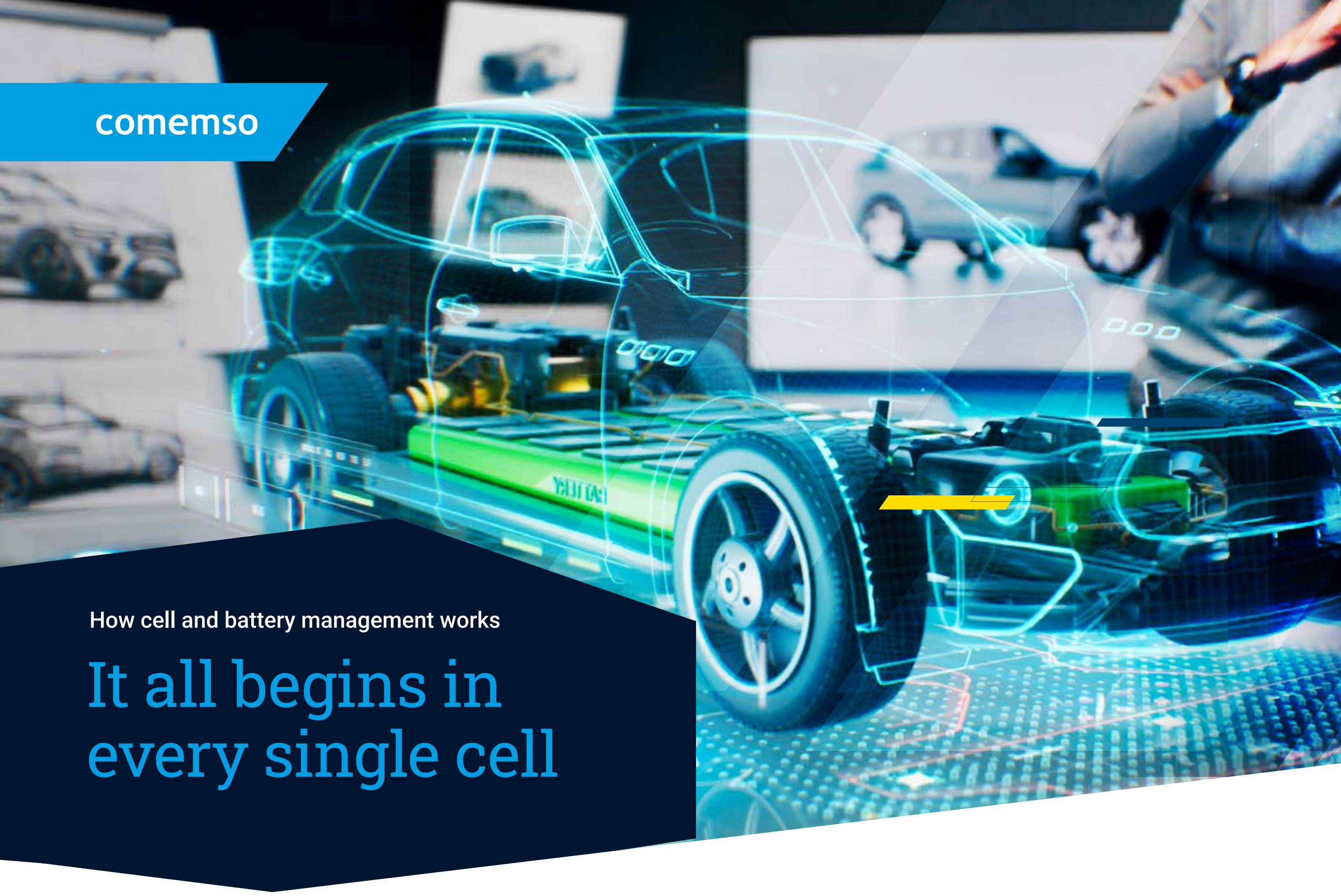
Battery Cell Simulation BMS Testing

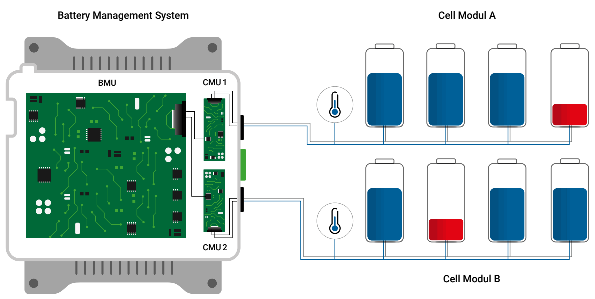
The Battery Cell Simulator



How cell and battery management works

It all begins in every single cell

Electric mobility is advancing rapidly worldwide. For today's mobile energy storage systems, this means not only delivering very high performance but also ensuring reliable and safe operation. To this end, the voltage and temperature of each individual cell are constantly monitored. This task is carried out by a monitoring system known as the Cell Management Unit (CMU).



Individual battery cells are connected to form a cell module, each of which has its own CMU. To ensure that the voltage can be reliably measured, the CMU is connected to the positive and negative terminals of the cells via measuring leads. The additional connection to the temperature sensors is essential for the optimal charging and utilization of the batteries.

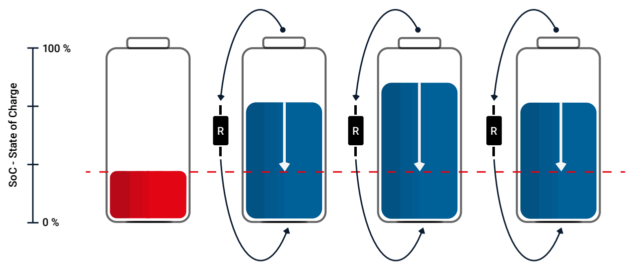
The Battery Management System (BMS) comprises the Battery Management Unit (BMU) and all the Cell Management Units. The BMU is the central control unit for battery modules such as drive batteries in electric vehicles or other types of energy storage systems.
It acts as the brain, consolidating all the information from the battery cell monitoring system. Using the battery cell voltages, the BMU determines the current state of charge (SoC) and handles all communication between the drive battery and the vehicle.

It also issues commands to balance the cells where necessary, to prevent the battery cells from becoming deeply discharged or overcharged.

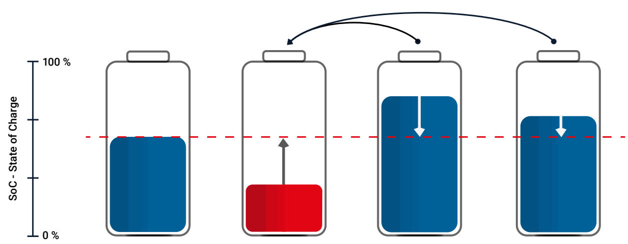
In battery-powered vehicles, the BMS is powered by the 12/24-volt on-board electrical system and therefore does not affect the range when the vehicle is stationary.
In contrast, cell management units are usually powered by electricity from the drive battery and therefore cause minimal charging losses. One reason for this is that, during the development of the CMU, care is taken to keep energy consumption to a minimum and to implement a sleep mode in order to minimize self-discharge as much as possible. The internal resistance of individual cells can vary significantly due to a wide range of factors, such as production variations or ageing.
This can result in varying charging and discharging curves, which may lead to critical deep discharge in the battery

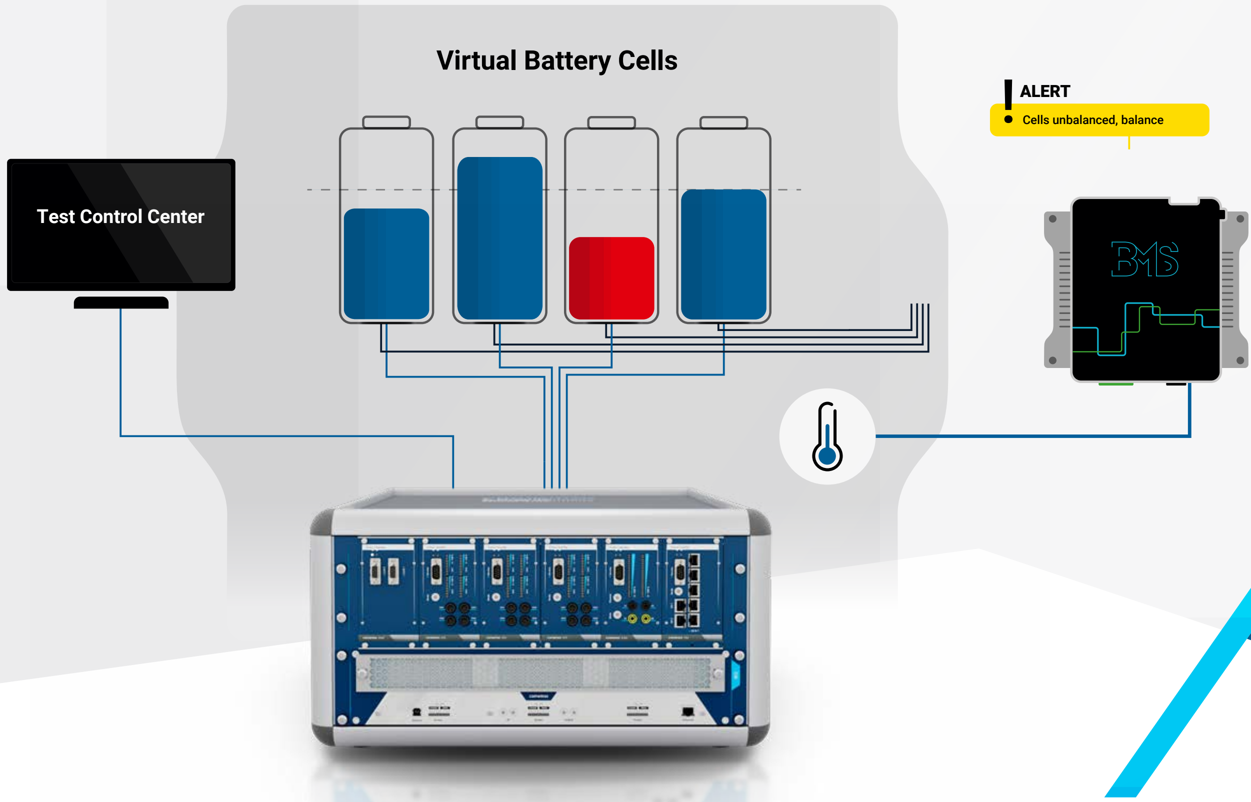
cells or cause the final charging voltage to be exceeded during the charging process. Depending on the type of battery, this can result in irreparable damage or even a fire in the battery modules!
If discrepancies in charge levels are detected, the charge levels of the individual battery cells can be adjusted using a balancing control system. This process is known as balancing. An electronic circuit, which is an integral part of every BMS, controls the uniform charging of each individual battery cell within the cell module. As soon as one cell reaches an SoC of 100% whilst the other cells have different voltages, the entire cell module is no longer charged. Balancing must be carried out by this point at the latest. The fully charged cell is discharged to the same level as the remaining cells. Thereafter, all cells continue to charge together.

Passive Balancing
In passive balancing, resistors are connected to the cells with a higher state of charge (SoC) using a defined algorithm, so that these cells are only charged slightly further or are even discharged. The remaining battery cells in the series connection that are not yet fully charged continue to be supplied with the full charging current until the SoC is balanced. This method of cell balancing is easy to implement and therefore cost-effective. However, it involves converting energy into heat, which reduces efficiency.



Active Balancing
With active balancing, on the other hand, charge is transferred between the battery cells. This process is controlled by the BMU. In this process, energy is transferred from cells that are already fully charged to neighbouring battery cells that have not yet reached their full charge. The advantage here lies in the higher efficiency, as only a small proportion of the energy is converted into heat. However, active balancing involves greater complexity in terms of circuitry. This results in higher costs for development and hardware.





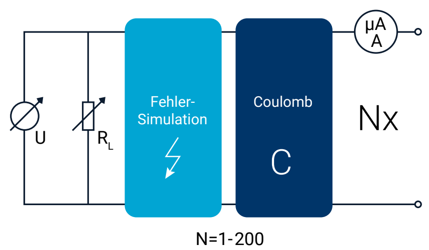
The virtual cell

Testing conditions using real batteries are dangerous, cannot be replicated and cannot be automated. To validate battery management systems, adjustable 'virtual battery cells' are required, which are implemented as cell modules within the battery cell simulator. As all electrical properties can be configured, the battery management system can be used to simulate all necessary states and faults.

High-precision current meters are used between the cell input of the BMS and the cell output of the cell module for quiescent current measurements and to detect unwanted leakage currents, which may occur, for example, due to faulty outputs of the battery management system or incorrect software control. Leakage current measurement enables early detection of faults in the BMS shutdown process, thereby preventing deep discharge and damage to the battery cells. In addition, the temperature sensors installed on the cells are replaced by a suitable galvanically isolated temperature sensor emulation, namely the NTC/PTC sensor simulation. This allows all data signals from the individual cell modules to be fed into the test bench or hardware-in-the-loop (HiL) system. The battery cells and temperature sensors from comemso emulate real-world behaviour, enabling the BMS to be operated in the laboratory.

Error simulation also makes it possible to generate faulty system states, thereby enabling the malfunction of a component and the necessary detection of such a fault to be tested in the laboratory. A comemso battery cell simulator is therefore an essential test instrument for verifying full functionality of the BMS.

Areas of application
Typical users of a battery cell simulator include algorithm developers for passive and active balancing, as well as developers of battery management systems, but also manufacturers of chips for battery management systems, energy storage and vehicle manufacturers, who wish to carry out functional testing prior to BMS integration into series production, as well as testing and certification laboratories.



Integrated fault simulation, including Coulomb and leakage current measurements

BMS Test System
with 144 virtual Battery Cells

comemso

Personalized advice
You can benefit from our many years of experience in electric mobility. We would be happy to advise you personally and work with you to find the right solution for your project. Our technical sales team looks forward hearing from you!

Most demanding requirements

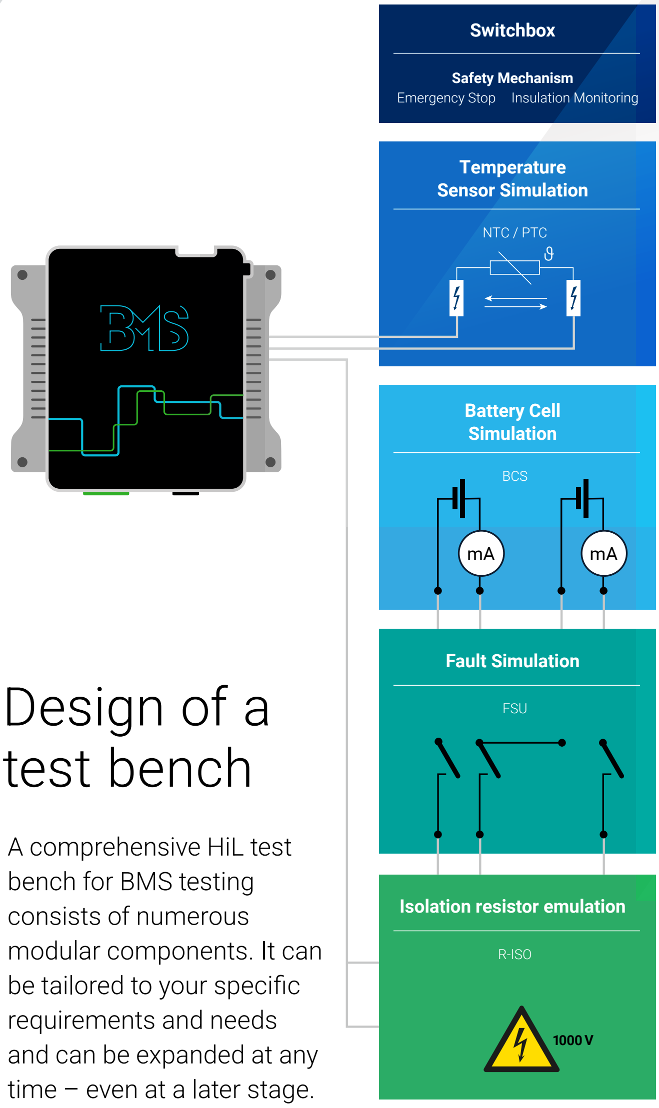
A battery cell simulator (BCS) must be capable of covering a wide range of areas for the functional verification of a modern BMS and must also demonstrate high voltage regulation accuracy even at high balancing currents in order to accurately emulate the state of charge of a battery cell. Precisely matched hardware and software controllers are required, whilst lean control algorithms guarantee behaviour that is both dynamic and safe.

comemso battery cell simulators are constructed exclusively from high-quality circuit components that ensure optimal noise suppression, smoothing the output signals and thus enabling the verification of passive and active balancing in the current range up to 6.0 A.
High-precision measurements of quiescent and leakage currents are performed in the µA range. Balancing algorithms are always validated using mA measurements across the full range or via Coulomb measurement.
The integrated fault simulation offers various simulations of short circuits, open circuits, polarity reversal and incorrect cell installation, depending on the selected variant. Thanks to the high isolation per cell, the total voltage of the battery cell simulator can reach up to 1500V, making it possible to create battery modules with up to 300 cells, each rated at 5 V. It provides a reproducible and reliable solution for the comprehensive functional verification of modern BMS systems for both software and hardware. All measurement parameters, such as voltage sources, current sources and current sinks, are fully calibratable, ensuring that comemso test systems are future-proof.

The component system for modular solutions

The comemso battery cell simulators are based on a modular design principle and offer a wide range of customized solutions in combination with standard components. It is this flexibility that makes it possible to create systems of various sizes and to meet individual customer requirements. For example, comemso offers portable table-top systems with 12–36 cells, which are ideal for chip manufacturers, start-ups or those new to the field in academia. The medium-sized systems, with 24–60 cells, are attracting interest from developers of battery management systems as well as those working on active and passive balancing.

Customized projects can also be accommodated with more than 240 cells on request. All systems enable battery management systems to be tested from the cell level right up to the pack level. All system sizes can also be configured as end-of-line variants for continuous operation in series production validation, in test and certification laboratories, or for final acceptance testing at the vehicle manufacturer.



Keep an eye on your surroundings

Under ideal conditions in the laboratory, a battery management system operates flawlessly. Even under adverse climatic and environmental conditions, it must always be ensured that all safety algorithms function correctly – in cold and hot conditions, and in sandy or salty environments. To ensure optimum performance throughout the entire service life of an electric vehicle, many Tier 1 suppliers use a climate chamber for development and/or end-of-line testing.

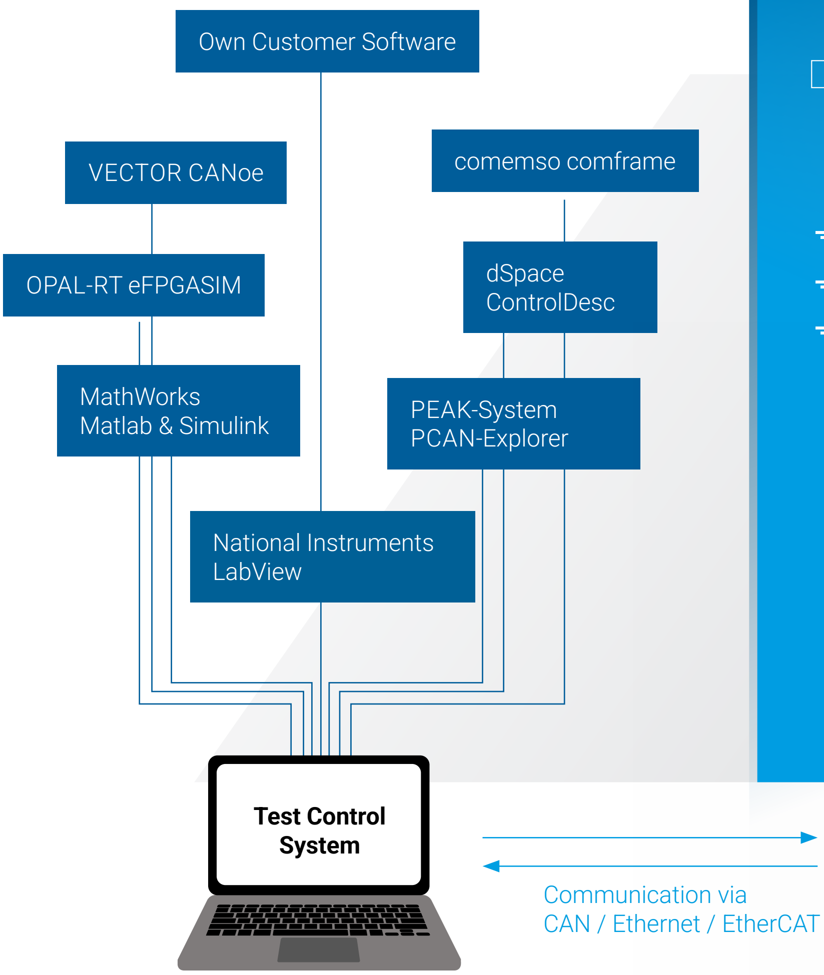
comemso has developed a highly efficient solution:
A test system featuring a climate chamber capable of accommodating up to 12 BMS units, enabling automated testing at both higher and lower temperatures. This allows end-of-line tests to be carried out more efficiently and in rapid succession. A multiplexer (MUX) speeds up the tests. It gradually multiplies the number of battery cells to the required test unit without the test specimens being under-supplied. In a further step, the next test temperature is set and the tests are carried out again in sequence. This saves a considerable amount of time when changing temperatures.

Design of a test bench

A comprehensive HiL test bench for BMS testing consists of numerous modular components. It can be tailored to your specific requirements and needs and can be expanded at any time – even at a later stage. This means you can start with a BCS comprising just a few cells. You can then flexibly expand this with additional cells and functions at a later date.

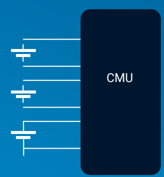
Hardware & Software fits together

For test systems that can be deployed quickly and at low implementation cost, comemso's battery cell simulators support globally established software solutions. They can be quickly integrated into existing software test environments. Using a test automation system, sequential test runs can be carried out around the clock without interruption.
The system saves time and delivers greater value by producing higher-quality test results. With a wide range of connectivity options, the system is an indispensable piece of testing equipment.

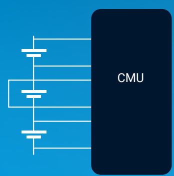


Integrated fault simulation

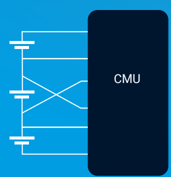
To ensure optimum results and precise cell voltage, an error simulation is built into the BCS electronics of each cell.



Connection failures
Broken cables in the connection between cells and the BMS, material fatigue...



Short circuits
Faulty battery cells, cell control faults, faulty electronic components ...



Reversed polarity
Wiring faults, reversed polarity in a cell ...

Thermal temperature monitoring

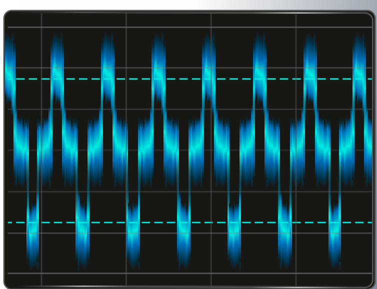
Battery cells operate within a narrow operating temperature range. The service life and cycle stability of the battery cell, as well as the functional safety of the battery, depend largely on the battery cell remaining within this range.
If the temperature exceeds a critical value, thermal runaway occurs. In this process, the temperature rises extremely rapidly within milliseconds and the energy stored in the battery is released abruptly. This results in extremely high temperatures and a fire that is virtually impossible to extinguish using conventional methods. To minimize the risk of thermal runaway, the BMS must ensure the thermal stability of the energy storage system. This is achieved by means of appropriate temperature sensors (NTC/PTC) in the battery cells or the battery module.
For this reason, modern battery cell simulators must not only ensure accurate current and voltage measurements, but also precisely emulate temperature. Galvanically isolated temperature sensor emulation for NTC and PTC resistors in the high-voltage range, as well as the simulation of short circuits and open circuits in the sensors, are also available.

Integration in automated test systems

The comemso battery cell simulator features two remote control interfaces. These are used to carry out the entire configuration process and to read out the measurement values from all sensors for the current voltage, current, error flags and hardware temperature. An unlimited number of cells can be addressed and read via the CAN interface and Ethernet ModBus.

For high-speed applications involving up to 120 cells, the system is equipped with an additional EtherCAT interface capable of communicating cycle times in the microsecond range.

All available interfaces are publicly accessible and documented – the test system software can be freely selected. Another benefit is full integration into existing software environments. These tools offer scripting and test generation capabilities for automating test scenarios, including comprehensive test reports. Furthermore, MATLAB models can be integrated for tests involving dynamic cell behaviour.



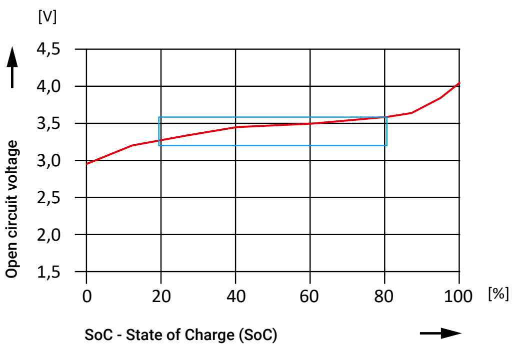
Voltage oscillation

Charging with alternating current (AC) can expose the BMS, the vehicle's on-board charger, to electromagnetic interference. On the one hand, the BMS can filter out this interference; on the other hand, the BMS should also be able to monitor dynamic cell behaviour, which would be overlooked if the filtering were too strong. To optimize the filtering accordingly, comemso has developed a new software function called 'Voltage Oscillation'.

A quasi-sinusoidal voltage with an amplitude of up to 35 mV (70 mVpp) – which can be set individually for each cell – and a frequency of 1 - 1000 Hz is modulated onto the DC voltage to emulate a noise signal.

Precision spot-on

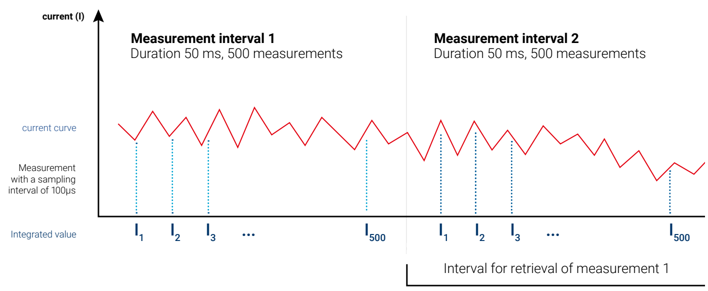
When determining the state of charge of the cells in a battery module, measurement error is of crucial importance. Even inaccuracies of ±10 mV can hinder active charge balancing. The accuracy of the cell measurement, in turn, depends on the CMU's voltage reference. The simplified discharge curve illustrates just how important accurate cell voltage measurement is.



The charging curve varies in flatness depending on the cell chemistry. However, the example shows that the flattest section is usually found in the range between 20% and 80% SoC and is relatively linear. In the figure, 20% corresponds to approximately 3.25 V and 80% to approximately 3.6 V. Between 20% and 80% SoC (60%), there is therefore a difference of 0.35 V (350 mV). If one now wishes to determine the SoC accurately for each individual percentage point, the voltage can be calculated. According to the sampling theorem, the CMU should measure the voltage with twice the accuracy, i.e. 2.9 mV.

To achieve this level of measurement accuracy for the CMU, the BCS must simulate with twice the accuracy (i.e. 1.45 mV) in accordance with the sampling theorem. This applies under all conditions and for different balancing currents. The most precise battery model is of no use if it cannot translate that precision into reality with the same level of accuracy.
comemso prioritizes precision and sets the standard at ±0.5 mV. For the end-of-line version, this value is even specified as ±0.3 mV.

Current measurement based on Coulomb's principle
To capture balancing behavior, precise current measurement at a high frequency is always essential. That is why comemso offers optional Coulomb measurement with its battery cell simulators. Each individual battery cell module features integrated measurement electronics that enable a measurement to be taken every 100 µs. A total of 500 measured values are summed over a measurement period and converted into a physical value. This integral value is then outputted via the communication bus. A measurement period lasts 50 ms.



Calibration and fine-tuning

As with any sensory device, the measurement accuracy of the battery cell simulator is subject to potential variations due to ageing. To ensure that measurements are always of the highest accuracy, annual recalibration is recommended.

comemso offers two options for this:
A) Send the BCS modules to comemso
B) Carry out the calibration yourself

The BCS SmartCal measures all the sensors in the emulated battery cell fully automatically and can re-adjust them in the event of deviations. Both adjustment options include a calibration report in accordance with ISO 9001. From BCS Gen. 8 onwards, fine-tuning or readjustment of the voltage sensors can be carried out easily using the comemso Toolbox. This allows even the slightest deviations in voltage inaccuracy to be eliminated. All that is required for adjustment is a USB connection to a PC and a simple CAN interface. Please note that no calibration report is generated during manual readjustment.

Battery models

Battery models have become an essential tool for the development of battery-powered systems when, for safety reasons, it is no longer possible to use real batteries. With the help of numerous adjustable parameters, such as the current state of charge (SoC) or the overall state of health (SoH), the virtual battery can replicate the behaviour of a real battery.

The state of charge is an important parameter for all battery-powered devices. When fully charged, this value is 100%. As the battery discharges, it drops to 0%. The state of charge is determined using the voltage measurement method. A fully charged battery can be identified by a higher voltage. However, the difference in voltage between a fully charged and a fully discharged battery state is often only a few volts. Alternatively, the current-integration method can be used to determine the state of charge (SoC). In this method, the value is determined from the coulomb value based on the battery current over an integration period. Both the current flowing into the battery and the current flowing out of the battery are measured in ampere-seconds and accumulated.

The comemso battery model operates in a linear manner and is specifically designed to simulate the behaviour of the BMS in response to various changes in SoC and SoH. In addition to static tests using test automation and MATLAB/Simulink-based battery models for dynamic testing, the BCS from Generation 8 onwards also offers simple integrated battery models that can be configured individually for each cell. The model is stored directly in the BCS hardware or read from it. This allows simple, dynamic battery behaviour to be simulated cost-effectively.

Integrated interface testing

Testing BMS via EVCC to OBC

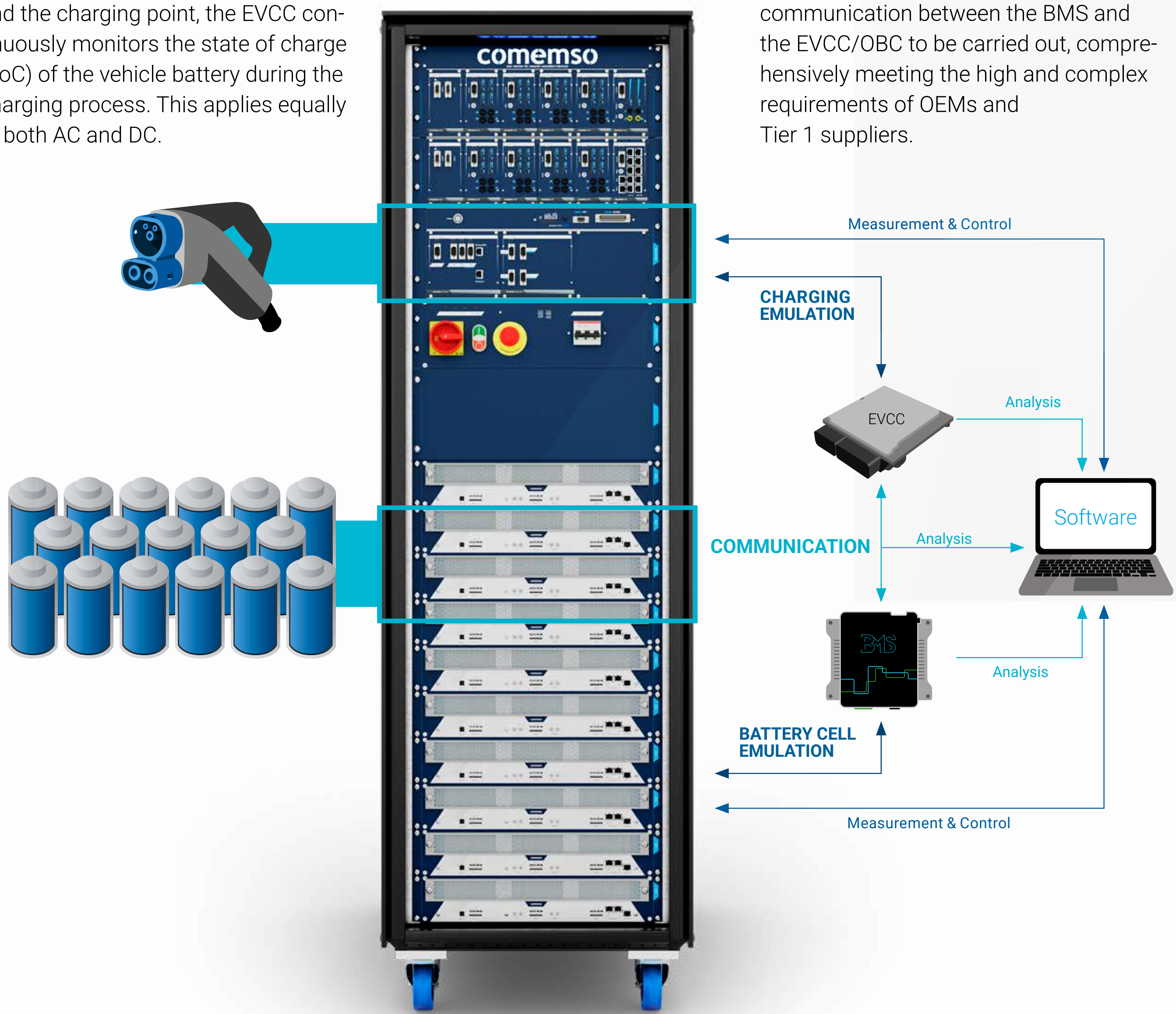
The rapid advancement of electric mobility has brought with it new challenges compared to conventional combustion-engine vehicles. The new focus is now on the electronics and software, which have to take on far more monitoring tasks.

This essentially involves two control units: first, the Battery Management System (BMS), and second, the Electric Vehicle Charge Controller (EVCC), which is located on the On-Board Charger (OBC). The BMS is responsible for monitoring the vehicle battery and regulating it where necessary. The EVCC, in turn, controls communication and the flow of current between the electric vehicle and the charging point during the charging process.

Acting as the link between the BMS and the charging point, the EVCC continuously monitors the state of charge (SoC) of the vehicle battery during the charging process. This applies equally to both AC and DC.

If the EVCC detects that the vehicle battery is fully charged or that an unexpected fault has occurred, it sends a message to the charging point so that the charging process can be interrupted and damage to the vehicle battery prevented. It is therefore extremely important to test all relevant parameters between the BMS and the EVCC using a combined test bench in the laboratory as early as the development phase, in order to identify potential sources of error safely, automatically and in a reproducible manner. This helps to prevent future risks. Years of practical experience, combined with insights from extensive electrical fault simulations, make the comemso integrated test bench a high-precision hardware-in-the-loop system.

This enables tests and analyses of the communication between the BMS and the EVCC/OBC to be carried out, comprehensively meeting the high and complex requirements of OEMs and Tier 1 suppliers.



Electromagnetic compatibility

Test systems must be robust and operate reliably at all times. This also means that they should be immune to electromagnetic interference and must not interfere with other systems. comemso's battery cell simulators meet the most stringent requirements of electromagnetic compatibility guidelines. This is confirmed by numerous successful test results in the company's in-house EMC test chamber.

"For many years, comemso has set itself high standards in the development of test and validation systems in order to deliver optimal solutions for its customers."

16 years Innovation

Understanding and simulating test processes

For 16 years, comemso has been developing test systems to optimize e-mobility systems. Today, we are more determined than ever to continue enriching the electric mobility market with innovations. To find the best possible solution, we always carry out our own practical tests. The insights gained from these tests are directly incorporated into the development of new solutions and products.

Technical Questionnaire for BCS systems

In order to provide you with as accurate a quote as possible, we would ask you to answer the following questions regarding your technical requirements.
Please fill in the gray fields, save the document and send it back to us.

Contact

Company
Street
Country
Department
Zip / City

Contact - Technics

Name
E-Mail
Phone

Contact - Sales

Name
E-Mail
Phone

Industry

- ☐ EV-Manufacturer ☐ BMS-Manufacturer ☐ Manufacturer
- ☐ Integrator ☐ Other

Area

- ☐ Research ☐ Development ☐ Production / End-of-Line
- ☐ Others

Project detailed

1. Simulation/ -emulation

Number of cells
Maximum cell voltage (V)
Cell voltage accuracy (DUT side)
Balance type
Compensating current (A)

Extra Features

- ☐ Coulomb measurement ☐ µA-measurement
- ☐ Simulation of noise effect
- ☐ Fault simulation (Short circuit, reverse polarity)
- ☐ Advanced fault simulation (Measurement cables for the BMS)

2. Temperature Simulation

Number of temperature channels
- ☐ Fault simulation (short circuit, cable break)

3. Isolation Resistance

Number of isolation resistance channels

4. BMS Current measurement

- ☐ Shunt Emulation (-150 mV to +150 mV)
- ☐ Hall-Effect Sensor Emulation (-6 V to +6 V)

5. Housing

- ☐ Rack system ☐ Table Top
- ☐ Integration in custom rack system / Table Top

6. Energy supply
Power/voltage available

Power (V) Voltage (A)

☐ 1-phase ☐ 3-phase ☐ with N

b. Emergency stop switch ☐ yes ☐ no
c. Isolation monitoring ☐ yes ☐ no

7. Control and communication software

Integration into existing software is planned ☐ yes ☐ no
Which interfaces? ☐ CAN ☐ Ethernet ☐ EtherCAT
comemso software with GUI and REST-API ☐ yes ☐ no

8. Test bench

Integration planned ☐ yes, with EVCC ☐ yes ☐ no

9. Project information

a. Sheduled project start
b. Project budget

☐ < 50.000 € ☐ 50.000 € - 100.000 €
☐ 100.000 € - 200.000 € ☐ >200.000 €

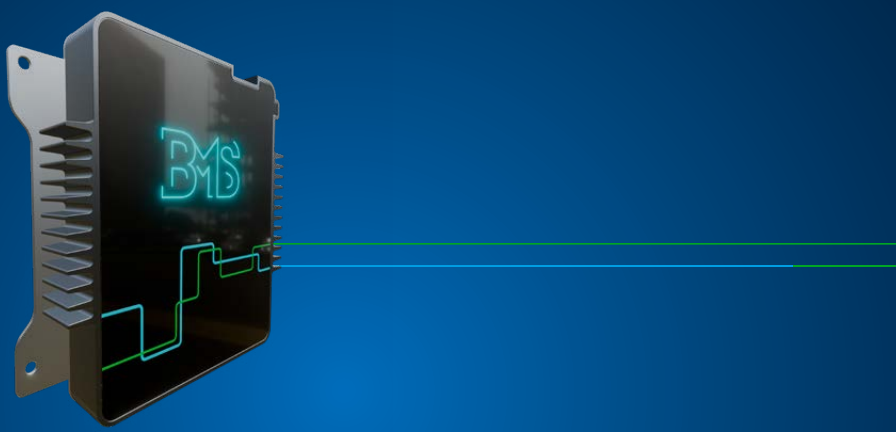
c. Existing specifications
☐ yes ☐ no

d. Planned future expansion
☐ yes, planned cells ☐ no

10. Further requirements

If you need help completing this questionnaire, our sales engineers will be happy to assist you. Please email us at:
sales@comemso.de

E-Mobility
Testing solutions worldwide



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