Virtual Vehicle Test Drives

Efficient testing processes at Suzuki, featuring component testing and virtual vehicle testing

Since 2000, Suzuki Motor Corporation has been efficiently intensifying their use of dSPACE simulators for the safe development of electronic control units (ECUs). So far, Suzuki uses several simulators for individual ECUs, including body and air-conditioning, as well as engine, transmission and all-wheel drive ECUs. But for the models Kizashi and Swift, a dSPACE virtual vehicle simulator takes over the efficient verification of all vehicle control functions.

Electronic control technology is evolving with features such as adaptive cruise control (ACC), electronic stability programs (ESP), and pre-crash safety systems. At the same time, more functions are integrated into a single ECU to reduce the overall number of ECUs per vehicle. Complex functions are distributed on several networked ECUs. Across-the-board validation of distributed functions is not possible with component simulators for individual ECUs, and real test drives are not safe for testing such complex systems with all the connections and dependencies between functions.

A virtual vehicle simulator is required to test the whole ECU network.

Requirements for the Virtual Vehicle

To efficiently validate all of a vehicle's distributed control functions the dSPACE virtual vehicle simulator has to meet the following preconditions:

- Information on each ECU and its functions has to be shared across the whole hardware-in-the-loop (HIL) system.
- Network tests must be possible, even if not all ECUs are available yet.

Component Simulator vs. Virtual Vehicle

To test a single ECU, e.g. for engine management, a component simulator is required. It comes with a dedicated setup for the ECU under test.
To test multiple ECUs or a complete ECU network including all communication aspects, a virtual vehicle simulator is required. Several simulators are closely integrated to represent a complete vehicle.
A virtual vehicle can be configured for different vehicle variants.

- Real loads must be includable and switching between load and model must be automated.
- Test execution must be easy, so that Suzuki's engineers can focus on function design, not test creation.
- Variant handling by switching between vehicle models or parameter sets must be easy to reduce HIL system downtime.
- Suzuki's inhouse tools, e.g., for diagnostics and RAM monitoring, have to be connected to the dSPACE virtual vehicle.

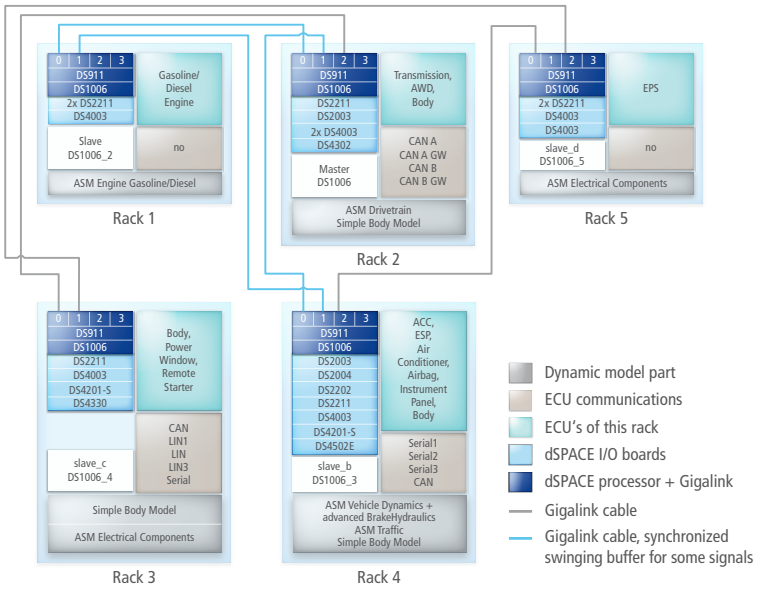
Virtual Vehicle Setup

The simulator consists of five integrated racks that are each configured for certain vehicle components, like engine, body electronics, driver assistance systems, etc. The controlled system models are all taken from dSPACE Automotive Simulation Models (ASM). Besides drivetrain and vehicle dynamics models, this setup also features models for the electrical system and the surrounding traffic to test ACC functionality. Test automation is performed by dSPACE AutomationDesk® together with the Real-Time Testing (RTT) extension. This virtual vehicle simulator can be configured and parameterized for the different variants of Suzuki Kizashi and Swift.

Flexibility of the Virtual Vehicle

The virtual vehicle simulator was designed to handle time-consuming tasks such as changing the target vehicle or vehicle configuration efficiently. For example, the test target engine can be switched from a gasoline engine ECU to a diesel engine ECU in just five minutes. The only manual tasks are releasing and attaching the ECU harnesses. Changing the optional vehicle features such as ACC or air-condition-

Configuration of the virtual vehicle: The dSPACE processor and I/O boards are installed in five racks.



ing, which vary according to the vehicle class, is simply a matter of changing settings in dSPACE ControlDesk®, the experiment software.

Test Process

Any problem detected by the virtual vehicle can be verified thoroughly and in great detail on a component simulator. For example, a closed-loop problem detected by automatic tests overnight can be investigated and corrected the next day on the component simulator. When the problem is solved the new, correct function can be restored to the virtual vehicle for further automatic testing. Unlike the component simulator, the virtual vehicle contains many parameters that are dynamic, which increases the depth of testing. As long as the tester uses the same test environment for the virtual vehicle simulator and the component simulator, it is possible to run common parameters, common environmental conditions, and common tests. By adding test cases on a daily basis, testers can thoroughly verify control functions with large numbers of conditions.

> "The biggest result of installing the dSPACE virtual vehicle simulator was that it enabled us to easily perform important tests that we couldn't even run before."
>
> *Katsuhiko Douhata, SUZUKI MOTOR CORPORATION*

The Advantages of Restbus Simulation

ECU functions that will be available on future ECUs and ECUs that are not yet available can be implemented by using restbus simulation and CAN gateway functions. Restbus simulation is a method normally applied to ECUs that are only available in virtual form and cannot participate in CAN communication. The CAN gateway functions simulate abnormal states such as data corruption or wrong values on the bus to falsify and correct ECU messages if the available ECU was developed for a different vehicle platform. Combining these methods allowed Suzuki to develop new functions even without a complete ECU network. If an ECU was missing some functions, they were implemented using the two methods. The whole implementation was optimized and the behavior of the other ECUs was tested in this way. Problems that might occur for new functions and ECUs that could have an impact on the whole ECU network were eliminated.

Use of dSPACE Products

Suzuki had been using dSPACE products for some years, so it was possible to transfer existing test

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Yasuhiro Hayashi is General Manager of the automobile electric design department at Suzuki in Shizuoka, Japan.

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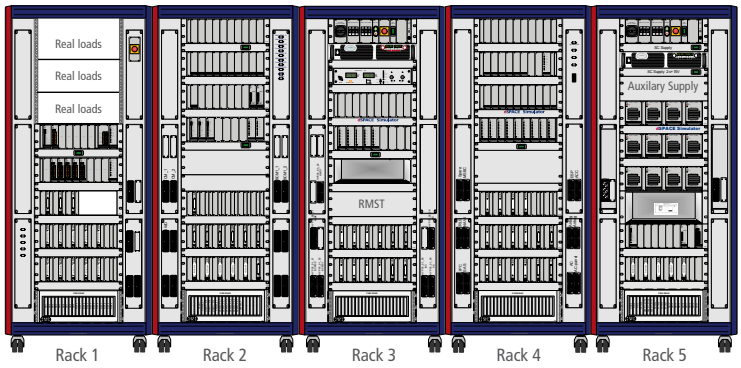
dSPACE as a Tool Supplier

Suzuki wanted to direct its efforts into developing the test target ECUs and network testing, but doing all the design work for the test equipment would have been very time-consuming. To save time, its virtual vehicle simulator was built up in cooperation with dSPACE engineers. Suzuki's engineers assembled the parameters and made the virtual vehicle compatible with Suzuki's existing simulators. These efforts paid off, and as soon as the new simulator was completed, full ECU function testing and network testing started. High rates of operation have been maintained right up to the present. Suzuki's workload was reduced because dSPACE is a one-stop supplier of simulator development tools, including turnkey engineering.



Setup of the virtual vehicle simulator for testing the complete ECU networks of the new Suzuki models Kizashi and Swift.

> "Compared with a real-world vehicle, verification on the dSPACE Simulator was easy and our benefits of being able to run automated and reproducible tests were huge."
>
> *Katsuhiko Douhata, SUZUKI MOTOR CORPORATION*

cases to the virtual vehicle. With the test automation software AutomationDesk, it was easy to program and extend the test sequences graphically, using high-level library functions. The test data is read from Microsoft Excel® files which were already used for test data handling. For time-critical operations, AutomationDesk also parameterizes and controls Python code, which runs in real time parallel to the Simulink® models.

By combining powertrain, vehicle dynamics, electrical system and environment models from the ASMs, an entire vehicle simulation system was constructed for the virtual vehicle. The ASMs provide the conditions needed for vehicle drive control, to develop functions such as ESP, traction control, and adaptive cruise control. dSPACE ModelDesk is the graphical user interface for intuitive parameterization and parameter set management for the ASMs. The many different variants involved can be handled fluently and easily by changing parameter sets in ModelDesk. Complete engine types, and parameters like engine displacement or distances for the ACC, were defined by graphical means and handled as parameter sets.

Suzuki's entire test track was replicated in ModelDesk to run virtual vehicle dynamics tests and compare them with results from real test drives. This was done for conditions like summer and winter, and for different types of road surfaces.

The state of the vehicle can be observed in 3-D animation MotionDesk, making verification simple and clear.

> "We were able to handle variants more easily than we had imagined by changing virtual test tracks, engines, transmissions, and other parameters fluently with dSPACE ModelDesk."
>
> *Yasuhiro Hayashi, SUZUKI MOTOR CORPORATION*

Future Development

To cope with the challenges of reducing fuel consumption, and electric current consumption, it's important to simulate the behavior of the respective systems early on. In addition to the ASMs already installed, Suzuki will use the ASM Electric Components simulation model to accurately calculate the power consumption of the electric devices that are planned for future developments.

Suzuki is promoting partnerships using HIL with other divisions – not only the electrical components division. The more tests that can be implemented across different divisions, the greater the data's usefulness and the higher its validity. ■

Katsuhiko Douhata
Yasuhiro Hayashi
SUZUKI MOTOR CORPORATION, Japan

> "We appreciate the convenient test creation in AutomationDesk's graphical user interface."
>
> *Yasuhiro Hayashi, SUZUKI MOTOR CORPORATION*

Conclusion

By using the dSPACE virtual vehicle for a large number of ECUs, the functions and loads were tested very efficiently. The virtual vehicle was well designed, with the relays operated via the PC, the replaceable parts arranged on tables in front of the simulators, and the parameters able to be processed via a database. For example, the accuracy of ACC simulation was confirmed. The distance and attenuation were compared with the values for an actual vehicle and found to be correct.