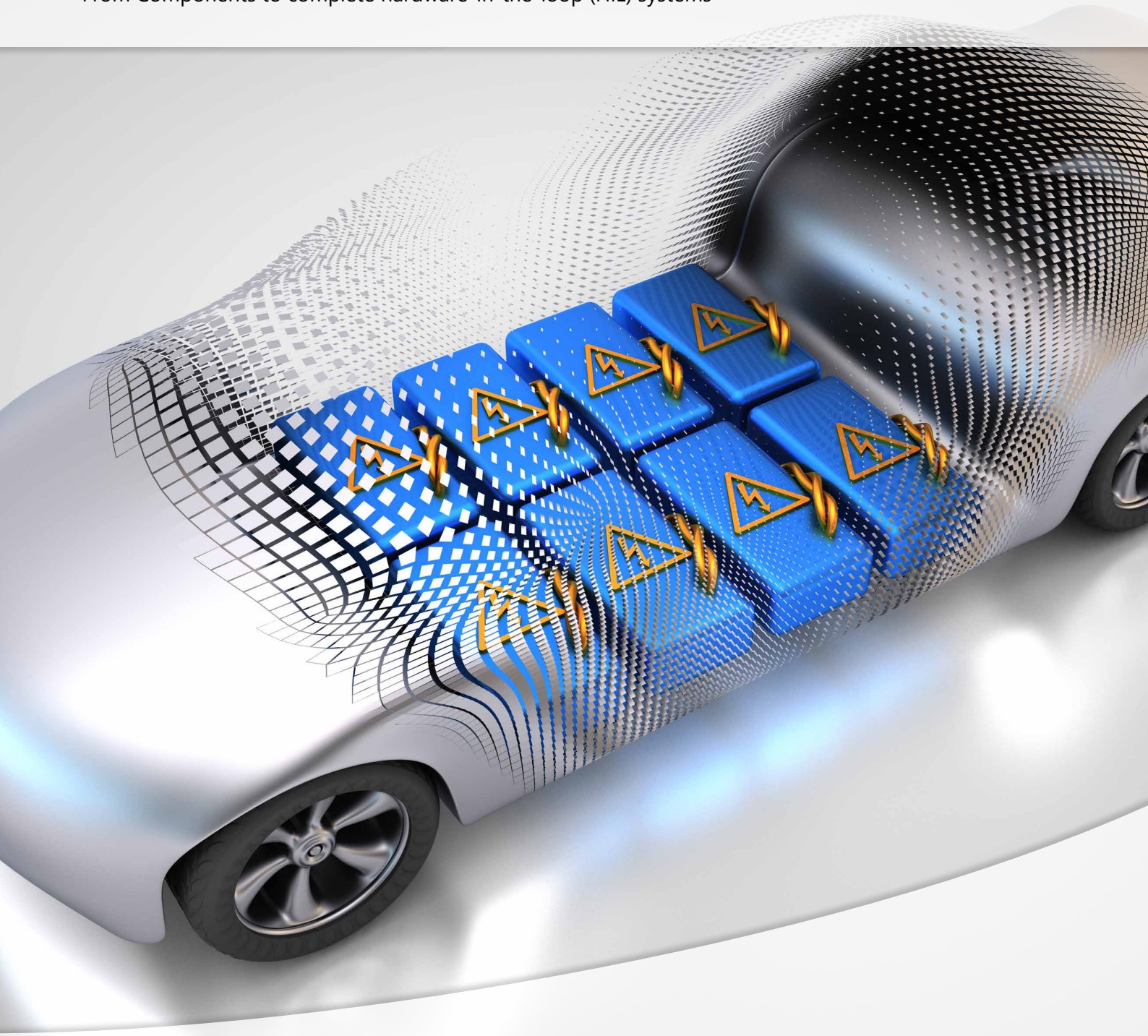
MicroNova
Software and Systems

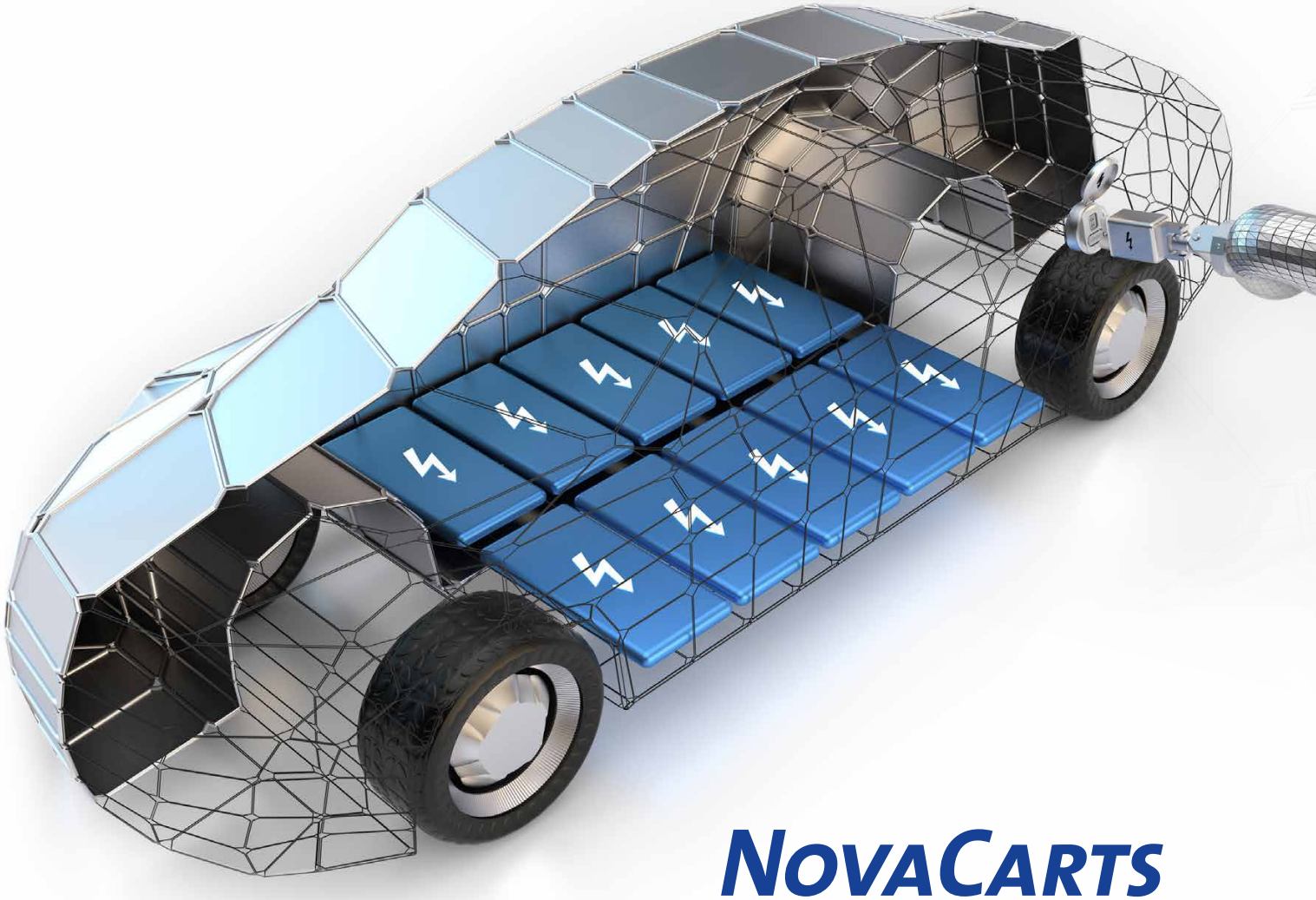
NovaCarts Hybrid Test Systems

From Components to complete hardware-in-the-loop (HiL) systems



- **Extremely versatile, highly scalable and reliably sustainable**
- **Cost-efficient adaption**
- **Short setup and configuration time**

NovaCarts



NovaCarts

NovaCarts I/O Boards and Modules – Perfect Tools for Rapid and Precise BMS Tests

Battery Management Systems (BMS) are fundamental components of electric and hybrid vehicles, since they guarantee safe and reliable battery operation as well as a long battery life. Consequently, comprehensive BMS tests are of great importance to automobile manufacturers and suppliers.

To ensure a high quality product, a variety of factors have to be taken into account during BMS testing:

- Individual cell voltage: This has to be simulated exactly, down to the millivolt, with a total voltage of up to 1,000 volts.
- Cell temperature
- Shunt voltage resulting from the battery's charge and discharge currents
- Highly dynamic circuit voltage caused by the contactor circuits
- Insulation errors caused by resistance between high- and low-voltage wiring
- Special signals, such as pilot or crash signals
- Switching behavior of the safeguards

The NovaCarts boards and modules have been designed with these requirements in mind and allow safe, completely simulated tests of battery control devices and cell controllers.

Key Features

MicroNova's high performance I/O boards and modules are part of the NovaCarts family, which is extremely scalable and can be combined to match any needs. What makes the NovaCarts boards and modules so special is that each component has a

- System-on-chip (comprising a standalone dual- or quad-core ARM processor and a high performance FPGA (field programmable gate array) and algorithm-based intelligence mapped in the software,
- Real-time Ethernet for data exchange and synchronization using standardized precision timing protocol (PTP) for exact, uniform time control of all I/O boards and modules,
- Linux-based NovaCarts HiL software with real-time capability.

These factors allow to implement most of the parameters and controls required for simulation largely within the board or module's FPGA technology, thus reducing the number of analog switches needed to an absolute minimum.

This approach offers several advantages: Firstly, users can easily change the relevant paramaters directly in the software in order to adapt them to specific test conditions. Secondly, the NovaCarts component can in most cases be adapted to new requirements through firmware updates, thus enabling them to be used over a long period. Since there is no need for costly hardware updates of the kind often required for simulation boards based on analog structures, the NovaCarts boards and modules are very cost-effective. At the same time, this architecture also makes it easier to maintain the components. As a general rule, users can simply upload the updates onto the NovaCarts I/O boards and modules from their workstation, meaning that they can generally perform maintenance themselves.

Short Setup and Configuration Times

Thanks to a real-time Ethernet interface with “plug & play” capability, the boards and modules are automatically recognized by real-time software and HiL configuration, and registered with the system. This makes it possible to put the NovaCarts components into operation quickly. Configuration is also completed in no time at all: New I/O channels can be integrated into the simulation without any great effort, as no I/O configuration in the simulation model is required for this purpose.

While developing the components, MicroNova put special emphasis on ensuring compatibility with existing systems and system scalability. In order to ensure that all systems and components of the NovaCarts family are mutually compatible, they all work with the same Linux-based HiL simulation environment with real-time capability. Additionally, the NovaCarts boards and modules offer the same functions as the large processing units used for the NovaCarts HiL Systems, such as a model execution platform, data exchange, and synchronization with other HiL computing units, as well as links to GUI and test automation.

This not only makes life easier for users – as they do not have to familiarize themselves with ever new programs or toolchains – but also ensures that existing parameters, characteristic curves, simulation models, and test cases can be carried over from project to project.

Wide Variety of Uses

The NovaCarts boards and modules can be used in NovaCarts HiL systems or autonomously (individually or combined) without having to have a real-time processor in control. It is therefore possible to implement applications of any size – from small, compact solutions with one board to the simulation of an entire vehicle.

In addition, all I/O boards and modules are based on an identical toolchain, such as real-time, operating, configuration, and development software. This means that the NovaCarts systems can be extended with little extra effort, thereby offering maximum investment security.

Complete Set of Boards and Modules for Comprehensive Testing

In the past, the testing of battery control devices required complex power packs and additional hardware. But now, the sophisticated NovaCarts components allow comprehensive and cost-efficient BMS and cell controller tests with a high-class hardware-in-the-loop (HiL) system, which does not require additional hardware. The components are specifically designed for the requirements of battery control device tests and are suitable for numerous application scenarios.

MicroNova offers the following boards and modules:

- NovaCarts Cell Simulation Board – NC-BEB1000
- NovaCarts High Voltage Source Board – NC-BEB1010
- NovaCarts Resistor Simulation Board – NC-BEB1100
- NovaCarts Insulation Error Simulation Board – NC-BEB1110
- NovaCarts Shunt Simulation Module – NC-BEM1000
- NovaCarts Pilot, Crash, Interlock Board – NC-GMB1300
- NovaCarts Multi I/O Board – NC-GMB3000
- NovaCarts Failure Insertion Board – NC-FIE4400
- NovaCarts Current Measurement Board – NC-GME3300
- NovaCarts High Speed I/O Board – NC-GMB3010
- NovaCarts CAN Switching Module – NC-SWM1010
- NovaCarts CAN Switching – Control Module – NC-SWM1011
- NovaCarts CAN Switching – Relay Module – NC-SWM1400
- NovaCarts CAN Switching – Terminal Control Module – NC-SWM1404

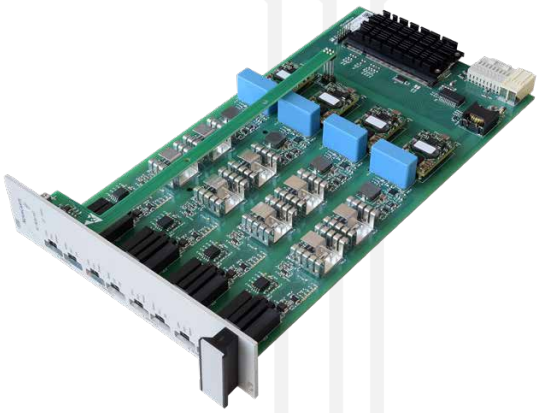
Supplies for boards and modules:

- NovaCarts Backplane – NC-BPM4400
- NovaCarts Chassis

Software & interfaces:

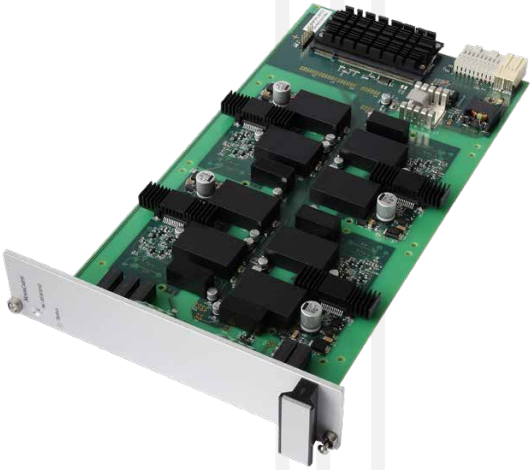
- NovaCarts I/O API – NC-IoAPI
- NovaCarts HRTRACE – NC-HRTRACE

NovaCarts Cell Simulation Board – NC-BEB1000



The board has been especially developed for validating battery management and charging systems. It simulates the electronic behavior of battery cells with an unprecedented degree of precision and speed. Since the cell simulation board is completely flexibly programmable, sophisticated algorithms – such as those used for electrochemical battery models – can be implemented directly on the board. Due to its great computing power and the short microsecond-based cycles involved, the cell simulation board is ideally suited for the development of future battery management functions, such as cell balanc-ing mechanisms. Furthermore, the board is already able to simulate starter batteries as well as new lithium-technology-based battery types (e.g. lithium solid-state batteries).

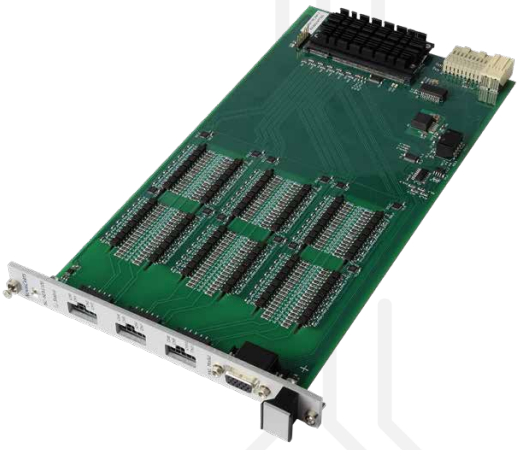
NovaCarts High Voltage Source Board – NC-BEB1010



This component simulates the voltage occurring in the intermediate circuit of hybrid vehicles, thereby allowing control device tests during the charging process that takes place during the connection of the preloading contactor or the unloading of the circuits. The board also models sinusoidal fluctuations, as might occur while charging from the power grid. It allows to replicate a highly dynamic circuit voltage of between -10 and 1,000 V. Jumps over the entire voltage range can be modeled down to a few milliseconds.

The board simulates charging and discharging processes with programmable time constants of between a few milliseconds and multiples of 100 ms. Sinusoidal voltages with frequencies of between a few Hertz and 500 Hz can be added to the intermediate circuit voltage, thereby enabling the board to act as two independent sources with a voltage of between -5 and 500 V.

NovaCarts Resistor Simulation Board – NC-BEB1100



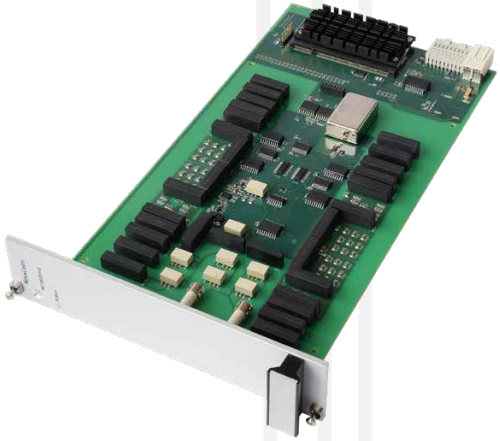
Especially designed to simulate the ohmic behavior of temperature sensors (e.g. PT100, PT1000), the board offers twelve independently controllable channels in real-time.

The high channel density of the board allows users to implement even HiL systems with numerous I/Os, both compactly and inexpensively. Since groups of four channels are galvanically isolated up to a peak voltage value of 1,000 V, the board is ideally suited for the simulation of temperature sensors required for the testing of battery control units.

NovaCarts Insulation Error Simulation Board – NC-BEB1110

This board has been developed to test the safety-critical error monitoring in electrical and hybrid vehicles.

In order to do this, specific isolation errors between high-voltage and low-voltage circuits must be applied. The insulation error board allows test engineers to integrate errors with a variable resistance of up to 10 MOhm between the high-voltage wires and the vehicle ground or the vehicle connection respectively. Thus, the insulation monitors used in the high-voltage control devices can be tested. Subsequent users can rely on the frictionless functioning of all these protective devices.



NovaCarts Shunt Simulation Module – NC-BEM1000

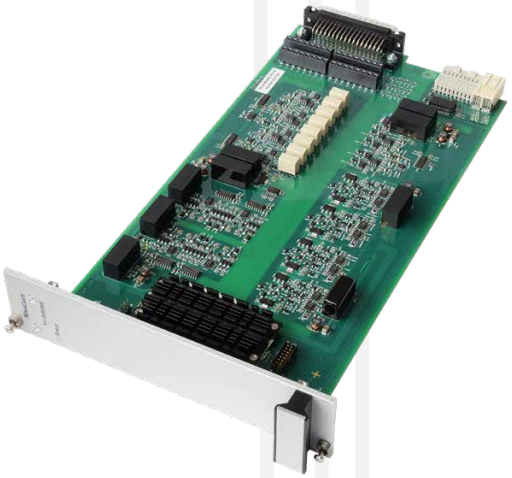
Developed for the test of battery management systems, this external module simulates the shunt voltage generated by the battery current with extreme precision. It can be located in the direct vicinity of the relevant BMS measurement input in order to ensure the required high level of shunt voltage accuracy. Thanks to the dynamics exceeding ten kilohertz, the module is even suitable for sophisticated battery applications, such as simulating starter batteries or future BMS functions. Furthermore, the module allows automobile manufacturers and suppliers to simulate functions, such as the specific performance leaps typically arising in conjunction with errors. A connection to the RT system is established via NC-BEB1100 (Resistor Simulation Board).

NovaCarts Pilot, Crash, Interlock Simulation Board – NC-GMB1300

This board controls, simulates, and manipulates all the relevant special signals in hybrid vehicles and measures the activation time of the safeguards. It allows to flexibly vary the resistance of the pilot-interlock current and simulate errors selectively. The pilot-interlock current can also be measured. Test engineers can greatly vary the crash signal parameters and thereby verify the threshold between the triggering of the security function and the activation of security devices, such as the disconnection of the high voltage lines. The board measures the time delay between crash signal activation and control device reaction down to the microsecond. In addition, the board offers a standard on-board diagnosis (OBD) error simulation for all signals as well as the simulation of battery balancing chips that are controlled over the I2C bus as a special feature.

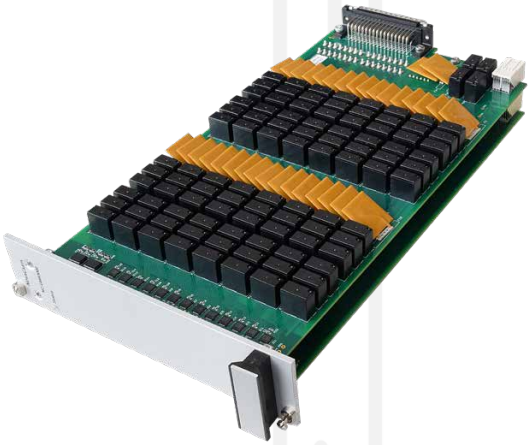
NovaCarts Multi I/O Board – NC-GMB3000

This universal input and output board can be used to simulate sensors as well as to perform actuator measurement. It offers eight digital and eight multifunctional input channels. The latter can be configured as analog, digital or PWM inputs. For digital and PWM input channels, users can also set the switching threshold. Furthermore, eight analog output channels are available, for example, to simulate the back measurement channels of control units or a temperature sensor. The board also includes eight digital output channels with PWM capability, which can be configured with low-side, high-side or push-pull functionalities.



NovaCarts Failure Insertion Board – NC-FIE4400

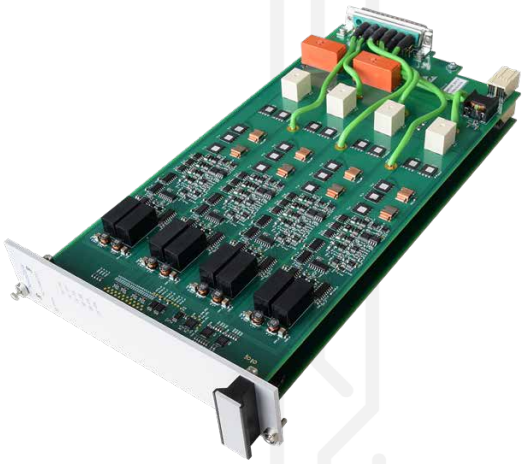
The NC-FIE4400 plug-in board is optionally available for failure insertion and can be connected to the NovaCarts Multi I/O board – NC-GMB3000. The extension board makes it possible to insert the following failures on the signal lines: interruption, cross-fault between signals, and short circuit to FailRail1 and FailRail2. It also offers an additional connection for real and dummy loads.



NovaCarts Current Measurement Board – NC-GME3300

This component is a universal current measurement board with additional relays, which can be plugged on top of a base card. Currently, the NovaCarts Multi I/O Board – NC-GMB3000 is supported. Since the current measurement is accurate in a wide range of currents, the board is suitable to measure currents from the double-digit ampere range to the microampere range.

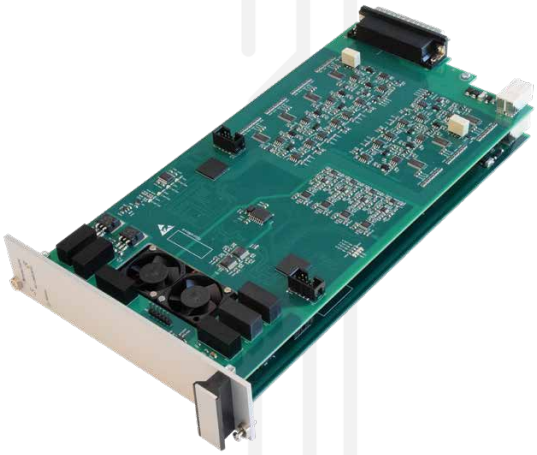
The board offers three channels ranging from 0 to 40 A and one channel with a measurement range from 0 to 10 A, all of which include the measurement of quiescent current. Two channels with a measurement range from 0 to 10 A complement the board. Furthermore, the board allows test engineers to measure and switch the voltage of the output pin based on Ground for five channels. In addition, every channel has an electronic fuse capability, which makes it possible to define a fuse current in the software for every channel.



NovaCarts High Speed I/O Board – NC-GMB3010

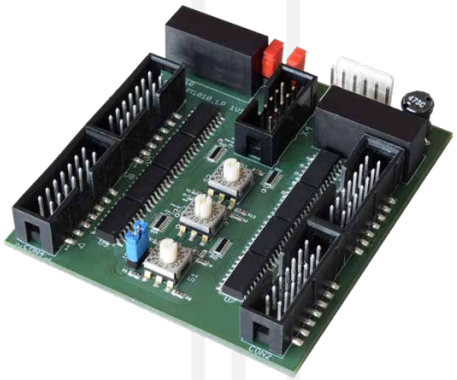
This high speed I/O board has been designed for the simulation of electrical motors. It contains a system-on-chip module (SoC), which consists of a sophisticated FPGA and a quad-core processor (Zynq UltraScale+). This allows the simulation models for electrical motors to be split into two parts: a high-speed part running on the FPGA and a low-speed part running on the processor or on a separate simulation node. It is also possible to simulate phase currents as well as signals of rotatable shafts and inverters. The board offers a high number of high-speed digital and analog signals.

The board is suitable for the simulation of DC/DC converters or electronic control units for inductive charging. The board offers eight analog inputs with a sampling frequency of 4 MHz. Additionally, the board provides 32 digital outputs and 32 digital inputs that can be operated with a frequency of up to 20 Mhz.



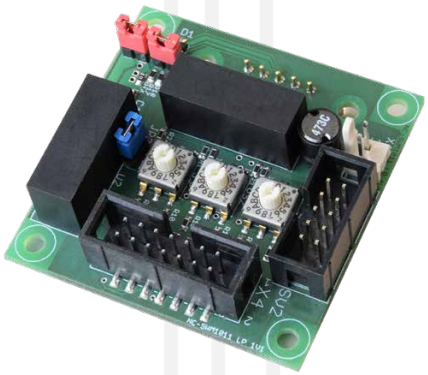
NovaCarts CAN Switching Module – NC-SWM1010

This top hat rail module offers 4x8 digital open collector outputs and is used to control relays in real part assemblies. The module has four connectors which make it possible to control the NovaCarts top hat rail modules for CAN multiplexers, LIN multiplexers or terminal controls etc.

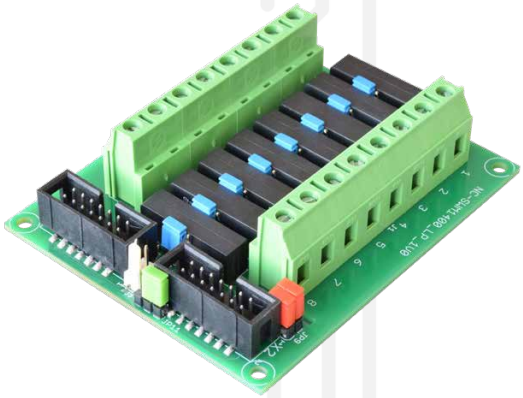


NovaCarts CAN Switching – Control Module – NC-SWM1011

This top hat rail control module can actuate up to 24 relay modules via SPI. It is used to control relays in real part structures. The module offers a connector which allows a cascading of the NovaCarts CAN Switching – Relay Modules – NC-SWM1400.

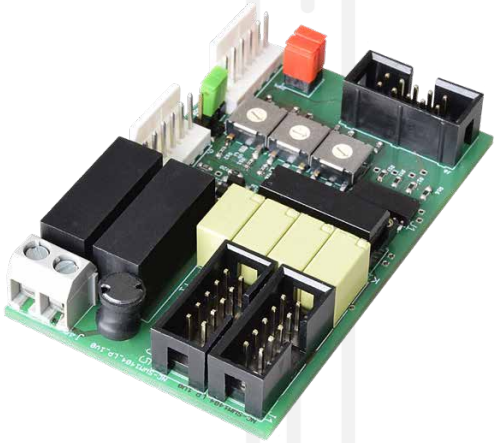


NovaCarts CAN Switching – Relay Module – NC-SWM1400



The relay module is a slave top hat rail module which controls eight high-voltage relays. It can only be used in combination with the NovaCarts CAN Switching – Control Module – NC-SWM1011. The relay module offers eight high-voltage relays for which eight signals can be switched as “normally closed” or “normally open” contacts via a jumper. The SPI data lines and the relay driver supply are provided by the control module and are passed through for another NC-SWM1400 module. Up to 16 NC-SWM1400 modules can be cascaded and controlled by a single NC-SWM1011 control module.

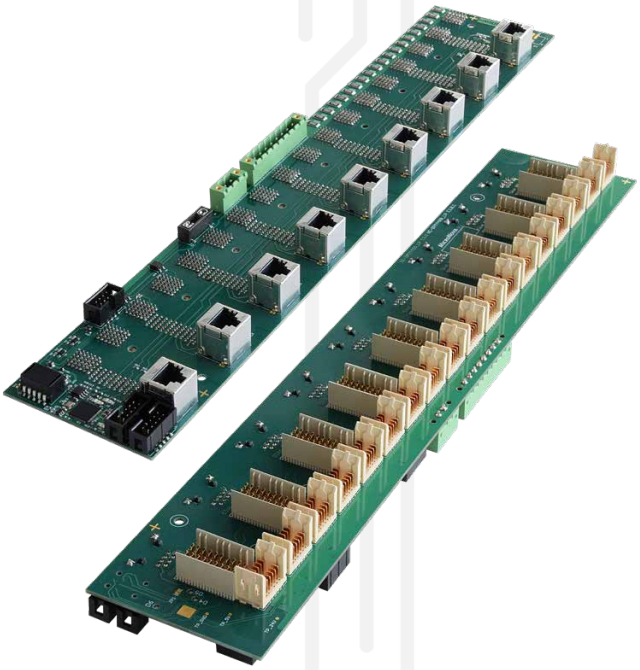
NovaCarts CAN Switching – Terminal Control Module – NC-SWM1404



The NC-SWM1404 module is a top hat rail module with four relays for terminal control. It has two connectors with four signal IN and four signal OUT lines each. For each relay, two lines can be switched simultaneously.

NovaCarts Backplane – NC-BPM4400

The relay module is a slave top hat rail module which controls eight high-voltage relays. It can only be used in combination with the NovaCarts CAN Switching – Control Module – NC-SWM1011. The relay module offers eight high-voltage relays for which eight signals can be switched as “normally closed” or “normally open” contacts via a jumper. The SPI data lines and the relay driver supply are provided by the control module and are passed through for another NC-SWM1400 module. Up to 16 NC-SWM1400 modules can be cascaded and controlled by a single NC-SWM1011 control module.



NovaCarts Chassis

The chassis is suitable for up to nine NovaCarts components. Due to the integrated Ethernet switch, the boards and modules can be directly connected to the real-time PC system. The chassis also offers four internal trigger lines as well as an active temperature management.

NovaCarts Battery HiL System

With NovaCarts Battery, MicroNova offers an extremely versatile HiL system for complete and extensive BMS tests. For example, a HiL system for state-of-the-art BMS testing used by an automotive supplier, would contain all relevant components from the NovaCarts boards and module portfolio:

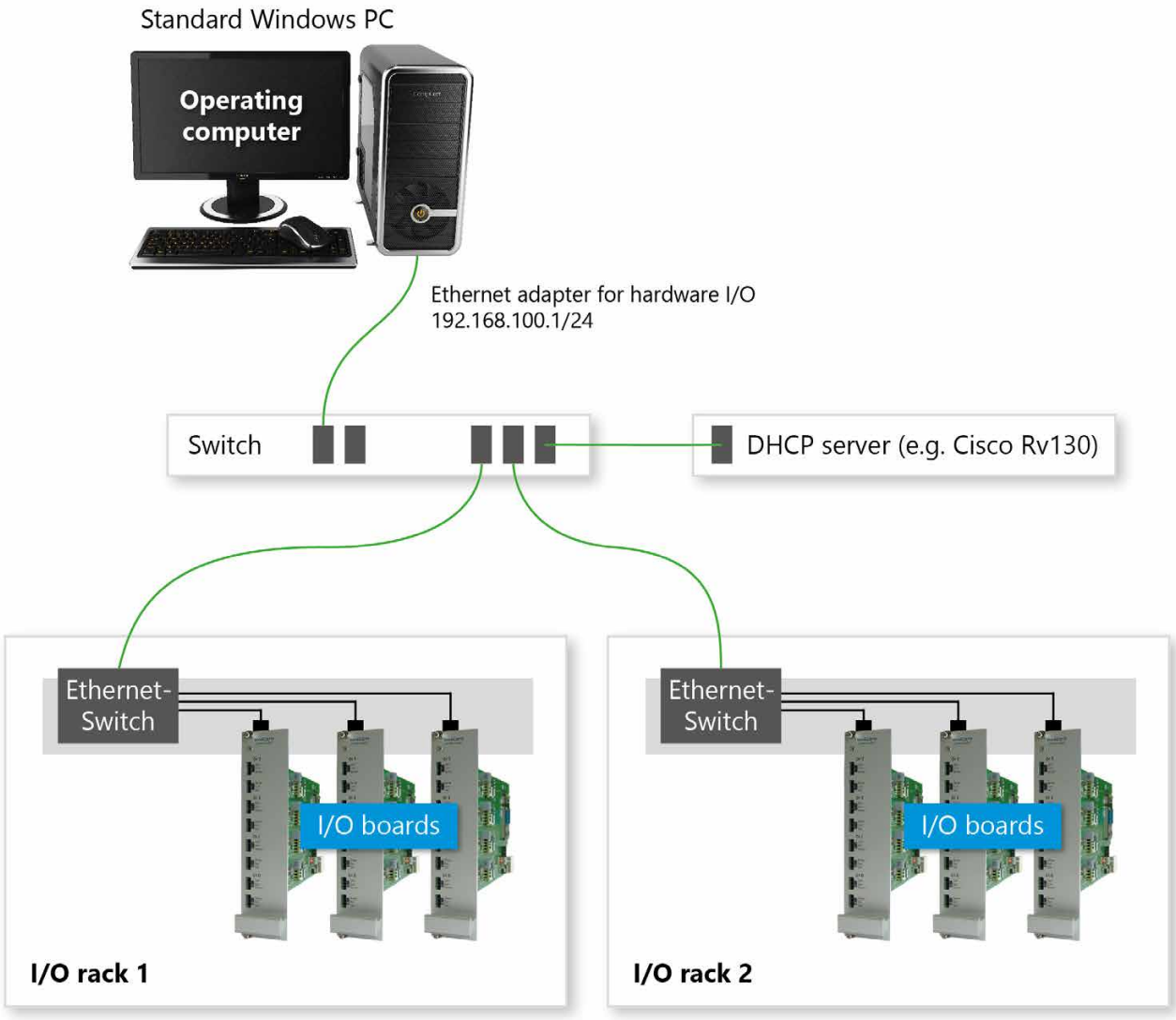
- **NovaCarts Cell Simulation Board** – NC-BEB1000, the heart of the HiL system, simulates all battery cells.
- **NovaCarts Shunt Simulation Module** – NC-BEM1000 simulates the charging and discharging currents of the entire battery.
- **NovaCarts High Voltage Source Board** – NC-BEB1010 simulates the entire voltage of the battery and the intermediate circuit.
- **NovaCarts Insulation Error Simulation Board** – NC-BEB1110 makes it possible to test the BMS' correct behaviour in case of errors that may occur during the vehicle's lifetime. The correct behaviour is necessary to protect customers from harmful voltages.
- **NovaCarts Pilot, Crash, Interlock Board** – NC-GMB1300 allows generating and manipulating special signals for the BMS operation.
- **NovaCarts Failure Insertion Board** – NC-FIE4400 makes it possible to generate OBD2-specific errors.
- **NovaCarts Current Measurement Board** – NC-GME3300 allows measuring the power consumption of the BMS from sleep mode to full operation.
- **NovaCarts Multi I/O Board** – NC-GMB3000 handles the standard not BMS-specific signals.

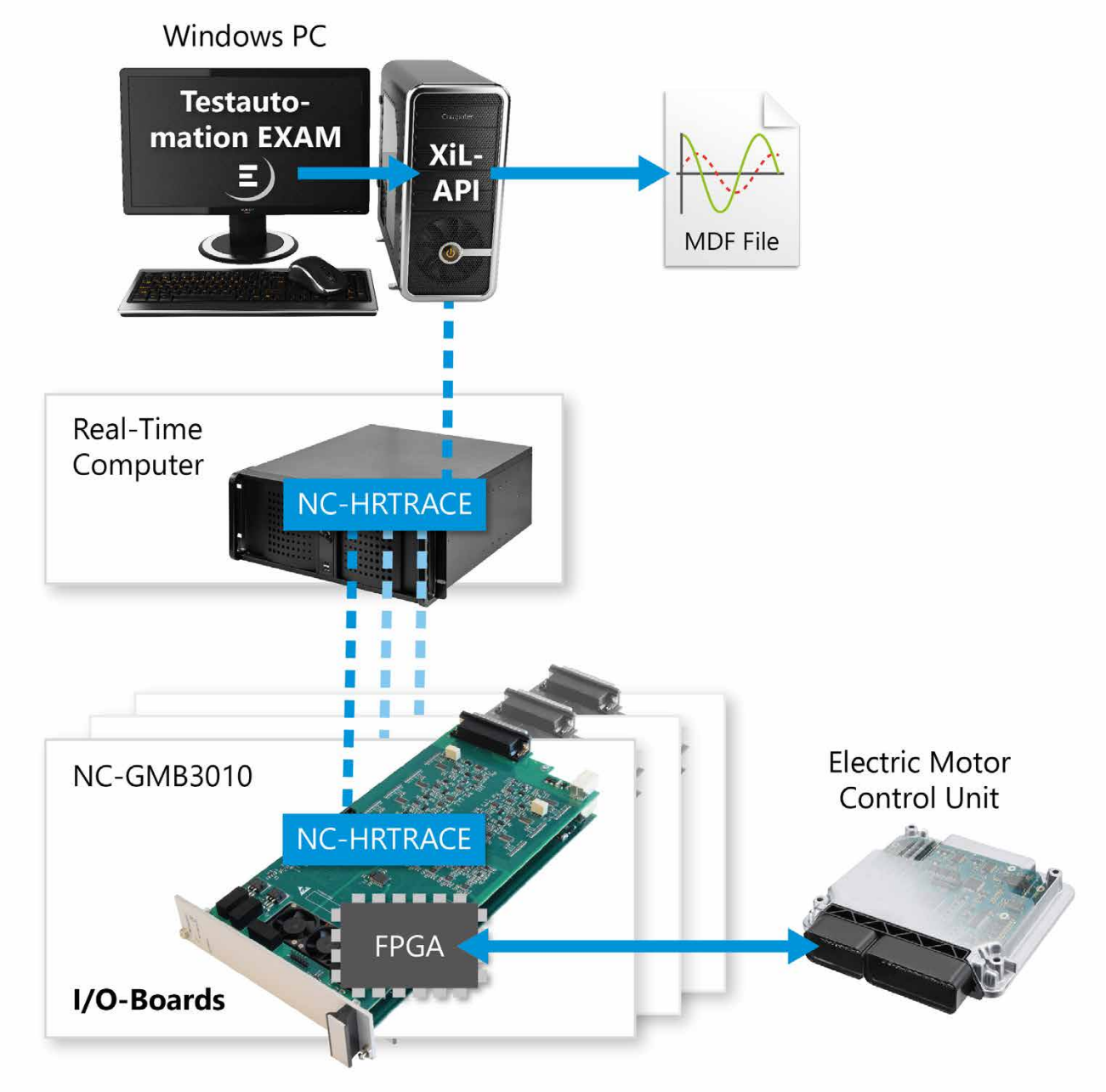
The test system naturally comes with standard HiL components, such as a real-time simulation computer, power supplies and high-voltage protection circuits. The BMS itself is contained in a drawer, making it easily accessible. In order to protect the users, the system interrupts all high-voltage signals when the drawer is opened. For measurement purposes, qualified personnel can temporarily disable the high-voltage protection by using a key lock. The HiL system is running the standard NovaCarts battery model.

NovaCarts I/O API

The software NovaCarts I/O API (NC-IoApi) enables NovaCarts boards and modules to be integrated into Windows environments, meaning that NovaCarts hardware can also be operated without a hardware-in-the-loop (HiL) system. Their use under Windows permits numerous applications to run that do not require an exact real-time simulation environment, for example as a stimulator.

NovaCarts I/O API is suitable for integrating NovaCarts hardware into all environments where Windows-DLLs can be called. This applies to current Windows computers as well as Vector VT systems. The interface can be used to set up powerful test systems with special NovaCarts I/O boards, for example for hybrid applications such as for simulating cells, insulation faults, high-voltage environments , or the special signals common in the hybrid area.





NovaCarts High Resolution Tracing (NC-HRTRACE)

The increasing complexity of control units for electric motors and the associated simulation models requires high-resolution recording of the time response of these models and the I/Os in order to ensure a fast and precise analysis. Given that the models and time response of the control unit firmware occur within microseconds or even hundredths of a nanosecond, measurement resolution up to such values must be commensurate. NC-HRTRACE provides a solution that supports users in analyzing over the entire bandwidth.

Simulations and Models

Special software and simulation models complement and enhance MicroNova's portfolio for BMS testing. One example is the cell controller simulation, which uses the I2C bus, enabling the communication between the different integrated switches. This allows users to test BMS functions without connecting "real" cell controllers, thereby reducing the high-voltage parts of the test system – as well as costs – to the minimum.

There are several software models available for the battery behavior modeling: the "equivalent circuit model", for example, simulates the behavior of individual cells very precisely in one working operation. This model covers nearly all application cases.

For very sophisticated testing projects, for example, the development of BMS for lithium-ion starter batteries, there is a physical-electrochemical cell and battery simulation model available, which has been developed by Fraunhofer Institute for Energy Economics and Energy System Technology IEE in Kassel. The model has been adapted to the specific requirements of real-time test systems and works ten times faster than the standard cell simulation. This allows a very exact simulation of the electrochemical behavior of lithium-ion cells, including temperature and aging effects.

Summary

The NovaCarts boards and modules create perfect conditions for comprehensive and extensive BMS testing with an unprecedented level of quality. They go way beyond the basic functions and cover all the special requirements for battery control device testing, including the modeling of the dynamic circuit behavior and the activation and manipulation of crash signals – all without the need for additional hardware.

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