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dSPACE MAGAZINE

1/2010

Ricardo: Battery Development Center for E-Mobility

BMW: Simulating Li-ion Battery Cells in Real-Time

GETRAG: Five Hybrid Variants in One Vehicle

Dr. Herbert Hanselmann
President

No one who is involved in any way with the automobile business will forget 2009. The crisis shocked numerous car makers and suppliers so greatly that they slammed on the spending brakes. They froze investments, suspended projects, slowed down projects, immediately cut outsourced development – they made all the short-term savings they could. It all happened so quickly that suppliers, service providers and even tool manufacturers hardly had time to react. Accustomed to success after 20 years of constant growth, we too were forced to rethink. We learned fast, and we kept our ship safely on course.

The question now is how long the economy will take to get back up to speed. The long-lasting growth trend, driven for years by ever-increasing investments in vehicle electronics, seems to be halted. What matters now is how things develop when companies release their spending brakes, which is already starting to happen. We are facing a different market, with changes that could lower the demand for current tools: reduced model ranges, more model designs based on fewer platforms, uniform and reusable architectures for vehicle electronics, global engineering, and possibly a slower rate of innovation for systems that don't seem so important.

But this new market also brings new opportunities. Now is the time to push forward with innovative technologies: the catchword is "green". It's too early to say whether this will overcompensate for the restricting factors mentioned above, but it is certainly possible. We, at all events, are doing all we can to stay at the forefront of green developments. This magazine includes several articles describing some of what was already achieved, and we have more in the pipeline. Our participation in research activities like ElektroMobil.NRW demonstrates just how serious we are about supporting green technology. This is a government-run program in the State of North Rhine Westphalia in which dSPACE, as the consortium leader, recently initiated a project that has since gained jury approval against stiff competition.

And our interest in non-automotive applications is of course as strong as ever. We love getting involved in new projects in very different fields. This issue also contains some interesting examples of these fields.

Last but not least, I would like to mention our new company headquarters. At the beginning of 2010, after being split up in ten different buildings on three different sites, we were at last reunited on one corporate campus in Paderborn. This streamlines our internal communication and increases our efficiency. Look for more details in our next issue.

Dr. Herbert Hanselmann
President

Embedded Success dSPACE

IMPRINT

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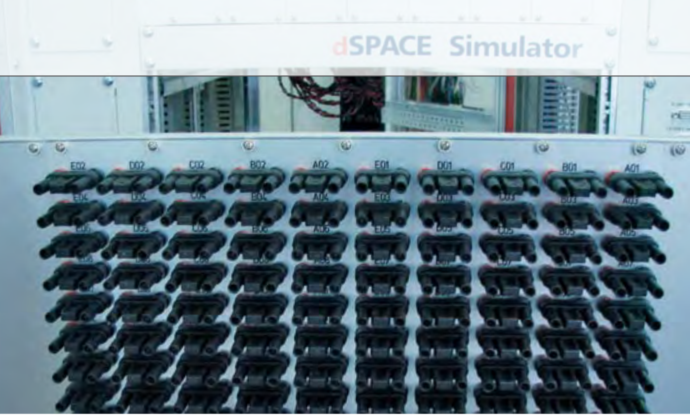
Virtual Energy Cells



No one can say with certainty how long conventional drives will continue to dominate the market. What is definitely certain, though, is that the age of electric drives has arrived. For the vehicles of the future, comprehensive ECU tests are more necessary than ever before, as the complexity and extent of the software increase at a breathtaking speed. The BMW Group is using a dSPACE Simulator to develop functions and test ECUs for a battery management system for lithium-ion energy storage. It simulates battery cells in real time, enabling developers to investigate whether the battery management system meets all requirements.

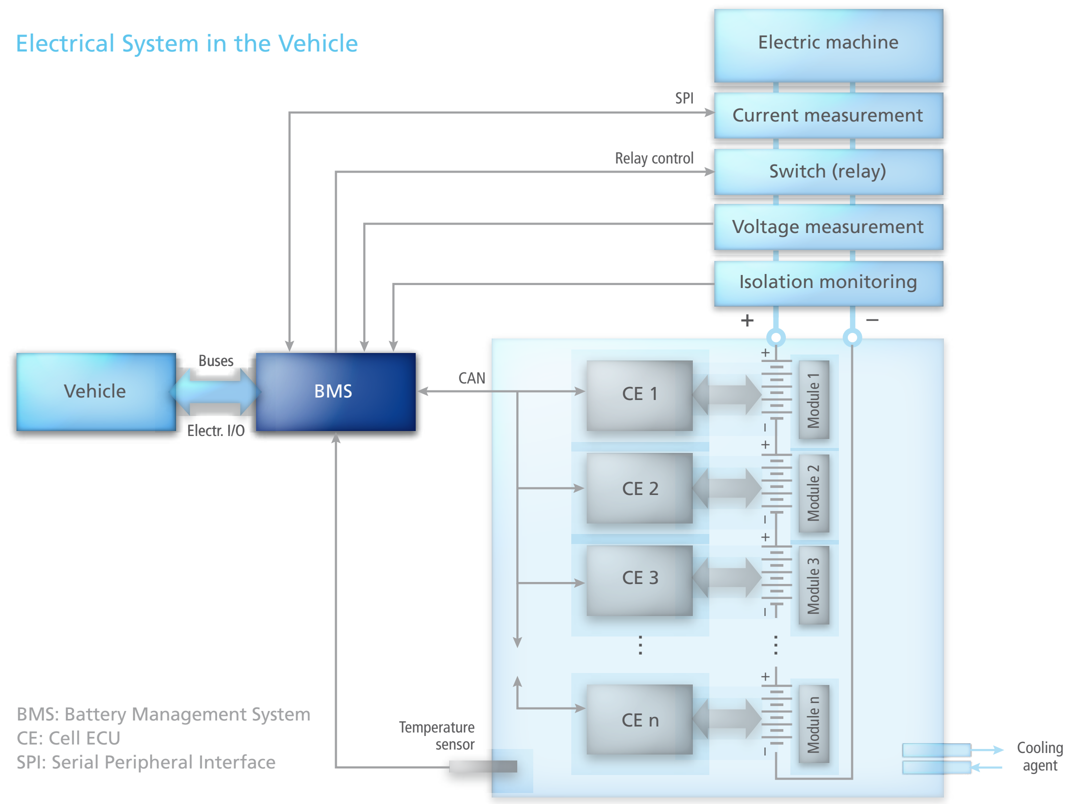


Figure 1: Battery management is performed by the BMS in conjunction with the cell ECUs (CEs), which are directly connected to, and monitor, the battery modules.

Challenge: Electric Mobility

The history of vehicle drives has reached an interesting evolutionary stage: Engineers are developing the drive concepts of tomorrow – and having to meet numerous new criteria on efficiency and safety. With the right combination of high energy, high power density, and long life, lithium ion batteries are a good economic choice in electrified drivetrains. This form of energy storage typically has a voltage range of several 100 volts and is dangerous when not operated within specified limits. One special challenge is to control the batteries in a vehicle safely and at the same time ensure maximum vehicle availability. Not only high safety requirements have to be complied with, but also optimum operating conditions for good performance and long life.

Battery Management Systems for High-Voltage Energy Storage

The requirements are monitored and implemented by an electronic control system called a battery management system (BMS). The BMS monitors the electric and thermic state of the batteries. It can influence each battery and its individual cells via various integrated control modules and actuators. Typical functions include protection against deep discharge, overcharge, and thermic overload. In a vehicle, the BMS is connected to the vehicle bus so that it can detect driving and operating states. Batteries have extremely high voltages and currents, so the BMS functionality is safety-critical. The development requirements defined in ISO 26262 must be fulfilled in order to ensure the functional safety of the system in a vehicle.

Structure of the Battery Management ECU System

To achieve the high voltages and currents for electrifying the drivetrain, the lithium ion batteries are made out of cascaded cell modules. At BMW, the cells are monitored and controlled by an extensive ECU system (figure 1). It consists of one cell ECU (CE) per battery module and one higher-level BMS, connected via CAN. The main job of each cell ECU is to measure the cell voltage and perform controlled cell discharge, while the BMS takes care of battery management.

Task of the Battery Management System

The BMS is the control center for all the electric, thermal and chemical processes in the battery. The following functions have been implemented:

Cell Balancing: To ensure an even charge state across the cells, the cells are symmetrized according to charge state analyses. This ensures that the cells have optimum performance and avoids cell overload, which in turn has a positive effect on long life.

Temperature Management: Cooling strategies regulate the temperature to prolong battery cell life and ensure optimum performance. Under extreme loads, overheating is avoided by limiting the current or regulating the cooling circuit.

Charge control: The charging efficiency is optimized by controlling the available energy and the energy available during charging.

Safety Functions: To guarantee constant safe operation at high voltages and currents, there are numerous safety functions that ensure that the battery's high-voltage contacts are not live unless the battery is in defined operating states. The battery is then safe to install, transport and store.

Isolation Monitoring: For safety reasons, both the battery poles must be completely isolated galvanically from the car body mass. The isolation monitor checks compliance with this requirement.

On-Board Diagnostics: If a fault or a threshold violation occurs during operation, it is entered in the fault memory and can be read out externally.

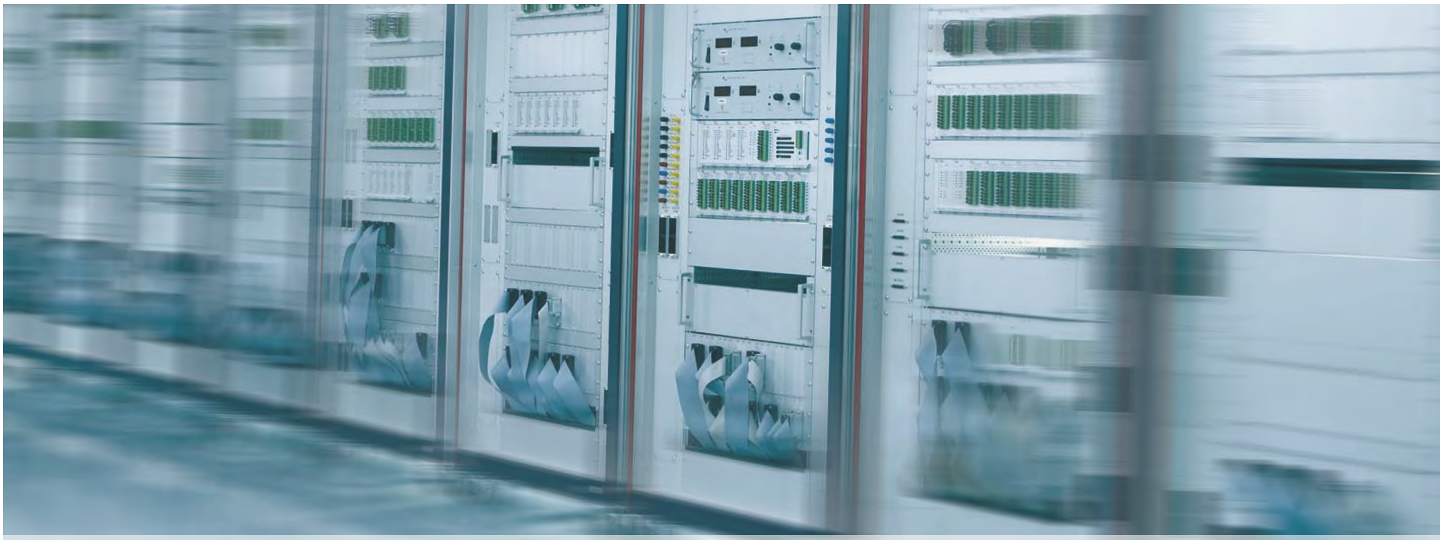
There are also further functions, such as those that indicate and check vital battery states:

- Measuring and displaying the charge state
- Monitoring the general state
- Determining the aging state
- Computing the available performance and energy
- Complying with current, voltage, and power limits

Conception of the HIL Simulator

To completely test the BMS and cell ECUs, the battery's different charge and operating states need to be present in a reproducible form. The solution is to run multi-stage simulations in accordance with the test requirements, both for individual battery cells and for the entire cell module. To ensure safety, the overall voltage is scaled down to under 60 V by adjustments inside the ECU. dSPACE has developed a very precise, very fast 60-V voltage source for this, which unlike normal power units can lower the voltage just as quickly as it can raise it. The overall voltage simulation must follow the single cell simulation dynamically in order to generate consistent values for the ECU.

The simulator structure for single cell emulation is as follows: An emulated cell voltage is provided to the ECU with high precision. The cells of CE1 are emulated with a highly precise voltage source from Scienlab electronic systems GmbH. The source supplies a galvanically isolated terminal voltage that can be regulated between 0 and 5 volts and take a load of up to 150 mA. These emulators are cascaded to form a cell module that supplies a voltage of 60 V. The currents and voltages of the individual cells can be measured directly on the emulator to test the cell balancing function.
The emulation of selected cells has lower precision, but also allows the insertion of electrical faults. Emulation of the necessary temperature sensors is also available for these cell modules. Further cell modules are integrated into the system by restbus simulation (figure 2).



Communication between the dSPACE hardware and the Scienlab Cell Emulator runs via a dSPACE low voltage differential signaling (LVDS) interface. A plug-on device (POD) from dSPACE converts the serial LVDS interface into a parallel microcontroller interface on the cell emulator side. This provides very fast data transmission (400 ns per measurement value) at a cable distance of up to 5 meters. The voltages of the complete cell stack can be adjusted in less than a millisecond.

HIL as Battery Simulation Environment

This configuration of the dSPACE hardware-in-the-loop (HIL) simulator makes it possible to simulate the entire energy storage. The simulation model is a battery model developed by the BMW Group. The necessary test cases are created and executed with test automation software. The simulator uses the test cases to represent the battery states at which the battery management system has to be tested. At the same time, the simulator can capture the ECUs' control currents and signals and evaluate how well they function. ECU testing provides information on whether the system detects faults, reacts to them correctly, and carries out the appropriate control strategy. Specific test sequences require highly dynamic processes such as sudden voltage drops and other transient events, as well as short circuits, to be simulated very precisely at the battery poles.

Electrical Failure Simulation

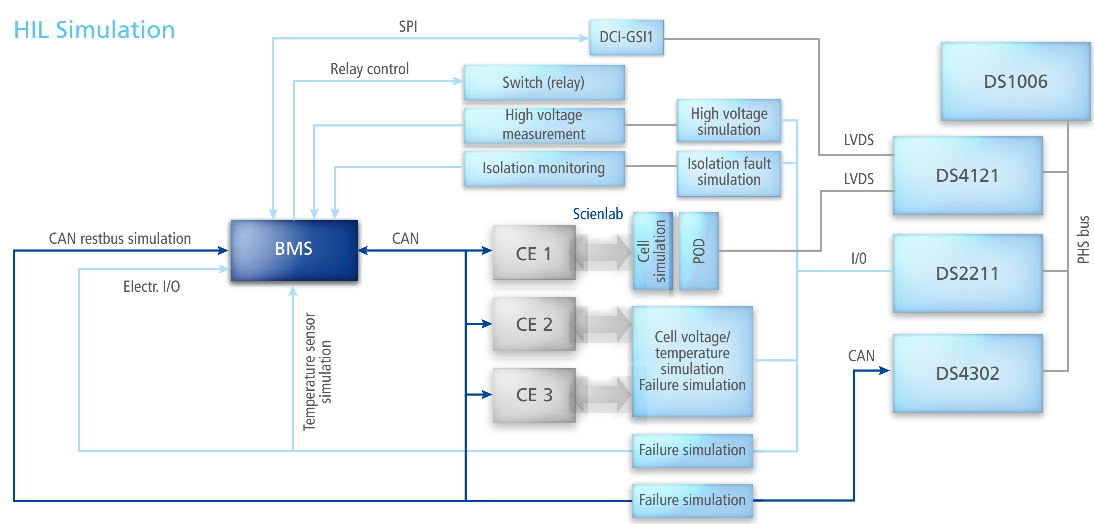
When faults occur in the battery or the cable harness, the BMS must always function correctly and react appropriately in all circumstances. Electrical failure simulation is therefore a vital part of HIL simulation. A failure insertion unit (FIU) can be used to feed in various types of faults to all I/O and communication channels, for example:

- Broken wire
- Short circuits to ground or to other ECU signals
- Loose contacts

This failure simulation is performed at the BMS's electrical I/O lines and CAN lines, and also at the cell ECUs.

Summary and Outlook

BMW currently has several dSPACE Simulators for developing and testing battery management ECUs. The systems are used in function development as well as in release tests for ECUs. HIL simulation has proven to be a reliable instrument for developing and testing battery management ECUs. HIL simulation will play a major role in future battery management development projects.



BMS: Battery Management System
CE: Cell ECU
SPI: Serial Peripheral Interface

DCI-GSI: dSPACE Calibration Interface - Generic Serial Interface

LVDS: Low Voltage Differential Signaling
POD: Plug-on Device

Figure 2: The BMS, some cell module emulators, and further real parts are integrated into the HIL simulator. dSPACE components round off the test environment.

Tests on Isolation Monitoring

For safety reasons, the battery poles must be separated from the vehicle chassis potential (IT network). The ECU is able to test whether the resistance of one of the battery's two poles to the chassis is too low. For HIL testing, defined resistances can be specified on the plus and minus sides in compliance with the BMW specification for each test to represent specific ranges of isolation values. The ECU must then detect these fault cases and react to them (e.g., by switching off the system).

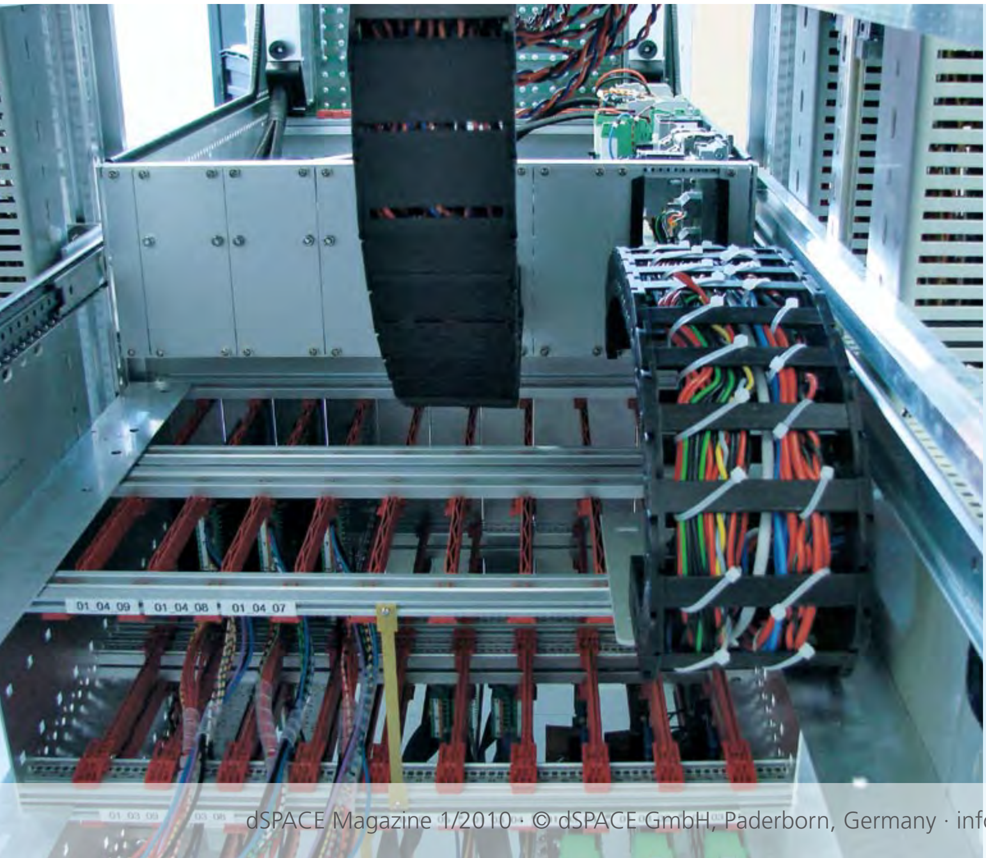
Evaluation of the Test System

HIL simulation makes it possible to simulate a battery realistically, generate all the states needed for further function development, and test the states systematically. This is done with electrical interfaces and with the communication interfaces (SPI, CAN incl. software gateway function). Powerful functions for simulating electric cable faults and isolation faults are also available; these are vital components in test sequences that verify ECUs. The dSPACE system has proved its stability and reliability in operation. The emulated cell and terminal voltages are precise enough to test elementary battery management functions such as cell balancing. The simulator fulfills the requirements for testing the BMS, both in function tests and in communication tests in the ECU network. ■

With the kind permission of the BMW Group.

Communication via SPI Interface

Communication between the ECUs and the sensors in the BMS runs via a serial peripheral interface (SPI). SPI is a very generic standard for synchronous, serial master-slave communication between integrated circuits. SPI is therefore designed for very short cable lengths. This poses challenges to simulator use, which usually requires cables that are longer than those in a vehicle. An LVDS SPI converter developed by dSPACE is therefore used to enable integration into an HIL system. The converter is located directly on the ECU and converts the SPI data into an LVDS protocol to achieve cable lengths of 5 meters. In the other direction, data arriving via the LVDS interface is converted into SPI and passed to the ECU.



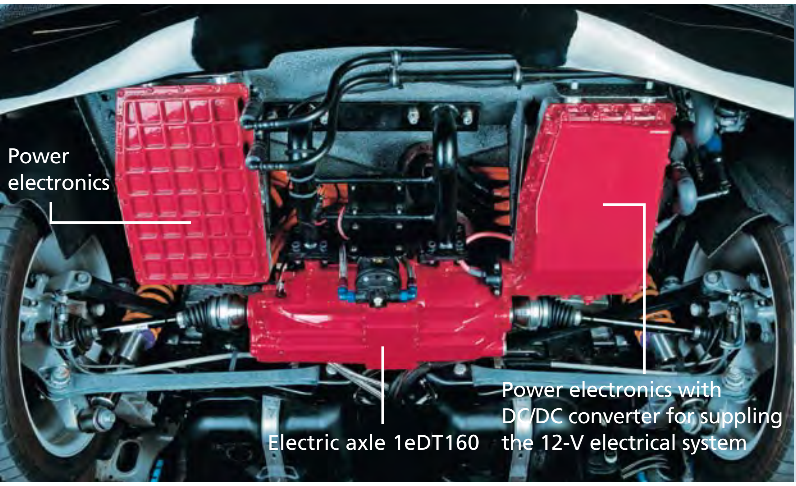
Conclusion

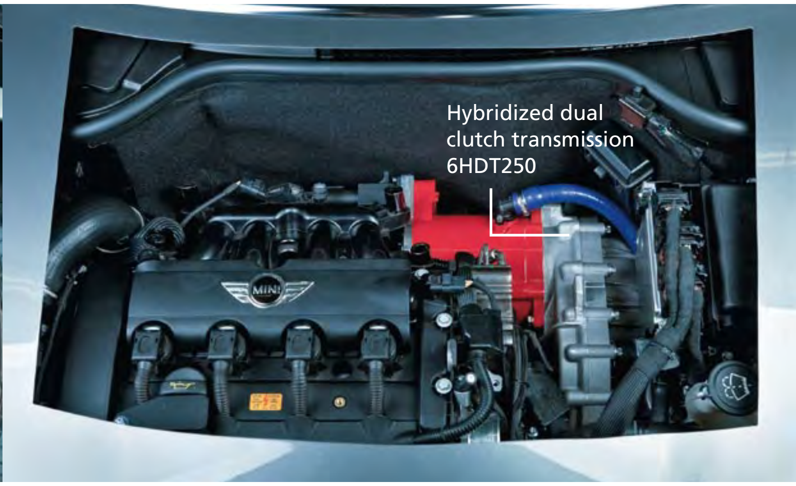
- Electrified drivetrain poses new challenges in developing and testing battery management ECUs
- Test system to virtually represent the electrical and thermic properties of a lithium-ion battery down to cell level
- Comprehensive function tests with electric failure simulation for a battery management system

Five in One

Different hybrid variants in one vehicle

Left: Underside view of the demo vehicle with the power electronics from BOSCH that control the electric machines, the electric axle 1eDT160 and the hybridized 6HDT250 dual clutch transmission. The right-hand FC supplies the vehicle's 12-V electrical system via an integrated DC/DC converter. For the axle, BOSCH supplied the motor, and GETRAG the single-gear transmission with an electromagnetic decoupling mechanism and a mechanical oil pump.
Right: View of the engine compartment with 6HDT250 PowerShift® transmission.





Hybrid drives and electric vehicles are hot topics in the automobile industry right now. But what few people know is that the first electric vehicles actually hit the roads in the early 20th century. In fact, until electric starters were invented, electric vehicles were used as widely as gasoline engine vehicles, especially in North America. Now with crude oil becoming scarcer and more expensive, and public awareness of environmental issues rising, the interest in alternative forms of propulsion is growing again.

In a joint hybrid project with BOSCH, GETRAG constructed a demo vehicle based on a Mini Clubman that represents different hybrid variants (torque split and axle split) and makes them "driveable". This allows different approaches to be compared directly. BOSCH was the cooperation partner that supplied the electric machines, the power electronics and the motor electronic control unit (ECU). GETRAG contributed the modified 6-speed PowerShift® dual clutch transmission (DCT), which is going into production as the nonhybrid version in spring 2010. With purely electromotive actuation of the clutch and gears, it is an ideal basis for hybridization.

Design of the Demo Vehicle

In the demo vehicle, both the electric machine flanged to the transmission and the rear-axle electric machine can be coupled and decoupled by an electromagnetic clutch according to the operating state. This avoids unfavorable operating points in the electric machine, such as the field weakening required at high motor speeds, and also reduces drag torques when the auxiliary hybrid functions are deactivated. The reason behind combining the two hybrid approaches in one vehicle is that their different driving behaviors can then be compared at the push of a button.

The demo vehicle can represent the following drivetrain configurations:

- Purely conventional drivetrain
- Purely conventional drivetrain with start/stop functionality
- Hybrid drivetrain with GETRAG PowerShift® transmission and electric rear axle
- Hybrid drivetrain with GETRAG torque split hybrid transmission
- Hybrid drivetrain with GETRAG torque split hybrid transmission and electric rear axle

Interactions and Dependencies

The task of designing a hybrid drive with a large number of interactions and dependencies can be mastered

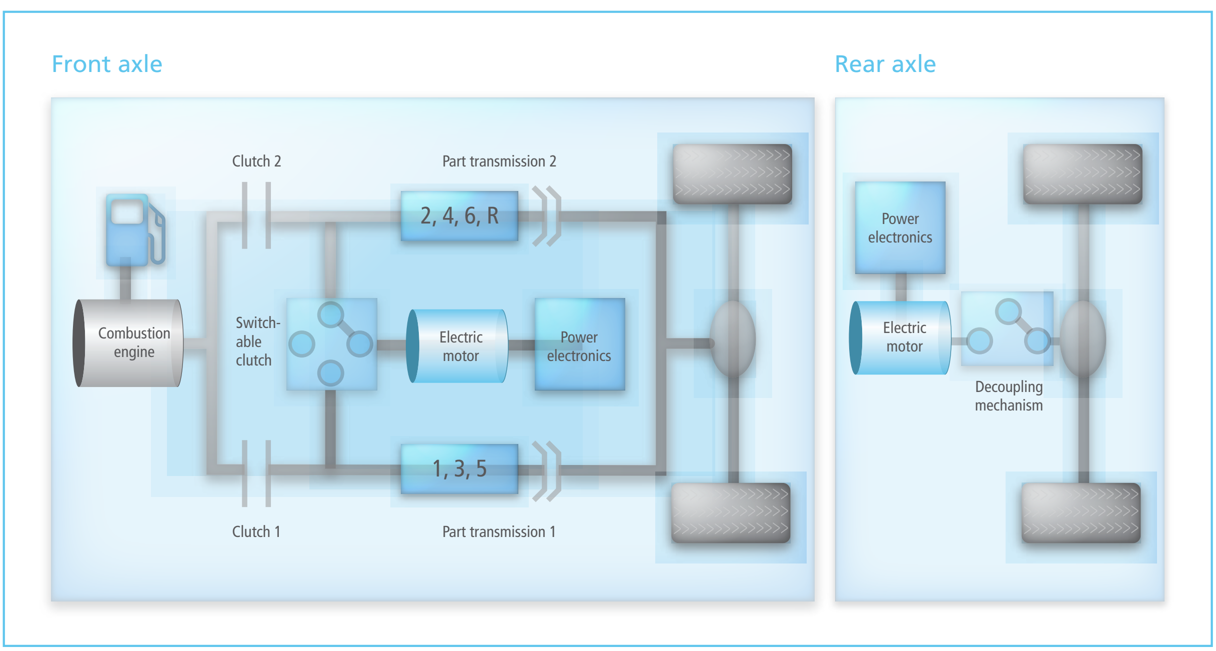
Application panel: Optimum access for the application with six CAN connectors, connection to the dSPACE system, main contactor control in electronic form.

by model-based development methods. For example, the battery and the electric machine interact with each other directly, and have to be adjusted to one another for optimum performance. The size of the electric machine, in turn, determines the extent to which the combustion engine can be downsized while preserving or even increasing the level of comfort and driving performance. Last but not least, the individual components and their current states decide how they can be used in driving operation.
The higher-level operating strategy developed by BOSCH receives data on the components' operating conditions and decides where to use each component at any given point in time. Optimal component design and the best possible component utilization during operation then determine how much fuel economy the hybrid drive can deliver. To investigate different operating strategies, the hybrid manager is implemented on a modified engine ECU from BOSCH, and the transmission software is implemented on a dSPACE system. Hybridizing the drivetrain necessitates intensive adaptations in the transmission software, such as modifications to the torque interventions and switching sequences.

Transmission Control Design

By using the dSPACE system, GETRAG has the flexibility and computing power it needs to implement the extended functionalities that control

> "The dSPACE system delivered the flexibility we needed to develop the control for the hybrid system."
>
> *Tibor Niedermayer, GETRAG*



The demo vehicle of the GETRAG-BOSCH hybrid project has a production motor, and its front axle is equipped with a dual-clutch, 6HDT250-type transmission with an additional electric motor. This modification allows the vehicle to run as a hybrid, with the electric motor supporting the combustion engine. Because the combustion engine and the electric motor are both coupled via the DCT, both types of drive can be used in a gear that is optimal for a specific speed, in other words, with the maximum possible efficiency. A separate electric drive unit is mounted on the rear axle, so the rear wheels can be used to drive the vehicle either as a hybrid or as a purely electric vehicle.

Left: Dipl.-Ing. Tibor Niedermayer is a development engineer for electrical hardware at GETRAG with responsibility for the vehicle's electrical functionalities.

Middle: Dipl.-Ing. (FH) Ingo Matusche is a development engineer responsible for the software of the axle-split hybrid at GETRAG.

Right: Dipl.-Ing. (BA) Thomas Hoffmeister is a development engineer responsible for the software of the torque-split hybrid at GETRAG.



the transmission together with the added electric machines. The production transmission ECU was replaced by a specially built, extended version so that all the additional functionality could be served and all the measurement variables integrated simultaneously and without additional hardware in dSPACE CalDesk.
The hardware system is subdivided into a highly integrated power stage mounted on the transmission, four brushless DC motors for dual clutch and gear actuation, a magnetic decoupling mechanism and ten output stages for controlling pumps, fans and additional consumers in the vehicle. In the trunk, a signal adaptations board with a field-programmable gate array (FPGA) conditions the captured signals for further processing by the dSPACE system and implements an emergency shutdown concept.
The currents of each electric actuator are captured, as well as the currents of the pumps and fans. Temperature capture goes one step further, acquiring not only the cooling agent and oil temperatures in the hybrid sections, but also the temperature of each single power stage in the transmission control. A total of 16 currents, 16 temperatures and 14 position sensors are captured. This ensures that a high-resolution, synchronized representation of a driving situation can be obtained at any point in time. High-resolution capture is performed for nine speed sensors in all, including wheel speeds, so that the current torque distribution can be determined. Four CAN interfaces support communication with the drivetrain components, the hybrid master and the high-voltage battery. Altogether, 150 lines connect the output and signal boards, and 170 lines lead to the dSPACE system.

Going Live in the Vehicle

Taking the idea of "everything in one system" one step further, an operating panel was developed so that the driver can switch and view the current driving state. This operating panel is controled by the dSPACE system.
One important development goal was to integrate all the additional functionality in such a way that the vehicle interior remains unchanged, apart from the extra controls and the additional technology in the trunk. This demonstrates the vehicle's suitability for everyday use and the know-how of the GETRAG-BOSCH hybrid partners.

Great Potential Savings

Simulations have already shown that in the New European Drive Cycle (NEDC), fuel consumption is reduced by approx. 6% (micro hybrid), 18% (axle-split hybrid) and 24% (torque-split hybrid) in comparison with consumption in the unhybridized 6DCT250 PowerShift® transmission. These figures are for an operating strategy that is oriented towards comfort and vehicle dynamics. With a consumption-oriented strategy, the fuel economies achieved by torque split and axle split are even greater. Hybridization provides electric power in addition to the conventional drivetrain, and this improves driving performance. The time taken to accelerate from zero to 100 km/h is shortened from 7.8 s with conventional automatic transmission to 7.5 s with the GETRAG PowerShift® transmission, 7.1 s with the hybridized PowerShift® transmission, and 6.7 s with the combination of PowerShift® transmission and electric axle. ■

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Conclusion

- Demo vehicle built with integrated hybrid variants: torque-split and axle-split hybrid
- dSPACE system replaces transmission ECU
- Different hybrid variants tested and compared
- Up to 24% fuel economy and up to 1 s faster acceleration to 100 km/h
- Current status: The hybrid drivetrain's customer-value driving functions are being put into operation

Located in Detroit, Michigan, USA, the new Battery Systems Development Center offers turnkey engineering and development of complete high-voltage battery-packs.

Electric vehicles are eco-friendly, quiet and economical. However, their future depends on efficient battery technology. For these vehicles to finally break through, their battery systems must offer higher performance than up to now – i.e., their charging times and weight must be reduced. To master these challenges, Ricardo has opened a battery development center for the comprehensive development of battery systems – with the help of a dSPACE simulator.

Improving Battery Technology for a Greener World

The development of new vehicle technologies has enormous potential to reduce harmful emissions and improve fuel efficiency. Hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs) are among the most promising candidates for "greener" transportation technologies. To be fully accepted, these advanced vehicles must provide the same reliability and robustness as conventional ones. One major component in their success will be their high-voltage batteries.

Ricardo Inc., a leading provider of technology and consulting for the automotive industry, is at the helm of this technological revolution with the opening of its new Battery Systems Development Center in Detroit, Michigan, USA.

"While there has been a great deal of theoretical discussion on renewable energy, Ricardo is applying the technology by taking it off the whiteboard and into the real world," said Ricardo Inc. President Kent Niederhofer. "In 2008 we launched TVFE™ as a total vehicle fuel economy solution, and in 2009 we opened the Battery Systems Development

The Battery Eldorado

Integrated development facility for hybrid and electric vehicle battery systems

Center, which is among the industry's most complete battery development facilities, working with many customers from cell suppliers to the Tier 1s and OEMs on battery systems for hybrid and electric vehicles."

Tackling Battery System Challenges

The center brings engineering design and evaluation experts and resources together to engineer fully integrated, turnkey battery systems and their electronic management systems. "The Center is a state-of-the-art, benchmark facility that enables Ricardo to evaluate and optimize batteries throughout the development cycle, from the early stages to battery pack production and integration into the vehicle," said Karina Morley, Ricardo's global vice president of controls and electronics. "The center is unique in terms of the breadth of services it provides. For instance, we can work with cell suppliers to develop complete battery packs. We can also conduct pack evaluations and pack subsystem design for battery pack OEMs. Our virtual vehicle development environment allows vehicle OEMs and battery pack OEMs to evaluate the pack in a simulated vehicle. We also have the ability to evaluate the performance of packs connected to a hybrid powertrain on our dynamometers."

The test chambers are equipped with robust safety and filtration systems – ideal for working with cells and packs using unvalidated support systems.

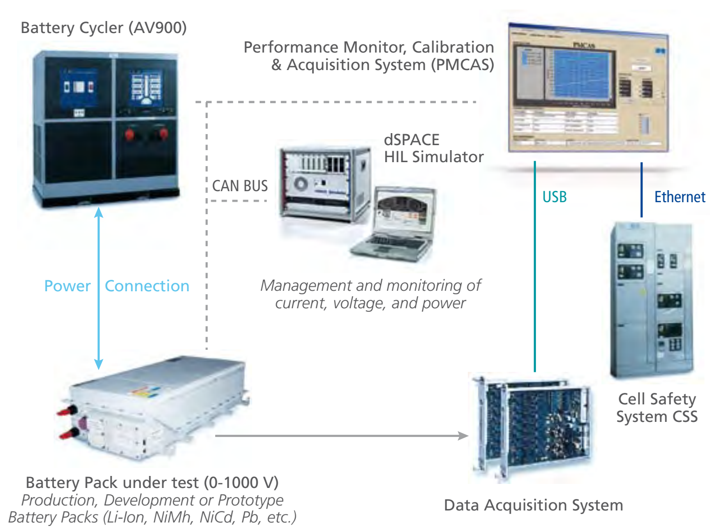
Additionally, the center has a large garage facility where battery packs can be integrated into vehicles for further evaluation. While the center is being touted for its battery development capability in the area of hybrid and electric vehicles, its services are equally applicable to non-automotive industries that can benefit from advanced battery pack development. These include applications such as agricultural equipment, defense and off-road vehicles.

> "We use dSPACE simulators on many projects and are pleased with their performance."
>
> *Karina Morley, Ricardo Inc.*

Virtual Vehicle Development Using dSPACE HIL Simulator

One of the most unique aspects of the Battery Systems Development Center is its virtual vehicle development capability, which allows fully simulated vehicle integration to be conducted in a safe, controlled and repeatable environment.

"This environment incorporates a dSPACE HIL simulator that is programmed to act as the virtual vehicle to verify the operation of battery systems," said Morley. "A vehicle, or portion thereof, is modeled and simulated on the dSPACE HIL system.



The setup for testing battery packs. The dSPACE HIL Simulator is the heart of the virtual vehicle, and simulates all vehicle components necessary for the tests.

Integration of a battery pack into a car.

Glossary

PHEV – Plug-in hybrid electric vehicle – a hybrid vehicle with batteries that can be recharged by an external electric power source

TVFE™ – A customized Ricardo solution to provide maximum efficiencies and minimum energy losses, and decrease loads on vehicles.

A typical use scenario for the dSPACE HIL Simulator is examining the effect of frequent charging and discharging on the battery pack, as typically occurs in everyday road traffic. To emulate this effect, the battery packs are connected to the battery cyclers." Of special interest are the consequences for the batteries' life span. Other aspects are heat development in the battery, its mechanical robustness, and so on.
"We have used dSPACE Simulators on many projects in the past and have been pleased with their performance," Morley said. "The simulator meets our expectations and is performing well. Its unmatched test capabilities allow us to test a wide range of virtual vehicle configurations at minimal cost, because we can avoid the high cost of integrating real components such as powertrains, engines or chassis dynamometers. Some tests wouldn't be possible at all without the HIL simulator."

High-Safety Test Chambers for Advanced Battery Tests

Up to now, the center houses three test chambers equipped with robust safety and filtration systems. "The level of chamber safety that exists is another major factor that distinguishes us from other test sites," said Morley. "This allows us to work with cells and packs using unvalidated support systems in a safe manner. There are battery test centers out there that specialize in pack testing, but our center is truly a resource for battery systems development, not repetitive testing," Morley continued. "With our test center, we are also prepared for future tasks in other business areas that Ricardo is involved in. This would include the test and development of battery systems or ultra-capacitor systems for applications such as wind turbine and solar cell systems, military systems, and potentially even aerospace applications." ■

Kent Niederhofer,
Ricardo Inc.
Kent Niederhofer is President of Ricardo Inc.

Karina Morley,
Ricardo Inc.
Karina Morley is Global Vice-President, Controls and Electronics, of Ricardo Inc., and based at Ricardo's Detroit Technology Campus.

About Ricardo Inc.
Ricardo Inc. is a leading independent technology provider and strategic consultant to the world's transportation sector industries. The company's activities range from vehicle systems integration, controls, electronics and software development, to the latest driveline and transmission systems and gasoline, diesel, hybrid and fuel cell powertrain technologies. Its customers include the world's major vehicle, engine and transmission manufacturers, Tier 1 suppliers and leading motorsport teams.

The automobile industry sees its future in the continuous development of innovative, networked in-vehicle systems. One answer to the growing complexity this will bring is to perform systematic standardization based on AUTOSAR. Strategies for introducing the new standard are being investigated in three reference projects at DENSO CREATE. The company is intensively comparing current procedures and methods with those required by AUTOSAR, with the aim of solving possible conflicts and ensuring that the introduction of AUTOSAR at DENSO runs smoothly.

Process Requirements

DENSO CREATE, a 100% Japanese subsidiary of the DENSO CORPORATION with responsibility for the areas of IT and software development, has carried out a process optimization project for introducing AUTOSAR. AUTOSAR provides a way of describing software in great detail to make it easy to reuse. The various stages of an AUTOSAR-compliant development process produce descriptions of the software architecture, the overall system, and the system configurations for individual electronic control units (ECUs). However, there are also conventional development projects running. These have other design steps that must be integrated seamlessly and without conflicts. Three aspects are particularly important:

- It must be possible to define the function architecture with the necessary level of abstraction.
- A control engineer using tools such as Simulink® or dSPACE AutoBox to develop prototypes must have full freedom to design and must not be restricted by AUTOSAR.
- An ECU supplier must retain the ability to optimize the implementation of a software architecture in specific ways.

One Step at a Time

In three reference projects, DENSO CREATE is examining a sequence of major steps and methods which make up an AUTOSAR-compliant development process (figure 1). Architecture modeling and function algorithm modeling are treated separately in these steps:

Function Architecture Design: Define and visualize the necessary function blocks and signals. This step produces a formalized description of essential requirements and can be in the nature of a whiteboard. Early consistency checks can be performed with tool support.

Control Model Design: Add algorithms to the defined functions to complete them. This classic form of function modeling is performed with MATLAB®/Simulink® and TargetLink.

Network Topology Design: Define the ECUs and how they are networked.

Function Mapping & Communication Design: When the functions have been mapped to the ECUs, define the local and global communication.

Software Structure Design: Define the software structure to be implemented on the ECUs. It may be necessary to transform a structure so that software development meets the given requirements.

Implementable Model Design: Adapt the model to the selected software structure and refine it for the purpose of production code

DENSO CREATE investigates strategies for introducing the AUTOSAR standard

Talking AUTOSAR

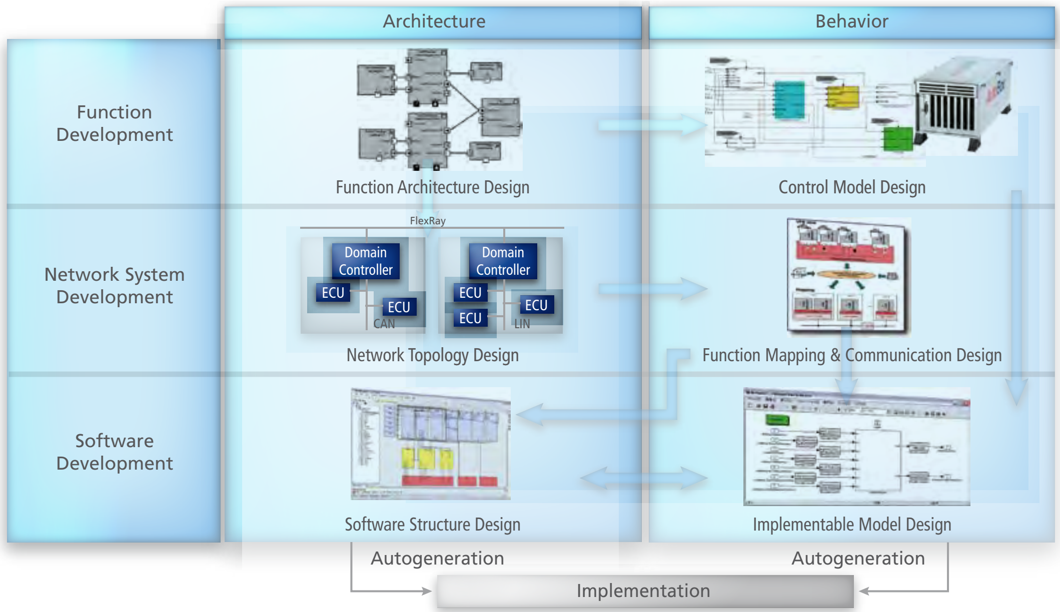


Figure 1: Sequence of major steps and methods in an architecture-based development process.

generation with TargetLink. Example: Add scaling information and link it to measurement and calibration variables.

Autocode Generation: When the design phase has been completed, generate the software components of the application layer from the implementation models by autocoding with TargetLink. Also generate the run-time environment (RTE), and configure and generate the basic software. Example: Generate the communication drivers from the network description.

Implementation: Finally, translate the C source code into object code, link the objects, and load the software to the ECU.

Each step has its own subset of AUTOSAR description elements specified for it. This ensures that only the really necessary elements are defined in each step.

Roles and Responsibilities for Optimum Efficiency

Efficiency is a major criterion for the new process. The individual steps were studied closely from this point of view to determine the necessary work methods, costs, and volumes. This made it possible to identify responsibilities, define roles, and optimize the procedures for work groups. It was found that control developments, for example, could be carried out in largely the same way as before, without the responsible engineers having an in-depth understanding of AUTOSAR. AUTOSAR-compliant modeling and implementation needs to be performed by a specialist team equipped with suitable development tools.

New Design Environments with Available Solutions

Having gained a thorough knowledge of the new process, engineers next investigated a tool chain for implementing it. User groups met several times to make basic decisions, after which DENSO CREATE was able to set up a design environment based on dSPACE products and supplemented by commercially available solutions.
For the fundamental design of the function architecture, DENSO and DENSO CREATE used SystemDesk from dSPACE. MATLAB/Simulink/dSPACE RTI and AutoBox were used to verify control functions. SystemDesk was then used to derive the software architecture from the function architecture. At this point, EB tresos® from Elektrobit was used to configure the basic software – including RTE generation for connecting the application software to the basic software. The AUTOSAR-compatible application software was developed with TargetLink. First implementation information was added to the controller models, and then TargetLink converted them into efficient, AUTOSAR-compliant code.

> "SystemDesk gave ample support to the most crucial area, linking control algorithm development and the AUTOSAR Basic Software on a model basis, giving us an overview of our desired ECU design development process."

Masahiro Goto, DENSO CORPORATION

Nobuhide Kobayashi, DENSO CREATE Inc.
Nobuhide Kobayashi is Project Manager of Software Development Department at DENSO CREATE in Aichi, Japan.

Yasuo Tatematsu, DENSO CREATE Inc.
Yasuo Tatematsu is Project Manager of Software Development Department at DENSO CREATE in Aichi, Japan.

Various Application Practices

DENSO CREATE carried out three subprojects in total, each with its own focus (figure 2), with applications from different vehicle domains.

- The first subproject focused on proving that the tools could be integrated seamlessly.
- The second subproject looked at how to reuse existing software. Information was gathered on the methodical development and integration of such software, for example, on the issue of whether sensor and actuator functions should be developed as software components.
- The third subproject studied the software in an existing climate conditioning ECU and converted it to AUTOSAR.

Looking Toward the Future

DENSO CREATE will continue to develop the process, with a special focus on making the tool chain seamless. This will cover issues such as automatically transforming specifications between process steps and a mechanism for synchronizing the various development tools in distributed development work. Last but not least, the performance of verification features such as the new SystemDesk Simulation Module and ways of integrating them into the process have to be studied in detail. This will optimize the process for future and complex tasks and further enhance its efficiency.

Nobuhide Kobayashi, Yasuo Tatematsu, DENSO CREATE Inc.
Masahiro Goto, DENSO CORPORATION

> "We are extremely grateful to dSPACE, not only for providing AUTOSAR-compliant tools, but also for working with us on-site in considering how to apply AUTOSAR appropriately. We are also grateful for the full training environment and for the efficient way in which tools were introduced."

Nobuhide Kobayashi, DENSO CREATE Inc.

Figure 2: Three subprojects with applications from different vehicle domains.

		Trial #1 Vehicle Dynamics System	Trial #2 Display System (Dashboard)	Trial #3 Air Conditioning System
Purpose of Trial		Perform architecture based development	Establish how to reuse legacy software	Establish how to adapt production program
Development Size	Number of SW-C/Runnables	6/11	26/299	41/141
Development Size	Number of DataElements/ Communication messages	42/5 (trans.), 5 (recv.)	56/3 (trans.), 18 (recv.)	59/5 (trans.), 14 (recv.)
Development Size	Basic software (BSW) module used	Mainly COM Stack (partially MCAL)	Mainly MCAL (legacy COM is used)	COM Stack, ECUM, MCAL etc.
Result	Learning AUTOSAR specification	■ VFB, RTE, COM, ECUM	■ VFB, RTE, COM, ECUM ■ MCAL	■ VFB, RTE, COM, ECUM ■ MCAL
Result	Set up engineering environment (Development environment, Design direction)	■ Resolve inconsistency among tools ■ Experience debug know-how (Understand BSW structure etc.)	■ Plan the direction how to implement legacy software into AUTOSAR structure ■ Experience debug know-how	■ Execute with experiences of trial #1 and #2 (Evaluate tool chain and design direction)
Man-months		9.3 man-months	13.4 man-months	18.0 man-months

Systematic Drive Safety

Integration testing with a modular FPGA platform for SIL-3 drives technology

E-Darc is a new FPGA-based drive controller being developed by control system manufacturer Ferrocontrol. With the aid of dSPACE hardware and software, Ferrocontrol is testing the safety and reliability of individual models to ensure that they comply with the strictest quality guidelines.

At Ferrocontrol, we develop, manufacture and distribute automation components and complete automation solutions in the field of drives technology (hardware and software) for the manufacturers of processing machines and also for end users. Our goal is to develop a controller that is easy to configure and maintain, even for complex systems, so that highly automated production processes can be designed efficiently and economically. To meet these requirements, we developed the FPGA-based drive controller E-Darc.

E-Darc, the FPGA-Based Drive System

E-Darc is especially suitable for multi-axle applications in drives and automation technology, such as in timber processing or window-frame machining centers, and for CNC processing centers in general. Axle modules with output currents from 2 to 32 A and supply modules in a range of 5 to 25 kW cover a wide range of user requirements. The number of controllers that are addressed depends solely on the available supply power: E-Darc itself has

Figure 1: The E-Darc drive controller consists of several modules for controlling several axles together.

no limits (figure 1). We designed the system so that the entire drive control is on one FPGA in parallel, "caste in VHDL" so to speak. This quasi-analog control provides the greatest possible dynamics, even for position and rotational speed control. Oversampling procedures are used for capturing position and current measurements to improve the quality of control without producing additional latencies within the control loop. Actual value filters are therefore not necessary. Overlaid functionalities such as the profile generator and the controller's state machine are executed on a soft-core processor, the Nios II®. Because this processor is also on the FPGA, there is one central component that executes the entire firmware of the axle controller. We developed the control algorithm with MATLAB®/Simulink® and later translated it with a VHDL autocoder from Synopsys (figure 2).
In addition to E-Darc, Ferrocontrol offers an optional supply module called RePower. This uses energy recovery and draws only active power from the supply mains.

Development with dSPACE

Development tools and hardware from dSPACE were used in the development of E-Darc (figure 2). Our drive system is built up of separate hardware modules such as the field bus communication, encoder evaluation, and power unit. To check how the maturity of individual modules was progressing, we used simulation on a dSPACE HIL test bench, which decisively sped up the development process for the whole system. The classic development process for an FPGA platform consists of steps for VHDL coding, synthesis and place&route. This enables us to develop modules and algorithms separately from one another and to test them extensively in very early development phases, repeatedly feeding the test results back into the development process. We ran integration tests to test the interaction between the single modules. The tests were created with the aid of the in-Step test database from microTOOL and then automated with dSPACE AutomationDesk. The achieved seamless process makes it easier to verify the functional reliability of safety-critical modules according to SIL 3.

Modular Design of the E-Darc System

The E-Darc's modular axle controller design contains not only pluggable incremental encoder cards, but also field bus cards. It supports the following encoders:

- Resolver
- SSI
- Hiperface®
- EnDat® 2.1
- EnDat® 2.2 (Safety)

> "With the dSPACE HIL test bench, we ensure that E-Darc drive controller complies with strict quality guidelines, for example withregard to safety technology."
>
> *Andreas Potthast, Ferrocontrol Steuerungssysteme*

Two slots are available for a wide variety of application cases. The plug-on field bus module ensures that the system is upgradable and independent of any specific field bus system; the modules currently available are for CANopen, SERCOS III and Ethercat. To ensure the axle controller has high interference im-

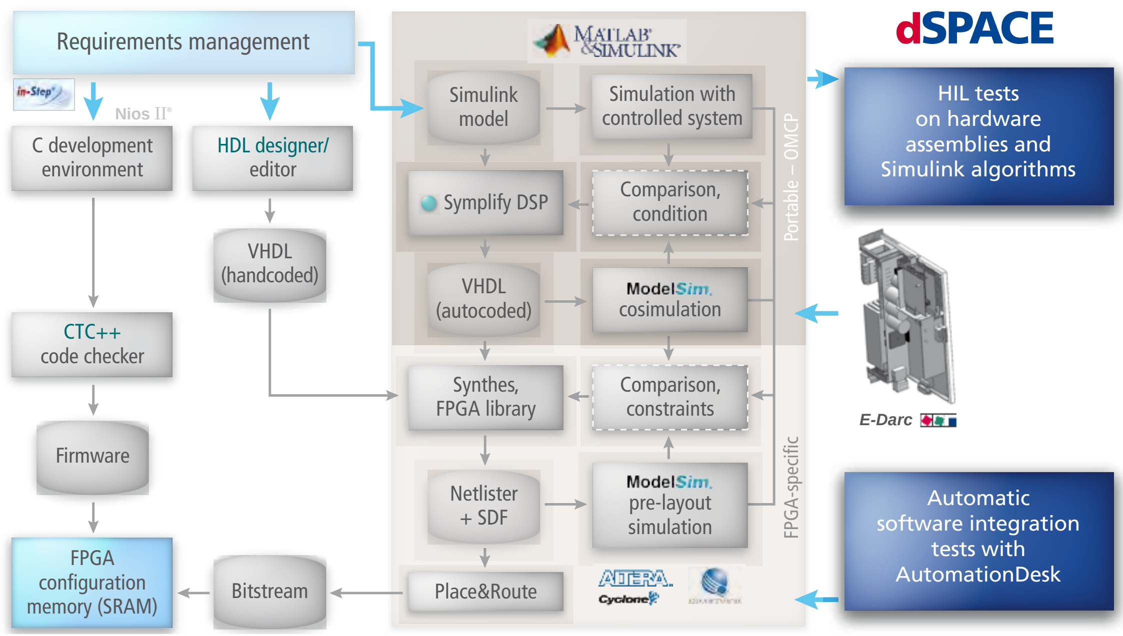


Figure 2: The development process for the E-Darc drive controller.

munity, the individual modules are connected to one another via purely digital interfaces (SPI, Serial Peripheral Interface). This means we can test and develop individual modules independently of the axle controller. Using the DS4121 ECU Interface Boards and a DS551 ECU Interface Plug-on-Device (POD) connected to an FPGA Evaluation Board (figure 3), we can simulate all the SPI communication nodes for each module and therefore test all the modules separately. The FPGA Evaluation Board has a standardized SPI interface for this purpose, in addition to connecting to the POD of the IP core. The POD communicates with the ECU Interface Board via a fast LVDS at a frequency of 20 MHz.
With the dSPACE Real-Time Interface Blockset, we can exchange various parameters under MATLAB/Simulink via a “shift register” similar to a dual-port memory.

Optional Safety Module

This modular system (figure 4) can optionally be equipped with a safety module that has safety technology certified according to Performance Level e (ISO 13849) and SIL 3 (EN 61508). The module can be parameterized freely and provides a variety of safety functions (figure 5).

Software Integration Test According to Quality Guidelines

For certification of the safety module, it is the entire development process that is examined, not just the hardware itself. This process (figure 2) of hardware and software development for E-Darc is subject to the strict quality guidelines that were previously established in the group’s medical engineering division and then adopted by Ferrocontrol. A decisive part is played by integration testing, in which hardware and software are brought together for the first time (black-box tests) and the basic functionality is verified.
For the specification and execution of these tests, the test case database was generated with in-Step and the integration tests were automated with AutomationDesk. Requirements management was carried out completely in in-Step. We link the individual requirements with test cases of varying levels of detail to make the development process seamlessly monitorable and traceable.
The test bench shown in figure 3 is used as a platform for the test sequences generated with AutomationDesk. At its core is a modular system from dSPACE, consisting of

Glossary

FPGA – Field programming gate array, designed to be configured by the user after manufacturing.

VHDL – Very High Speed Integrated Circuit Hardware Description Language.

SIL 3 – Safety integration level for assessing the reliability of electric/electronic/programmable electronic systems.

CNC – Computerized numerical control is an electronic method of controlling tool machines.

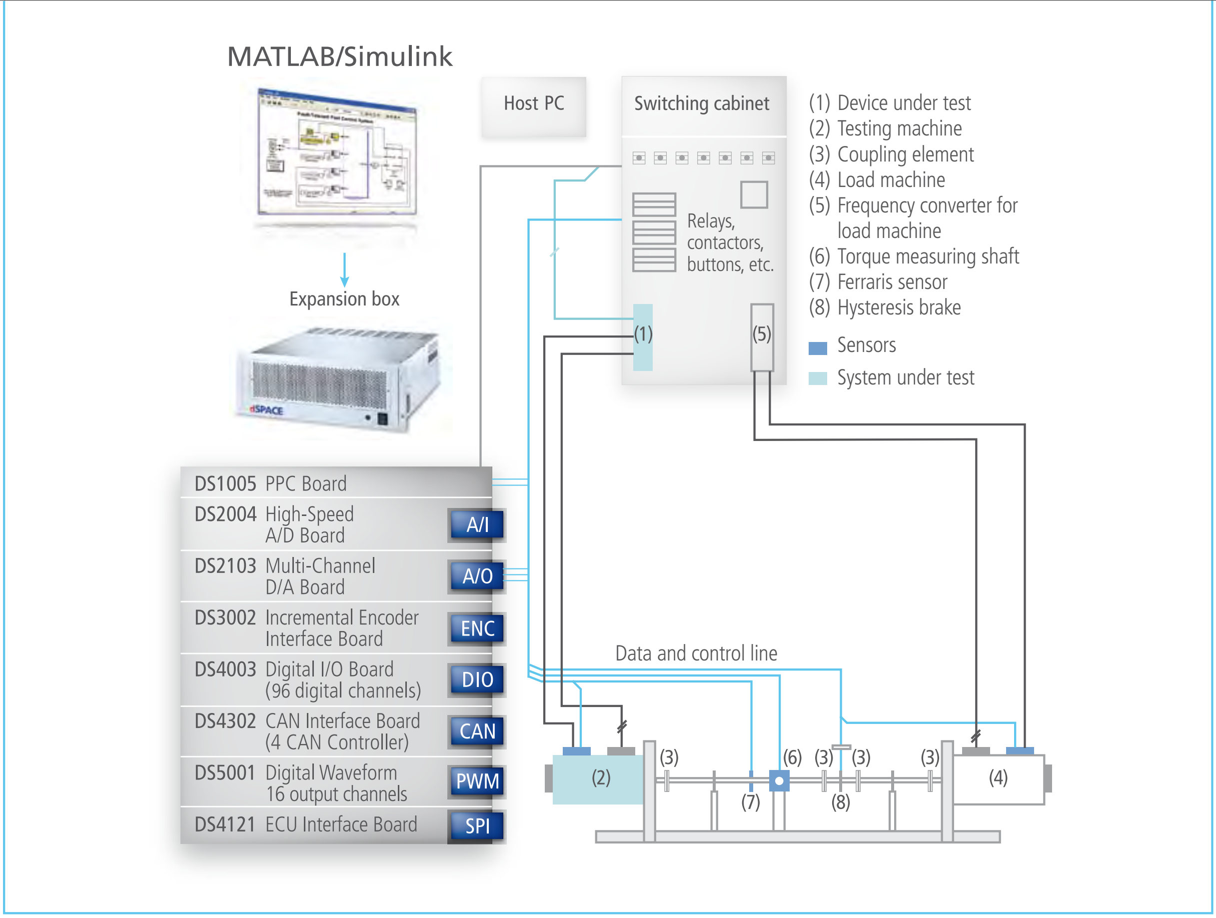
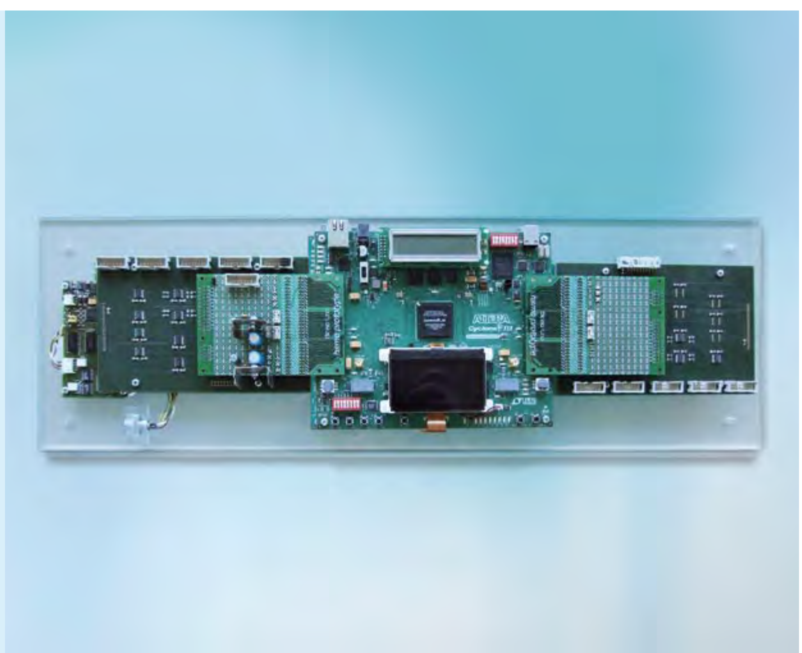


Figure 3: Integration and HIL test bench.

a DS1005 PPC Board to which the I/O boards are connected via the PHS (peripheral high-speed) bus. This system's versatile and flexible I/O, which can be used to control and monitor all of the E-Darc's external interfaces, makes it possible to achieve the extensive test depth that is indispensable to testing safety-critical systems:

- Using the load machine, for example, it is possible to simulate very different and complex load profiles that represent processes on real customer machines. After

Figure 4: FPGA Evaluation Board (Altera 3C120) with DS551.



Summary

- Extensive module tests, based on prototyping with a connected FPGA platform, speed up the development of the E-Darc drive system. Errors are detected earlier.
- A complete test case database with automated tests derived from the test cases is an important element for the certification of drive assemblies in the E-Darc for functional safety.
- Automated tests permanently reduce the testing workload involved in introducing new firmware versions.

these test runs, there is no more danger that an error could damage a real machine or destroy a tool.

- The RTI CAN MultiMessage Blockset made it possible to represent the necessary CANopen master, into which a DBC file based on the current object directory was integrated in Simulink. This CANopen master can simulate the entire CNC control of a machine.

When a test sequence has been completed, AutomationDesk generates a test report showing whether the new firmware version can be released for the modules in question. Entering the test results into the test case database manually to document the current status of the firmware is very time-consuming, however. A software interface to transfer the test results to the database automatically, such as the one available for the DOORS requirements management software, is planned for the future. ■

Dr.-Ing. Andreas Pottharst
Head of development
Ferrocontrol Steuerungssysteme
Germany

Dr.-Ing. Andreas Pottharst

Dr.-Ing. Andreas Pottharst is in charge of the development department for drives and PC technology at Ferrocontrol Steuerungssysteme in Herford, Germany

Company Profile

As a manufacturer of control systems, Ferrocontrol has been an innovation partner to the window manufacturing and timber processing industries for 36 years. As of 2006, the company belongs to Eckelmann AG, whose headquarters are in Wiesbaden. Ferrocontrol's products and services cover the entire spectrum of window manufacturing, controls for stock-keeping, wood-cutting centers, saws, welders and corner finishers, as well as metal fittings machines; up to buffer systems for the shipment process, systems for logistics, production control, and control systems.
In the development of industry-specific solutions tailored to the requirements and wishes of customers and the market, the company's policy is to develop, plan, and manufacture its own hardware and software components.

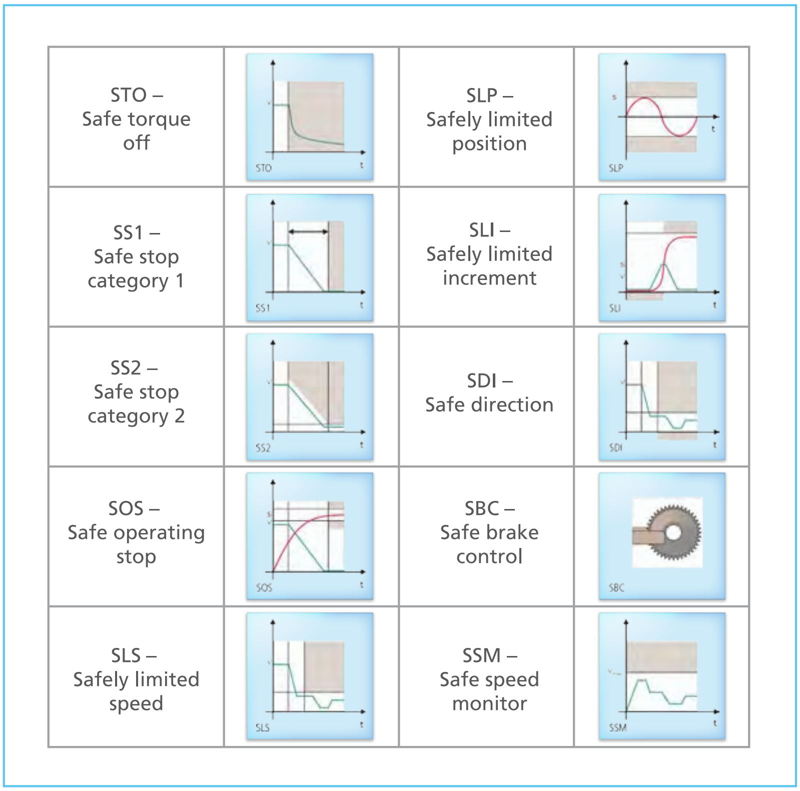


Figure 5: Safety functions of the E-Darc safety module.

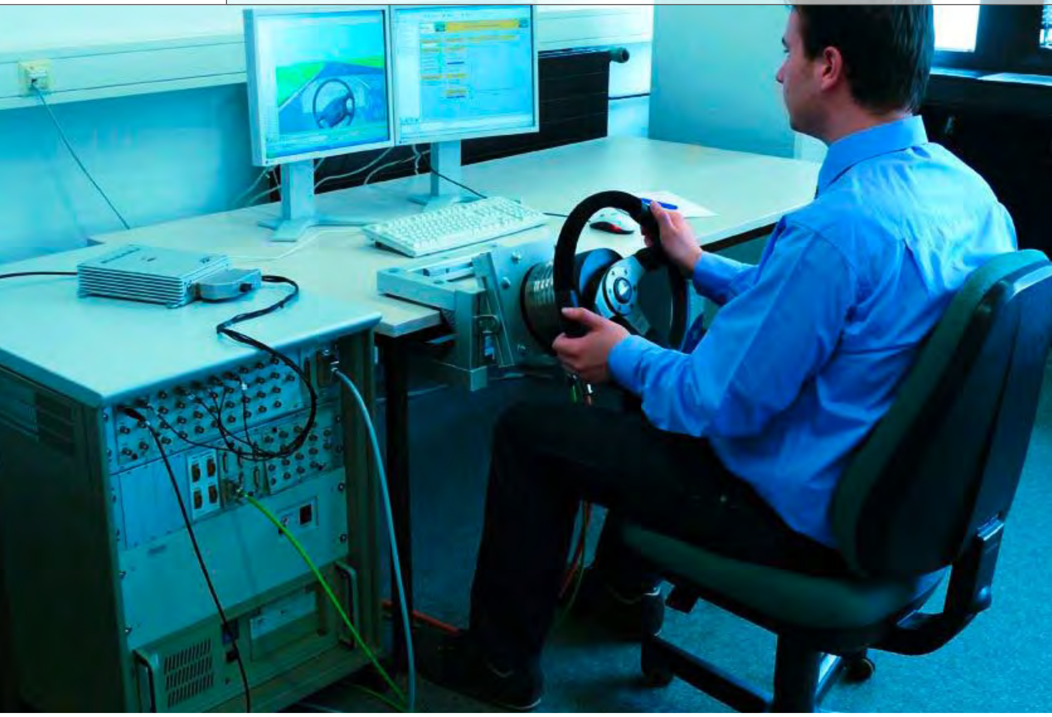


Figure 1: HIL test bench with a feedback steering wheel.

Innovations in Power Steering

Increasing demands on energy efficiency, comfort and safety are driving the development of mechatronic systems in motor vehicles. These demands are especially relevant for steering systems. In this field electromechanical power steering is gaining in popularity, and the functionality of these systems is extendable via software and steadily increasing. The system under development must fulfill both individual haptic requirements and specific safety-critical requirements.
In order to meet these challenges, DMecS GmbH & Co. KG has worked together with the Cologne Laboratory of Mechatronics (CLM) at the Cologne University of Applied Sciences to develop a feedback steering wheel (figure 1). This allows the front-loading of tests on prototypes to a hardware-in-the-loop (HIL) test bench.

Simulation Environment for the Feedback Steering Wheel

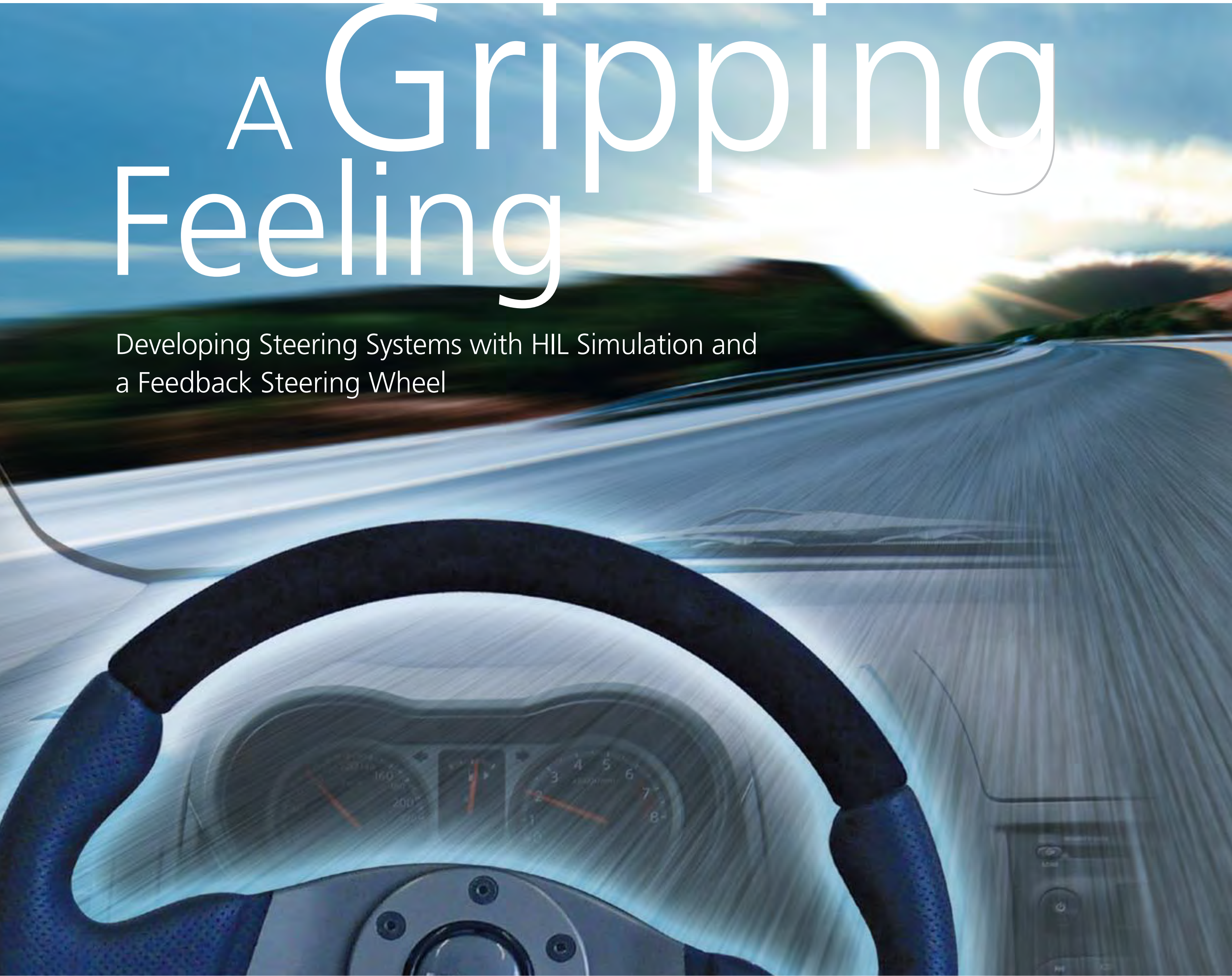
The test bench consists of several different real-time capable models. The simulation model for the steering system, consisting of the steering mechanics and the electric power steering (EPS) actuator with a controller, interacts with the models of vehicle, road and driver.
The Automotive Simulation Models (ASM) from dSPACE are used to simulate the vehicle and the road. The ASM Vehicle Dynamics Simulation Package is an open Simulink model for the real-time simulation of vehicle dynamics applications. This model allows a realistic simulation of the vehicle dynamics and the forces acting upon the steering system. The open structure of the ASM models made it easy for the developers to integrate their own EPS system models.

For the road, dSPACE ModelDesk was used to create individual road sections with special surface characteristics. This environment was used to develop and fine-tune the steering system with typical driving maneuvers, where the developer assumes the role of the driver through the use of the feedback steering wheel. For automated tests, the ASM driver models were used, which perform maneuvers repeatedly under identical conditions.

The engineering company DMecS is using a dSPACE Simulator to analyze the system behavior of steering systems. This allows testing at an early stage of development, before performing test drives. Innovative algorithms for generating steering characteristics and assistant systems are tested, evaluated and optimized realistically with regard to their acceptance by drivers through the use of a feedback steering wheel.

A Gripping Feeling

Developing Steering Systems with HIL Simulation and a Feedback Steering Wheel



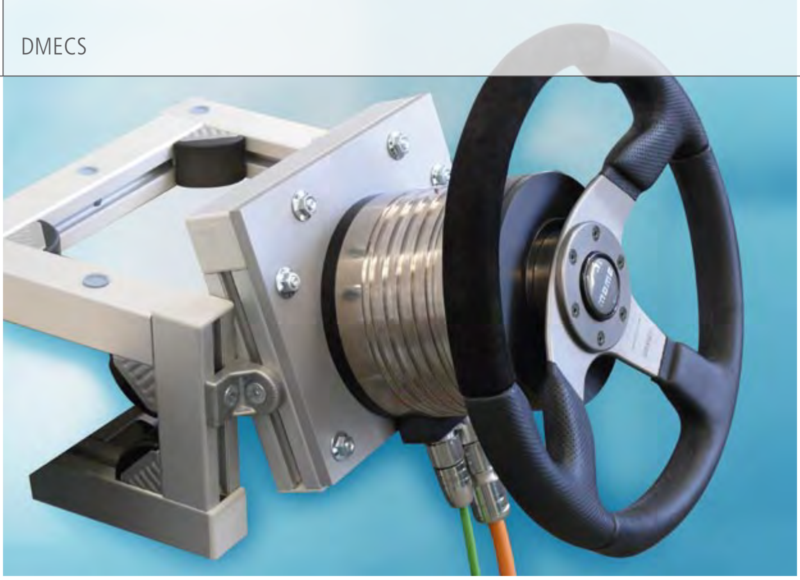


Figure 2: The feedback steering-wheel provides realistic haptic feedback.

> "The completely open Automotive Simulation Models (ASM) made it easy for us to implement our own steering models and new steering system algorithms."
>
> *Thorben Herfeld, DMecS GmbH & Co. KG*

Feedback Steering Wheel and HIL Test Bench

To provide a realistic steering feel, the mechanics and the electronics of the feedback steering wheel meet high demands. The careful design of the mechanical and electrical components minimizes undesired influences on the steering feel such as inertia, cogging, friction and signal propagation delays. The remaining deficiencies are reduced to an almost imperceptible level through suitable extensions of the HIL actuator control. The ASMs and the model of the steering system are implemented on a dSPACE Simulator in the HIL test bench. The simulator contains modular real-time hardware with a DS1006 Processor Board and the interface boards necessary for controlling the feedback steering wheel. Thus the available processing power is sufficient for the entire simulation model and any possible extensions.

Use Cases for the HIL Test Bench

For model-in-the-loop and software-in-the-loop simulation, the EPS controller and the ASM vehicle model run on a dSPACE Simulator. The feedback steering wheel is used to assess the steering feel and adjust it by modifying the controller structure, parameters and characteristic curves. In addition, by implementing control algorithms with TargetLink, the influence of fixed-point arithmetic can be analyzed and minimized appropriately. If the controller is run on a production-level ECU (figure 3), additional implementation issues (such as signal propagation delays and special interfaces) can be analyzed separately to minimize their impact on the steering feel.

Developing Algorithms for Steering Systems

The test bench was used to successfully develop various algorithms for generating steering feel. For example, the basic characteristic of one algorithm matches the steering feel conveyed by hydraulic power steering, and it also adjusts the steering assistance according to the current driving speed. This way the algorithm enables torque-free parking as well as increased centering at higher speeds.

Other algorithms use the tire forces to provide the driver with information on the traction potential of the tire contact patches. A special vehicle dynamics observer was used for these algorithms. In addition to the usual vehicle dynamics values, such as the slip angle or the yaw rate, this observer also estimates the tire forces without using tire models.

In addition to generating steering feel via software, an electromechanical steering system makes it possible to actively influence the current driving situation. For this purpose, assistance systems which stabilize the vehicle in critical situations were developed and tested.

Conclusion

- Development tasks for a steering system were front-loaded from the test drive phase to the simulation phase on a HIL test bench
- Innovative algorithms for steering characteristics and active steering intervention were tested realistically, analyzed and optimized with regard to driver's acceptance
- Efficient implementation supported by the open structure of the Automotive Simulation Models (ASM)

By using the HIL test bench with the feedback steering wheel during the development, it was possible to analyze and optimize the driver acceptance of these algorithms in advance.

Thorben Herfeld
Mechatronic System Development
DMecS GmbH & Co. KG

Jan Guderjahn
Cologne University of Applied Sciences
Cologne Laboratory of Mechatronics

Jan Guderjahn, research assistent in the Cologne Laboratory of Mechatronics at the Cologne University of Applied Sciences.

Thorben Herfeld, development engineer of mechatronic systems at DMecS in Cologne.

> "dSPACE's seamless tool chain supported us when we were developing the HIL test bench. From parameterizing the ASM real-time simulation with ModelDesk, to analyzing and synthesizing the algorithms with ControlDesk, to setting up the HIL test bench and visualizing the vehicle model with MotionDesk."

Jan Guderjahn, Cologne Laboratory of Mechatronics

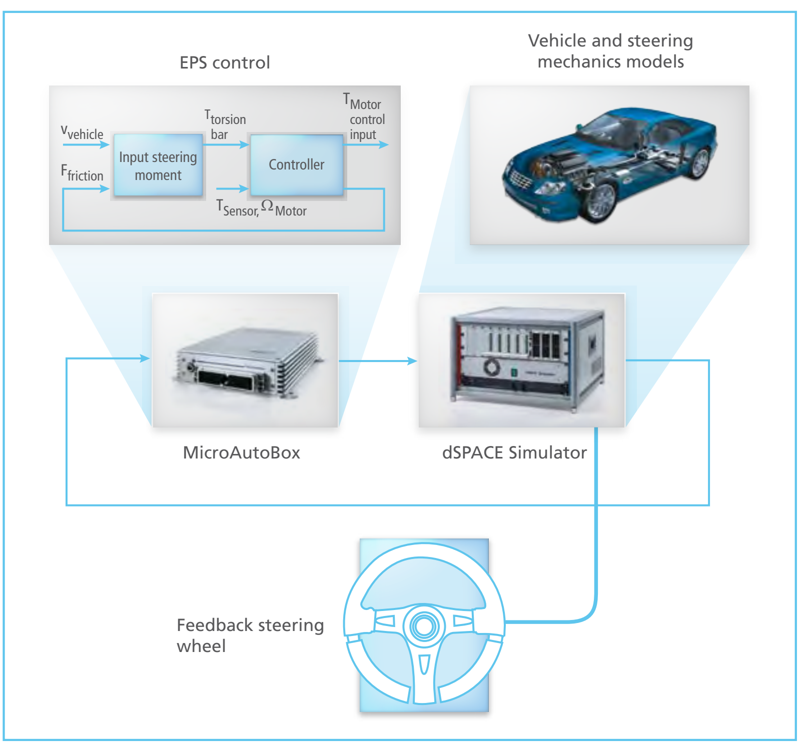


Figure 3: Test bench based on a HIL simulator, external prototyping system and the feedback steering wheel.

Summary and Outlook

The applications described above show that using a HIL test bench in the early stages of development can reduce the overall development time. Model-based system development that takes the haptic behavior of the steering into account makes it possible to fine-tune the entire system in the HIL simulation at an early stage. This reduces the amount of time and effort needed for fine-tuning and testing in test drives.

Besides the development of steering systems, the approach of using suitable HIL test benches can be applied to other systems with haptic feedback as well, such as braking systems or the sidesticks and pedals used in aviation.

Making Power Windows safe

Delphi Electronics & Safety is developing power window controls with TargetLink

At its Mexico Technical Center, Delphi Electronics & Safety is developing new algorithms for power window functions. The goal is to provide maximum protection against power window injuries. Delphi is simulating, implementing, and testing the new functions with the help of dSPACE prototyping systems and the TargetLink production code generator.

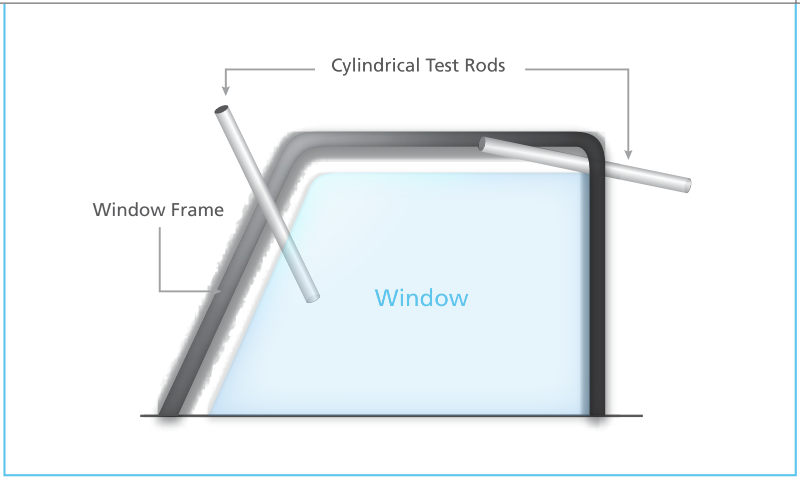


Figure 1: Test method for anti-pinch technology. Test rods are inserted to measure the actual closing forces that occur.

Safety Issues in Power Windows

Like other vehicle domains, vehicle interiors have a constantly increasing number of electronic functions. And comfort functions also have safety issues that must never be neglected. A power window can cause serious, or in some cases fatal, injury to passengers. Strong countermeasures are needed to prevent this happening.

Anti-Pinch Technology Standards

The anti-pinch technology of a power window has to meet standards issued by the EU and the United States. Test methods are available for this (figure 1). For example, the maximum force a power window is allowed to exert on any object is 100 N. Compliance with this limit must be monitored and enforced in a range of 4 mm to 100 mm from the top window frame. It is also important to deactivate the anti-pinch mechanism immediately before the window seal is reached, so that the window can close tightly. In addition, to avoid damage to the window motor, blocking must not last too long. The anti-pinch algorithm used in this project is based on the "Method for Monitoring Movable Elements" patented by Delphi. The method monitors the Hall effect feedback signal of the power window motor to detect if an object has been pinched.

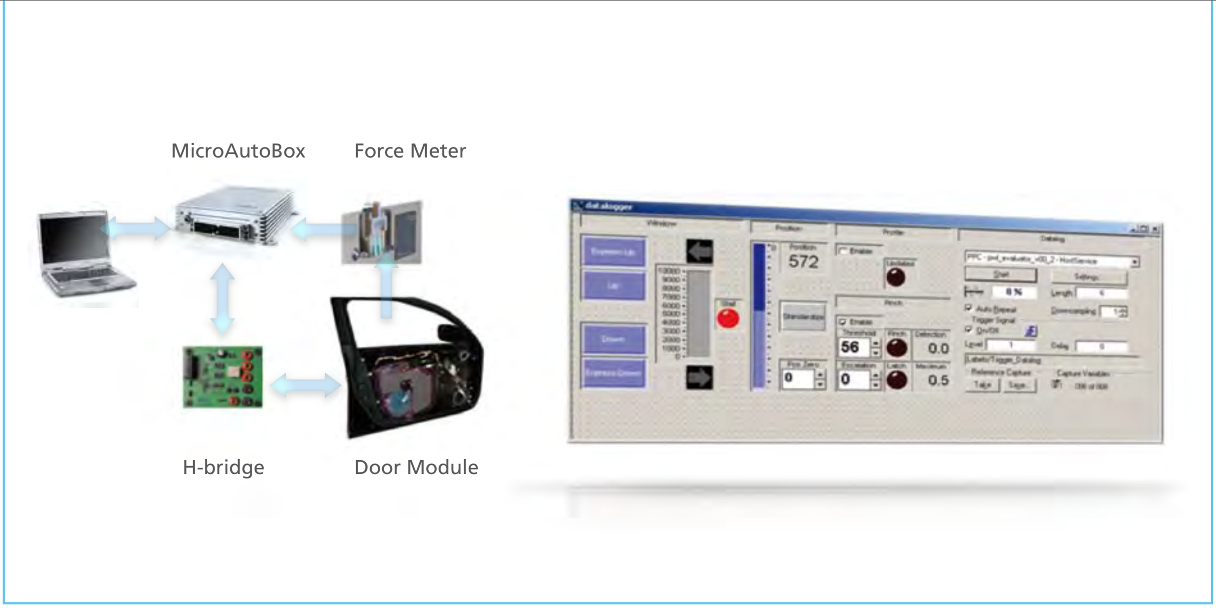


Figure 2: Left: Test bench for algorithm validation with MicroAutoBox. Right: ControlDesk experiment layout.

The Development Environment

Delphi developed the algorithm in Simulink®/TargetLink and validated the concept with a dSPACE MicroAutoBox and ControlDesk (figure 2). ControlDesk was used not only to adjust the algorithm parameters, but also to record the signals to provide test vectors for simulation runs later in Simulink/TargetLink. As well as performing test bench validation, the developers also created a Simulink/TargetLink environment for closed loop simulations, so that they could use model-in-the-loop (MIL) and software-in-the-loop (SIL) simulations to develop algorithms for the overall system.

> "The code generated by TargetLink is efficient, well-structured, and very readable."
>
> *Salvador Canales, Delphi Electronics & Safety Mexico, Technical Center*

The relevant power window behavior was represented by a state-space model of a DC motor and by look-up tables. The wave form of the Hall effect was superimposed on the motor model's position signal.

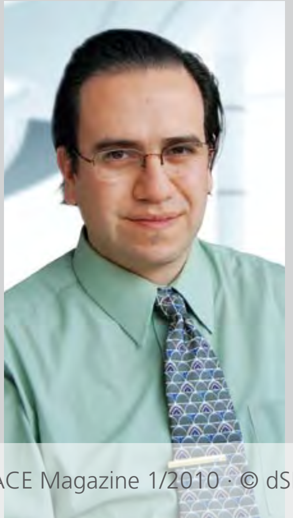
Anti-Pinch Algorithms

The algorithms are subdivided in several function blocks, two of them are described here: position control and stall detection. The position control provides information on the current window position and the last direction of motion before blocking occurred. To set the lower and upper position limits of the window (home indexing), the window is lifted from the lower pinch position to the upper one in an initial operating state before the position control is switched to the normal operating mode. In this mode, the position control sums all the window position changes across its entire lifetime to determine the current window position. The aging on the window seal is also estimated from the number of complete closures performed by the window. The position control is triggered by the edges of the Hall signal and is predominantly modeled in Stateflow® (figure 3).

The stall detection has a dual purpose: it prevents injuries from power window crushing, and stops the motor overheating at the window's lower and upper position limits. The algorithm for stall detection essentially compares the current value of a timer with a threshold value. The timer is restarted each time a Hall signal edge is detected, and a blockage is diagnosed if the timer's value exceeds the threshold value. The latter is not constant,

Left: Ernesto Wiebe-Quintana
Advanced Analysis Engineer
Ernesto Wiebe-Quintana is an advanced analysis engineer working on advanced development projects for Controls and Security Applications at Delphi.

Right: Salvador Canales
Electrical Analysis Engineer
Salvador Canales is an electrical analysis engineer, responsible for advanced development projects for Controls and Security Applications at Delphi.



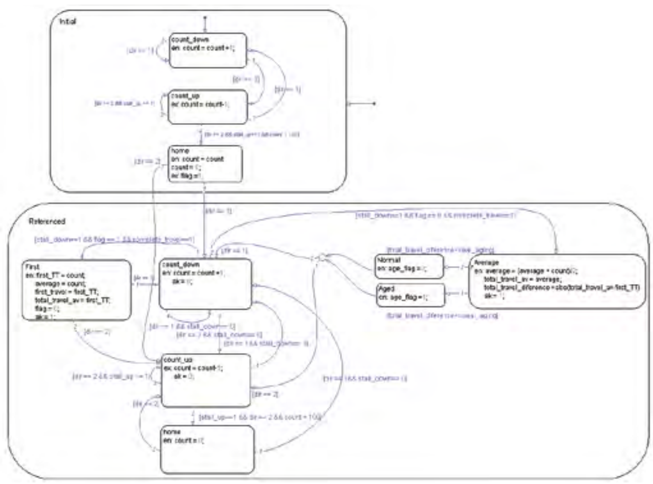


Figure 3: Excerpt from the algorithm for position control in normal operating mode.

Outlook

The individual functions have all been implemented. The next tasks will be to integrate the overall functionality in a door ECU and validate the system under all the specified operating conditions. Finally, aging test verification has to be performed to calibrate and validate some of the algorithm parameters in conjunction with the side door.

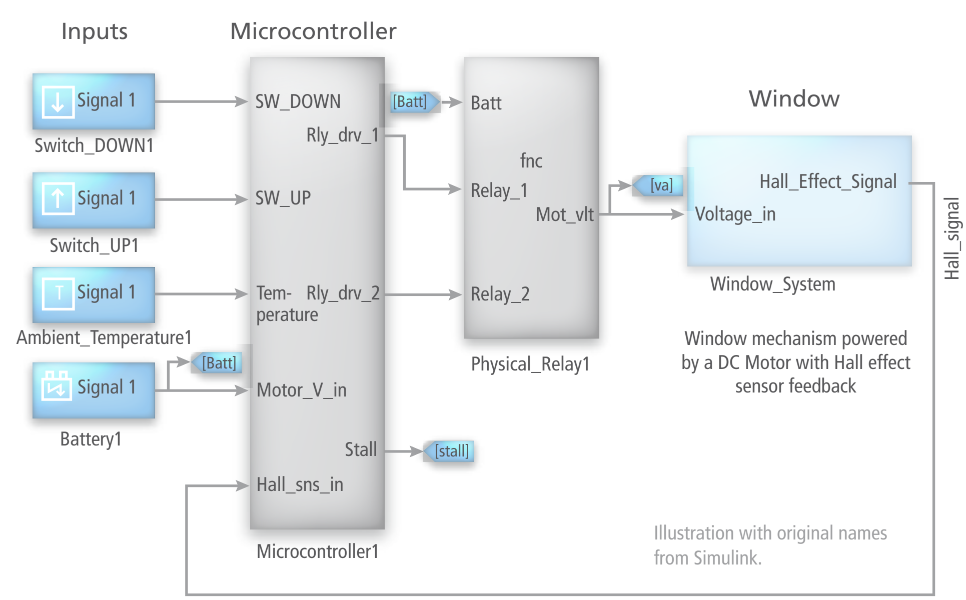
but is computed as a function of battery voltage and temperature.

TargetLink in Action

The entire functionality of the power window control was designed in Simulink/TargetLink and then autocoded with TargetLink. The generated code was highly efficient and clearly structured. Moreover, simulation in MIL and SIL modes proved extremely useful in advancing controller design and fixed-point software development. For offline simulation, signals recorded in rapid control prototyping were reused, and additional test vectors were also developed (figure 4). To specify the position control's software interfaces, the TargetLink Property Manager was used frequently to convert the Stateflow sections of the anti-pinch protection into production-ready C code. TargetLink's ability to flexibly generate code for look-up tables was harnessed to autocode the stall detection, making it possible to use different types of search and interpolation routines, to partition the code into different files, etc. ■

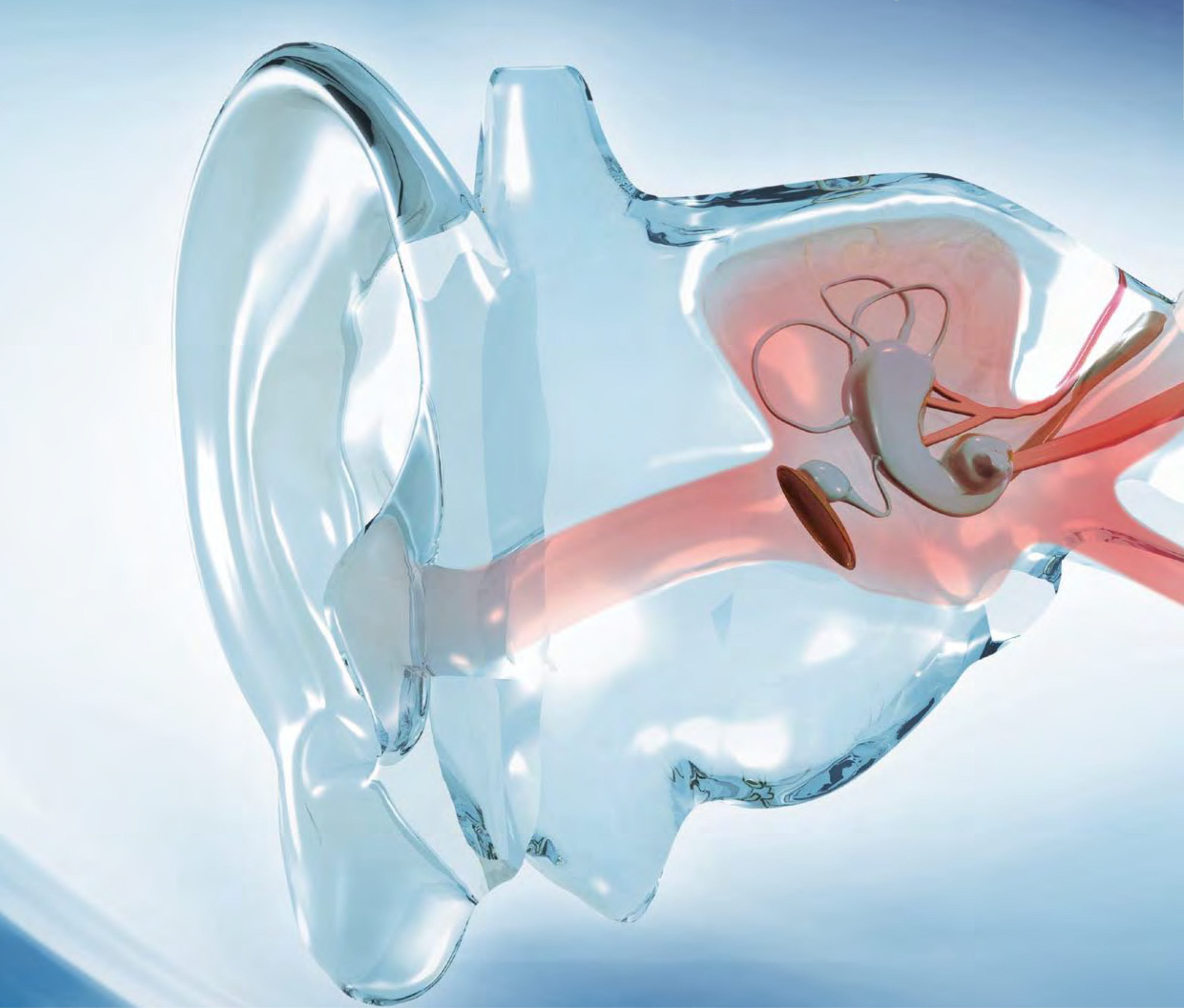
Ernesto Wiebe-Quintana
Advanced Analysis Engineer,
Salvador Canales
Electrical Analysis Engineer;
Delphi Electronics & Safety
Mexico Technical Center

Figure 4: Simulation environment in Simulink/TargetLink.



All Ears

Biomechanics: Research on the middle ear helps develop new hearing aids



The ability to communicate is an elementary part of our lives. And without good hearing, communication becomes difficult if not impossible. This is why researchers continue to work on optimizing prostheses that improve hearing. Now researchers at the Universität Stuttgart in Germany have opened up a new avenue of exploration for developing middle ear prostheses. Their investigations concentrated on the impact of the ossicular chain in the middle ear, which directly affects hearing.

How We Hear

The hearing organ must convert air pressure fluctuations into neural impulses to make them accessible to the brain. It does so via a complex chain of elements with overlapping functions. Simply put: Sound waves enter the auditory canal as air pressure fluctuations and put the auditory ossicles (the hammer, also known as the malleus, the anvil or incus, and the stirrup or stapes) in the middle ear in motion. The footplate of the stapes rests on the inner ear. Behind it lies the inner ear fluid, which fills the vestibular system and the cochlea. The movements of the stapes footplate put the inner ear fluid into motion, which excites the sensory hair cells. The deformation of these cells creates electric signals, which are sent to the brain via the auditory nerve and cause the actual perception of sound.

The Impact of Rocking Motions on Hearing

To improve the prosthesis, the research team at the Universität Stuttgart wants to ascertain how the ossicular chain must be stimulated for humans to hear as well as possible.

The stapes performs both piston-like and rocking motions, depending on the frequency.

- At low frequencies, there is mainly piston-like motion.
- At high frequencies, additional rocking motions also occur.

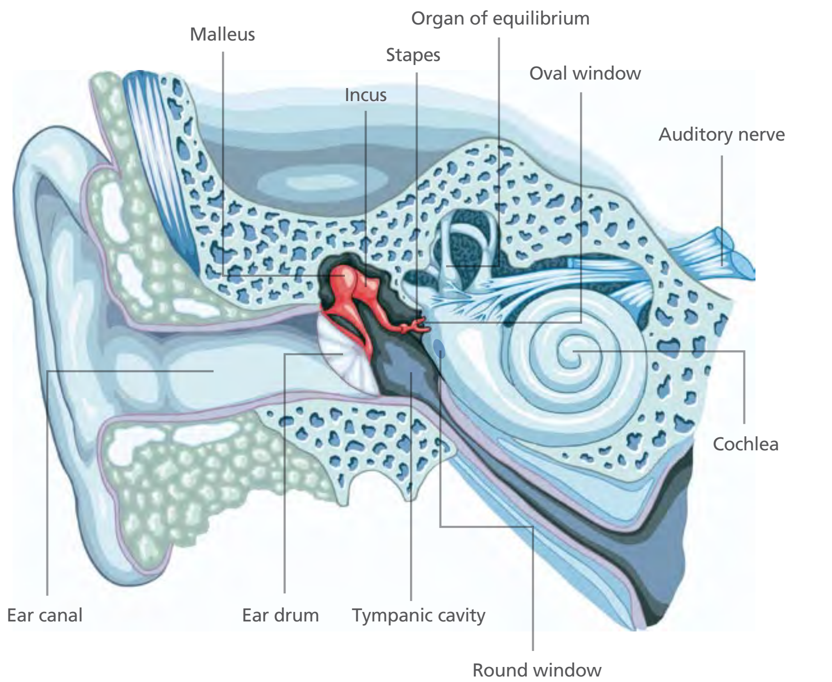
Researching the Impact of Rocking Motions

The classic theory on hearing states that only the piston-like motions of the stapes footplate directly influence hearing, not the rocking motions. The goal of the research team at the Universität Stuttgart and at University Hospital Zürich in Switzerland is to discover whether, and to what extent, the rocking motions excite the hair cells and trigger signals to the brain to produce auditory perception. In-vivo experiments were therefore performed on guinea pigs.

Test Setup with Modern Microsystem Technology

The test setup consists of:

- An anesthetic and monitoring device for the experimentee
- A vibration-damped test rig in a booth isolated from acoustic background noise and electromagnetic radiation
- An apparatus to mechanically excite the stapes with a piezoelectric actuator
- Data acquisition of the stapes motions and the nerve potential



The anatomy of human hearing.

Mechanical Stimulation of Hearing

In comparison to acoustic excitation via a loudspeaker, mechanical excitation at the head of the isolated stapes makes it possible to specify the form of the footplate's motion. The actuator with its three independent piezoactuators can then carry out any kind of complex spatial motion. In particular, piston-like stapes motions can be generated, as well as pure rocking motions. In comparison, with acoustic excitation, the relationship between the rocking and piston-like motions of the stapes is a fixed, frequency-dependent relationship, determined by the dynamics of the chain. A motion corresponding to acoustic excitation can also be superimposed at the head of the stapes. This makes it possible to compare the measured nerve potentials with the results from other research groups.

> "Insufficient measurement methods were the reason why it was assumed that the rocking motions of the stapes footplate do not cause an auditory event. State-of-the-art microsystem technology at long last lets us superimpose rocking motions onto the hearing organ in a high-frequency range and measure them."
>
> *Dr. Ing. Albrecht Eiber, Institute of Engineering and Computational Mechanics, Universität Stuttgart, Germany*

"Insufficient measurement methods were the reason why it was assumed that rocking motions of the stapes footplate do not result in nerve stimulation," explains Dr. Albrecht Eiber from the Institute of Engineering and Computational Mechanics at the Universität Stuttgart. "State-of-the-art microsystem technology has at long last enabled us to measure the rocking motions and their impact in the high-frequency range."

When investigating the vibrations of the auditory ossicles in the nanometer range, it is common to use laser Doppler vibrometers. In this experiment, a 3-D laser captures the speeds of the stapes head simultaneously in all spatial directions and amplifies the electric voltage of the electrophysiological response by the experimentee's auditory nerve via a very high-ohm biosignal amplifier.

Surgical Intervention in the Middle Ear

The stapes of the guniea pig is laid open surgically while maintaining the inner ear function. The actuator and the laser beams thus have direct access to the head of the stapes. A specially designed needle and the finest ophthalmic surgical threads couple the piezoelectric actuator to the head of the stapes. These meticulous surgical tasks and the monitoring of the experimentee's anesthetic status were performed by PD Dr. med. Alexander Huber from the Universitätsspital Zürich.

Drive Concept of the Actuator

The time progression of the stapes motion determines the frequency content of the signal, and thus also the excitation of the inner and outer hair cells at the frequency-specific location of the basilar membrane. The acoustic click stimulus commonly used in electrocochleography has a wide frequency spectrum. The dynamics of the vibrating system for

> "The DS1005 PPC Board drives the actuator. With the three independent piezo actuators, the elementary piston-like and rocking motions of the stapes can be defined precisely and excited highly dynamically."

Dr. Ing. Michael Lauxmann, Institute of Engineering and Computational Mechanics, Universität Stuttgart, Germany

acoustic excitation, consisting of a loudspeaker, transmission tube, ear channel and middle ear, mean that stimulus behavior over time in the inner ear is noticeably low-pass filtered. A short, high-frequency click on the sonic converter has an extremely limited bandwidth and experiences a delay due to the signal execution time. This makes it possible to reproduce an acoustic click by direct stimulus at the head of the stapes using a slower mechanical drive system.
The modular hardware by dSPACE optimally generates the stimulus forms necessary for the experiment. "The dSPACE DS1005 PPC Board is used to drive the actuator," explains Dipl.-Ing. Michael Lauxmann from the Institute of Engineering and Computational Mechanics at the Universität Stuttgart. "With reference to the dynamics of the ossicular chain and the actuator, we calculate beforehand how we need to operate the actuator in order to achieve the desired stimulus for the head of the stapes. We use a multi-sinus signal to identify the system dynamics."

Recording the Nerve Potentials

Measurement is performed via an amplifier with a high-ohm input and a high amplification factor. However, the signal of the stimulus response contains a high level of disturbance resulting from the experimental environment and the basic activity of the nerves. For this reason, a number of stimulus responses are recorded and the uncorrelated disturbances are reduced by averaging. To do so, clicks are output at intervals of 50 ms, for example. To obtain consistent measurement data, the physical condition of the experimentee and the positions of the electrodes need to be monitored, as in a real surgical operation, and should remain as constant as possible.

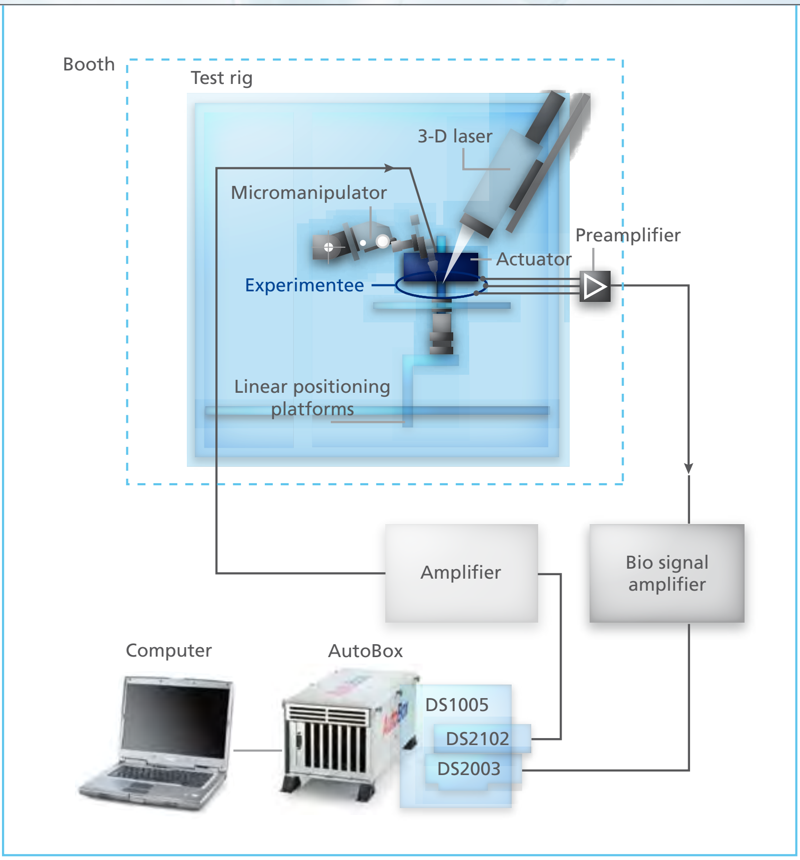
Impact of the Stapes Footplate's Rocking Motions

By imprinting both the elementary piston-like and rocking motions, the nerve potentials known from electrocochleography were verified. The experiments showed for the first time that in contrast to what was previously thought, rocking motions do in fact trigger nerve stimuli. The form and latencies of the sensory cells' responses to rocking motions, depending on the intensity of the stimulus, correspond to the neural responses previously only observed in the case of piston motions.

Stimulus and Data Recording with the dSPACE AutoBox

The dSPACE AutoBox is used to operate the test rig and record the data. "Following good experience

Dr. Ing. Albrecht Eiber (right) and Dipl. Ing. Michael Lauxmann (left), Institute of Engineering and Computational Mechanics, Universität Stuttgart, Germany.



Components and signal flow of the experiment setup.

with dSPACE when running test benches in mechatronics, we decided to choose dSPACE for our biomechanical experiments as well," reports the commissioned researcher, Dr. Albrecht Eiber. One part of the system is the DS1005 PPC Board, where the measurement program runs in real time. Additional modular hardware components from dSPACE, like the DS2102 High-Resolution D/A Board, perform the analog output of the measurement program values, and the DS2003 Multi-Channel A/D Board reads in the input of analog signals.
The modular setup of the dSPACE system and its high flexibility allow us to match the measurement environment quickly and optimally to any kind of inquiries in the field of biomechanics," continues researcher Dr. Eiber. The dSPACE experiment software ControlDesk controls the measurement program on the real-time processor. The execution of the experiment is automated and accelerated by MATLAB 2008a. In addition, dSPACE provides a library of MLib functions for data transfer between the memory of the measurement processor and the RAM from MATLAB.

After the experiment is carried out, the data is transferred to MATLAB. This keeps time between the two measurement cycles to a minimum, since there are fewer manual steps and because it is not necessary to document the experiment setup parameters manually. The automated test sequence is as follows:

- Input of the stimulus via ControlDesk
- Starting the measurement procedure via MATLAB command lines
- Saving the measurement data and controlling the measurement via MATLAB

> "Following good experience with dSPACE when running test benches in mechatronics, we decided to choose dSPACE for our biomechanical experiments as well."
>
> *Dr. Ing. Albrecht Eiber, Institute of Engineering and Computational Mechanics, Universität Stuttgart*

Positive Measurement Results and the Need for Further Research

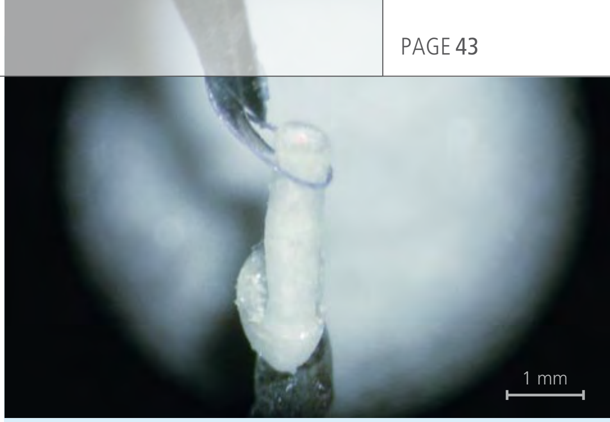
The collected data challenges the theory that only piston-like stapes motion causes the sense of hearing, not rocking motion. The results show that all complex stapes footplate motions, piston motion and rocking, activate the inner ear and thus cause an auditory event. For statistical evaluation of the experiments, further experimentees must be studied.
If further experiments prove that

Glossary

Basilar membrane –
Membrane in the cochlea whose movements are converted into nerve impulses via the hair cells. The impulses are carried to the brain by the auditory nerve, where they generate the actual perception of sound.

Electrocochleography –
Examination method used in ear, nose and throat medicine to measure the potentials generated in response to acoustic stimuli inside the cochlea.

Short and long axes –
The stapes has two characteristic stirrups that start at the footplate and meet at the head of the bone. The footplate is oval in shape, so it has one short and one long axle.



A thread is used to connect the actuator needle and stapes.

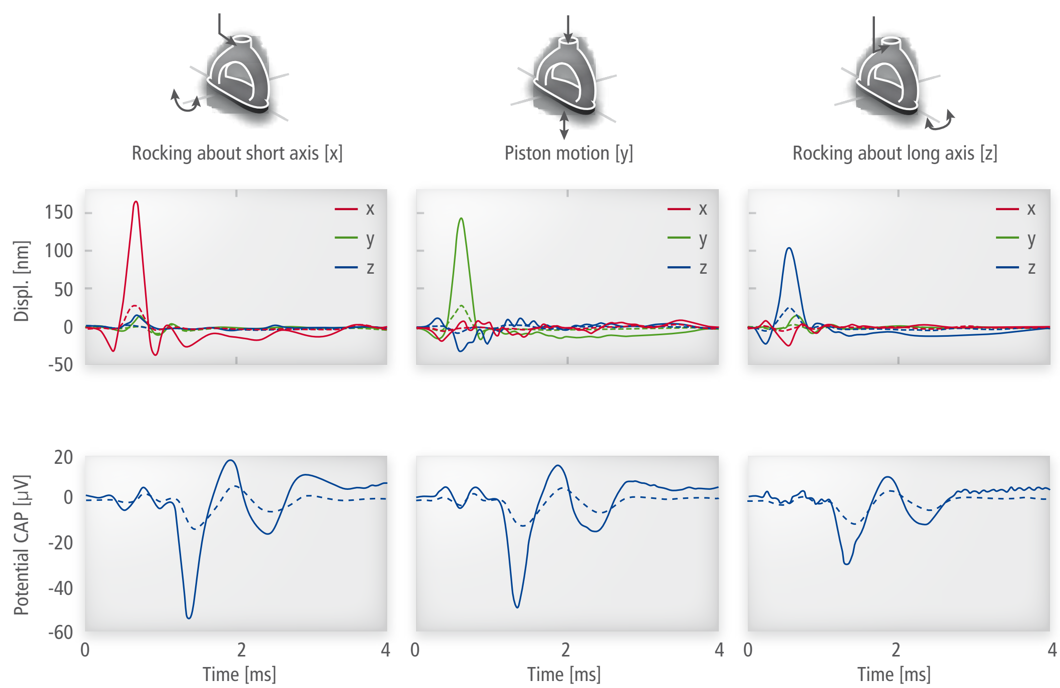
rocking motions of the stapes also set off a hearing stimulus, this will have a long-term impact on the goals for the improvement of middle ear prostheses. If so, any implant can no longer be evaluated solely on the basis of the piston-like stapes that it generates. The complex spatial motion of the stapes would be the new criterion for evaluating an implant's performance. ■

> "The modular setup of the dSPACE system and its high flexibility allow us to match the measurement environment quickly and optimally to any kind of issues in the field of biomechanics."

Dr. Ing. Albrecht Eiber, Institute of Engineering and Computational Mechanics, Universität Stuttgart

Summary

- A research team at the Universität Stuttgart contributes vital knowledge for developing newer middle ear prostheses that improve hearing.
- The experiments investigate whether the rocking motions of the stapes cause a hearing stimulus in the middle ear.
- dSPACE products help answer complex questions in the field of biomechanics.
- The modular setup and flexible use of the dSPACE equipment provided ideal conditions for performing research.



Source: Dissertation Christian Breuninger, Institut für Technische und Numerische Mechanik, Universität Stuttgart, Germany

Compound action potential (CAP) for piston-like and rocking motions of the stapes footplate. The continuous line shows a strong stimulus, the dashed line shows a weaker stimulus.

The island of Graciosa in the Azores could soon be powered entirely by regenerative energy.

New Energy – Wind and Sun Bring Independence

Purely regenerative energy supply for an entire island

One of the Azore Islands in mid-Atlantic: Plenty of sunshine. Constant wind. And miles away from any power grid or any filling station for diesel generators. The obvious answer? Switch to regenerative energy sources for the entire island's electricity supply. In other words, power from the sun and the wind.

Purely Regenerative Energy Supply

An autonomous, CO_2-neutral power supply based on regenerative energies for remote areas – islands or villages – that are far away from the main power grid: That's what we're planning and developing at Younicos. Our first project is for the island of Graciosa in the Azores. At the moment, diesel fuel for the island's generators is brought in regularly by sea. Wind farms and photovoltaic systems could make this a thing of the past and give the island a less expensive alternative. 70-90% of the required energy would come from the sun

and the wind, and the remaining 10-30% could be generated from locally produced biofuels. Add a 3-megawatt sodium sulfur battery as electricity storage to compensate for large supply fluctuations, and the island will be completely independent of fossil fuels.

However, before turning the whole island and its inhabitants into a test object, we reproduced their power grid at our Berlin test facility. Our power supply concept is undergoing two years of close scrutiny here. We are thoroughly testing the transition from conventional to regenerative energy, simulating extreme situations, checking and optimizing different control strategies, and verifying that our concept is both real-world-proof and economical. The test setup is the first-ever experimental plant of this kind in the megawatt range that we know of.

Test Facility

The test setup comprises a complete power supply grid. Obviously, Berlin does not have the same wind and sun conditions as the Azores. So we use simulation models for the wind and solar power to obtain data for

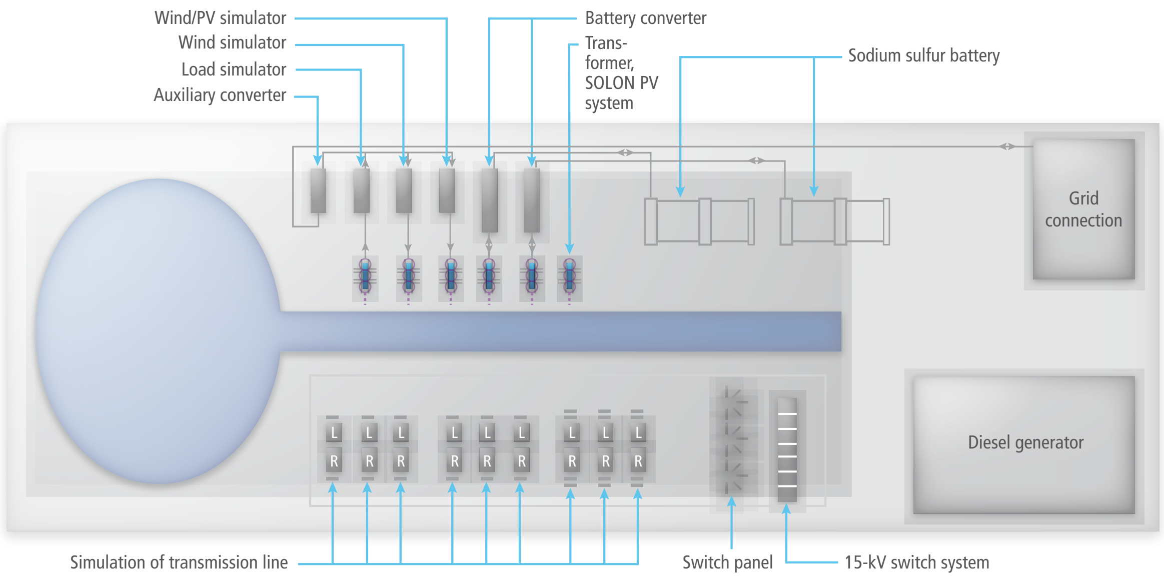


Figure 1: The wind and solar energy of Graciosa, one of the Azore Islands, is simulated at the test facility in Berlin.

power supply control. The weather data for the simulation is measured on Graciosa itself and then processed in real time in the simulation at the test facility. This ensures that our concept satisfies real-world requirements.

The facility consists of the following components (figure 1):

- 2 x 500-kW NaS batteries with a total capacity of 6 MWh
- 2 x 500-kW battery converters
- 1-MW diesel generator representing a conventional power supply
- 210-kW photovoltaic system
- 2-MW wind farm simulator consisting of a converter with an integrated wind turbine for converting wind measurements into power input
- 1-MW load simulator consisting of a converter for running through a load profile
- Transmission links at medium voltage level, assembled from transformers and power lines, and represented by concentrated elements R, L and C
- Switch panel for setting up different grid topologies
- Short circuit generator for optimizing the protection concept in future grids

dSPACE hardware for controlling the battery converters and for simulating the wind strength, solar radiation and load conditions.

> "The tests on the world's first autonomous regenerative energy supply in the megawatt range run smoothly with dSPACE rapid prototyping hardware."
>
> *Mohamed Mostafa, Younicos*

We took great care to achieve a redundant design that would make the system robust and less error-prone. At the same time, the system had to be modular and extendable. The system's internal communication structure between the converters and the battery management system had to be as small and efficient as possible to keep it flexible, reliable, and easy to maintain.
The overall hardware structure of the test setup and the functions of the individual components are shown in figure 2.

Battery and Converter for Stability

The energy obtainable from the wind and the sun fluctuates, and long-term predictions are impossible, so the NaS batteries and the converters are vital for stabilizing the power grid. Controlling and coordinating these components, i.e., arbitrating between the available power and the power demand, are the core tasks of the battery management system and the converter control.
The batteries (figure 3) charge when the photovoltaic and wind generators are producing more electricity than is being consumed. They dis-

Figure 2: The detailed hardware structure with its functions in the test setup.

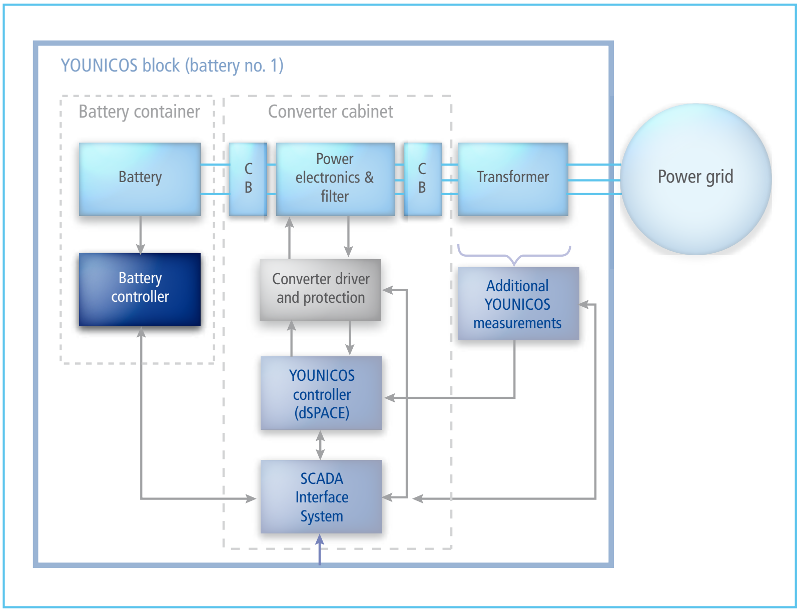


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Figure 3: The sodium sulfur battery evens out power fluctuations and serves as storage for "lean" times.

charge when the generators are providing less electricity than the island requires. The fast control in the converters keeps the frequency and voltage in the grid stable. With its high cycle stability, the NaS battery is ideal for combining with renewable energy sources, where times of increased power generation and times of low power generation alternate irregularly.

Developing the Converter Control

The battery converter control has two main components: a real-time controller and a communication system.

To find the optimum control for the converter, we use rapid prototyping to test different voltage and frequency control algorithms that we designed in MATLAB®/Simulink®. For the actual tests, we use the AC Motor Control Solution from dSPACE. This consists of a DS1005 Processor Board and DS5202 FPGA Base Board with a piggyback module. The algorithms are implemented on the DS1005 by means of the dSPACE Real-Time Interface (RTI), and then executed on the board. The DS5202 provides the necessary I/O connection between the processor board and the converter. If any changes are made to an algorithm, they can quickly be transferred from MATLAB/Simulink to the DS1005 by using RTI.

The communication system monitors the interfaces between the battery, the converter, and the control, and also coordinates the battery and the converter. The system can be accessed from anywhere via a web terminal to query its status or make changes. This makes it easy to per-

Features of the NaS battery

High energy density	3 times higher than that of lead acid batteries
High capacity/duration	Discharging 6 hours at 100% or 8 hours at 75%
Lifetime	15 years, or approx. 4,500 charge cycles
Charge properties	No self-discharge No memory effect
Easy maintenance	Inspection once every 3 years
Fast response time	2 ms
Operating temperature	300 °C

Glossary

Cycle stability – An indicator of whether battery charging and discharging causes deterioration with associated performance loss.

Sodium sulfur battery – Rechargeable battery with anodes made of molten sodium and cathodes made of granite tissue soaked in liquid sulfur.

Self discharge, memory effect – Important factors in rechargeable battery use. In self-discharge, the battery loses energy even when not connected to a consumer. The result is a loss in capacity.

Figure 4: Another Younicos project also uses energy from the sun: This solar power system feeds an autonomous charging station for electric vehicles.

form remote control and remote maintenance. This is absolutely essential for a system used in remote areas or on islands, as there is not always an engineer close at hand.

Simulating Consumption, Wind, and Sun

We use our own models for simulating wind turbines and solar power plants. They are implemented and executed on several dSPACE DS1005 PPC Boards. Real wind and sun data measured on the island of Graciosa provides the input parameters for ascertaining the currently available power. This available power is then compared with a consumption profile that represents the island population's energy requirements throughout the day. Converters then perform energy distribution. Each battery is coupled to the simulated supply grid via a converter. At the test facility, the input of wind and solar energy into the electricity supply grid is simulated with the aid of two converters. The load on the grid is represented by another converter that runs through a scaled load profile of the island. In addition, a real 210-kWp (kilowatt peak) solar plant feeds into the island grid. The solar panels are installed on the roof of the Solon SE building.

The Test Objectives

During the test phase, we aim to demonstrate that a stable energy supply based on renewable energies is technically feasible and economically attractive. The amount of renewable energy fed into power grids has so far been limited because it fluctuates and impairs grid stability. We intend to show that the battery and the intelligent converter control together stabilize the island's grid, making it no problem to obtain an increasingly large part of the power supply from renewable energy sources.
When the two-year test phase has been completed, the results obtained from it will be used to change Graciosa's power supply completely to wind and solar energy. ■

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Scenery from the Google 3D warehouse rendered with MotionDesk.

A Feast for the Eyes in MotionDesk

Realistic graphical visualization in 3-D animation

The realistic visualization of moving objects and their environment is indispensable to hardware-in-the-loop (HIL) simulation. The new version of MotionDesk shows simulation results in an online animation with significantly enhanced graphics. Optimized performance and handling are also included.

Enhanced 3-D Graphics

The new version of MotionDesk, dSPACE's 3-D animation software, includes a highly detailed, finely drawn 3-D landscape environment that gives driving scenes a real-world feel. As with previous versions, users can integrate their own 3-D objects to produce extremely convincing roads and scenes.

Sophisticated anti-aliasing smooths lines and edges to avoid unwanted jagged outlines. Texture filtering is also applied to suppress "pixel flickering", in which pixels appear on the wrong objects. This makes the entire image smoother and more harmonious. With modern graphics cards, these graphical enhancements hardly have an impact on performance, so they can also be used on less powerful computers.

Flexible Instrument Display

MotionDesk animates not only the vehicle itself, but also its individual instrument displays. The values shown by the speedometers, engine speed indicators, status displays, etc., are always up-to-date. Four types of display are available (figure 1):

- Numeric digital displays for force vectors, etc.
- Dial gauges for speedometers, engine speed indicators, etc.
- Bar displays for fuel-level indicators, etc.
- LEDs for gear indicators, indicator lights, etc.

There are extensive configuration options for each individual instrument that let you design its appearance, size, and value range. The displays can be positioned wherever required: relative to moving objects so that they move synchronously to the objects; on the dashboard; as head-up displays on the windshield; or as labeled force vectors at the

vehicle's wheels. Or they can also be inserted into the scene statically – at the bottom edge of the picture (figure 2).
The display values of a simulation are saved and can be displayed on the instruments again at a later time.

Figure 1: The display instruments can be placed on moving objects.

Optimized Blockset

The MotionDesk blockset was completely worked over for the new version. The blockset acts as the interface between Simulink, the dSPACE simulation hardware, and

> The optimized graphics make the scenes more realistic, giving users the feeling they are in the middle of the action.

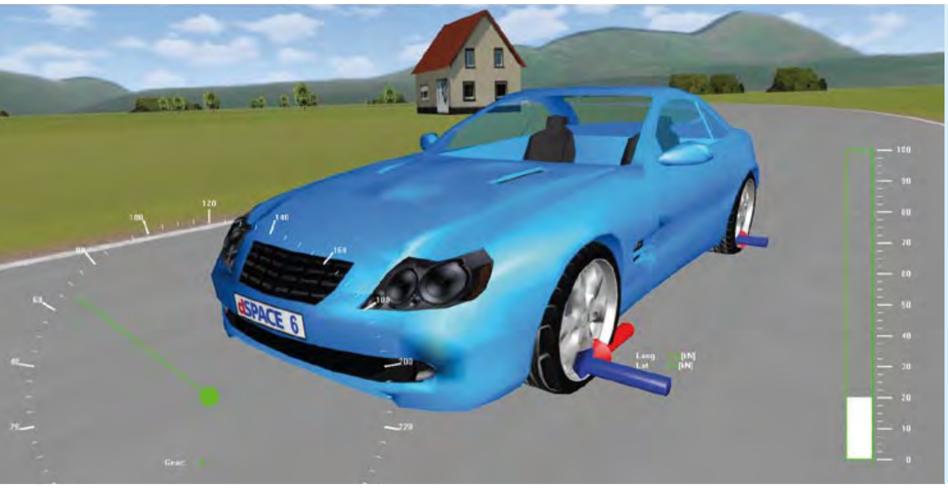


Figure 2: Instruments can be displayed inside or outside the vehicle.

Profile of MotionDesk

- Version 2.1.4
- 3-D animation software to visualize simulated mechanical systems in real time
- Intuitive graphical scene design
- 3-D object library with objects in VRML2 format
- Online and offline animation modes

MotionDesk. It transfers the motion data (such as the kinematic chain in the simulation of a robot arm motion) from a Simulink model to MotionDesk. The handling and configuration have been simplified for enhanced usability: For example, blocks can now be grouped and more clearly arranged. In addition, model initialization under Simulink is faster, and processing time during real-time execution has been reduced.
The new MotionDesk version is available with an online license or a more inexpensive offline license. Simulation runs can also be made without connection to a hardware-in-the-loop simulator. This early testing boosts the simulation quality and saves valuable time on the HIL simulator. You can switch between online and offline simulation whenever required, without having to modify your project. ■

Quad Power

Performance boost for HIL simulation with new DS1006 Processor Board

dSPACE has upgraded the DS1006 Processor Board – the heart of dSPACE real-time systems – with a Quad-Core AMD Opteron™ processor. The board now has even more power to meet the growing demands of hardware-in-the-loop (HIL) simulations. Large, processor-intensive models can be distributed easily across the processor cores and executed synchronously.

Simulation Needs Performance

HIL simulation is always hungry for greater computing performance. There are countless examples, such as the HIL simulation of electric motors for hybrid drives. These require high computing speeds because some tasks necessitate very short cycle times, for example, to allow oversampling even at high switching frequencies. Gasoline engines with variable valve timing and valve lift are another example. The usual mean-value models no longer suffice for these; more precise and therefore more processor-intensive models are required. The same applies to diesel engines with in-cylinder pressure measurement. The new DS1006 supplies the performance needed for all these application cases and still has enough in reserve for further tasks. Various performance tests have shown that the new DS1006 is up to 60% faster than its predecessor in multiprocessor systems.

The Solution: Multi-Core Processors

For a long time, the usual method of boosting processor speed was to increase the clock rate. This method is coming up against its physical limits, however, as the heat build-up it causes is becoming unmanageable. The second common way in which speed is boosted is to im-

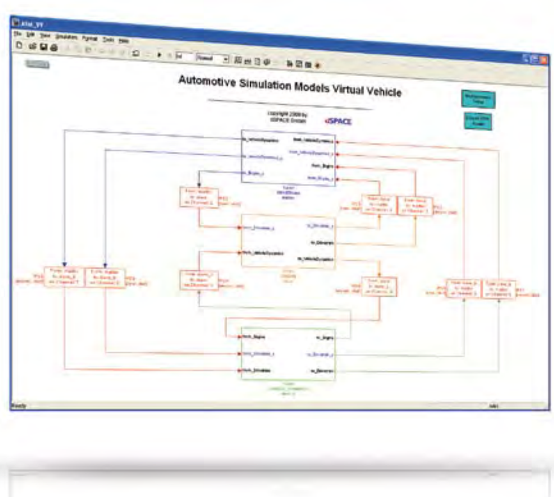


Figure 1: Example of distributing a model across several cores of the DS1006. An ASM virtual vehicle consisting of three submodels (Drivetrain, Engine (with Soft_ECU_Gasoline) and Vehicle-Dynamics) is distributed across three of the four cores of a DS1006 and interconnected via 9 IPC blocks.

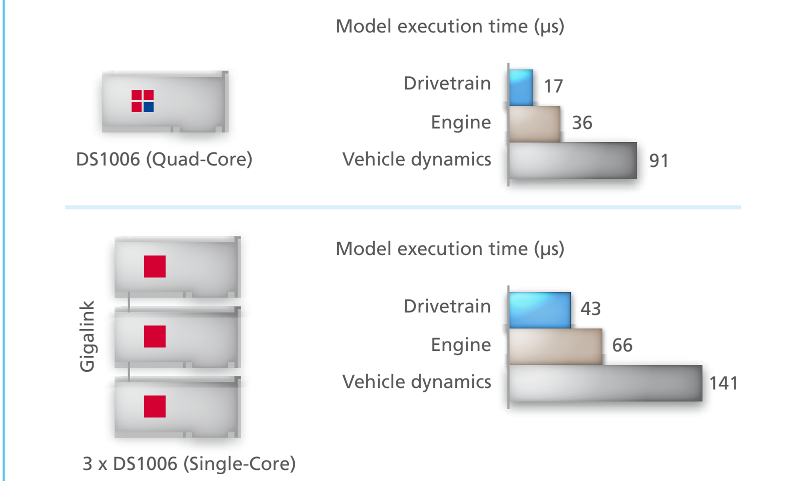


Figure 2: Performance of the quad-core DS1006 2.8 GHz compared with its predecessor DS1006 2.6 GHz (each without I/O). Three submodels of the ASM virtual vehicle run simultaneously on three cores of the quad-core DS1006: drivetrain, engine and vehicle dynamics.

prove processor architecture, but here too, there is very little room for further improvement. Multi-core processors, i.e., ones with several CPU cores, are the way out of this dilemma. Each of the CPU cores has greater performance than earlier single-core processors, and the rapid data communication between the cores is a real bonus. The challenge of harnessing the great power of multi-core processors for real-time simulation therefore lies in thinking out how to handle all the different tasks, in other words, how to most usefully distribute and parallelize them, and how to organize communication between them.

Made-to-Measure Power

Where several DS1006 single-core boards used to be necessary in the past, only one single quad-core DS1006 Processor Board will often be needed in the future. This not only makes HIL simulators more cost-effective, it also provides greater flexibility for extensions. Naturally, multiprocessor systems can also be built in the usual way by connecting several new quad-core DS1006 processors together. Users can tailor the computing power to specific requirements in this way – whether they “only” want to process CPU-intensive models, or need the modularity of multiprocessor systems to build a virtual vehicle from the test systems for individual ECUs or vehicle domains.

Graphical Control via the Real-Time Interface

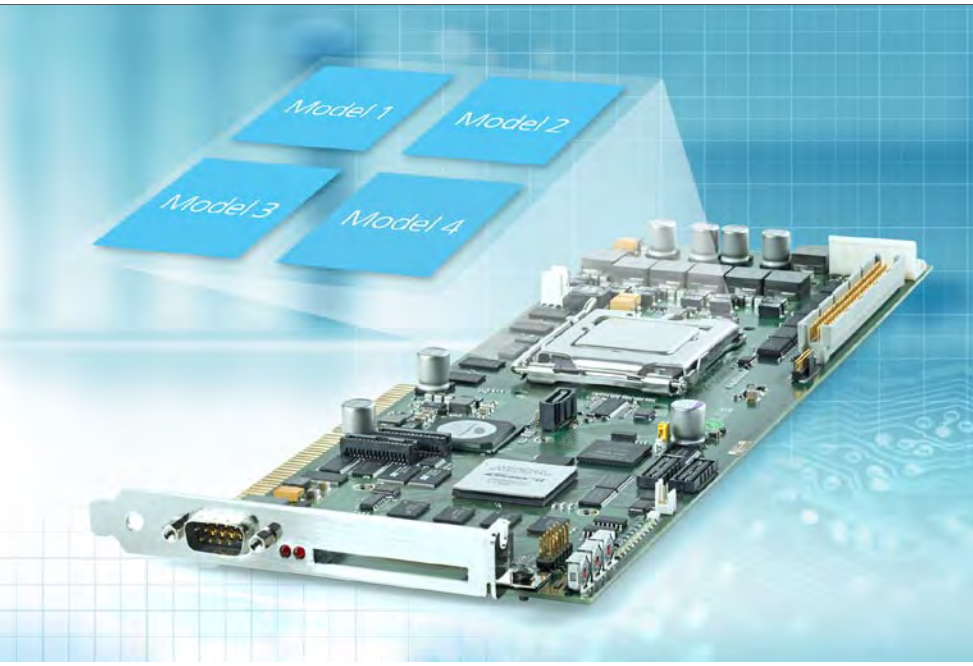
The Real-Time Interface for Multiprocessor Systems (RTI-MP) is an implementation tool that supports users when they scale large, processor-intensive models on their systems. Users can perform all the necessary steps on this one user interface, whether they want to use a single quad-core DS1006 board or build a system from several boards. RTI-MP lets users partition the models to ensure optimum utilization of the processor cores, and define and specify the communication channels for data transmission between the cores of the quad-core DS1006 in the same way as for multiprocessor systems. The communication parameters can be defined via interprocessor communication (IPC) blocks. This is done independently of how communication is actually performed physically, i.e., whether there are internal Gigalinks between several processor cores or optical Gigalinks between different processor boards. The cores of the new quad-core DS1006 not only compute several tasks synchronously, they can also execute several unsynchronized models at once.

Comparison: The New DS1006 and Its Predecessor

The performance of the new quad-core DS1006 board is clearly shown when various dSPACE Automotive Simulation Models (ASM) are computed (figure 2 and figure 3), with each submodel running on one core of the board. The cores are all connected via internal Gigalinks.
With the predecessor board, the single-core DS1006, each ASM model runs on its own board. The single-core DS1006 boards are connected via external Gigalinks.

Profile of the New DS1006 Processor Board

Quad-Core AMD Opteron™ processor, 2.8 GHz
512 kB L2 cache per core; 6 MB L3 cache
1 GB local memory for executing real-time models
128 MB global memory per core for data exchange with the host PC
2 MB on-board boot flash memory
Optional application flash memory on a CompactFlash board for automatic, host-independent booting of real-time applications

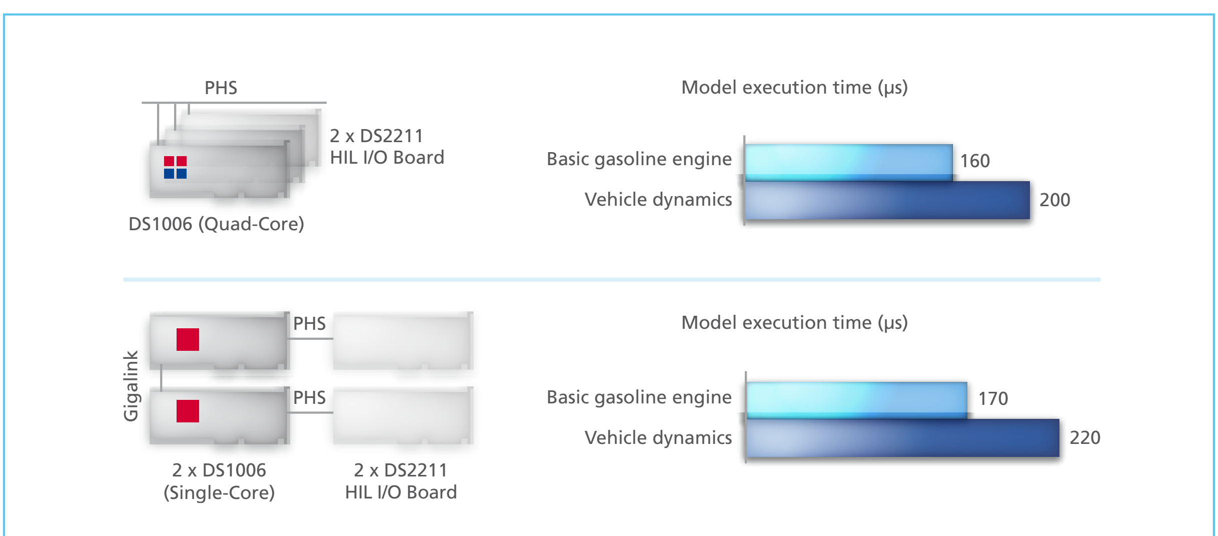


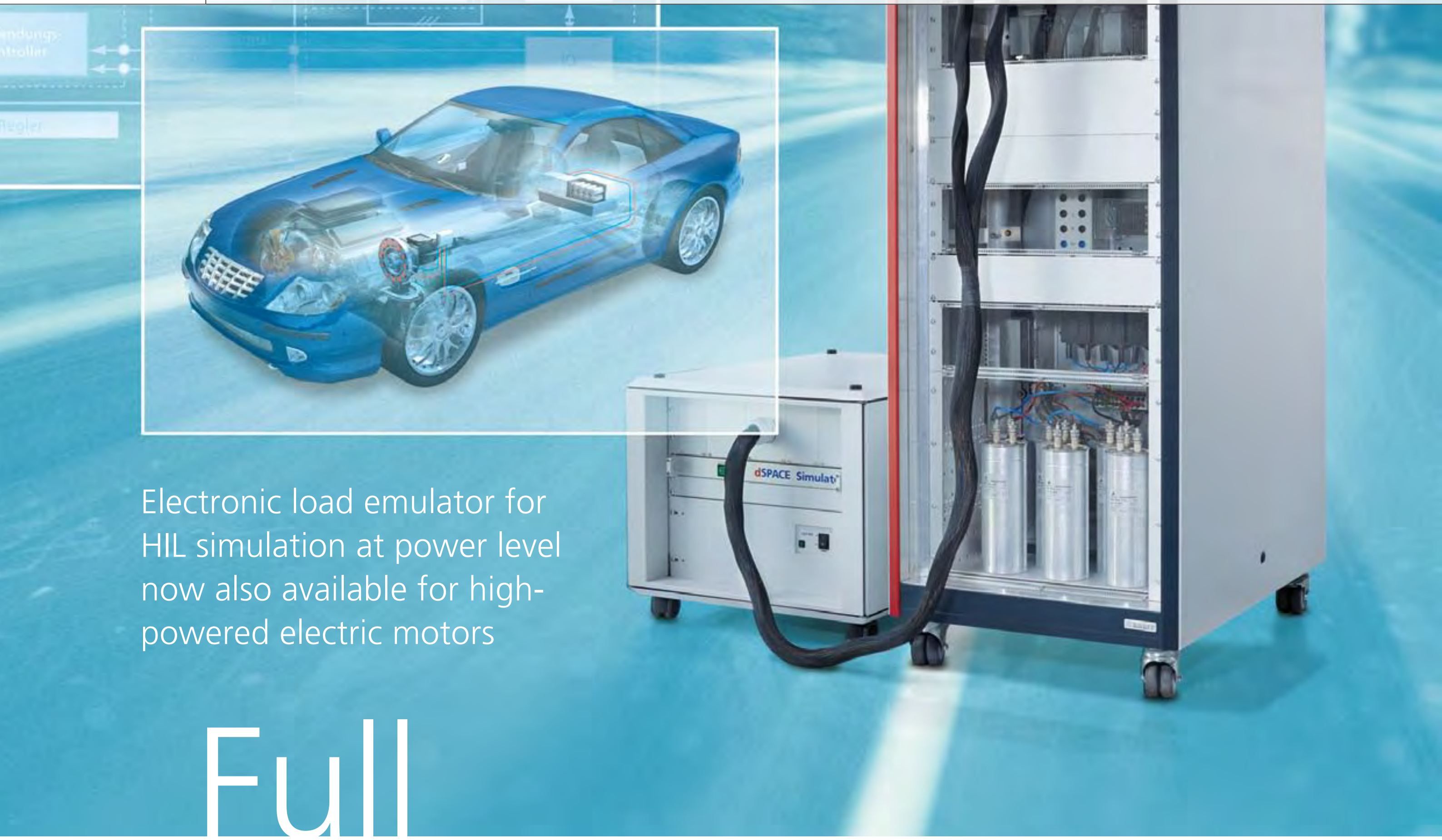
Without connected I/O (figure 2), the time saving is between 35% and 60%, depending on the model being computed. This is largely due to the bandwidth of the internal Gigalink connections, in addition to the higher clock rate and the improved processor architecture. Even with connected I/O (figure 3), the new board is faster, despite the fact that I/O access to both DS2211s runs via a common processor interface. The reason is the high speed of the internal Gigalink connections in the quad-core DS1006 – even though the number of signals transmitted here by no means uses the Gigalinks' full potential.

Conclusion

With the new Quad-Core AMD Opteron™ processor, the new DS1006 Processor Board provides considerably more performance than its predecessor. Various tests showed that it achieves up to 60% more speed than its predecessor in multiprocessor systems, depending on the model. As with other dSPACE boards, several of the new DS1006 Processor Boards can be used to build multiprocessor systems that increase performance even further. The HIL simulation of electric motors for hybrid drives, gasoline engines with variable valve timing, and diesel engines with in-cylinder pressure measurement are typical examples of applications that require greater computing performance. Users can conveniently partition all the computing tasks with the Real-Time Interface for Multiprocessor Systems (RTI-MP) software, whether they are handling a single DS1006 or a system made of several boards.

Figure 3: Performance data of the quad-core DS1006 2.8 GHz compared with its predecessor DS1006 2.6 GHz (with I/O boards). Each main component of an ASM virtual vehicle, in this case the basic gasoline engine and vehicle dynamics, runs on one core of the quad-core DS1006.





Electronic load emulator for HIL simulation at power level now also available for high-powered electric motors

Full Power

Green Success

dSPACE has been using electronic load simulations for the hardware-in-the-loop (HIL) simulation of small-sized electronic motors, such as those used in electrical steering systems, for several years. Now the new electronic load emulator is ready to push the power range up considerably. So large drive motors in hybrid or electrical vehicles can now be simulated at the electrical power level.

Simulating an Electric Motor at Power Level

If the HIL tests for an electrical drive system have to include the power stages, testing at signal level is not enough. One way is to operate a real drive motor on a test bench; but another option is to simulate the electric motor at the electrical power level (figure 1). This involves simulating the electrical behavior of a real motor by mapping the real terminal voltages and currents and feeding them to the ECU. Compared with a mechanical drive test bench, a purely electrical test bench of this kind is easier and safer to operate. Tests can be run at a very early stage, even if the real drive motor is not yet available. Moreover, it is also possible to simulate different motor types. Unlike mechanical test benches, these simulators have no restrictions on dynamic processes.

The new electronic load emulator covers voltages of more than 600 V and power outputs of up to 100 kW. Thus, it is suitable for the HIL simulation of current and future electrical drive systems.

How the Electronic Load Emulator Works

The electronic load emulator emulates the variable, active parts of the voltages u_{EMK} induced in the motor coils, while the inductive behavior of the motor coils is represented by equivalent substitute inductivities L_{Motor}. The induced voltages u_{EMK} are calculated in real time by an electric motor model and implemented by the electronic load simulator.

How the Electronic Load Emulator is Implemented

The load emulator uses inverters from the ServoOne series by LTi. The electric motor model for computing the induced voltages is implemented on a dSPACE real-time system by means of Simulink®. The model components that can be simulated include the drivetrain. Various sensor and actuator simulations are added to the real-time system for this, according to project-specific requirements. A hybrid ECU requires at least one appropriate simulation of an engine speed sensor (such as a resolver).

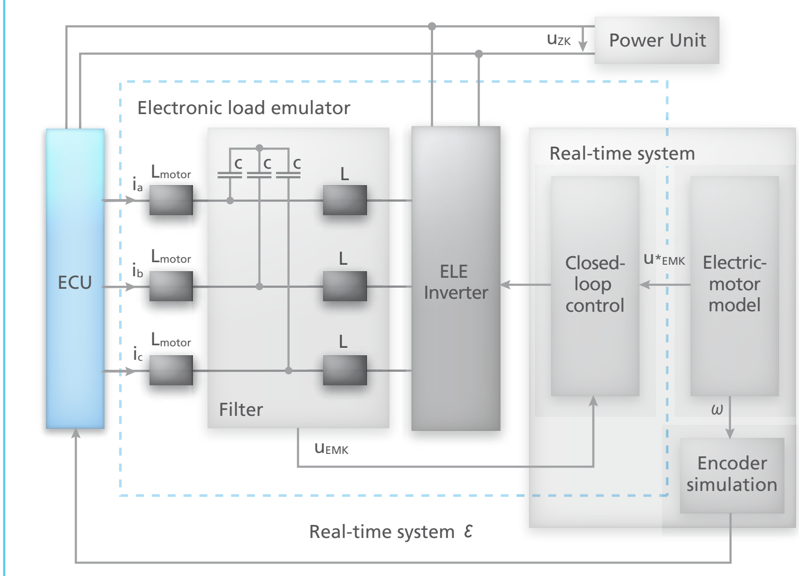


Figure 2: Overall HIL system with electronic load emulator. (ELE = Electronic Load Emulation, EMF = Electromotive Force)

Applications

The concept of the electronic load emulator can be used for simulating all types of motor. The physical properties of each motor, such as motor inductivity, torque generation and power consumption are represented very realistically. For variable inductivities (such as in an interior permanent magnet, IPM motor or with saturation effects), mean values have to be used in the load emulator due to the constant substitute inductivities. Nevertheless, correct representation of the torque and the power is possible. Any desired hybrid and electrical vehicle configurations can be simulated by using different electric motor models in conjunction with variable drivetrain models (for example, Automotive Simulation Models or ASMs). The concept is also suitable for various industrial HIL applications.

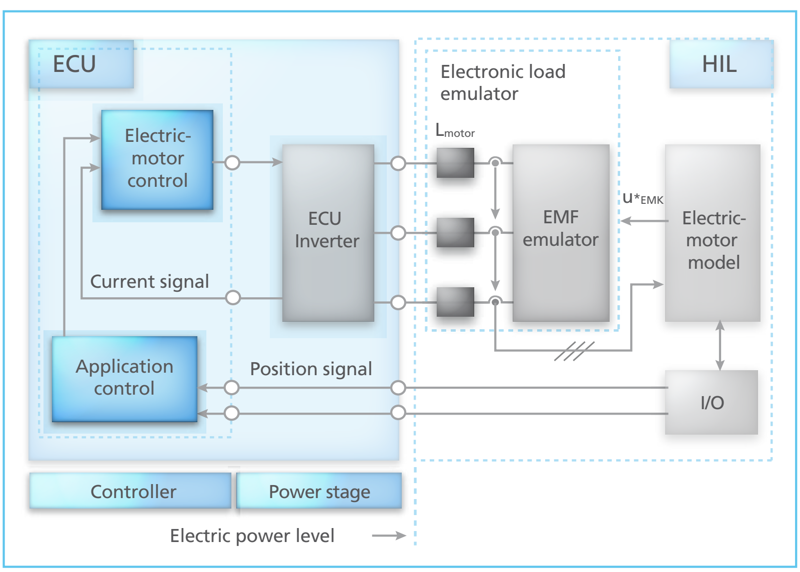
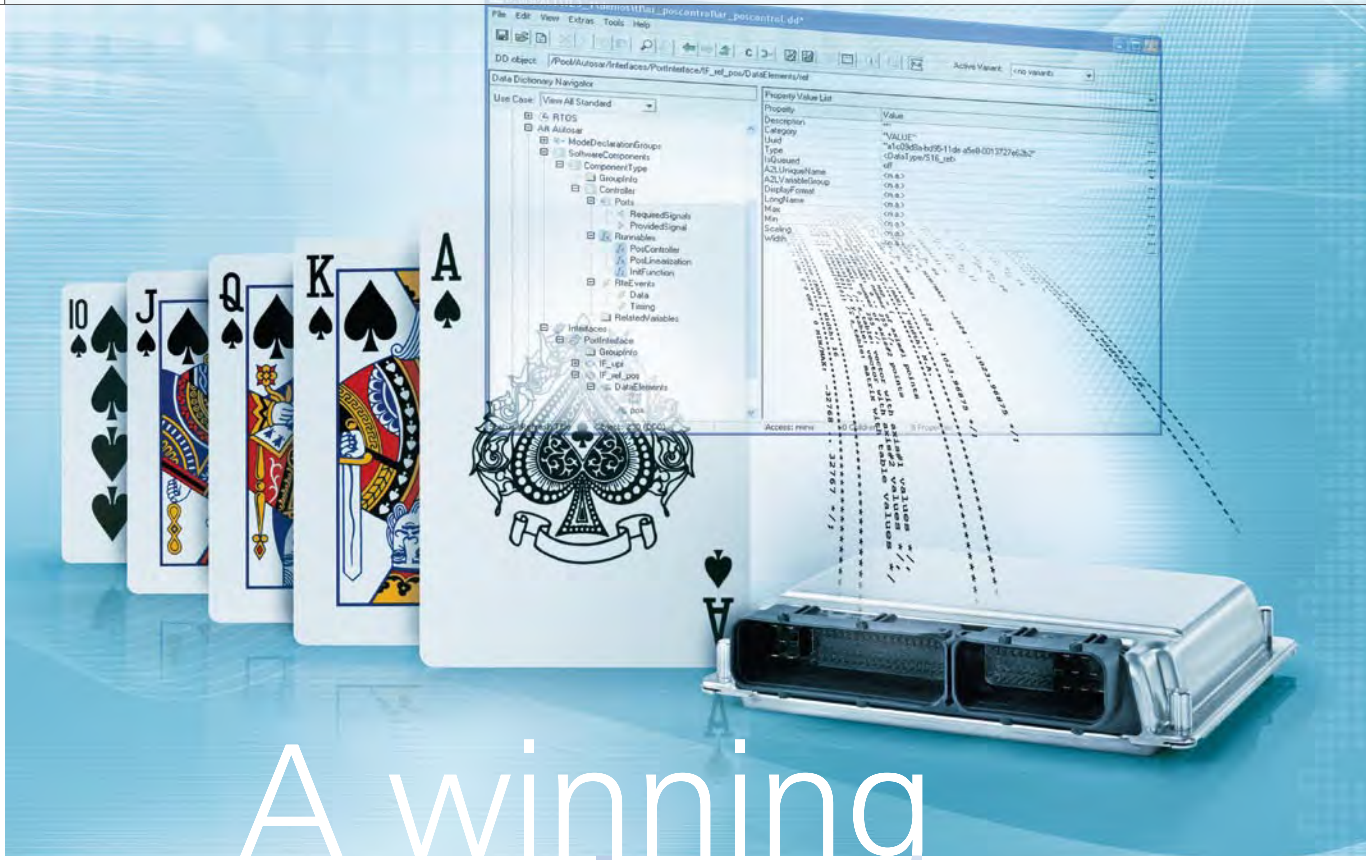


Figure 1: Electronic load emulator for simulating an electric motor at the power interface.

Conclusion

The new generation of electronic loads means that solutions for the HIL simulation of electrical drive motors are now available. They can be used anywhere where flexible, comparatively easy-to-use simulation at power level is important, but the use of an expensive mechanical motor test bench needs to be avoided.



A winning Hand

TargetLink 3.1 brings impressive features into play

TargetLink 3.1 has major extensions to the code generator's core functionality and to AUTOSAR support, as well as improved integration in MATLAB®/Simulink®. Enhanced usability is also on the table.

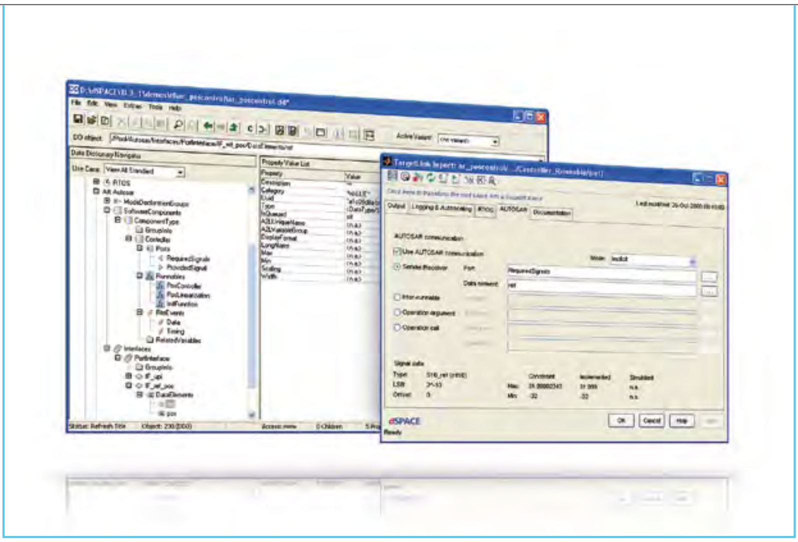
A solid player, now perfected even further – TargetLink Version 3.1 makes production code generation more attractive and more powerful.

Code Generation Straight from the dSPACE Data Dictionary

One major innovation in TargetLink 3.1 is that code can now be generated not only from models, but also directly from the central data container, the dSPACE Data Dictionary. This is an immense advantage for software integration and software integration testing. Variables that are handled by more than one developer, such as interface variables, measurement and calibration variables, or legacy code parameters, can be defined in the dSPACE Data Dictionary and assigned to individual modules. Code and A2L files (ASAP2) are then generated for these variables directly from the dSPACE Data Dictionary, independently of any specific modules. For example, all the calibration parameters of an entire project, including the legacy variables, can be managed in the dSPACE Data Dictionary and generated in one single C file and one single A2L file. In addition, software integration tests are much easier because of TargetLink's new model referencing and incremental code generation features.

Vectorized Code with Variable Vector Widths

With TargetLink 3.1, users have even more flexibility when generating code for vector signals. Code for vectors can be generated with vector widths that are not defined by a fixed number but determined by a macro. This means that developers can reuse the same code for different vector widths (for example, for 4-, 6- and 8-cylinder engines), which considerably reduces the effort involved in code reviews and tests.



The new TargetLink AUTOSAR blockset: Simpler model migration and seamless integration into the Simulink world.

Traceability from Requirements to Code

TargetLink 3.1 makes it easier to track requirements through to the generated code, which in turn simplifies process-compliant workflows that follow standards such as IEC 61508 or ISO 26262 with TargetLink. If requirements are linked to models, TargetLink inserts them into the generated code as comments. In addition, the automatically generated documentation clearly tells which requirement was implemented in which model parts to ensure a completely transparent development process.

Native Support for Bit Operation Blocks

The extended TargetLink block library now gives users native support for bit operations such as bit set, bit clear, bitwise operations, extract bits and arithmetic bit shifts. The new bit operation blocks not only provide TargetLink's typical user-friendly signal specification and visualization, but also lead to highly efficient code with the help of interblock optimization.

Extensive New AUTOSAR Support Features

The new TargetLink AUTOSAR blockset is directly integrated into the regular TargetLink blockset. This not only makes it easier to migrate from conventional TargetLink models to AUTOSAR, but integration into the Simulink world is also seamless. When the TargetLink AUTOSAR Migration Tool is used, conventional TargetLink models can be migrated to AUTOSAR at the push of a button and then used for generating both conventional and AUTOSAR-compliant code, dramatically reducing model maintenance work. TargetLink now supports AUTOSAR Standard 3.1 as well as numerous other AUTOSAR features such as client-server communication for complex data types, signal acknowledgement and signal invalidation in data transmission, and per instance memories. TargetLink's interaction with dSPACE SystemDesk and other architecture tools has also been further optimized to enable a seamless, iterative AUTOSAR development process.

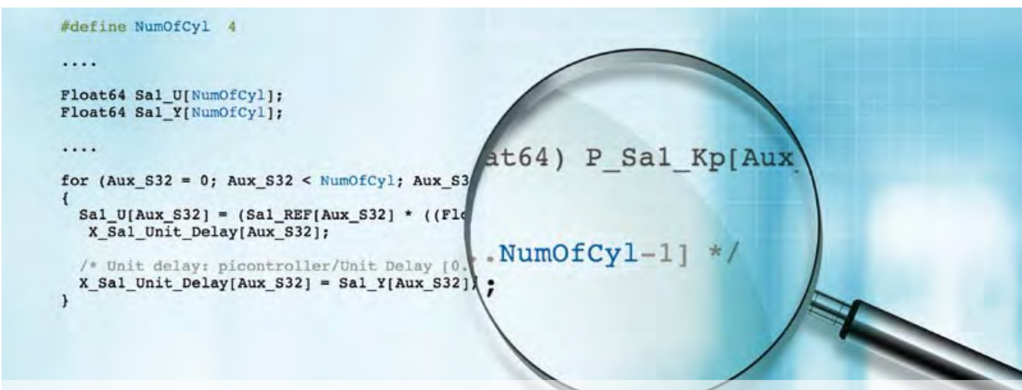
Enhanced Usability and MATLAB/Simulink Integration

Day-to-day work with TargetLink is even easier with Version 3.1. For example, the Data Dictionary Manager now has its own message browser to display messages. User-configurable (context) menus can be inserted in the Data Dictionary Manager and underlaid with user scripts. Different sets of code generation options can be stored in the dSPACE Data Dictionary in a uniform manner, making it easier for developers to exchange them. TargetLink 3.1 also provides more advanced dialogs to link a model with the dSPACE Data Dictionary, plus enhanced Simulink integration of TargetLink demo models and TargetLink-specific menus.

Extensions to the TargetLink Simulation Module

The TargetLink Simulation Module (TSM) in TargetLink 3.1 now also supports the execution of processor-in-the-loop simulations (PIL) for the Infineon TriCore TC 1767 controller in conjunction with Tasking compilers. ■

In TargetLink 3.1, the same code can be reused for different vector widths, because the widths are defined flexibly via a macro.



Vehicle Dynamics Tests for Commercial Vehicles

To improve the safety of commercial vehicles in road traffic, the new regulation of the United Nations Economic Commission for Europe 13-H stipulates that electronic stability systems (ESP systems) must be installed in commercial vehicles from 2011 onward. For the first time, this regulation permits the use of simulation models to verify that the ESP systems function correctly. dSPACE's new **simulation model ASM Truck** already provides all the features required for testing and validating ESP functions for directional stabilization and rollover protection.

With virtual vehicle dynamics tests, testing activities can be moved from the road to the simulation system. This significantly reduces the workload and costs involved in testing the enormous number of different vehicle variants available in the commercial vehicle industry. ASM Truck is an open MATLAB®/Simulink® model that is used together with ASM Trailer to simulate a vehicle with a trailer. Because of its open implementation in Simulink, the model can be extended in any way desired and adapted to special test tasks. ■

ControlDesk: Bus Navigator Now Supports LIN

In ControlDesk 3.5 (part of dSPACE Release 6.5), the Bus Navigator now also supports LIN. Entire CAN and LIN networks can be displayed in an easy-to-understand tree. This is your central, intuitive access point to the CAN and LIN communications configured in a real-time model, including all variants. The tree also provides a convenient way to generate layouts for RX and TX LIN frames. ■

Powerful Ethernet Support

In the automotive field, developers increasingly need to wire up dSPACE rapid prototyping platforms (MicroAutoBox and AutoBox) to Ethernet-based systems such as embedded PCs and Human Machine Interfaces (HMIs), or to connect them via WLAN. Ethernet is a particularly important interface in the development of driver assistance systems.
Since mid-2009, you can add Ethernet to commercially available dSPACE systems by connecting an adapter to the LVDS interfaces to enable communication via 100 Mbit/s UDP-IP.
The Ethernet interface can be configured directly in Simulink with the RTI Ethernet Blockset. Interpreting the raw data in the Ethernet frames as physical signals is often complex and error-prone, so to simplify the process, dSPACE is offering an addable Encode/Decode Blockset as of 2010. In conjunction with a configuration file that describes the data in the Ethernet frames, the blockset allows the automatic generation of interface blocks that set up the connection between the receive and transmit blocks in the RTI Ethernet Blockset and the Simulink subsystem that processes the signals. ■

Developing ECU Tests More Efficiently

The new version of dSPACE's test automation software, **AutomationDesk**, enhances the openness of test development and improves teamwork.

AutomationDesk 3.0 already supports parts of the new ASAM standard, HIL API. The standard defines the interfaces between test automation tools such as AutomationDesk and hardware-in-the-loop (HIL) simulators. This makes it easier to reuse ECU tests developed in AutomationDesk on any desired HIL simulator. In addition, Version 3.0 supports the import and export of projects, tests, and custom libraries as XML files. This means that tests developed with either proprietary or third-party tools can be migrated to AutomationDesk. Tests can also be generated and used from programs such as Microsoft Excel.

For smooth teamwork between several people working on one project, AutomationDesk now supports highly granular version control. Individual tests or even individual test steps can be placed under version control and edited separately. This simplifies testing tasks enormously, especially in large development teams. ■

We Proudly Introduce: External, Electric Failure Simulation

dSPACE now offers users of hardware-in-the-loop (HIL) simulation an external failure simulation unit. The dSPACE **External Failure Insertion Unit (FIU)** can be added to all existing dSPACE simulator systems.

It just needs to be connected between the electronic control unit (ECU) and the HIL simulator. The external FIU can be used for different simulators and projects as required. Three versions are available – with 90, 180 and 270 channels respectively. Optional Break-Out Box (BOB) panels at the front of the external FIU provide easy access to all signals from and to the ECU.

You can define different failure patterns on a PC with ControlDesk Failure Simulation, an extension to dSPACE ControlDesk. To integrate and execute the failure patterns in automatic test sequences, dSPACE AutomationDesk is used. While the test sequence is executing, a failure pattern can be activated and deactivated to test the ECU's diagnostic functions. ■

dSPACE Release 6.5 Supports Windows® 7

Release 6.5 from dSPACE supports all industry-relevant Windows 7 versions. dSPACE Release 6.5 serves the 64-bit versions of Windows 7 in WOW64 mode. The software CalDesk as an exeption is not compatible with Windows 7. ■

New dSPACE Distributor in India

DynaFusion Technologies Private Limited signed an official agreement as sole authorized distributor of dSPACE products in India.
DynaFusion specializes in providing embedded software and hardware control solutions for the automotive, commercial vehicle, aerospace and industrial automation sectors. The company will distribute and support dSPACE products through its Bangalore Head Office and Regional Offices in Delhi and Pune. Existing Indian dSPACE customers will also be supported by DynaFusion.
The management and key engineers of DynaFusion have been associated with dSPACE products for over

DynaFusion

15 years. They are also well experienced in the areas of mathematical modelling & simulation, digital signal processing, and test & measurement.

dSPACE Strengthens Its Presence in China

As of February 1, 2010, dSPACE customers in China are receiving exclusive, direct support from the dSPACE office itself. dSPACE China is performing all sales and support activities for all dSPACE products. The Chinese market has changed: Customers are increasingly asking for dSPACE products that demand specialist know-how. The size and complexity of hardware-in-the-loop simulators are constantly growing, and they require highly specialized consulting, training and support on-site. This service will now be provided directly by dSPACE specialists in China. "We have successfully marketed our products in China for 10 years with our distributor HiRain. Now our customers' requirements are growing, and the dSPACE portfolio has become much wider, so direct communication and a stronger presence are needed," says Henry Feng, General Manager of dSPACE China. dSPACE is therefore working on expanding its Representative Office in Shanghai, which opened in 2008, and strengthening its successful presence in China.

Experimenting with Virtual ECUs

SystemDesk is dSPACE's architecture, modeling and simulation software that enables AUTOSAR ECUs to be simulated as early as the design phase. To perform easy-to-run analyses, it can connect to external calibration tools such as dSPACE CalDesk.
In SystemDesk, RTE code is generated for modeled AUTOSAR ECUs. A2L files can also be generated. These contain information on the variables that can be set and measured, and are read into CalDesk or any other calibration tool. While SystemDesk simulates the virtual ECU, in other words the code that already exists, CalDesk synchronously captures the signal measurement values via XCP on Ethernet and visualizes them. The variable values can be calibrated while this is going on, so their effects can be checked immediately. Users have CalDesk's entire experiment interface, with plotters, slidebars and displays, at their disposal.

The result is that the behavior of the available ECU software can be tested, varied, and retested conveniently, directly on a PC.

dSPACE Roadshows in France

In 2009, dSPACE SARL hosted three one-day roadshows on electronics and control engineering in Versailles, Paris und Toulouse.
More than fifty people from over twenty companies attended the roadshow. The participants included: Valeo, PSA Peugeot Citroën, Delphi, Université de Lille, Université de Picardie, Phineo, Renault, E2Cad, IFP, ESG France, Meïto, NSI, Sherpa Engineering, CNM Paris, Continental Automotive, Actia, Aboard Engineering, Laplace, and Liebherr Aerospace.
dSPACE experts and the cooperation partner BTC Embedded Systems highlighted parts of the product range. They gave a closer detailed look into modeling and simulation with AUTOSAR software architecture; implementing, generating and simulating production code; tools from BTC Embedded Systems for dSPACE's production code generator TargetLink; as well as electric drives and hybrid solutions.
In the afternoon experts explained how to implement control laws for sensors and actuators, giving additional advice on how to use dSPACE tools and their new features. Feedback was very positive, showing once again that the dSPACE roadshow "Rencontres Electronique et Automatique" has become a tradition. ■

TargetLink Certified for ISO 26262 and IEC 61508

TÜV SÜD (German certification authority) has certified the production code generator TargetLink for use in the development of safety-related systems. After extensive testing, the TÜV experts confirmed that TargetLink is suitable for software development according to ISO DIS 26262, IEC 61508 and derivative standards (such as EN 50128, which governs safety-related software on the railways). Some of the areas covered by the TÜV are:

- TargetLink's software development process and software modification process
- Problem reporting and handling for users

In addition, a TÜV-approved reference workflow has been produced for using TargetLink for the model-based software development of safety-relevant systems. The reference workflow supports and guides TargetLink users when they put the requirements of the new ISO 26262 and the IEC 61508 safety standards into practice in their production projects. ■

IEC 61508 and ISO 26262
IEC 61508 is the internationally recognized generic standard for the development of safety-related electronic systems.

ISO 26262, the standard for functional safety in road vehicles, replaces IEC 61508 for the automobile industry.

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System Architecture | Rapid Prototyping | ECU Autocoding | HIL Testing | ECU Calibration

Green Success

HIL Simulation Charged up and Ready to Go

Any new technology has to be sound and fail-safe. Like the electronic control units (ECUs) for battery management in hybrid vehicles and electric vehicles. This is where dSPACE comes into play. As the experts in hardware-in-the-loop simulation, dSPACE offers special simulation models and real-time hardware. To put the ECUs through the ultimate tests. Reality enters the laboratory – with models for lithium-ion batteries and nickel metal hydride batteries for realistic battery management tests. And real-time hardware for high voltage accuracy and galvanic separation – precise, quick, and safe.

The battery alone does not make up a car. This is why dSPACE offers HIL hardware and the right real-time models for the complete vehicle, with electric motors, internal-combustion engines, transmission, vehicle dynamics, driver assistance systems, and much more.

Even with the newest technology, you will be in the lead.

Embedded Success dSPACE