Methods and tools for the development of vehicle systems:

Measurement, simulation, virtualization

Global competition, high safety requirements, and automotive emissions and fuel consumption call for advanced electronically controlled systems. These need to be developed, tested, and calibrated within a prescribed time and on a limited budget. To do this, hundreds of different driving situations and operating conditions have to be considered. To master the complexity and the high demands on efficiency and quality of automotive software engineering, it is essential to systematically use computer simulations of the system, vehicle, driver, and environment; to virtualize system components and electronic control units; and to perform comprehensive and efficient measurements on the test bench and in test drives.
The work of developers, testers, and calibration and test engineers will increasingly shift to virtual environments on the computer. Tasks that were previously performed one after the other can then be done in parallel. They will help secure simulation-based validations on the one hand and use physical measurement data as a calibration reference or to generate simulations and environment models on the other. An intelligent interaction of measurement, simulation, and virtualization gives rise to several development methodology advantages that pay off through a reduction in costs, time taken, and failure rates.

**Virtual ECUs**

Virtual ECUs can help with a timely integration of ECU functions of different suppliers in the form of prototypical simulation models or relevant ECU software components. Unlike ECU prototypes (“A-samples”), virtual ECUs are easy and inexpensive to multiply and transfer. At the same time, they can be seamlessly integrated into existing development processes and environments.

With ISOLAR-EVE (ETAS Virtual ECU), ETAS offers a solution that makes it possible to virtualize an individual ECU or an entire ECU network on a PC (figure 1). It quickly and easily integrates functional models, application software components, and basic software modules from various sources so they can be tested and calibrated with the virtual ECUs generated. In doing this, the solution supports both AUTOSAR and proprietary software.

**Open to all tasks**

ISOLAR-EVE is interoperable with development, testing, measuring, and calibration tools offered by ETAS and other vendors (figure 2). With this goal in mind, the solution was built on the open source Eclipse platform. Aside from that, it offers open, flexibly configurable interfaces that conform to automotive standards. The virtualization platform’s openness makes it easy to integrate with special editors, version control systems, or specific tools for tasks such as debugging or code coverage analysis. The same is true for software testing environments and for measuring and calibration tools. In addition, ISOLAR-EVE supports the generation of virtual ECUs with functional mockup interfaces (FMI) for co-simulation of systems in various vehicle domains. It also supports integration into vehicle dynamics simulations, such as IPG CarMaker. Over and above that, virtual ECUs can be packaged together as S-functions for integration into Simulink® simulations.

Each virtual ECU’s microcontroller abstraction layer (MCAL), which is generated to be specific to a configuration, provides access to interface functions that are implemented as hardware in the real ECU, including analogue and digital I/O and network interfaces such as CAN, LIN, or FlexRay. In addition, virtual ECUs can be simulated or connected to an environment simulation in a closed control loop. For example, residual bus simulations generated using tools such as BUSMASTER or CANoe can be used on virtual ECUs.

If virtual ECUs generated using ISOLAR-EVE are run on a real-time
LINUX-based PC (RTPC), they can be connected both to hardware components of the overall system and to hardware-in-the-loop test systems. A special MCAL for PC hardware interfaces is created for this purpose. Several virtual and real ECUs from different vehicle domains can be connected together using the multi-real-time PC technology from ETAS.

**Applications**

When using ISOLAR-EVE, not only is a virtual ECU’s application software largely identical to the corresponding software of the real ECU, but so is its basic software – including RTE and OS. This means many integration and release tests can be carried out using virtual ECUs and other suitable test concepts.

Developers can use ISOLAR-EVE to test both the application software and the basic software of different manufacturers. The spectrum here ranges from component tests, including AUTOSAR conformity testing, to integration testing and downstream functional validation (figure 3). In this process, the virtualization platform makes it possible to generate test interfaces at all levels of the architecture – be it on the level of the application software, the basic software, the runtime environment (RTE), or the microcontroller abstraction layer (MCAL). The solution helps verify, implement, and validate the functional behavior of:

1. individual software functions;
2. several software functions and components integrated into one ECU;
3. software functions and components spread over several ECUs;
4. application and basic software that is identical to ECU source code; and
5. ECU networks.

Once produced, virtual ECUs can be customized for the relevant application by flexibly configuring and populating them on a Windows® PC. Compared to real ECUs, the software of virtual ECUs can be actualized very quickly. For reproduction and debugging of errors, software developers can use their standard software tools on the PC and record data on its hard drive. Virtual ECUs also enable ECU software calibration on the PC. They can be connected in the same way as real ECUs to measurement and calibration tools such as ETAS INCA and calibrated – for example, in a closed-loop simulation. The data acquired can then be used in subsequent stages of the process.

**Physical measurements**

Conversely, measurement data from experiments on vehicles or at a test bench serves as an important basis for simulations and virtualizations. On the one hand, this data can be used as a source of reference for calibrating functions in the virtual environment. On the other hand, it can be used both to stimulate simulations
and to generate data-based models, which often make system behavior easier to describe and more precise to predict than physical calculations.

The results from tests on real objects will continue to be decisive for the releases, because problems that cannot be attributed to errors in system design or to deviations from design implementation can be identified only from test bench or in-vehicle test results.

In the past, isolated measurements were usually conducted to respond to individual issues. However, this approach fails short when it comes to safely predicting and managing the behavior of more complex systems such as modern high-tech internal combustion engines, hybrid powertrains, or advanced braking and driver assistance systems. A big advantage here would be to summarize all possible measurement tasks by measuring “everything” at the test bench or in the vehicle in one attempt. This approach means that measurements gathered once can be systematically reused, different measurement values easily correlated, dependent functions optimized, and complex error patterns understood. At the same time, measurement results from, say, OBD acceptance tests can be seamlessly documented. In addition, it is extremely sensible from a commercial viewpoint to make best possible use of test benches and test vehicles by maximizing the number of measurement tasks integrated into a given test.

**Measuring everything**

In-vehicle measurements require a seamless and chronological recording of measurement signals from different sources. Tools such as the FETK ECU interface or the ECU and bus interface modules of the new ES800 hardware can work in conjunction with more powerful processors, data buses, and transfer protocols to record ECU data at the rate of up to 120 megabytes per second while time stamping this data with extreme precision (figure 4). This is the principal reason why testing engineers can increase the scope of measurement tasks to go beyond the satisfaction of their own inquiries. To save time and expense, the goal must be to record all signals from the vehicle electronics on as few testing days as possible without interruption. In this way, data volumes measuring in the hundreds of terabytes can be accumulated in short amounts of time. These measurement data files contain tens of thousands of signals that can be recorded in more than 60 different time frames.
Summary and outlook

First, individual stages of the development of new electronically controlled vehicle functions such as design, prototyping, implementation, verification, integration, and validation can all be seamlessly connected by using virtual ECUs. Second, virtual ECUs can be duplicated any number of times, which makes it easier for work processes to be performed in parallel and for tasks to be better assigned. Both these factors can do a lot to speed up software development and improve software quality. At the same time, using virtual ECUs brings down development costs because they make it possible to recognize errors or flaws at the design and implementation stages and resolve them early on. As a result of this, there is much less of a need for elaborate breadboard assemblies, challenging hardware-in-the-loop test systems, test benches that cost a lot to purchase and operate, or expensive test vehicles. Software- and hardware-in-the-loop tests will increasingly complement each other in the future, with fluid boundaries. In this process, tools such as ETAS ISOLAR-EVE and real-time PC technologies from ETAS are key to bridging the gap between these methods of testing.

Test drives will mainly be used to create the database for computer simulations and to back up validations that have been performed in these simulations. Data acquired during the course of developing simulations and tests can be used repeatedly for diverse purposes. A prerequisite for other engineers, teams, departments, or companies using the available data effectively is the efficient managing and accessibility of this data via powerful databases, search algorithms, and visualization, navigation and selection mechanisms.

In spite of the growing complexity of powertrains and assistance systems – and equally the ever-growing number of sensors and ECUs – it will be possible to further shorten testing stages and significantly reduce the number of prototypes and test vehicles using the ETAS approaches to measurement, simulation, and virtualization presented here.

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