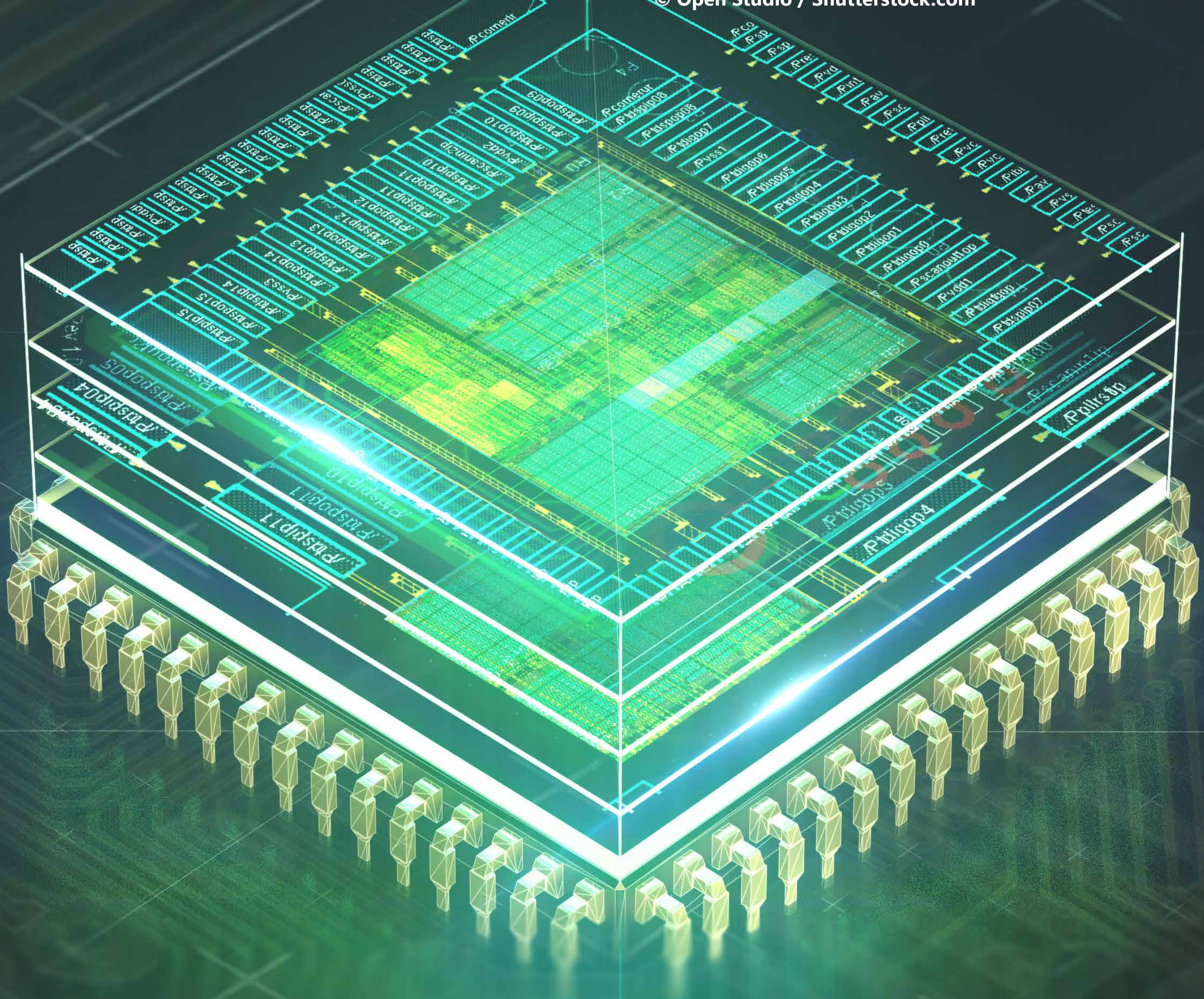
Virtual Test Bench for Validating a Steering Control Unit

Electronic control units for automotive applications are becoming increasingly complex – new strategies are therefore required for validating the software. MicroNova is working with the VW Group to develop a virtual test procedure for the reliable validation of steering software.

TEXT: Robert Evert, Andreas Drews, Stephan Schmidt PICTURES: © archy13 / Fotolia.com; © Open Studio / Shutterstock.com



Automotive manufacturers and suppliers need new approaches and test systems for the validation of new driver assistance systems all the way through to autonomous driving. The aim of Volkswagen Group Components is the comprehensive and efficient validation of the software of a steering control unit.

Volkswagen and MicroNova have been developing various approaches to virtual testing since 2016, i.e. PC-based simulation for the validation of control unit software, on the basis of their long-standing cooperation in the field of HiL (hardware-in-the-loop) testing and test automation. The virtual electronic control unit (vECU) has always been at the center of all approaches. The jointly developed concept is an extension to previous HiL or SiL (software-in-the-loop) test benches.

This innovative approach by the testing experts at VW and MicroNova offers significant benefits. The steering software can be validated very early on in the development process in dynamic tests up to a classification according to ASIL D (see box). In addition, errors can be identified at an earlier stage and hence more cost-effectively. Linear scaling up using greater processing power also makes it possible to run tests in parallel. This provides the basis for the dynamic and cost-efficient installation of further identical test stands or their relocation to the cloud. Moreover, test cases can be more complex than with conventional systems, as the entire test bench can simply be halted whenever necessary – for example, to read out data memories or adjust configurations.

Virtual testing and virtualization of the ECU

The terms software-in-the-loop, virtual testing and virtual test bench are frequently used buzzwords in ECU development. The core element of all implementations in these areas is the separation of the software test from the target hardware, i.e. the control unit. The test is usually carried out on PC systems, although calculations can also be offloaded to other hardware such as graphic cards or FPGAs if necessary. These systems can be run locally or in cloud data centers.

If this type of virtualization is extended to other connected peripherals, such as actuators, sensors and the vehicle bus, the result is a test bench that could also be implemented as an HiL system. According to the experts at MicroNova, such an expansion of the test systems used is unavoidable due to the stringent demands of testing control units for automated vehicles. The concept developed by VW and MicroNova allows test cases to be executed on a virtual test bench, with only minimal adjustments compared to conventional hardware test benches. HiL systems can therefore be supplemented and test capacities significantly expanded.

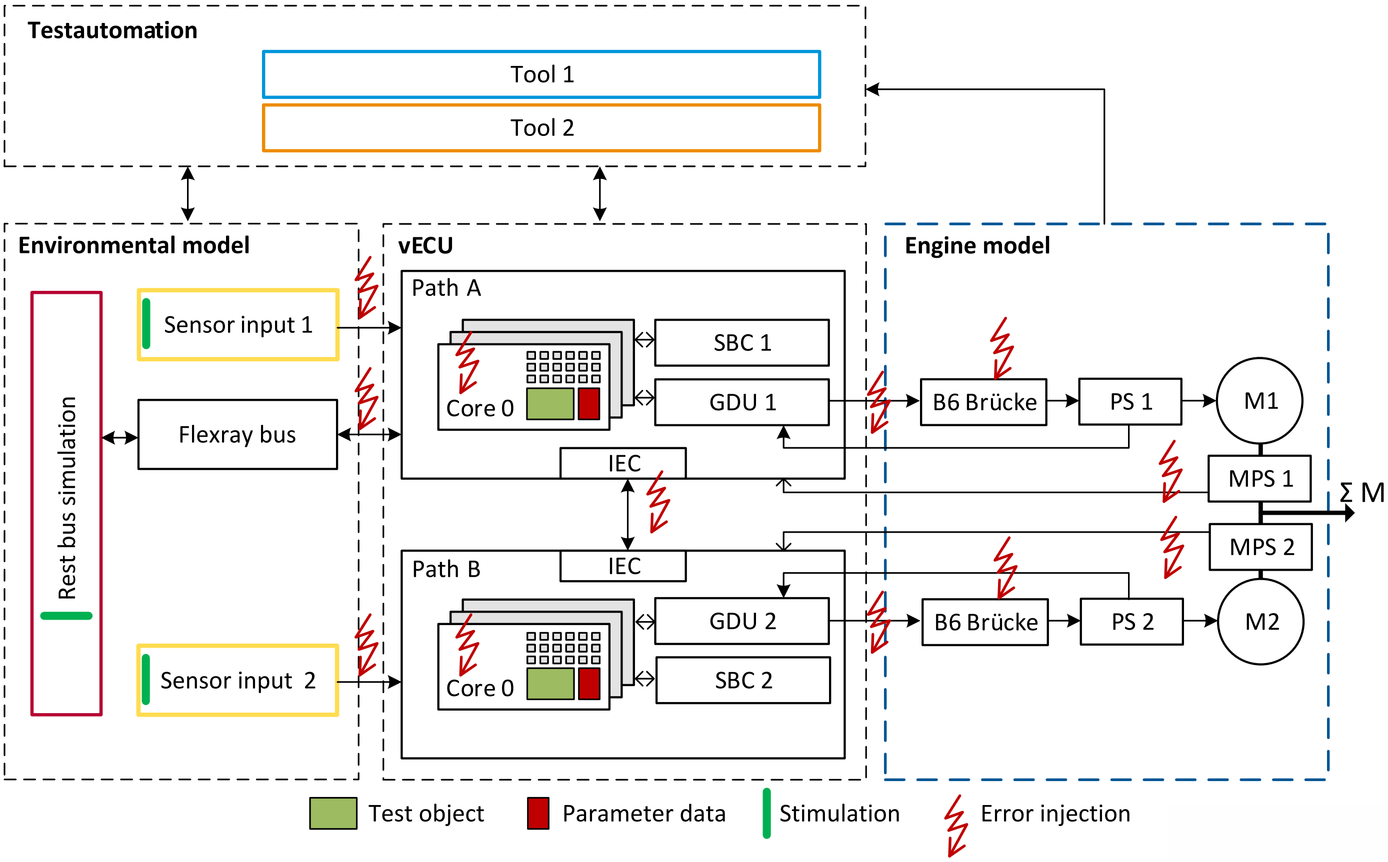
Implementation of the virtual test bench

The virtual test bench is based on a co-simulation of three software products. The main focus is on the simulation of the ECU at instruction level within a SystemC model that models data transfer between the individual components. The processor models used range from processor emulation to RTL (register transfer level) simulation, depending on the desired depth of simulation. The individual components are shown in the overview (Fig. 1). The system for testing VW's steering software is based on a replica of the processor and other connected components for system monitoring, engine control (GDU) and bus communication. In this case, the depth of simulation includes not only the execution of the individual instructions of the processor, but also the implementation of all registers present as hardware, as well as the simulation of processor timing. The detailed representation of cache accesses and memory areas allows test engineers to identify errors deep within the system.

The virtual test stand consists of two redundantly configured threads, each with a multi-core processor. The processor communicates with the vehicle bus system, performs inter-ECU (IEC) communication and receives sensor signals from user inputs for steering and other assistance functions. It also provides a motor control function (hp). The motor model was implemented in the form of a circuit simulation, which also partially takes into account transient switching processes of the motor control function. The rest-bus simulation originates from a hardware test bench and is connected via a simulated vehicle bus in a slightly modified form.

Functional safety in accordance with ISO 26262

Risk assessment in accordance with ISO 26262 involves classification according to ASIL (Automotive Safety Integrity Level) A to D. Here, ASIL D represents the highest requirements, such as those necessary for autonomous driving. The new concept of the virtual test bench allows the steering software to be validated up to ASIL D classification at a very early stage in the development process.



1 Overview of virtual test bench with test automation.

At the beginning, a test automation solution (e.g. EXAM) starts the simulation for the test object, i.e. in this case the unmodified steering software (marked green in Fig. 1). The required calibration or learning data are automatically loaded at startup. It is possible to capture and manipulate data at any point in the virtual test bench thanks to the simulation properties. These may be memory areas, hardware registers, or input/output lines of the micro-controller within the processor model. Physical variables can also be specified and measured at the sensors and in the motor model. As the external system has no influence, this procedure ensures that the test is as reproducible as possible, thereby ensuring consistently high test quality and reliable verifiability of the results.

Possible applications of the system

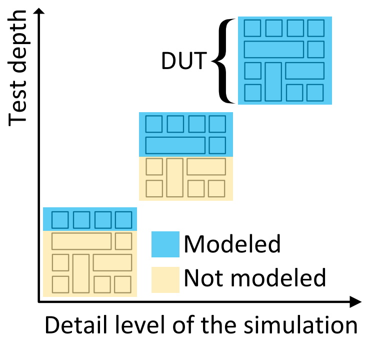
The virtual test bench offers a wide range of testing options that can be adapted to specific requirements. Fig. 1 shows examples of possible activation points in blue. As in real test benches, these are triggered via the bus system or via sensor inputs. What's more, the test bench provides a variety of interfaces that can be used to cause specific malfunctions and to measure whether the software under test shows the desired response. It is also possible to undertake significant interventions in the test bench, allowing memory areas to be modified and the possibility of causing unsafe states or manipulation of the micro-controller's inputs/outputs. Such modifications are not possible at all on conventional hardware test benches, or only at great cost. The same applies, for example, to timeouts in monitoring functions or moving mechanical parts. In the ideal case, the system behavior of the virtual test bench corresponds completely to that of a hardware test bench.

The virtual test bench still has some limitations due to the model character of the components used: While ECU simulation, for example, is already very accurate, the accuracy of motor simulation has so far been limited to basic motor behavior in selected operating states. An example test case consists of providing the sensors "Sensor input 1" and "Sensor input 2" with implausible or invalid values and at the same time interfering with the thread communication (IEC). The system must also achieve a safe baseline state in this extreme case.

Conclusion

The virtual test bench that MicroNova developed for VW has already been successfully used in several test loops of the steering software. The dynamic tests went beyond the possibilities of many hardware test benches. "Virtual ECU Level 4 was a new innovative way for us to validate high-availability steering systems for autonomous driving," explains Matthias Glück, Project Manager Virtual ECU at Volkswagen AG. "Many tests were made easier and much more efficient as a result. We will continue to leverage the potential and opportunities we see with vECU L4 to expand and improve our testing procedures."

This will ensure comprehensive validation of safety-critical components at various points in the development process. High availability of the steering system is essential, in particular with regard to autonomous driving, and must be demonstrably proven during testing. Virtual test benches will be indispensable in the future for these technical requirements, such as high scalability and the large number of test variables that autonomous driving entails.



2 The unmodified software must be executed on a fully simulated processor in order to validate safety-critical software systems. This procedure is also called Level 4 vECU in relation to an AUTOSAR-compliant software structure and does not require an assessment of the differences between the target software and the test state.