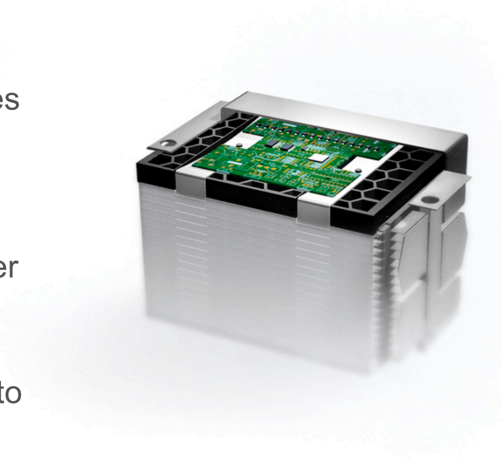
Keysight Technologies

Secure and Precise Testing of Battery Management Systems

SL1091A

Safe Use of Energy Storage Devices

The introduction of new storage technologies and the interconnection of multiple energy storage cells to form modules or packs requires an intelligent battery management system (BMS). The BMS is also growing in importance due to the increasing use of batteries in the area of electric mobility (e.g. passenger cars, forklift trucks and conveyor vehicles), for power tools or stationary storage. It assumes key safety, control and regulation functions. For example, it monitors various parameters such as voltage, current and temperature in order to determine the state of charge (SOC). In addition, the BMS is responsible for thermal and energy management, cell balancing and performance. Reliable functionality can only be guaranteed if the BMS is validated by a variety of tests with different cell states, environmental conditions and error scenarios. For a safe as well as time- and cost-efficient testing of the BMS, it is advantageous to replace the components connected to the BMS (e.g. individual cells, sensors). This permits realistic emulation of the characteristics with respect to accuracy and dynamic response.



KEYSIGHT TECHNOLOGIES

Key Benefits

- **Safety for personnel and products**
  Since real components are emulated when conducting BMS testing with the Scienlab solution from Keysight, the risk of hazards from cell chemistry and electrical energy of the battery are significantly minimized. This also ensures maximum safety for personnel and products in critical operating points.
- **Real-time capable interfaces**
  The standardized and real-time capable interfaces of the emulators guarantee fast data transfer of 1 Gbps between the test systems and the HiL system. They are extremely reliable and permit fast integration in any HiL test environment.
- **Parameterized cell models**
  Our test system can support BMS development, at the customer's request, with high-precision parameterized cell models for each cell type. These can have different levels of complexity and detail and in this way emulate the behavior of any real cells.
- **Maximum measuring precision**
  The voltage measuring accuracy of ± 1 mV and the current measuring accuracy of ± 2 μA ensure exact voltage and current adjustment and therefore optimum emulation of the cell characteristics. The ease of calibration of the BMS test environment guarantees reliable system quality.
- **Dynamic control**
  Highly dynamic bidirectional voltage sources induce voltage jumps in under 80 μs. A small signal bandwidth of typically 1 MHz means that even high-frequency current pulses, such as those that occur during active balancing, can be emulated without any trouble.

Fields of application

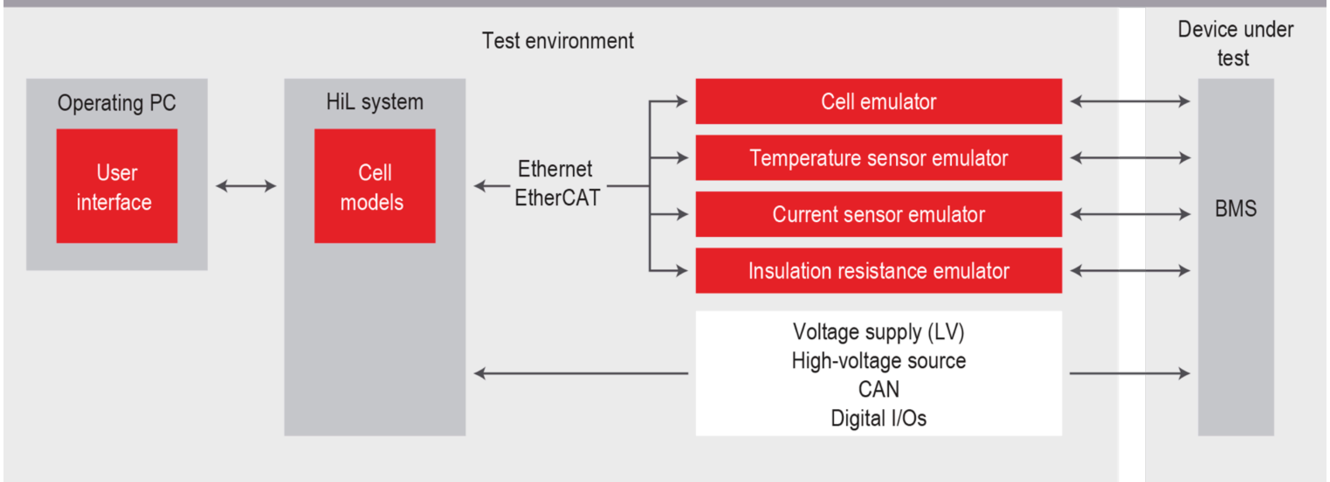
- Reproducible testing and optimization of the BMS
- Emulation of individual cells, as well as modules and packs at cell level
- Validation of all BMS development steps with respect to hardware and software
- Testing of newly developed algorithms (balancing, SOC, SOH)
- Tests with passive and active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

The solution

Support in every step of BMS development

As a service provider and manufacturer of test systems, Keysight offers customer-specific solutions for the reliable development and validation of battery management systems. The services range from modeling and characterization of the battery cell, through model implementation, to the customized and modular Hardware-in-the-Loop (HiL) system. The test environment permits fast, flexible and reproducible tests for emulating the behavior of real battery cells, current and temperature sensors, as well as communication with external systems. Cell models for each cell type with different levels of complexity and detail can be provided for this purpose. The models are calculated using real-time computations integrated in a HiL system.

Structure of a HiL test environment for validation of the BMS

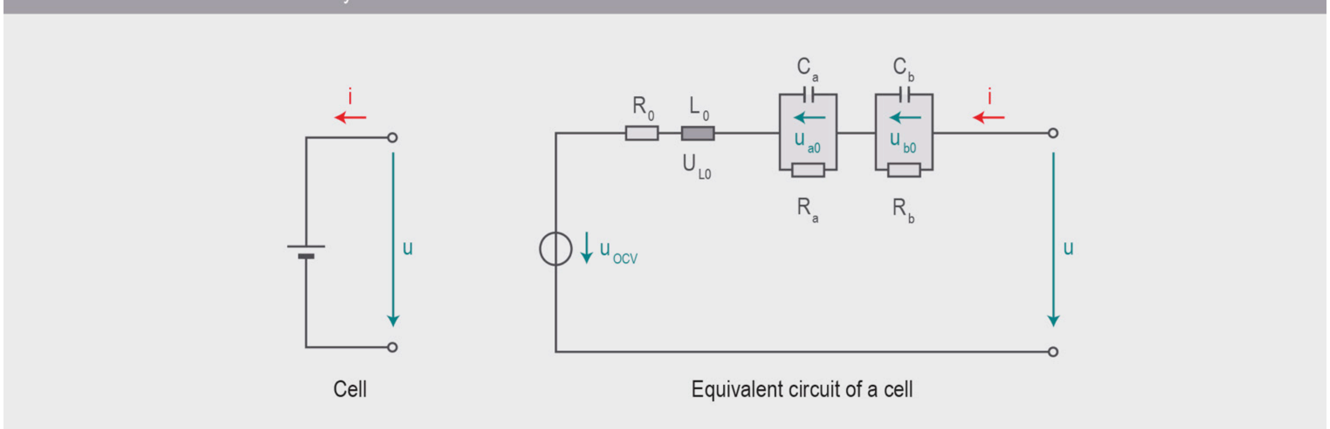


Simulation of all battery characteristics

The BMS test environment emulates all the components connected to the BMS. The real cells are emulated using cell emulators. A wide range of cell types by triggering with parameterizable cell models and controlling them in real time. All functions of a BMS can be tested under different environmental conditions in combination with temperature sensor emulators, current sensor emulators and insulation resistance emulators. The output voltage range of the cell emulators covers the typical battery voltages and is also rated for innovative areas of application like cells with high-voltage materials. The emulators permit a smooth and uninterrupted transition between source and sink mode.

An additional high-voltage source provides the option of testing the response of the BMS to incorrect measurement of the output voltage. As well as CAN communication with the vehicle, the BMS test environment also delivers digital control signals and the supply voltage for the BMS.

Parameterizable model of a battery cell



Modeling of cells

Different models can be selected for emulating the behavior of real cells. As well as parameterizing the elements of an equivalent circuit, complex models for emulating the influence of temperatures, SOC, SOH, etc. can also be implemented.

Reproducible measurement results

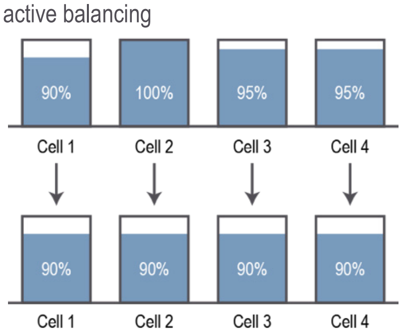
The high-precision measuring technology is traceably calibrated and guarantees measuring and adjusting accuracy. All the channels in the systems are synchronized via the internal data bus, which means that all measured values and set value outputs are reproducible.

Safety first

Verifying the safety functions is the top priority when developing a BMS. In addition to the desired operating points of a BMS, variable error scenarios are also simulated, e.g. open circuit, short circuit, overvoltage/undervoltage, overtemperature/undertemperature and overcurrent. This permits critical operating points for the device under test to be safely approached, and guarantees the safety of the test laboratory and personnel. In addition, the insulation strength at the connections of all emulators is 1 kV between each other and with PE.

BMS test environment

Extensive Tests for Successful BMS Development

Test scenario	Our solution
Safety algorithms of the BMS • Recording of cell undervoltage and overvoltage • Recording of overcurrent • Recording of overtemperature and undertemperature • Recording of short circuit/open circuit • Verification of the cell connection time • Verification of the internal insulation monitor in the BMS	• Emulation of different cell types in each operating point at all times • Emulation of the current sensor • Emulation of standardized, resistance-based temperature sensors: Pt50, Pt100, etc. • Short circuit, idle and polarity reversal of each cell emulator channel possible • Additional internal voltage measurements upstream of the output relays • Emulation of an insulation resistance (insulation fault) at the battery terminals
Verification of the algorithms for determining SOC, SOH, SOF • Determination of the state of charge (SOC) of the battery module or pack • Determination of the state of health (SOH) of the battery • Determination of the state of function (SOF) of the battery • Determination of the state of charge after one, several or partial charging cycles • Testing of the charging control	• Emulation of modules and packs at cell level • Implementation of different battery models (e.g. lithium ion cell model) • Control of the cell voltage in accordance with the implemented model • Verification of the algorithms through true-to-charge recording of the balancing currents per cell and consideration in the model calculation • Emulation of different current sensors for recording the charging/discharge current of the battery such as shunt and Hall effect sensors as well as sensors with a CAN interface • Emulation of cell aging using non-linear parameter dependencies between e.g. internal resistance and capacity in the models as well as determination of the charging cycles • Selection of models of varying complexity for different development stages • Simulation-based enhancement of the individual algorithms • Modeling and visualization using products from e.g. dSpace, National Instruments
Testing balancing functions • Verification of error-free algorithms for cell balancing • Detection of the max. cell voltage during charging and active balancing • Verification of error detection during balancing • Verification of the same SOC in each cell after charging/balancing • Verification of the balancing current within the specified range • Testing of active and passive balancing circuits • Testing of inductive and capacitive balancing circuits • Assembly and connection technology oriented towards the cell with low-inductive connection	• Verification on the basis of exact battery models • Emulation of the cell impedance, including for high frequencies, with passive output filters at the connections to the device under test • Avoidance of unexpected induction voltages at high current gradients during active balancing  Balancing
Communication with the peripheral devices (e.g. vehicle) • Communication from the higher-level control system • Error insertion by Failure Insertion Unit for all electrical signals and bus interfaces	• Communication via CAN interfaces • Dynamic environment simulation of all connected sensors • Connection of all digital inputs and outputs • Remaining bus simulation via HiL test environment

TECHNICAL DATA

Cell emulator

Voltage	0 ... 8 V
Measuring and adjusting accuracy	<1 mV
Max. output current	±5 A (parallel operation: ±10 A)
Max. output power	±40 W (parallel operation ±80 W)
Max. voltage rise time (3 V –> 5 V)	<-80 µs
Insulation strength	1 kV to other emulators and to PE
Current measuring accuracy at ±10 mA	±2 µA + 0.05% of measured value
Current measuring accuracy at ±5 A	±1 mA + 0.05% of measured value

Temperature sensor emulator

RTD sensors	Includes Pt100, Pt500, Pt1000, Ni & KTY
Insulation strength	1 kV to other emulators and to PE
Adjusting range	0 … 5 kΩ
Resolution	0.1 ohms
Max. adjusting accuracy	±0.1 Ω ±0.1% of adjustment value

Current sensor emulator

Adjusting range	±100 mV
Max. adjusting accuracy	±10 µV ±0.1% of adjustment value
Insulation strength	1 kV to other emulators and to PE

Insulation resistance emulator

Adjusting range	1 kΩ … 100 MΩ
Max. control accuracy at 1 kΩ … 1 MΩ	1% of adjustment value
Max. control accuracy at 1 MΩ … 100 MΩ	2% of adjustment value
Insulation strength	1 kV to other emulators and to PE

Voltage source

High-voltage adjusting range (voltage)	e.g. 0 … 650 V, others on request
Low-voltage supply	e.g. 24 V, others on request

I/O

Input/output	Digital, PWM

Interface communication

With the HiL system	Ethernet, EtherCAT (1 kHz, real-time-capable)
With the peripheral device	CAN

BMS test environment as system cabinet

BMS test environment as desktop unit

Customized System Configuration

The modular design of the BMS test environment enables customers to put together a test environment adapted to their application with parameterized cell models and software for triggering the system. Standardized interfaces mean that the system can be implemented in any HiL test environment. The modular system architecture also permits subsequent extension of the test environment and therefore adaptation to new test requirements at any time. Different variants are available here.

The Right Solution for Every Step of Battery and BMS Development

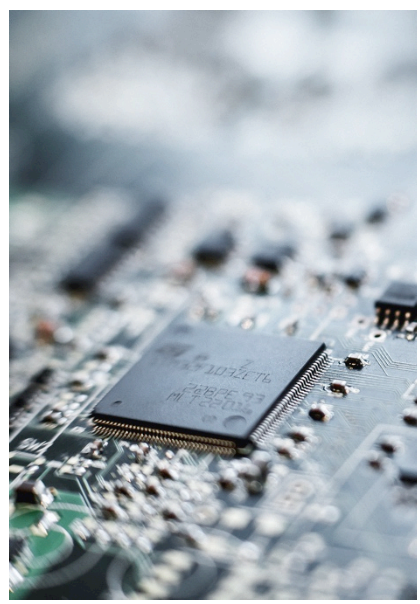
As an established manufacturer of energy storage test systems, Scienlab has a sound knowledge of batteries and BMS. In addition to the BMS test environment, Scienlab offers an extensive range of services around BMS and battery development. We also realize customized BMS and energy storage on request – from development to validation using proprietary test systems in the test lab. Scienlab is certified to DIN ISO 9001:2008 and manufactures products in accordance with the ECE and EC regulations as well as with type approval by the German Federal Motor Transport Authority (KBA) if necessary.

Everything from one source – from the idea through to on-site commissioning

Our employees are the guarantee for individual engineering services of the highest standard:
all products are developed and produced at the Bochum location – from hardware production and software development through to system acceptance. We have a deep understanding of user needs. This is further developed in a continual dialog with customers and forms the basis for products that allow our customers to perform their tasks with maximum efficiency and reliability. The resultant high-end solutions provide our customers with a decisive competitive edge.

What Scienlab test systems offer at a glance

- Evaluation and optimization of existing battery systems and BMS
- Selection and characterization of suitable cells for the specific application
- Fully model-based software development and code generation based on MATLAB/Simulink or provision of the software environment for software development by the customer
- Creation of cell models for implementation in model-based development
- Provision of components, methods and services for all aspects of BMS development (hardware and software)
- Consultation on and optimization of the battery system design with respect to assembly and connection technology, thermal management, electromagnetic compatibility (EMC) and safety
- Development and production of customer-specific battery systems and BMS incl. operating strategy (cell monitoring and balancing, SOC determination, protection)
- Validation using Scienlab battery and BMS test environments



Learn more at: www.keysight.com

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