dSPACE NEWS

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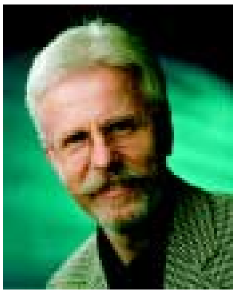
See how to test networked ECUs with dSPACE Simulator

Summer 2001

EDITORIAL



Perhaps you know the saying, “Good things come in small packages”. Sometimes they come in big packages too. Look at the front page of this Newsletter and you will see what I mean. It shows a fairly big simulator we are doing for Audi. Its purpose is detailed HIL simulation of powertrain and vehicle dynamics control all in one.

What makes this architecture unique, and the size somewhat bigger, are two things: One is that this simulator can run engine management, transmission control, and vehicle dynamics control with all 3 ECUs attached, with no ECUs attached (not a HIL any more in that case), or any combination of ECUs. No model-building or compiling is required to switch between real and emulated (i.e. simulated in software) ECUs. One model does the job, saving on maintenance for the 8 models that would otherwise be required for the 8 possible combinations of 3 ECUs attached or not attached.

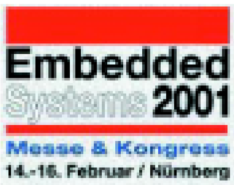
The second unique characteristic of this simulator is that the engine, transmission, and vehicle dynamics simulator can all be separated and run as stand-alones if so desired. This architecture makes full use of our multiprocessor technology, where processors are connected via high-speed optical links.

This simulator project is certainly a highlight. It is a challenging project, and we thank Audi for trusting dSPACE to handle it. I should not fail to mention, though, that we are also producing more “regular” simulators all the time, and in increasing numbers. In my Spring 2000 editorial column, I wrote that some 400 HIL simulators had already been built by dSPACE or by customers on dSPACE platforms. Today, we have reached more than 600. We are constantly expanding our capacity in this area as fast as we can to meet the demand. That includes placing more specialists close to the customer or even putting them on site. If you watch our job ads, you will know we are about to set up another project engineering center in Germany soon, and it will focus on HIL simulator engineering. Back in the early nineties, dSPACE was promoting HIL simulation to become a standard approach for testing, and it has indeed become one.

Dr. Herbert Hanselmann

MISCELLANEOUS

We’re on for 2002 in Nuremberg – See You There?



A must in our trade fair diary: The Embedded Systems in Nuremberg, Germany. Once again, it proved its ability to introduce engineers from various fields to the dSPACE tool chain. Our presentation of the new versions of ControlDesk and TargetLink attracted the most attention.

Along with the exhibition part, a dSPACE paper on automatic code generation for OSEK compatible operating systems was presented at the Embedded Intelligence conference. Dr. Lutz Köster illustrated the dSPACE approach, how to link Simulink or Stateflow designs to an OSEK operating system.

Reflecting dSPACE’s continuing growth, we unveiled our new booth, occuping almost 50 m² of floor space.

For your personal copy just check our paper box on page 8.

All in all, a very successful show. Thanks for visiting us, and we look forward to seeing you again next year.

dSPACE NEWS

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dSPACE GmbH
Technologiepark 25
D-33100 Paderborn
Tel.: ++49 5251 1 63 80
Fax: ++49 5251 6 65 29
info@dspace.de
support@dspace.de
www.dspace.de

Editor: Thomas Michalsky
Layout: Beate Eckert, Ute Bergmann

dSPACE Contributors:
Bernd Becker, Robert Bevington, Günther Gruhn, Louise Hackett, Herbert Hanselmann, Thomas Pöhlmann, Christine Smith, Ravi Venugopal

Active Control of Combustion Pressures

CUSTOMERS

- Reducing emissions of gas turbine engines at Honeywell
- dSPACE Prototyper supporting the control strategies
- ControlDesk for experiment control

Honeywell Engines and Systems recently introduced an advanced technology program to reduce emissions from the Vericor line of gas turbine engines for industrial and marine applications. One of the key technologies being developed for this program is the active control of combustion pressure oscillations that are excited in gas-fired, low-emission combustion systems. The ability to reduce the risk of these pressure oscillations enables safe operation of the engine in regimes that minimize emissions. In the first phase of this program, the concept was developed and tested on the combustor of the engine in under a week using dSPACE Prototyper.

The control strategy is based on injecting fuel into the combustor using a high-speed valve as an actuator, while a pressure sensor is used to provide a feedback signal. The controller drives the valve so that fuel is injected into the system in such a way that the dynamic pressure oscillations are canceled. While only one sensor was used for pressure feedback, several additional pressure and flame sensors were used to analyze

Electronic control unit for industrial and marine engines.

the system dynamics, as shown in the illustration below. The first step in the development of the controller was to establish the optimal location of the valve and this was achieved via system identification. dSPACE Prototyper was used to drive the valve with various test signals and capture data from the sensors. The data was then analyzed using MATLAB, with the result that the best response could be obtained by modulating the fuel through the premixer. In the next step, several control strategies were implemented in the Simulink/RTI environment, and the dSPACE system provided a powerful method for rapid implementation and evaluation of these strategies. dSPACE Prototyper proved itself as a powerful processing platform, capable of handling both control and system monitoring functions at high sample rates. ControlDesk was used to tune parameters and monitor data during real-time operation.

The most successful controller produced a 75% reduction in the amplitude of 320-Hz oscillations and proved that active combustion control is an effective method of attenuating thermoacoustic pressure oscillations. In the next phase of the project, the active combustion control system will be tested on a full-scale combustion rig and then on a complete gas turbine engine. The development team is planning to have a production-ready solution when the engine enters production in 2002.

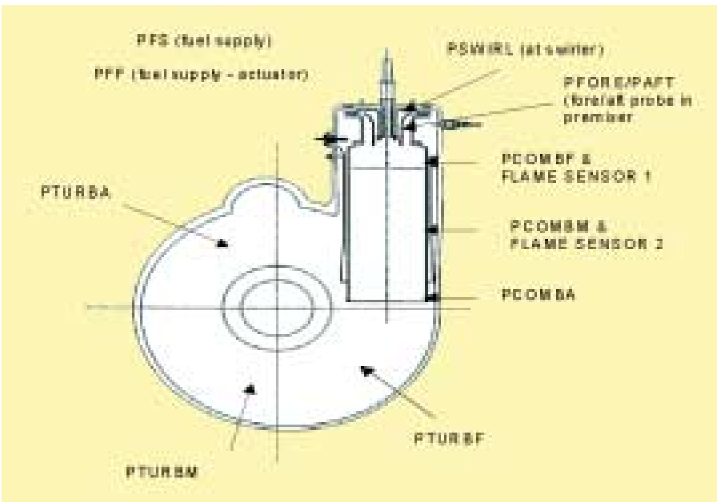
Mike Scott
Senior Controls Engineer
Honeywell Engines and Systems

Software Versions on "Solutions for Control" Release 3.0

dSPACE software runs under Windows 95 / 98 / 2000 and NT 4.0.

- RTI 3.6 / 4.0
- ControlDesk 2.0
- MLIB/MTRACE 4.2
- RealMotion 1.1 (only Windows NT)

For more detailed information, please refer to *www.dspace.de*.



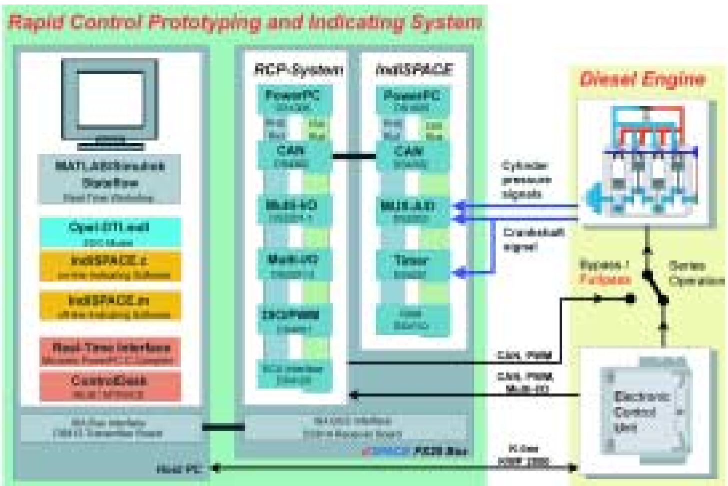
Test setup for active combustion control on ITG combustor rig.

New Concepts for Individual Cylinder Control

CUSTOMERS

- Direct download of Simulink models to dSPACE Protoyper
- ControlDesk for on-line adjustment of experiment parameters
- Development system for broad use, e.g., at Bosch/Germany

When it comes to diesels, engine developers are looking for new approaches to fulfill increasing requirements on fuel consumption or emission levels. One example is the application of cylinder pressure based diesel engine management. With the advent of new piezoresistive and optical sensors, closed-loop engine control can be achieved. A dedicated development system was set up at the Institute of Automatic Control at the Darmstadt University of Technology . This system comprised dSPACE Prototyper, dSPACE modular hardware, the indicating software and Simulink models.



System configuration.

Our diesel engine management is based on the pressure of the combustion chamber measured against the crankshaft angle. This gives us vital information on the combustion process. The subsequent design and optimization of diesel engines along with the development of the electronic control unit (ECU) is based on this data. Thanks to new miniaturized sensors, the pressure measurements do not require additional drillings in the cylinder, as they can be mounted as add-on devices to the glow plugs or the injection valves. This enables cylinder pressure based engine management featuring a torque based engine control. Within the scope of a special research program of the German research society, “Deutsche Forschungsgemeinschaft, SFB 241: Innovative Mechatronic Systems”, we developed such a management system and tested it using a 2.0 liter, 75 kW Opel-DTI diesel engine. To do so, we set up a test stand with dSPACE Prototyper. From this arrangement we derived an online indicating system which already reached product level and is commercially available. Bosch has acquired this indicating system for use with dSPACE AutoBox, to name just one example. The featured test stand consists partly of dSPACE Prototyper and partly of modular dSPACE hardware, which we customized.

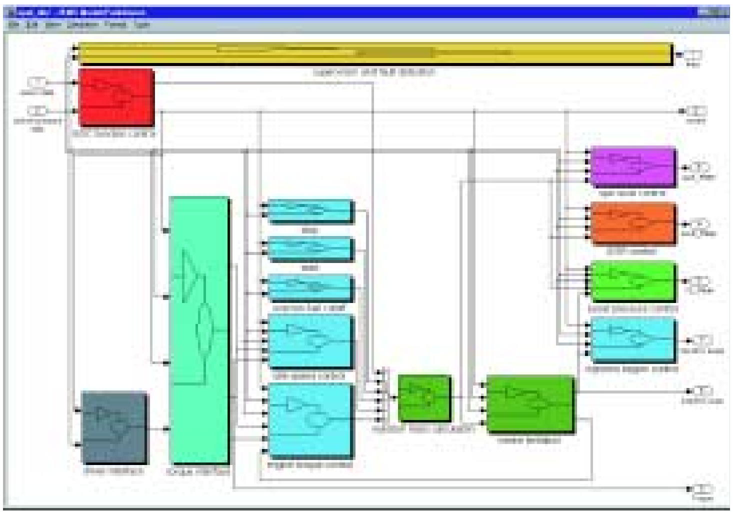
Engine test stand: Opel-DTI diesel engine and asynchronous machine.

Multiple Components of the Development System

The indicating system used to measure cylinder pressure and trace additional dynamic engine signals enables real-time data capturing and processing with a resolution of 0.75°, 1°, 3° and 6° crank angle. This data is evaluated and transferred via CAN to dSPACE Prototyper, where the engine control is performed. The control functions on dSPACE Prototyper are implemented graphically via Simulink blocks. To connect the dSPACE hardware with the Simulink environment, we use Real-Time Interface (RTI). For experiment control and visualization, we have the latest version of ControlDesk. We also make use of the test automation feature integrated within ControlDesk. The information obtained can then be processed offline with MATLAB and dSPACE’s MLIB/MTRACE.

Engine Management

By evaluating the series CAN messages, PWM signals and actuator control, the diesel engine can be operated with dSPACE Prototyper in three different modes:



ECU function level of Simulink model.

- Series Operation: The series parameters are applied.
- Bypass: Extracted ECU functionalities are performed on dSPACE Prototyper.
- Fullpass: All engine control functions are performed on dSPACE Prototyper.

As a result, a suitable engine management system can be developed step-by-step. We examined the series production ECU's functionality and mapped the relevant data on dSPACE Prototyper accordingly. The function design for the cylinder pressure based diesel engine management is performed completely in fullpass mode. The substantial new functions implemented so far:

- Cylinder-selective calculation: the indicated torque and the friction torque are calculated in real time with a resolution of 1° crankshaft angle
- Engine torque interface: enables the driver's torque demand in relation to engine speed and accelerator pedal position with reference to external torque demands
- Global feedback control: the engine's output torque is fully controlled in compliance with the exhaust behavior of the series production engine
- Adaptive cylinder torque balancing feedback control: enables the compensation of cylinder torque differences to the mean indicated cylinder torque, in compliance with the exhaust behavior of the series production engine
- Providing characteristic cylinder pressure values: real-time calculation of the thermodynamic and signal-based cylinder pressure values with a resolution of 1° crankshaft angle for future functions
- Diagnosis interface: the integrated diagnosis interface features supervision and fault detection functions

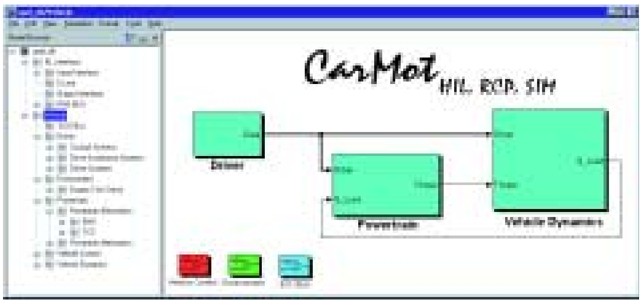
The functions based on Simulink models are calculated with a sample time of 1 ms. In addition to the new cylinder-pressure based functions, we also implemented the standard ECU control functions on dSPACE Prototyper. This includes the control of the injection mass and the injection timing for all cylinders, boost pressure and spin level control. The similarity to the series production ECUs can be validated by switching the test stand from fullpass to series mode.

Conclusion

For diesel engines, both a torque control system and a torque balancing system running on dSPACE Prototyper, in conjunction with our implemented online indicating system, were evaluated. The compensation of mean torque inequalities of 10-15 Nm is possible, reducing mean torque differences to values around 0.1 Nm. The implemented algorithms proved the considerable potential of cylinder pressure based diesel engine management systems for meeting and maintaining future engine specifications and requirements. Since the ECU is part of a fully structured vehicle model including vehicle dynamics and engine, it is ideally suited to perform hardware-in-the-loop simulation (HIL), which is also based on dSPACE technology.

Oliver Jost
Institute of Automatic Control
Darmstadt University of Technology
Germany

The unveiled online indicating system is a ready-to-go solution and available either as a single processor (IndiRCP for in-vehicle experiments) or multiprocessor version (IndiRCP-MP for lab-based experiments).
Please inquire at the Institute of Automatic Control/Darmstadt University of Technology/Germany,
www.tu-darmstadt.de/iat



Structured overall model with all relevant vehicle components.

CLAAS Takes TargetLink to the Fields

CUSTOMERS

- **CLAAS opts for TargetLink for transmission control**
- **TargetLink is four times better than supplied library functions**
- **TargetLink boosts coding speed like an additional programmer**

Alongside the CLAAS products for farming, CLAAS Industrietechnik, a subsidiary of the CLAAS Group, also produces hydraulic components and transmissions. When it came to developing the transmission control for the TRAXION transmission for application in XERION, CLAAS' new basic machine, TargetLink played an important part in production code generation. Our team of developers used TargetLink to generate the control software for the hydrostatic part of the transmission, not only considerably boosting computing speed, but also cutting the time needed by over 50% compared with handcoding.

CLAAS XERION at work.

Innovative Transmission Systems

The continuously variable TRAXION transmission is based on the principle of power split technology. It consists of a mechanical part and a hydrostatic transmission. In conjunction with a specific gear arrangement, this ensures continuous adjustment. The variable characteristic is achieved when an adjustable swash plate changes the displacement of a hydraulic pump. Mechanical clutches within the transmission are also engaged in a very specific manner.

What is Controlled?

The controller for the hydrostatic part of the transmission adjusts the swash plate of the hydraulic pump so that the desired speed is reached at the transmission output. RPM sensors at the transmission input and output and valve current meters are the key input variables.

The actuators are electro-hydraulic and operate proportionally to achieve continuous adjustment to the angle of the swash plate.

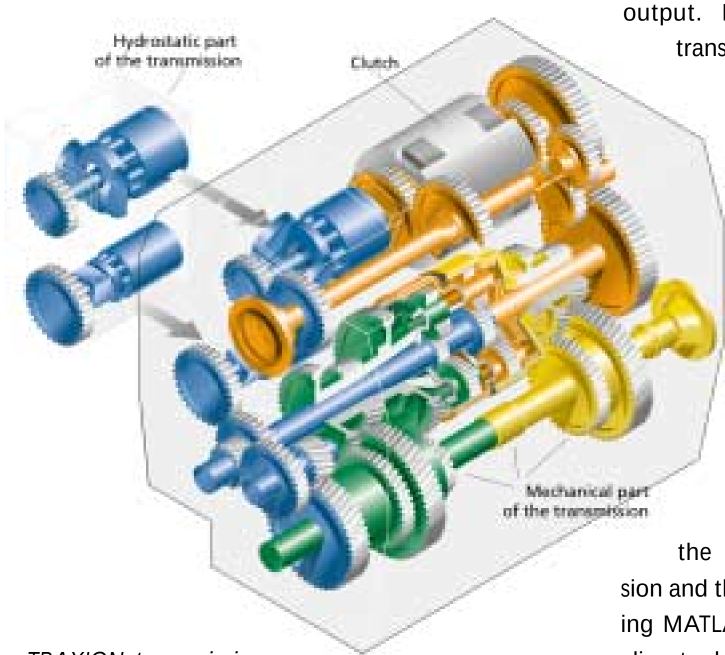
We developed and specified a model of the hydrostatic transmission and the control structure using MATLAB/Simulink, the modeling tool from The MathWorks.

TargetLink – Far Better than Supplied Library Functions

After C implementation with supplied library functions for integer computation returned unsatisfactory results, we decided to use a production code generator for our second attempt. Our specifications were that it must be easy to learn, have very good integration into MATLAB/Simulink, and generate efficient production code.

Even during the evaluation phase, TargetLink produced an improvement in run-time behavior of 400% compared with the library functions. The comprehensive simulation and optimization options helped us to generate high-quality code. The ability to record the minimum and maximum values of the variables during simulation was particularly helpful in scaling.

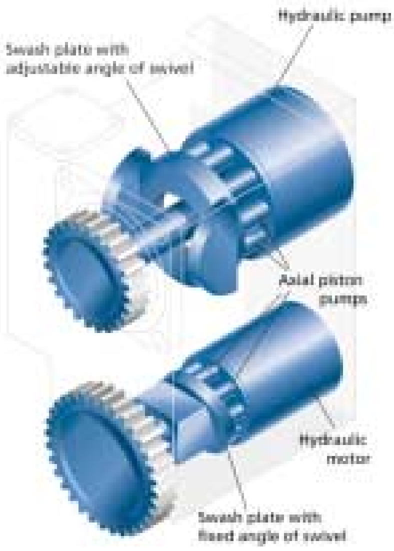
When the code had been generated, the TargetLink code was implemented on a test ECU (electronic control unit) together with the handcoded I/O functions and tested on a real transmission unit. The result: The code generated by TargetLink can be transferred to the production ECU without any modifications.



TRAXION transmission with hydrostatic and mechanical part.

As Reliable as a Swiss Clock

TargetLink made it possible to significantly enhance the performance of the controller previously designed in MATLAB/Simulink. Our requirements with respect to code quality, readability and integration capability were fully met. However, the decisive factor was the short learning curve needed for learning. It took us only half a day to produce the first useful results. As controller development progressed, TargetLink code consistently proved to be reliable. The development time for the control of the hydrostatic part of the transmission was reduced to half the time originally planned for.

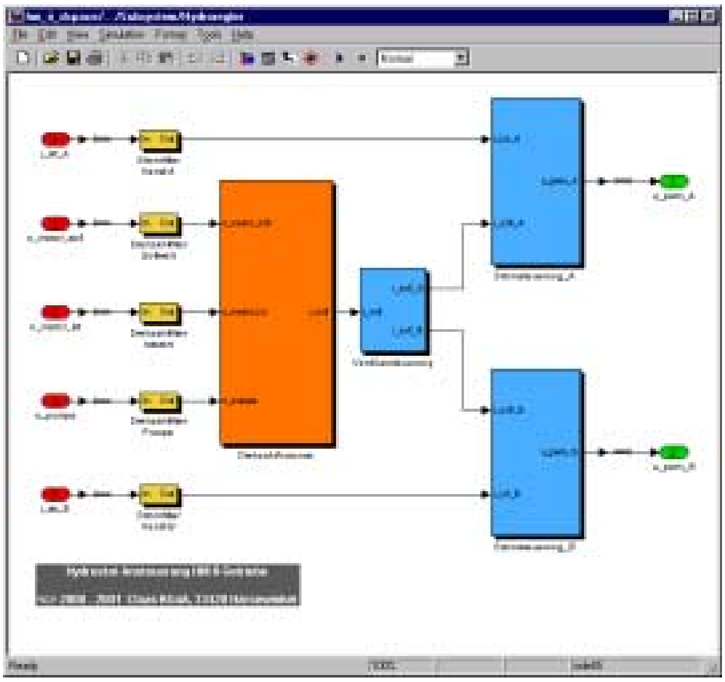


Hydrostatic transmission.

Future

At CLAAS, we are convinced of TargetLink's value and are already using it in two further projects: a project for automatic steering and a project for automatic reel speed control of the cutterbar in combine harvesters. To sum up, we would say that TargetLink has become an important tool for our development departments. We are looking forward to using TargetLink in other applications.

Andreas Wilken
CLAAS KGaA
Germany



Excerpt from the hydrostatic transmission controller.

The Principle of Hydrostatic Transmission

Hydrostatic transmission units consist of a hydraulic pump and a hydraulic motor. The hydraulic fluid transfers the force from the hydraulic pump to the hydraulic motor. On the hydraulic pump, there are several axial pistons arranged in a ring and sliding on a swash plate while rotating with the cylinder block. The swash plate itself is fixed in this version. The pumping action is produced by the entire assembly with the axial piston pumps rotating on the swash plate.
By adjusting the angle of swivel of the swash plate on the hydraulic pump, it is possible to vary the volume of hydraulic fluid delivered in the hydraulic pump and therefore also in the hydraulic motor. This means that the output speed of the hydrostatic transmission unit can be regulated continuously.
The hydraulic motor operates on the completely opposite principle. The hydraulic fluid now exerts pressure on the axial pistons, which are also arranged in a ring, thus applying force to a swash plate. Here too, the swash plate is fixed, thereby generating torque on the axial piston pump assembly, which is fixed rigidly to the drive shaft. In this way the hydraulic energy is converted back into mechanical energy.

Project Information

Software:

- **Model design: MATLAB/Simulink**
- **Production code generation: TargetLink**
- **Model size: approx. 300 Simulink blocks**

Control unit hardware:

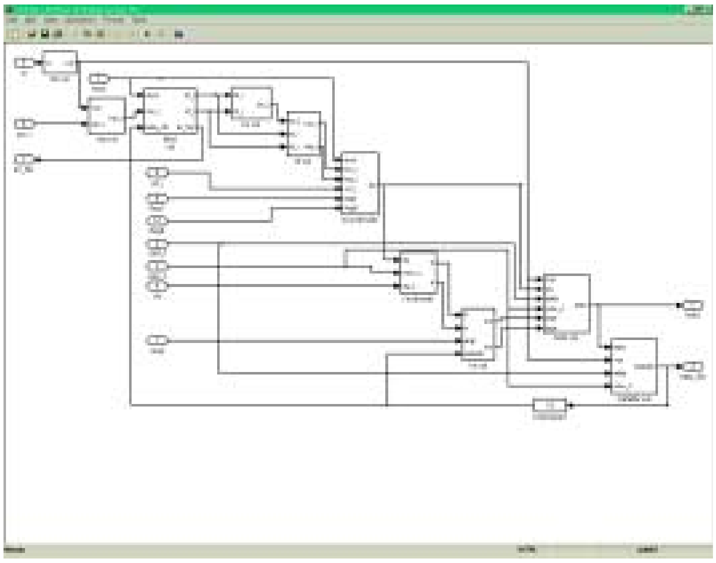
- **Processor type: Infineon C167CS**
- **Operating system: osCAN by Vector Informatik**

TargetLink for ESP Controller Development

CUSTOMERS

- **Porting time for multiple processors massively reduced**
- **Implementation of functions without any assistance from programmers**
- **TargetLink code for production-type controller**
- **100% ANSI-C-compliant code with TargetLink**

The most recent automotive controllers tend to serve more demanding functions, which increases the complexity of the implemented control logic. For example, the Electronic Stability Program (ESP) system developed at Unisia Jecs Corp. supports oversteer and understeer control. Compared to ABS, the code of the ESP system is up to 3 times longer. The demand for shorter development cycles increases the pressure on design engineers to come up with new products. We therefore evaluated the dSPACE production code generator, TargetLink, and its impact on the development process.



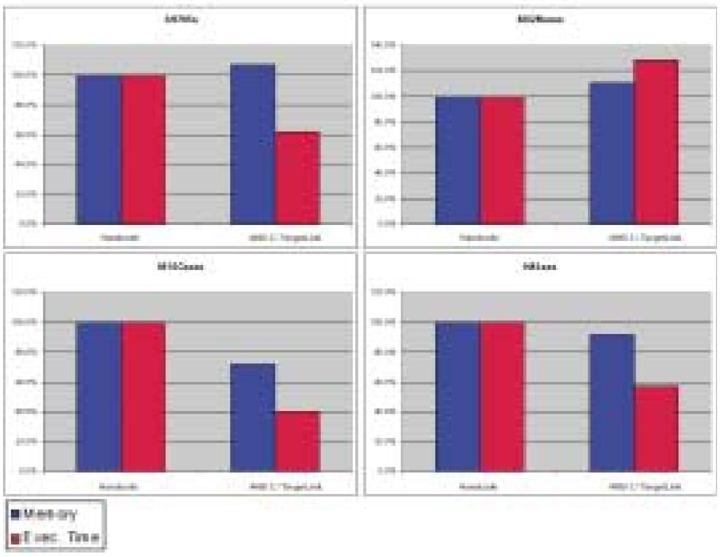
Simulink model for slip-angle estimation with an observer.

A Natural Decision

The control logic is developed on the basis of a MATLAB/Simulink/Stateflow environment. The conversion of the graphical specification into C code is usually done manually for use in a production-type electronic control unit (ECU). Consequently, we investigated if a tool can be applied to generate the production code automatically. Since TargetLink works hand in hand with Simulink, we decided to evaluate TargetLink's suitability.

Starting Small

We chose the vehicle slip-angle estimation module for the evaluation, which is the core element of the ESP controller. The corresponding algorithm performs a slip-angle estimation, which is implemented by an observer methodology. The input data includes steering angle, yaw rate and lateral acceleration. The controller also contains error-sensitive integrators and various other types of control functions, which increases the code size considerably. We compared the handwritten C code with the code generated by TargetLink. This comparison covered code size and execu-



Memory consumption and execution time on each processor.

Papers

L. Köster, T. Thomsen, R. Stracke:
"Connecting Simulink to OSEK: Automatic Code Generation for Real-Time Operating Systems with TargetLink"
(SAE Paper 2001-01-0024)
English **04**
German **05**

H. Schütte, M. Plöger, K. Diekstall, P. Wältermann, T. Michalsky:
"Test Systems in the ECU Development Process"
English **06**
German **07**

T. Pöhlmann: "Nissan Sentra: Wesentliche Funktionen des Steuergeräte-Codes mit automatisch generiertem Code programmiert"
German **08**

tion time, and was carried out according to ANSI specifications. In other words, no processor-specific code was generated since at that time there was no optimization module available for our processor types.

The Comparison

For evaluation purposes, we tried the TargetLink code on various types of processors, with either RISC or CISC cores, from Mitsubishi and Hitachi. We particularly had a close look at portability and compared the hand code with the generated code. What we found was this: The TargetLink-generated code for the ESP controller performed identically on each examined processor. In contrast, the ESP controller we coded manually always required further modifications, even though our programmers thought they complied with the ANSI standard fully. This is especially important when transferring the code to a different processor type. With TargetLink, the time for porting the code is decreased by 75%. The maximum increment in code size is only a few percent, except for the Mitsubishi M32R. The code for the H8S and the M16C is actually smaller than the hand code. Since the TargetLink code shows improved execution times, we achieved a better performance than we initially thought by going for the SH705, H8S and M16C.

Hand code for the H8S needs further amending due to overflow.

The Consequences

Based on our findings, we decided to opt for TargetLink as the tool to code the ESP controller. TargetLink has now become the standard for generating production code in our development department. In our opinion, TargetLink's most important feature is the ability to generate the code directly from the Simulink diagram. Our engineers achieved a highly-efficient development process with TargetLink without any assistance from programmers. This is extremely important in a real vehicle environment, especially when carrying out off-site tests such as winter test drives.

> Please note that this article only reflects TargetLink's capability to generate ANSI C compliant code. If you use the optional TargetLink Optimization Modules, you can generate target-specific code, which takes full advantage of processor and compiler-specific features.
> TargetLink Optimization Modules with TargetLink 1.2 are now available for various types of processors, such as Mitsubishi M32R, Hitachi H8S or Motorola HC12.

Future Plan

We intend to use TargetLink for coding projects with greater complexity and even more code. This will require improved libraries. Here we expect further progress with the use of TargetLink 1.2.

Hitoshi Kobayashi
Motohiro Higuma
Chassis & Drive Train
Control Systems
Development Dept.
Unisia Jecs Corporation

dSPACE Training

For more details, please visit *www.dspace.de* or check the corresponding field on your response card. Further dates available on request.

dSPACE Systems

Paderborn, Germany:
- August 21/22, 2001

ControlDesk Basics

Paderborn, Germany:
- September 11, 2001

ControlDesk Advanced

Paderborn, Germany:
- September 11/12, 2001

Test Automation

Paderborn, Germany:
- September 12/13, 2001

TargetLink

Paderborn, Germany:
- July 19, 2001
- August 30, 2001
- October 18, 2001

HIL Simulation

Paderborn, Germany:
- October 10/11, 2001

INFO 01

dSPACE Goes to China

MISCELLANEOUS

dSPACE's official distributor in China is now China HiRain, a Beijing-based company with a branch office in Shanghai. Founded in April 1998 with just four employees, China HiRain has already expanded to a staff of 36, including 12 field application engineers and 12 technical sales personnel. The company's primary goal is to promote first-class tools for CDA/DSP/CAE (Control Design Automation / Digital Signal Processing / Computer Aided Engineering) in China and provide the best possible engineering support to Chinese customers.

The team serving the Chinese market with dSPACE tools.

China HiRain helps its customers to streamline the development processes to achieve better and more cost effective products in less time.

Customers of China HiRain come from a wide range of industries, such as automotive, aerospace and communications. More than one hundred engineers attended the dSPACE seminars held in Shanghai and Beijing in March 2001. China HiRain Technologies also distributes for The MathWorks, so the company covers the whole control engineering cycle.

The highly motivated team at China HiRain has achieved 30% profit growth every year since its founding. For further information, just point your browser to www.hirain.com.

China HiRain Technology Co. Ltd.
Shangfang Plaza No. 27
Room 620
Bei San Huan Zhong Lu
100029 Beijing
P.R. China

Our Most Successful SAE to Date

At the SAE 2001 World Congress and Exposition, held March 5-8, 2001 in Detroit, the dSPACE Simulator Compact made its debut as the latest addition to the simulator product line-up. The simulators' cutting-edge technology with integrated software and hardware provides convenient and flexible systems that make virtual testing a reliable and cost-effective alternative to on-road, in-vehicle tests. Driving cycles, data acquisition, instrumentation, monitoring, and test scenarios are created and executed graphically within dSPACE Simulator. "dSPACE Simulator Compact employs the same unique technology as our bigger simulators when it comes to capturing and generating crank angle-based, purely time-based, and crank angle-triggered time-based signals of injection, ignition, engine knock, and camshaft – including cam phasing – at less than a tenth of a degree of crank angle resolution," said Herbert Hanselmann, President and CEO of dSPACE.

Unveiled at SAE: dSPACE Simulator Compact with peripheral components

As for the event overall, SAE officials were concerned that with some of the largest exhibitors withdrawing this year, attendance would suffer. But judging from the action on the show floor and the traffic at the dSPACE booth, the fear was unfounded as registered attendance is expected to exceed totals for 2000. dSPACE took this opportunity to shine and display why it is the leader in solutions and systems for development of embedded electronic controllers, with TargetLink, ControlDesk, MicroAutoBox, Vehicle Dynamics Simulator with the Alpha version of the new 3-D animation tool MotionDesk, and Engine Simulator demonstrations.

In addition to product demonstrations, SAE was a great opportunity for sharing technical know-how and techniques. dSPACE's newly formed Product Management group members joined local Michigan-based dSPACE team members in support.

MISCELLANEOUS

Thomas Thomsen, TargetLink Product Manager, presented the technical paper, Connecting Simulink to OSEK: Automatik Code Generation for Real-Time Operating Systems with TargetLink (see paper box on page 8). Visteon, a major dSPACE customer, provided our booth's centerpiece attraction. It was a 1500cc V2 Fuel Injected Standard Cruiser Victory Motorcycle test vehicle, displaying an easy–to–use bypass methodology to develop and assess new functionality within the existing powertrain control module using dSPACE Prototyper. Additionally, Michael Burke from Visteon presented a technical session entitled "The Automotive Embedded Software Development Lifecycle."

Even for motorcycles: dSPACE Prototyper to develop new powertrain control module.

We would like to thank all of our customers that attended SAE and came to the dSPACE Customer Appreciation Reception held at the Detroit Renaissance Center.

Japanese User Conference

The dSPACE User Conference in Japan was held on April 4, 2001 in Tokyo. With 265 attendees our expectations were well exceeded. Experts from the automotive industry and mechatronic sector came together to talk about their experience with dSPACE solutions, providing us with positive feedback throughout.

The conference kicked off with a session on the latest dSPACE products, such as dSPACE Prototyper, TargetLink and dSPACE Simulator. These presentations were complemented by Dr. Herbert Hanselmann's speech on the dSPACE business strategy.

Our cooperating partner TESIS also contributed a presentation on modeling, which encompassed engine design and vehicle dynamics. The highlighted models are used increasingly by Japanese users of dSPACE Simulator to simplify the system setup.

The conference continued with applications by dSPACE power users, for example, DENSO, Fujitsu, Honda R&D, Nissan, Saitama University and Toyota. Toyota showed how they apply dSPACE Simulator based on the DS2210 HIL I/O Board. Honda R&D illustrated how they use dSPACE Simulator to develop ECUs for automatic transmissions. Nissan gave an insight into their design approach for engine controller development, which comprises the entire dSPACE tool chain, including Target-Link. Last, but not least, DENSO presented how they successfully make use of the model-based development environment provided by dSPACE and TESIS products.

The aim of the user conference is to provide an exchange forum in a comfortable atmosphere; the evening party was just the right setting. The conference's attendees appreciated this approach because they could talk with other engineers who work for competitive companies. So, a big thank you to everyone who made the conference a tremendous success.

Nobuo Murakami
LinX Corporation
Japan

Making contact: dSPACE users from different companies.

Audi: Complete Powertrain Simulation

CUSTOMERS

- Networked HIL simulators
- Simulation of complete powertrain
- Operation like a real car
- Simulink-based simulation with TESIS DYNAware models

Audi is to apply dSPACE Simulators to the task of developing powertrain electronics for an increasingly complex networked vehicle. SPEA (German: Simulationsprüfstand vernetzter Elektroniksysteme im Antriebsstrang) is the first simulation rig to provide a complete powertrain simulation in real time.

The rapid growth of networks in vehicle electronics has led to an increase in the cost and complexity of experimental vehicles. Consequently, the use of development rigs has risen and is already the established practice for interior electronics at Audi. For powertrain electronics, however, the introduction of hardware-in-the-loop simulators (HIL simulators) is essential; the electronic control units (ECUs) contain complex control algorithms with sensitive fault recognition and cannot be operated realistically without an HIL environment. In addition, a given vehicle can include numerous powertrain variants (engines, transmission types, etc.), which multiply the cost of building a rig unless simulation is applied.

HIL at Audi

Individual powertrain ECUs have been developed and tested successfully at Audi with HIL simulators from dSPACE for several years. However, such simulators are tailored to the needs of each specific ECU; that is, their behavior in a network is given a low priority, and partnering ECUs are either absent entirely or at best simulated only crudely. The challenge presented by SPEA was to improve and apply HIL technology to the development and testing of distributed powertrain functions.

User Requirements

The requirements for SPEA were produced in close cooperation with the intended users. The priorities were maximum configurability and operation as close as possible to that of a real vehicle. Further specifications were maximum reusability of HIL components, minimum downtimes for reconfiguration and upgrades, and extensive features for monitoring and manipulating CAN messages. Displays had to be set up, and the chosen vehicle configured, from a single PC.

Chosen Architecture

The baseline architecture incorporates engine management (twin ECUs for some variants), transmission control and chassis control (ESP, air suspension). Physically, the architecture comprises one dSPACE Simulator (central unit) as the master controlling three further dSPACE Simulators (I/O Units for engine, transmission and chassis control) via high-speed optical links. Each I/O Unit contains all the necessary signal conditioning hardware and electrical loads (partly simulated, partly real components) for its ECU(s). The central unit generates the exterior view using the RealMotion 3-D tool, shortly to be replaced by its successor, MotionDesk.

Operation from the PC – and soon from a real vehicle.

The existing Simulink models from TESIS (engine, transmission and running gear) were integrated into a single powertrain model. This runs completely in the central unit. The excellent performance of the multiprocessor system with three processor boards made it possible for the simulation to run at speeds exceeding those of stand-alone HIL simulators.

This architecture has several major advantages:

- The interfaces between model components (for example, between engine and transmission) exist purely in software. This avoids problems with timing due to hardware protocols and feedback delays and simplifies the hardware interfaces between the SPEA units.
- Reconfiguring SPEA to behave as a different model variant (for example, conventional automatic

transmission instead of CVT, V8 engine instead of V6) only requires the model on the central unit to be reconfigured, and not each simulator individually.

- The commissioning process is simplified; missing I/O Units can be replaced by ECUs simulated in the central unit (SoftECUs), without rebuilding any code. This also allows SPEA to be used while components are upgraded or disconnected.

Operation Like a Real Car

In the SPEA cockpit, all the driver controls relevant to powertrain systems are installed as in a real vehicle. These components are connected to the central unit and wired to the appropriate ECUs, for example, the accelerator pedal sensor to the engine ECU via discrete wiring, or the steering angle sensor to the ESP electronic control unit via the powertrain CAN bus. Parallel to these, additional sensors provide independent information about pedal positions, steering angle, etc. The sensors also transmit this information to the central unit via a dedicated Simulation CAN bus.

Expandability and Reusability

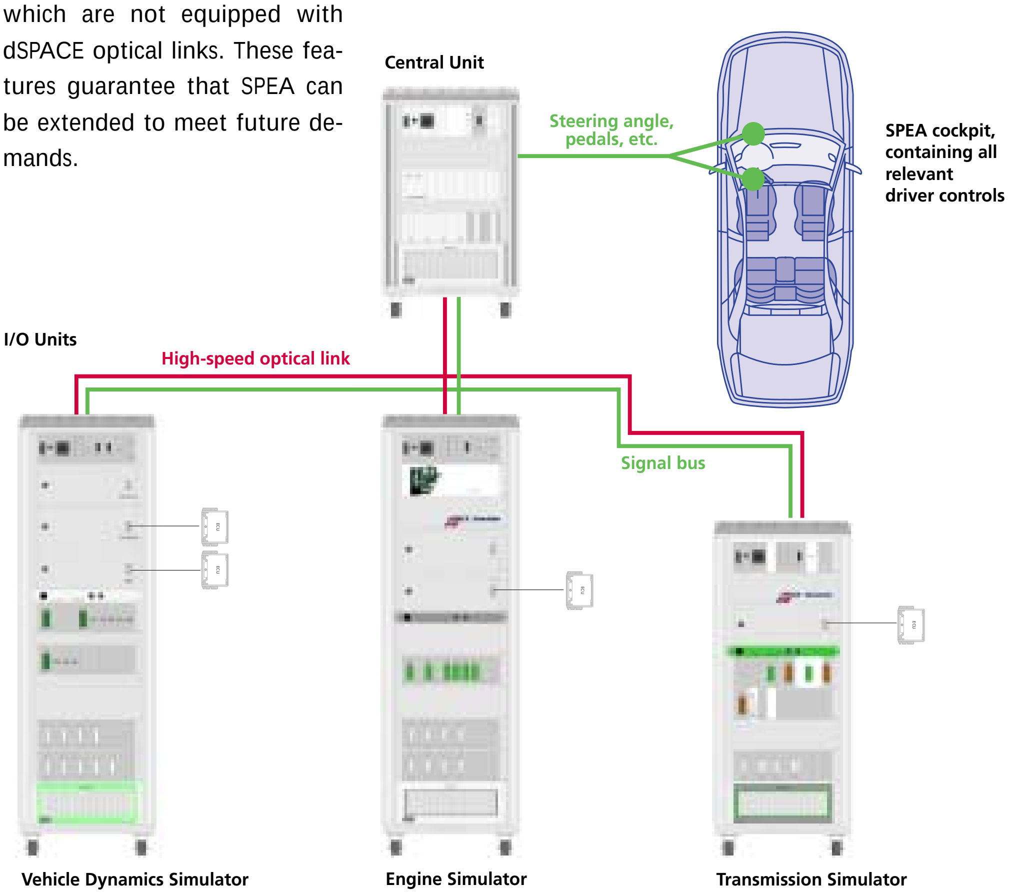
In addition to signal conditioning hardware, each I/O Unit contains adequate processing power to allow it to be reconfigured per software and used as a standalone HIL simulator. Because the SPEA powertrain model incorporates the same models used in existing single-ECU HIL simulators, it profits from every improvement and modification to engine, transmission or chassis models made during the development of new ECUs. The Simulation CAN bus can be used to exchange information between the standard SPEA components and any additional simulators which are not equipped with dSPACE optical links. These features guarantee that SPEA can be extended to meet future demands.

Conclusion

dSPACE has demonstrated a willingness to extend its product family to meet the challenges posed by Audi's requirements and succeeded in resolving the conflict between the need for maximum flexibility and the simplest possible operation. SPEA provides Audi engineers with an environment in which powertrain systems for all vehicle variants can be tested and functional prototypes can be developed and proven. It will become an irreplaceable tool for the development and testing of powertrain control systems for all future Audi models.

Adrian James,
Audi AG,
Germany

HIL test of distributed powertrain functions: each dSPACE Simulator can be used in a network or as a stand-alone system.

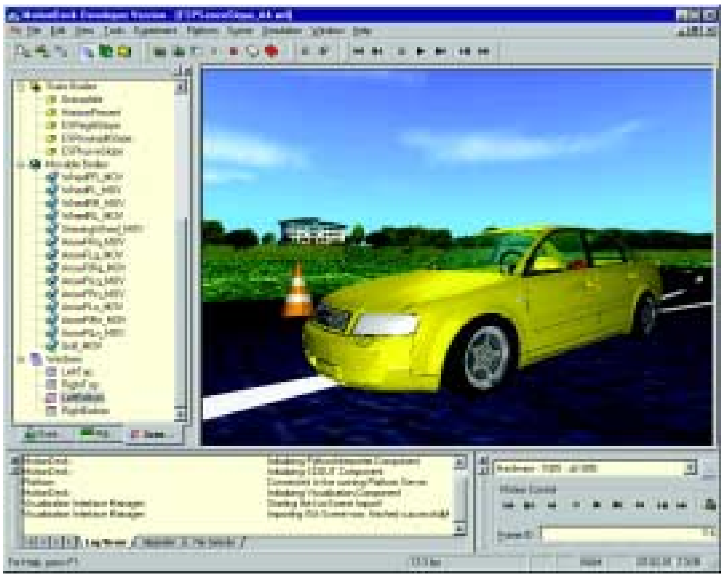


MotionDesk: Seeing is Believing

PRODUCTS

- 3-D online animation of simulated moving objects
- Graphical scene design
- Realistic visuals achieved via textured rendering
- Intuitive scene navigation

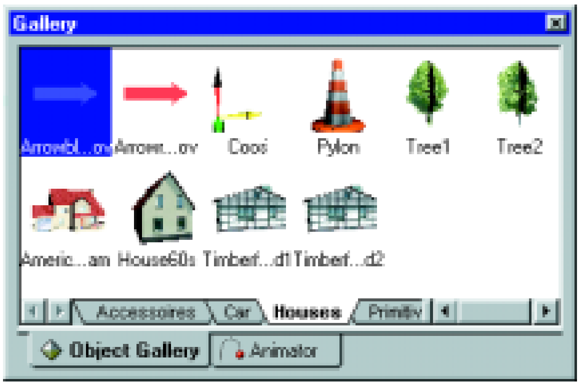
Vehicle dynamics simulations without 3-D online animation are inconceivable. To give 3-D animation within the dSPACE tool chain a new meaning, the 3-D animation tool MotionDesk is under development



Typical driving scene in MotionDesk.

Visualizing Simulations

Real-time simulations are usually visualized abstractly by time histories or instruments. However, it is difficult to infer the actual movement of the simulated object, such as a car, by simply viewing plots displaying forces or angles. MotionDesk offers the solution to this problem. It displays the movements of objects simulated on dSPACE Simulator. Any modification made to the running simulation is visualized on the screen immediately. The graphical user interface of MotionDesk is similar to ControlDesk and allows intuitive handling of scenes and animations. MotionDesk is fully compatible with its predecessor RealMotion. Real-time applications animated with RealMotion can also be animated with MotionDesk without any changes to the underlying interface to the real-time process. MotionDesk is much easier to operate, and the animation much more realistic.



Examples of an object gallery.

Extensive 3-D Object Library

A wide range of 3-D objects for vehicle dynamics simulation, such as car components, streets, trees and houses, is available in a 3-D object library. If the available objects do not fulfill the requirements, the library can be expanded easily, as 3-D object geometries are described in the VRML 2 standard.

Interactive Scene Editing

The objects are assembled into a scene interactively under Internet Scene Assembler (third-party product from ParallelGraphics). The scene can be displayed in various rendering techniques: wire frames, flat shapes, Gouraud shading, or texture mapping, to get realistic-looking virtual world.

Online Animation

To achieve the right view in the virtual world, observers can be defined with various behaviors, e.g., static in the scene or following a moving object. To visualize the active forces, corresponding force vectors can be superimposed during online animation.

When the animation is run, MotionDesk acquires the motion data from dSPACE Simulator and animates the moveable objects in the scene. The motion data can be recorded and replayed for a detailed analysis after simulation.

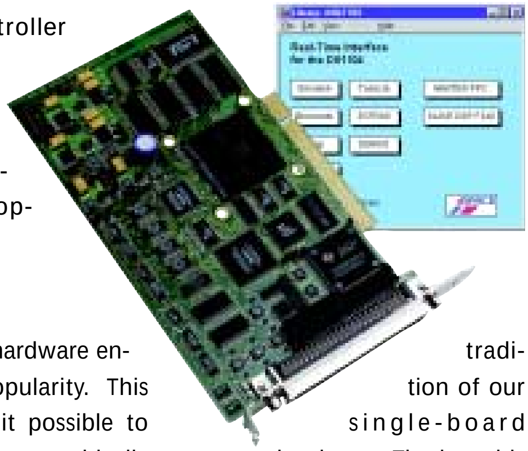
Further Fields of Application

Although MotionDesk is mainly used to visualize automobiles, it can also be used for other applications, such as robotics or flight simulation. Only the 3-D object library has to be expanded by the essential objects.

Release of MotionDesk is planned for spring 2002.

Pushing up Rapid Control Prototyping

You could be fooled into thinking it was a graphics card, but in reality, it is a powerful prototyping system from dSPACE: the DS1104 R&D Controller Board. This board is the "younger brother" of the DS1103 PPC Controller Board, and provides a cost-effective alternative for many controller developments.



Success Story

Our single-board hardware enjoys immense popularity. This hardware makes it possible to develop controllers graphically on a PC and then test them on real machinery – without manual programming. Graphical programming allows the control algorithm to be modified extremely fast: simply make your changes, and within seconds you will see the effects. No wonder our single-board hardware is often used for training purposes.

A Great Tradition

The new DS1104 R&D Controller Board carries on the successful tradition of our single-board hardware. The board is perfectly tailored to controller development in the field of drives and robotics. In addition to space vector modulation and three-phase PWM generation, it also offers a range of other I/O channels – for example, ADC, DAC, digital I/O or an incremental encoder interface. This makes the prototyping system an option in a wide range of development projects.

Full dSPACE Software Support

The controller runs on the DS1104's real-time processor, a PowerPC 603e with 250 MHz. Your PC performs the function of an input-output medium. For experiment setup and management, you can use the comprehensive range of dSPACE software products, particularly Real-Time Interface and ControlDesk for graphical programming and experiment management. The configuration of the I/O channels is performed completely in graphical form.

The complete system including hardware and software is even more reasonably priced with our special ACE Kit offer for universities. So if your PC has a free slot, why not turn it into a rapid control prototyping system?

PRODUCTS

- **New rapid control prototyping hardware**
- **Single-board solution with PCI Interface for your PC**
- **Available for universities in the cost-effective ACE Kit**
- **Release planned for summer 2001**

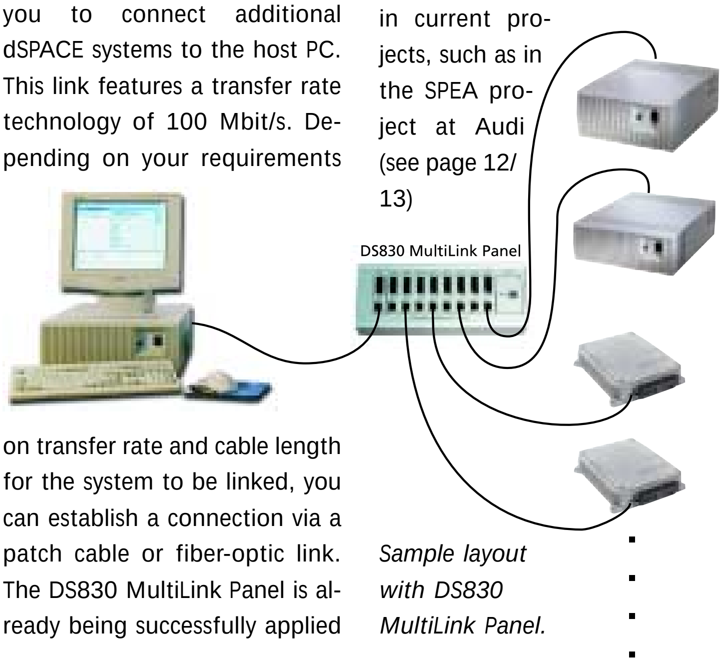
INFO 03

Increasing the Scope

Flexibility is crucial when it comes to extending the topology of your dSPACE system. With the new DS830 MultiLink Panel, you now have the advanced option of linking up to 16 dSPACE systems to only one host PC.

The linked systems might be expansion boxes, AutoBoxes or MicroAutoBoxes. Your benefit: all parts of the dSPACE system are under the supervision of only one host PC.

The DS830 MultiLink Panel requires only one ISA, PC card (PCMCIA) or PCI slot and corresponding Link Board, allowing you to connect additional dSPACE systems to the host PC. This link features a transfer rate technology of 100 Mbit/s. Depending on your requirements on transfer rate and cable length for the system to be linked, you can establish a connection via a patch cable or fiber-optic link. The DS830 MultiLink Panel is already being successfully applied in current projects, such as in the SPEA project at Audi (see page 12/13)



Sample layout with DS830 MultiLink Panel.

Events

Europe

PCIM
June 19–21
Nuremberg, Germany
Messezentrum Nürnberg, Hall 12
Booth #310a

VDI Getriebe in Fahrzeugen
June 19-20
Friedrichshafen, Germany
Graf-Zeppelin Haus

MessComp
September 4-6
Wiesbaden, Germany
Rhein-Main-Hallen

Elektronik im Kfz
September 27-28
Baden-Baden, Germany

HIL in der Fahrzeugtechnik
October 22-23
Essen, Germany
HdT Essen

USA

American Control Conference
June 25–27
Crystal Gateway Marriott
Arlington, VA
Booth #A3

Embedded Systems Conference Summer
July 9–12
Navy Pier
Chicago, IL
Booth #116

Guidance, Navigation and Controls Conference
August 6–9
The Queen Elizabeth Hotel
Montreal, Quebec, Canada
Booth #6

Embedded Systems Conference Fall
September 4-7
Hynes Convention Center
Boston, MA
Booth #1033

Representatives

Australia
CEANET Pty Ltd.
Level 4, 2 Bligh Street
Sydney NSW 2000
P.O. Box R202
Royal Exchange NSW 1225
Tel.: ++61 2 9232 3699
Fax: ++61 2 9232 3332
info@ceanet.com.au
www.ceanet.com.au

China
China HiRain Tech. Co. Ltd.
Shangfang Plaza No. 27
Room 620
Bei San Huan Zhong Lu
100029 Beijing, P.R. China
Tel.: ++86 10 82 02 19 50
Fax: ++86 10 62 07 36 00
www.hirain.com

Czech and Slovak Republic
HUMUSOFT s.r.o.
Novákových 6
180 000 Praha 8
Tel./Fax: ++420 2 684 41 74
info@humusoft.cz
www.humusoft.cz

France
The MathWorks France
20 rue Troyon
92316 Sevres Cedex
Tel.: ++33 1 41 14 67 14
Fax: ++33 1 41 14 67 15
info@mathworks.fr
www.mathworks.fr

India
Cranes Software Intern. Ltd.
29, 7th Cross, 14th Main
Vasanthanagar
Bangalore - 560 052
Tel.: ++91 80 2250 260
Fax: ++91 80 2250 413
dspace@cranessoftware.com
www.cranessoftware.com

Israel
Omikron Delta (1927) Ltd.
10 Carlebach St.
Tel-Aviv 67132
Tel.: ++972 03 561 5151
Fax: ++972 03 561 2962
info@omikron.co.il
www.omikron.co.il

Japan
LinX Corporation
1-13-11 Eda-nishi
Aoba-ku, Yokohama-shi
Kanagawa, 225-0014 Japan
Tel.: ++81 45 979 0731
Fax: ++81 45 979 0732
info@linxworld.co.jp
www.linxworld.co.jp

Korea
Darim System Co. Ltd.
Expo VentureTown
DoRyong-Dong 3-1
YuSung-Gu
Taejon
Tel.: ++82 431 260 4747
Fax: ++82 431 260 4748
ksh@mail.darimct.co.kr

Netherlands
TSS Consultancy
Rietkraag 37
NL-3121 TC Schiedam
Tel.: ++31 10 2 47 00 31
Fax: ++31 10 2 47 00 32
info@tsscon.nl
www.tsscon.nl

Poland
ONT
ul. Obozna 11
30-011 Kraków
Tel.: ++48 12 636 32 60
Fax: ++48 12 632 17 80
info@ont.com.pl
www.ont.com.pl

Sweden
FENGCO Real Time Control AB
Hallonbergsplan 10, Kompassen
Box 7068
SE-174 07 Sundbyberg
Tel.: ++46 8 6 28 03 15
Fax: ++46 8 96 73 95
sales@fengco.se
www.fengco.se

Taiwan
Scientific Formosa Corporation
11th Fl. 354-1 Fu-Shin N. Road
Taipei, Taiwan, R.O.C.
Tel.: ++886 2 2505 05 25
Fax: ++886 2 2503 16 80
info@sciformosa.com.tw
www.sciformosa.com.tw

United Kingdom
The MathWorks Ltd.
Matrix House
Cowley Park
Cambridge CB4 0HH
Tel.: ++44 1 223 423 200
Fax: ++44 1 223 423 255
info@mathworks.co.uk
www.mathworks.co.uk

dSPACE GmbH
Technologiepark 25
D-33100 Paderborn
Germany
Tel.: +49-5251-1638-0
Fax: +49-5251-66529
info@dspace.de
support@dspace.de
www.dspace.de

dSPACE Inc.
22260 Haggerty Road -
Suite 120
Northville - MI 48 167
Tel.: (248)344-0096
Fax: (248)344-9879
info@dspaceinc.com
support@dspaceinc.com
www.dspaceinc.com