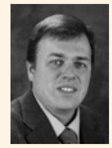
Hardware for ECU Testing

During functional tests a modern and flexible test system must control the I/O interfaces of the ECU. Test cases make different demands on the connection and the operation of sensors and actuators, as well as the signalling or errors and measurement of signals. Beside the different challenges to the test system this article describes a new test hardware by Vector Informatik.

Author



Dr. rer. nat.
Stefan Krauß
is Product Manager
of test tools at Vector
Informatik GmbH in
Stuttgart.

1 Introduction

Electronics and software have become indispensable components in the automobile. Verification of development results therefore not only covers the mechanical systems, but to a great extent also the electronic control units (ECUs) and their software. The complexity of the highly networked systems places high demands on the testing process. Therefore, systematic and comprehensive tests are necessary in all phases of development.

A number of test methods are applied in functional verification of the electronic systems, **Figure 1**. Due to the complexity of the vehicle network it is hardly possible to master the integration of untested ECUs. Prior to classic test runs with fully built test platforms (such as driving trials) and integration tests on test fixtures, the ECU's vital organs must be tested separately.

To test an individual ECU, the test system not only needs to operate the communication interfaces of the device under trial (DUT), but its input and output interfaces too. The first task places high demands on the test software primarily, since besides pure bus access to CAN, LIN, FlexRay or MOST, the ECU's software or protocol interfaces have to operate fully and reliably (like diagnostics via UDS or calibration via CCP/XCP). To control the ECU's sensor and actuator connections, on the other hand, the test system needs suitable hardware components. The layout of these interfaces has a large impact on performance, flexibility and last but not least the costs of a complete test system.

2 Requirements of the Hardware Interfaces

Which requirements are placed on a test system in driving the hardware interfaces, first of all depends on the planned tests and special aspects of the ECUs to be tested. In comprehensive testing, many fundamental requirements apply equally to nearly all ECUs in the automobile. Moreover, there is the wish to have the ability to deal with test cases that are not discovered until the definition of the test system. Everyday practice demands a high degree of flexibility from the test systems, so the requirements described below apply to most test platforms.

2.1 Sensor and Actuator Connections

Since ECUs often check the sensors and actuators automatically, it is essential that they be connected or present during the test. If an external component is defective, or does not even exist, the relevant system will usually generate error memory entries, deactivate specific functions in the ECU or generate error messages. The sensors and actuators are therefore necessary even for tests in which the functionality of a sensor or actuator itself is irrelevant.

In the simplest case, the tester just serves to connect original sensors and actuators directly to the ECU. Many developer workstations are equipped with simple interconnection boxes for this purpose, which house the necessary components and have a suitable cable connection. On large test benches the original sensors and actuators are provided to the ECUs being tested in a similar way.

An alternative to connecting original sensors and actuators is to use substitute components. For example, a properly sized resistor may be an acceptable substitute for a lamp. Since the ECUs only have simple measurement circuits for testing the components connected to them, the substitute sensor or actuator may generally be designed to be just as simple. These represent a compact and simple solutions compared to the use of original components.

2.2 Operation of Sensors and Actuators

To test the functionality of an ECU, the test system must drive the external components and simultaneously acquire their reactions. The ECU thereby operates in a simulated environment. Depending on the situation, an open or closed control loop may be required to simulate the environment. In the latter case, the simulation considers the reactions of the ECU in computing the sensor signals sent to the ECU (hardware-in-the-loop, HiL).

Essentially two strategies come into consideration for incorporating sensors and actuators in automated functional tests:

- Precisely those components that will later be installed in the vehicle are connected and controlled by the test system. Suitable mechanical and optoelectronic devices such as actuating robots are used to simulate events for the original sensors and actuators. The test setup is designed for a specific set of conditions and is modified in case of changes.
- The test system that is directly connected to the ECU simulates the sensors and actuators. In this case, the

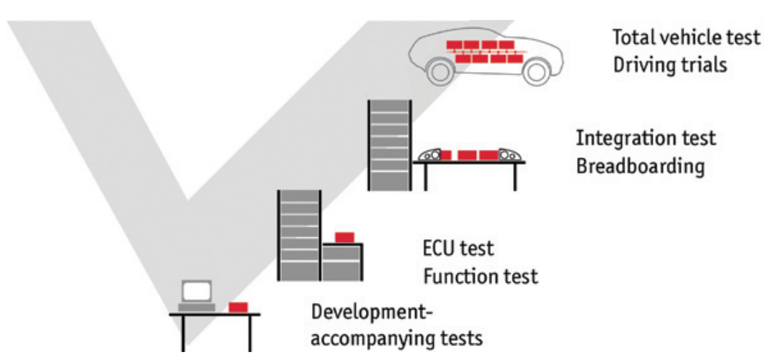


Figure 1: In the different development phases several test procedures are used

test system is capable of electrically emulating sensor outputs and loads. While it measures the activities of the ECU at the ECU outputs, it places signals representing relevant sensor positions at the inputs.

When original components are used, the tester does not need to be concerned about how realistic the simulation is, but the simulation is limited to the properties of the components used. This limits the flexibility of the test bench. Systematic testing of ECU behavior in response to slight differences in sensors and actuators (component variance) is not possible, for example. In contrast, universal simulation capability offers the additional advantage, that the test bench may be used for different ECUs without requiring major modifications.

In conjunction with tests, when sensors and actuators are simulated, this usually does not imply that there is a simulation model in the test system that represents their physical properties precisely. It is sufficient, for example, if the test system provides the voltage expected from a sensor or simulates the load of an actuator by suitable current flow. From the perspective of the ECU, the test system nonetheless simulates the sensors and actuators, although perhaps not in every detail.

2.3 Signalling of Errors

To test the reactions of an ECU to errors in the connected environment, the test system must represent relevant errors. Potential error conditions include:

- Problems with the connection lines of sensors and actuators: line breaks, short circuits between wire pairs, short circuits of individual lines to ground or battery voltage.
- Defects of the sensors and actuators themselves, such as excessively high or low internal resistance of an actuator or excessively high current consumption of an active sensor.
- Sensor signals outside of the specified value range, like physically impossible values of a rotary encoder or implausibly high temperature values of a temperature sensor.

Detailed tests under these error conditions are especially important, because they occur very sporadically during vehicle trials and on test fixtures, and they therefore exhibit poor reproducibility. Such causes of errors are frequently neglected in the development of hardware and software too, because the developer's primary focus is on the desired functions. To achieve system reliability, however, it is crucial that the ECUs also react properly in error situations.

Figure 2: Modules of the VT system are designed as plug-in cards

2.4 Measurement

In the test cases, reference values are specified for certain relevant control variables, which are compared to actual values at the ECU outputs. The test system must therefore be capable of measuring the relevant variables at a resolution and precision appropriate to the test case. Coming into consideration as measurement variables are momentary values as well as mean values and effective values. Increasingly, characteristic parameters such as frequencies and duty cycles of pulse-width modulated signals are in demand, since many actuators are now driven with PWM signals, such as brightness control of the LEDs in the instrument cluster.

3 Integrated Solution for I/O Control

Vector Informatik supports analysis, simulation and automated testing of ECUs with the powerful development and test tool CANoe [1]. Vector hardware interfaces also provide for a reliable bus access to CAN, LIN, FlexRay or MOST. Test benches of a wide range of complexity can be set up using drive control of measurement and test hardware via GPIB or the serial port and integration of standard I/O cards from various producers.

To control the hardware I/O lines in an ECU test, Vector offers a compact solution in the Vector VT system, **Figure 2**. The ECU's I/O lines are connected to the modular system, and original sensors and actuators may be connected if necessary, **Figure 3**. The PC with CANoe is connected via a fast real-time network interface. This enables setup of flexible test systems without a lot of integration and wiring effort. The VT system is well-suited for small test setups at developer workstations as well as for comprehensive test benches in the test laboratory.

The VT system simplifies the layout of test benches substantially by integrating all of the circuit components needed to switch an I/O channel in one module, **Figure 4**. Examples of such I/O channels might be the output of an ECU for driving a headlamp or the input for the connection of a brightness sensor. Since all channels are connected with two wires, the system supports all input and output types relevant in practice, including motors driven via an H-bridge in the ECU.

The modules are equipped with relays that serve to connect ECU lines to the connected original sensors and actuators. Moreover, errors such as line breaks and short circuits can be emulated. If original components are unavailable, or if error states are to be simulated, the integrated load and sensor simulations are used as an alternative. Furthermore, if the integrated measurement and simulation components should prove to be insufficient, it is possible to connect external measurement and test equipment via bus bars.

The measurement and stimulation equipment contained in the modules, as well all other components, are designed for the voltage ranges typically used in the automotive environment. Where necessary, devices for signal conditioning are already integrated. The modules can also handle high currents like those occurring when lamps and motors are driven.

4 Summary

Automated testing of ECUs places many different requirements on a test system's control of I/O channels. Therefore developers need suitable components for connecting and operating sensors and actuators. Furthermore, units must also be reserved for error display and measurement. The Vector VT system offers the tester a compact and at the same time high-performance solution for interfacing an ECU's I/O channels to a test system with CANoe. The modular system provides all significant components for each channel such as the measuring unit with signal conditioning, load and sensor simulation and the necessary relays. With its functions and properties, the system makes it easy to set up test systems for ECUs that can be applied flexibly in the automotive field.

Reference

[1] Riegraf, T., Beeh, S., Krauß, S.: Efficient Testing in Automotive Electronics. In: ATZ 109 (2007), issue 7-8, pp. 648-655

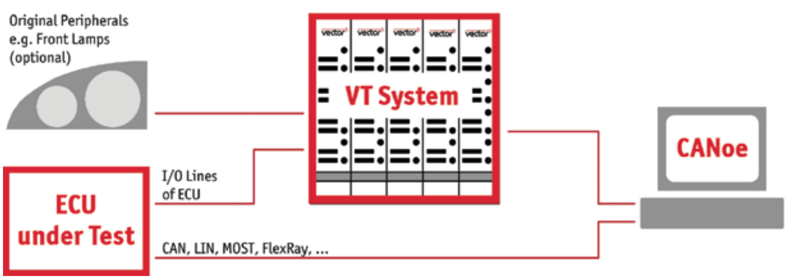


Figure 3: I/O lines used in ECU testing are controlled by the VT system

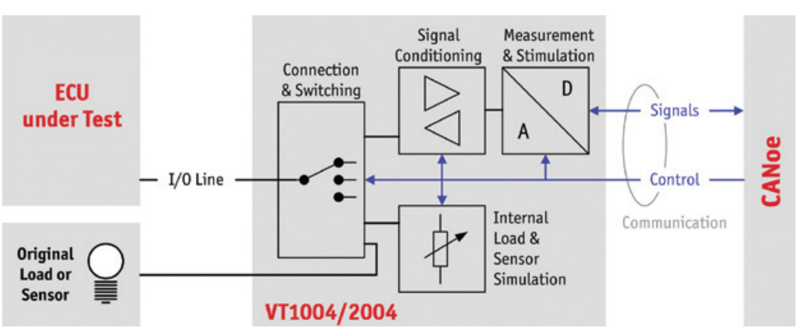


Figure 4: All components needed to test an I/O channel of the ECU are contained in VT modules