Functional testing of a vehicle ECU requires testing of the most significant error conditions as well as actual functionality in the vehicle. Systems used for this type of testing must fulfill stringent testing requirements. Vector’s VT System is a modular test system tailored specifically to meet the needs of the passenger, commercial and agricultural vehicle industries. It allows the engineer to perform effective functional testing during the early development phases of the vehicle.

The complexity of electronic and software systems installed in today’s automobiles requires comprehensive testing in the developmental phases of the ECU. Generally, errors detected early on are easier and cheaper to correct than errors found in the later phases of development. In this process, ECUs are rigorously tested individually in functional tests with special attention given to the numerous error cases. Faulty behavior detected in rare cases or in situations that are impossible to reproduce in normal operation represent a tremendous problem for manufacturers if those errors are not discovered before the ECU has reached the field.

Functional Testing of ECUs
To test its functionality, the ECU is stimulated via its hardware and software interfaces and its reactions are evaluated. It is important to present the ECU with a test environment that matches the environment in the real vehicle as closely as possible. This can be accomplished in a number of different ways. What is most important here is that the ECU should not be able to perceive any difference between the simulated environment on the test bench and the actual environment in the vehicle.

In many cases, ECUs automatically check sensors and actuators so it is imperative that they are connected during the test. If these external components are missing, the ECU will generate faults or deactivate certain functions. As a result, real actuators and sensors are usually connected to the ECU for testing. An alternative would be to simulate the loads and sensors. The great advantage of sensor and actuator simulation lies in the potential for automating test flows with suitable models, a Hardware-In-The-Loop (HIL) test is also possible.

ECU Testing in Error Situations
Additional devices are necessary to simulate error conditions during an ECU test; like the VT System from Vector. They are inserted in the circuit between the ECU pin and the sensors and/or actuators to which it is connected (Figure 1). Specifically, these test components enable testing of the following error conditions:

- Damage to the electrical wiring: Line breaks, short circuits to ground or battery voltage, short circuits between connection lines
- Sensors or actuators are damaged: Sensors do not output any values, the values lie outside of the accept-
The PC with CANoe is connected via the computer’s Ethernet port using the real-time capable EtherCAT protocol. This means that flexible test systems can be constructed with minimal integration and wiring effort. Different modules are available for driving the various ECU inputs and outputs. However, all modules share these properties:

> Incorrect input values, especially incorrect sensor data: From the ECU’s perspective the sensor is working properly and measured values lie within the allowable range. However, they are implausible or contradict other sensor values.

The ECU must react in a defined way in these cases and generate appropriate diagnostic entries. In turn, these entries can be checked by the test system – in this case over the diagnostic interface.

**Compact Test Systems with the VT System**

Systems based on CANoe and the VT System demonstrate that the stringent requirements of high-performance test systems – with regard to their interfaces and test hardware, test automation, user control of software interfaces and options for rest-of-bus simulation – can also be implemented in a compact test system for the bench.

With CANoe, the user gets a mature and widely used tool for analysis, simulation and test automation. Vector hardware interfaces provide reliable bus interfaces to CAN, LIN, FlexRay and MOST. External measurement and test hardware from various manufacturers may also be connected via GPIB, the serial port or Ethernet.

The VT System is a modular I/O system that controls the ECU’s inputs and outputs for functional testing with CANoe. It allows users to set up compact test benches of widely varying complexity (Figure 2).

![Figure 1: The VT System is placed between the ECU and the actuators/sensors for testing.](image1)

![Figure 2: VT System modules enable setup of very compact test systems as well.](image2)
If necessary, real sensors and actuators can be connected to the module. Using relays on the VT module, users can toggle between the use of externally connected original equipment components and the simulation residing in the module.

On each ECU pin, relays can be used to generate errors such as line break and short circuits between lines, to ground or to supply voltage.

All modules and measurement devices are designed for voltages and currents typically used in vehicle electronics. Additional signal conditioning hardware is not required.

VT System modules are automatically registered onto CANoe and are ready for use after a minimal configuration effort. All measurement, output and control signals can be accessed through CANoe and may be used in test scripts together with bus signals, or evaluated in analysis windows.

The VT1004 load and measurement module is connected to the outputs of an ECU. In the vehicle, these outputs are normally connected to actuators such as positioning motors and lamps. The module contains an electronic load for each channel to simulate these actuators. The voltage at the ECU output is measured at a sampling rate of 250 kSample/s; it is then processed in the module and the results are transmitted to CANoe as momentary, mean and effective values. The module can also measure PWM signal parameters. It can handle high continuous load currents of up to 16 A, such as those occurring when lamps and motors are driven.

The VT2004 stimulation module is connected to the inputs of an ECU. To simulate sensors, it has a decade resistor on each channel that can be controlled by a test script. Alternatively, the sensor can be stimulated by voltages; voltage curves or sequences stored on the module can be reproduced with high precision. The module can also generate PWM signals and simulate a potentiometer on a channel how it is used for fuel level sensors, for example.

The VT2516 digital module controls ECU inputs or outputs that utilize digital signals, e.g. lines in the vehicle that are connected to switches, encoding jumpers, small indicator lamps or LEDs. ECU inputs are stimulated by digital signals with configurable levels; besides bit sequences stored on the module, PWM signals may also be output here. In the opposite direction, the module can measure digital or PWM signals and voltages output by the ECU at each channel. Using selectable resistors, loads can be simulated or pull-up or pull-down circuits implemented.

An ECU's power supply lines are connected to a power source through the VT7001 module (Figure 4). Precise current measurements are acquired over a wide range making it possible to check quiescent states, for example, or ana-
The VT7001 module is designed to analyze the power consumption of different software variants. It also generates control voltages for external power supplies, allowing simulation of defined disturbances on the power supply lines. The module is rated for continuous currents of up to 70 A, enabling it to supply ECUs with high power consumptions. An ECU's two supply current inputs, Terminal 15 and Terminal 30, can be controlled separately.

Furthermore, there are modules for bus connections, execution of simulation and test in real-time on the VT hardware, as well as for the integration of custom I/O circuits in the VT System. Other modules are in development. The ECU's I/O channels do not need to share these test setups in all cases, as the VT modules are provided separately for each channel. This simplifies test automation and programming, facilitating the clear representation of multiple errors and more complex user operations.

Based on its modular organization, the VT System is ideally suited for both small test setups at the developer's bench and comprehensive test benches in the test laboratory. Together with CANoe, the test engineer has a flexible and high-performance solution for automotive compact test systems. Test automation is implemented in an efficient and seamlessly integrated package using CANoe and VT System.

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