DATA SHEET

Keysight Technologies

Scienlab BMS Environment

SL1010A

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System Description

Highlights

As an established energy storage test system Manufacturer, Keysight has a sound knowledge of Battery Management Systems (BMS) and batteries. Based on many years of engineering experience, Scienlab created a testing solution which leaves nothing to be desired.

The modular system architecture enables individual compilation including ready-to-use cell-models. It also enables flexible control of the system. The emulators are implemented by standardized interfaces into HiL environments such as Vector or dSpace.

Fields of application

- Reproducible testing and optimization of the BMS
- Emulation of individual cells as well as modules and packs at cell level
- Validation of all BMS development steps with respect to hardware and software
- Testing of newly developed algorithms (balancing, SOC, SOH)
- Testing of fault cases (over-temperature, over-voltage, etc.)
- Tests with passive and active balancing circuits (Inductive and capacitive)
- Verification of measuring accuracy in various operating situations
- Validation of end products

BMS Environment – Hardware in the Loop solution

System architecture

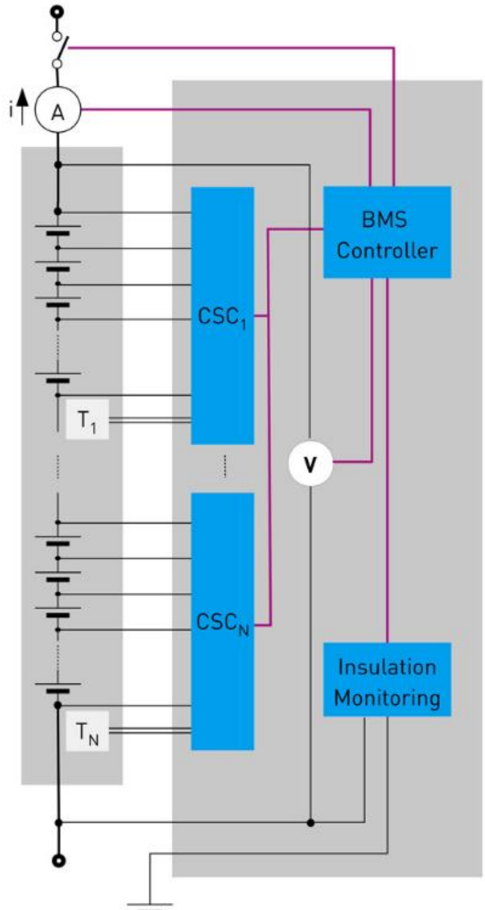


Figure 1: Battery & BMS

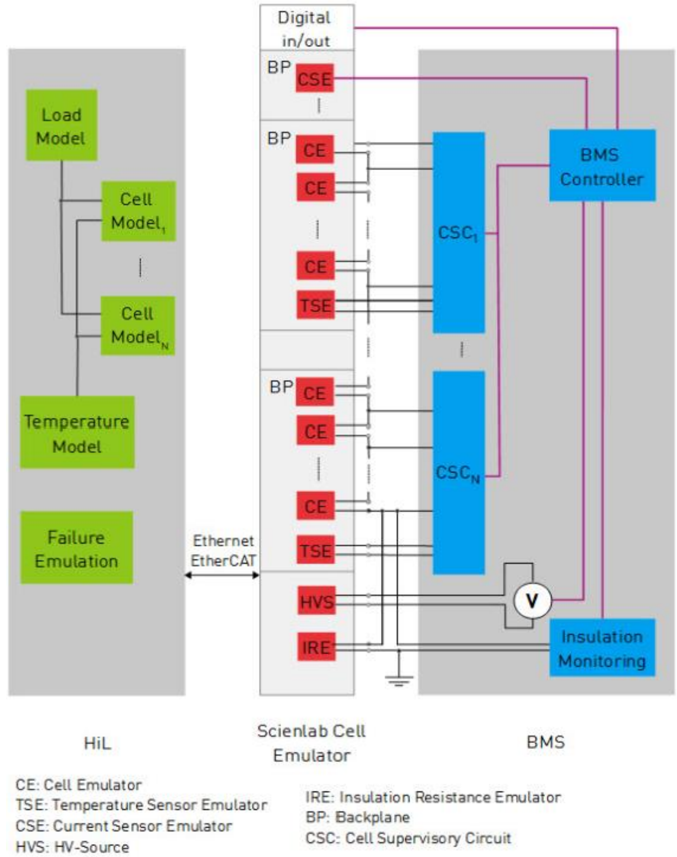


Figure 2: BMS Environment

Delivered documentation

BMS Environment documentation:

- CE Declaration of Conformity
- Operating Instructions Scienlab BMS Environment
- Getting Started Scienlab BMS Environment
- Circuit Diagram
- Acceptance and Calibration Report
- Documentation of the Simulink Battery-HiL-Model
- Documentation of GUI

Cell Emulator (CE) Channels

SL1010A-801 Cell emulator (±1A)

SL1010A-802 Cell emulator (±2A)

SL1010A-803 Cell emulator (±5A)

One cell emulator plug-in card includes two channels of two independent cell emulators. The dielectric strength of both channels each other, to PE and to another plug-in card is 1 kV. The amount of in series connectable channels is limited only by the sum of single cell voltages (<1 kV). The range of output voltages covers typical battery voltages and is prepared for new operation fields like cells with high voltage materials.

The cell-emulators have analog class AB amplifiers and allow a continuous and uninterpretable transition between source and sink operation. To minimize internal power losses, the analogue amplifier positive and negative operation voltages are variable and operating depending on the output voltage.

Description	SL1010A-801	SL1010A-802	SL1010A-803
Voltage	0 to 8 V	0 to 8 V	0 to 8 V
Current (parallel operation)	±1 A (±2 A)	±2 A (±4 A)	±5 A (±10 A)
Power (parallel operation)	±8 W (±16 W)	±16 W (±32 W)	±40 W (±80 W)
Electric Strength	1 kV	1 kV	1 kV

Table 1: Output CE

Cell-emulators feature a high precision measurement technique with traceable calibration and guarantees its measurement accuracy within the specific operating- and temperature range. The maximum control deviation is identical to the specified systematic error (that means, the setting accuracy and the measuring accuracy are identical). Keysight recommends annual calibration. Calibration and adjustment are possible without removing the system from its installation. All system channels are synchronized via the internal data-bus and all data logging and set-value outputs are synchronous.

By use of this measurement signal processes alias effects will be avoided by pulsed balance systems and charges of short-term current pulses will be correctly acquired, also.

Description	Measurement	Maximal systematic error	Resolution
Voltage (measured and set value)	0 to 8 V	< ±0.2 mV (offset), ±0.01% of measured value	64 Bit (float)
Current measurement	I ≤ |5 A|	< ±1 mA (offset), ±0.05% of measured value	64 Bit (float)
Charge measurement	I ≤ |5 A|	< ±50 µC per 50 ms integration time, ±0.05% of measured value	64 Bit (float)

Table 2: Measurement accuracy cell emulator

In addition to the current measurement, every Cell Emulator offers a positive and negative charge acquisition. This additional measured value to determine e.g. the state of charge (SOC).

The output stage has a signal rise- and fall-time of 20 µs typical. The small signal bandwidth is typical 1 MHz. A high bandwidth is necessary to emulate high-frequency current-pulses of the active balance-circuitry a sufficient low internal resistance at the cells even at a higher frequency range. Output stages with a lower bandwidth are not able to react on current load changes fast enough, this would result dynamic voltage errors.

A rise-time of set-point changes is achieved in the software by connecting a dU/dt limiter. By this parametrization, you can choose different compromises between rise-time and over-swing.

Voltage step	Chosen dU/dt	Rise/Fall time	Overswing	Setting time
0 V to 8 V	8 V/ms	800 µs	< 1 mV	< 1 ms
8 V to 0 V	8 V/ms	800 µs	< 1 mV	< 1 ms
3 V to 5 V	maximum	< 80 µs	< 1 V	< 1 ms
5 V to 3 V	maximum	< 80 µs	< 1 V	< 1 ms

Table 3: Output dynamic cell emulator

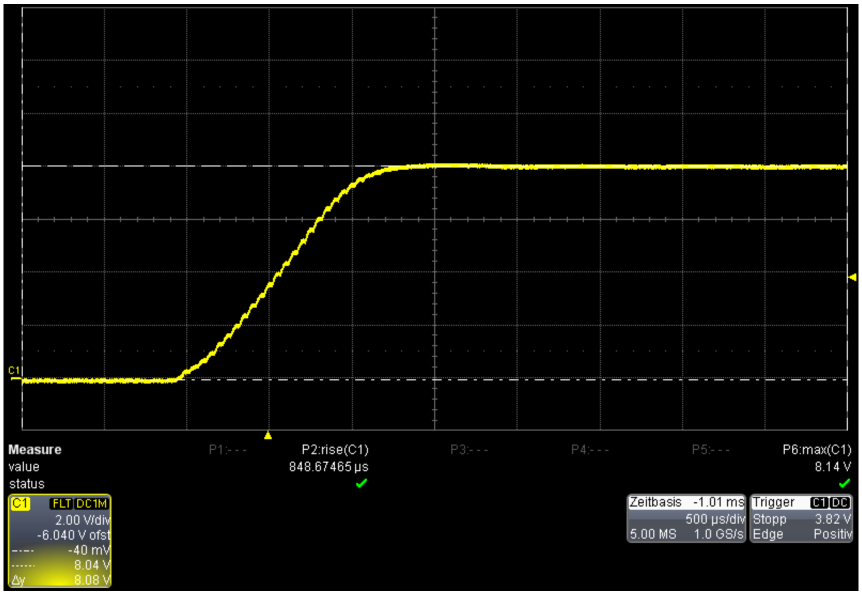


Figure 3: Voltage step from 0 to 8 V (850 µs set) 0 incl. output filter

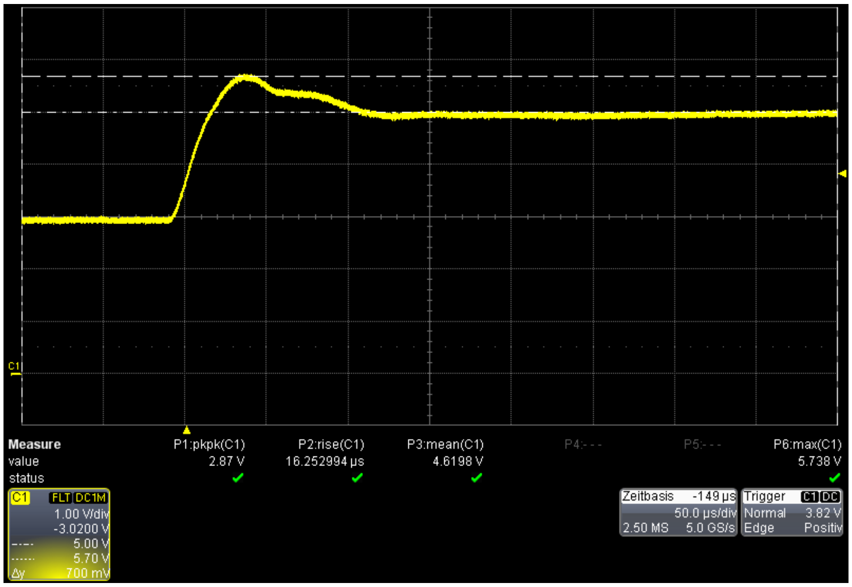


Figure 4: Voltage step from 3 to 5 V (max) incl. output filter

Residual ripples and noise are low in the analog output stage. Figure 5 shows the interfering voltages at the output of the impedance filter (input of BMS) at a measurement bandwidth (-3 dB) of 1 MHz. It is valid over the entire operating range of the Cell Emulator in voltage mode.

Description	Specification
Effective values	Typical 160 µV
Peak-to-peak value	Typical 1.06 mV

Figure 5: Interference Voltage of the cell emulator

Integrated Failure Emulation (Cell Emulator)

- Open circuit
- Short circuit
- Reverse polarity (effective output voltage ±8 V)
- Over-/ under-voltage

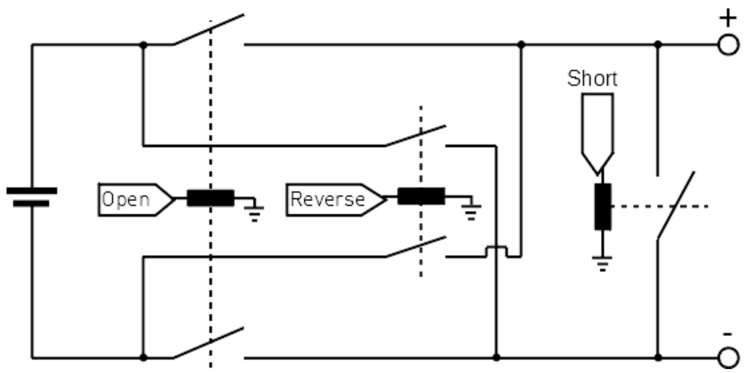


Figure 6: Schematic of the on board cell emulator failure emulation

Cell Emulator Options

SL1010A-401 Current measurement extension

For currents lower than ±10 mA, the measurement accuracy can be extended.

Description	Measurement	Maximal systematic error	Resolution
Voltage measurement	0 to 8 V	< ±0.2 mV (offset), ±0.01% of measured value	64 Bit (float)
Current measurement (Optional SL1010A-401)	I ≤ |10 mA|	< ±2 µA (offset), ±0.05% of measured value	64 Bit (float)
Current measurement	I ≤ |5 A|	< ±1 mA (offset), ±0.05% of measured value	64 Bit (float)
Charge measurement (Optional SL1010A-401)	I ≤ |10 mA|	< ±100 nC per 50 ms integration time, ±0.05% of measured value	64 Bit (float)
Charge measurement	I ≤ |5 A|	< ±50 µC per 50 ms integration time, ±0.05% of measured value	64 Bit (float)

Table 4: Measurement accuracy cell emulator

SL1010A-102 Output filter for impedance compensation

For each cell-emulator plug-in-card (CE), output filters are installed on a profile rail (e.g. in a testing cabinet). These passive filters allow an acquisition of current and charge even with high frequency changes at the output (such as active balancing).

The current/charge must not be absorbed in a current sink, otherwise the measurement of current (amperes) and charge (coulombs) is wrong and the SOC cannot be calculated. The filter compensates for the cable inductance in the system wiring and allows emulation of the cell terminal voltage with the correct cell-impedance at the filter output. This enables a cable length between cell-emulator and filter of up to 8 m. The top-hat rail filters are 1 cm wide per channel. This allows for a short, direct wiring of BMS modules beneath the top-hat rail.

Figure 7: Output filter

Temperature Sensor Emulator Channels (TSE)

The Temperature Sensor Emulator emulates cell temperatures by setting a voltage proportional to a temperature sensor output voltage.

It is designed as a compatible plug-in-card to the cell-emulator. Each plug-in-card includes 4 Temperature Sensor Emulator channels, isolated against each other and to other system components up to an electric strength of 1 kV. Each channel is capable to emulate typical temperature sensors like Pt-100, Pt-1000 and NTC (10k, 100k). To compensate long feed lines and its resistance, a resistance measurement (4-wire) will be used.

SL1010A-201 Temperature Sensor PT100 – including cables and calibration

SL1010A-202 Temperature Sensor PT1000 – including cables and calibration

SL1010A-203 Temperature Sensor NTC 10 kΩ – including cables and calibration

SL1010A-204 Temperature Sensor NTC 100 kΩ – including cables and calibration

Description		Specification	Step width [Ω]
SL1010A-201 Pt100 (etc.)	Setting range 1	0 to 5 kΩ (others on request)	0.076 Ω
	Accuracy	± 0.1% of set value	
SL1010A-202 PT1000	Setting range 2	800 Ω to 4 kΩ	0.076 Ω
	Accuracy	± 1% of the set value	
SL1010A-203 NTC 10K (etc.)	Setting range 3	500 Ω to 475 kΩ	8.39 Ω
	Accuracy	± 1 % of set value	
SL1010A-204 NTC 100K (etc.)	Setting range 4	2.6 kΩ to 3.5 MΩ	53.3 Ω
	Accuracy	± 1 % of set value	
Cycle time		< 1 ms	
Electric strength		1 kV	

Table 5: Specifications of the temperature sensor emulator

Integrated Failure Emulation:

- Open circuit
- Short circuit (0 Ω)

Note:

Resistive sensors will be connected to a series resistor (R_V) and a reference voltage (U_{ref}) typically. The Scienlab Temperature Sensor Emulator can be connected in the same way. The limits and accuracies are described below.

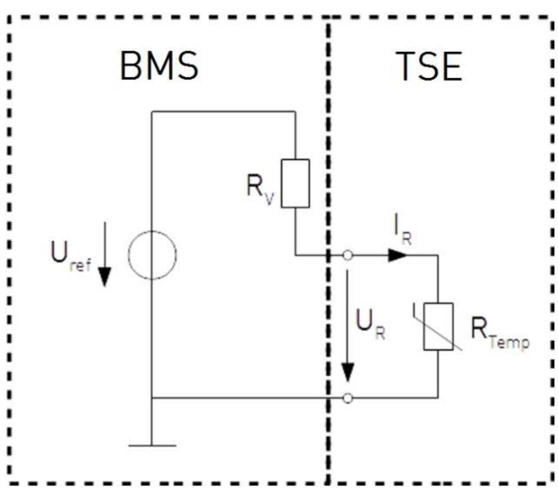


Figure 8: Equivalent circuit diagram

Voltage and current at the emulated sensor must not exceed the two following values:

$$|I_R| \leq \quad I_{R,max}$$

$$, with \;\; I_{R,max} = \frac{500\ V}{R_{Temp,max}}$$

$R_{Temp,max}$ describes the maximum value of the Scienlab TSE depending on the setting range.

Different sensor ranges can be selected by the DIP switch on the circuit board (see section Performing initial commissioning)

Emulated Sensor	$R_{Temp,max}$	$I_{R,max}$
e.g. PT100	4.99 kΩ	100 mA
--	112 kΩ	4.46 mA
e.g. NTC (10 K)	475 kΩ	1.05 mA
--	550 kΩ	909 µA
e.g. NTC (100 K)	3.5 MΩ	143 µA

Table 6: Sensor range and output current limits

The accuracy of the schematic of the Temperature Sensor Emulator (TSE) depends upon the measurement current of the temperature sensor input of the BMS. For the calibration process of the TSE three operating points are determinated. Each of these three operating points triggers a different schematic accuracy error. The accuracy of the TSE is a combination of these three errors. If these three errors are within the tolerance range the accuracy (±1% of the Resistance set point) of the TSE is ensured.

The accuracy of the Schematic of the TSE is put together by the following three errors:

1. input offset current (I_0)
2. output offset voltage (U_0)
3. gradient failure / gain error (F_R)

The accuracy of the TSE depends on the schematic of the BMS and the operating point. The deviation of the target value R and the real value $R^{|}$ can be calculated with the following formula.

$$R^{|} = \frac{R \cdot (1 + \mathrm{F_r}) \cdot (\mathrm{U_{ref}} + \mathrm{I_0} \cdot \mathrm{R_V}) + \mathrm{U_0} \cdot \mathrm{R_V}}{\mathrm{U_{ref}} - \mathrm{I_0} \cdot R \cdot (1 + \mathrm{F_r}) - \mathrm{U_0}}$$

If the three described errors (I_0, U_0 and F_R) are not exceeding the limits shown in Table 7, the accuracy shown in **Error! Reference source not found.** will be guaranteed. The measured values of I_0, U_0 and F_R of each TSE Channel will be recorded in the calibration protocol which is part of the delivery scope of the BMS Environment.

Error	Maximum limit
input offset current (I_0)	+6.066 x10^{-10} A
output offset voltage (U_0)	+1 mV
gradient failure / gain error (F_R)	±287.4 mV

Table 7: TSE error limits for I_0, U_0 and F_R

Current Sensor Emulation (CSE)

The Current Sensor Emulator emulates the charge- and discharge current of the battery pack by setting a voltage referring to the output voltage of a shunt- or hall sensor.

The Current Sensor Emulator is designed as a compatible plug-in-card to the cell-emulator. Up to 4 front ends for shunt or hall sensors can be connected. All channels are isolated against each other and to other system components up to an electric strength of 1 kV.

SL1010A-301 Shunt emulator including cable

SL1010A-302 Hall emulator including cable

Description		Specification
SL1010A-301 Shunt	Setting range	± 200 mV (offset) (others on request: ± 100 to 500 mV)
	Positioning accuracy	± 20 µV (offset) ± 0.1% of set-point
SL1010A-302 Hall	Setting range	± 5 V
	Positioning accuracy	± 500 µV (offset) ± 0.1% of set-point
Cycle time		< 1 ms

Table 8: Output current sensor emulator (shunt and hall)

Integrated Failure Emulation:

- Open circuit (via external. HiL control)
- Maximum channels selectable between Shunt and Hall Emulators are 96

Insulation Resistance Emulator (IRE)

SL1010A-IRE Insulation Resistance Emulator

The Insulation Resistance Emulator allows an emulation of insulation errors at battery pack voltages for R_ISO tests. It can be chosen if a battery positive or negative pole insulation resistance must be emulated to PE.

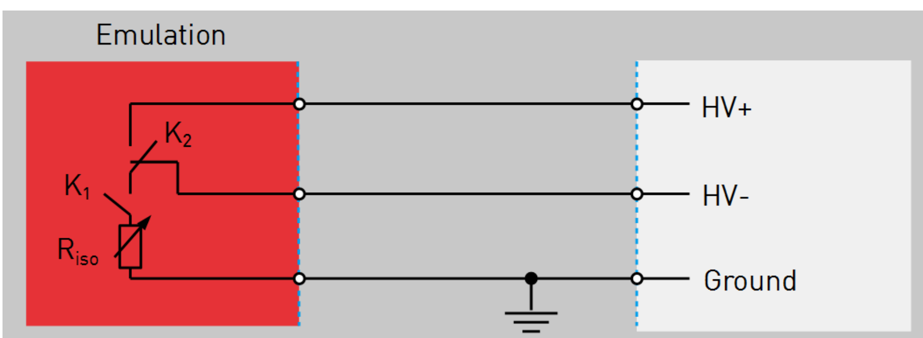


Figure 9: Schematic of the Insulation Resistance Emulator

Approach:

- 1. Select between HV+/Ground or HV-/Ground (K_2)
- 2. Choose insulation resistance value R_{iso}
- 3. Closing relay K_1 to initiate test case

Description	Specification
Setting range of R_{iso}	1 kΩ to 100 MΩ
Positioning accuracy 1	1% @ 1 kΩ to 1 MΩ
Positioning accuracy 2	2% @ 1 MΩ to 100 MΩ
Cycle time	<1 s
Dielectric strength	1.25 kV
Max. current	32 mA

Table 9: Insulation Resistance Emulator

HV Source

SL1010A-HV2 HV Source (1000 V)

Controllable high voltage sources can be used to emulate the DC link of the battery. A BMS has typically 2 HV Measurements. The first one is the sum of the series connection of all cells. The other one is located after the output relay, at the connection to e.g. inverter.

Figure 10: Source: FuG

- Type: FuG MCP 140-1250
- Voltage range 1...1000 V
- Current range: 0...100 mA
- Voltage accuracy: ± 0.04 % full scale
- Ethernet interface
- 19" 3 U rack model
- Maximum quantity allowed = 4

Cabinet Options

Safety

- Following safety requirements are given for the entire system
- System limits to protect specimen (DC-voltage, DC-current) parametrizable
- Self-protected cell-emulators will switch off in event of fault
- Over-temperature protection
- Emergency stop
- Door contact switch
- Emergency stop input for e.g. lab emergency stop
- Designed for durability operation and long lifetime

Interface

- Gbit/s Ethernet interface (including a Gigabit Ethernet-switch)
- 1 kHz (1 ms cycle time) TCP/IP update ratio at a dedicated multipoint-communication with a Gigabit-Ethernet capable HIL-system

Electricty feed-in

- 3, N, PE; 400 V; 50 Hz; pre-fuse (provided on-site) 16 or 32 A gG (depending on system size)
- 10 m supply cable (via cabinet's roof) with CEE-plug

Dimensions

- Dimension (W x D x H) mm: see Table 10 (displayed height is without cooling unit and rollers)
- Rollers (approx. 8 cm high)
- Cooling units (removeable): height 0,45 m
- Emulator cables: 4 m each

Cabinet option	Dimensions (WxDxH) mm
SL1010A-702	800x800x1200
SL1010A-706	800x800x2000
SL1010A-713	1600x800x2000
SL1010A-720	2400x800x2000
SL1010A-727	3200x800x2000

Table 10: Dimensions of each cabinet option

DUT Test Environment

Integrated Testing Area:

- Comfortable possibility to set up BMS (BMS Master Unit & CSC) into the test environment
- Integrated in emulator cabinet
- Incl. cabling between emulators and testing cabinet
- Top-hat rails as transition points for all emulators
- Easy cabling between emulator outputs and BMS
- Exchangeable board for various BMS
- Door contact for emergency stop

Figure 11: Example of a BMS Environment with test area (red)

	SL1010A-D01 (120 channels)	SL1010A-D02 (240 channels)
Dimensions (DxWxH) m	(400 x 400 x 800) mm	(400 x 400 x 1400) mm

Table 11: Dimensions of the integrated test area

SL1010A-D01 Compact integrated testing area for DUT – supports up to 120 channels

SL1010A-D02 Large integrated testing area for DUT – supports up to 240 channels

External Testing Board

This option offers an external testing board for connection between the BMS to the emulator outputs. A grounded plate includes all the clamps of the selected components and output filters (if selected).

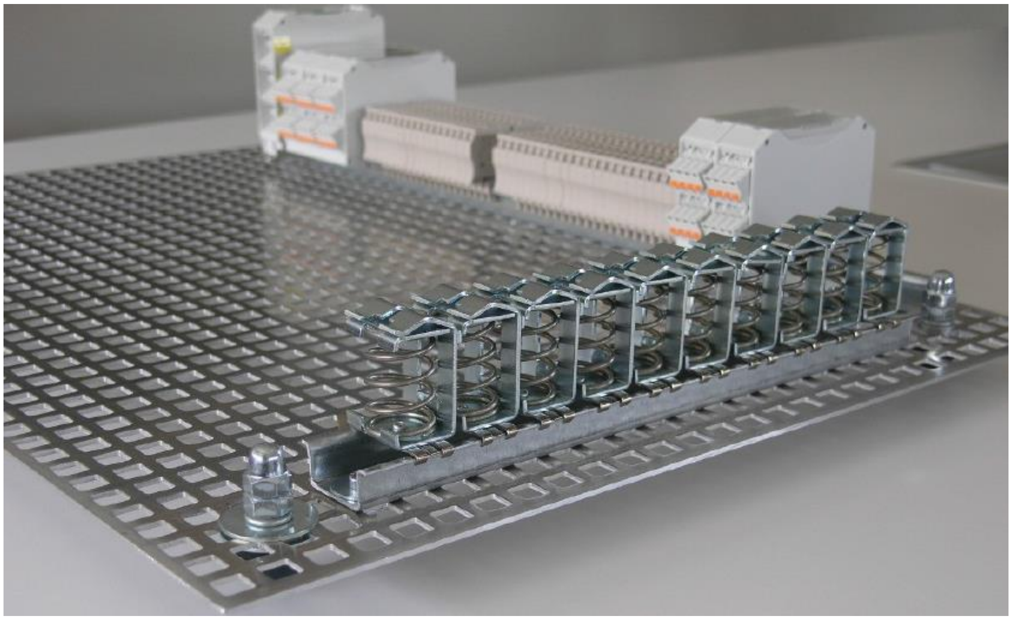


Figure 12: Example of external BMS Testing Board

SL1010A-D05 (60 channels)	
Dimensions (WxD)	(400x600) mm

Table 12: Dimensions of the external BMS Testing Board

SL1010A-D05 Small Testing Board - supports up to 60 channels

Software

General information

During the development and verification of a BMS it is necessary to test all interfaces and features of the DUT to ensure correct operation. Thus, it is possible to ensure efficient and safe operation of a battery with a final product. For fast and safe testing it is of advantage to emulate the component that is connected with the BMS while testing.

At the analogue interfaces of the BMS, components such as cells and sensors must be emulated.

Therefore, Keysight emulators of the BMS environment are utilized. A BMS has even more interfaces that are necessary for the operation of a battery, such as communication, control- and measurement signals and imitation of the electrical system.

Besides the emulators, Keysight offers a HiL solution for the BMS environment “BMS Environment”. Keysight is working together with Vector Informatik and dSpace.

The HiL-system accomplishes the following tasks:

- Modelling of the BMS environment
- Calculation of all target values on the basis of a model
- Control of Scienlab emulator
- Control of HiL-components (in-/outputs, CAN, etc...)
- Control of test bench components
- Implementation of automated test sequences

Keysight’s Scienlab PowerHiL BMS Environment is controlled by a state of the art real-time system. The powerful real-time PC calculates up to more than 100 cell models simultaneously in real-time with a sample rate of 1kHz. The real-time system offers CAN interfaces for simulation of several devices.

The user interface for the BMS Environment offers the possibility to control all emulators, I/O’s and communication interfaces manually. It also offers access to the signals, measured by the HiL system and to the model. Because of the large number of variables, signals and set-point values, it is possible to automate tests.

Signal Measurement Generation

Many BMS contain digital, PWM and analog in- and outputs for functions like:

- control of output relays
- cooling system
- activation
- fan speed feedback
- fault feedback
- heating system
- activation
- temperature feedback
- fault feedback
- interlock
- approval to the charger

Communication

The real-time system offers CAN interfaces which can be used for the simulation of e.g.:

- Vehicle CAN bus
- Charger CAN bus
- Debug CAN interface (for development)
- Measurement of communication between real components
- Manipulation of the communication between bus participants (man-in-middle)

Note: This option contains only the basic communication interfaces without a residual bus simulation.

Note: Some BMS units use SPI or Iso SPI for communication between master and slave modules. If required, Keysight can provide a specific offer for the integration.

Software Engineering

The Scienlab BMS Environment offers fast, flexible and reproducible tests of battery management systems (BMS) by emulating the behavior of cells, sensors and communications.

For testing the different functions of a BMS, the Cell Emulators have to react like real cells. For different steps of the development, cell models with different levels of complexity will be needed. After the development of BMS and battery test systems, Keysight used this knowledge to create extensive models to emulate the behavior of cells and other components of a battery pack.

To parametrize the cell models with the correct parameters, procedures to measure and characterize cells are necessary. Beside the identification of the parameters for the model, these procedures bring up necessary values for the parametrization of the BMS (cell limits, SOC estimate, etc.).

Finally, a real-time hardware will be needed to calculate the cell models during the BMS tests.

Battery Model

The basic Battery model is part of the delivery scope and characterizes the behavior of a cell in one operating point. Furthermore, the open-circuit voltage is described as a result of the SOC

Cell model as a parametrizable Matlab/Simulink block or as a TwinCAT3 function block

The model structure is shown in Figure 13. The values of all the Cell model parameters can be change by the user on the graphical user interface or in an automated test case.

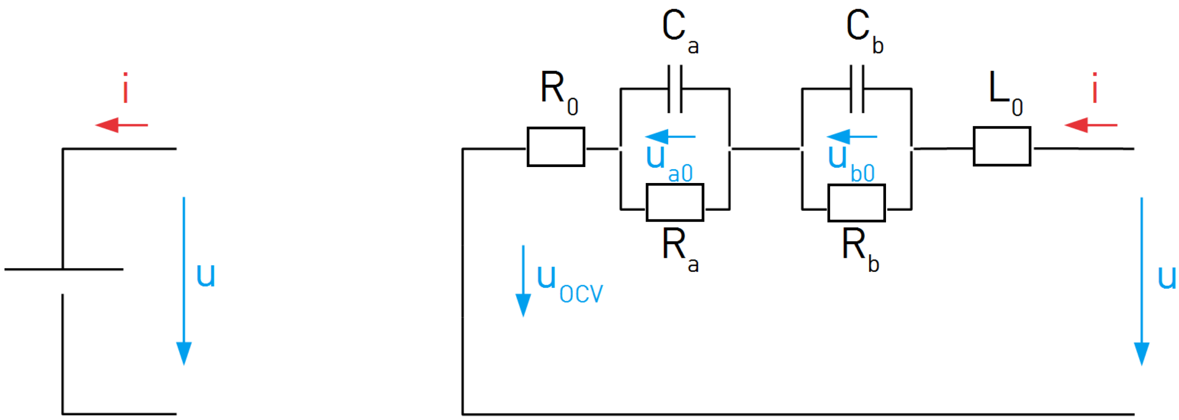


Figure 13: Structure of a cell (left) and a Li-Ion cell model (right)

- Model-parameters (specified as constants):
- Open-Circuit Voltage UOCV(SOC) [V]

- Internal resistance R0 [Ω]
- Internal impedance L0 [H]
- R-C elements (Ra, Rb [Ω], Ca, Cb [F])
- Initial voltages of the capacitors (Ua0, Ub0, [V]);
- Description of the model
- Parametrization example

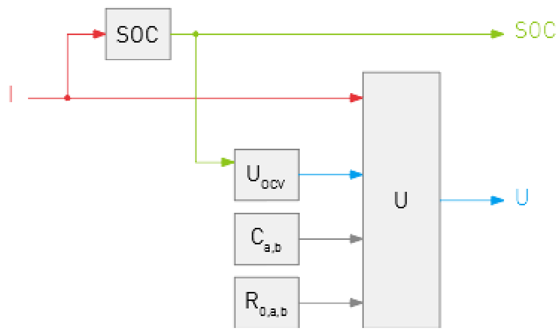


Figure 14: Basic cell model with constant parameters

A block diagram of the model is shown in Figure 14.

Test Automation

Because of the large number of variables, signals and set-point values, it is difficult to get reproduceable results in manual operation mode. For this case, the real-time system comes with a test automation software.

The test automation tool enables the user to simplify test design by combining different programming languages and graphical notations in one integrated design environment, to define and reuse test cases for and across product lines by supporting parameters, ECU variants and test variants.

Graphical User Interface

The Graphical User Interface (GUI) it part of the delivery scope. Scienlab provides a GUIs for CANoe (Vector) or Control Desk (dSpace) which is individually matched to the delivered hardware setup.

The user interface of the BMS Environment offers the opportunity to control the emulators I/O's and communication interfaces manually. Moreover, it offers the access to the HiL-system measured signals as well as to the model.

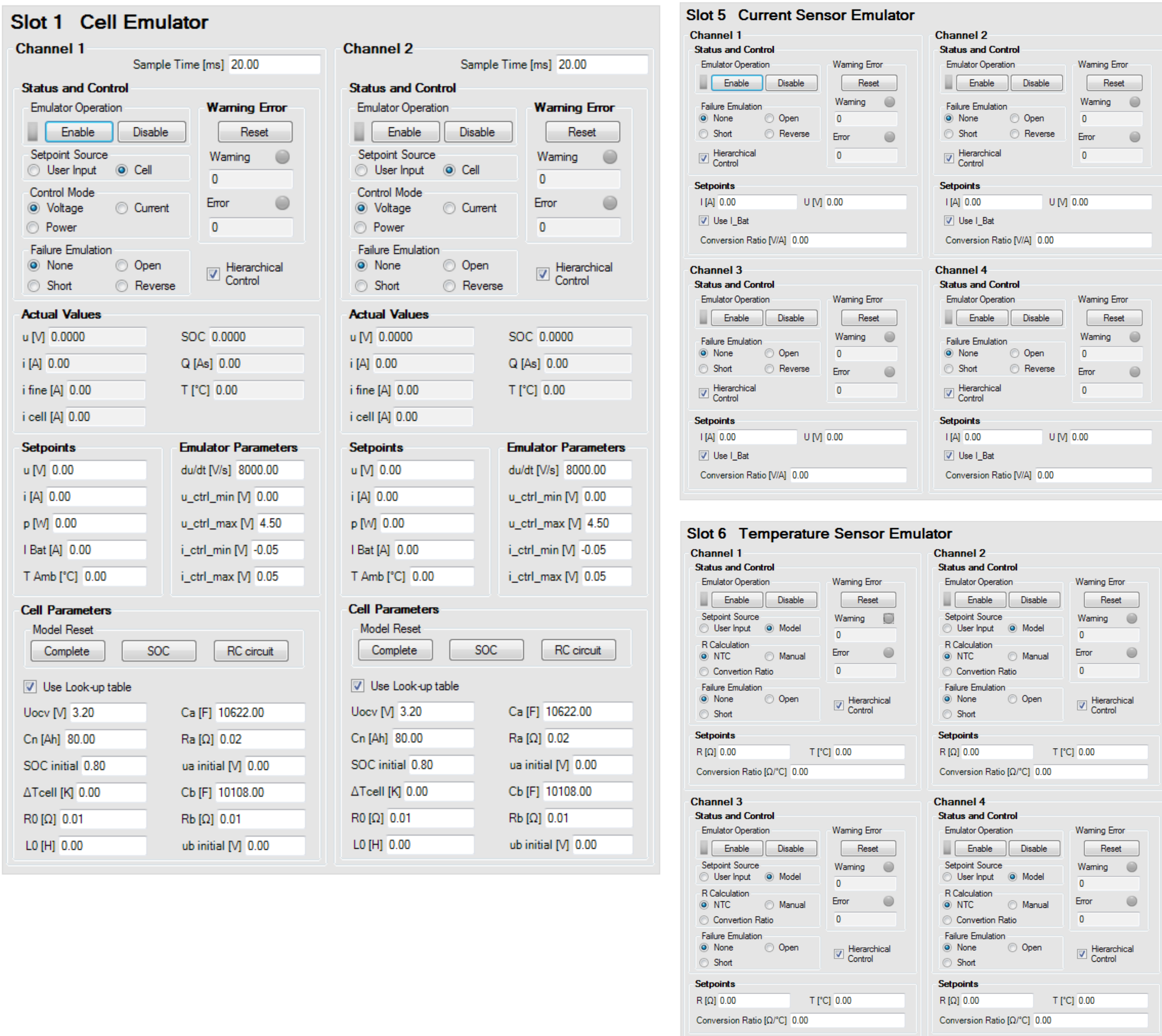
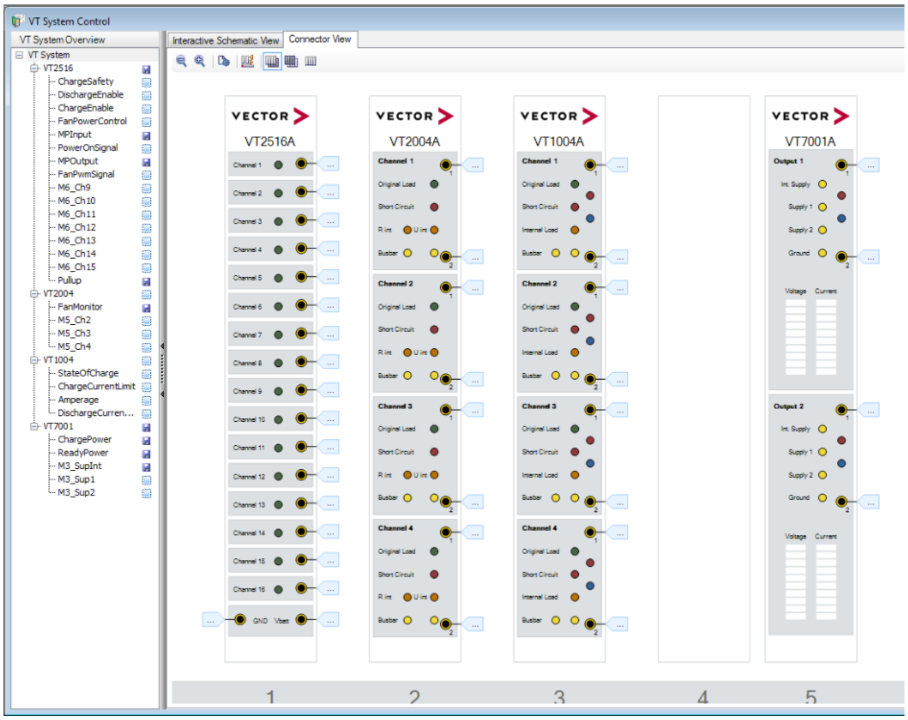


Figure 15: Example GUI #1



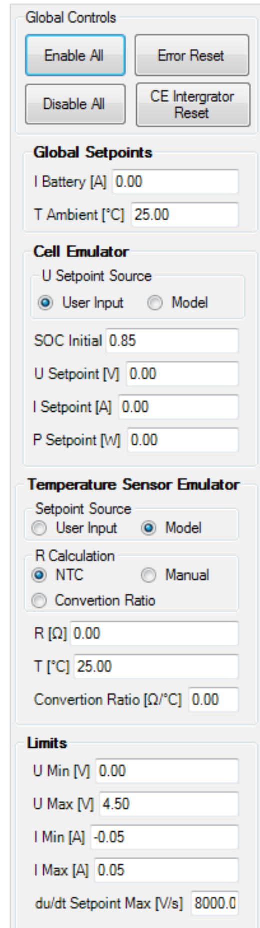


Figure 16: Example GUI #2

The BMS Environment values can be defined before starting (SOC, cell temperature, ambient temperature, status of the systems for example cooling, heating, relay). By activating the system, these values are transmitted to the outputs of the BMS Environment. While testing, more status changes can be made. Modifications such as charging/ discharging can be specified in the real time model measurement by consideration of the degree of complexity. The initial values of the model are transferred to the emulators and displayed in the user interface as status values. Users have a continuous overview of the system status. At the same time, measurement values chosen by the user can be saved in a report file. Subsequent analysis of the BMS reaction by environmental impact are possible.

Furthermore, it is possible to emulate several fault cases to evaluate the desired reactions of the developed BMS. It is also important to analyze the reaction of a BMS in critical working points.

Future Channel Extension

The Future Channel Extension enables you to expand the number of cell emulators, temperature sensor emulators and current sensor emulators.

SL1010A-851 Future cell emulator channel extension

SL1010A-852 Future temperate sensor emulator channel extension

SL1010A-853 Future current sensor emulator channel extension

System Cooling Selection

Cooling option	Article number	Inlet/ Outlet	Description
SL1010A-K01 Air cooling with fan – 2.5 kW	SK 3209.XXX	$^1/_2$ "	Air/Water heat exchangers roof-mounted
SL1010A-K02 Air cooling with fan – 4 kW	SK 3210.XXX	$^1/_2$ "	Air/Water heat exchangers roof-mounted
SL1010A-K03 Air cooling with compressor – 2kW	SK 3385.XXX	-	Cabinet cooling per air-air-heat exchanger TopTherm roof-mounted cooling units 'Blue eye'
SL1010A-K04 Air cooling with compressor – 3.8 kW	SK 3387.XXX	-	Cabinet cooling per air-air-heat exchanger TopTherm roof-mounted cooling units 'Blue eye'

Table 13: Cooling options

Service Options

Service features depend on the customer facilities, expertise and overall scope of the project. For that reason, it is not possible to give exact service efforts without knowing the requirements and goals of the customer. Keysight offers the following services to ensure a successful project execution and to reduce the ramp-up time for our customers.

HS003A-100 Project Management

Project Management is highly recommended for each test bench project. By ordering the project management service an experienced project manager is dedicated to your project and acts as direct communication interface from Keysight to the customers Project Management Team.

The project manager takes over the responsibility:

- To observe internal project progress and secure that project schedule/ project milestones are kept.
- That any unscheduled occasions with relevance for the project are immediately communicated and discussed with the customer.
- To consult and support the customer in case of any questions related to the project that might occur during project execution.
- To provide complete and accurate project documentation to the customer.

R9001A-201 Installation Service

The scope of the Installation Service depends on the customer's facility. Share all relevant information and requirements regarding test bench components that require installation, such as connection to the local grid and the local water supply, with your local field engineer so that the scope of service personnel and material costs for installation can be calculated.

Note: Installation can be executed by the customer.

R9001A-202 Commissioning – Test Solution

The Commissioning for the test solution is offered to guide the customer during first usage of the test bench after installation. Commissioning Service is recommended for each test bench project. It includes:

- Local presence of experienced test bench engineer during first usage of the test bench.
- Consulting of customer personnel with regards to intended usage of the test bench (e.g. initial test with customer specimen)
- Review of executed hardware installation of Keysight products.
- Review and consulting to software settings of operation software.
- Travel expenses

Note: Commissioning – Test Solution is offered on a daily base. Keysight recommends at least two days of commissioning service for each test bench project.

HS0003A-103 DUT Residual Bus Simulation

In order to work with the test bench directly after delivery, send the device under test (DUT) to Keysight. The DUT is integrated into the test bench and is commissioned together with the BMS Environment. It includes:

- Residual CAN bus simulation of the customer DUT
- Integration of an existing CAN .dbc-file in test-bench Simulink model
- Integration of the DUT Parameters into the graphical user interface
- Commissioning of the Test Bench including the DUT at Keysight Bochum

Note: The .dbc-file has to be available to Keysight engineers six weeks prior to the commissioning at Keysight.

HS0002A-102 Remote Support Service

Keysight offers the Remote Support Service to support, consult and train the customer's operation personnel. Remote Support Service is executed via remote (phone/ Internet). It includes:

- Customer DUT Issues and Test Case Consulting
- Direct access to an experienced system specialist via Phone/Internet.
- Support for failure analysis and trouble shoot
- Software and programming support & consulting for Test Cases
- 1 package = 1 day (8 hours)

HS 0004A-100 Staff Training

Staff Training is made up of:

- Software Training (depends on which HiL was chosen)
    - dSPACE: ConfigurationDesk (SCALEXIO Hardware introduction, hardware resource assignment)
    - Vector: CANoe (VT-System, hardware resource assignment)
- Matlab model, CAN-Bus configuration.

After the Staff training the participants will be able to:

- Control the BMS Environment
- Write and implement test cases
- Implement changes to the battery model
- Observe and analyze measured data

Note: The Staff training is for maximal of four people and a duration of two days. The training will take place on customer site (on request).