

dSPACE

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to AUTOSAR**

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President

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dSPACE NEWS

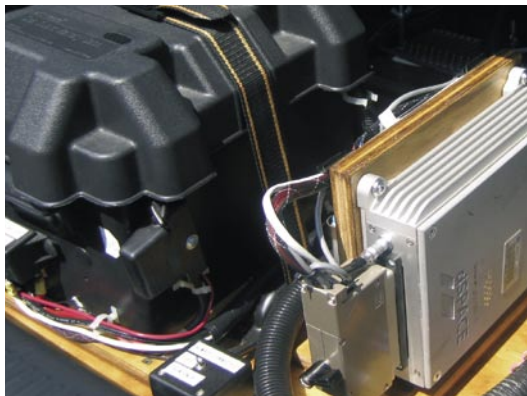
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- 4** *General Motors is employing CalDesk, the universal measurement and calibration tool, together with MicroAutoBox, for advanced transmission projects.*



- 6** *Maiden flight of "Barracuda", EADS' new unmanned aerial vehicle. 45 % of the flight control software was generated using TargetLink from dSPACE.*



TargetLink inside! Perhaps inside your car too. Our customers are frequently reluctant to reveal precise details of use cases. And the people we have contact with often don't know the take rate for a specific model with a particular feature which has been developed with TargetLink. Though our own research tells us there are well over 1 million vehicles on the road with TargetLink-implemented functions.

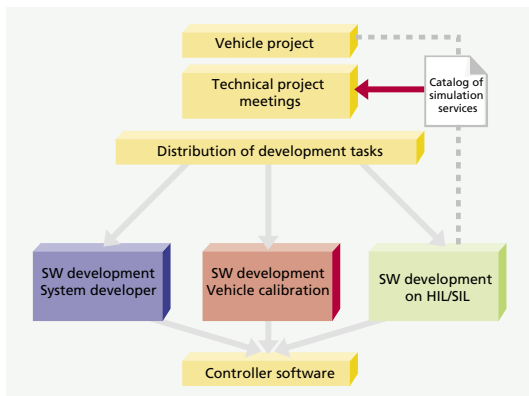
Judging by the number of licenses sold, and other information we have, there are a very large number of production projects we haven't heard about. We actually know of more than 100 – and we're still counting. Most of them have long since gone into production, some in vehicles with a high sales volume. And some very interesting applications will go into production by the end of this year. Most projects are for the powertrain, followed in equal proportions by chassis electronics, other safety and brake systems, and comfort or driver assistance applications. TargetLink frequently contributes 80-100 % of the software in an electronic control unit.

You can use a code generator in a project with the vague intention of going into production, but that's not the same as actually putting the code it generates in the final vehicle. And the code generator itself might be equipped for production use in theory, but does it actually fulfill the countless requirements of

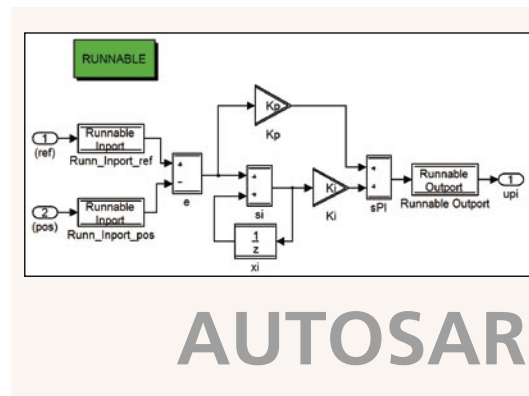
software specialists and existing constraints? These can vary from OEM to OEM and from supplier to supplier. A lot of development work has gone into getting the details of TargetLink right, and giving it sufficient off-the-shelf adaptability – plus vital support functions, such as the dSPACE Data Dictionary. This avoids the costs, and above all the risks, of customize code generators – or ones developed by customers themselves. Quality assurance and long-term maintenance for code generators like that are time bombs. The workload is too great for one customer alone. Moreover, customer-specific developments often depend on just a few people, and the documentation leaves a lot to be desired. There is no economy of scale. With safety-relevant functions especially, stakeholders face such stiff requirements that a professionally maintained code generator is the only sensible option, allowing the enormous cost of maintenance and quality assurance to be shared by many users.

TargetLink has proven itself a match for real-world challenges. As shown by the fact that suppliers now have more licenses than OEMs. It's sometimes said that OEMs don't generate code under really tough conditions, the suppliers do that for them. In our experience that is not always true, though as often as not, suppliers have been the more critical customers.

*Dr. Herbert Hanselmann
President*



16 AUDI AG has developed a process for vehicle dynamics development in which hardware-in-the-loop and software-in-the-loop simulation is an integrated part of every project.



20 TargetLink 2.2 generates code for AUTOSAR software components as an application-specific part of the AUTOSAR software architecture.

XCP on CAN and CalDesk at General Motors

- Access to the ECU installed in the new six-speed transmission
- Measurement, calibration, and bypassing with the same tool
- XCP on CAN and CCP running parallel on the same CAN channel

▼ Synchronous bypassing for time-critical parameters. The wait mechanism in dSPACE XCP on CAN allows synchronous data exchange between ECU and RCP system.

General Motors is employing XCP on CAN for software development and CalDesk, the universal measurement and calibration tool, to parameterize the electronic control unit (ECU) for advanced transmission projects. The dSPACE XCP Service provides dedicated features for bypassing functions in fast ECU rasters, and CalDesk gives the company an integrated environment for measurement, calibration, and bypass applications. Using CalDesk has numerous advantages compared to working with a combination of different tools: For example, measurements on ECUs and prototyping platforms can be run according to a common time base, with simultaneous parameter adjustments.

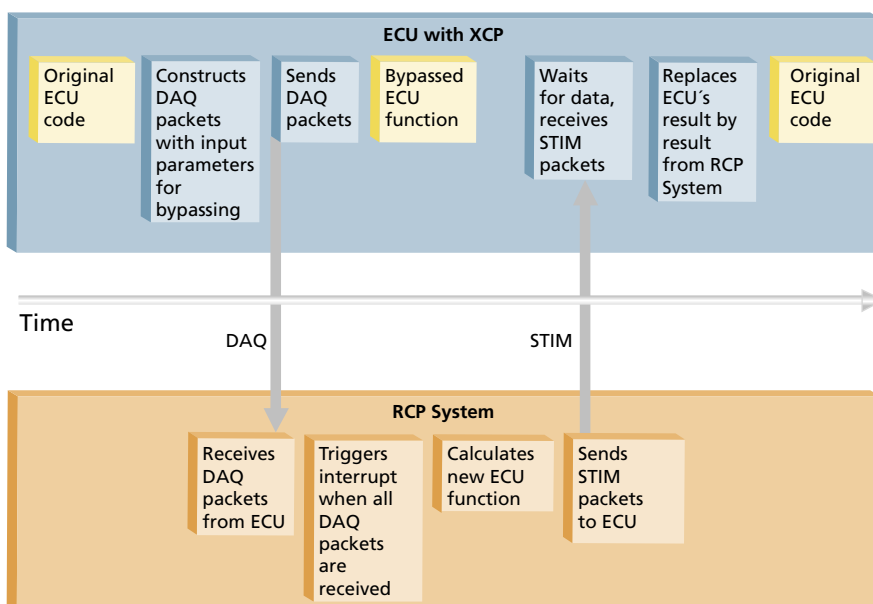
Accessing ECUs in the Transmission

ECUs in the transmission area are becoming more compact, and increasingly being installed in inaccessible places. This makes it all but impossible to connect additional interface hardware in or on the ECU for software development purposes as is the case with General Motors' new six-speed transmission, where the ECU is located inside the actual transmission. General Motors Advanced Transmission Group is using CCP for calibration and measurement, while bypass communication between the ECU and the prototyping hardware (MicroAutoBox in this case) is established

via XCP on CAN. The dSPACE XCP on CAN Service runs in parallel to CCP on the same CAN channel, without the two affecting each other. The CCP implementation was already available in the development ECU software, and is being used for measurement and calibration tasks. The XCP on CAN Service and the necessary bypass hooks (service calls) were integrated into the ECU code. Unlike CCP, the dSPACE XCP Service provides special mechanisms for function bypassing, such as task-synchronous writing of variables, ensuring data consistency, and several error detection options for bypass communication. The dSPACE XCP Service is designed for a wide range of applications, from measurement and calibration to bypassing and right through to ECU flash programming.

CalDesk – Bringing Together ECU Calibration and Rapid Control Prototyping

Employing an integrated experiment environment featuring calibration and measurement access to both the ECU and the dSPACE prototyping hardware was a crucial requirement for GM in this project. CalDesk has been chosen for this. CalDesk allows vehicle ECUs and their buses, and rapid control prototyping platforms, to be accessed simultaneously. It is capable of handling any number of devices in a single experiment. Thus, CalDesk



users have an integrated environment for performing function prototyping, calibration, measurement, data analysis and even ECU flash programming tasks in a single tool.

The Advantages of CalDesk

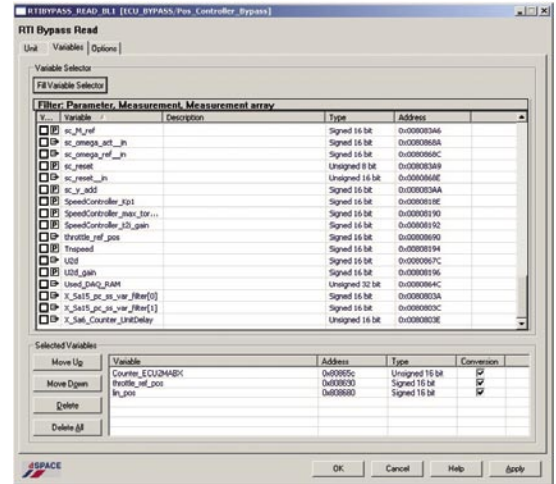
Using CalDesk has a lot of advantages:

- A single tool for various use cases
- Common time base for variable measurement on ECUs and dSPACE prototyping systems
- Simultaneous parameter adjustment on ECUs and dSPACE prototyping systems in the same step (proposed calibration)
- The same automation interface used for access to ECUs and dSPACE prototyping systems

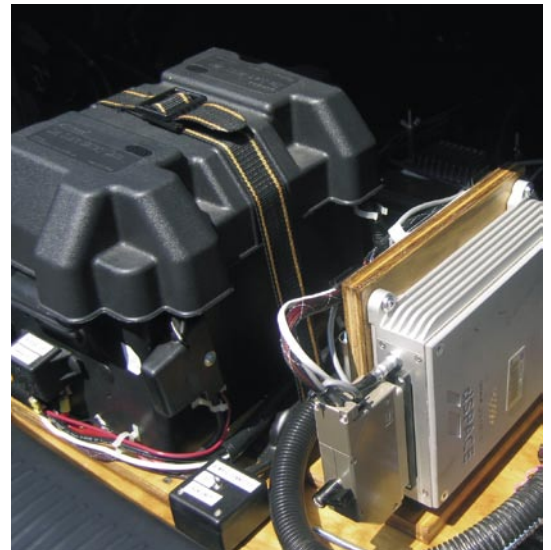
Bypass Implementation on the Transmission Control Module

Many new algorithms for the transmission control module are being developed by means of the external bypass approach in connection with dSPACE prototyping systems. Depending on the type of data to be exchanged via XCP on CAN, different implementation methods are used. Where input and output data do not require consistency in terms of the associated ECU task cycle, the respective model inputs are received via CAN on the RCP system, and the bypass model is calculated in a timer task. Typically, the RCP system responds in the same ECU task cycle; however, this behavior is not guaranteed. Time-critical data is handled differently: An interrupt is triggered on the prototyping system when the respective model inputs are received. A dedicated mechanism of the dSPACE XCP Service is used to ensure data consistency. This mechanism allows a time interval to be defined for the ECU to wait for new data sent by the

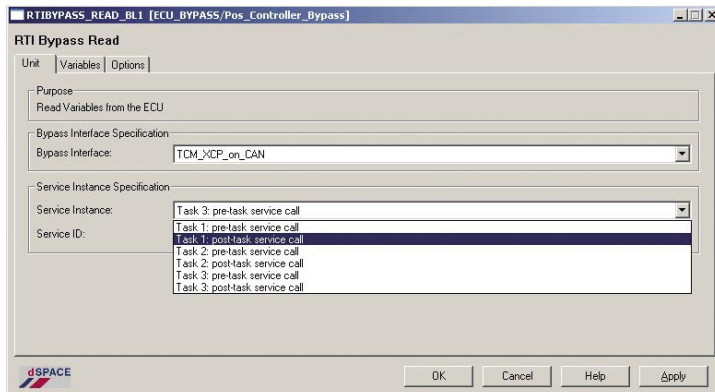
RCP system. Thus, model outputs are always guaranteed to be available without ECU task cycle delay. In addition, provisions are in place to ensure that the ECU does not overrun and that all data is retrieved. The transmission control module provides multiple tasks with different priorities and activation rates. Two bypass hooks have been implemented in each of the first three ECU tasks, of which the fastest ECU task features an activation rate of less than 7 ms. The first bypass hook, called “pre-task”, serves for capturing bypass model inputs using the XCP DAQ mechanism at the beginning of the ECU task. The second service call, “post-task”, allows bypass model outputs to be written to the ECU synchronously by means of the XCP data stimulation method. All bypass hooks are described in the associated ASAP2 file, so that the user does not have to worry about implementation details. Using the RTI Bypass Blockset in the modeling environment, he or she can simply select the name of the service call from a list and associate it with the variables to be read from or written to the ECU.



▲ The ECU variables can be selected via the variable browser of the RTI Bypass Blockset.



▲ Prototyping hardware: MicroAutoBox installed in the trunk.



▲ Service calls selected via the RTI Bypass Blockset, in this case the “post-task” service call for writing bypass model outputs to the ECU.

Keith
Lang
General Motors Powertrain
Advanced Power
Transfer Group
USA

Barracuda's Maiden Flight

➤ EADS develops Barracuda, the unmanned UAV demonstrator

➤ Automated production code generation with TargetLink

➤ 45% of flight control software generated using TargetLink

Barracuda, the unmanned aircraft designed by EADS Military Air Systems as a demonstrator and development platform for future unmanned aerial vehicles (UAVs), undertook its maiden flight in San Javier, Spain, on April 2, 2006. Its on-board flight control computer has several subsystems, including the autopilot system, whose code was generated using TargetLink. This UAV demonstrator has enabled EADS to make a quantum leap to the future market of unmanned aircraft, hitherto dominated by the USA.

Why Unmanned Aircraft?

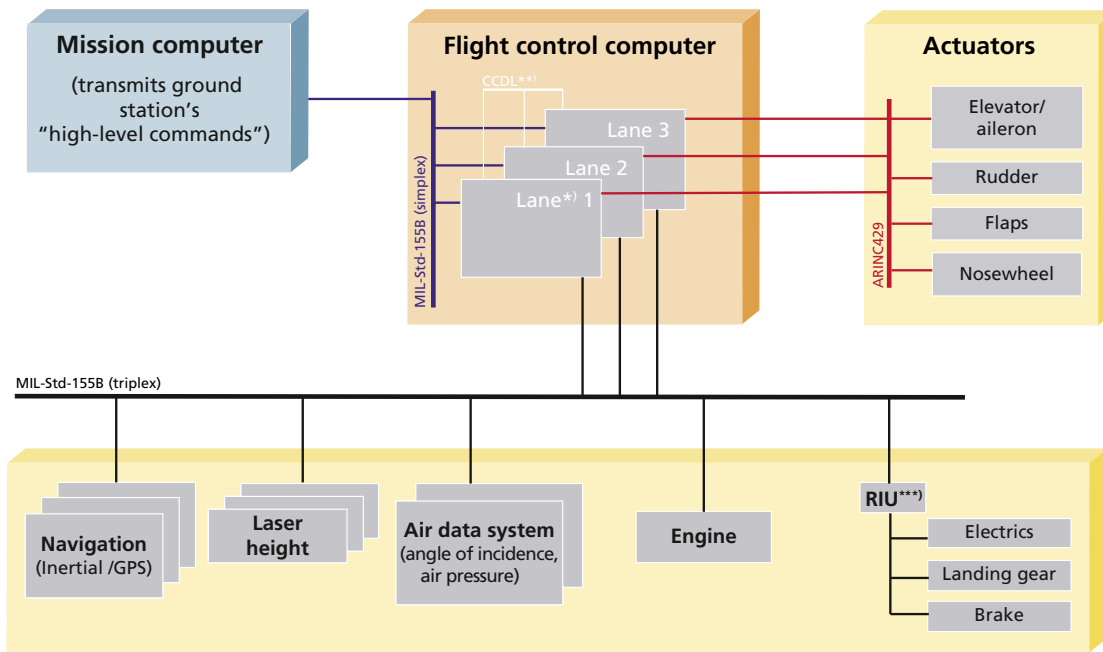
Because they fly autonomously, UAVs have unbeatable advantages over manned aircraft: they save pilots from engaging in risky missions and can undertake extreme flight maneuvers with accelerations which would be too stressful for human pilots. UAVs are also extremely well suited to long and monotonous use, as unlike a human crew they never tire. Due to the high degree of automation, pilot training is unnecessary – simply software updates are all that is needed. UAVs also need no life support systems such as oxygen supply and pressurized cabin. Deployment options for UAVs are mainly in monitoring and reconnaissance, and they can also be inexpensive substitutes for satellites, for example, as transmission stations or for map creation.

Barracuda – The Electric Aircraft

The Barracuda does honor to its namesake, a predatory fish that swims with the swiftness of an arrow, consisting as it does of carbon-fiber compound and containing numerous technical refinements that TargetLink helped to develop. Apart from the landing gear and nose-wheel steering, the aircraft is completely electrical, and unlike conventional aircraft, it has electromechanical actuators instead of hydraulic. The triplex redundant flight control computer (FCC) makes the Barracuda extremely reliable. The modular avionics concept of the UAV demonstrator allows a wide variety of systems to be integrated, such as radar, electro-optical or infrared sensors, laser target markers, and detectors for radio-magnetic emitters, to mention just a few. This open and modular avionics system makes it the ideal development platform for future UAVs.

► Barracuda, fully autonomous in flight (length 8.25 m, wingspan 7.22 m, take-off weight approx. 3 tones), serves as a development platform for unmanned aircraft of the next generation.





◀ Schematic overview of the interaction between the triplex redundant flight control computer and the other systems in Barracuda.

*) Redundant channel; **) Cross channel data link; ***) Remote interface unit

TargetLink for All Algorithms

When designing the software for the flight control computer of the Barracuda, we utilized Simulink® and Stateflow® for developing the model in addition to TargetLink for code generation for the following elements:

- Flight control
- Autopilot
- Flight management
- Air data calculation
- Navigation
- Signal consolidation in the triplex redundant system. The essential signals and state variables are compared with each other and equalized at a frequency of 50 Hz.

More Stringend Than Required

Overall, we generated about 45% of the FCC source code automatically using TargetLink. The hallmark of

“TargetLink was exactly the right tool for implementing the short development cycles needed for the highly dynamic project for our UAV demonstrator Barracuda.”

Dr. Achim Schönhoff,
EADS Military Air Systems

our process is that the system is designed in Simulink and Stateflow and subsequently the updated models

are imported to TargetLink by using a comprehensive script environment. At the start of the project, we often converted new models into code on a daily basis, and after that less frequently. The object code underwent 1-2 days of continuous testing, with subsequent system tests requiring 2-3 days. The EADS philosophy during the entire course of development was to be even more meticulous than would have been required for a maiden flight in closed airspace over a closed zone of the open sea. This means that although we used Level D of certification standard RTCA DO-178B for software verification, software design and coding were performed in accordance with DO-178B Level A (the maximum aerospace standard for software certification). This way, we keep our options open for further certification that would enable us to make trial flights with Barracuda at Manching airport.

Pioneering Work for Intelligent UAVs

The Barracuda will help us to perform important pioneering work on the next generation of UAVs. Typical future scenarios for UAVs include combining them with other aircraft or even enabling them to switch from monitoring to reconnaissance automatically.

Dr. Achim Schönhoff,
Kai Harth
EADS Deutschland GmbH
Military Air Systems
Germany

Track Tests in Laboratory

- **Coupling of MTS test rig and dSPACE Simulator**
- **Real and simulated components in the loop**
- **ASM replaces nonexistent components and environment**

A new proof-of-concept test bench for developing and validating mechatronic chassis systems was presented at Automotive Testing Expo Europe 2006 by MTS Systems Corporation. The Mechatronic Development and Validation (MDV) test bench – jointly developed by MTS and dSPACE – consists of a mechanical rig for testing semi-active suspensions and a dSPACE Simulator for real-time vehicle dynamics simulation. This combination of a real test rig and real-time simulation shifts test tasks from the track to the laboratory. Beside track test savings it provides new test capabilities in early development phases.

Demo System at Automotive Testing Expo Europe 2006

The proof-of-concept system presented at Automotive Testing Expo Europe 2006 is an integration of an MTS hydromechanical rig with a dSPACE Simulator. It demonstrates how the two test systems can be synchronized in real time and how a large amount of real-time data can be managed and exchanged. The test bench simulates rough road inputs on the tire side of a suspension and force inputs on the body side. It consists of one quarter of a suspension with a variable rate damper, its ECU, a hydromechanical MTS test rig,

an MTS rig controller, and a dSPACE Simulator Full-Size.

The MTS test rig contains the suspension's road and body actuator (in the demo z-axis only), both controlled in real time by the MTS rig controller.

The damper is actively controlled by the original ECU. The three nonexistent corners of the vehicle are simulated.

Their ECU ports are connected to

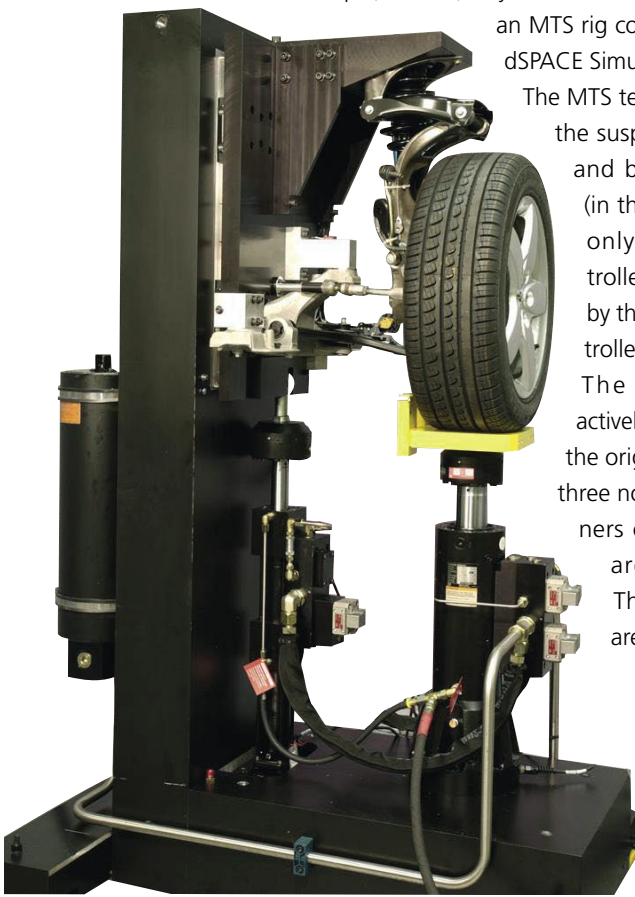
the I/O of the simulator, and the corresponding wheel positions are calculated by the ASM vehicle dynamics model (ASM = Automotive Simulation Models). All signals simulated and generated in the vehicle dynamics model are available to the I/O of the simulator. The ECU receives inputs from the real suspension and the model through the simulator. In contrast to closed simulation models, ASM's open and modular model structure enables real parts and simulated parts to be combined in this way.

dSPACE Simulator and ASM also provide the environment (road, driver, maneuvers), which is communicated to the MTS rig controller in real time at 2048 Hz via two SCRAMNet+ connections. Using the powerful DS1006 Processor Board for model and I/O processing guarantees the low latencies which are essential for real-time communication.

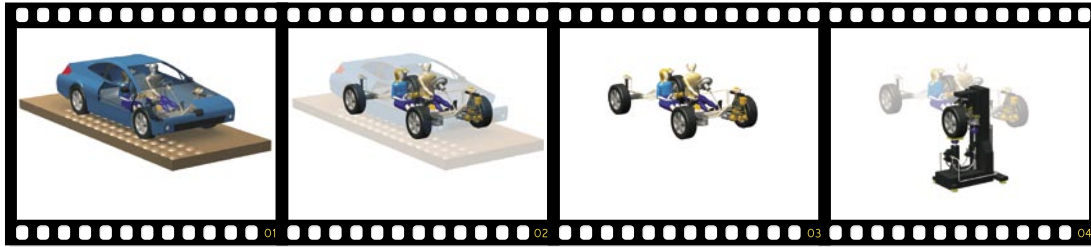
The main components of the dSPACE Simulator Full-Size are the DS1006 Processor Board, a DS2211 HIL I/O Board, and a SCRAMNet+ Interface. The host tools are AutomationDesk for test automation, ControlDesk for instrumentation, MotionDesk for animation, and ModelDesk for model parameterization.

Benefits of MDV Test Benches

Early test studies can be done with an MDV test bench, if test tracks are too expensive and pure HIL simulation is not sufficient or not applicable. MDV test benches are an efficient alternative to track and road testing, performing repeatable, highly accurate



◀ Demo test bench at Automotive Testing Expo Europe 2006 in Stuttgart (Germany).



▲ From the track to the laboratory with test rigs that physically simulate the road.

simulations for improved vehicle performance and safety characteristics.

The combination of real-time simulation and real test rigs allows closed-loop operation with real ECUs. MDV test benches can be used for failure simulations and safety-critical tests that cannot be done on a test track. MDV test benches can be used throughout the development and validation phases of a vehicle product development cycle to support system identification, algorithm development, and calibration. Using dSPACE Automotive Simulation Models in the loop with real components makes mechanical testing more realistic. The mathematical models which make the tested component operate under realistic conditions can be modified easily, so compared to track testing, more can be tested in less time. By relying less on the proving ground and more on the test lab, especially for validation and calibration tasks, mechatronic system engineers will achieve the time and cost savings necessary to support a greater volume and variety of mechatronics-related test scenarios.

Application Examples

MDV benches can be used for virtually any active chassis or drivetrain system, allowing original equipment manufacturers (OEMs) and suppliers to develop and validate mechatronic ground vehicle systems in a lab setting more efficiently. In many cases, MDV bench functionality can be added to an existing physical test bench. Two areas where this can be done are drivetrain and suspension test systems:

Dynamometer-based (measuring torque and rotational speed) drivetrain test systems for transmissions and all-wheel drives are two types of benches to which MDV functionality from dSPACE and MTS can be added. In these applications, the test bench simulates realistic loads and tractions on the drivetrain components, with the relevant electronics in the loop.

Suspension test systems, such as seven posters and kinematics and compliance systems, can likewise be

developed or upgraded to include MDV functionality. In these applications, the model represents portions of the vehicle and the environment that are not present in the lab to reproduce driving events for the purpose of algorithm development, validation, or evaluation.

Further information on the MDV test systems can be obtained from MTS at info@mts.com



▲ The mechatronics development and validation concepts demonstrated with the proof of concept apply to other MTS test benches, such as the Dynamic K&C.

In both cases, the goal is to increase development and validation productivity and prepare the system for more focused track and road evaluation.

Dan Barsness
Market Development Manager
MTS Systems Corporation, USA

Verifying Air Spring Systems

- Realistic software verification of a chassis control on the HIL simulator
- ASM Vehicle Dynamics Model extended by Conti air spring model
- High performance in load and verifications tests

Chassis engineers are starting to resolve the conflict between comfort and driving stability in medium-class and luxury cars, even in extreme situations. The main challenges facing them as they strive to meet present-day standards are to engineer the suspension strut, and to design software-supported systems for air spring and damper control. To optimize the development times for production-level software, Continental AG is using hardware-in-the-loop (HIL) simulators and the ASM Vehicle Dynamics Simulation Package from dSPACE.

Comfort and Safety

The Competence Center Chassis Control in Continental's Chassis & Powertrain business unit designs and implements algorithms for controlling the vertical dynamics in vehicles. Working closely with customers, the company uses its years of experience in the devel-

- Increasing drive stability by targeted damping in cornering, starting up, and braking
- Increasing damping forces by means of ESP and ABS

Hardware-in-the-Loop Simulation of an Air Spring System

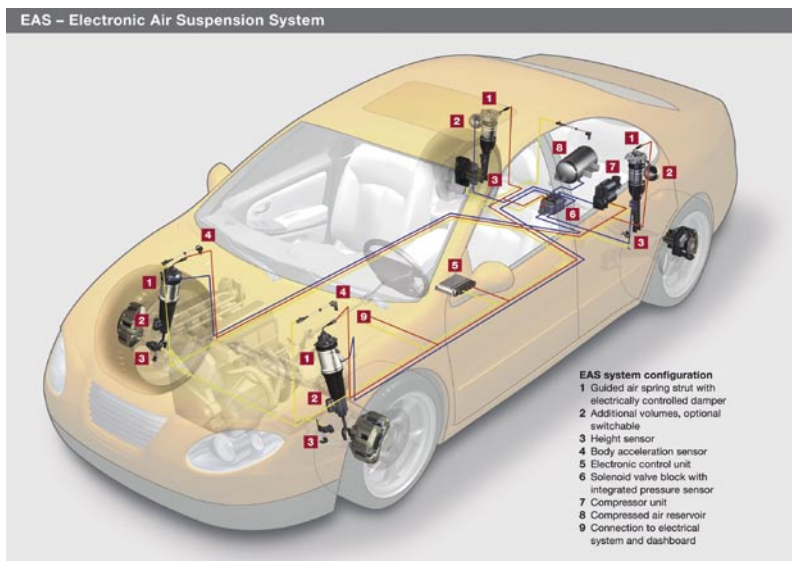
When a software module has been implemented or modified, the developer usually performs initial verification in a laboratory vehicle, to collect test results on local function behavior. Because of the complexity of the closed chassis control loop, system integration can only be tested completely by means of a modern simulator.

Flexible HIL System

A hardware-in-the-loop simulator from dSPACE was installed in the year 2000, with the ability to simulate a complete vehicle including four wheel suspension systems (4-corner HIL). As part of further development

"Close contact with dSPACE in the update phase of the HIL test bench meant the test system could go back online quickly and efficiently."
Andreas Rieckmann

Photo: Continental AG



▲ The air suspension system with a closed-loop air supply combines comfort and safety.

opment of software components for controlling air spring systems and electronically controlled dampers to produce modules covering tasks such as these:

- Level control system for customer-specific level requirements
- Automatic load leveling
- Speed-related level control
- Reducing car body movement by a skyhook control strategy

of the chassis algorithms, and particularly because of increasing integration of a closed air supply (CAS), the HIL system was updated in close cooperation with dSPACE. The modular concept of a dSPACE HIL system allows existing hardware to continue in use for CAS after a few modifications.

Open Simulation Models

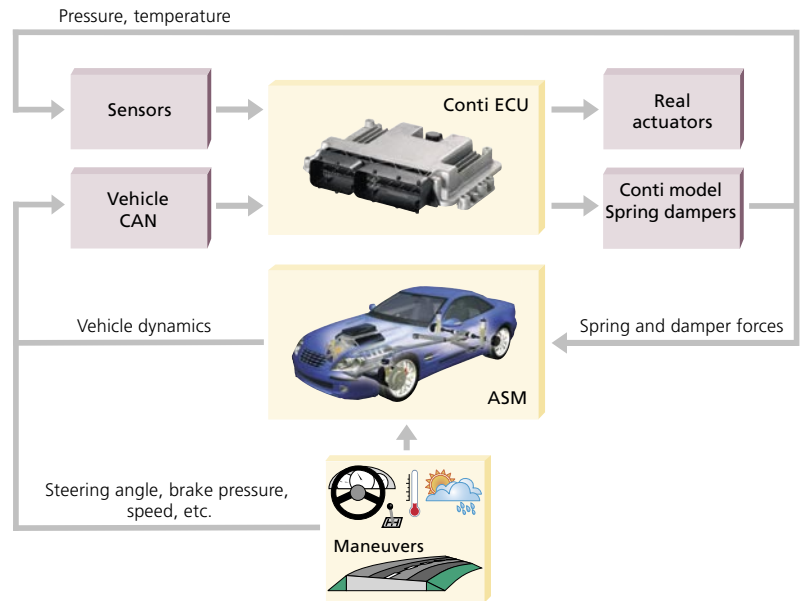
The really decisive advance that came with the HIL update was in the simulation software. In the original HIL system, the actual vehicle model was encapsulated, so the user could only modify it by suitable parameterization. In contrast, the new software contains an open real-time simulation model from the Automotive Simulation Models (ASM). It was therefore easy to inte-

“By integrating our own models in the Vehicle Dynamics Simulation Package, the simulation environment was adapted to our requirements for a closed control loop.”
Andreas Rieckmann

grate the self-developed Conti models for the CAS, the air springs, and the adjustable dampers into the ASM vehicle model. With the intuitive parameterization software, ModelDesk, maneuvers and road models can now be created to fit very diverse test requirements.

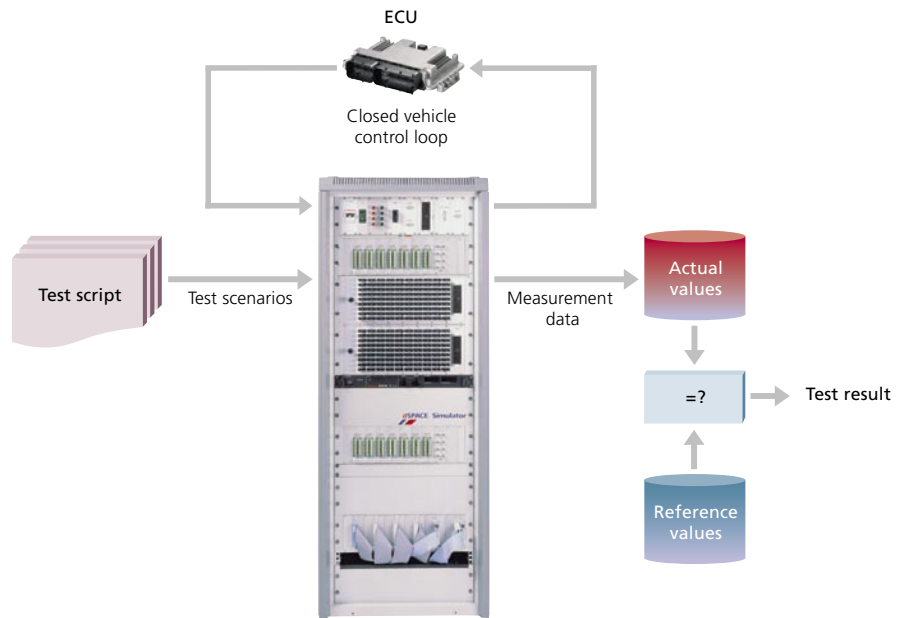
High Simulator Performance for Specific Test Strategies

The HIL simulator performs two essential tasks in software verification. The first is to subject a software update to nonstop operation, in which the production ECU (Electronic Control Unit) runs through a defined test cycle for several days, before handover to the customer. The test cycle can generate special, recurrent load cases for the air spring and damper control via Python script programming. This methods simulates real-world load cases for the ECU and the software. The other task, also script-controlled, is to verify individual function modules. The expected controller output values are compared with the actual controller output values using a suitable test profile. In implementing



▲ Hardware-in-the-loop simulation of an air spring system.

▼ Script-controlled test sequence.



Glossary

CAS – Closed air supply; highly compressed air is pumped back and forth between a reservoir and the air springs as required.

4-corner HIL – HIL system for fully load-bearing level controls and dampers, effective on all 4 wheels.

Skyhook – Strategy for keeping the car body as steady as possible regardless of road surface conditions, as if the vehicle was hooked up in the sky.

this, we focused particularly on test automation, the main aim being to reduce the number of test loops in software verification so that the overall development time for creating a production-level ECU is shorter.

*Andreas Rieckmann
 BU Chassis Powertrain
 CC Chassis Control (CC CC)
 Continental AG, Germany*

Active Seat Suspension

Team project within DaimlerChrysler AG

Active suppression of vibration in commercial vehicles

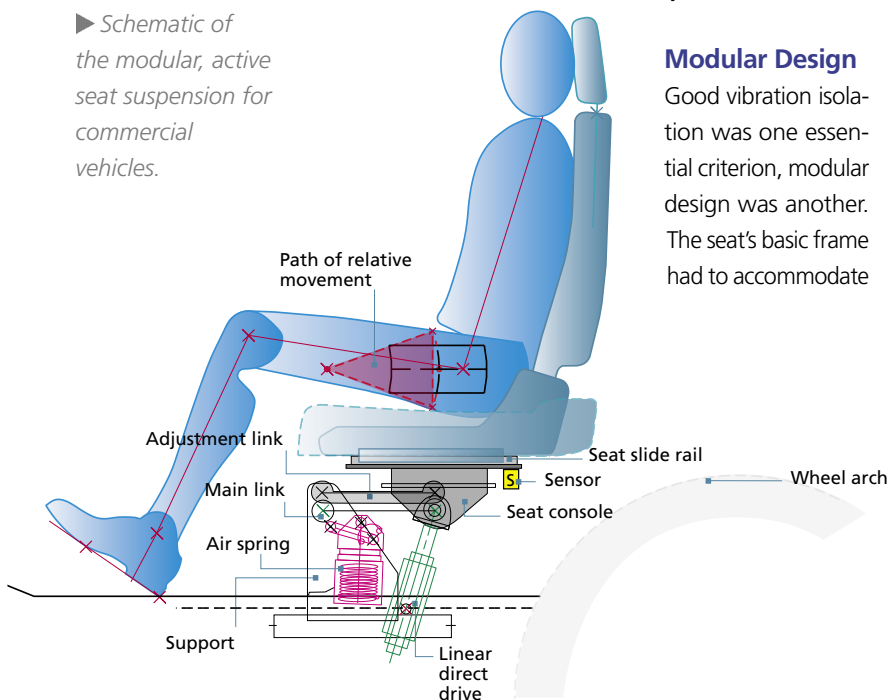
dSPACE prototyping system speeds up controller development

A joint project between DaimlerChrysler Research and Technology and the company's advanced engineering truck group developed a mechatronic truck seat system. The system aims to reduce the annoying vibration that truck drivers are subjected to while driving. A dSPACE prototyping system based on a DS1005 PPC Board provided fast results for developing and verifying a prototype of the controller. And since the seat system is modular in design, the basic seat model can be reused in multiple ways, which cuts down on the number of different parts.

Mechatronic Concept

Truck drivers' performance and condition behind the wheel greatly depend on their being in good physical and mental shape. The seat they sit on has a lot to do with this. Conventional, passive seat suspension systems for commercial vehicles use springs and dampers to isolate vibration. Since there is virtually no more room for improvement in these, the team developed an active seat suspension for commercial vehicles that uses actuators in addition to the spring-damper elements. Passive support of the seat is provided by an air spring integrated into the seat frame. The air spring compensates for vibration and is also used for seat height adjustment. This is supplemented by a compact electrical linear direct drive for active vibration isolation, which acts as an actuator and is supplied by the vehicle's electrical system.

Schematic of the modular, active seat suspension for commercial vehicles.



Modular Design

Good vibration isolation was one essential criterion, modular design was another. The seat's basic frame had to accommodate



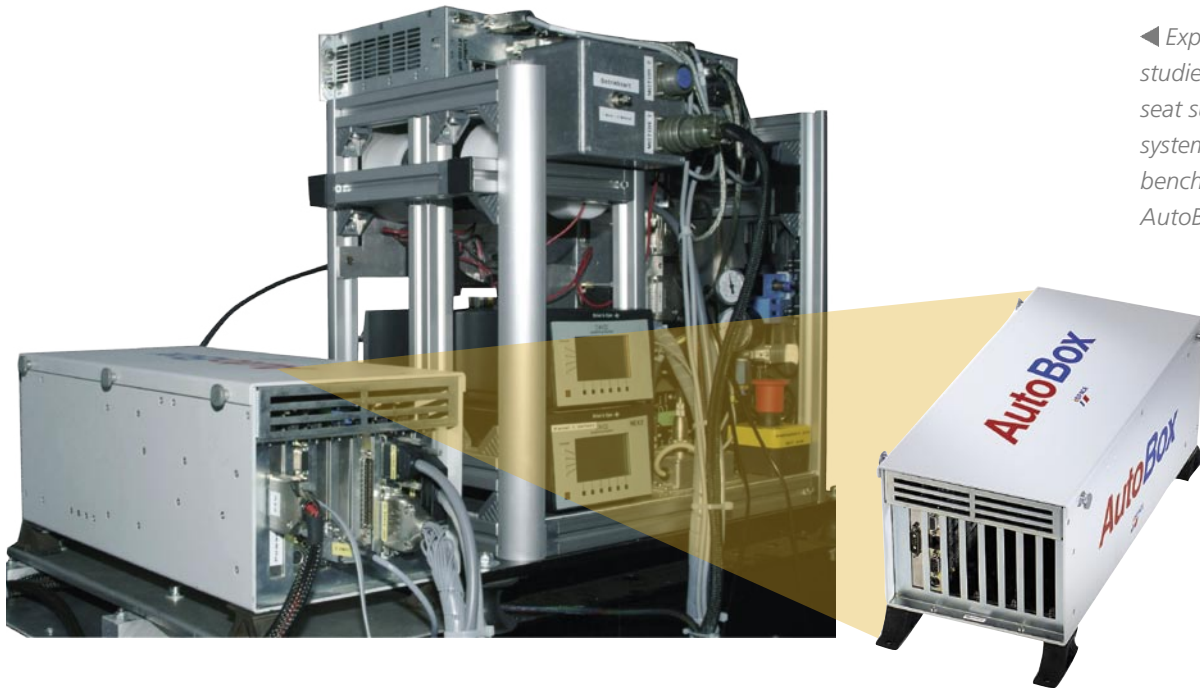
The prototype of the active seat suspension, integrated into a driver's cab.

two seat suspension systems: the conventional passive one and the new active one. The modular seat system also had to be installed in various truck series with different floor structures and wheel arches.

Model-Based Control Design

The seat control considerably improves the vibration isolation compared with passive seat suspension systems. It was designed completely on a model basis. The control was optimized with reference to essential requirements such as minimizing the vibration stress for the seated person, while keeping the relative motion between

◀ Experimental studies of the active seat suspension system on the test bench with dSPACE AutoBox.



the seat and the cab floor within reasonable bounds. The control requires only the acceleration and the relative seat motion as measurement data, and proved to

“The dSPACE system enabled us to implement various controller concepts quickly and simply. We used ControlDesk to fine-tune the controller parameters and to capture relevant variables during operation.”
Simon Kern

be extremely robust in handling vehicle occupants of different weights and in varying sitting positions. An acceleration sensor provides information on the status of seat motion.

Fast Results with dSPACE

The controller structure was designed graphically using MATLAB®/Simulink® and first simulated offline using the model of the controlled system. Next the controller structure was replaced by dSPACE hardware. The DS1005 PPC Board supplied the computing power for our real-time system and was also the interface to the I/O board. The DS2201 Multi-I/O Board measured the required input and output signals, and provided the output value for the actuator signal. Finally, relative motion given by the electrical actuator was captured via the DS3002 Incremental Encoder Interface Board.

Validating the Controller Design in Tests

To initially test for compliance with the design specifications without using a real vehicle environment, the design results were validated online on DaimlerChrysler’s vibration comfort test bench in Sindelfingen, which included a real driver’s seat, sensors, and actuators. Measurements made on the test bench and in later test drives proved that the active seat suspension considerably reduces physical stress for the truck driver. However, the improved vibration isolation also results in greater relative motion between the seat and the cab floor. This takes some getting used to and as a first impression impairs the subjective comfort level.

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Germany*

More Torque, Less Fuel

➤ **FEV Motorentechnik:
Operating strategy
for hybrid drive**

➤ **Electric boost**

➤ **Verified by dSPACE
Simulator**

A combination of a turbocharged engine and an electric motor delivers the same power as a larger naturally aspirated engine, but consumes less fuel and cuts toxic emissions. A project running at FEV Motorentechnik aims to optimize the operating strategy for these “downsized engines”. They consume considerably less fuel, yet have excellent acceleration behavior. FEV is using a hardware-in-the-loop (HIL) simulator from dSPACE to validate the engine control.

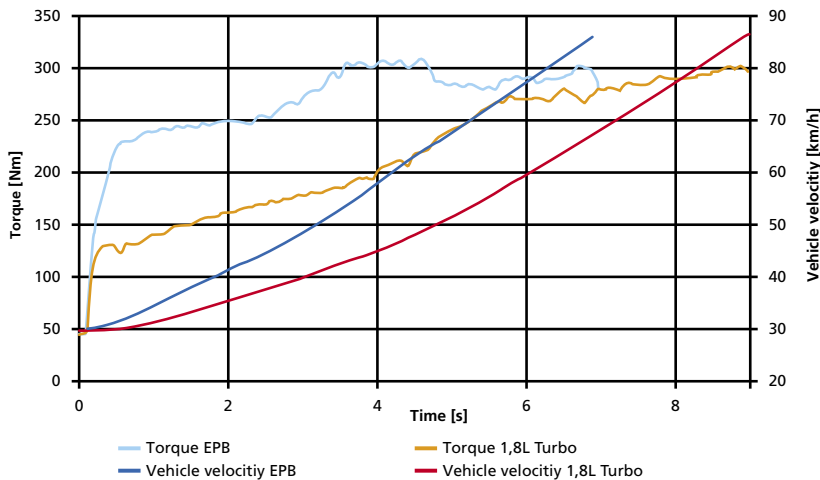
At low engine speeds, turbocharged engines have lower torque than naturally aspirated engines of equal power. Combining the turbocharged engine with an electric motor considerably improves dynamic torque behavior. The electric motor delivers high torque at low engine speeds, so it can ideally compensate for

Downsizing

Downsizing involved replacing the original engine, a 3.0-liter naturally aspirated engine, by a 1.8-liter

“The hardware-in-the-loop set-up enables us to save both time and costs in optimizing the algorithms.”

**Marco Jentges, FEV Motorentechnik GmbH,
Aachen**



▲ *Full-load acceleration from 30 km/h to 80 km/h in third gear. Electric Power Boost (EPB) compared with a 1.8-liter turbocharged engine.*

the turbocharged engine’s torque shortfall. However, the addition of an electric motor must not be allowed to affect the vehicle’s total weight or the overall space requirement of the engine. The electric motor is therefore combined with a turbocharged engine that has a smaller engine displacement, to form what is called a downsized engine. At FEV Motorentechnik, we developed various operating strategies for controlling downsized engines and validated them with an HIL simulator from dSPACE. Our goal is to optimize both motor and engine control to harness the fuel-saving potential, while at the same time improving road performance.

turbocharged engine, to which we added an electric motor. The Electric Power Boost (EPB) vehicle from FEV Motorentechnik delivers the power of the original vehicle, which has a larger engine, but emits a smaller volume of pollutants and consumes less fuel. The electric power is used for boosting torque during start-up and acceleration. Because additional energy for the electric motor is required only in short bursts, the power supplied by double-layer condensers (super caps) is sufficient. In conventional vehicles, the way the engine operates is largely decided by the driver. In contrast, hybrid powertrains make great use of the stored algorithms. It is particularly important for the vehicle to have optimum road behavior.

Operating Strategy

The hybrid control distributes the driver’s desired torque to the drive aggregates. The control can be optimized according to major concerns such as energy consumption and acceleration behavior. Concerns such as these are expressed in the following objectives:

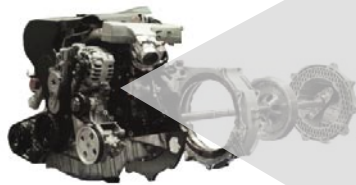
- To ensure drivability
- To minimize fuel consumption

- To minimize toxic emissions
- To ensure the durability of engine/ motor components
- To minimize noise levels

These objectives are to some extent mutually exclusive, so that they need to be weighted and evaluated. For example, running the electric motor over a long period initially allows pollutant-free driving, but depletes the stored electric energy in the medium term. Thus, reducing pollutants and fuel consumption cannot be the sole focus of the control strategy.

HIL Simulation

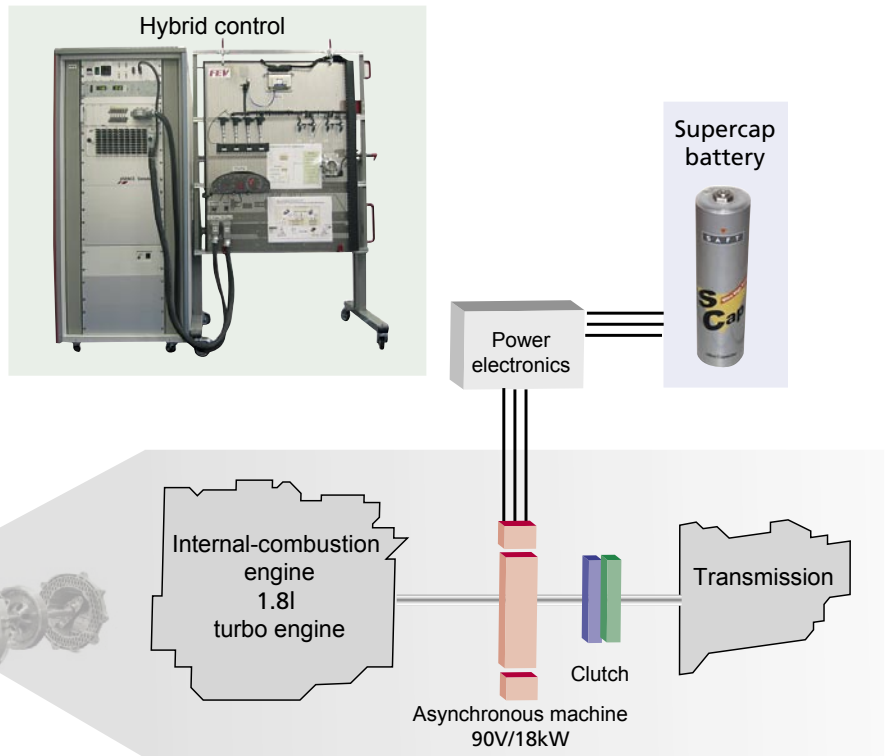
Even though not all powertrain components were available, at FEV Motorentechnik we were able to study



the effect of the operating strategy on the powertrain behavior at an early stage. The HIL simulator from dSPACE was used for this. The real components in the set-up were the engine control of the original vehicle and the hybrid control. In addition to these, some of the original engine's actuators and the cockpit module were connected to one another on a breadboard, via the engine cable harness. The core components in the dSPACE Simulator are the DS1005 PPC Board for computing real-time simulation and the DS2211 HIL I/O Board for simulating and measuring all engine signals. Where powertrain components were not available, they were modeled with MATLAB®/Simulink® and downloaded to the DS1005 via Real-Time Workshop. The models were for the combustion engine, the electric motor, the super cap unit, the clutch, the transmission, the entire longitudinal dynamics of the powertrain, and the driver. Two major criteria, reduced consumption and driving behavior, were studied in several simulation runs.

Results

The measurement results are impressive proof of the difference the EPB vehicle can make, compared with a vehicle with no electric motor. To accelerate from 30 km/h to 80 km/h, the vehicle with the 1.8-liter turbocharged engine needs 8.4 seconds, and the EPB vehicle 6.4 seconds. The basic vehicle with a 3.0-liter naturally aspirated engine requires around 7 seconds. As regards fuel con-



sumption, the EPB vehicle reduced this by around 24% in the New European Drive Cycle (NEDC), as compared with the 3.0-liter naturally aspirated engine. The great benefits of combining hybrid technology with downsizing are therefore considerably reduced consumption under all relevant driving conditions and excellent acceleration values. Using the dSPACE Simulator at FEV Motorentechnik meant that we could begin running comparison tests at an early stage of development, even though not all components were available.

▲ *Topology of the hybrid powertrain.*

*Marco Jentges
Electronics and Mechatronics /
Hardware-in-the-Loop
FEV Motorentechnik GmbH
Aachen, Germany*

Glossary

Breadboard – System that provides a simple way of building an electronic circuit without etching or soldering

Super-Caps – Double-layer condensers with high short-term power density

New European Drive Cycle (NEDC) – Legislated drive cycle used to determine levels of toxic emissions and consumption

Strategic Use of HIL and SIL

- dSPACE Simulator integrated in the development process at Audi
- Controller calibration and parameterization in the simulation
- Optimum mix of simulation and test drives

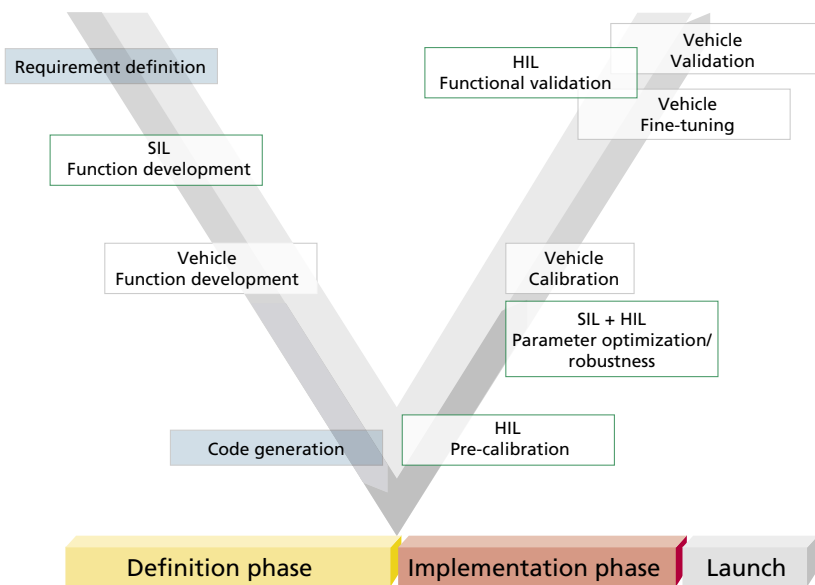
Hardware-in-the-loop (HIL) and software-in-the-loop (SIL) simulations have long been used to test electronic control units (ECUs) and software. Now they have a new application field: calibration and parameterization of a vehicle stability controller, using simulation. A virtual calibration procedure like this requires far more precise models and new approaches to optimizing vehicle dynamics, and also raises a lot of development process issues.

AUDI AG has developed a process for vehicle dynamics development in which HIL and SIL simulation is an integrated part of every project. The company set up a team of HIL/SIL specialists to function as service providers within the department, processing development tasks by means of virtual procedures.

Aims of the Development Process

Our development process aims to fulfill as many different customer and process objectives as possible, and to add maximum value.

- Optimum controller functionality, for example, for a short braking distance
- Good function validation, ensured by great test depth
- Fast response to technical modifications by means of model-based function development and parameterization
- Expertise in ECU networks, which are growing in importance as the number of functions and ECUs in vehicles increases
- Maximum added value by systematically automating time-consuming development tasks



▲ Optimum mix of simulation and test drives: Using HIL and SIL simulation at an early stage reduces the number of test drives.

AUDI AG is using dSPACE Simulator for this. The tasks of the HIL/SIL team comprise vehicle-specific parameterization of various functions in vehicle dynamics control, and the development of new brake systems and stability functions in ECU networks.

A good understanding of the underlying system is vital to achieving these aims. Using HIL and SIL simulations at an early stage supports this. They enable us to use make much more systematic and goal-specific use of the test vehicles. Methods, model quality, and process are all equal factors in simulation potential and must be worked on continuously.

Methods

To improve the methods, we are working on objectivizing the vehicle dynamics properties. A quality evaluation process was introduced for this. We have defined objective properties for assessing vehicle dynamics. These enable us to compare different controller configurations from a purley phenomenological point of view. The quality criteria for vehicle dynamics are combined to form task-specific quality vectors. The quality vectors can then be used to implement auto-

matic optimization of controller parameters in the simulation. This optimization process can be used on the HIL and SIL systems from dSPACE.

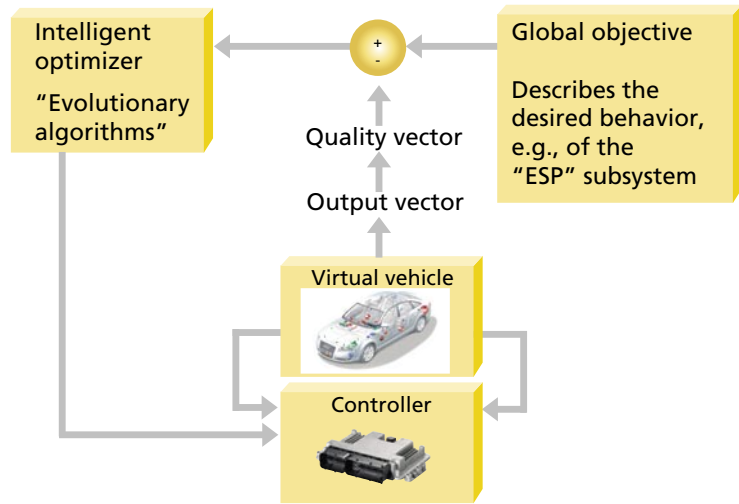
Model Quality

The level of model quality that is required depends on the task, for example, function development, pre-parameterization, optimization, or functional software tests. We introduced model classes to handle this and defined the steps needed to achieve class-specific model quality. Beginning with a predecessor model extended by target data, there are several steps that finally lead to a completely validated model for concrete test vehicles.

To achieve good model quality, we first divide the entire dynamics model of the vehicle into model modules. The parameters of the modules are derived from the test benches and from the simulation results of the responsible department, so that the modules can be validated and tested separately.

The modules are the building bricks for creating specific variants of the overall vehicle.

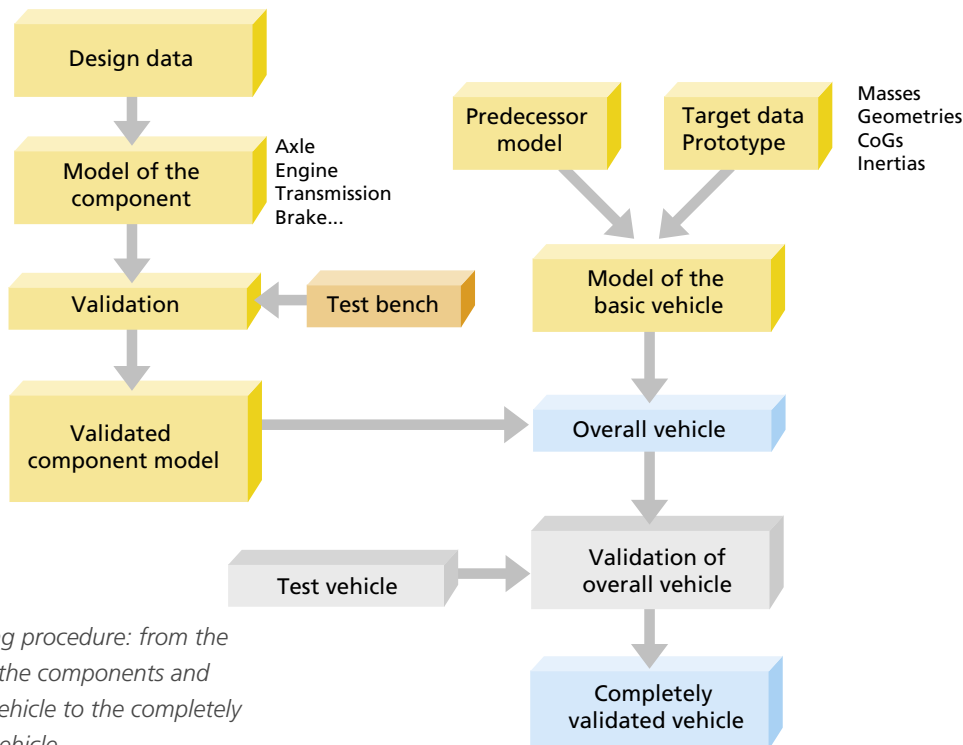
Measurement data obtained from driving maneuvers in the test vehicles are used to validate the overall model of a specific variant. This ensures the comparability of simulation and test drive.



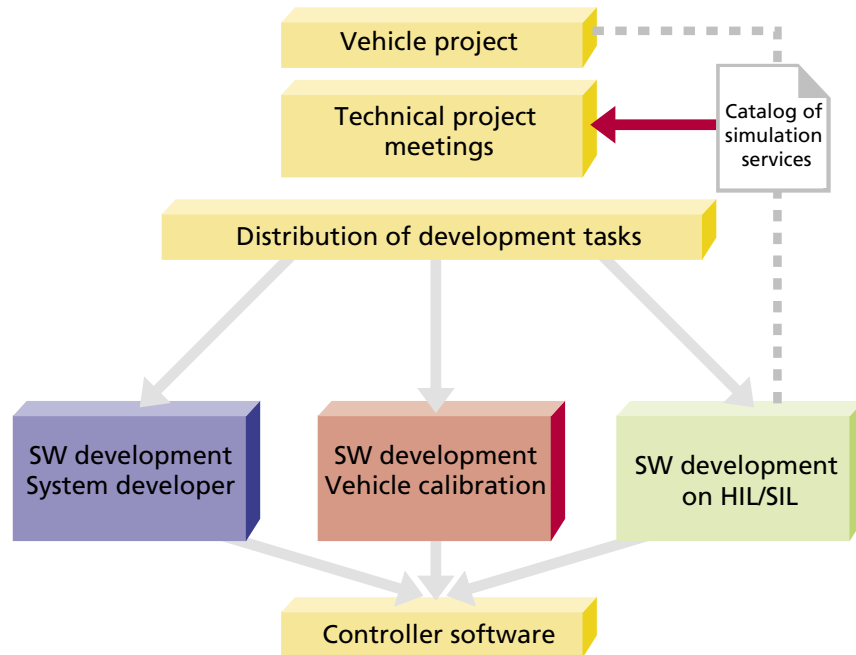
▲ Vehicle dynamics objectivized to improve methods.

Process Integration

Our catalog of simulation services is the key to integrating simulation tasks into the vehicle development process. The developers responsible for specific functions can commission defined simulation tasks at technical project meetings, using the catalog of services as a basis. The catalog of services precisely describes the scope of the tasks to be performed, the simulation quality that is achievable, and the model class that is required.



▲ Modeling procedure: from the models of the components and the basic vehicle to the completely validated vehicle.



▲ *Process flow: integration of HIL and SIL simulation.*

There were two main motives for introducing the catalog:

- It gives the responsible function developers a stable planning basis in the vehicle project.
- Method development and modeling tasks can be performed much more in tune with requirements than was previously the case.

Conclusion

HIL and SIL show considerable potential for calibrating, optimizing, and validating vehicle dynamics controls. Automated parameterization is already possible with real-time-capable models. The requirements for this are that the vehicle dynamics are objectivized, the

strengths of the simulator and the vehicle as tools. Through systematic further development of the success factors methods, model quality, and process, we are working on continuously shifting the mix in the direction of simulation.

*Jörg Pfau
Development vehicle dynamics control
Teamleader HIL/SIL Simulation
AUDI AG
Ingolstadt, Germany*

“Many development tasks can be performed considerably faster in HIL and SIL simulation than in the vehicle. This saves us a lot of time.”
Jörg Pfau

process is seamlessly integrated, and the model has a module structure. With the service catalog as a basis, we can set up HIL and SIL simulation in vehicle projects. This is our contribution toward achieving an optimum development mix of simulation and test drives, in which full use is made of the specific

Glossary

Objectivization – Describing subjective vehicle behavior by means of objectively measurable, physical variables.

Quality vector – Vectorial collection of quality criteria.

Phenomenologically – here: Investigation of the vehicle behavior that is finally relevant for the driver/vehicle interaction.

DS5202 – Amazingly Adaptable

dSPACE has a new board for hardware-in-the-loop simulation: the DS5202 FPGA Base Board. Its main components are a field programmable gate array (FPGA) and a piggyback module with I/O drivers that can be integrated flexibly. As these components are always tailored to specific applications, according to customers' specifications, this is an extremely flexible new development that considerably broadens the scope of potential applications for dSPACE boards. The first applications are for designing and testing hybrid systems.

Simulating electric motors requires very fast, high-resolution signal conditioning, which up to now was difficult and expensive to achieve in real-time applications. Algorithms that formerly ran on powerful dSPACE processor boards, and whose high sampling rates caused a large load on the processor, can now be shifted to the FPGA.

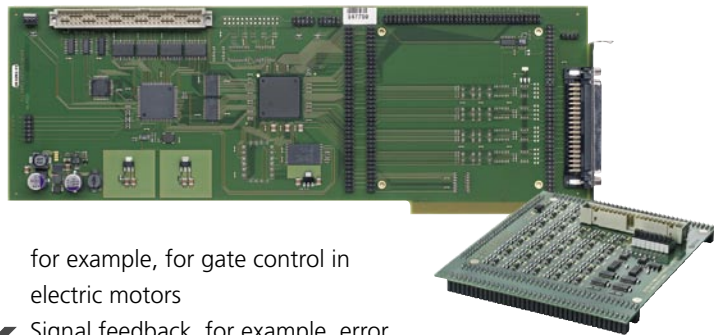
Components

The FPGA module is programmed by dSPACE for each specific application, giving users very fast, high-resolution signal conditioning that precisely fits requirements. The time resolution of the signals depends on how the FPGA is programmed. The resolution can theoretically be increased to a maximum of 280 MHz via digital frequency synthesizer (DFS). Even with complex FPGA algorithms, the typical working range is 40 ... 80 MHz. The piggyback module can be used to integrate I/O drivers flexibly and to implement special combinations of analog/digital inputs/outputs and bus drivers, for example, for a serial peripheral interface (SPI) bus system. The board is connected to the hardware-in-the-loop simulator via a PHS++ bus interface and S-functions, which dSPACE programs in Simulink on a per project basis.

Application Scenarios

The first customer projects are focusing on simulating electric motors. In one case, the DS5202 is simulating engine speed/position sensors for an electrical motor. In another application it is measuring the control signals of an IGBT (Insulated Gate Bipolar Transistor) output stage for an electrical motor. The following features are being implemented:

- Extended pulse width modulation (PWM) measurement for electric motors
- Signal conditioning during PWM evaluation,



- for example, for gate control in electric motors
- Signal feedback, for example, error signals for gate control in electric motors
- Dead time measurement between 2 IGBT control signals
- Error flag when minimum dead time not reached
- Middle-synchronous frequency measurement
- Clock rate recovery, for example, for generating a trigger synchronously with frequency measurement

- **New DS5202 FPGA Base Board**
- **Ideal for simulating electric motors**
- **Customer-specific configuration**

▲ *The DS5202 with piggyback module.*

Glossary

Digital Frequency Synthesizer (DFS) –
Generates a clock rate by multiplying or dividing an input clock rate.

Serial Peripheral Interface (SPI) –
Bus system standard for a synchronous, serial data bus that can be used to interconnect digital circuits.

TargetLink Connects to AUTOSAR

- Model-based designing for AUTOSAR ECUs
- Generating AUTOSAR-compliant code
- Software component descriptions generated automatically

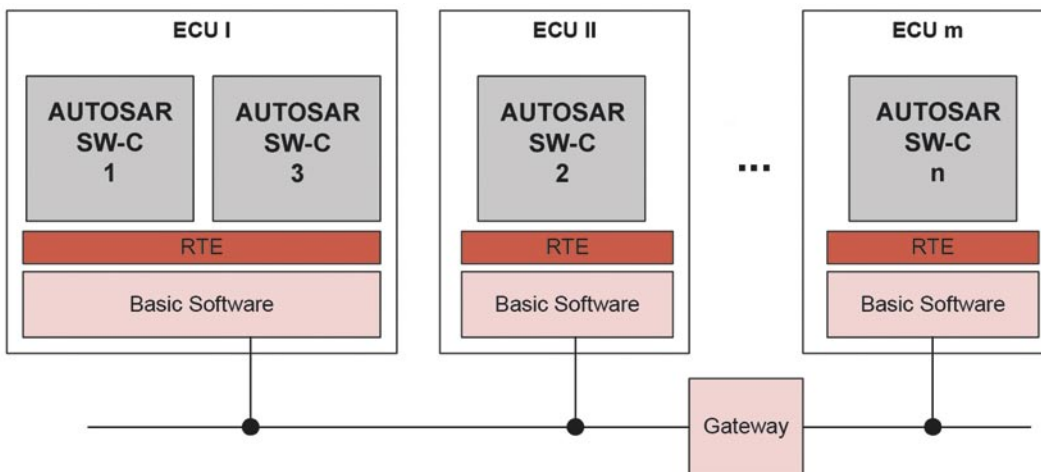
The AUTOSAR initiative is without doubt one of the automotive industry’s most forward-looking and important undertakings. TargetLink 2.2 therefore includes a TargetLink AUTOSAR blockset for generating code for AUTOSAR software components. These contain the actual function code for an electronic control unit (ECU), which is TargetLink’s natural domain. As always, TargetLink 2.2 not only generates code for AUTOSAR software components, but also gives extensive support for modeling and simulating them.

AUTOSAR-Compliant ECU Software Development with TargetLink 2.2

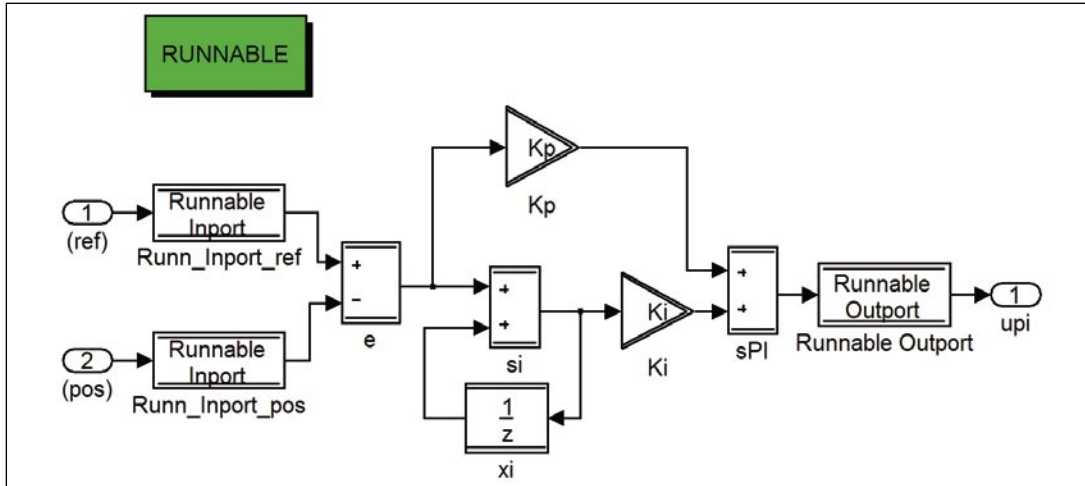
In the AUTOSAR software architecture, function code is encapsulated in AUTOSAR software components (SW-Cs), which communicate with one another and with services in the AUTOSAR basic software exclusively via well defined, standardized interfaces. These interfaces are made available by the run-time environment (RTE). Function code that meets these requirements can be generated via an optional AUTOSAR module for TargetLink 2.2, which supports modeling and code generation for SW-Cs.

Modeling and Simulating AUTOSAR Software Components

For users who need to model SW-Cs, TargetLink 2.2 provides special TargetLink AUTOSAR blocks for specifying AUTOSAR’s structural elements, such as runnable entities, ports, etc. This combination of TargetLink AUTOSAR blocks and the proven TargetLink blockset gives developers an easy-to-use and extremely powerful modeling tool for implementing controller models in AUTOSAR-compliant components. All the specifications required for the SW-Cs are made in the familiar TargetLink/Simulink® environment, which makes the modeling of AUTOSAR software components particularly attractive and efficient. TargetLink also supports the simulation of SW-Cs in the MIL/SIL/PIL simulation modes, though not every AUTOSAR communication mechanism can be simulated completely realistically in Simulink.



▲ TargetLink 2.2 generates code for AUTOSAR software components (SW-C) as an application-specific part of the AUTOSAR software architecture.



◀ AUTOSAR software components are modeled by means of the additional TargetLink AUTOSAR blockset. Shown here are the blocks for runnables and AUTOSAR inports/outputs.

Code Generation for AUTOSAR Software Components

When the specification has been completed at block level and in the dSPACE Data Dictionary, actually generating AUTOSAR-compliant code takes only a few clicks. Since communication with each software component runs exclusively via the RTE, the code generated by TargetLink contains the RTE macros needed for data exchange. TargetLink supports various AUTOSAR communication mechanisms, such as sender/receiver communication and client/server communication.

In addition to generating the actual C code, TargetLink 2.2 also provides a standardized description of the AUTOSAR software components in XML format. This description is needed for tool-supported integration of the code, as it contains information on structure elements such as runnable entities, ports, etc.

Generating AUTOSAR software components with TargetLink provides all the usual advantages of model-based design.

These are some of the other new features in TargetLink 2.2, in addition to AUTOSAR software component generation:

- **Function interfaces with pointers to structures:**
TargetLink 2.2 now also supports pointers to structures in the function signature, which is particularly efficient where there are a large number of function parameters and which improves the structuring of the generated code.
- **TOM and TSM extensions:**
New modules for TargetLink 2.2 include processor-optimized code generation (TOM) for MPC55xx/Diab and target simulation (TSM) for TC1766/Tasking and S12X/Metrowerks.
- **More flexible code generation:**
TargetLink’s numerous code generation options have been extended, for example, with regard to variant coding, and by access functions for structures and bitfields. Further Code Generator settings can be made in a convenient user interface.
- **Extended modeling options:**
TargetLink 2.2 not only allows numerous blocks to inherit properties, it also supports bus-capable blocks and nested graphical functions.
- **Multi-edit functionality in the Data Dictionary Manager:**
The properties of multiple data dictionary objects such as variables can now be modified simultaneously, which greatly simplifies the handling of large data volumes with the Data Dictionary Manager.
- **Requirements Management Interface:**
TargetLink 2.2 simplifies connection to the Requirements Management Interface of the Simulink Verification & Validation Toolbox to link TargetLink blocks with requirements.

Flexible Direct Injection

➤ **RapidPro module for direct injection**

➤ **Variable control of injectors**

➤ **Software-configurable module**

In the endeavor to cut fuel consumption, exhaust gas emission, and noise emission, and at the same time boost engine power, automobile manufacturers are employing new combustion chamber processes, and new injection methods and strategies. The PS-DINJ 2/1 (DS1664) is a new direct injection module which when used in conjunction with the RapidPro prototyping platform provides universally configurable control electronics for direct injection diesel and gasoline engines with solenoid injectors. The current and voltage signals are software-configurable, so the module can be adapted to different injectors and is therefore reusable, saving time and costs.

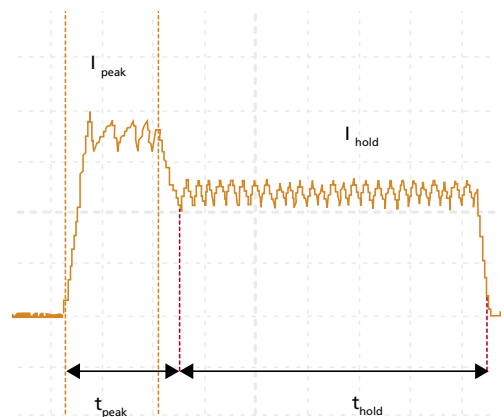
Developing Better Injection Systems

The optimization of injection systems for gasoline and diesel vehicles today requires flexible control of the injection components, particularly in advance development. The available production ECUs are usually not suitable for this task, as they are tailored to their specific production applications and therefore inflexible. The control solutions frequently used up to now were expensive, and had to be modified or developed for each project, also at great cost. The modular RapidPro prototyping platform from dSPACE is a completely new approach, and is moreover extremely efficient. Because it is software-configurable, the new DS1664 module can be adapted to a large number of different solenoid injectors. The RapidPro system's modular design can handle injection systems with up to 12 cylinders.

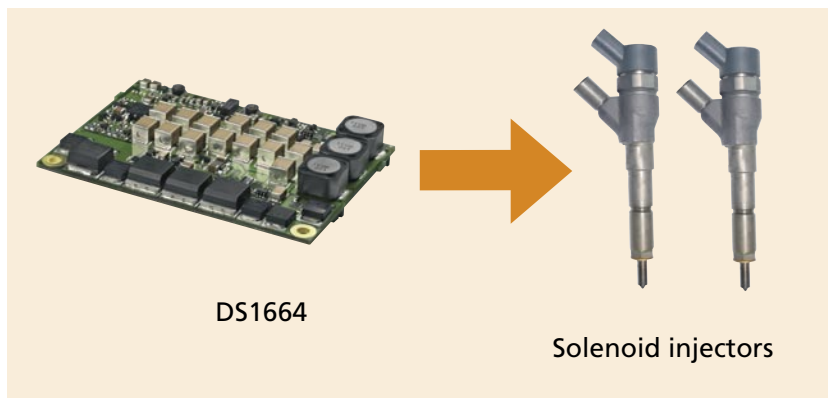
For further information, please see www.dspace.com/goto?releases

Universal Injector Control

The DS1664 module requires two slots in a RapidPro Power Unit and provides integrated current control for the peak current I_{peak} and the hold current I_{hold} (see illustration), and a voltage control for the boost voltage (software-configurable between 6 and 100 V). An external boost voltage can be fed in. Safety and fault detection functions such as short circuit and overtemperature detection are also on-board. The control signals for injection start and duration $t_{peak} + t_{hold}$



▲ Typical current curve during injector control.



DS1664

Solenoid injectors

▲ DS1664 module plus RapidPro prototyping platform: universal, configurable control electronics for gasoline and diesel direct injection systems.

are generated by the RapidPro Control Unit and can be freely parameterized in real time via a Simulink® blockset. Up to 10 injections per cylinder (pre-, post-, and main injections) can be implemented at a resolution of 0.1° crankshaft angle within one engine cycle. One module can control up to two injectors (sequentially) depending on the operating mode. In single operation mode, the maximum output current is software configurable between 2 A and 30 A, continuously up to 15 A (in dual mode 20 A/10 A).

Faster Bypassing

The DS541 DPMEM POD (plug-on device with dual-port memory) is a dSPACE off-the-shelf product that fits Freescale's VertiCal architecture for the MPC55xx microcontroller. Because it provides direct access to the microcontroller bus, the DS541 achieves very low latencies in function bypassing. It is also ideal for tasks other than bypassing, such as ECU calibration.

- Off-the-shelf POD for VertiCal architecture
- Function bypassing and ECU calibration
- On-board DPMEM and LVDS interface

Minimal Latencies in Function Bypassing

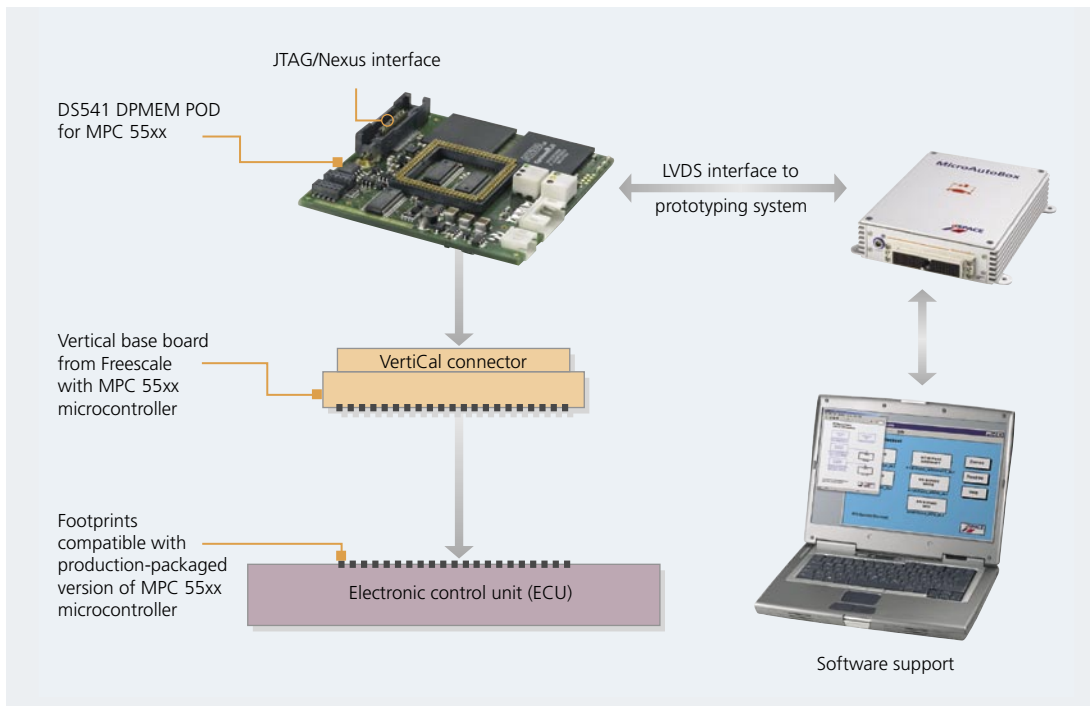
The new DS541 from dSPACE minimizes communication latencies between the prototyping hardware and the electronic control unit (ECU) during bypassing. This makes it ideal for bypassing ECU functions that require fast execution rates and a large number of model inputs and outputs. The DS541 is a top board for the MPC55xx VertiCal Base Board from Freescale, which can be connected to the ECU simply by installing it in place of the ECU's original microcontroller. Low latencies, combined with high signal integrity, are achieved by several factors: direct access to the microcontroller bus via the VertiCal connector, very short signal line lengths between the dual-port memory and the MPC55xx, and a fast LVDS interface. The available Simulink blocksets support two variants of

external bypassing: address-based and service-based bypassing.

ECU Calibration via Nexus or CAN

The DS541 has an additional RAM component that allows it to be used as a memory for calibration data. If the POD's voltage supply is connected to the vehicle battery, the data is retained after the ECU is switched off. The calibration interface can be, for example, the ECU's CAN bus, or the JTAG/Nexus interface available on the DS541 itself. The Nexus connection can also be used as an interface for debugging ECUs or for flash programming. Further plug-on boards can be connected via the DS541's VertiCal connector, for example, for memory emulation.

For further information, please see www.dspace.com/goto?releases



▲ The new DS541 simply plugs onto an MPC55xx VertiCal Base Board from Freescale.

Automated Tests in Real Time

- Tests executed synchronously to model
- Python is the test description tool for real-time tests
- Test execution in real-time on the processor board

Real-time, hardware-in-the-loop (HIL) simulation on special processor boards has become a standard for testing mechatronic electronic control units (ECUs). Harnessing the full potential of the simulator hardware requires powerful tool automation, however. AutomationDesk is a test automation and test management tool that meets this need. You can create tests either graphically or via script programming and run them on a PC. From AutomationDesk 1.4, Python scripts can run on the DS1006 Processor Board in real time, i.e., synchronously with the model, independently of the PC. This means you can implement tests with tough requirements regarding timing accuracy and reactivity.

Describing Real-Time Tests in Python

A test automation package containing Python, the object-oriented scripting language, and AutomationDesk has long been available from dSPACE. From AutomationDesk 1.4, which comes with

Release 5.2, Python scripts can run on the DS1006 Processor Board in real-time, i.e., synchronously with the model.

All test actions are performed on a real-time basis, so the solution opens up completely new test options on the HIL simulator. Reactive tests that can react to changes in model variables within the same simulation step (called

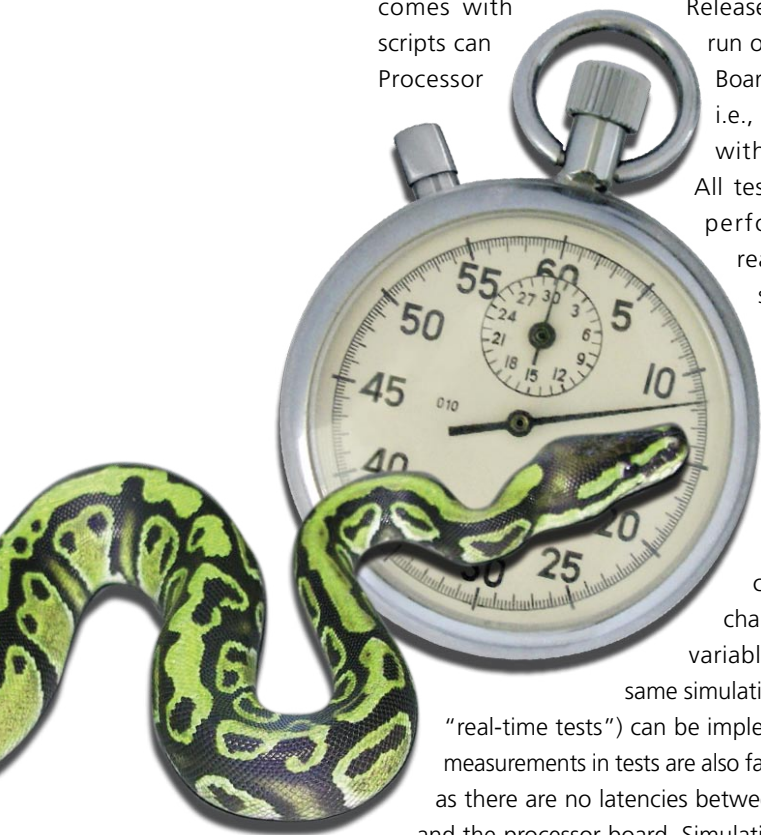
"real-time tests") can be implemented. Time measurements in tests are also far more precise, as there are no latencies between the test PC and the processor board. Simulation step size is now the only thing restricting the maximum time resolution of the measurements.

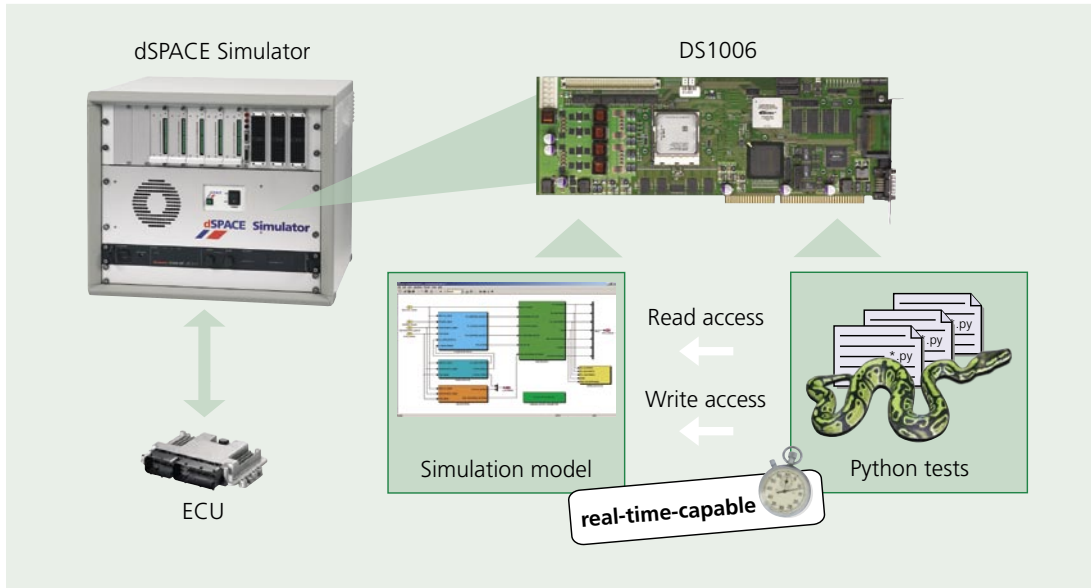
Real-Time-Capable Python Interpreter

A real-time Python interpreter, running on the DS1006 Processor Board along with the model, allows the script to execute synchronously. The interpreter can execute several real-time tests simultaneously and independently of one another. The tests can interact with the simulation model in real-time via the memory on the processor board. You can therefore observe and influence the ECUs connected to the HIL simulator in every individual simulation step. The Python interpreter is added to the application during the translation process via a Real-Time Workshop build option. You can formulate real-time tests using standard Python scripts from the new libraries that dSPACE provides (for example, for accessing model variables and executing several test branches within one real-time test in parallel). You can also create your own libraries and reuse them in several tests. The tests you have created can be loaded from the PC to the simulator's processor board and executed regardless of whether there is a real-time test already running. Even though executing the real-time tests requires additional memory capacity and computing time, it is no problem to implement typical test scenarios, which run in parallel to complex engine and vehicle dynamics models, at simulation step sizes of 1 ms.

PC and Processor Board Work Hand in Hand

Because the real-time tests run on the processor board, the PC is no longer needed once they have





▲ Real-time-capable Python interpreter for the DS1006 Processor Board.

been loaded and started. However, in some cases it may make sense to combine test execution on the PC and the processor board. Future versions will support this, making it possible for Python scripts running on the PC and on the processor board to call each other's functions and exchange data. For example, the real-time test can collect result data for a certain period and transfer the data to the PC, which then generates a report. Or a real-time test can access a diagnostics system connected to the PC to query a fault memory entry in the ECU.

Summary and Outlook

AutomationDesk 1.4 provides the real-time-capable Python interpreter for the DS1006 Processor Board. Several real-time tests can be loaded separately and executed synchronously to the simulation model. The

tests have read and write access to model variables. The functionality for real-time testing will be extended step by step. Various libraries will be added for convenient access to HIL hardware (such as FIU, CAN, and diagnostic access) and for easier data exchange between the PC and the processor board. There will be library functions for extended real-time data acquisition, allowing data recording to be started and stopped according to model variables. The Python interpreter will be further developed to include the DS1005 PPC Board and multiprocessor systems (based on DS1005 and DS1006).

Advantages of Python Real-Time Tests

- Real-time tests programmed in Python standard language
- Test descriptions can be extended by user (libraries)
- Test action descriptions with precise timing information
- Reproducible execution of test cases
- Simulation models need no modification for real-time tests
- Read and write access to model variables possible in every simulation step
- Dynamic reloading and execution of tests during model simulation

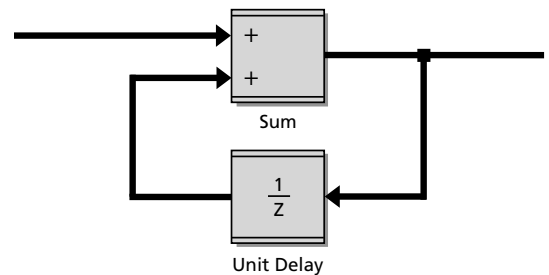
Tracking Down Run-Time Errors

- Automatic run-time error analysis of TargetLink code
- Navigation straight from analyzed code to model
- Tool integration ensures high-precision analysis

Generating the actual function code is not the only way in which TargetLink, the production code generator, helps engineers to develop software for electronic control units. TargetLink users have a wide range of tools for verification and validation at their fingertips – partly in TargetLink itself, and partly in extension solutions like MTest. Another innovative tool has just joined these: the TargetLink-PolySpace integration, which offers protection against run-time errors.

The Sources of Run-Time Errors

Even though no human programmer can ever attain the degree of correctness of automatic production code generators, the code that these generate is not necessarily free of run-time errors. The reason for this is that errors can creep in during model design, while the function is still being developed. For example, if there is no protection against division by zero or out-of-range values at model level, the code that is generated may contain run-time errors, as any potentially erroneous specification is translated into code 1:1. Run-time errors like these have their sources at model level and should preferably be eliminated at that level. The TargetLink-PolySpace integration greatly simplifies this process.

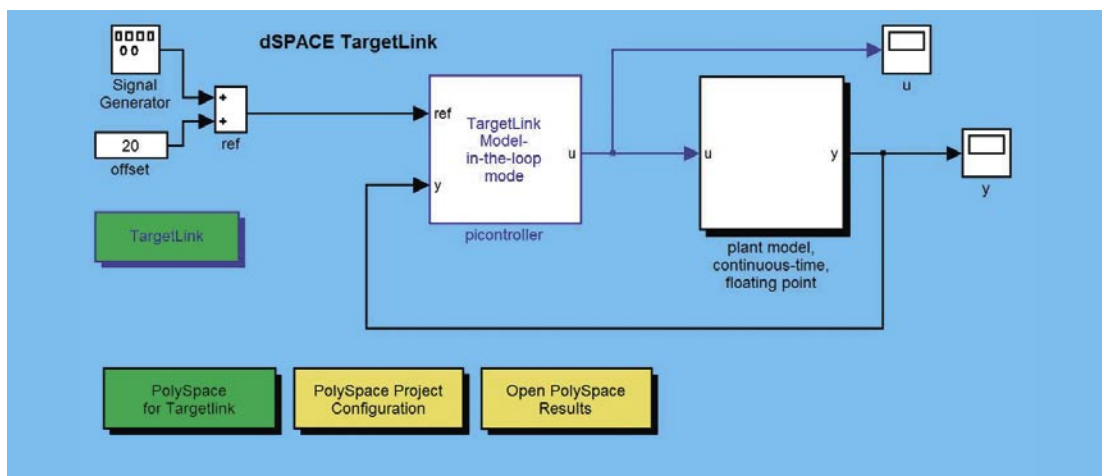


▲ Model fragment containing feedback that may cause overflow/underflow.

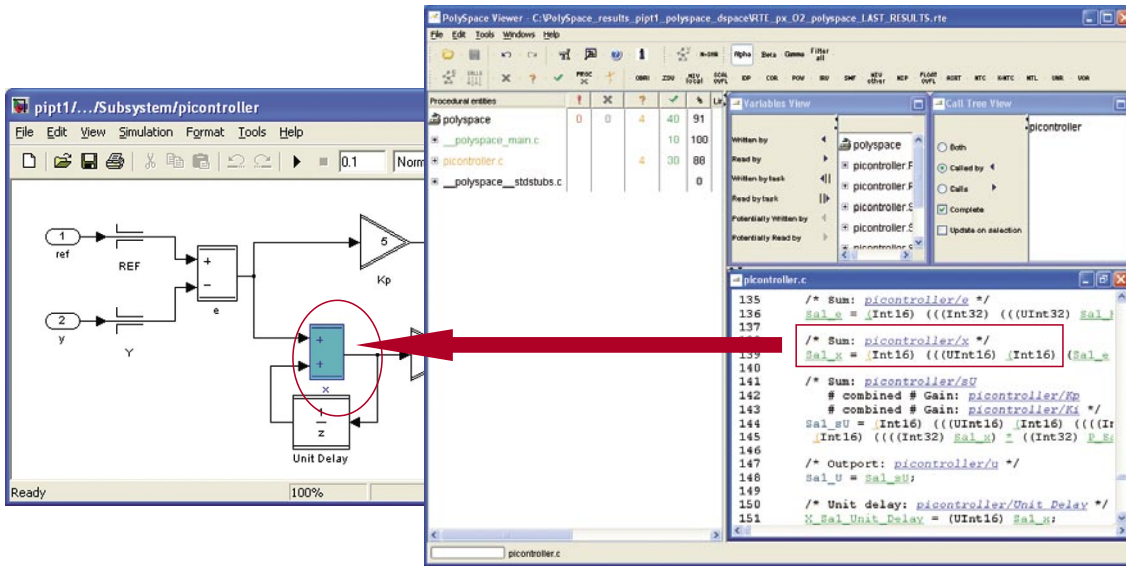
What Can the TargetLink-PolySpace Integration Do?

Integration means that TargetLink can be directly connected to the PolySpace Verifier, which uses static

analysis to analyze the generated code with the aid of what is known as abstract interpretation. This technique returns information on run-time errors with a precision that is comparable with a mathematical proof. Individual code fragments are classified according to whether they will never have any run-time errors, will always have a run-time error, will never be executed (dead code), or may sometimes have a run-time error. Only this last group requires



► Code analysis is configured and run from model level, using additional TargetLink-PolySpace blocks.



▲ The PolySpace Viewer uses colors to indicate potential run-time errors in the code and allows navigation straight to the model.

closer analysis by developers, as these are the cases where, due to the abstractions, the PolySpace Verifier cannot precisely determine whether a run-time error can really occur or not.

Advantages of the TargetLink-PolySpace Integration

Users of both tools benefit greatly from the TargetLink-Polyspace integration in the following ways:

- It takes just a few clicks to run the code analysis from model level. The configuration parameters for the PolySpace Verifier, and the TargetLink subsystem that the code belongs to, are also specified in the model.
- The PolySpace Viewer uses colors to classify the operations in the generated code (green = will never have a run-time error, orange = may sometimes have a run-time error, etc.). Users can navigate straight from the code to the corresponding locations in the model. This makes it easy to trace the critical points back to the model, examine them, and if necessary correct them.
- The precision of the analysis can be greatly enhanced by additional information at model level, such as value range limits for calibratable parameters, and input values. The PolySpace Verifier reads this information from the dSPACE Data Dictionary and uses it in the analysis. This

- reduces the number of code lines whose run-time behavior cannot be precisely determined.
- PolySpace Verifier explicitly recognizes TargetLink’s optimized code generation using the compute-through-overflow technique, which again makes it easier to analyze the generated code.

The tool integration produced by PolySpace and dSPACE not only speeds up the development process, it also smooths the way to verifying the production code that is generated.

Glossary

- Dead code –**
Fragment of code that can never be executed.
- Compute through overflow –**
Calculation method for arithmetic operations in which overflows are allowed to occur in intermediate results provided the final result can be given correctly.
- Abstract interpretation –**
Method of analyzing the semantics of a program, using abstractions to reduce the computation load.

Further information on the TargetLink-PolySpace integration (PolySpace for Model-Based Design) can be obtained from PolySpace at contact@polyspace.com

AUTOSAR and ASAM – Current Activities

Inside view of
standardization
bodies

AUTOSAR and ASAM

dSPACE's
commitment

Generally accepted standards are indispensable in industry. Developing and introducing them is a complex process, however – as is integrating them into existing products. We spoke to dSPACE staff members Joachim Stroop, Spokesman for the AUTOSAR Template Team, and Dr. Jobst Richert, ASAM Board member, about the importance of standards and their effect on dSPACE products.

A lot of coordination and development work is involved in introducing and establishing standards. Why does dSPACE support standardization efforts?

Stroop: From the point of view of the users, standards provide excellent investment protection. Products that completely support a standard are interoperable with complementary tools on the market. Moreover, standardization efforts frequently reflect technological advances. For example, AUTOSAR aims to establish a domain-specific component architecture for vehicle electronics. We are cooperating on developing new technologies and giving innovations early support.

Richert: dSPACE's position is that if file formats or APIs give tool suppliers no competitive advantage, a standardized solution must be found and supported. However, the standards must be completely viable in practice, to prevent proprietary solutions becoming established in parallel. This requires technical expertise, which dSPACE can contribute by involving its specialist engineers in many technical work groups and at management level.

What standardization activities do you currently regard as the most important, and what areas is dSPACE involved in?

Richert: dSPACE's longest association with standardization activities is with ASAM and its predecessor, ASAP. When ASAM was founded in December 1998, dSPACE was one of the founder members. The fields

covered by the standardization of automation and measurement systems are relevant to virtually all dSPACE products.

Stroop: AUTOSAR is a development partnership that aims to develop a standardized concept of electronics/electronics architecture and use it commercially. AUTOSAR's approach is so wide in scope that a large number of further standards have been involved, for example, the FlexRay communication protocol. We have been Premium Members in the AUTOSAR partnership since 2004 and are actively involved in the central work groups drawing up the specifications. With our years of experience as tool manufacturers, we are contributing to ensuring the infrastructure and to introducing an AUTOSAR development process.

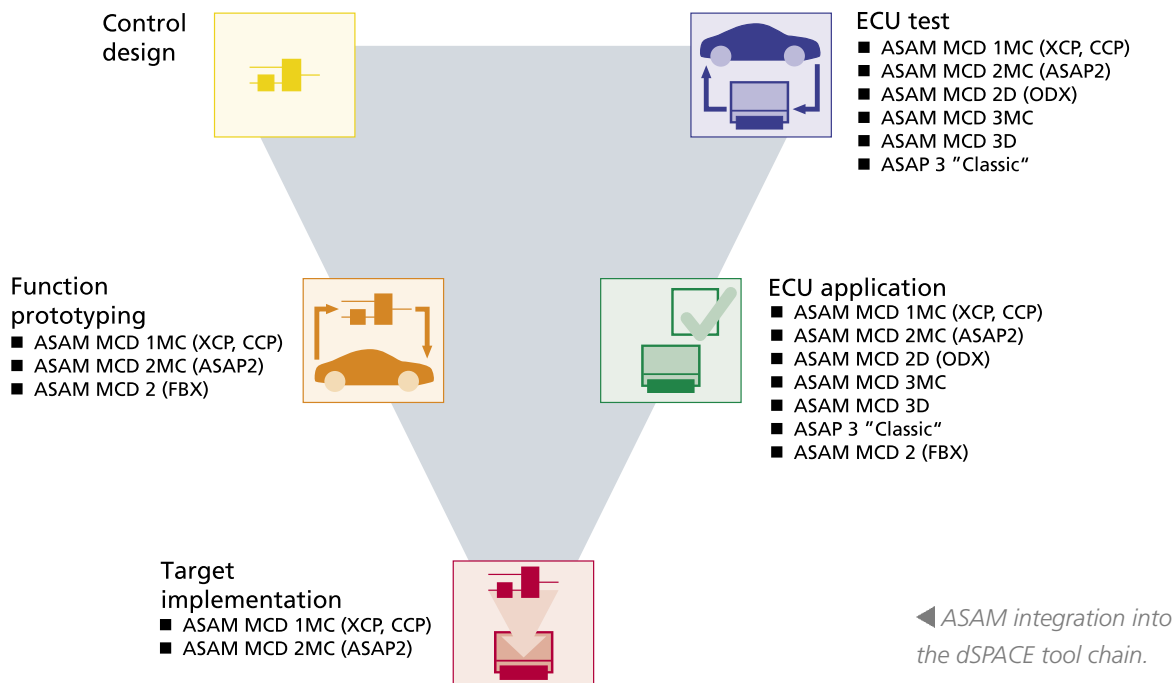
Since ASAM was founded in 1998, and AUTOSAR in 2003, there have been considerable developments in both bodies. What are the current concerns?

Stroop: The first AUTOSAR standards came out in May 2006, so AUTOSAR has now reached the result publication phase. The objective up to completion of AUTOSAR's current phase will be to finalize the specification and ensure a consensus for it. Everyone involved has invested an enormous amount of work to achieve these results. The current status is being deployed in initial field trials and is also the basis for various tool developments.

Richert: ASAM has a longer history, so the situation is different. The standards published in the Automotive Electronics field (ASAM AE) play a particularly important role in virtually all phases of the ECU development process. This is obviously reflected in the dSPACE tool chain.



▲ Joachim Stroop, Spokesman for the AUTOSAR Template Team and Product Manager for System and Function Design Tools at dSPACE.



The ASAM AE standards used to be mainly isolated interface and format standards, but they are now going in the direction of process support according to the V-cycle. Integrating the working results from the MSR consortium into ASAM has also had a particular impact.

In the past, ASAM's other fields of activity, such as ASAM GDI and ASAM ODS, were only important to individual projects at dSPACE. The aim in the medium term is for dSPACE products to support these standards, for example, ODS-based storage of hardware-in-the-loop data. At the moment there is not enough demand for such solutions.

Membership of several bodies takes a lot of time and human resources. What advantages are there in active participation, particularly in the ASAM and AUTOSAR organizations?

Stroop: When a company is represented on both bodies, there are obviously synergies that can be harnessed. dSPACE is in the fortunate position of having an inside view of both bodies and being able to influence them both. We are ideally situated to spot cross-relations such as overlaps in content or potential synergies, so we can plan product developments accordingly.

How does the widespread use of ASAM affect dSPACE products?

Richert: We place great importance on ASAM and have integrated the interface specifications into various parts of our tool chain. The standard is a fixed part of the process for implementing, testing, and calibrating ECUs. New ASAM standards are being added every year. The last one was ODX support in CalDesk, for example. Future ones will include the new exchange format for calibration data, CDF 2.0, and further XCP transport layers.

Does AUTOSAR influence dSPACE products to the same extent as ASAM?

Stroop: We're just beginning to integrate AUTOSAR into dSPACE products. One example is currently the integrated AUTOSAR connection in TargetLink 2.2. Obviously, we won't stop at just one product. You can look forward to further developments in the future.



▲ Dr. Jobst Richert, member of the ASAM Board and Section Manager for SW Development at dSPACE.

Thank you for talking to us.

For a detailed report on TargetLink 2.2, see page 20.

dSPACE Japan's User Conference

- **First conference of new subsidiary**
- **A full house in the Tokyo Conference Center**
- **Participants appreciated first-hand information**

The first Japanese User Conference presented by our new subsidiary, dSPACE Japan K.K., took place in Tokyo on May 23, 2006. Around 270 participants came to the Conference Center Shinagawa to hear about projects with dSPACE systems and compare notes with other users. The attendance figure reflects intense interest in other companies' development work. The participants came from DENSO Corporation, JATCO CO. Ltd., Nissan, Toyota, Honda, Hitachi, YAMAHA, TTDC, Mazda, ISUZU, and others.

Held in the pleasant atmosphere of the Tokyo Conference Center, the User Conference provided an opportunity to meet dSPACE users, product experts and everyone else interested in using dSPACE systems. Demo systems displayed current product developments at the conference exhibition.

cases at Mitsubishi Electric Himeji. The presentation by Noboru Yabe, Yamaha Motor Co. Ltd., discussed the use of a simulation bench for Moto GP (Moto Grand Prix) engine development. Akira Ohata from Toyota Motor Corp. showed their precise engine simulation technology with multi-processing. Two guest speakers from France, Nicolas Bellot and Nicolas Lacour from

"It was meaningful as we could communicate with users of dSPACE-related products and we could obtain information on current technological trends."

Participant from Hitachi Engineering Co. Ltd.

Insights into Current Projects

Leading Japanese automobile manufacturers and automotive suppliers gave comprehensive insights into their development projects and their work with dSPACE systems. Takao Nishimura, DENSO Corp. described how they introduced the dSPACE calibration system for their driving assist system. JATCO Ltd., represented by Kenji Nakajima, provided a snapshot of the current status of its development work on an

"Every program section such as the exhibition of actual products, presentations of products and user case studies, are well arranged and supply a better understanding."

Representative from Transtron Inc.

electronic control for an automatic transmission, using dSPACE tools. Motomi Yamada from Mitsubishi Electric Corp. presented hardware-in-the-loop application



▲ Experienced engineers introduced the dSPACE products and answered questions.



▲ The participants listened intently to the development experts.

Volvo 3P, explained the requirements for an HIL bench for a light-duty vehicle, and how it was designed. They finished with the presentation of the Virtual

“The User Conference was meaningful as I could learn about the latest trends and case studies on dSPACE products.”
Engineer from Isuzu Motors Ltd.

Vehicle Simulator which they use for the execution of function and network tests.



▲ Demo systems at the conference exhibition displayed the latest developments from dSPACE, like production-close prototyping with RapidPro.

New Developments at dSPACE

dSPACE presenters gave inside information on the whole dSPACE product range and the latest product developments, like the FlexRay solution, stand-alone prototyping with RapidPro, and dSPACE’s Automotive Simulation Models (ASM).

Lively Panel Discussion

A panel discussion on the vision of future tools of automotive electronics rounded off

the event, with Akira Ohata, Toyota Motor Corp.; Shigeaki Kakizaki, Nissan Motor Co. Ltd.; Satoshi

“The panel discussion with automobile manufacturers was very interesting.”
Expert from Yazaki Corp.

Shimada, Honda R&D Co. Ltd., Dr. Herbert Hanselmann, President of dSPACE GmbH and Hitoshi Arima, President of dSPACE Japan K.K., acting as moderator. The topic was covered from the point of view of the OEM, suppliers’ quality assurance, and the need for enhanced productivity. Another highlight was a discussion on the importance of model-based design and its introduction to companies, and how important it is for employees to become experts on it. dSPACE Japan K.K. would like to thank all participants for coming and sharing their experience and knowledge. This first Japanese User Conference organized by dSPACE Japan K.K was a great success and will be repeated regularly.

North American User Conference 2006

- **Three-day conference in Plymouth, Michigan**
- **Over 40 companies attended**
- **Technical sessions and workshops**

The latest advancements and industry trends in software control development were discussed throughout technical sessions and workshops at the 4th biennial dSPACE North American User Conference. The key topic was production code generation tools. The event, held May 2-4, 2006, in Plymouth, Michigan, was attended by more than 130 participants from over 40 different companies – representing a wide and diverse cross-section of the embedded electronic controls industry.

The complexity that is inherent with the development of embedded control products is not hindering the competitive desires of global manufacturers to incorporate these hot commodities into their product lines.

OEMs from a growing number of industries – including automotive, aerospace, robotics and industrial automation – are seeking embedded control solutions to deliver state-of-the-art features and functions in their end products. While the development of embedded systems is multi-



▲ A 2007 GMC Yukon, with TargetLink inside, was on display at the User Conference.

“As a fairly new dSPACE user, I felt that the 2006 dSPACE User Conference was a great way to share ideas with the dSPACE user community, talk with members of the dSPACE GmbH team, and learn more about some of the new dSPACE products.”

Julien Parouty, Engineering Specialist, General Dynamics Land Systems

▼ The growing demand for software development tools was the topic of a panel discussion hosted by Paul Hansen of The Hansen Report.

faceted, the process can be greatly simplified with the use of flexible, integrated software development tools. This was a recurring theme at the conference. The event was attended by more than 130 participants from over 40 different companies – representing a wide and diverse

cross-section of the embedded electronic controls industry. In our participant feedback survey, all respondents said they would recommend this event to their colleagues. Participants included: ASAM, Bombardier, BMW, Caterpillar, DaimlerChrysler, Delphi, Detroit Diesel, Eagle RTEC, Eaton Corp., EnSoft Corp., FEV Engine Technology, Ford Motor Company, Freescale, General Dynamics, General Motors, GKN Automotive, Hitachi America, IAV, John Deere, Magna Drivetrain, Lawrence Tech University, MSC, Moog, Motorola Automotive, Nissan, OSC Embedded Systems, PACCAR, PolySpace, Raytheon, Reactive Systems, Ricardo, Siemens VDO, Software Beret, The MathWorks, TRW, Vector Cantech, Visteon, WTI and Xerox.

Keynote Speech

The three-day conference kicked off with a keynote speech delivered by dSPACE GmbH President and CEO Dr. Herbert Hanselmann, who talked about the significant



growth and influence that dSPACE has had in the world of developing embedded control systems over the past 18 years. Introducing the key topic of the conference, automatic production code generation, he noted that he was involved in the research and development of code generation tools since 1981.

In 1999, Dr. Hanselmann said dSPACE unveiled its first commercial software product for automatic code generation from Simulink. The product, TargetLink, has since been used in a large number of vehicle production programs for powertrain, chassis, body software and numerous other applications. Currently, he said there are more than one million vehicles on the road with TargetLink inside.

The first vehicle to have TargetLink code on board was the Nissan Sentra CA 2000. Dr. Hanselmann reported that Nissan was able to reduce its development time to 60%, and it only took the project team 3 months, from start to finish, to generate production code using TargetLink.

TargetLink has been in the marketplace for the past seven years. In that timeframe, Dr. Hanselmann said the product



◀ The conference featured 20 technical presentations and four workshops.

innovative and reliable and we want to keep it that way," he said.

Panel Discussion

Paul Hansen of The Hansen Report – the world’s foremost expert on automotive electronics – moderated a candid panel discussion on ways to improve product quality and time-to-market through the use of compatible electronic control unit (ECU) development tools.

“Real productivity gains can be achieved with highly integrated (development) tools, but these are not a magic bullet to reaping benefits,” said panelist James Kolhoff, Director of Software Development for GM Powertrain. He explained that use of tools requires training and organi-

“I learned not only about capability which is coming online, but also about capability in equipment I already had that I didn’t know about.”

**Rory Johnson, Senior Engineer,
GKN Automotive**

has been successfully used to generate up to 80-100% of the algorithm code in a wide range of vehicle production projects. Among the many cars with TargetLink code on the road today are the Chevrolet Suburban, Avalanche and Tahoe, GMC Yukon and Yukon XL, Jeep Grand Cherokee and Commander, Volvo S80, Jaguar XK, Ford Mondeo and Galaxy, plus several models from Mercedes, Nissan, BMW, Porsche and other OEMs.

In conclusion, Dr. Hanselmann expounded on the growth and progress that has occurred within the company’s other product lines, and emphasized that the company is committed to spending money for ongoing research to continue improving and perfecting its product offerings. “dSPACE has a long-standing reputation for being



▲ The 2006 North American dSPACE User Conference was held at St. John’s Conference Center in Plymouth, Michigan, USA.

“Excellent coordination with vendor displays! It was nice to attend a function where the conference content and suppliers were so well integrated.

Awesome technical content and facilities!”

John Glab, Controls Engineer, Ford Motor Co.

zational acceptance and cooperation – not just internally, but with affected suppliers as well.

The panel agreed that achieving integration at a systems level is critical to achieving efficiency and quality.

“You have to have processes in place to facilitate the utilization of tools and technologies,” said panelist Salim

“I was very impressed by the 2006 User Conference. It was very interesting to learn from applications across different fields and industries and to gather new ideas and viewpoints.”

*Alexander Bauer, Senior Design Engineer
Converter Control, Bombardier*

Momin, Director of the Virtual Garage Lab for Freescale Semiconductor, Inc. “That is the key.” The panelists also talked about the need to perform validation in a cost-effective way, and agreed that advanced tools, such as automatic code generation, can deliver big payoffs.

In conclusion, the panelists concurred that ECU development will not slow down as long as new customer and market requirements demand more sophisticated features and functions. The greatest challenge is figuring



▲ The User Conference concluded with a 9-hole golf scramble at the St. John's championship golf course.

out how to build a flexible compute platform that supports interoperability for tools.

Other executives who served on the panel discussion were Mark Thomas, Director Electronic Systems, Detroit Diesel, and Dr. Hanselmann, dSPACE GmbH.

Presentations, Workshops, Exhibits

A total of 20 presentations were given by dSPACE users, providing direct insight into how the embedded electronics industry is evolving within their own organizations. Users shed light on the internal ECU challenges that their companies have encountered, and the gains that their design teams made using dSPACE ECU development solutions.

New to the conference this year was a series of workshops on automatic code generation and model-based testing, hardware-in-the-loop design considerations, rapid control prototyping and calibration, and effective test automation techniques.

The workshops provided opportunities for conference attendees to delve into highly technical areas with dSPACE engineers.

Another new addition to the conference was an exhibit hall. Featured on display were two production vehicles, a 2007 GMC Yukon and a 2006 Jeep Grand Cherokee, utilizing ECU code generated from dSPACE's TargetLink. Special thanks to our first-time exhibitors: ASAM, The MathWorks, IAV, PolySpace, OSC Embedded Systems, Reactive Systems, FEV, Freescale and EnSoft.

dSPACE extends its sincere thanks and appreciation to all user conference participants.



► dSPACE, Inc. Applications Engineer Chris Pasztor demonstrates the virtual vehicle, supported by a mid-sized HIL simulator, a multi-processor, MotionDesk and ControlDesk.

Hybrid with dSPACE

Research institutes and industry working on alternative propulsion systems are increasingly turning to dSPACE tools, which have long been used for developing conventional drives. A variety of products are involved, from MicroAutoBox to networked systems of several hardware-in-the-loop (HIL) simulators. To show the wide range of different uses the tools are put to, here is a selection of customer projects:

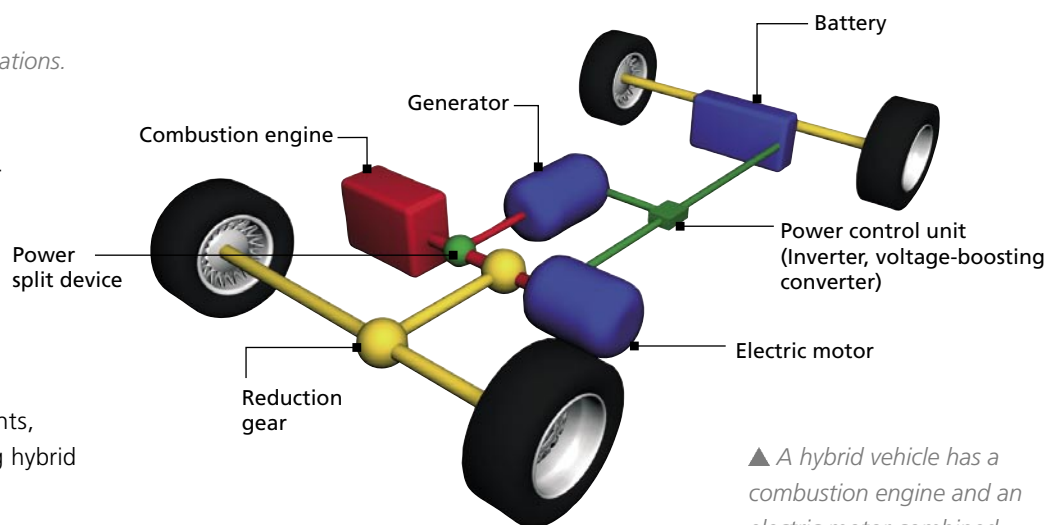
- **Testing and developing hybrid drives**
- **A variety of dSPACE products used**
- **Excerpt from customer list**

Company	Application	dSPACE Product
General Motors	Network testing of ECUs for IC engines, electric motors, and high-voltage electrical systems in hybrid vehicles	Networked hardware-in-the-loop simulators
DaimlerChrysler AG	Developing a hybrid system	Two hardware-in-the-loop simulators
DaimlerChrysler AG	Generating code for an ECU controlling the electric motor of a hybrid truck	TargetLink
General Motors	Hybrid drives	Two networked hardware-in-the-loop simulators
ZF Sachs AG	Testing and developing drive components for hybrid drives	Hardware-in-the-loop simulator
Hyundai Motor Company	Developing a control algorithm for an ECU in a hybrid vehicle	MicroAutoBox
FEV Motorentechnik GmbH	Developing and testing optimization strategies for start-up and acceleration	Hardware-in-the-loop simulator
University of Munich	Optimizing energy management for a parallel hybrid drive concept	AutoBox with modular hardware
Ford	Verifying embedded controller software for a vehicle system controller (VSC) for the Ford Escape Hybrid and other hybrid electrical vehicles (HEVs)	Hardware-in-the-loop system

▲ *Some examples of hybrid applications.*

FEV Motorentechnik's hybrid application is described more fully on page 14 of this issue.

For more details of dSPACE's new DS5202 FPGA Base Board, see page 19. This new dSPACE board can adapt to varying requirements, so it is ideally suited to simulating hybrid applications.



▲ *A hybrid vehicle has a combustion engine and an electric motor combined.*

Housewarming, World Cup and More

Housewarming for new dSPACE building

Local residents and dSPACE staff get together

World Cup kick-off

On the day that the FIFA World Cup began, dSPACE's new building in Paderborn was officially opened. Residents of the neighborhood, dSPACE staff, and representatives from the construction companies and city council partied together – and also celebrated Germany's successful World Cup start. A second building is already planned at the new location.

Late in the afternoon on June 9, the party began with inaugural speeches from company founder and President Dr. Herbert Hanselmann, Mayor of Paderborn Heinz Paus, and architect Martin Wäschle. They paid particular tribute to dSPACE's successful development, culminating in the new building. With plans for a further building on the new site already underway, Dr. Hanselmann described what the Giefersstrasse location will look like in future. dSPACE's

growth strategy will be a major part in this, with 70 new jobs planned for 2006 alone. The new building is right next to a residential area, so dSPACE invited the residents to join the party and get to know their new neighbors.

Kick-Off

With the kick-off to the FIFA World Cup taking place on the same day, large LED monitors and a projection screen were set up around the party tent. So the around 600



*The architect presented
a tree for the gardens.*

Happy faces after the match.

people at the party were able to watch the football match between Germany and Costa Rica live. Fans in football shirts and bearing flags, whistles, etc. provided stadium atmosphere. The German team's advances into the penalty area were accompanied by drumming, hooting, and frenzied applause. The fact that Germany won the game gave the party added zing. After that of course, there was plenty of music and good food.

Technical Details of the New Building

Concrete core temperature regulation – Water pipe coils set in the concrete ceiling ensure draught-free heating and cooling.

Air conditioning – An air conditioner regulates the temperature and fresh air supply in windowless zones such as the wide hallways with their integrated meeting facilities.

Cavity floor – A double floor construction in hallways and offices accommodates cables and pipes.

Electrostatic discharge floor – Special flooring in the production zones

Transformer – The building has its own integrated transformer station (630 kVA) for the electricity supply.

The new building is 5240 square meters in size and accommodates mainly departments that need a lot of space, such as production, logistics, and simulator construction, plus customer engineering, sales, and some administrative units.



Soccer, music, refreshments – Something for everybody.



Dreaming of the next housewarming party?



We're a typical university spin-off: everybody bikes.



The Speedos – on a mission to pump energy into the party.



Evening in the party tent.

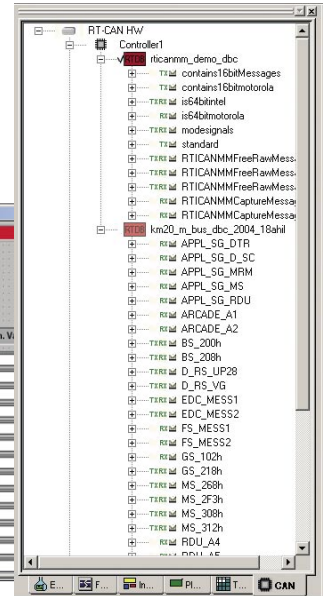
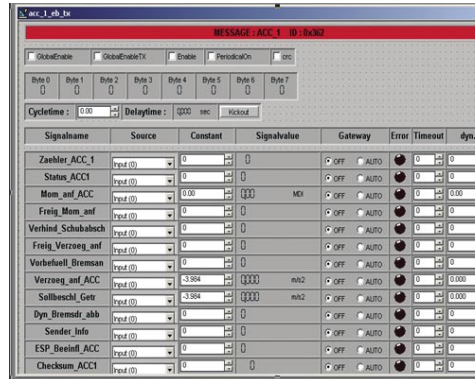


Footballing nations added color.

ControlDesk 3.0 Gets a CAN Navigator

The new CAN Navigator is an innovation in ControlDesk 3.0, now available in dSPACE Release 5.2. It displays the CAN bus communication in simulation models after it was configured with the Real-Time Interface CAN MultiMessage Blockset (RTICANMM). The CAN Navigator links the implementation software (RTICANMM) to the experiment software (ControlDesk). It gives RCP and HIL users an improved display of messages and signals, and also easier access to them. Users can now create and view RX

and TX layouts whenever they need to.



RapidPro: Thermoelement Module



The new DS1638 module for RapidPro provides 8 galvanically isolated measurement channels for type-K thermoelements (NiCr-Ni) with a measurement range of -200 to +1370 °C and one 24-bit A/D converter per channel.

The sampling rate for each converter is software-settable in the range 0.1 Hz to 50 Hz. This allows numerous application areas, such as engine, transmission, and exhaust tract. The module has its own splitter cable, so the standard Sub-D connector on the RapidPro units does not need modifying. A high-precision cold junction compensation is integrated into the connector, along with a memory that identifies the connected thermocable and thermoelements. Characteristic curve linearization is performed on the module itself, which transfers the measurement values to the RapidPro Control Unit loss-free. Support of further thermoelements such as type J is planned.

What's New in Release 5.2

➤ Last support of MATLAB® R13: Release 5.2 is the last dSPACE Release that supports MATLAB R13 (R13SP1 und R13SP2). With the exception of the dSPACE's production code generator, TargetLink, subsequent dSPACE Releases will no longer support R13.

➤ Change from CD to DVD: dSPACE is changing its installation medium from CD to DVD with Release 5.2. This is due to the increasing size and number of our products available for installation.

Events



EUROPE

MI – 10. Internationaler Fachkongress Fortschritte in der Automobil-Elektronik

September 20-21, Ludwigsburg, Germany
Forum am Schlosspark, booth 9
<http://www.m-i-c.de>

VDI/VDE Elektrisch-mechanische Antriebs-systeme

September 27-28, Böblingen, Germany
CongressCentrum
<http://www.vdi-wissensforum.de>

2006 CCA/CACSD/ISIC

October 4-5, Munich, Germany
Technische Universität Munich
<http://www.elet.polimi.it/conferences/cca06/>

Aachen Colloquium

October 9-11, Aachen, Germany
Eurogress Aachen, booth E40
<http://www.ac-kolloquium.rwth-aachen.de>

USA

Convergence 2006

October 16-18, Detroit, MI, USA
Cobo Center
<http://www.sae.org/events/convergence/>

Automotive Testing Expo North America 2006

October 25-27, Novi, MI, USA
<http://www.testing-expo.com/usa/>

Asia

KOAA Show 2006

September 26-29, Seoul, South Korea
Korea Exhibition Hall
<http://www.koaashow.com/>

FISITA 2006

October 23-26, Yokohama, Japan
Pacifico Yokohama
<http://www.fisita2006.com/>

Embedded Technology 2006

November 15-17, Yokohama, Japan
Pacifico Yokohama
<http://www.jasa.or.jp/et/>

For further events, please visit www.dspace.com

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- Request information via our Web site www.dspace.de/goto?dspace-news-info

Your opinion is important. Please send your criticism, praise, or comments to dspace-news@dspace.de – thank you!

Job Opportunities



Due to our continuous growth, dSPACE is looking for engineers in

- Software development
- Hardware development
- Applications
- Technical sales
- Product management

Current offers at www.dspace.com/goto?jobs

Papers



“FlexRay Projects Made Easy”

Joachim Stroop and Dr. Ralf Stolpe, dSPACE GmbH

“Differentiation via ECU Software – Concepts for External Bypassing”

André Rolfmeier, dSPACE GmbH

Training



dSPACE offers training on these topics:

- dSPACE Real-Time Systems
- ControlDesk
- RapidPro
- Rapid Control Prototyping with CalDesk
- TargetLink
- Hardware-in-the-Loop simulation
- AutomationDesk
- MotionDesk
- RTI CAN MultiMessage Blockset
- Automotive Simulation Models
- CalDesk

For more information, please visit www.dspace.com/goto?training

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