# Cool When It's Hot

- Behr-Hella Thermocontrol: Development processes with dSPACE tools
- Production code generation with TargetLink
- Verification and integration tests with dSPACE Simulator

**Air-conditioning is now almost a standard feature in new vehicles. Improved comfort and the improved active safety that comes from a more pleasant driving environment are the main reasons why air-conditioning is so widespread. To tackle the ever-increasing workload involved in developing control strategies, Behr-Hella Thermocontrol has used dSPACE tools to set up a model-based development process that will allow more efficient work in many phases.**

Modern, fully automatic air-conditioning systems are complex, with numerous control loops, sensors and actuators. Climate control is affected by a large number of thermodynamic systems and environmental conditions, such as humidity, sunshine and ventilation, and of course the temperature inside and outside the vehicle. Thus, new ECU hardware and software can only be tested completely in a real vehicle. However, prototypes of new vehicle models are rarely available, and the real loads have not yet been determined. So at Behr-Hella Thermocontrol, we have created a simulation environment that allows comprehensive testing off-vehicle.

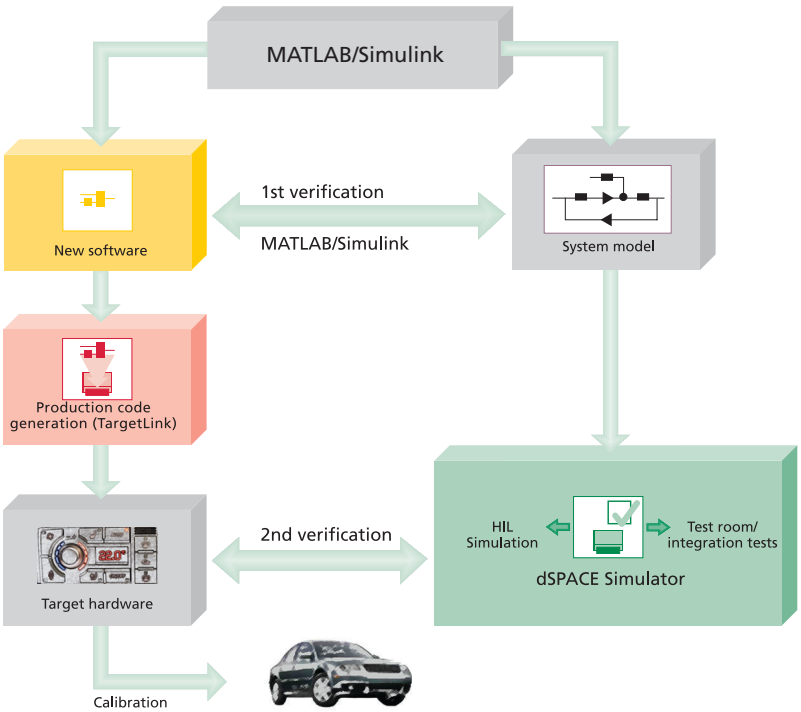
## Production Code Generation with TargetLink

We are using more and more MATLAB®/Simulink® to develop our ECUs. With appropriate system models, also available in MATLAB/Simulink, we can simulate new software modules or functions in interaction with the associated subsystems. The plan is to run this initial verification phase without real-time hardware.

For new functions, there is a prototyping phase, where we are successfully using dSPACE's MicroAutoBox in advance development. Next we program the ECU software. We do this with dSPACE's TargetLink, which automatically generates production code from our Simulink models. Software-in-the-loop (SIL) with TargetLink enables us to detect and remedy any function or quantization errors at an early stage. TargetLink is now being used successfully in several ECUs.

## Verification and Integration with dSPACE Simulator

Once the new ECU software is running on the target hardware, we use dSPACE Simulator in a second verification process: to test the interaction of hardware and software, with the real vehicle emulated by




▲ *Development process with dSPACE tools.*

models. This is hardware-in-the-loop simulation (HIL), and it enables any errors to be detected and corrected early on. dSPACE Simulator and the models also enable us to perform hardware/software integration tests in the test room. Ideally, in future we will need the real vehicle only for final tuning.

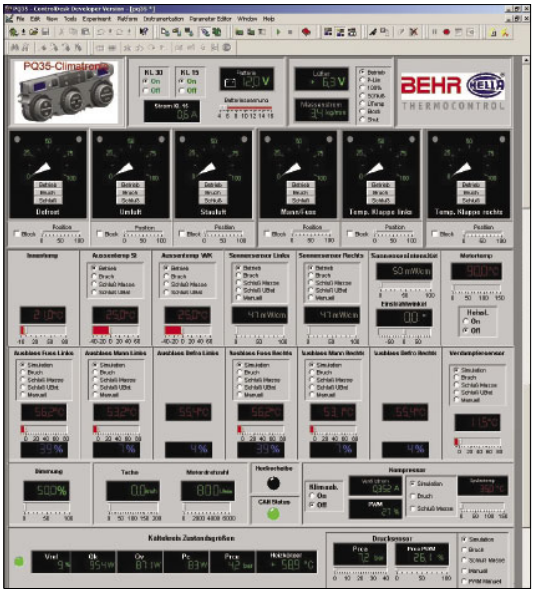

▲ *Air-conditioning ECUs from Behr-Hella Thermocontrol – developed with dSPACE tools.*

Our dSPACE Simulator is based on standard, modular dSPACE hardware: the DS1005 PPC Board for real-time computation and several A/D, D/A and digital I/O boards. In addition, we use several DS4302 CAN Interface Boards to simulate the CAN communication in the vehicle.

There is a controllable power supply and a universal connector system, and we have also integrated two in-house developments: a power module with four current sinks and four power switches, and a board that meets our special requirements regarding signal conditioning. Using this system, we have created a uniform hardware platform for testing our air-conditioning control units.

## Intelligent Use of Models

All models are based on MATLAB/Simulink. We do the modeling ourselves. We have the great advantage of being able to draw on Behr's know-how in thermodynamics and fluid dynamics. Moreover, we can easily integrate many of our customers' models such as look-up tables and specifications to the benefit of both of us.




▲ *ControlDesk and the upcoming AutomationDesk are central tools for automatic testing.*

We perform virtual test drives with our simulation environment. Typically, the process begins with a test drive in a real vehicle, during which we capture measurement values such as outside temperature, solar intensity, vehicle speed, engine speed and engine temperature. These measurement values form the basis for realistic simulation and are later fed into the simulation by means of ControlDesk Test Automation, dSPACE's software for test automation. We can "reconstruct" the test drives that were actually made in real time, using dSPACE Simulator.

The results of our work with dSPACE tools are very encouraging. SIL and HIL simulations, and virtual test drives with dSPACE Simulator, mean we can achieve comprehensive and practical verification, especially after software or hardware modifications are made. This gives us improved product quality. We plan to make more intensive use of dSPACE tools for prototyping and automatic production code generation. Our objective in HIL simulation is to model an entire vehicle from the point of view of climate control, and to develop fully automatic integration tests on the basis of dSPACE Simulator. As beta testers in this field, we have already had an opportunity to use AutomationDesk, a new dSPACE tool that promises great potential.

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