BMW: Production Code for Distributed Controller

- New damper control at BMW Group
- TargetLink used in the automated development process
- Time saved and quality increased

Active suspensions greatly enhance ride comfort – for example, by reliably damping the movements of the vehicle body. The BMW Group has developed a new damper control for dynamic stabilization, based on a distributed controller consisting of a central electronic control unit (ECU) and satellite ECUs. Production code for the extensive function model was generated with TargetLink in a largely automated development process. Other tools equipped with FlexRay were also used.

Suspension Control System

Controlled damping systems ensure that in all situations, modern cars have the ideal combination of comfort and safety. Conventional suspensions can only compromise between the two. The BMW Group's new damper control keeps car body movements, wheel load variations, and disturbances all under control. The complex control system consists of several sensors and actuators, and a total of five ECUs.

▲ *Modern damper controls from BMW ensure comfort and safety.*

Distributed Controller

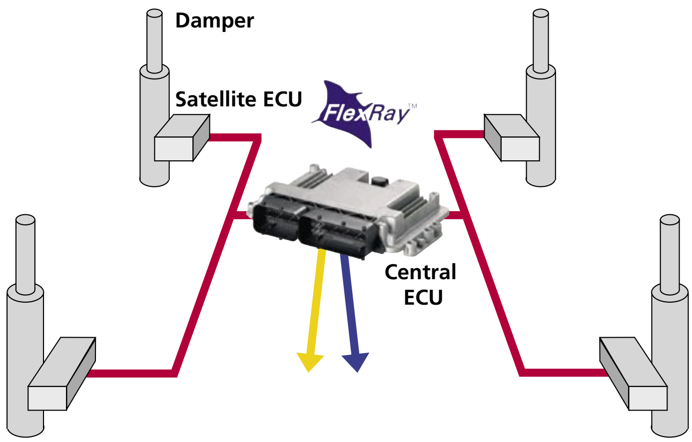
The controller was designed as a system comprising a central ECU and intelligent satellites. The four satellites are located close to the wheel suspensions and communicate with the central ECU via the FlexRay bus. The ECU evaluates the vehicle states captured by the acceleration pick-ups and calculates the general control strategy. The satellites then directly control the active dampers. In addition, a large volume of operating data is captured in the vehicle and fed in.

Using a distributed controller allows the use of system-independent control models that can be partitioned across the ECUs involved. The advantage: All the control algorithms are created in a single Simulink® model and can therefore be simulated as a whole.

Tool Chain and Processes

The software development process was designed to meet several requirements. One of these was that the development of several systems in one single model had to be supported. Rapid prototyping, code generation, and hardware-in-the-loop (HIL) simulation all had to be served by the same model. Model conversion and code generation had to be seamlessly automated and versionable. The tools Simulink® and TargetLink were integrated into a largely automated tool chain for model conversion and code generation. A sequence control with its own user interface automates various work steps, facilitates data handling, and ensures modular versioning and management. The model was constructed from over 50

> *"On the basis of TargetLink, the production code generator, we have set up a seamless, automated development process, thereby achieving greater efficiency in development."*
> ***Tobias Schmid***



▲ *The control system has a distributed design. The intelligent satellites communicate with a central ECU via the FlexRay bus.*

subsystems. The subsystems can be individually selected and versioned in the user interface, and then translated into production code by TargetLink. This enabled us to achieve the goals of simplifying the modeling process, reproducing tests more easily, and streamlining the entire process. The tool chain meets the requirements of the BMW development process.

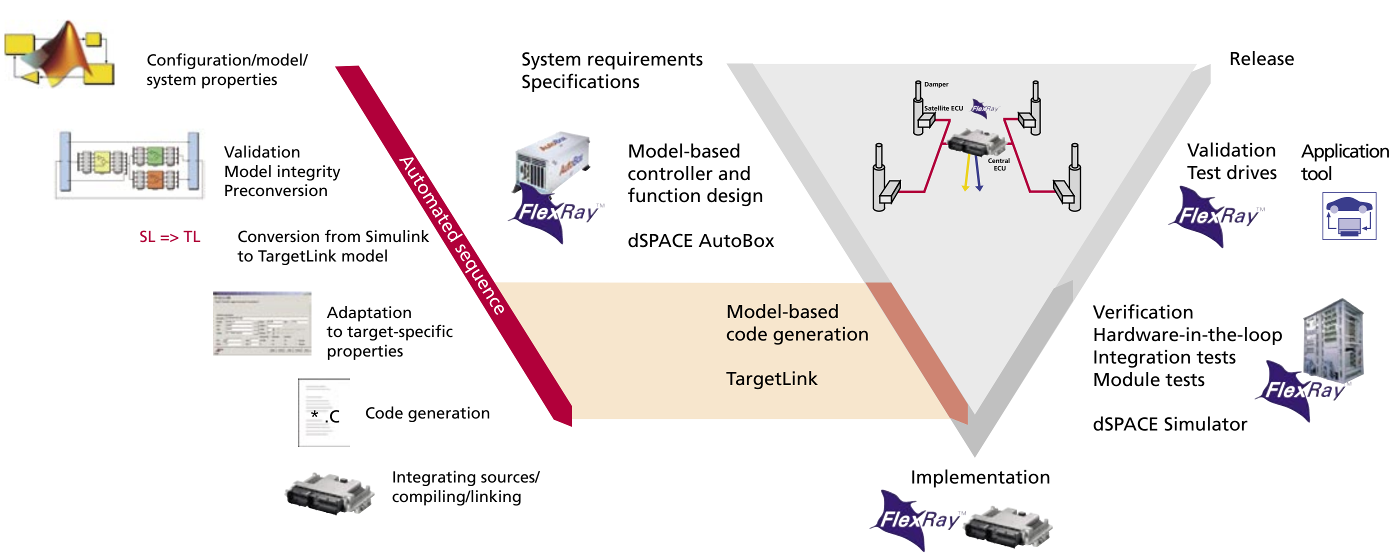
Prototyping and Implementation

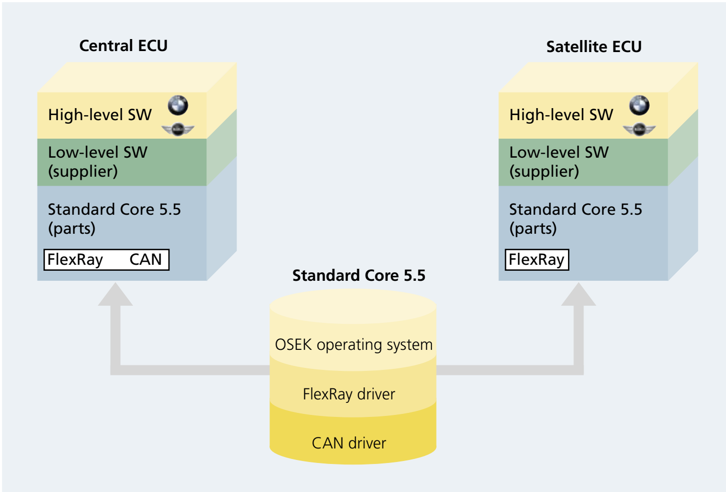
The function algorithms that were developed with Simulink were first tested with a dSPACE AutoBox connected to the FlexRay bus. The tested model was then used directly for production code generation and implementation. To prepare implementation on the target processors, a model-in-the-loop (MIL) reference simulation of the essential functional units was produced and then in the next step compared with TargetLink code by means of the software-in-the-loop (SIL) procedure. This allows problems such as fixed-point effects in the satellites to be detected and solved. One particular challenge was that the satellites had Star 12 (HC12S) fixed-point processors, while the central ECU was equipped with the floating-point processor MPC 565, so very specific methods are required for generating production code from a model. Processor-in-the-loop (PIL) simulation was used to test the algorithms and the resource requirements directly on the target processors before the ECUs were parameterized. This has the particular advantage that problems with memory management and execution times are detected during early development phases. These are evaluated with the support of TargetLink's diagnostic functions. The TargetLink code generated for the subsystems was integrated into the BMW Standard Core Software. The BMW Standard Core Software comprised low-level functions from various suppliers, drivers for FlexRay and CAN, and an OSEK operating system. The overall function model was modeled from 12,000 blocks, from which 100 KB of code was generated for the central controller and 11 KB each for the satellites.

Verification and Validation of Controller Functions

The ECUs were tested in a hardware-in-the-loop test environment based on a network of dSPACE Simula-

▼ *The development process follows the V-cycle and is automated in parts. The design tools used have FlexRay interfaces.*





▲ *The components to be implemented are an operating system from the BMW group, low-level software from the ECU suppliers, and the high-level software generated by BMW.*

tors. This simulated the entire system and performed fault simulation tests on it, from component tests on the individual ECUs right through to network tests. Finally, AutomationDesk was used to verify the damper control against the function model. The model simulation (MIL) was compared with the results of the real system (HIL) using the same stimuli.

> *"Using TargetLink, we were able to generate production-ready code for the system-independent function model of our distributed controller that meets the high requirements of the BMW Group."*
> ***Florian Büttner***

Results

By implementing this damping control, the BMW Group has succeeded in considerably improving comfort and safety. For example, body movements were greatly reduced, in each driving situation, compared with the predecessor systems.

The tool chain that was set up, with its largely automated procedures, makes the process to a large extent seamless and ensures very good reproducibility. This considerably reduced the time needed for controller development and also enhanced the quality of the code that was produced, and greatly facilitates the development and implementation of control systems.

The design tools from dSPACE proved a complete success, from the prototyping phase to implementation and right through to release tests on the ECUs. Using FlexRay, the brand-new bus system, requires powerful, well coordinated tools, and dSPACE was able to provide us with these.

Project Status and Outlook

The system is currently undergoing in-vehicle tests and the generated code is being calibrated. Meanwhile, improvements are also being made to the development process. Further tests (code coverage, static code check) are being integrated, and data handling and exchange are being improved. A method of reusing the acquired scaling information in conversion from Simulink to TargetLink is also under development. Further production projects with TargetLink are being planned on this basis.

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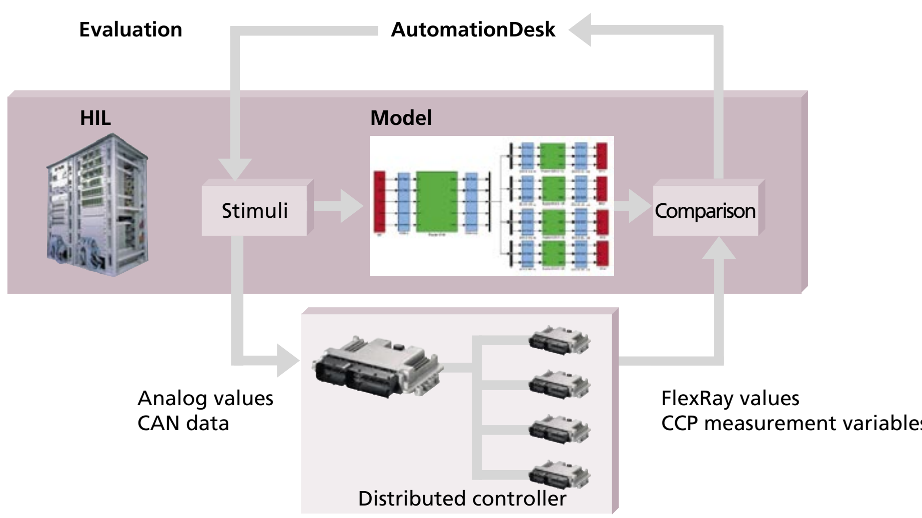

▲ *Following software implementation, the behavior of the system in an HIL environment is compared with the simulation of the function model in order to verify controller functions.*