery Board
Size
A4
Number
Revision
0.1
Date: 6/23/2022
File: C:\Hardware\..\Sheet2-Infineon.SchDoc
Sheet of
Drawn By:


TI 180-pin Docking Station Modifications for direct connection to the Infineon TLE9012 BMS board connected to Li-Ion cells.
F28379D Control Card Socket
3V3
RX/TX referred from F28379D
GPIO13 60 RX
GPIO12 58 TX
GPIO25 77 ERR
GPIO26 79
GPIO27 81
R1 1k8
R3 22k
J2
J1
D1
R2 10k
GND
CNuart
The resistor R35 = 0Ohms on the TLE9012 board if UART_LS used.
The resistor R37 = 0Ohms on the TLE9012 board if UART_HS used.
CON3
UART_LS
UART_HS
ERR
VIO
PWM1
PWM0
GND
CON4
Thermisters
CON2
Battery
TLE9012 BMS Balancing and sensing board V5
0 to 5 thermisters
3 to 12 cells
Analog
The ERR pin is open-source at the full battery voltage and therefore the resistor network and diode protection is necessary!
NOTE: If TI docking station 3.3V is used and connected to pin 4, resistor R56 (0 Ohm) on the TLE9012 board should be removed, otherwise, do not connect.
For battery string voltage and current measurements
+5V
CNanalog
ADCINA14 25 Vbatt
ADCINA4 21 Ich
ADCINA2 15 Idis
To battery board CN7
Only one TLE9012 board and one battery board can be connected in this way.
Optional LED signalization to Digilent PmodLED
JLED
GPIO63 128
GPIO64 129
GPIO65 130
GPIO66 131
PMOD
Title
BMS TI Docking Station Connections to TLE9012 and Battery Board
Size A4
Number
Revision 0.1
Date: 6/23/2022
File: C:\Hardware\..\Sheet3-Infineon.SchDoc
Sheet of 2
Drawn By:


TI 180-pin Docking Station Modifications for connection to multiple Infineon TLE9012 BMS board via the TLE9015 transceiver board.
Shown as MOB
0 to 5 thermisters
3 to 12 cells
Analog
GND
Connect ground of battery board 1 to ground of the TLE9015 supply if the analog connection is used.
TLE9012 BMS Balancing and sensing board V5
Thermisters
Battery
TLE9015 transceiver v2.0
To other TLE9012 boards
Up to six TLE9012 boards and six battery boards can be connected in this way.
F28379D Control Card Socket
RX/TX referred from F28379D
Check that this is in fact open-drain and not open-source!
In which case the internal GPIO pull-up can be used.
WARNING: This connection has not been verified!
Will be verified with the Infineon Aurix.
For battery string voltage and current measurements
To battery board CN7
Optional LED signalization to Digilent PmodLED
Title
BMS TI Docking Station Connections to TLE9012 and Battery Board
Size
A4
Number
Revision
0.1
Date: 6/23/2022
Sheet 3 of
File: C:\Hardware\..\Sheet4-Infineon.SchDoc
Drawn By:

Appendix D: Bill of Materials of the battery board

Item	Designator	Footprint	Value	Manufacturer	Manufacturer Part No:	Description	Qty	Mouser/Digikey Part Numbers with links
1	BH1, BH2, BH3, BH4, BH5, BH6, BH7, BH8	BattHold - 2x18650	2x 18650	Keystone	1049	Thru-hole Mount Battery Holder for 2 x 18650 cells	8	534-1049 https://www.mouser.in/ProductDetail/Keystone-Electronics/1049?qs=%2F7TOpeL5Mz78b0pqEFIl5w%3D%3D
2	C1	1210	10uF	Samsung	CL32B106KAJNNNE	Surface Mount Capacitor, 10uF, 10%, 25V, X7R	1	187-CL32B106KAJNNNE https://www.mouser.in/ProductDetail/Samsung-Electro-Mechanics/CL32B106KAJNNNE?qs=349EhDEZ59oSQgVQQaIQpg%3D%3D
3	C2, C3, C4	0603	100n	Various		Surface Mount Capacitor, 100nF, 35V	3	It looks like it is available in our store
4	C5, C6	0603	10n	Various		Surface Mount Capacitor, 10nF, 35V	2	It looks like it is available in our store
5	CN1, CN2, CN5, CN6	Morsetti era 2x300 estrai bil e		Phoenix Contact	1766770	Power Connector, 2-pole, 7.62mm	4	277-5943-ND https://www.digikey.in/product-detail/en/phoenix-contact/1766770/277-5943-ND/348824
6	CN3	Molex - SDA-705550 056	Bq76PL455EVM	Molex	70555-0056; Mating connector: 50579422	Connector, 22-pin Molex-SDA-705550056	1	538-70555-0056 https://www.mouser.in/ProductDetail/Molex/70555-0056?qs=RQ%2FpGXtJgJy7uhuzy6M11A%3D%3D
7	CN4	Molex - SD-43045 - 001	Temperature	Molex	0430451601; Mating connector: 0430251600	Connector, 16-pin, Molex-SD-43045-001	1	WM7490-ND https://www.digikey.it/product-detail/en/molex/0430451601/WM7490-ND/3044582
8	CN7	FKV10S B	Analog out	3M		Pin header, 10-pin, 2.54mm DIN 41651 straight	1	https://www.eve-electronics.com/din-41651-box-header-10-pin-straight-white-pitch-2-54-mm-spbh10s-3000.html
9	D1	DO-214AB	S8xC	Taiwan Semiconductor	S8KC V7G	Diode General purpose, 8A, 800V	1	S8KCV7GCT-ND https://www.digikey.in/product-detail/en/taiwan-semiconductor-corporation/S8KC-V7G/S8KCV7GCT-ND/7944433

10	D2, D3	SOT-23	BAT54S	On Semiconductor	BAT54SLT1G	DIODE ARRAY SCHOTTKY 30V SOT23-3	2	BAT54SLT1GOSCT-ND https://www.digikey.ee/product-detail/en/on-semiconductor/BAT54SLT1G/BAT54SLT1GOSCT-ND/917811
11	FA0, FA1, FA2, FA3, FA4, FA5, FA6, FA7, FA8, FA9, FA10, FA11, FA12, FA13, FA14, FA15, FA16	FASTON 6.3MM	FASTON 6.3mm	TE Connectivity	726386-2	Terminals GDS-FLACHSTECK 6.3	16	571-726386-2 https://www.mouser.in/ProductDetail/TE-Connectivity-AMP/726386-2?qs=sd1rtLGwt4569WB7PEOdPA%3D%3D
12	J0, J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11, J12, J13, J14, J15, J16, JG	JUMPER2	JUMPER 2			Jumper, 2-pole, 2.54mm	18	It looks like it is available in our store
13	NTC1, NTC2, NTC3, NTC4, NTC5, NTC6, NTC7, NTC8	0603	10k	Epcos	B57330V2103F260	Thermister NTC, 10kOhm 0603	8	495-5816-1-ND https://www.digikey.co.uk/product-detail/en/epcos-tdk-electronics/B57330V2103F260/495-5816-1-ND/4360615
14	R7, R8	0603	10k			Surface Mount Resistor, 10kOhm 1% 0603	2	
15	R1, R2	2512	0R025, 2W	Vishay-dale	WSL2512R0250FEA18	Surface Mount Resistor 0.025ohm,	2	WSLH-.025DKR-ND https://www.digikey.com.br/product-detail/en/vishay-

						1% 2W 2512		dale/WSL2512R0250FEA18/WSLH-025DKR-ND/2695357
16	R3, R4, R5, R6	0805	120k			Surface Mount Resistor, 120kOhm, 1% 0805	4	
17	U1	SO-8	LM358B	TI	LM358BIDR	General Purpose Dual Operational Amplifier	1	296-LM358BIDRCT-ND https://www.digikey.in/product-detail/en/texas-instruments/LM358BIDR/296-LM358BIDRCT-ND/10716094
18	U2	DBV-5	INA196	TI	INA196AIDBVR	Current shunt amplifier, 20V/V	1	296-26068-1-ND https://www.digikey.in/product-detail/en/texas-instruments/INA196AIDBVR/296-26068-1-ND/2254842
19	U3	DBV-5	INA197	TI	INA197AIDBVR	Current shunt amplifier, 50V/V	1	595-INA197AIDBVR https://www.mouser.in/ProductDetail/Texas-Instruments/INA197AIDBVR?qs=VBduBm9rCJRFzn96d6NyWw%3D%3D
20	Li-Ion 18650 cells						16	
21	Connector receptacle**						1	WM2920-ND https://www.digikey.in/product-detail/en/molex/0050579422/WM2920-ND/531468
22	Single wire Crimping socket 22-24AWG**						22	WM2564CT-ND https://www.digikey.sg/product-detail/en/molex/0016020088/WM2564CT-ND/1656206
23	Connector receptacle***						2	WM2490-ND https://www.digikey.dk/product-detail/en/molex/0430251600/WM2490-ND/531406
24	Single wire Crimping socket 20- 24AWG***						32	WM2258CT-ND https://www.digikey.dk/product-detail/en/molex/0462355001/WM2258CT-ND/2354690
55	Stand-offs, M4, Nylon, 16mm						6	486-3411-ND https://www.digikey.in/product-detail/en/schurter-inc/9641-6200/486-3411-ND/2644363
26	Shorting link with crimped faston connectors						1	

**To connect to the supplied EVM cable. Alternatively, can be directly soldered to the battery board. B26
***Cable for temperature measurements