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dSPACE MAGAZINE

3/2009

Hyundai – The fast track to variable valve control

Mitsubishi Motors – i-MiEV runs on electricity

Liebherr – Fuel cells deliver emergency power for aircraft

Dr. Herbert Hanselmann
President

The automotive industry is well aware that it must invest in green technology. Not always necessarily for plausible reasons of physics or because it is always cost-efficient, but because of ever-present public and political pressure. What people tend to overlook is that reducing fuel consumption is one of the most expensive means of climate protection. In automotives, the cost of cutting emissions by one ton of CO_2 is one order of magnitude higher than in the power industry. From an economic viewpoint, our priorities should be different.

As it is, some serious scientists are challenging the apocalyptic CO_2 theories, and there are just as competent experts who do not see the age of oil ending so soon. They can point to numerous incorrect predictions from doom-and-gloom prophets in the past. There are even some people, not just hair-brained eccentrics, who say that the earth's mantle also contains non-fossil (abiotic) oil, which is still forming today. Researchers recently verified that, in principle, anorganic carbohydrate synthesis is possible in the earth's mantle (as published in the scientific journal "nature geoscience").

No matter who's right, saving energy is always a good thing, especially whenever energy is being wasted or when saving it can be done at a comparatively low cost. But we shouldn't ignore the issue of cost. The first place to make reductions is wherever they have the most effect. It cannot be said often enough – road vehicles are not the best place for that. In Europe, for example, they contribute only 12% to overall CO_2 emissions, and changing this percentage effectively is a long-term endeavor. The burning coal seams in India and China are each estimated to emit as much CO_2 as 50 million cars. These things have to be viewed in proportion.

Whatever viewpoint is correct, dSPACE is already actively involved in green technology. Our prototyping systems and code generator have been used in ecotechnology for quite a few years now. By the way, this Magazine issue comes with a special supplement edition on TargetLink, our code generator: TargetLink is celebrating 10 years of success!

For green cars we offer special solutions for HIL simulation. Numerous hybrid and electric vehicle concepts were and are being tested with dSPACE systems. Our support for electric drive development goes back 20 years – we're building test benches with real or simulated electric motors to electrify cars and aircraft systems. Battery simulation is one area we focus on. We have simulation models for electrical engineering, we have experts in power electronics, and we are constantly expanding these fields. If you need help, just ask us.

Dr. Herbert Hanselmann
President

Embedded Success dSPACE

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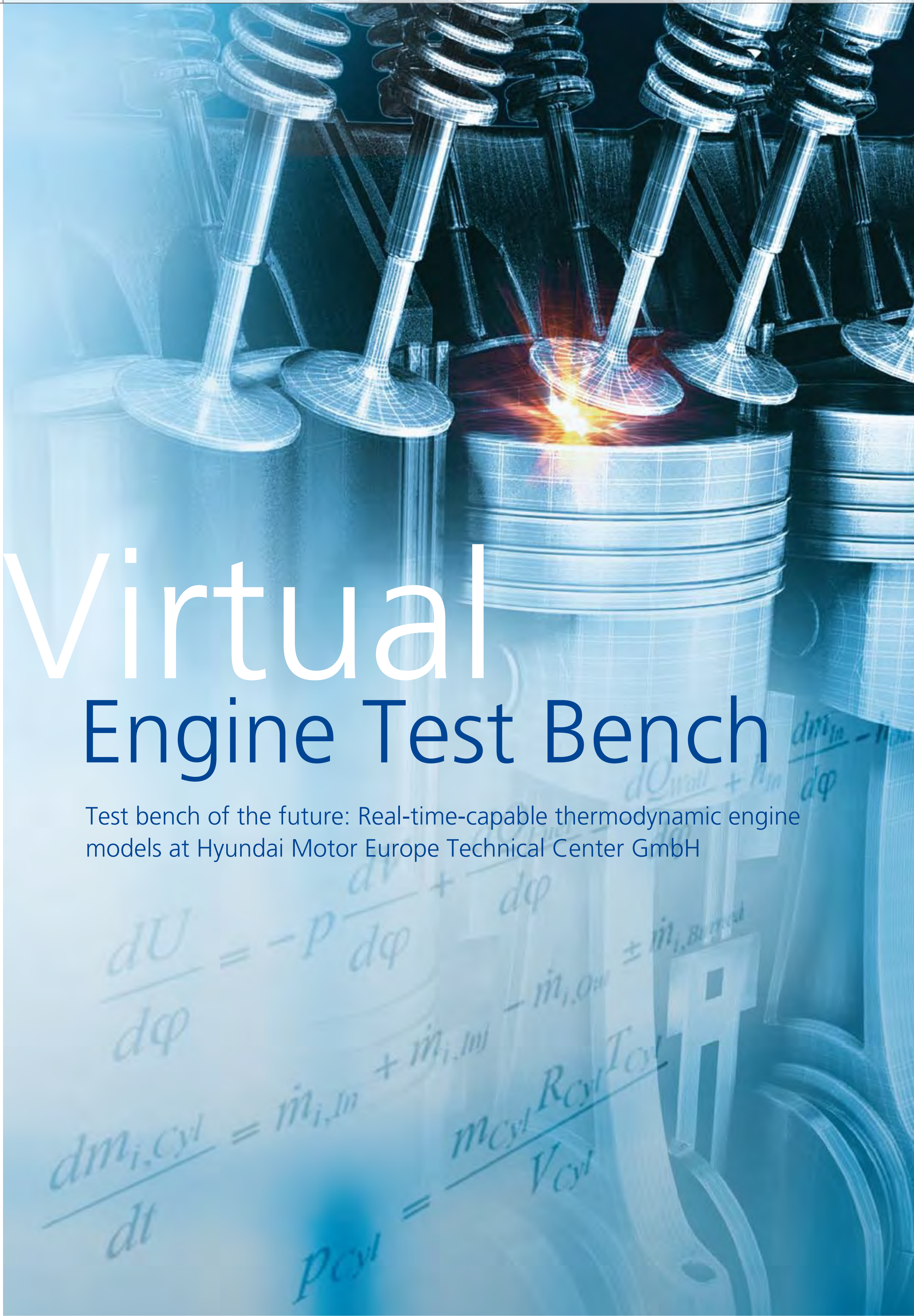


Virtual Engine Test Bench

Test bench of the future: Real-time-capable thermodynamic engine models at Hyundai Motor Europe Technical Center GmbH

Variable valve systems improve the efficiency of modern gasoline engines. Testing the engine control units designed for them requires novel, detailed simulation models with high physical resolution. Rapid prototyping systems can be used in such precise simulation environments to test engine control functions in very early stages when no control units are available: another step towards a virtual test bench.

Direct injection reduced fuel consumption in diesel engines, and new control concepts now promise to do the same for gasoline engines. Among them are homogeneous charged compression ignition (HCCI), variable valve control timing (VVT), and continuous variable valve lift (CVVL). These replace the classic throttle-based cylinder charge control and reduce gas exchange losses, which greatly improves fuel consumption (see Technology Background on page 11). However, this new freedom to control valve opening and closing events and also valve lift (CVVL) involves extra work in developing and calibrating engine control functions. It also creates new demands on hardware-in-the-loop simulation (HIL) on a virtual engine test bench. Up to now, mean value models were used, but these need now to be extended to represent the effects of the new control organs on engine processes. On the positive side, the new detailed engine models will also allow some classic calibration tasks to be moved from a real engine test bench to a HIL test bench. Thus, the new physical, real-time-capable engine models streamline the model-based development process and make development as a whole lot more efficient.

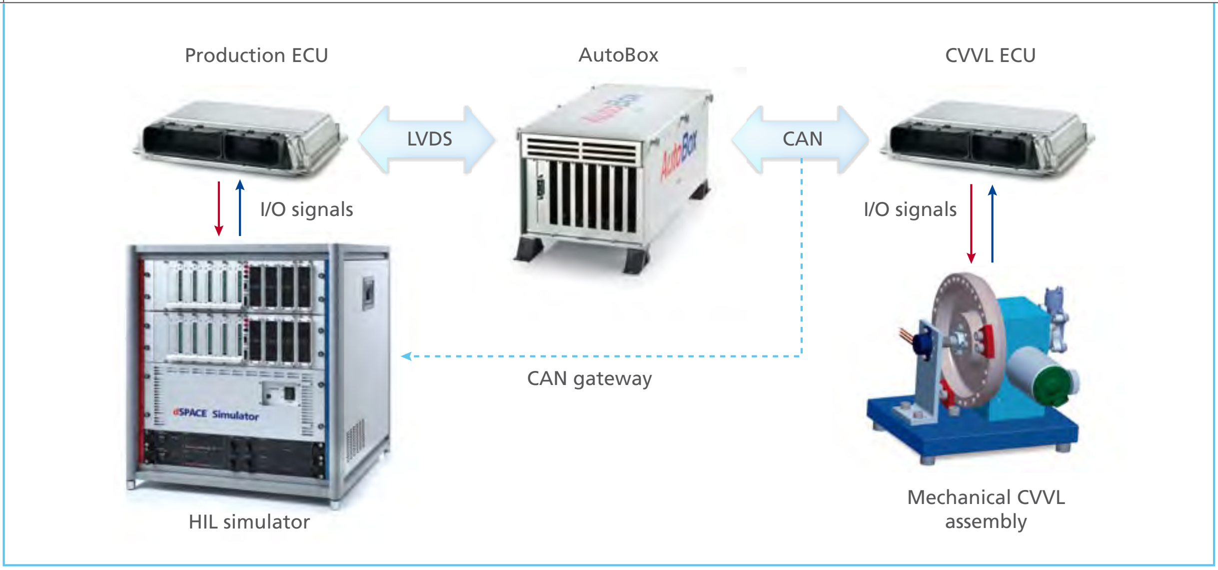


Figure 1: Design of the HIL system with a production ECU, a rapid prototyping system for the new CVVL functions, and a real load for determining the actual valve train value.

Development of Continuously Variable Valve Lift

In an advanced engineering project at the Hyundai Motor Europe Technical Center (HMETC) in Rüsselsheim, Germany, engine control functions are being analyzed for a gasoline engine with continuously variable valve lift. An existing gasoline engine electronic control unit (ECU) has been extended by an ECU function for variable valve lift by using a dSPACE AutoBox as a prototyping system in bypass mode (see Technology Background). The new ASM Gasoline Engine InCylinder models are based on in-cylinder pressure, and are used to test and calibrate the new functions on the HIL test bench at an early stage of development. ASM Gasoline InCylinder models are part of the Automotive Simulation Models (ASM) from dSPACE.

Structure of the Controller Prototype

To develop the new engine controls, the existing production ECU for a throttle-controlled gasoline engine is being used alongside a dSPACE AutoBox that executes the new functions. The throttle-based cylinder charge control on the production ECU was deactivated. The new variable valve lift functions on the prototyping system replace the old cylinder charge control and are executed by the ECU in bypass mode (see Technology Background). Most of the existing structure of the production ECU can therefore be left as it was.

Functions of the HIL Simulator

The task of the HIL system is to simulate, in real time, the interaction between the charge request on the production ECU, the charge control on the prototyping system, and the engine charge calculated by the model. The new in-cylinder-based engine models in ASM Gasoline InCylinder are used to calculate the effect of variable valve lift on the engine process. This new generation of engine models calculates the cylinder charge as a function of the gas mix flowing through the inlet and outlet valves, making it easy to include the effect of variable valve trains in the simulation. In this project, the modular structure of the open model made the integration of the valve lift variability on the inlet side easy.

Technical Implementation

The production engine ECU was extended by a DCI-GSI bypass and calibration module to make a development ECU, which was connected to the prototyping system dSPACE AutoBox via a fast low-voltage differential signaling (LVDS) connection (figure 1). The required cylinder charge is calculated on the production ECU and is transferred to the functions under development on the AutoBox via the LVDS connection. The functions calculate the required valve lift and send it via CAN bus to another satellite ECU, the CVVL driver, which contains the valve lift position controller. To implement realistic feedback for the CVVL driver's position sensors, the mechatronic part of the valve train was constructed as a real load so that the CVVL driver ECU can operate in a closed control loop. In addition, a substitute model of the CVVL system was installed on the HIL system. The HIL simulation of the variable valve lift can therefore use either the measured lift from the real load, or the modeled lift.

Patrizio Agostinelli

Patrizio Agostinelli is responsible for developing new control concepts for advanced gasoline engines at Hyundai Motor Europe Technical Center in Rüsselsheim, Germany.

> "By using the HIL simulator and the new in-cylinder pressure-based engine models, we were able to develop and validate new algorithms for the charge control of a gasoline engine with continuously variable valve lift very quickly and very efficiently, and then to use them successfully in a prototype vehicle."

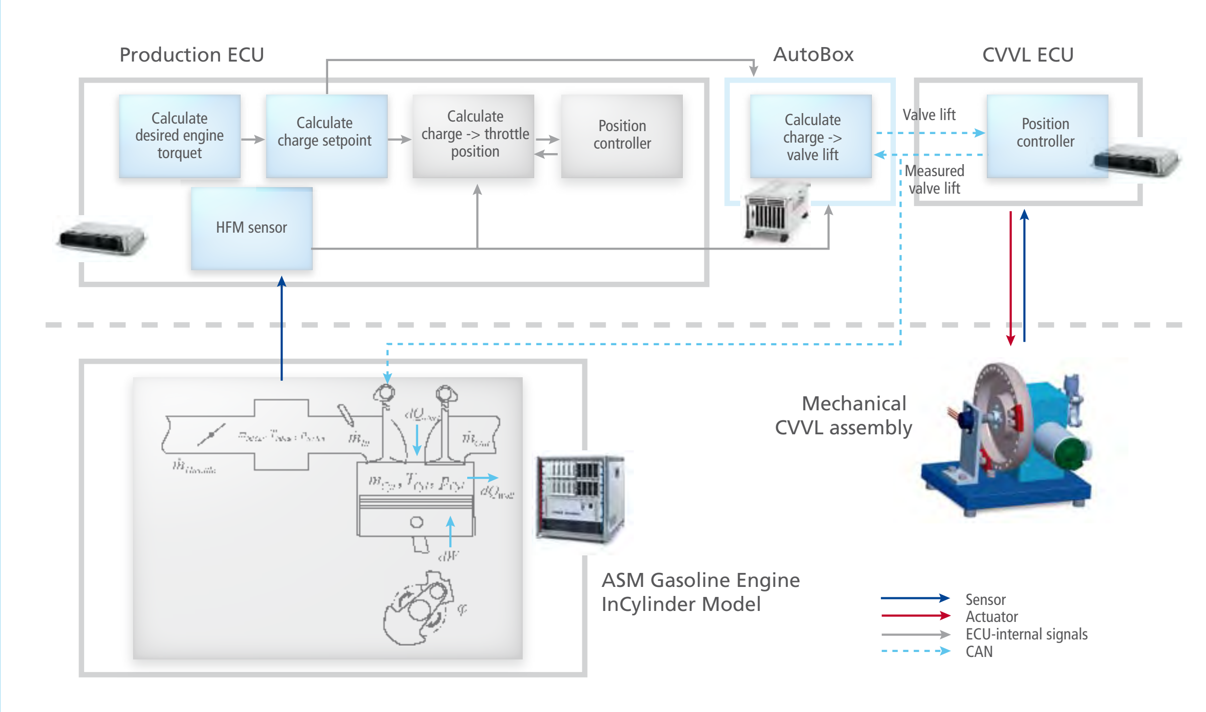
Patrizio Agostinelli, Hyundai Motor Europe Technical Center

The necessary signals between the AutoBox and the CVVL driver are passed to the HIL simulation via a CAN gateway. This means that the HIL system can also be put into operation without a real load plus CVVL driver, which increases maintainability and flexibility, and helps pinpoint possible sources of error.

Function Structure of Controller and Controlled System

The production ECU calculates the driver torque demand from the current engine speed and accelerator position, after which the required reference variable, the cylinder charge, is determined (figure 2). The task of the charge control consists in calculating the appropriate charge influencing control variables for any given required cylinder charge. Leaving aside the effect of valve timing for the sake of simplicity, it can be said that in conventional systems, the main control variable is the throttle. In CVVL operation, the control variable is the lift of the inlet valve. The conversion from one variable to the other is executed on the AutoBox, usually via a model-based feedforward control overlaid by an adaptation algorithm that compensates for any model error. The calculated reference valve lift is sent to the CVVL driver, which is in charge of the valve lift control and returns the actual lift. The actual lift is used together with other variables, such as intake pressure/temperature, engine speed, and valve timing, to calculate the actual cylinder charge. For adaptation, the measured cylinder charge is also required. To obtain it, the ECU evaluates the mass flow in the air intake system via a hot film air mass meter (HFM).
In this set-up of a production ECU

Figure 2: The development ECU, consisting of a production ECU and the AutoBox, is connected to an HIL simulator.



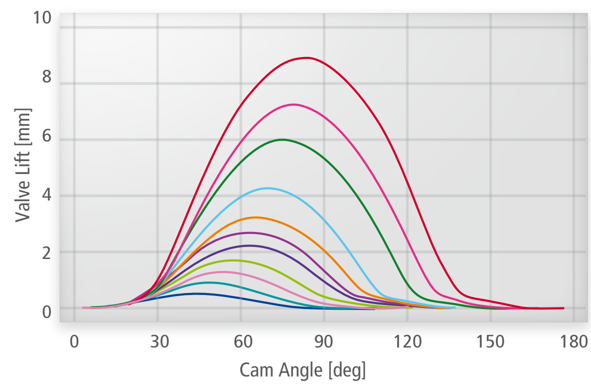


Figure 3: Variable valve lifts for CVVL integrated into ASM Gasoline Engine InCylinder Models.

with rapid prototyping and HIL systems, all the necessary measurement variables can be obtained from the plant model executed on an HIL simulator. For example, the engine model provides the simulated mass flow in the air intake system. Physically based simulation makes it possible to simulate the mass flow as a function of the controlled inlet valve lift (figure 3).

Evaluation of the Development System

This combination of an HIL simulator, a prototyping bypass system and physical engine models enables plausible real-time simulation of new engine ECU functions in a very early development phase. The engine model was parameterized relatively quickly by means of test bench measurement data, so that the modeled and the measured values were a good match. The in-cylinder pressure model calculates the pressure and mass flow values with sufficient precision, and the ECU can be operated without errors. Even engine operating conditions with valve timing and lift combinations that were not measured on the engine test bench can also be simulated plausibly.

The open models make it easy to extend the simulation model. The required parameters and measurement variables can easily be found and visualized in real-time calibration.

Benefit: Precalibration by Simulator

Not only pure function tests can be performed. The parameters of the controller can also be precalibrated at an early stage on the HIL system, so the rapid control prototyping system goes into operation on the engine test bench with a suitably parameterized controller. This means that some of the necessary experimenting activities can be moved from the expensive engine test bench to the comparatively inexpensive HIL simulator. By combining HIL and rapid control prototyping in controller development, users have more flexibility in calibrating and structuring the controller. Moreover, it also enables them to modify the parameters and submodels in the plant itself, making it easy to study different variants. This task would require time-consuming and cost-intensive adaptation work on the test bench.

Benefit: Frontloading by Linking RCP and HIL

Another advantage is that the models, layouts and automated tests from the HIL test bench can be reused after the extended functionality has been transferred from the rapid prototyping ECU to the production ECU. This new ECU also has to be tested thoroughly. Developers can use the existing model and the experiment environment from the earlier development phase for this. In other words, the new physical models improve integration between the development process on the HIL system and the development process on the real test bench, both during the controller development phase and during subsequent function testing. ■

Patrizio Agostinelli
Hyundai Motor Europe Technical Center GmbH, Germany

Conclusion

The new valve adjustment techniques also necessitate new methods and models for HIL testing. The physical engine models made it possible to test the ECU project on the HIL system at a very early stage of development, without the new functionalities being implemented in the production ECU. Instead, a bypass system was used in conjunction with a production ECU. The in-cylinder pressure-based engine models made it possible to perform not only pure function tests but also precalibration tasks for the new controller concept on the HIL test bench, which reduced the number of real test bench trials that were necessary. In downstream development steps, being able to reuse test scenarios is a great advantage. Since they were already implemented for the production ECU with the rapid control prototyping system, they can now be used for the subsequent prototype phase.

The Hyundai Motor Europe Technical Center (HMETC) in Rüsselsheim, Germany.

Technology Background

The technologies and development methods used in the CVVL engine test bench

Future Gasoline Engine Concepts

Combustion engines run on a mixture of fuel and air. Engine designers use two characteristics to describe the mixture. The first is the air/fuel ratio that is required to burn off precisely the injected quantity of fuel, called the stoichiometric ratio. In a gasoline engine, it is 14.6, though it also depends on the fuel. In other words, 14.6 kg of air is required to burn 1 kg of fuel. The second important characteristic is the lambda value. This indicates the extent to which the mixture already taken in deviates from the stoichiometric ratio. In gasoline engines, the engine performance is controlled via the quantity of gas mixture that is taken in. The appropriate amount of fuel for the fresh air quantity is injected before the cylinders, where it mixes with the air. This fuel/air mixture is mostly stoichiometric, i.e., there is always precisely the right amount of air to burn the fuel. Thus, in gasoline engines with their gas mixture intake, there is no direct way of controlling engine performance via the injected fuel quantity, as the control always maintains a lambda value of one. To allow a specific quantity of fuel to be injected, the quantity of fresh air has to be controlled.

The classic method of implementing this type of charge control is to use a throttle. This reduces the cross-section area in the engine's intake system, thereby controlling the air pressure before the inlet valves. The appropriate fuel for the given air pressure is injected before the inlet valves to form the fuel/air mixture. When the inlet valves open, this mixture is sucked into the cylinder at the currently set air pressure. The lower the air pressure that the throttle sets, the lower the mass of the mixture in the cylinder after the inlet valve closes. The volume of the mixture remains approximately constant. This means that the mass of fuel that is taken in is also lower, as it is in a constant ratio to the mass of the air. The setting of the intake manifold pressure can therefore be used to implement a charge control. The disadvantage of this method is that the lower the air pressure before the valves, the more work is needed to draw in the mixture. This so-called gas exchange work has to be performed by the cylinders in which combustion takes place, so it reduces the power available at the crankshaft.
With variable valve trains, i.e. with variable valve timing and/or variable valve lift, the quantity of mixture in the gasoline engine can be set for the entire load/engine speed map without using a throttle. The gas exchange work, and therefore also fuel consumption, can be reduced because the mixture can be taken in under ambient conditions across the entire load/engine speed range (figure 4).

In addition, the internal exhaust gas recirculation and the proportion of residual gas in the cylinder can be controlled by varying the spread of the inlet and outlet valves. Removing the throttle and improving the air/fuel mix increases the gasoline engine's efficiency and reduces fuel consumption.

HIL Tests

Hardware-in-the-loop (HIL) simulators allow reproducible and automatable function testing of elec-

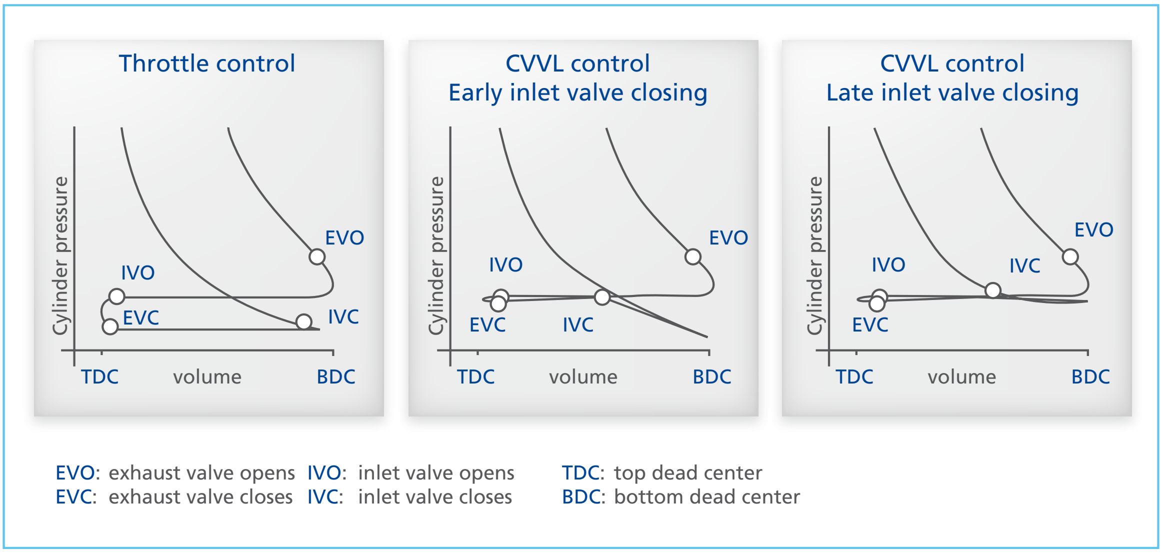


Figure 4: Gas exchange work for gasoline engines with throttle (left) and with variable valve lift (center and right).

tronic control units with a virtual engine. The ECU actuator signals are read by I/O boards and provided to a real-time engine model, which calculates the engine behavior from the available information and generates plausible sensor values that are returned to the ECU as electric signals. This makes it possible to run tests in a closed control loop with a simulated engine.

Engine Simulation Models

Real-time engine simulation currently uses what are called mean value models. With these, all the simulated engine operating data is averaged across one working cycle, i.e. for two crankshaft rotations of the engine, and simulated. This type of model provides sufficient quality for the majority of HIL test benches. It is a sensible compromise between simulation precision, computing time requirement and parameterization effort. However, future engine concepts will make tougher demands on real-time-capable simulation models. Diesel engines with in-cylinder pressure measurement and gasoline engines with variable valve control times and valve lift require new, real-time-capable models that describe the engine process far more precisely than the current mean value models. These in-cylinder pressure models make it possible to calculate the cylinder charge, for example, by simulating the flows through the inlet and outlet valves. No look-up tables for cylinder charging are used. Instead, the mass flow between the air system and the cylinder is calculated as a function of the valve opening and closing timing and the current valve lift, so that the quantity of the mixture in the cylinder is provided automatically by the simulation. This means that the simulation can also take into account changes in valve lift and valve timing. Figure 5 shows the basic simulation approach, which is based on the first law of thermodynamics, mass balances for fresh air, fuel and exhaust gas, and the ideal gas law. The states inside the cylinder are calculated as functions of the combustion, piston work, wall heat losses and enthalpy flows through the inlet and outlet valves. This enables values such as pressure, temperature and masses to be represented as time-dependent behaviors with a step size of 100 µs for now.

Rapid Prototyping

Rapid prototyping is a proven technology for implementing and testing new control algorithms on the real plant. A control algorithm that was developed in Simulink can be downloaded directly to powerful prototyping hardware via autocoding. The algorithm can be connected to the plant via the I/O interfaces already defined in the Simulink model. In the ECU development process, a distinction is made between fullpassing and bypassing.

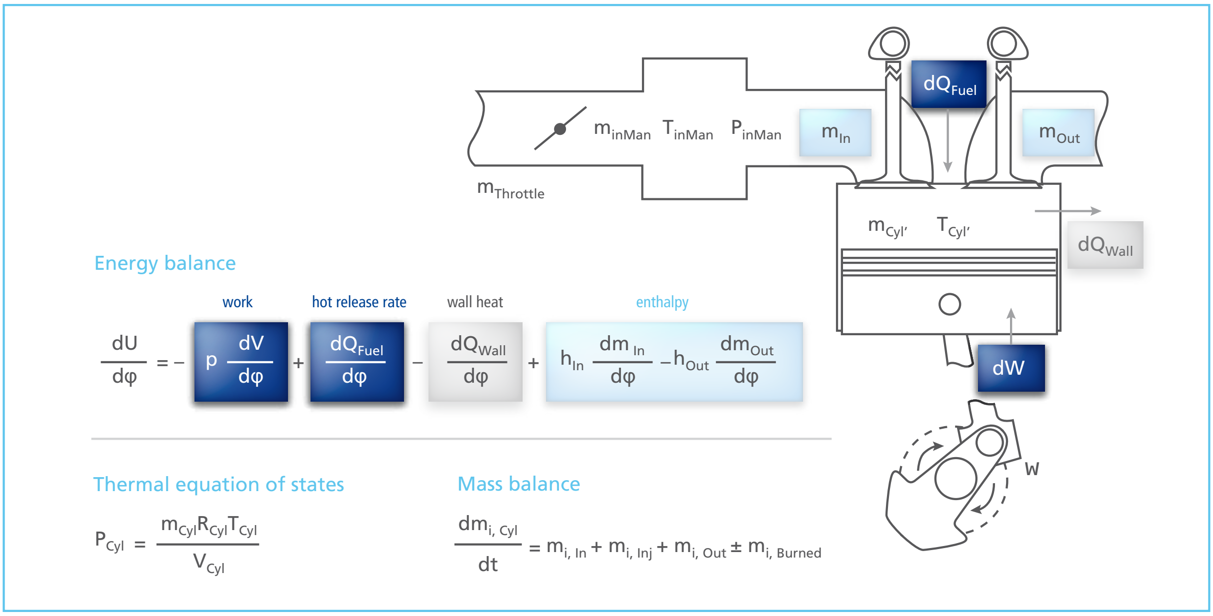


Figure 5: Equations in the in-cylinder pressure model.

In fullpassing, an entire ECU is represented on the prototyping hardware and controls an engine, etc. In bypassing, an existing engine ECU is extended by a functionality on the prototyping hardware (figure 6). For example, cylinder charging is not controlled by means of the throttle. Instead, the desired charge is forwarded to the new control algorithm on the prototyping ECU as a reference value. The algorithm then calculates the necessary valve lift. This set-up allows the previous ECU to remain in use.

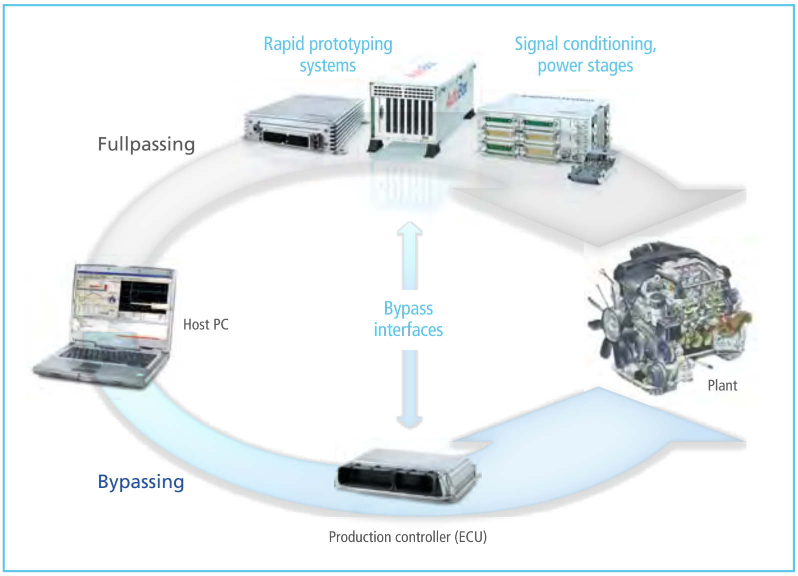


Figure 6: Rapid prototyping in fullpassing and bypassing.

Glossary

CVVL – Continuous variable valve lift allows the lift, duration or timing of intake and exhaust valves to be changed while the engine is in operation.

DCI GSI – Low-latency bypass interface for connecting dSPACE prototyping systems to a host PC

HCCI – Homogeneous charged compression ignition. A form of combustion in which well-mixed fuel and air are compressed to the point of self-ignition in the entire combustion chamber.

LVDS – Low-voltage differential signalling, an interface standard for high-speed data transmission.

Driving with no emissions

First Mitsubishi electric vehicle ready for launch

Dr. Kazuya Hayafune, Vice Corporate General Manager, MiEV Development, Development Engineering Office

Masahiro Kaneda, Manager, Electronics Engineering Dept., Development Engineering Office

Mitsubishi's new electric vehicle, i-MiEV, lives and breathes by its complex electronics. Mitsubishi ran rigorous tests to ensure the quality of the software, yet still managed to cut the time-to-market.

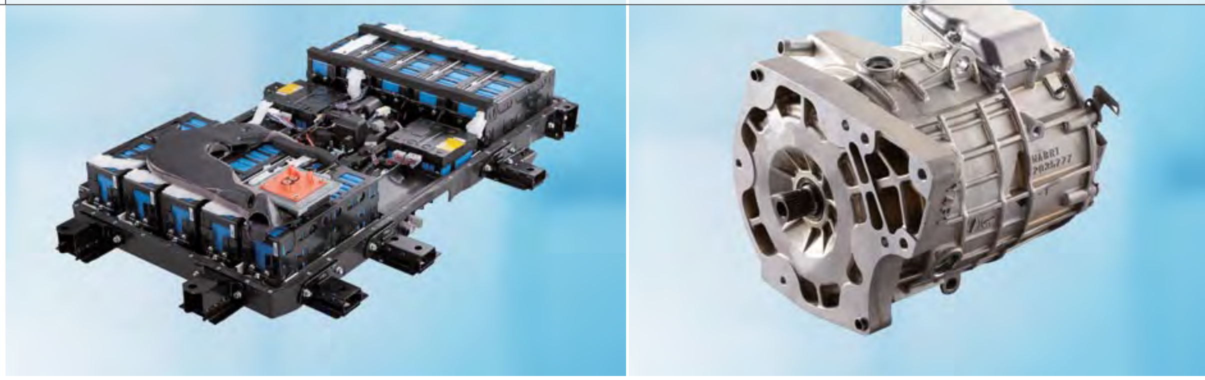


Figure 1: The battery pack and electric motor of the i-MiEV enable emission-free driving.

> "In accordance with design content, dSPACE Simulator offers a very high level of general versatility and can be used for almost any vehicle and ECU."
>
> *Dr. Kazuya Hayafune, MITSUBISHI MOTORS CORPORATION*

Development Outline

The i-MiEV (Mitsubishi innovative electric vehicle) next-generation electric vehicle is literally an aggregation of electric and electronic components. Because its various functions are achieved by distributed control using an onboard network, ensuring the quality of the total vehicle system as well as that of the electronic control unit (ECU) software is vital. And at the production development stage, the quality of complex systems has to be verified within the limited time available.
As a means of ensuring quality in the shortest possible time, software reliability testing was conducted using a hardware-in-the-loop (HIL) simulator made by dSPACE.

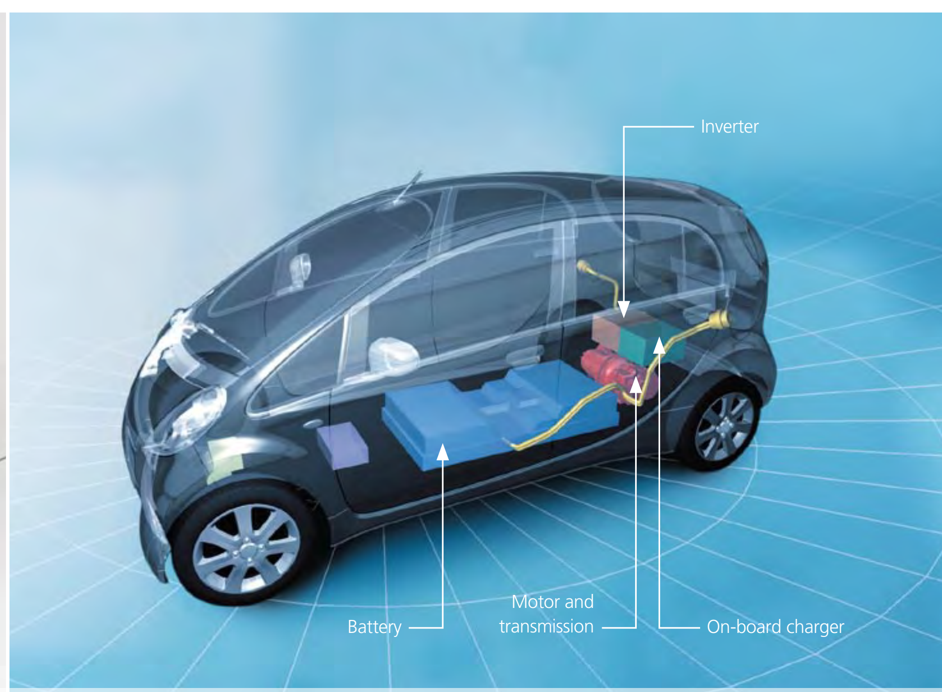
ECU Structure and System Specifications

The i-MiEV's electronic platform is characterized by a distributed control format that uses five dedicated ECUs.

In addition to performing the conventional vehicle functions of driving, cornering, and stopping, electric vehicles also need the ability to recharge from a home power socket and rapid charger, and to run on an electric motor.
For all this to be possible, the ECUs that control the electric vehicle

Figure 2: Recharging the battery.

Figure 3: Schematic of the power train.



Technical Details for 2009 Japan Spec

Max. power	64PS/47kW
Max. torque	180 Nm
Max. speed	130 km/h
Battery	Lithium ion
Total voltage	330 V
Total energy	16 kWh
Range	160 kilometers (Japan 10-15 driving pattern)
Curb weight	1100 kg
Battery recharge	Approx. 7 hours (AC 200V/15A)
Fast battery recharge	Approx. 30 minutes (80% charged)

Figure 4: Team members responsible for electrical reliability of the i-MiEV.

require reliable means to transmit vehicle control information.

> "A dSPACE HIL simulator consists of visually easy-to-understand components like AutomationDesk. We found that this test automation software is extremely easy to use."
>
> *Masahiro Kaneda, MITSUBISHI MOTORS CORPORATION*

System Design Outline

The five ECUs are connected through a key bus – a controller area network (CAN) bus. Multiple communication lines are provided as backups for when the key bus malfunctions.

Issues and Corresponding Requirement

- *Issue 1:* Ensure the quality of the software of Mitsubishi's first dedicated electric vehicle ECUs.
- *Issue 2:* Ensure the quality of the software of the overall electric vehicle system.
- *Issue 3:* Achieve issue 2 within a limited development period.
- *Requirement:* No defect should occur during any user operation whatsoever.

Solutions

- *Issues 1 and 2:* In line with the requirement specifications, the focus was on software processing as well as the branch conditions and state transitions of the vehicle's total system. Specifically, we designed software tests for all inputs to the ECUs and vehicle systems.
- *Issue 3:* Targeting all inputs resulted in an enormous number of test patterns. To reduce this number efficiently, an orthogonal design was used. dSPACE Simulator was used to reduce the number of testing man hours by automatic test execution.

The Role of, and Expectations for dSPACE Simulator

In executing the testing, it was necessary to adapt the test design content for the test patterns quickly and accurately. For the sake of analysis, a high level of replication was needed when software bugs were detected.

Therefore, a dSPACE Simulator Mid-Size was used to simulate user operation and the inputs to the ECUs accompanying it during the design process. An actual vehicle was used for the real load on the HIL simulator. The test automation software AutomationDesk was used as a means of creating test patterns quickly.

Evaluation of dSPACE Simulator

dSPACE Simulator proved extremely effective in ensuring the quality of the software of the i-MiEV on schedule. If it had not been for the dSPACE Simulator, verifying software quality within the time available would have been problematic.

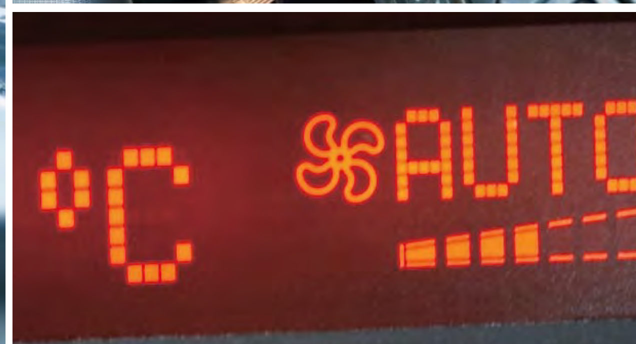
Future Development

While HIL-based verification was used on the right-hand side of the V-cycle in vehicle development, in the future a means of assuring software quality at a more upstream stage (left-hand side of the V-cycle) will be sought. ■

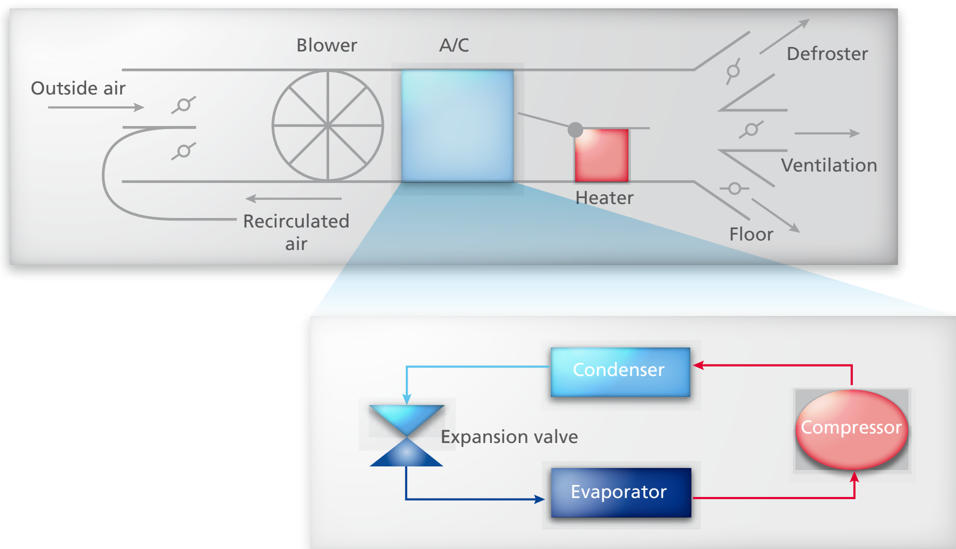
Dr. Kazuya Hayafune, Masahiro Kaneda
MITSUBISHI MOTORS CORPORATION, Japan

Climate Under Control

Volvo Technology develops climate control software with TargetLink



Volvo Technology, the center for innovation, research and development in the Volvo Group, has been continuously refining and extending its established Climate Control Module (CCM) over the years. The software is used by several international car, truck and construction equipment brands. Volvo Technology makes intense use of TargetLink during the controller development, autocoding and tuning phases.



Simplified view of the climate unit (HVAC: heat, ventilation and air condition).

Better Climate with CCM

Volvo Technology's main role for climate control developments is to deliver software which fulfils modern climate comfort requirements and addresses issues such as air demisting, odor and noise control, and energy efficiency. Current development is focused on improved efficiency in calibration for new vehicles and incorporation of new features and requirements. The development cycles are highly test-driven, and testing and tuning using prototypes and pre-series vehicles are common. dSPACE's production code generator TargetLink plays a major role in Volvo Technology's development process for function design, autocoding, tuning and testing.

What Makes a Good Climate Control?

Good climate control lets drivers select their preferred setting and then get exactly the comfort they expect. This means that the temperature in the passenger compartment is kept within a predefined range, there is no draught, the fan is not too noisy, it does not get cold when the sun goes in, the windscreen does not mist up, and so on. To achieve all this, a climate controller has several control objectives:

■ Temperature Control

This controls the heating, cooling, blower and air distribution to achieve fast heat-up/cool-down and a stable interior temperature in the passenger compartment during different driving conditions. It also compensates for disturbances such as high/low ambient temperature, sun load and vehicle speed.

■ Demisting Control

The purpose is to keep the windscreen free from ice and mist. The control mainly uses the blower, defroster and cool/reheat with air conditioner (A/C) and heating system.

■ Odor Control

The odor control, commonly known as AQS (Air Quality System), prevents unpleasant odors from entering the compartment via the outside/recirculated air flaps.

■ Parking Climate

Passenger cars and commercial vehicles both have functions for controlling the interior climate while parked. In trucks, where the driver often stays in the cab overnight, this is particularly important and sets strict requirements on temperature comfort and noise.

Typical Hardware for Climate Control

Climate control requires a number of hardware items to make the control software work the way intended. One of them is the climate unit, often referred to as HVAC (heat, ventilation and air Condition). The recirculation enabled by the climate unit is primarily used for improving the cooling performance in a hot climate by recycling the air already cooled and dried. Another use of recirculation is for preventing odors and pollution from entering the compartment. The part of the HVAC that cools the air is the air conditioner (A/C), consisting of compressor, condenser, expansion valve and evaporator. A number of sensors are also important for climate control. Some of them, such as the passenger compartment temperature sensor and the evaporator temperature sensor, are typical of an Electronic Climate Controller (ECC). Other sensors such as the vehicle speed sensor or the ambient temperature sensor primarily exist

for other systems in the vehicle, but are also important to the ECC.

Inside the CCM

The CCM is part of the electronic system in the vehicle and is connected to other subsystems on the networks via CAN and LIN. Some sensors and actuators are also hardwired to the CCM. The Climate Control itself provides all the functions described above, i.e., temperature control, demisting control, odor control, and parking climate. The CCM has been modularized into several functions. The controller input signals are processed first. This includes basic filtering and error handling as well as some sensor fusion and modeling to the data needed for the control algorithms. The controller structure is then function-oriented rather than actuator-oriented. This means that the modules for temperature, demisting and odor control all request actuator actions. After controller actions are prioritized, manual overrides from the driver are taken care of, and finally actuator actions are sent.

> "We autocode almost 100% of the application layer of our Climate Control Module with TargetLink."
>
> *Dr. Mats Andersson, Volvo Technology*

Overview of the Development Process

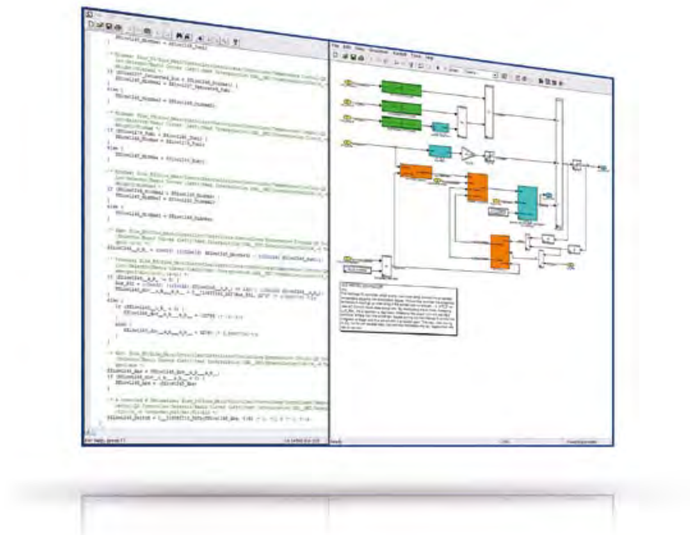
The CCM is an established product and so is the development process for it with TargetLink. Typically, new developments require the fine-tuning or extension of functionalities already present in the CCM, so that existing resources like software requirements, TargetLink models and test cases from previous projects are reused and adapted to meet the new requirements.
In a simplified view, four different types of activities can be identified in the process:

- Software requirement specification
- Control design and implementation
- Controller tuning
- Test & validation.

The development process is highly test- and experiment-driven and iterative. This is because a lot of the testing and fine-tuning for the CCM can only be done in-vehicle due to the difficulty in modelling the subjective perception of occupant comfort. This means that changes and updates to the control design need to be made iteratively to compensate for behavior overlooked in the initial stages of software requirement specifications and control design.

Software Requirement Specification

Requirements are supplied by the customer on a system level. These are often end customer use cases in the form of "Head level temperature must be between X and Y °C". During the first iteration of the requirement specification phase, the system requirements are decomposed into meaningful software requirements. Some software requirements are also reused from previous projects. In subsequent iterations, some software require-



Controller model and code: TargetLink was used to autocode almost the entire application layer of the CCM.

Dr. Mats Andersson (left)
Manager of Control and Simulation group at Volvo Technology, Sweden

Björn Fridholm, M.Sc. (center)
Control developer at Volvo Technology, Sweden

Henrik Weiefors, M.Sc. (right)
Control developer at Volvo Technology, Sweden

ments need to be adapted as a result of in-vehicle tests and tuning.

Controller Implementation

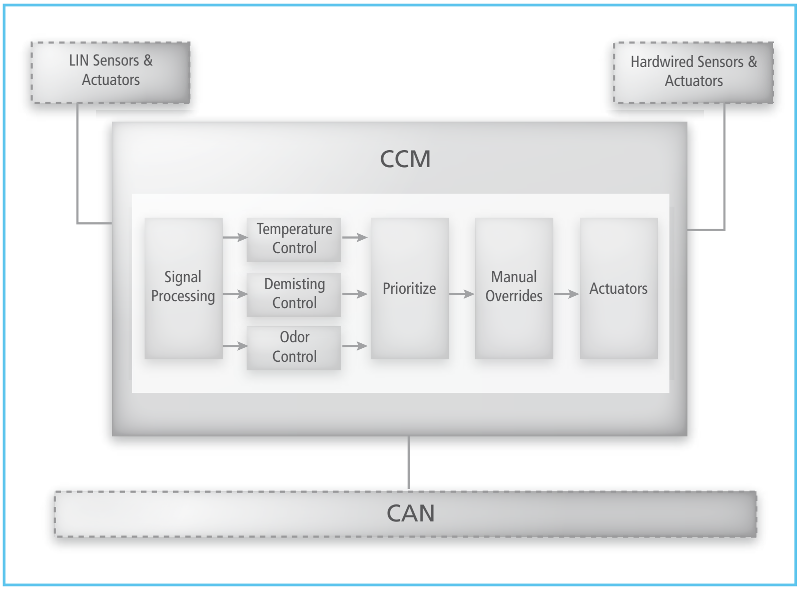
The core functionality of the CCM exists in the form of a TargetLink model from which code has been deployed for various production projects. The actual control design is carried out entirely by Volvo Technology using the TargetLink Stand-Alone Blockset. The largest part of the control design work is done in the first iteration of the development process, where the existing TargetLink model is adapted to meet the new software requirements. In subsequent iterations, the control design is modified to reflect necessary changes in software requirements during the course of the project.

Control design and implementation with TargetLink almost go hand in hand. Close to 100% of the application layer of the CCM is autocoded by TargetLink in the form of efficient fixed-point code. Moreover, TargetLink's flexibility enables the generation of interfaces that are very well suited to a later integration into the software architecture of the CCM.

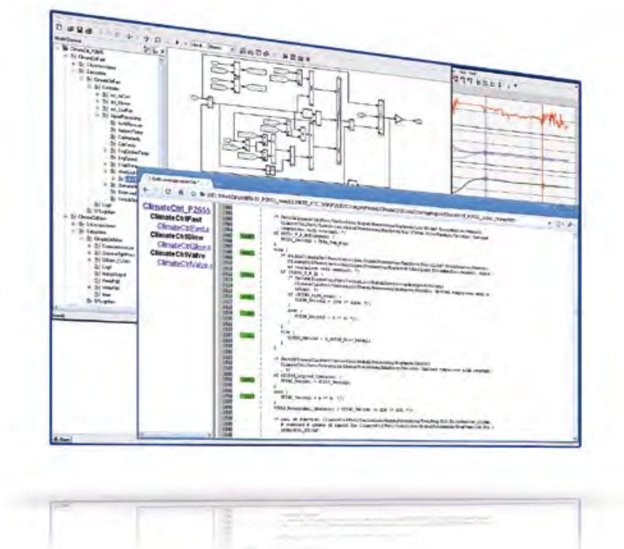
Open loop and closed loop simulations are used to inspect the basic behavior of the controller as well as the generated code. Actual stimuli which were captured in vehicles and some simplified plant models are used for the simulations.,The overall system behavior of the controller is examined in floating-point arithmetic with Model-in-the-Loop (MIL) simulations. Software-in-the-loop (SIL) simulations are used to verify the behavior of the generated code for the controller. TargetLink's integrated simulation concept is used to compare MIL with SIL simulations to detect improper scalings in the implementation model. The result of the Control Design and Implementation phase is a properly scaled TargetLink model and code generated from it.

Controller Tuning

Climate control essentially means controlling the air into the passenger compartment. The plant models used during the control design and implementation phase do not capture all of the subjective aspects of comfort and noise. Consequently the final tuning of the controller is performed in-vehicle, often starting in a prototype vehicle where some of the hardware is changed from an existing vehicle. In order to carry out the tuning, the TargetLink code generated for the implementation model is integrated into the real-time frame of the application, compiled, and flashed to the climate ECU of the vehicle. Moreover, a TargetLink-generated ASAP2 file is used to adapt the calibration parameters, so that the CCM can be tuned efficiently and its functionality verified. Initial tuning experiments and tests are performed in a controlled environment such as a climatic wind tunnel. Later in the project, road tests are most common. The refined controller tuning is gradually refined as the overall project evolves.



Physical interfaces to the Climate Control Module (CCM) and CCM controller modularization.



Code coverage analysis with TargetLink.

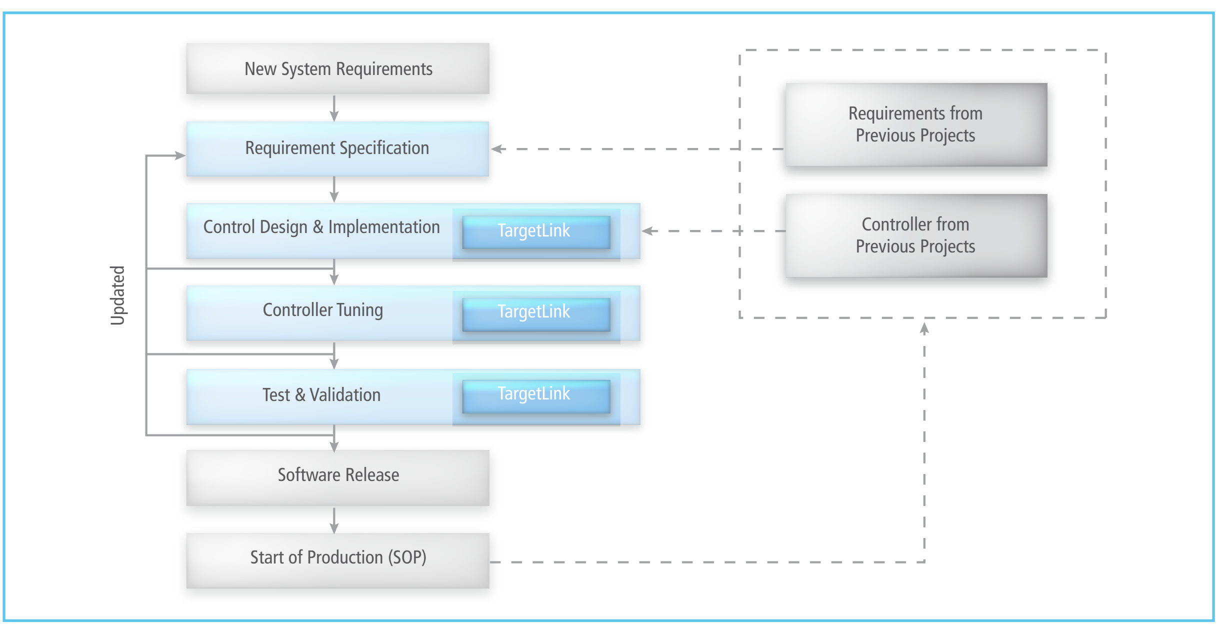
Test and Validation

Extensive testing is done before the software is delivered for vehicle production. Typically, model-in-the-loop and software-in-the-loop tests in TargetLink are executed for module testing. This involves functional as well as structural tests. TargetLink's code coverage feature is used extensively to ensure sufficient coverage of the generated code. There are also general tests, and the results of those are compared to previous simulations and evaluated together with tuning. This is often done manually, since the tests are general and need to be evaluated by a highly skilled climate control engineer. System and software integration testing is carried out on the actual ECU using a dSPACE hardware-in-the-loop simulator. Generally, many test cases are reused throughout the different development phases in model-in-the-loop, software-in-the-loop and hardware-in-the-loop mode which makes the testing process efficient. ■

Dr. Mats Andersson,
Björn Fridholm,
Henrik Weiefors,
Volvo Technology, Sweden

Conclusion

- Volvo Technology's Climate Control Module (CCM) has been refined and extended over the years
- Successful use of TargetLink for controller development, autocoding and tuning
- Almost the entire application layer of the CCM was autocoded with TargetLink
- CCM is used by several international car, truck and construction equipment brands



Iterative development process for the Climate Control Module (CCM).

A flock of birds colliding with an aircraft can knock out its engines and its power supply. When this happens, emergency power systems have to supply energy to vital onboard systems.

Developing an aircraft emergency power system based on a fuel cell

Never Without Power

The electricity an aircraft requires during a flight is normally generated via the engines. To ensure that there will always be a sufficient current supply to the flight controls and essential onboard functions even if the engines fail completely, modern aircraft have a ram air turbine (RAT) – a deployable turbine that generates current via the airstream. RATs have a disadvantage, however: Their output depends on the flight situation. Liebherr-Aerospace Lindenberg GmbH is using dSPACE hardware and software to develop an alternative, fuel-cell-based emergency power system that supplies electricity no matter what the situation is.

The "Miracle on the Hudson"

A good example of what RATs can do was seen when an Airbus A320 ditched in New York's Hudson River in January 2009. Multiple bird strikes had significantly damaged all the Airbus´ engines and greatly reduced its regular power supply. The RAT deployed immediately, supplying additional energy to vital onboard systems so that the aircrew could execute safe emergency ditching. However, RATs can only save lives if they have sufficient air speed. In some flight situations, such as when the plane is gliding at a difficult angle, the power can drop dramatically because the airstream is too weak. Liebherr-Aerospace Lindenberg is therefore working on a backup power system based on a fuel cell that will provide power in any situation regardless of ambient factors.

The FCEPS Backup System

The Fuel Cell Emergency Power System (FCEPS) consists of a fuel cell and two tanks, one for hydrogen and one for oxygen, that are connected to the fuel cell via pressure reducers. When the two gases in the fuel cell react with each other, electric current is generated. This current is independent of ambient conditions and can be used in an emergency to ensure that the aircraft's vital systems – the electric flight control and important cockpit instruments – function reliably so that the pilot can maintain control of the plane. The fuel cell itself also generates heat, which is transferred via a liquid cooling circuit to a heat exchanger that takes the heat to a suitable heat sink. The water that is produced (in addition to exhaust gas) is removed by separators and reused within the process.

Figure 1: In an emergency, ram air turbines can be deployed into the airstream (as shown here below the aircraft's right wing) to generate power for vital onboard systems. The weakness of the RATs is that the power they supply depends on the speed of the airstream. Liebherr-Aerospace Lindenberg is therefore working on an alternative system with the aid of dSPACE equipment.

Dirk Metzler

Dirk Metzler is an Aerospace System Engineer at Liebherr-Aerospace Lindenberg GmbH in Germany.

The Test Bench with dSPACE Equipment

The dSPACE system consists of a PX extension box with various I/O boards, a RapidPro Signal Conditioning Unit and a RapidPro Power Unit. The ControlDesk test and experiment software provides the graphical user interface for input, signal recording, and monitoring of all processes. With this system, between 70 and 100 signals are examined on the FCEPS test bench at a rate of 100 Hz. The signals cover a wide range of parameters such as the hydrogen/oxygen supply and cooling, and electrical parameters for the fuel cell and power electronics, such as total voltage, voltage of individual cell elements (minimum, maximum, mean value), current and power.

Comprehensive Tests on Different Scenarios

With the dSPACE system, the FCEPS can be tested comprehensively by simulating different operating states and realistic scenarios. The control models were designed by means of MATLAB®/Simulink®. Testing mainly focuses on the system's quick start capability and on control optimization for the cooling circuit.

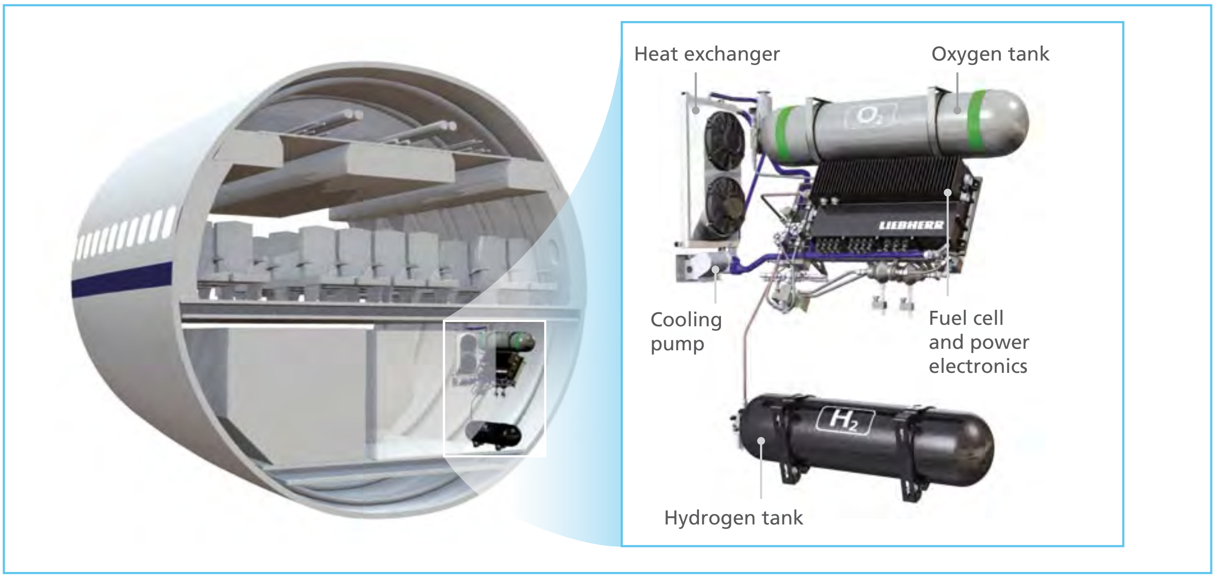
If the FCEPS is ever modified or extended (for example, for extra tasks in addition to backup power supply), the dSPACE system still has plenty of free capacity. With its modular design, it can be adapted to modified tasks very quickly. Liebherr-Aerospace Lindenberg intends to carry out tests with such a system in an aircraft environment; the existing dSPACE platform with a suitable extension (the dSPACE AutoBox) is ideal for this.

The Future: More Than Just Emergency Power

The next major challenges for the fuel cell team will be to optimize the start time and the weight of the FCEPS. Airbus, Boeing and other aircraft manufacturers have expressed an interest in FCEPS. So the FCEPS is more than just a backup power system, it is also a pioneer for further

> "Thanks to the dSPACE equipment, we were able to implement the fuel cell system and test it comprehensively – quickly and conveniently."
>
> *Dirk Metzler, Liebherr-Aerospace Lindenberg GmbH*

Figure 2: The FCEPS backup system from Liebherr-Aerospace Lindenberg can be installed almost anywhere in the fuselage – unlike RATs, which can be installed in only a few places because they have to be deployed into the airstream.



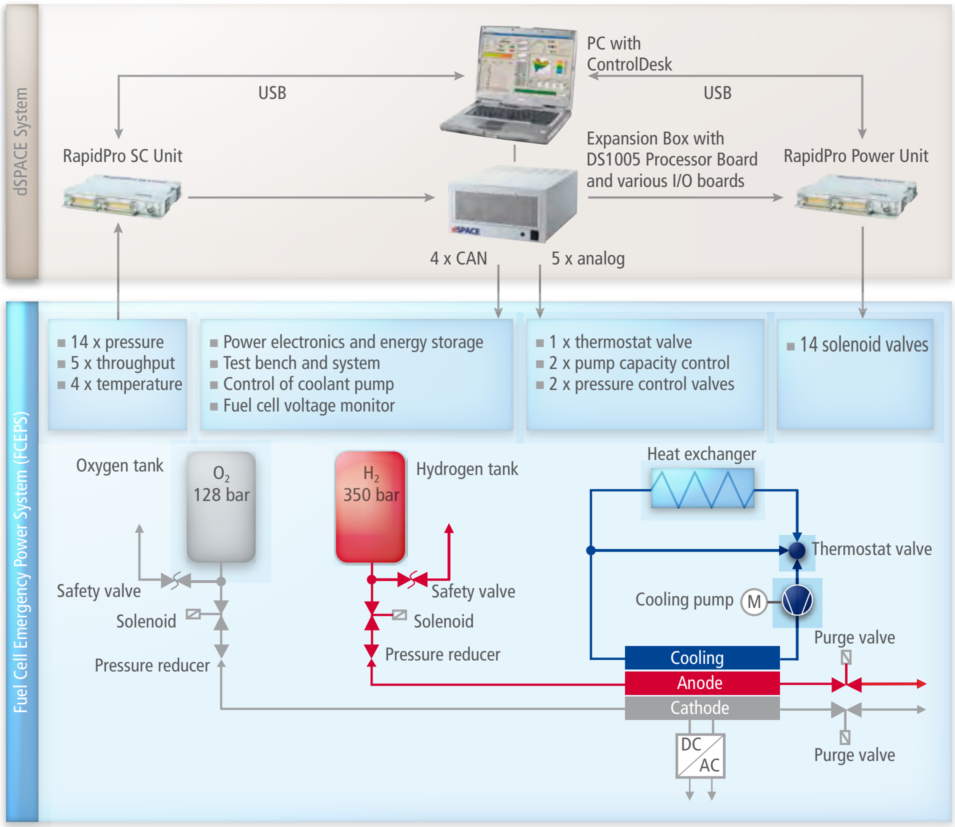
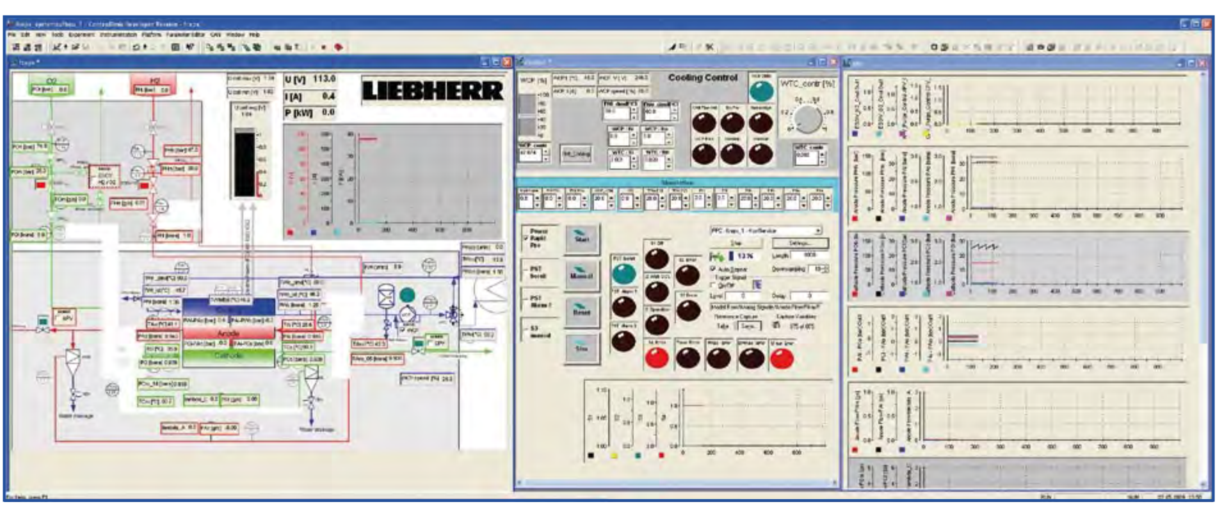


Figure 3: Schematic of the FCEPS and the dSPACE system on the test bench. Up to 100 signals are recorded, and then monitored and regulated with dSPACE ControlDesk. This system allows a wide range of scenarios to be tested thoroughly and comprehensively.

fuel cell applications in aircraft. There are plans to run a fuel cellsystem nonstop to generate all the electricity required in an aircraft, instead of using the engines for this as at present. The waste air from the fuel cell system could also be used for inerting the fuel tanks (i.e., preventing explosive gas mixtures), and the water could be recycled on board – incidentally also reducing the quantity of water carried onboard to save weight. ■

Dirk Metzler
Liebherr-Aerospace Lindenberg GmbH
Germany

Figure 4: The ControlDesk user interface shows the structure of the FCEPS (see figure 3). Window on left: The oxygen and hydrogen tanks at top left, the fuel cell in the middle, the heat exchanger and exhaust gas system at bottom right. Center window: The cockpit consists of command switches for the system, an area for the cooling control, and optical LEDs for indicating status and errors. Two control loops have been implemented for the cooling circuit, one for the fuel cell's input temperature and one for its output temperature. Various operating states can be simulated.



Silence is golden

Active exhaust silencers in vehicles

Noise pollution impairs the quality of life just as much as any other form of pollution, but noise cannot always be avoided. So even as far back as the 1930s, researchers began looking for ways to cancel it out with antinoise. The algorithms for active exhaust mufflers are known, and their advantages are clear, but to date it is not possible to produce electronic silencers for vehicles, except under ideal conditions. The challenge is to get these silencers out of the laboratory and onto the road.

Advantages of Active Noise Control

- More efficient reduction of dominant engine orders, so silencers are smaller
- Lower exhaust backpressure, resulting in higher engine performance and in some cases lower fuel consumption
- Customizable vehicle sound
- Versatile silencer design, meaning more reusable components
- Simplified development processes and shorter development times

The purpose of an exhaust system is not only to lead combustion exhaust gases away from the vehicle safely, but to reduce noise emissions also, i.e., to muffle the sounds caused by the combustion process.

The ActiveSilence® system from Eberspächer goes further; not only muffling noise better than anything before it, but also modifying the entire sound profile of the vehicle.

The Basic Idea

Using the principle of destructive interference, a sound source generates a sound with the same amplitude and frequency as the unwanted sound. When the two sounds are overlaid with a phase shift of precisely 180°, they cancel each other out. This principle also plays an important role in active noise control (ANC) for exhaust systems. The control works perfectly under idealized laboratory conditions, but getting it onto the road is a major challenge. The ANC system's components such as the loudspeaker are very sensitive, and the exhaust system's ambient conditions make it difficult to achieve an optimal system. The loudspeaker and the microphone have to withstand exhaust temperatures that range from -30 °C during a cold start to +700 °C during peak performance, plus moisture, shocks and vibrations. The control also has to handle rapidly changing parameters such as engine speed and sound pressure level.

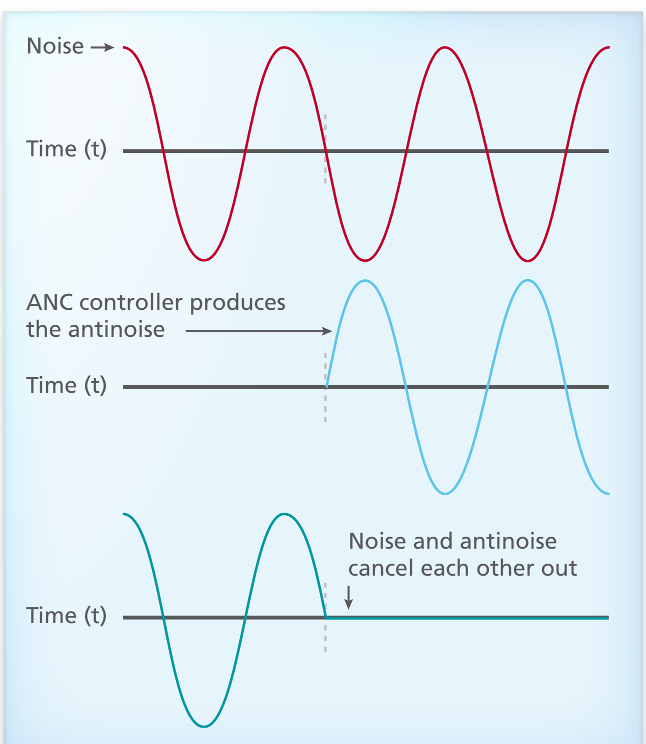


Figure 1: Active silencing by antinoise.

The Control Design

The primary sound components in an engine's exhaust system are the harmonics of the ignition's frequency, meaning that combustion engines can be classified as narrow-band sound sources. Our studies show that the most practical approach to active noise control in this case is an adaptive narrow-band feedforward control. The reference signal with information on the state of the combustion engine (speed, load) comes from the engine ECU via the CAN bus (figure 2). The ANC controller uses the information to control the loudspeaker with a 180° phase shift (feedforward part) and generate the secondary noise to cancel out the engine noise. The microphone picks up the residual noise, which the ANC then minimizes.

The control requirements are tough:

- Maximum efficiency over the greatest possible frequency range to suppress a broad noise spectrum
- Flexibility with regard to installation so that the system can be used for various engine families from different manufacturers
- Adaptivity to varying physical parameters such as temperature, vibrations, and shocks
- High robustness and reliability in all system elements
- Simple control electronics

The ANC controller generates the secondary noise via a secondary sound path. The transfer function between the controller output (control

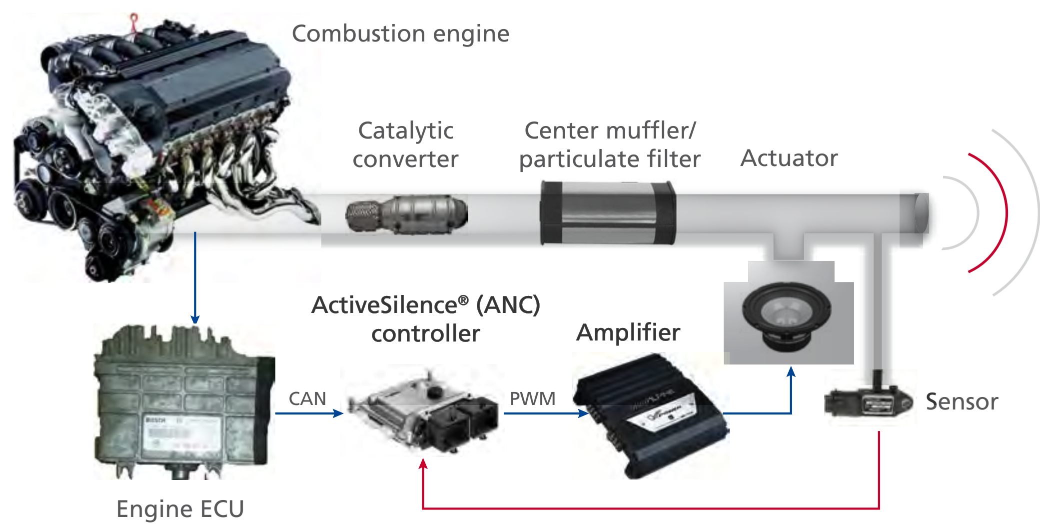


Figure 2: The control design.

> "The MicroAutoBox enabled us to develop a cost-efficient, integrated solution and to further optimize the overall system."
> *Dr.-Ing. Jan Krüger, Eberspächer*

signal) and its error signal input (error microphone signal) is called the transfer function of the secondary sound path (figure 3).

The ANC controller

- Reduces dominant engine orders in a frequency range of 35-400 Hz
- Increases frequencies selectively to achieve a target sound
- Identifies the transfer function of the secondary sound path even with engine noise

Model-Based Development Process

In the model-based development process, various simulations showed that the control returned the correct results.
The first step toward practical application is to implement the ANC algorithm on a dSPACE MicroAutoBox used as a prototyping system. To do this, we simulate the engine noises by replaying recorded exhaust noises via a loudspeaker in the laboratory. This lets us check whether the controller functions correctly on the MicroAutoBox. With dSPACE ControlDesk, we can adjust and optimize parameters such as the necessary filter length of the embedded controller. At this point, the MicroAutoBox is ready for use in the demo vehicle. The ANC controller is given further reference data such as engine speed, engine load, and vehicle speed via the vehicle powertrain CAN. Using the results of previous analyses, we study the properties of the overall system and optimize its total performance. The dynamic behavior of the system, particularly its effect on the criteria for the transmission function, is investigated in detail. The MicroAutoBox allows us to develop and refine an inexpensive and integrated solution.

The Test Vehicle Setup

We installed the ANC system in exhaust systems for a 4-cylinder gasoline engine. The direct injection system is fitted with a dual exhaust

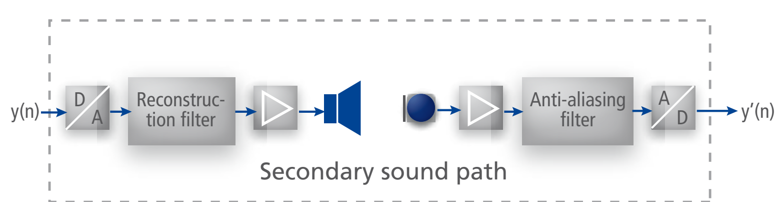


Figure 3: Transfer function between controller output and error signal input.

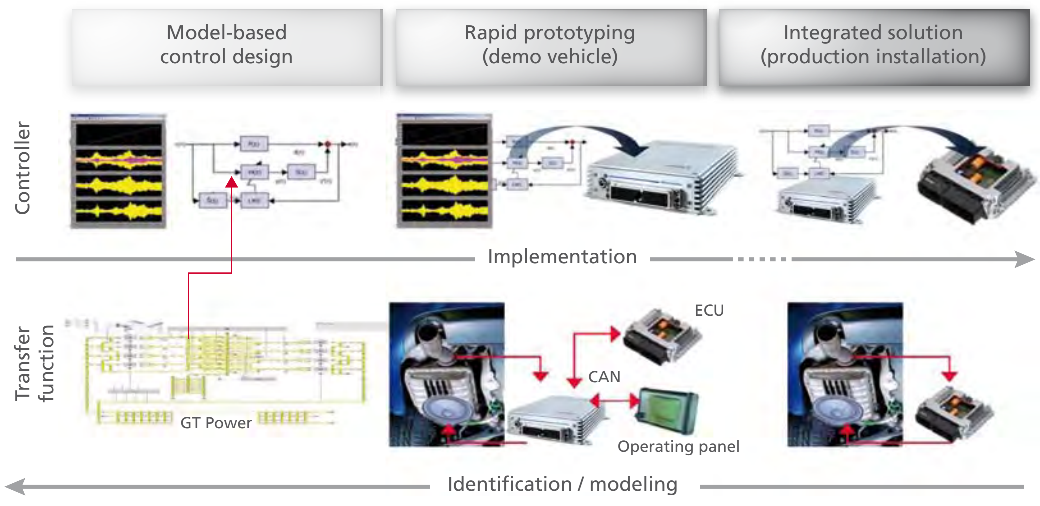


Figure 4: The development process – from model-based development to integratable control.

system as standard, so two active silencers were used to replace the conventional rear-exhaust silencer. The active silencer contains a microphone and loudspeakers that were specially developed to withstand the high temperatures and provide high output performance. All the other exhaust system elements, such as the catalyst, remained as they were. The exhaust system needs other electronic components in addition to the conventional silencer system. We used the following in this project:

- A dSPACE MicroAutoBox for real-time algorithm processing
- An amplifier to control the "canceling" antinoise loudspeaker with around 40 W maximum power
- An operating console in the driver's cab for setting predefined sound profiles and monitoring system status
- A microphone amplifier to return residual noise to the controller

Results

With more than 50,000 kilometers driven within 18 months, we were able to install and test the ANC system in various vehicles. We found a considerable reduction in exhaust noise in every case. Moreover, not only can the noise be reduced, the sound can also be improved. This means that the ANC system can be adapted to the vehicle, the driving situation, and the driver's wishes. The ANC system's acoustic performance was tested on a chassis roll test bench at full acceleration, with wide-open throttle (WOT) in third gear. We adjusted the controller so that it reduces the dominant engine orders 2, 4 and 6. The exhaust noise was measured at a distance of 0.5 m and at an angle of 45° to the exhaust tailpipe.

When the ANC system is switched off, the sound level is around 5 dB(A) higher than with the standard production system, because the original

Dr.-Ing. Jan Krüger: Programm Manager for ActiveSilence® Technology

In 1999 he completed his doctoral thesis on active silencers. He has been responsible for developing exhaust system acoustics at Eberspächer since 2000.

About Eberspächer

Founded	1865
Headquarters	Esslingen am Neckar
Employees	5,575
Turnover	€ 2,239.9 m (2008)
Products	Exhaust technology: catalytic converters, soot filters, silencers Auxiliary heating systems for cars, transporters, trucks, buses, construction machines and boats

passive silencer is no longer present. With the ANC system switched on, however, we measured a significant reduction of 2 to 8 dB(A) compared with the production system. We therefore achieved an improvement in noise levels over almost the entire engine speed range. The same measurements were performed for the 2nd engine order. The positive effect of the ANC system was clear here. Reduction started at an engine speed of 1200 revolutions per minute (40 Hz), and the noise was reduced by 10 to 20 dB over a wide range.

The noise level was also considerably reduced with other engine orders, so the exhaust noise had practically no additional effect on the noise level in the vehicle interior. We demonstrated that – especially in our demo vehicle – it is possible to achieve a degree of acoustic comfort that is otherwise present only in luxury vehicles.

Dr.-Ing. Jan Krüger
J. Eberspächer GmbH & Co. KG
Esslingen
Germany

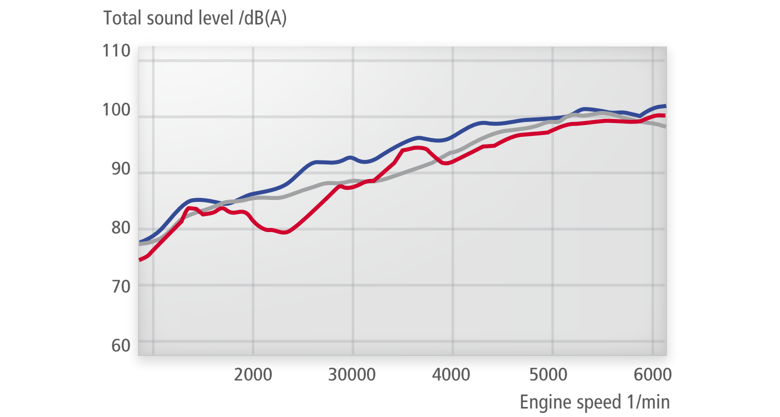


Figure 5: Overall sound level for a 4-cylinder gasoline engine (gray = standard production system, blue = ANC system switched off, red = ANC system switched on).

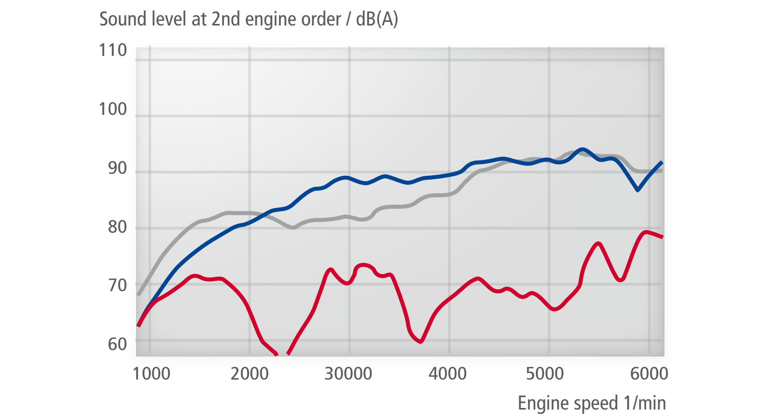


Figure 6: Sound level of the 2nd engine order for a 4-cylinder gasoline engine (gray = standard production system, blue = ANC system switched off, red = ANC system switched on).

Summary

We successfully took the ANC system out of the laboratory and put it on the road as the ActiveSilence® system. It performed beyond our expectations, even under adverse conditions. We verified all its functional benefits, such as reducing the noise, the volume of the silencers, and the exhaust backpressure. Our next step will be to reduce system costs. The system will be put in production vehicles only if the additional costs for loudspeakers and controller hardware and software can be offset either by greater functionality or by some other added value for the customer.

Glossary

Sound – Gas pressure fluctuations that consist of a basic frequency changing over time and its harmonics. The harmonics determine the characteristic acoustic impression of a sound.

Engine orders – An engine order states a frequency (harmonic) in an engine's frequency range that is a multiple of the engine speed. For example, the 2nd engine order is the harmonic that corresponds to twice the engine speed.

Plug & Play

Various ECUs tested by automated sequences

Delphi Diesel Systems has successfully developed automated integration and feature tests for various ECUs for diesel engine management systems. The challenge was to adapt the test system to other ECU versions as smoothly as possible. A wide range of dSPACE software and hardware offered the seamless tool environment for this task.

Figure 1: GUI created with the use of the Python module Tkinter. These graphical interfaces can be used to configure AutomationDesk projects.

The Challenge

The growing complexity of embedded controllers for automotive applications has dramatically increased the need for HIL (hardware-in-the-loop) bench testing and validation. ECU (electronic control unit) software releases, in fact, have to meet an ever-increasing number of tough customer requirements. For this reason, Delphi Diesel Systems (DDS), supported by dSPACE Ltd., has been working on developing a series of HIL-based automated tests to be utilized with different ECUs for diesel engine management systems.

HIL-Based Automated Tests

Nowadays, manual ECU testing is a viable alternative only for a very limited set of validation tasks. This explains why every tool vendor has been working hard to provide customers with real-time platforms capable of supporting the development and execution of automated tests.

> "The interaction of the dSPACE tools was very efficient and saved us a lot of time."
>
> *Giuseppe Raffa, Delphi Diesel Systems*

dSPACE has succeeded in tackling this problem thanks to AutomationDesk, which has been playing a crucial role for many DDS development activities since early 2008. Apart from the flowchart-like approach, which noticeably simplifies both test design and sequence debugging, this tool basically has two main advantages:

- AutomationDesk is Python-based. Consequently, any custom script or library developed in standard Python can easily be integrated into automated tasks. DDS has already put AutomationDesk projects in place that incorporate ControlDesk macros, third-party Python modules, such as Pylab and Matplotlib, and Tkinter-based GUIs. An example graphical interface is shown in figure 1. In addition to this, DDS has developed its own Python library to enhance standardization, code components reuse and version control in the development process of new automated sequences.
- AutomationDesk includes a COM interface that allows the user to invoke dSPACE ControlDesk (test and experiment software) MATLAB® and, above all, CalDesk, dSPACE's measurement and calibration software. No additional code is needed, as these tools can be called by means of standard AutomationDesk library blocks. The possibility of interacting with the dSPACE calibration environment CalDesk (in particular, via CCP on CAN) proved extremely effective, simply because the ECU software can be monitored or re-calibrated while the sequence is running, with no other tool necessary.

As a result, all the HIL-based automated tests developed by DDS have been implemented using the components shown in figure 2.

Hardware Set-Up

To maximize the return on investment, DDS chose a simulator based on dSPACE double mid-size configuration (figure 3). Being an off-the-shelf product, this platform allowed the company to reduce initial costs without any significant performance limitation.
Thanks to the open architecture of the double mid-size system, which incorporates a DS1005 processor board and a DS2211/DS2202 pair of HIL boards, DDS achieved the following results:

- Easy management and support of different ECU configurations. A simulator is connected with the embedded controller via an ECU-specific test harness that features a standardized structure. Consequently, when the HIL simulator has to be used for a different project, a suitable interface loom is needed. However, since this installation takes minutes, the chosen platform significantly increases the bench uptime.

- The majority of the ECU pins are always assigned to DS2211 channels. In fact, in comparison to the DS2202, this HIL I/O board is equipped with an angular processing unit (APU). This design solution automatically frees up many channels on the DS2202 that are currently exploited to drive additional boards and controllers which need to be interfaced with the main ECU.

Adapting the HIL simulator for future projects will require relatively little effort. A new harness will have to be designed, but this can be done in such a way that a certain ECU functionality will always be mapped to the same simulator channel. With this in mind, the platform configuration can undoubtedly be simplified.

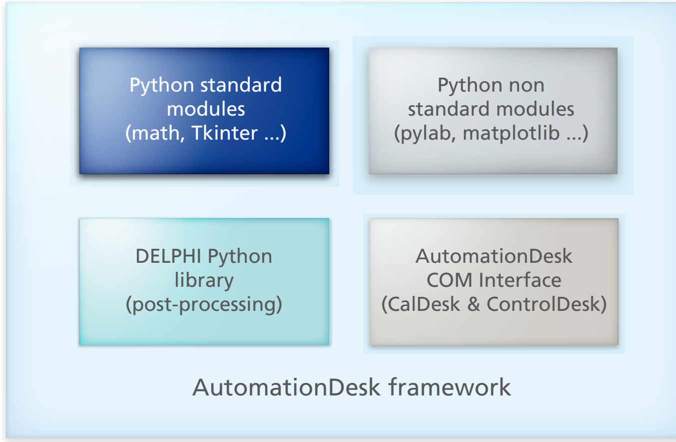


Figure 2: Components used by DDS to implement HIL-based tests. They can be integrated into AutomationDesk sequences.

CPU Load Evaluation

Thanks to the architecture described above, DDS has developed automated test sequences for both integration and feature tests. Among them, the CPU load test is one of the most interesting. Quantifying the CPU usage when the controller receives a variety of stimuli is the key to assessing whether a given hardware-software integration actually meets the initial requirements and what margins may be available to further developments.
As shown in figure 4, AutomationDesk

Figure 3: Double dSPACE Simulator Mid-Size.

Glossary

Tkinter – Standard module used to create object-oriented GUIs in Python: For more information see M. Lutz, "Programming Python", 3rd edition published by O'Reilly.

Matplotlib – Python plotting library for creating 2D figures. For more information see www.matplotlib.sourceforge.net

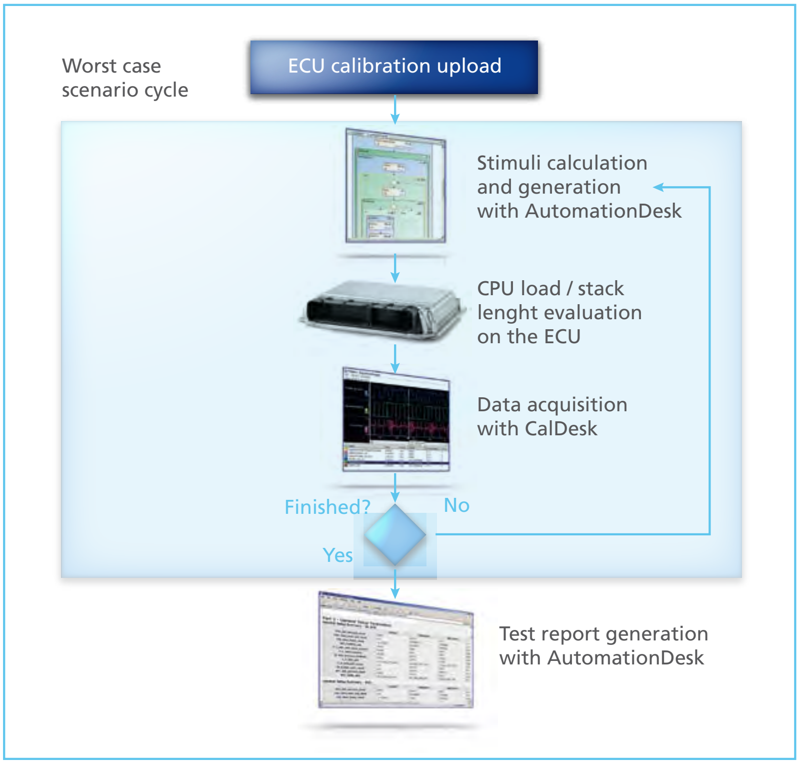


Figure 4: CPU load test developed by DDS.

enabled DDS to implement an automated sequence that stimulates the embedded controller according to selected worst-case scenarios. The ECU software includes a function measuring the CPU load in terms of percentage of main cycle time spent on required tasks; the results are made available to calibration tools through a series of measurement parameters that can be used to evaluate the average CPU load in each test condition. To generate a testing report, these parameters are finally post-processed in such a way that they are displayed as a function of the received stimuli.

Endurance Test Implementation

DDS has always been focused on safety and reliability. Consequently, a set of automated sequences that aim at coping with possible endurance-related problems have been designed. The principle underlying this group of tests consists of creating faulty conditions on the ECU physical interface to evaluate the robustness of the controller both from the hardware and the software point of view.

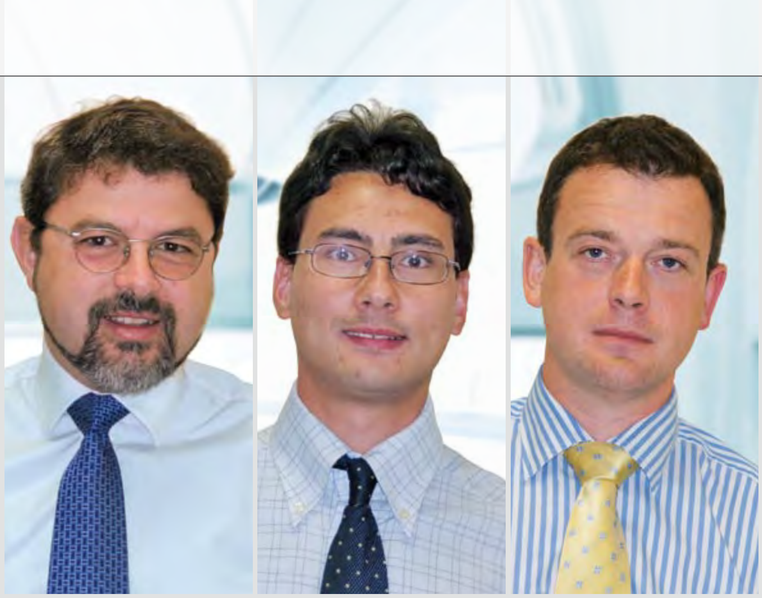
An example of these tests is summarized in figure 5. Cutting off the battery voltage repeatedly while the controller is operating is an effective way of testing how the ECU non-volatile memory responds. A sequence of this kind, which can be executed hundreds of times overnight, can quickly be implemented by driving the power supplies included in the simulator according to predefined cycles.

> "Thanks to the dSPACE HIL architecture, adapting the test system for future projects will require relatively little effort."
>
> *Riccardo Carrozzo, Delphi Diesel Systems*

Future Development

Several AutomationDesk-related development activities are going on at DDS. The currently available HIL-based sequences need to be improved to incorporate a wider range of configuration parameters and facilitate their execution. Furthermore, more comprehensive integration tests will certainly be created to deal with potential problems arising from new ECU functions and automatically generated code.
More precisely:

- Other software performance metrics will have to be taken into account as well. For instance, a variant of the CPU load test sequence implementing a stack size measurement is now available.
- Integrating GUIs into AutomationDesk projects is a key priority, in order to build a user-friendly test-process management environment. This can be used effectively to configure and launch the desired set of test sequences, without requiring a developer-level knowledge of AutomationDesk.
- A combined sequence to evaluate injection management and rail pressure control performances is currently under study. The final target consists of creating a complete set of automated test sequences that will be executed



Riccardo Carrozzo (left) –
HIL Team Manager. He coordinates activities focused on modelling and HIL validation.

Giuseppe Raffa (center) –
Principal System Engineer. He designs HIL / ECU interface harnesses and develops automated tests for embedded controllers.

Darren Walker (right) –
Core Software Manager. He is responsible for core software engineering, encompassing ECU platform software, and associated tools and processes.

as a standard HIL bench validation before starting any in-vehicle validation activity.

Conclusion

AutomationDesk has enabled DDS to develop a variety of automated tests, which have been shared across different ECU projects. In fact, this dSPACE tool, with its wide set of built-in block libraries, has allowed developers to interface seamlessly with calibration tools, such as CalDesk, and with the real-time HIL simulator. Moreover, integrating customized, standard and third-party Python modules has significantly facilitated the final data post-processing, thus guaranteeing high-quality test reports.

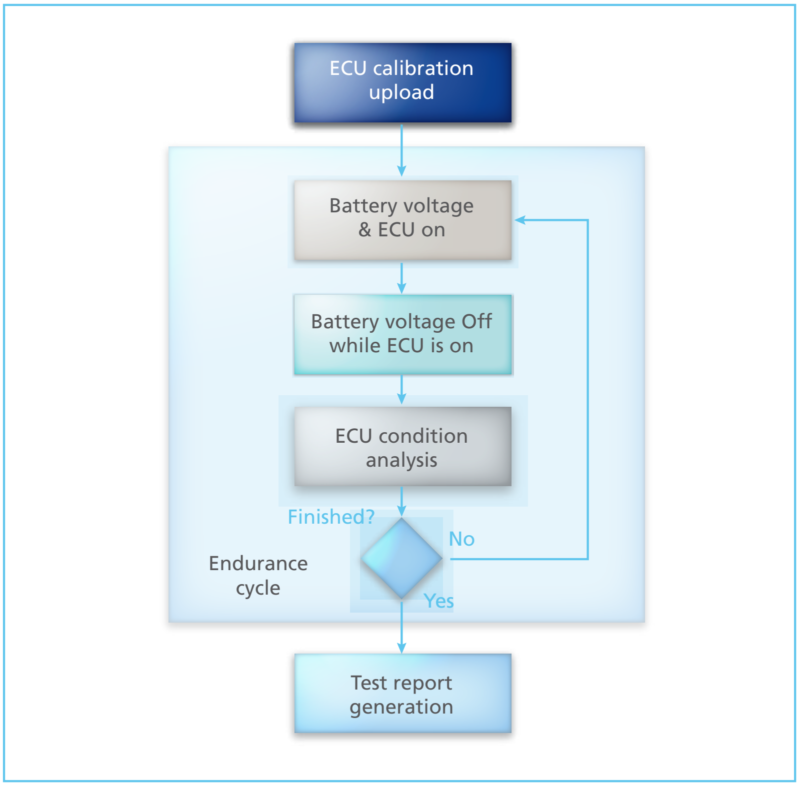
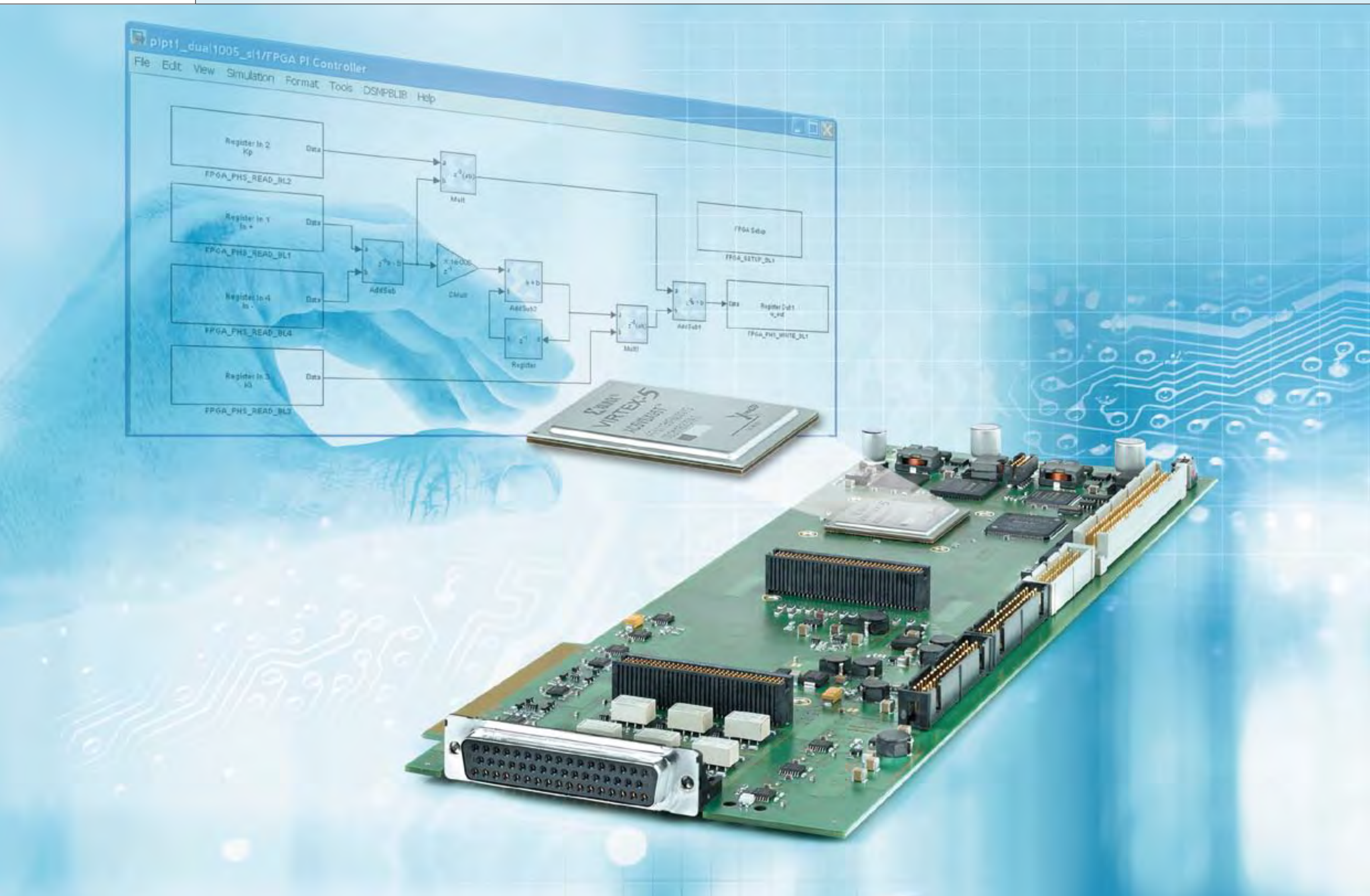


Figure 5: Endurance test developed by DDS.

The reusability of these automated sequences has been improved even further thanks to the openness of the selected hardware platform, namely the dSPACE mid-size HIL simulator. In fact, every time the bench has to be switched to a different controller, only a suitable interface harness has to be installed. Two real examples of HIL-based automated sequences are finally presented. They illustrate not only the effectiveness of integrating AutomationDesk and CalDesk, but also how DDS intends to improve the quality and reliability of its embedded controllers.

Riccardo Carrozzo, Giuseppe Raffa,
Darren Walker
Delphi Diesel Systems
United Kingdom



Speed and Flexibility

FPGA

For applications with extremely short latencies and cycle times

Tougher laws on emissions and fuel consumption make new drive concepts with highly sophisticated sensor systems a necessity. This also affects rapid control prototyping (RCP) and hardware-in-the-loop (HIL) simulation. To help meet these tougher requirements, dSPACE has produced its new DS5203 FPGA Board. Installed directly on the I/O interface, the board can be programmed any way you like. It is an invaluable assistant that not only performs signal conditioning, but also calculates models that require high dynamics.

FPGAs for Versatility

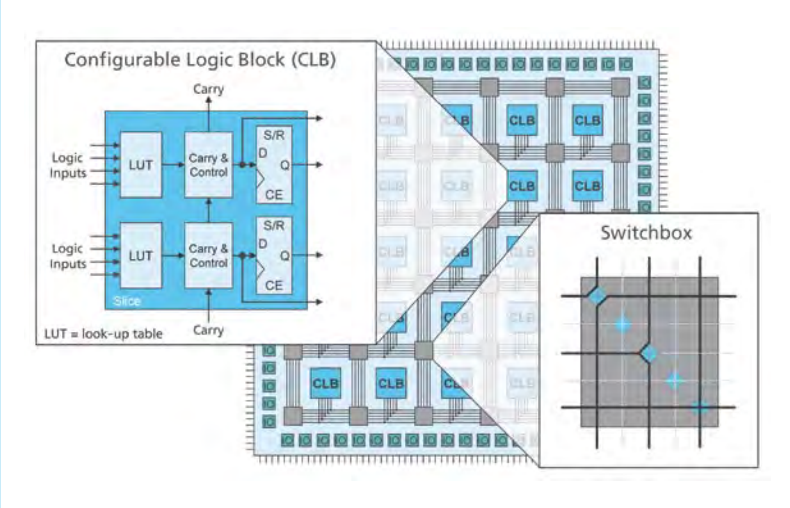
Field-programmable gate arrays (FPGAs) are programmable logic circuits. Essentially, they are programmed by combining and connecting their logic elements and memory cells in many different ways. Each logic element consists of a programmable truth table (look-up table, LUT) with 4-6 inputs, one output, and one flip-flop (1-bit register) for directly representing simple logical operations (AND, OR, etc.) To implement complex digital signal processing algorithms such as FFTs or even entire embedded microcontroller cores, several logic elements are used together.

The FPGA architecture supports genuine parallel processing, achieved by inserting hardware blocks multiple times. The hardware functions, and their interconnections via the FPGA's logic cells, are described in a hardware description language such as VHDL. This allows an FPGA's behavior to be described in text form without its structure having to be known. The FPGA manufacturer supplies a tool called a synthesis tool that generates the FPGA's actual configuration.

Graphical Programming: Straight from Simulink® Model to FPGA

The most convenient way to configure an FPGA is graphical modeling, for instance with the Xilinx® System Generator (XSG), a Simulink® blockset for configuring Xilinx FPGAs. The XSG contains simple logic elements and complex blocks such as Fourier transforms and FIR filters. dSPACE provides both the hardware (DS5203 FPGA Board) and the software (RTI FPGA Programming Blockset) to connect the XSG models to the FPGA's interfaces.

The DS5203 FPGA Board contains a programmable Virtex® 5 Xilinx FPGA and preconfigured I/O driver components. The RTI FPGA Programming Blockset is a convenient way to connect the I/O board's I/O driver components and to model the connection to a processor board, so processor boards (such as dSPACE's DS1006 used as the central board for calculating complex models) can be connected to the FPGA quickly and simply. Thus, FPGA programming is seamlessly integrated into the Simulink environment, which the user already knows from working with dSPACE's prototyping or hardware-in-the-loop systems. When the FPGA board is used, the synthesis, build, and programming of the FPGA or processor can be run directly from Simulink for optimal convenience.



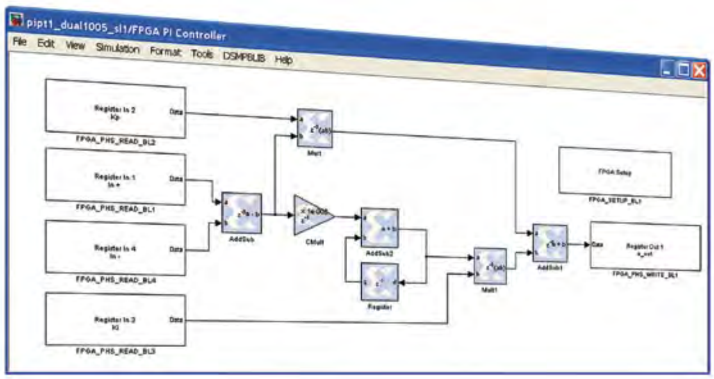
Field-programmable gate arrays (FPGAs) consist of a large number of logic elements that can be interconnected flexibly. This makes FPGAs useful for an extremely wide range of applications.

Further Requirements for Programming

In the synthesis process, each function and each model block is individually mapped to dedicated hardware and requires space on the FPGA. Since floating-point data types consume an extremely high amount of resources, only operators for fixed-point data types can be run usefully on today's FPGAs.

To achieve a reasonable compromise between precision and space requirement, it helps when an FPGA expert supports the model developer in defining the bit widths of different functions. The FPGA expert also helps in optimizing FPGA-specific properties such as signal execution times and the timing of switching. Offline simulation or joint simulation of the Simulink model and the VHDL code helps developers identify any problems before implementation on the actual FPGA.

Because of these requirements, an FPGA expert will probably support the software developer responsible for modeling if a function has to be implemented on an FPGA. Either the two of them work together and run joint simulations of their intermediate results, or the FPGA expert solves the FPGA tasks first and then passes the solution on to the soft-



Simulink model with XSG blocks for the DS5203 FPGA Board: a PI controller as an example.

ware developer. The result is a growing pool of solutions that can be reused for future tasks.

FPGAs in Use

The core of a dSPACE system is the processor board. If the processor board cannot calculate a model in the necessary cycle time, a part of the model has to be moved out to an FPGA.
Even though an FPGA has a considerably slower clock rate (the DS5203 has 100 MHz) than a processor (the DS1006 Processor Board has 3 GHz), it can solve numerous tasks faster. This is because its logic elements work in parallel, and this often more than compensates for the lower clock rate. Moreover, the FPGA on the DS5203 is connected to the I/O directly, so the entire bandwidth of converters can be used with minimum latencies, and very fast control loops can be implemented. This is increasingly an issue in the development of automotive ECUs, which always have more requirements for fast, complex, and highly reactive control circuits for reducing emissions and consumption. Cylinder pressure-based control and knock analysis, for example, are two applications fields that demand powerful signal conditioning. The potential of an FPGA is ideal for these.

Great Advantages for Electrified Powertrains

Powertrain electrification is fast gaining ground as a means to reduce fuel consumption. Mechanically coupled auxiliary aggregates (such as hydraulics and cooling water pumps) are being replaced by electrical aggregates that run as and when required and need no energy otherwise. To develop controllers for these electric drives, different interfaces need to be served flexibly. They include interfaces for position sensors such as resolvers and encoders, and also for addressing power stages for block and sine commutation. When ECU tests are run on an HIL simulator, parts of the electric drive model have to be implemented on the FPGA. Otherwise, the high dynamics requirements cannot be met. In electric drives, the ECU controls the power flow directly, usually at 20 kHz. Modeling the highly dynamic effects at the power stages with sufficient precision requires cycle times considerably lower than one microsecond. This can only be achieved by using FPGAs, with at least the motor current calculation running on an FPGA board.

Technical Details of the DS5203

In contrast to the DS5202 FPGA Base Board, which provides an I/O configuration that is precisely tailored to a specific application, the new DS5203 is freely programmable and can be flexibly adjusted to a wide range of different scenarios.

The DS5203 has a very powerful FPGA, the Xilinx Virtex-5 SX95 FPGA, with 94,298 logic cells and 640 special DSP blocks. The DSP blocks include fast, resource-saving multiplication of two signals.
For connecting external sensors and actuators, the DS5203 provides 6 ADC,

The new DS5203 FPGA Board.

Profile of the DS5203

Type:	FPGA board freely programmable via Simulink blockset
FPGA:	Xilinx Virtex-5 SX95, 100 MHz
I/O:	6 ADC, 6 DAC (14-bit, 10 MSPC), and 16 digital channels, extendable
Bus:	dSPACE PHS++

6 DAC (14-bit, 10 MSPS), and 16 digital I/O channels.
The number of I/O channels can be increased by a plug-on module if required.
Connection to the processor board is done as usual via the PHS bus.

The FPGA's 100-MHz clock rate lets even demanding tasks be implemented with very short cycle times. ■

Summary

Programming the DS5203 FPGA Board with the RTI FPGA Programming Blockset and the Xilinx System Generator is a good way to consistently develop a processor application and an FPGA application together from Simulink.
The interaction between the two applications can be tested in offline simulation before they are loaded to the real-time system. Thus, users can react flexibly and quickly to tougher requirements - for example, for signal conditioning, using new interfaces, or speeding up model parts.

Limited availability outside of Europe and Asia, please inquire.

Interview

With Jürgen Klahold, Product Engineer for Hardware-in-the-Loop Simulators, dSPACE GmbH

Mr. Klahold, please tell us some typical applications for dSPACE's new DS5203 FPGA Board.
With the electrification of powertrains, highly dynamic electric drives are being used in vehicles more often. Developing the necessary ECUs presents particular challenges, in prototyping and in HIL testing. The DS5203 provides the right solutions for this.
But it also opens up new potential for extended signal analyses, such as those needed for modern knock control.

What functions can the DS5203 perform, especially in testing these applications?
The high dynamics of electric drives demand simulation with a very short cycle time. If the effects of power stages also have to be included, cycle times far below one microsecond must be achieved. This is not possible unless at least a part of the controlled system's model – like the coil model – is moved out to an FPGA.

What are the strengths and advantages of the board?
The FPGA Board can be programmed directly from Simulink®, so it integrates seamlessly into the familiar tool chain. It has a powerful FPGA and extensive I/O interfaces on the actual board. If these are not enough, more interfaces can be added by means of a plug-on module.

How do users benefit from using the board?
Users can create applications that access the board's I/O directly and with virtually no latencies, so they can utilize the entire bandwidth of the signal converters. This lets them close control loops with very short cycle times, and also implement new interfaces.

Thank you for talking to us, Mr. Klahold.

Platform Independence Thanks to New Standard

Standardized HIL API enables platform-independent HIL tests

Up to now, a lot of work was necessary to use existing tests on any HIL simulator. With the new ASAM standard, HIL API, this is much easier. The HIL API is a standardized interface to connect test automation tools like AutomationDesk to any kind of HIL system. The result is that the test automation software has a higher level of investment protection.

What Does HIL API Mean?

API stands for application programming interface. The HIL API is a standardized interface that enables users to access HIL simulators according to a standardized method. Now, when using the HIL API, they find it easier to connect test automation tools such as dSPACE AutomationDesk to any kind of HIL simulator.

Why Does this Standard Exist?

The testing departments at numerous OEMs and suppliers have recently been asking dSPACE for one single test automation tool for accessing HIL simulators from different suppliers. The advantages were obvious: Only one software tool needs to be purchased, test engineers only need to be trained for one tool, and libraries are developed and maintained for just one single tool. In addition, the software's independence from the HIL simulator guarantees that the software has a high level of investment protection.
dSPACE therefore set up a workgroup with the goal of standardizing the access to HIL simulators. Various OEMs,

suppliers and tool manufacturers sat together with the leading spokesman, Dr. Jobst Richert (dSPACE GmbH), to define the standard. In July 2009, ASAM (Association for Standardisation of Automation and Measuring Systems) officially adopted this standard, named as HIL API.

What Was Standardized?

Not only was the access to HIL simulators standardized, but also the access to electronic control units (ECUs). The HIL API is divided into the following areas:

- Access to HIL simulators
- Access to ECUs during measurement and calibration
- Access to diagnostics
- Electrical failure simulation

How Do Users Benefit?

To develop ECU tests independently of HIL systems, test engineers previously needed to pay attention to defining and using abstraction layers when developing these tests. If they neglected to do so, they had to perform numerous adaptations to use the tests on a HIL simulator from another supplier. The HIL API makes the platform-independent development of tests development much easier: A HIL API-based test can be executed on another HIL system without any problems – provided that a HIL API interface was implemented for the other HIL simulator.

It makes no difference if users already have HIL simulators from different manufacturers, or simply do not want to decide on just one manufacturer.

> With the HIL API, just a click is enough to use test sequences on different simulation hardware.

If their test automation tool already supports the HIL API, they are on the safe side and attain a high investment protection for their test software.

dSPACE will implement the HIL API for its HIL simulators and will adapt the test automation software AutomationDesk accordingly for the HIL API. Parts of the standard will be implemented as early as in the upcoming version of AutomationDesk (fall 2009). As a result, AutomationDesk users can benefit from the new standard's advantages right from the start. For more precise information on the release date for AutomationDesk 3.0, visit the dSPACE website.

How Does Hardware Replacement Work?

To reuse test sequences on different simulation hardware, all users have to do is to replace the underlying HIL API library. All manufacturers of simulation hardware that support the HIL API standard will provide the necessary library with the hardware. Users just have to click a button in AutomationDesk to specify which HIL API library they want to use, which will also determine the simulation hardware the tests will run on.

What's the Outlook?

In the future, the HIL API will be expanded in Version 2.0. For example, access to bus systems will be standardized. In addition, a further workgroup is currently working on standardizing a test exchange format. This will enable users to exchange the tests they created in AutomationDesk with other testing tools, or use tests in AutomationDesk that were created with a different tool. ■

Using the HIL API in test automation leads to hardware independence.

AUTOSAR Now Boosts Rapid Prototyping and HIL

RTI AUTOSAR Package 1.0

The AUTOSAR standard is increasingly being applied in the early prototyping and test phases, not just in developing production components. The new RTI AUTOSAR Package from dSPACE makes it easy to integrate AUTOSAR software components and compositions into the MATLAB®/Simulink® environment and execute them on dSPACE real-time hardware.

A Powerful Package

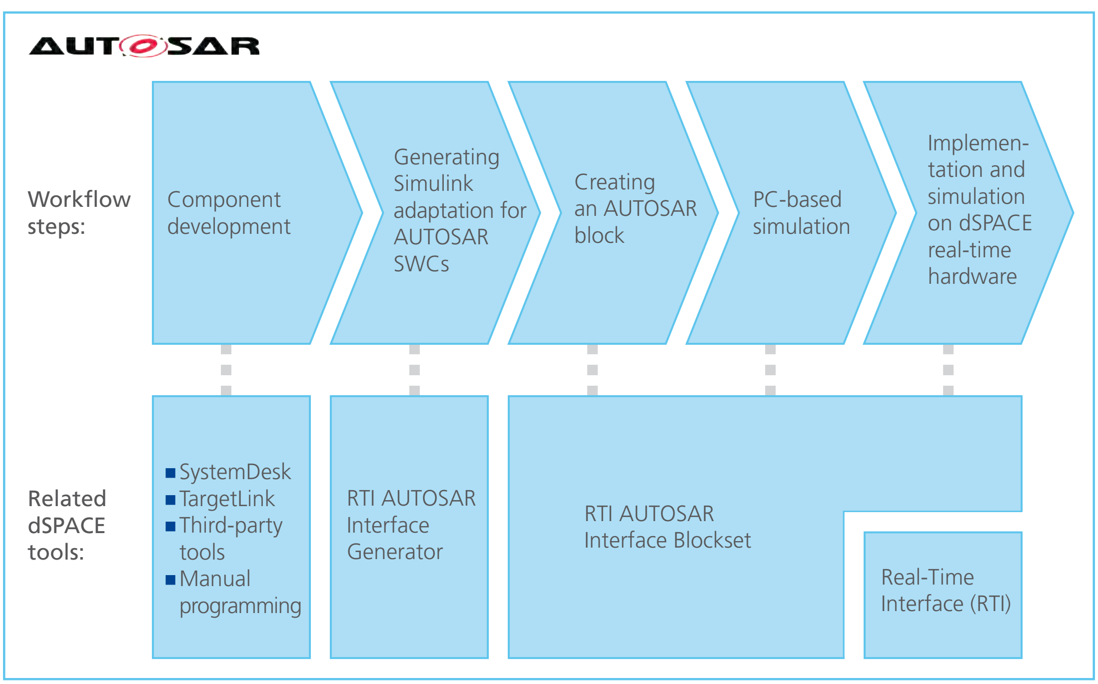
The new RTI AUTOSAR Package gives embedded software developers a fast, convenient method to integrate AUTOSAR components from different sources (SystemDesk, TargetLink, handcode) into the MATLAB®/Simulink® environment, combine them with other Simulink blocks, and simulate them on a PC. The components can be executed on the dSPACE real-time hardware using Real-Time Interface (RTI) in the usual way. This provides an enormous range of opportunities. For example, when new control functions are being developed in MATLAB/Simulink, they can be linked with existing AUTOSAR components and tested together with them. Moreover, new AUTOSAR components can be quickly loaded to the dSPACE prototyping hardware components with the RTI AUTOSAR Package to perform tests in the actual vehicle. For hardware-in-the-loop (HIL) test scenarios, AUTOSAR-compliant software components can be implemented on application level as soft ECUs on dSPACE HIL simulators.

Behind the Scenes

As part of the of the RTI AUTOSAR Package, the RTI AUTOSAR Interface Generator is the user's "first

Work in the familiar MATLAB/Simulink environment: Import AUTOSAR software components, and combine them with Simulink and RTI blocks.

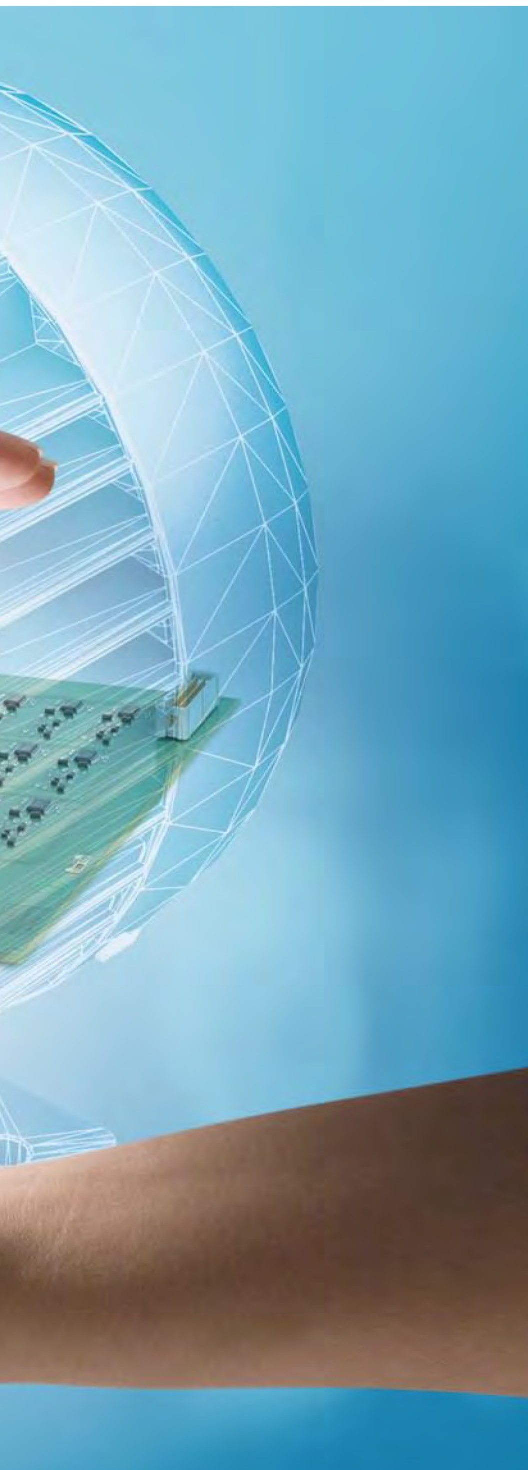
contact" with the AUTOSAR software components and its associated C source files. With just a few clicks, it generates an RTI SWC container holding the imported components, already prepared for Simulink. It can also be automated via a command line interface. The RTI SWC container can be loaded to MATLAB/Simulink via the RTI AUTOSAR Interface Blockset. The generated blocks represent the specific behavior and the interfaces of the original AUTOSAR software components. To help you get started, the RTI AUTOSAR Package contains a descriptive, easily expandable demonstration example, which you can use as the basis for further projects. ■



Workflow: With the RTI AUTOSAR Package, it is just a few short steps from AUTOSAR file import to Simulink integration, PC-based simulation, and implementation and simulation on the dSPACE real-time platform.

All Under One Roof

EMH Solution – New integrated HIL simulation of electric motors



For HIL simulation of electric motors, numerous inputs and outputs are necessary for the control variables and sensor signals. dSPACE now offers an integrated FPGA-based solution that combines all of the essential I/O functions on just one board.

There are currently many control system interfaces available to connect hardware-in-the-loop (HIL) systems to the ECU of an electric motor. For low-performance motors, i.e. for electric steering, the electrical performance level of the ECU or the mechanical level is often suitable as an interface to the HIL system. However, for drive motors of hybrid vehicles and electric vehicles, the signal level is the preferred choice; especially when emphasis is placed on testing the ECU software and when operating the power stage is not necessary.

Simulating a 3-Phase Motor and Service Calls at Signal Level

When simulating at the signal level, the power electronics is removed, and only the signal processing portion of the ECU are connected to the simulator. The control signals of the power switch of the inverter stage are read in by the simulator and serve as the basis for the real-time simulation of the power electronics and electric motor. To close the control loop in the HIL simulation, the simulator must calculate the sensor signals for the rotor position and the motor voltages. dSPACE's product range has long included special boards for this connection at signal level, for creating and measuring PWM signals (pulse width modulation) and PSS signals (position sensor simulation).

New Integrated I/O Solution

For the first time ever, the new electric motor HIL (EMH) solution, based on the dSPACE DS5202 FPGA Board, offers several necessary I/O channels to simulate up to two electric motors "under one roof." This gives users a compact, cost-effective way to start working with the HIL simulation of electric motors.

Highly Precise PWM Signal Measurement

To simulate a B6 inverter stage, for example, measurement of the 6 gate control signals of the ECU (figure 2) must be highly precise. With the EMH solution, measure-

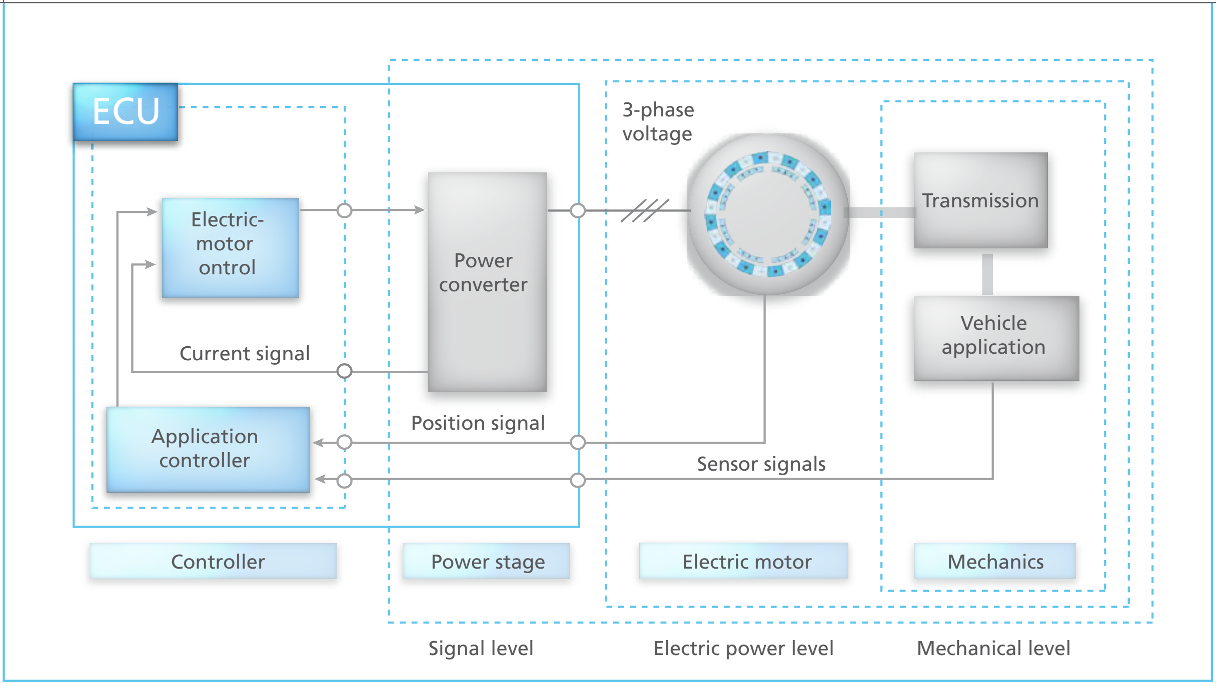


Figure 1: Interfaces for electric motor simulation.

ment is done at a time resolution of 25 ns. At defined sampling times, the duty cycle, period times and power-up times of individual signals, as well as the dead times between neighboring signals are determined in a bridge arm, and made available for the real-time model on the processor of the HIL simulators (i.e., a DS1006 Processor Board). The EMH solution usually determines the sampling times independently at the middle of the PWM period, whereby an interrupt is triggered on the processor, depending on the operating mode, so that the model of the power electronics of the electric motor is calculated synchronously with the PWM frequency. This avoids any beats. During this, the oversampling and the downsampling can be modified. Depending on the PWM frequency, the sampling times lie between approx. 30-60 µs. With the 16 channels of the EMH board, all the gate signals for two 3-phase electric motors can be read in.

> The EMH solution combines all necessary I/O functions for electric motor simulation – compact, high-performance, cost-effective.

Simulating the Position Sensor Signals

Because the control of electric motors must have an exact rotor angle position to control the voltage and calculate the speed, this must be simulated by the HIL system at a high resolution. The position sensor simulation offered by the EMH solution is based on the proven angle processing unit (APU) principle, which is already reliably used with the DS2211 HIL I/O Board. The EMH board has 4 independent APUs (figure 3), which users can allocate to different sensor simulation channels. This flexibility enables, for example, the simulation of two electric motors with independent or independent axles. The EMH solution offers:

- An analog sensor simulation group with 3 analog outputs to simulate resolver, sine encoder, or analog user-defined signals
- A digital sensor simulation group with 3 digital outputs to simulate incremental encoders, Hall sensors or digital user-defined signals
- 3 further independently usable digital outputs

All analog signals are resolved at 100 ns, all digital signals at 25 ns. Because the board contains comprehensive signal conditioning, an electric motor ECU can be connected directly at signal level.
With the universal RS485 UART interface, many different protocols can be implemented. In addition to the TwinSync protocol by LTi, further protocols for incremental encoders, such as SSI (synchronous serial inter-

Glossary

B6 inverter – Inverter with a switch bridge of 6 switch elements for 3-phase alternating current.

SSI (synchronous-serial interface) – Standard for protocol-based incremental encoder. Other variants are Hiperface and EnDat.

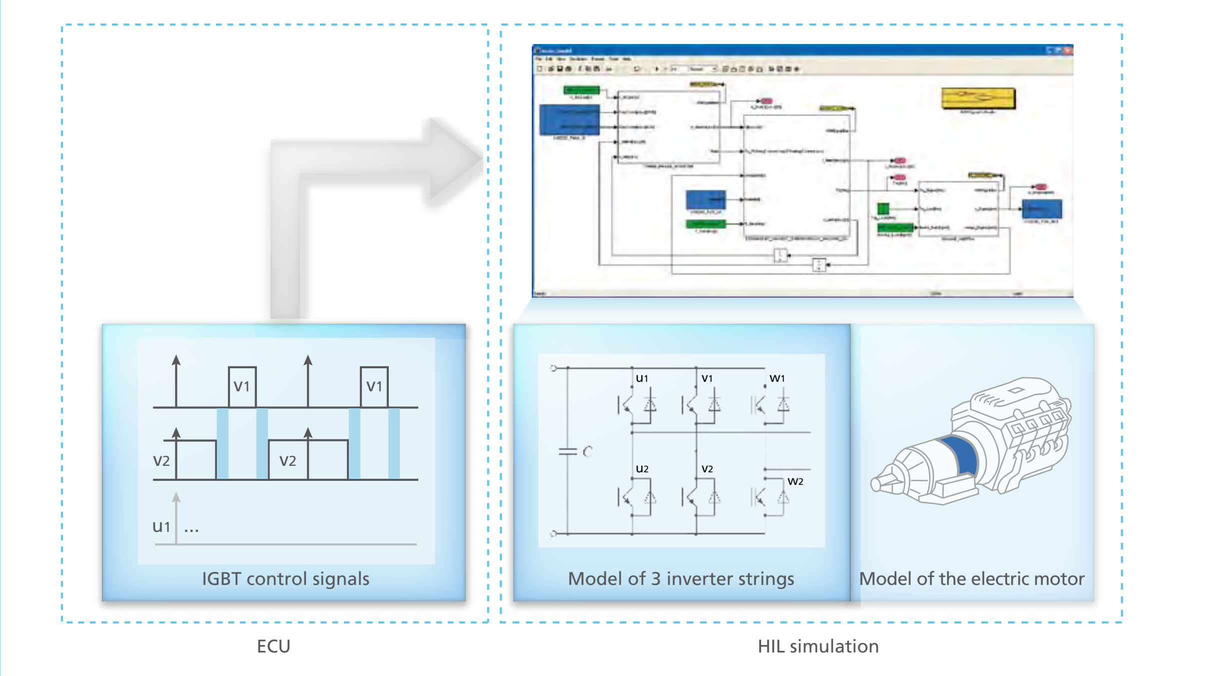


Figure 2: Highly precise PWM measurement is just one of the functionalities of the electric motor HIL solution.

face), Hiperface and EnDat will soon be available.

Additional I/O Solutions

Besides PWM sensor signals and position sensor signals, the EMH solution offers other signals which are usually necessary to simulate electric motors.
For example, 6 fast, bipolar DAC (digital analog converter) channels can be used to simulate the engine voltage. The resolution is 12 bit, the output drivers cover a voltage range of +/-10 V. An additional unipolar DAC channel controls an external battery simulation power unit – no further I/O board is necessary in the HIL system when pure E-motor simulation is being performed. 4 bipolar analog inputs are also available altogether, which, for example, can be used to measure the current of the power supply unit.

Besides this, there are 13 digital outputs for universal tasks (i.e., to control the relay box). 3 of these digital outputs are multifunctional. Besides the PWM output functions and digital output functions, they also provide a way to perform angle-synchronous signal generation. ■

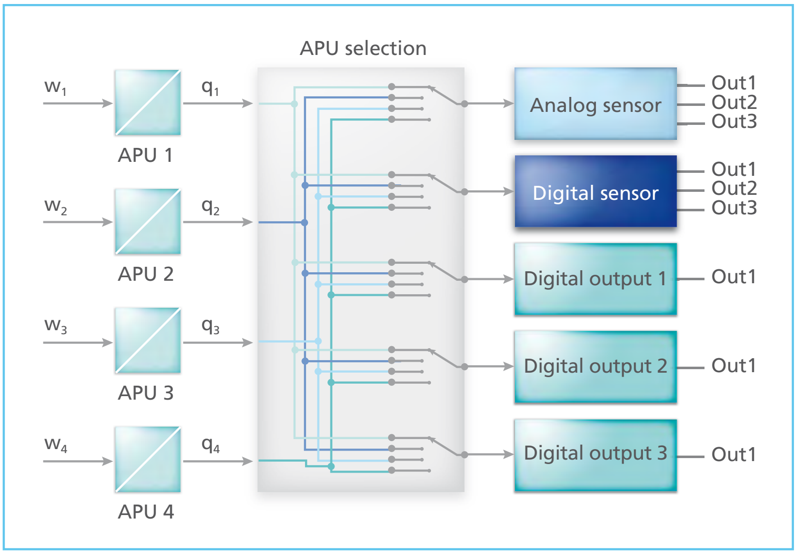


Figure 3: Four independent APUs allow a incredibly precise simulation of the position sensor signals with regard to time.

Summary

The new electric motor HIL solution is a cost-effective, high-performance solution for the HIL simulation of electric motors at signal level. It can be used in dSPACE Simulator Mid-Size and in dSPACE Simulator Full-Size for individual ECU tests, or for integration tests with network simulators containing several dSPACE simulators to simulate hybrid vehicles and even electromechanical drives.
It also lets users set up compact systems for industrial applications, such as for testing industrial servo converters.

With the new RapidPro power stage modules, dSPACE offers universal support for electric motors in 12 V and 24 V applications. The modules can be configured via software and support the control of DC motors and stepper motors, as well as brushless motors such as BLDC motors and synchronous motors. Peak currents of up to 60 A and continuous 42 A are possible.

Full Power

Universal RapidPro power stage modules for electric motors

Many Different Application Fields

Electric motors are being used in several fields, from automobiles to commercial vehicles, rail vehicles, wind power plants, and even production machines. To develop and test the relevant electronic control unit (ECU) functions, it is necessary to control the electric motors directly with the prototyping system via power stages. The universal RapidPro power stage modules PS-HCFBD 1/2 (DS1767) and PS-HCHBD 2/2 (DS1768) are the perfect solution. They quickly and flexibly integrate several types of electric motors (DC motors, step motors, brushless motors such as BLDC motors and synchronous motors, 12 V and 24 V applications) into the dSPACE prototyping environment. Off-the-shelf availability means that users can set up the RapidPro system according to their application's specifications. The cost-intensive, time-consuming task of developing systems on their own is a thing of the past. The development of a vehicle ECU, for example, clearly demonstrates the RapidPro modules' versatility: Whether in comfort electronics or auxiliary units such as an oil pump or a water pump – with the DS1767 or DS1768, the corresponding components are integrated quickly into the prototyping environment.

Software Configuration

For maximum flexibility in the development process, the RapidPro power stage modules DS1767 and DS1768 can be completely configured by the

The new RapidPro modules DS1767 and DS1768 are ideal for developing components of a 24 V electric system, such as those used in commercial vehicles.

configuration software Configuration-Desk. Parameters such as the maximum output current, the polarity of the input signals and digital low-pass filters for current measurement can be set.

Diagnostics

The DS1767 and DS1768 offer extensive diagnostics possibilities. Via ConfigurationDesk, users can have warnings issued for excessively high current and temperature values, as well as error messages for current measurement errors and interruptions in the output signal path.

Highly Precise Current Measurement and Dynamic Control Loops

The newly developed digital current measurement of the DS1767 and DS1768 make it possible to implement dynamic control loops with a high control quality, even in environments in which heavy disturbance signals are present due to fast switching of power transistors. Users thus reach their development goals of achieving utmost precision and latency-free current measurement.

AC Motor Control Solution

With the additional FPGA-based AC motor control solution, which can be used in combination with the RapidPro hardware and the DS1768, dSPACE offers a flexible solution to control many diverse electric motors. The solution is based on the DS5202 FPGA Base Board and a special RTI blockset for MATLAB®/Simulink®. It is specially designed for fast current/voltage measurements, connection of diverse position encoders and control of AC motors such as asynchronous motors, brushless DC motors (BLDCs) and permanent magnet synchronous motors (PMSMs). The fast I/O needed for the rapid prototyping of AC motors is achieved by the efficient cooperation between the DS5202 FPGA Base Board, the different piggyback modules, as well as the DS1005 or DS1006 processor boards.

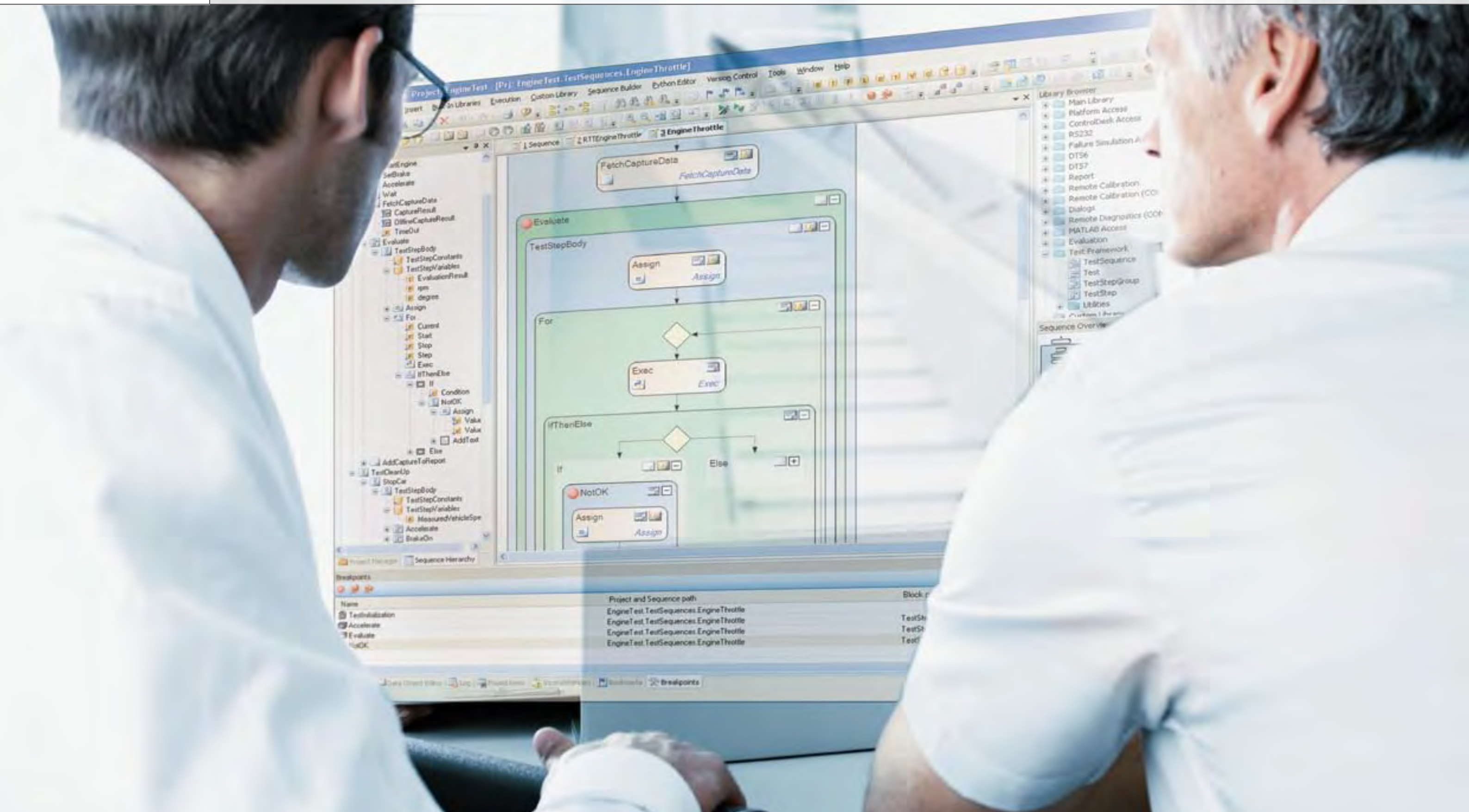
The Modules at a Glance

PS-HCFBD 1/2 (DS1767)

- Software-configurable, high-current, full-bridge module
- 12 V and 24 V applications
- Support of DC motors and step motors
- Peak current: 60 A, continuous: 42 A_{RMS} (depending on the temperature)
- Highly precise, galvanically separated phase current measurement and voltage measurement
- Extensive protection from overheating, overcurrent and overvoltage

PS-HCHBD 2/2 (DS1768)

- Software-configurable, high-current, half-bridge module
- 12 V and 24 V applications
- Control of BLDC motors and synchronous motors
- Peak current: 60 A, continuous 42 A_{RMS} (depending on the temperature)
- Highly precise, galvanically separated phase current measurement and voltage measurement
- Extensive protection from overheating, overcurrent and overvoltage
- Low-side or high-side driver mode for controlling actuators such as valves



Getting Better and Better

The past, present, and future of test automation

A talk with Dr. Klaus Lamberg, Product Manager of test and experiment software, about AutomationDesk (dSPACE's test software) and future developments in the area of testing.

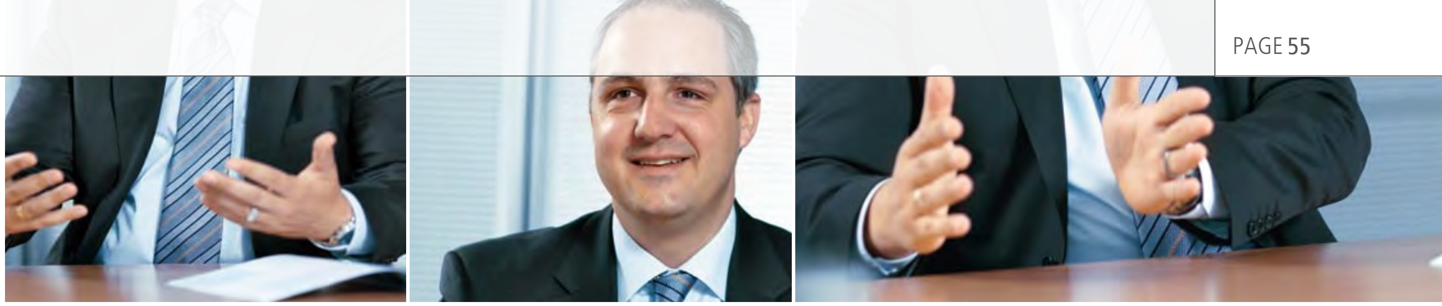
Dr. Lamberg, dSPACE has a long history in the field of test automation. Where are they today?

Since the mid 1990s, test automation is becoming an increasingly important topic because HIL simulation is being used more often throughout the field to test electronic control units (ECUs). Back then, in the 1990s, we were involved in a whole row of test automation projects together with our customers. We set up specific test environments in cooperation with our customers and implemented them. The knowledge we gained from these projects flowed into the development of AutomationDesk, which came out in 2003. A lot has happened since then. One highlight is Version 2.0 (released in 2007), which offered many features to improve test development. The feedback from our customers was absolutely positive. The versions that followed included the Debugger and an evaluation library, among other things. As a result, we can now offer a very mature product for developing and performing automated ECU tests.

Even though these success stories are remarkable enough, we continue to go further – in the direction of process integration and more openness.

How does dSPACE support process integration and openness?

To improve process integration, we offer the DOORS Connect & Sync Module, the interface between



AutomationDesk and the requirements management tool DOORS®. This keeps the test specifications in DOORS® and the corresponding test projects in AutomationDesk synchronized. One way we achieve openness is by connecting AutomationDesk to other HIL systems. We have already done this successfully for various external systems.

> Testing is an important part of the entire process. It cannot just be done on the side.

In addition, we have to see where the testing challenges lie for our customers, now and in the future. The current issues are ones such as systematic test processes, test reusability, organizing and structuring test tasks, cooperating in teams, and integrating the test tasks into the entire process.

How is dSPACE meeting these issues?
The next AutomationDesk version (due at the end of 2009) will include a standardized interface between the test automation tool and the test system, the new HIL API (see page 44), which was recently made a standard by the ASAM board. This interface makes it easier to use AutomationDesk with different test systems, even from other suppliers, and thus also provides test reusability. The result is investment protection not only for the test software, but also for training the users and for test development. In addition, AutomationDesk supports XML import and export, which allows AutomationDesk-independent storage of test projects and exchange with other tools.
However, it is very important to concentrate not only on technical features, but also on the work methods and, especially, the experience. This is where the issue of services comes into play. On the basis of the experience we have gathered in numerous projects, we can help our customers steer their processes and test projects right from the start towards working in teams and towards reusing the existing tests.

Does this mean that you don't get far with just the test software?
Exactly. Testing is a complex, expensive, and responsible task within the development process. You can't just do it on the side.
Our experience shows that the more systematic and well thought out the approach, the more efficient the test environment at the end, and the higher the reusability of tests in other test systems and test projects. Within this context, we can give our customers the best boost when they start their testing.

> The winning combination of AutomationDesk and our project experience helps our customers become productive very quickly.

What are the developments you see for the future?
On the whole, we see that more and more customers want to switch from the software they developed on their own to commercial products. They have realized that maintenance, service and continuous development cause an extreme amount of work. So they leave the task of creating test software to the tool manufacturers. In addition, there is a great deal of activities towards standardization, which, by the way, was originally initiated by dSPACE, such as the HIL API. The prerequisite is, of course, that the tool system supplier and the test system supplier also support this standard – which is most certainly the case for dSPACE.

Another standard, which dSPACE significantly helped to prepare, is currently being put into action by the ASAM board: A text exchange format that uses XML to exchange tests between different test tools, and which makes test reusability possible.

We also think that the increasing virtualization of product development brings new possibilities for the field of testing. The growing importance of models on the ECU level and system level will shift testing down to earlier development phases. We call this "virtual HIL testing". Virtual HIL testing will complement classic HIL testing. The goal is to reach an even higher level of maturity in even earlier development phases – a development in which we will play a significant role.

Thank you very much for your time, Dr. Lamberg.

Japan Meets the Challenges

The News from the dSPACE Japan User Conference 2009, held by dSPACE Japan K.K.

Ecofriendly engineering requires highly sophisticated control systems, but developing these costs a lot of man-hours and money. Plus, to be successful, a good design has to pull together a multitude of cutting-edge electronics technologies in development processes and products. Model-based development is the answer: streamlining development, improving software quality, and enhancing safety. Numerous engineering fields are using it more often – as seen in the diversity of user applications presented at the dSPACE Japan User Conference 2009.

Hosted by dSPACE Japan K.K. in Tokyo on June 19, the conference featured customers' use cases, and provided information on the latest products and advancements. These focused on model-based development and its increasing use for safety, the environment, and comfort functionalities.
In his opening address, Dr. Herbert Hanselmann, President of dSPACE, described the spread of model-based development in various fields and the increased use of dSPACE tools. Since its beginning, dSPACE has achieved impressive results in mechatronics. Recent years have seen dSPACE technology spread to railroads, aerospace, construction machinery, medical technology, and other fields. There is a palpable sense that the merits of model-based development are widely appreciated nowadays. In the customer case sessions, many customers agreed on the advantages of model-based development.

Figure 1: dSPACE Japan's President Hitoshi Arima talked about smart power grids.

Figure 2: Exhibition area: full of detailed discussions about cutting-edge dSPACE products.

Figure 3: Demo station for ASM Electric Components Model and the electric drive simulator.

Automatic Pilot for Aviation Applications

In his contribution from the aviation industry, Hideto Fujii of Mitsubishi Heavy Industries described how MicroAutoBox is being used in research on automatic formation flight. Intro-

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ducing model-based development led to the realization that control system developers can work up to the implementation stage, so software developers can concentrate on developing the aircraft dynamics simulator and expanding its functions. This efficiently utilizes human resources and considerably reduces the development time; particularly since manual work on specification documents and coding are not necessary. Recognizing the value of dSPACE's prototyping systems, Hideto Fujii mentioned the contribution of ControlDesk's powerful monitoring and online tuning functions.

> "Introducing model-based development has resulted in efficient utilization of human resources and a considerable reduction in development time."
>
> *Hideto Fujii, Mitsubishi Heavy Industries*

Magnetic Levitation Benefits from Prototyping

University research also benefits. Professor Xiaoyou Zhang of the Nippon Institute of Technology reported on how prototyping is being applied to research into technology for controlling the magnetic levitation systems used in mag-lev linear-motor trains and various other fields.

Per Bypass in the Fast Lane

Hideki Takamatsu of Toyota Motor Corporation described how dSPACE bypass systems are currently being used in automobile development. He stated that the principal requirements at the front line of development were the creation of added value and the swift introduction of products onto the market. Conventional development methods need to be rethought to meet the growing system complexity, the increase in onboard ECUs as vehicle control devices, and the expanding scale of hardware and software. One way to reform development methods is prototyping, including the bypass system. This can reduce development man-hours by between 10% and 30%. At the same time, conventional document creation is not necessary, and considerably less production reworking is needed to deal with problems detected during vehicle testing. Hideki Takamatsu said that prototyping also demonstrates vehicle performance at an early stage. It has helped achieve efficiency improvements in advanced development and has contributed to the construction of new development processes through linking with model-based development support tools.

At another customer case session for automotive industry clients, Nobuhide Kobayashi from DENSO CREATE spoke in detail about cases of constructing vehicle system development environments using AUTOSAR at each system architecture phase.

Green Success with dSPACE Products

One of dSPACE's leading product categories is test environments that allow the integration of high-end electronics technologies for hybrid and high-output motor control development. Masahiro Kaneda of Mitsubishi Motors reported on the use of the HIL simulator to develop Mitsubishi's i-MiEV electric car. With respect to electric car development, he said that because various functions are distributed across an onboard network, it is vital to ensure the quality of the total vehicle system as well as that of the ECU software. (For details, please see page 14.)

The biggest issue in Green Success is the efficient, swift development of unique and innovative products that enhance system efficiency functions while minimizing the impact on the

> "Prototyping, including the bypass system, is a means of rethinking conventional development methods, and can reduce development man-hours by between 10% and 30%."
>
> *Hideki Takamatsu, Toyota Motor Corporation*

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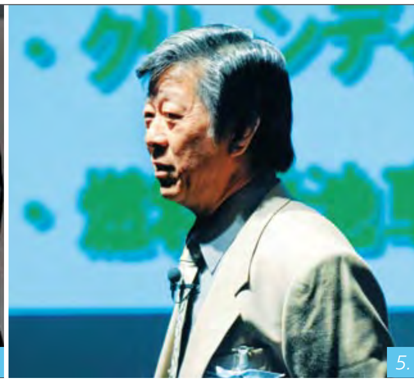
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Figure 1: Rapid prototyping use case: High-speed nanoscale servo control for an atomic force microscope from The Fujimoto Research Laboratory, Yokohama National University.

Figure 2: Dr. Herbert Hanselmann, CEO, dSPACE.

Figure 3: Mr. Hideto Fujii, Mitsubishi Heavy Industries, Ltd.

Figure 4: Mr. Hideki Takamatsu, Toyota Motor Corporation

Figure 5: Mr. Kazutoshi Mizuno, Nissan GT-R Chief Vehicle Engineer & Chief Product Specialist held the keynote speech. He pointed out, that "High performance and service engineering should advance at the same rate, otherwise it will not be possible to provide customers with the products they want."

environment. When introducing dSPACE's latest products, Mr. Hagen Haupt, dSPACE GmbH, focused on the ASM (Automotive Simulation Model) Electric Component Models, which are dedicated automotive models. Conference visitors were highly interested in the venue's electric drive display. Takashi Miyano of dSPACE Japan's Engineering Division described an electric drive development tool. He explained that the tool could develop electric motors with the same flexibility, high efficiency, and other advantages offered by conventional dSPACE products, and seamlessly integrate applications using hybrid functions or electric motors with existing HIL systems.

Energy Supply with Smart Power Grids

Smart grids were another hot topic. Because power generation systems and its infrastructure are so diverse, this field will most likely see an increase in the requirements for a whole range of applications. One factor behind this is the current growth in equipment that needs to be controlled by software. dSPACE Japan's President Hitoshi Arima mentioned dSPACE's impressive product track record already achieved in this field. Engineers use the products to perform generator or power transmission infrastructure simulations and also in related equipment, in training simulators and in simulators for generating abnormal states. In these fields, too, the quality of the software that delivers security and safety can have major social impacts. dSPACE will continue to enhance its engineering services and provide test environments for improving environmental performance. The goal for the future is to propagate the use of model-based development centered on HIL simulators, harnessing the potential that these have for improving software quality.

Thank You

This conference clearly benefited from the active support of guest speakers and partners. We would like to sincerely thank everyone who so generously cooperated, and we hope that visitors gathered much useful information and went back home with many tips on developing control systems. ■

Green Success

Ecofriendly engineering solutions were a major topic at the dSPACE Japan User Conference 2009. Even in this new field, customers rely on dSPACE's well coordinated development tools and services.

dSPACE FlexRay Systems: Support for Protocol Data Units (PDUs)

The newest version of the dSPACE FlexRay Configuration Package – your tool for integrating dSPACE

hardware into FlexRay networks – now also enables you to send and receive protocol data units (PDUs). One of the many application areas of these PDUs is within the context of AUTOSAR (AUTomotive Open System Architecture). PDUs contain various signals, which can be accessed comfortably in the Simulink® model with just one Simulink block per PDU. The data source for the dSPACE FlexRay Configuration Package consists of FIBEX files that are imported and automatically checked by the package for consistency. The dSPACE FlexRay Configuration Package makes it much easier to configure FlexRay and subsequently integrate it in Simulink. And it almost completely frees users from the burden of FlexRay's typical complexity.

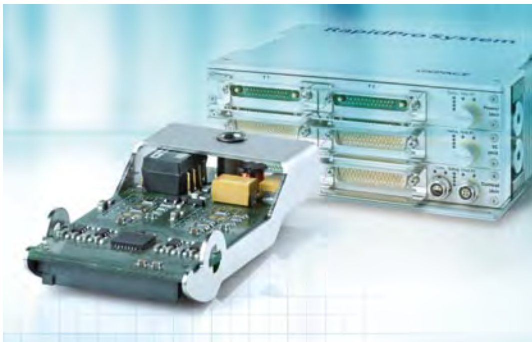
MicroAutoBox: Calculating Larger Models Faster

All MicroAutoBox variants now offer more performance, especially for the larger real-time models. This is achieved by the IBM PPC 750GL processor, which reaches noticeably faster cycle times for model calculation than previous processors because of the doubled Level2 cache (1 MB). Depending on the actual application, the model size and the model structure, it is possible to increase the computing speed by a factor of 1.6 to 2.5. In addition, the SRAM memory of all MicroAutoBox variants has been doubled in size from 8 MB to 16 MB, which makes it possible to load larger models as of Release 6.4.

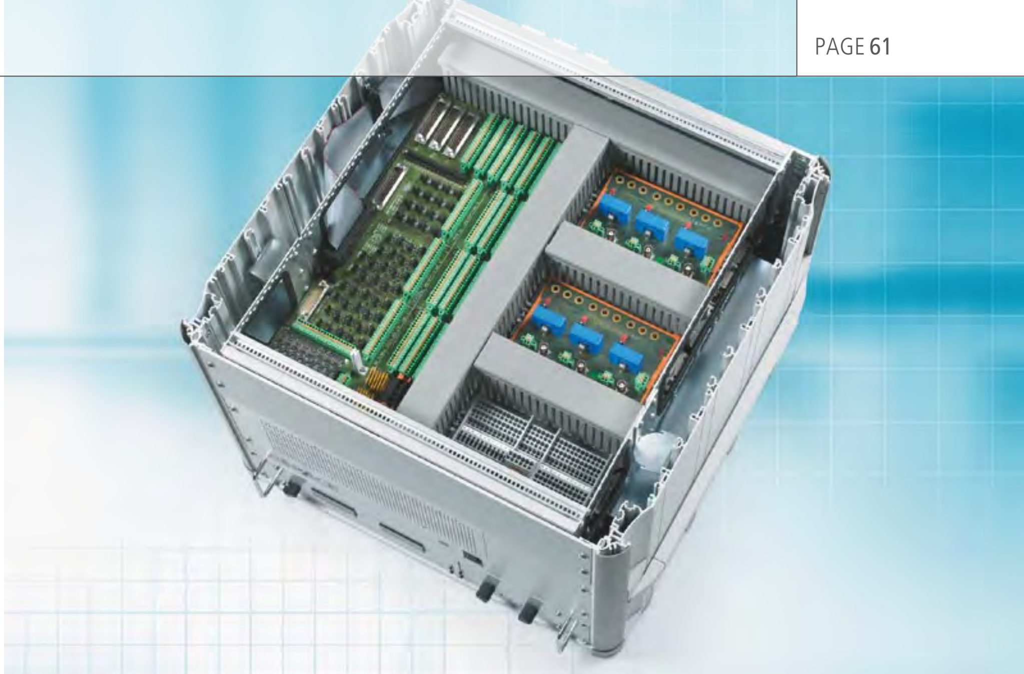
Thanks to model-, source- and object code compatibility, existing models can be reused directly, and existing executables can be loaded directly and run.

RapidPro: Integrating Bosch Lambda Probes LSU ADV

The latest version of the RapidPro DS1634 module (SC-EGOS 2/1) has the added ability to connect the new Bosch lambda probe LSU ADV to dSPACE prototyping systems, as well as Bosch lambda probes LSU 4.2 and LSU 4.9. The DS1634 provides input channels for two Bosch lambda probes and software configuration of the lambda measurement range and diagnostics functions.



HIL Simulation for Everybody



To provide an easy, uncomplicated way to start using hardware-in-the-loop simulation, dSPACE is running a special campaign offering a new simulator system: dSPACE Simulator EcoLine. The new system is available in five different packages, each tailor-made for a specific field. The attractive complete price for the hardware and software makes it an ideal ready-made system; for example, for software developers who want to test their new electronic control unit (ECU) functions directly at their desk. First-time users of HIL simulation will benefit especially from the reduced planning costs and configuration costs. More experienced users will appreciate the familiar functionality and convenient handling.

dSPACE's well-proven hardware and software is at the heart of the system. In addition to the standard software package, this includes battery simulation, a DS1006 Processor Board, a DS2211 HIL I/O Board and the DS5376 Wiring Board. Special modules are added to the central system to create the following off-the-shelf packages. ■

dSPACE Simulator EcoLine –	For Testing ...
Engine Solenoid	ECUs for engines with solenoid valves
Engine Piezo	ECUs for engines with piezo injectors
Vehicle Dynamics	vehicle dynamics ECUs
Transmission	transmission ECUs
Body Electronics	ECUs for body electronics
	www.dspace.com/EcoLine

dSPACE Release 6.4 Supports Vista 64

With the recently launched dSPACE Release 6.4, virtually all dSPACE products can run under Microsoft® Windows Vista® 64 – putting dSPACE ahead of the field when it comes to real-time development systems. With support for the 64-bit version of Windows Vista, the 4-GB memory limit of earlier 32-bit operating systems is a thing of the past. The applications and operating system no longer have to share the maximum addressable 4 GB: Each application has its own 4-GB memory area (WOW64 mode). Day-to-day development work benefits from this. For example, even large-scale Simulink® and TargetLink models can now be edited and compiled, even if other application programs are open simultaneously – so the frequency of time-consuming hard disk access is considerably reduced. ■

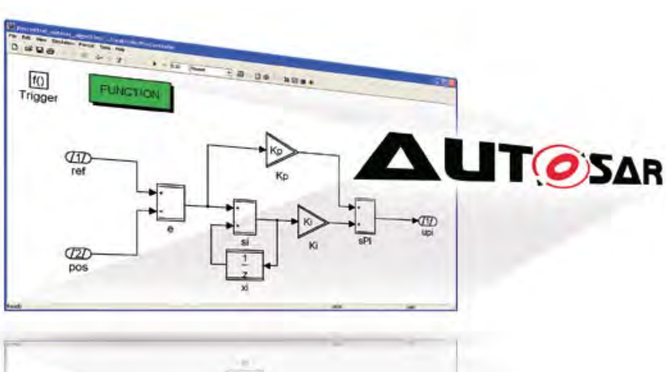
dSPACE Inc. President Kevin Kott (center) presents the dSPACE Embedded Success First Place Award to members of the Ohio State University EcoCAR team, Adalbert Wolany (left) and John Kruckenberg (right).

dSPACE Embedded Success Award: The Winners

North American University engineering students are well into the design phase of generating next-generation green vehicles as part of EcoCAR: The NeXt Challenge – a three-year collegiate competition with 17 participating student engineering teams. At the conclusion of year-one activities this past June, dSPACE, a platinum sponsor of EcoCAR, presented its own "Embedded Success Award." The award was granted to three teams demonstrating the most effective use of dSPACE hardware-in-the-loop equipment to simulate their vehicle architectures and develop their control strategies.
The first-place winner of the dSPACE Embedded Success Award was the Ohio State University. This team presented a comprehensive approach to using their dSPACE HIL system in all phases of control development, and demonstrated this with a professional HIL bench setup. Second-place honors went to the University of Waterloo. The University of Victoria was the recipient of the third-place award. For their achievements, each team received a dSPACE Automotive Simulation Model (ASM) software package. Ohio State University also took first-place in the EcoCAR year-one competition finals for its extended-range electric vehicle (E-REV) architecture, featuring a 1.8 L high-efficiency ethanol (E85) engine, coupled to a 67 kW front electric machine via a unique twin-clutch transmission design. The transmission allows the vehicle to operate in either series or parallel hybrid mode, and enables front axle regenerative braking for greater operating efficiency. EcoCAR challenges students to re-engineer a 2009 Saturn VUE to improve fuel efficiency and reduce emissions while retaining the vehicle's performance and consumer appeal. Teams are given three years, split up into one-year phases, to design and build a "green" prototype vehicle. Now that the first phase is complete, the next step for the EcoCAR teams is to turn their designs into functioning vehicle prototypes, which will be evaluated during the second year of the competition now under way. ■

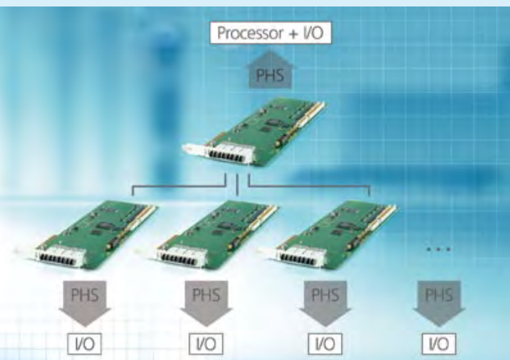
AUTOSAR Migration Made Easy with dSPACE TargetLink

The free TargetLink AUTOSAR Migration Tool lets you convert classic, non-AUTOSAR TargetLink models to AUTOSAR models at a click. Then you can generate AUTOSAR-compliant code and a component description from each converted model and import them into an architecture tool such as dSPACE SystemDesk. The tool itself can be configured flexibly to enable different types of AUTOSAR communication or requirements to be implemented in the software architecture.
The TargetLink AUTOSAR Migration Tool is the perfect assistant for easy migration of existing TargetLink models to the AUTOSAR world. The tool supports TargetLink versions 2.3.1 and 3.0.1. ■



Modular Systems Now Even More Modular

dSPACE's new DS802 PHS Link Board provides extended options for setting up modular and flexible real-time systems with a PHS bus. The link board enables developers to use I/O boards in expansion boxes that do not have their own processor boards, but utilize those in other expansion boxes instead. Up to now,



each expansion box had to have its own processor board.
With the DS802 PHS Link Board, this is no longer necessary, as all I/O boards are treated as one big master-slave system, which requires only one single dSPACE processor board in the master system. The DS802 PHS Link Board handles communication between the master system and the slave systems via optical links.
This setup is ideal for all applications that do not require the computing power of a processor board in every expansion box. Multiprocessor systems – systems with several processor boards – are only needed if high computing power or extremely short I/O access latencies are essential. ■

Jubilation on receiving the Business Presentation award: the BA Engineering and Padua team.

Number 1 in Presentation

Roaring engines, screeching tires, screaming fans: From August 5-9, Formula Student is revving up once again at the Hockenheimring. Formula Student is an engineering design competition in which international teams of students plan and build their own race car. But building a fast formula race car is not the only goal of this competition. Aspects such as design, financial planning and sales arguments also contribute to the success of the teams, which are evaluated by a jury of experts.

This year, the team that convinced the jury in the category of Business Plan Presentation was the 50-member BA-Engineering Team from Stuttgart, sponsored by dSPACE. Together with the University of Padua (Italy), they shared first place for their presentation of their marketing strategy. During the first dynamic disciplines on the race track, the team from the Duale Hochschule Stuttgart DHBW showed that their self-made "Sleek" could compete with the best.

In the Autocross competition, the team reached a time of 59.9 seconds and finished in mid-field. Overall winner of this year's Formula Student Germany competition was the team from the neighboring Universität Stuttgart. The teams are currently preparing for the upcoming competition in Italy. ■

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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 be to 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