

Comprehensive ECU Tests with Fault Simulation

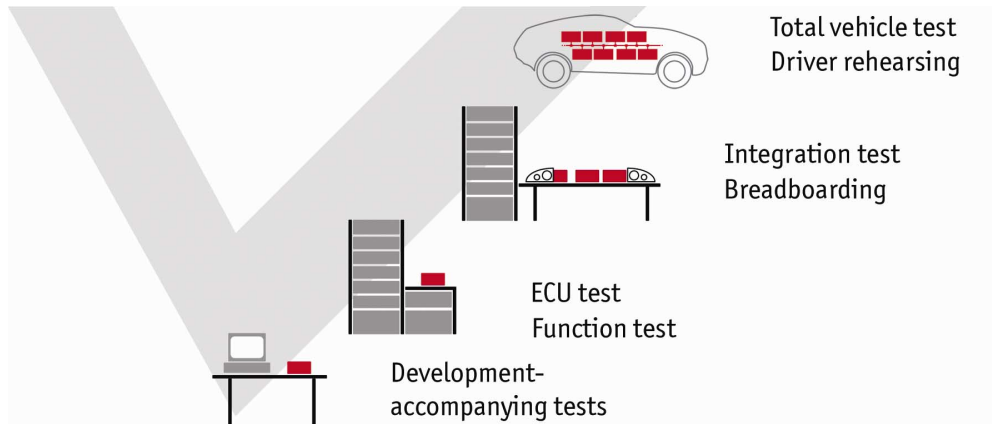
Fault simulation capability is needed in early test phases for efficient functional tests



Besides testing actual functionality, a modern test system for ECUs must also permit testing of the most important fault cases. This applies to the ECU's communication interfaces as well as to its I/O interfaces. Suitable test systems can be implemented early in the development process using special test strategies tailored to the needs of the automotive industry. The new compact test hardware VT System from Vector meets the various challenges that face such a test system.

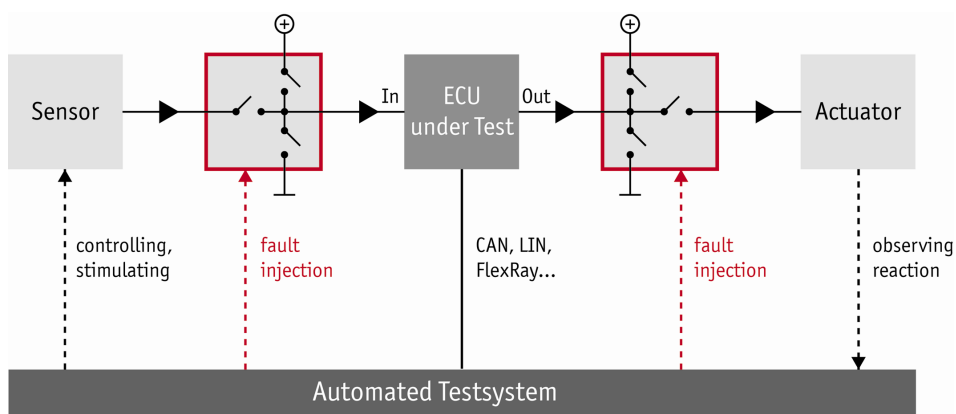
Electronics and software have become indispensable components in the automobile. Therefore, verification of development results not only covers the mechanical systems, but to a large extent the electronic ECUs and their software as well. The complexity of heavily networked systems places high requirements on the test process and the test tools used. Systematic and comprehensive tests are necessary in all development phases. Various test methods are applied in development (Figure 1). Before the classic test runs of

integration tests in the lab or through comprehensive driving trials, the ECUs are first individually tested thoroughly in functional tests.



[Figure 1: Different test methods are used in the various development phases.]

In testing ECUs, it is not just the so-called “good cases” that are of interest, i.e. processes that represent normal operation. Also important is broad coverage of potential fault cases. In testing normal operating functions it is usually sufficient to connect the ECUs to their original components, operate them and observe their reactions. Additional devices are necessary to cover fault states; they are placed in the circuit between the ECU’s ports and the original or simulated sensors and actuators (Figure 2). Such test components are often referred to as fault simulators. They might be used to disconnect lines to simulate line breaks, for example.



[Figure 2: Fault simulators are inserted between the sensors/actuators and the ECU.]

In testing an individual ECU, besides controlling the hardware's input and output interfaces, the communication interfaces of the DUT also play an important role. This places high requirements on the test software, since – besides providing pure bus access for CAN, LIN, FlexRay or MOST – it must be possible to comprehensively and reliably operate the ECU's software or protocol interfaces, e.g. diagnostics via UDS or calibration via CCP/XCP. So the layout of hardware and software interfaces has an enormous effect on the performance, flexibility and, last but not least, the costs of a complete test system.

Challenge of Functional Testing

In verification of ECU functionality, the primary task is to represent the ECU in an environment that mimics the real vehicle environment as closely as possible. The sensors connected to the ECU are operated to activate the functions to be tested, and the ECU's reactions are evaluated. There are very different ways to produce a suitable ECU environment. What is important is that the ECU must not be able to perceive any differences between the real environment and the environment simulated by the test system. In the end, the extent of efforts primarily depends on test objectives.

In the simplest case, an elaborate stimulation circuit is omitted and the ECU's inputs are operated directly by simple means, e.g. by manual switches between specific ECU lines. The ECU's outputs remain unconnected for the most part. Testing the ECU's reaction might only involve measuring the voltage at an output, for example. Such approaches usually do not lend themselves to automatic test execution, but they are easy to perform – especially during development.

Increasingly, many of today's ECUs can no longer be operated in this way. Since they automatically check the sensors and actuators in many cases, it is essential to connect them during the test. If an external component is faulty or is

not even present, the associated system may make fault memory entries, deactivate certain functions in the ECU or generate error messages. So the sensors and actuators are even needed for tests in which the functionality of a sensor or actuator is not really of importance.

A commonly used solution is to connect original sensors and actuators directly to the ECU. Many developer test benches are equipped with simple connection boxes for this purpose, which take the necessary components and have suitable cable connections. Similarly, original sensors and actuators are also provided to the ECUs under test on large test benches. However, automating the test processes is often problematic, since original components must be operated, e.g. by actuating robotics.

An alternative to connecting original sensors and actuators is to use substitute components. For example, a suitable resistor may serve as a practical substitute for a lamp. Since the ECUs are only equipped with simple measurement circuits to monitor their connected components, generally a simple sensor or actuator simulation is sufficient. Compared to the use of original components, this enables compact and simple test systems. Similarly, it is relative easy to automate user inputs with suitable test setups, e.g. by using relays or switches.

In so-called Hardware-in-the-Loop systems (HIL) the overall environment is modeled – including physical and dynamic processes in the connected components. In this case, however, simulation and test execution would require elaborate and cost-intensive test systems, and they would not always be available where they are needed. This also applies to the necessary knowledge of operators.

Simulation of Fault Situations

To test an ECU's reactions to faults in the connected environment, the test system must be able to produce various fault situations. Extensive tests under these atypical conditions are especially important, because they occur very seldom in driving trials or on the test bench and are difficult to reproduce. In the development of hardware and software, many fault situations are frequently forgotten, because the primary focus of developers is on the desired functions. To achieve reliability of systems, however, it is critically important that the ECUs also react properly in response to faults.

In conjunction with sensor and actuator connections, it is especially important to simulate the following fault situations:

- The electrical wiring is damaged: open circuits, short circuits to ground or battery voltage, short circuits between certain connected lines.
- Sensors or actuators are damaged: sensors do not supply any values, values lie outside allowable value range, or a component's electrical properties, e.g. internal resistance or current draw, do not conform to the specification.
- Incorrect input values, especially incorrect sensor data: from the perspective of the ECU, the sensor is operating properly and measured values also lie within the allowable ranges. Yet, the values are implausible or contradict other sensor values, and the ECU must recognize this.

In all cases, the ECU must continue to work in a defined way. Furthermore, the faults must be detected correctly, and relevant fault memory entries must be made. Therefore, besides fault simulation, it is also necessary to access the ECU's software interfaces – typically the diagnostics interface – to stimulate input signals and test output signals.

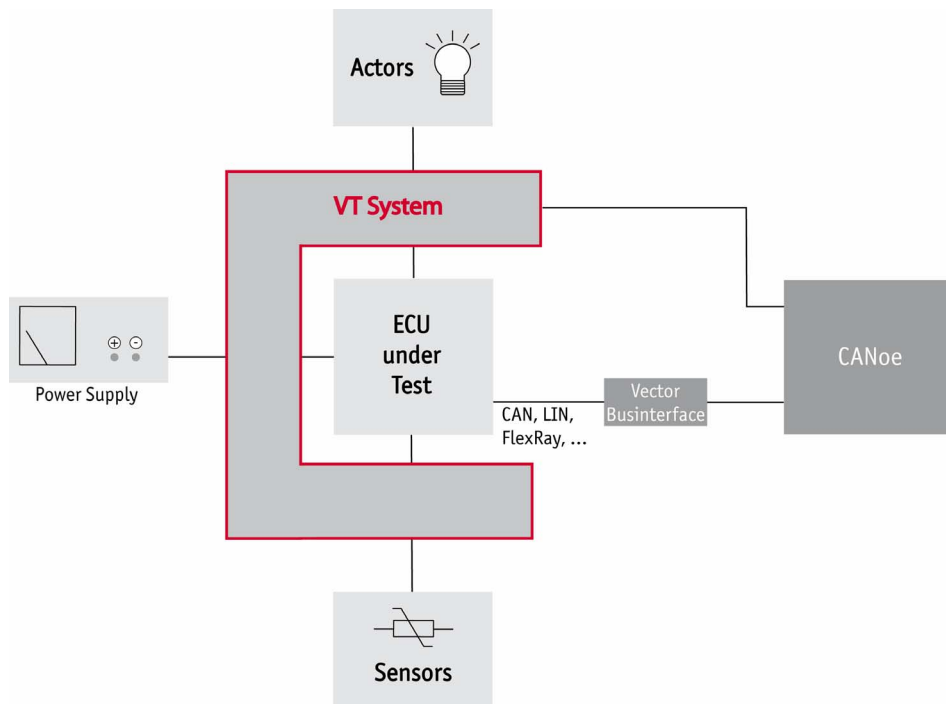
Integrated Solution for ECU Testing

Vector supports the analysis, simulation and test automation of ECUs with the high-performance development and test tool CANoe [1, 2]. Meanwhile, Vector hardware interfaces offer a reliable bus interface to CAN, LIN, FlexRay or MOST. Measurement and test hardware is controlled or driven via GPIB or the serial port, and integration of standard I/O cards from various manufacturers enables setup of test benches with a wide variety of complexity.



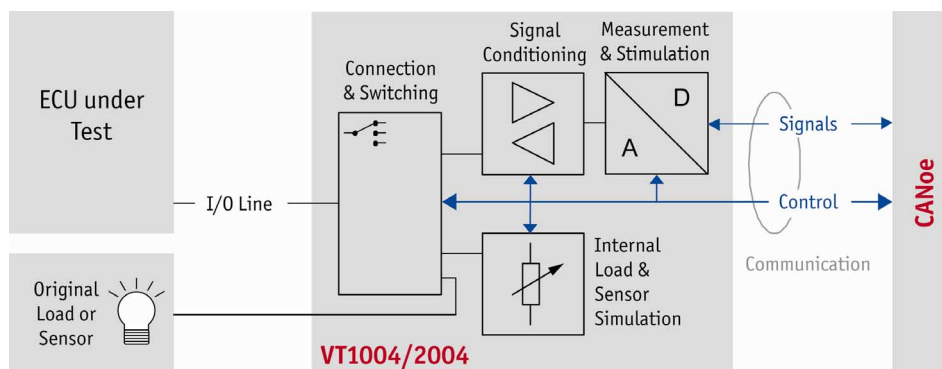
[Figure 3: The VT System consists of standard 19-inch housings with their own backplane into which the modules are inserted. This lets users implement individual and flexible test solutions depending on requirements.]

In driving the ECU I/O lines during an ECU test, Vector offers a compact solution with the VT System (Figure 3). The ECU's I/O lines – and if necessary original sensors and actuators – are connected to the modular system (Figure 4). The PC is connected to CANoe via a fast Ethernet-based real-time network. This makes it possible to assemble flexible test systems without great integration or wiring effort. The VT System is well-suited to both small test setups at a developers' desk as well as comprehensive test benches in the test laboratory.



[Figure 4: The VT System is placed in the I/O lines between the ECU and actuators or sensors.]

The VT System simplifies the process of setting up test benches immensely, since it integrates all components needed for an I/O channel's switching circuit in one module (Figure 5). Examples of such I/O channels might include an ECU's output for driving a headlight or an input to be connected to a temperature sensor. Since two-wire connections are made for all channels, the system supports all input and output types relevant to practice, e.g. driving motors via an H-bridge in the ECU.



[Figure 5: All components needed to test an ECU's I/O channel are contained in the VT modules.]

The measurement and stimulation devices contained in the modules are – like all components – designed for voltage ranges up to 32 Volt that are typically used in the automotive industry. They require units for signal conditioning, which are already integrated in the module. The modules can also handle the high currents that may occur when lamps and motors are driven. Relays on the modules serve to connect the ECU lines to the attached original sensors and actuators.

It is relatively easy to set incorrect sensor data with original sensors, since here the sensors just need to be operated to be implausible. However, the number of conceivable value combinations is large. For systematic testing, a high level of automation is therefore desirable; to make it possible to reproduce as many fault patterns as possible within a short period of time. Therefore, one approach is to replace the original sensors by electronic simulations. They are present on the VT modules for each channel and can be controlled in any desired way by CANoe as a test system.

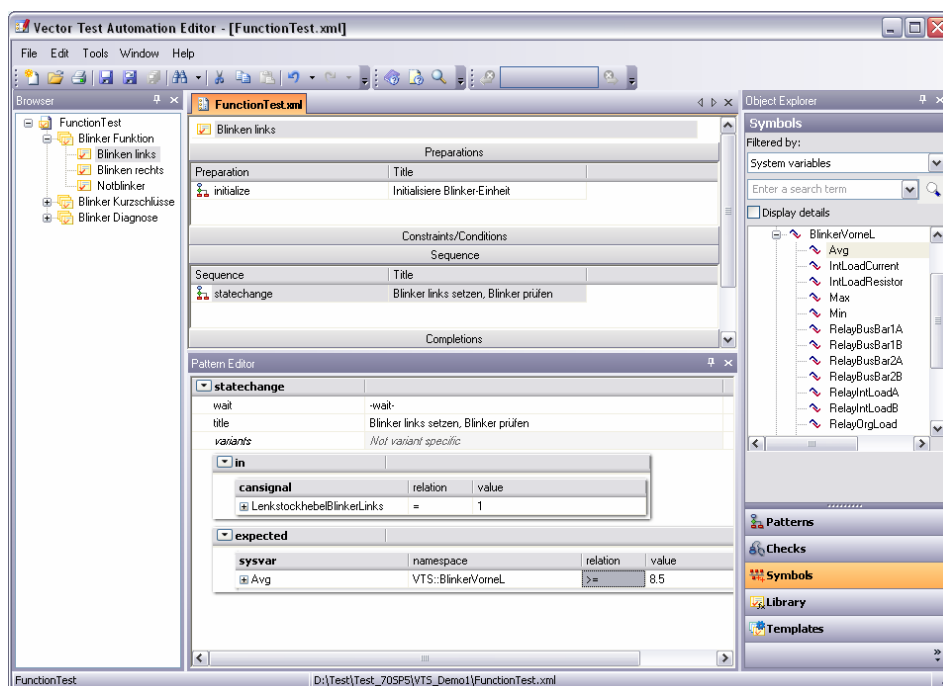
The sensors are simulated by a resistor decade or a voltage output with relevant signal conditioning. There are stimulation units for each of the VT System's I/O channels, so that all ECU inputs can be operated simultaneously. This enables simulation of multiple faults and more complex operating processes.

Additional relays are used to represent faults such as line breaks and short circuits. In operation, such faults typically occur due to damaged wiring and problems at the plug connectors. Even when there are just a few connection lines on an ECU, the enormous number of resulting combinations can hardly be fully tested. However, with their knowledge of physical conditions existing at the ECU, persons creating test cases can limit the selection of test cases to isolated faults and the most likely combinations. For example, short circuits only occur at adjacent pins on the connector. In the VT System, the necessary

switching options are once again available for every connected ECU pin, so that test case selection is unlimited, and multiple faults can be covered.

It is somewhat more difficult to simulate sensor and actuator damage. In this case, it is not possible to revert to the original components, since the effort required to prepare them is extremely high. That is why simulated components are used when working on the test bench. The simulation does not need to be “perfect”. In general, it is sufficient if the properties of sensors and actuators are simulated, and if they are detected and evaluated by the ECU. In the VT System, an electronic load is available for every ECU output for use in an actuator simulation or load simulation. In simulating faulty sensors, the sensor simulations described above are implemented as a resistor decade or output voltage. If there are not enough integrated components for a test, it is possible to connect external load simulations, sensor simulations or measurement and test instruments via bus bars.

Test case creation accounts for a significant share of overall test costs. Therefore, for efficient work processes the developer not only needs the right hardware support, but also an optimal interface to the test automation tool. In CANoe, after a simple configuration of the VT System, all relevant data is available as system variables. The user selects them via a graphic user interface in the Test Automation Editor and applies them in the test sequences (Figure 6). This means that the input and output signals, as well as most control signals, can be addressed as easily as the bus signals of the communication interfaces. The VT System is thereby seamlessly integrated in the CANoe test environment.



[Figure 6: The VT System’s measurement and output signals are directly accessible in CANoe – on the right side of the Test Automation Editor here.]

Flexible Test System for ECUs

Automatic testing of ECUs impose many different demands on the test system for controlling the ECU interfaces and I/O channels. For the most part, testing functionality in normal operation just requires operating the ECU’s sensor inputs and evaluating the reactions at the actuator outputs. To represent fault cases, additional components are needed in the test systems to enable simulation of implausible sensor data, wiring problems and sensor/actuator failures.

The VT System from Vector gives the test engineer a compact and at the same time powerful solution for connecting an ECU’s I/O channels to a test system with CANoe. The modular system provides – for each channel – all key components for load and sensor switching as well as their simulation. It also offers the equipment needed to create the different fault situations. These functions and properties of the VT System make it easy to set up test systems – together with CANoe – that can be used flexibly for ECUs in the automotive field.

Revised: 11/2008

Word count: 2,265

Character count: 14,305

Figures:

Figure 1: Different test methods are used in the various development phases.

Figure 2: Fault simulators are inserted between the sensors/actuators and the ECU.

Figure 3: The VT System consists of standard 19-inch housings with their own backplane into which the modules are inserted. This lets users implement individual and flexible test solutions depending on requirements.

Figure 4: The VT System is placed in the I/O lines between the ECU and actuators or sensors.

Figure 5: All components needed to test an ECU's I/O channel are contained in the VT modules.

Figure 6: The VT System's measurement and output signals are directly accessible in CANoe – on the right side of the Test Automation Editor here.

All figures: Vector Informatik GmbH

Literature and links:

[1] Riegraf, T., Beeh, S.; Krauß, S.: Effizientes Testen in der Automobilelektronik [["Efficient Testing in Automotive Electronics"](#)]. ATZ (Volume 108), Issue 7-8, 2007, pages 648-655

[2] <http://www.vector.com/canoe>

Author:



Dr. Stefan Krauß studied Computer Science at the University of Stuttgart from 1990 to 1995. After earning his degree he worked on the technical staff of the university's Institute for Computer Science in the Software Engineering department until 2001. Since 2002 he has been employed at Vector Informatik GmbH in Stuttgart, and is currently Product Manager for the VT System.

Vector Informatik GmbH
Ingersheimer Str. 24
70499 Stuttgart
Germany
www.vector.com

Editorial contact: Holger Heit
Tel. +49 711 80670-567, Fax +49 711 80670-58567,
E-mail: holger.heit@vector-informatik.de