ECU Testing for Electric and Hybrid Vehicles
Intelligent Measurement of Dynamic Current Consumption

Electrically powered vehicles pose special challenges to test systems: in particular, ECUs must utilize electrical energy efficiently in development and testing. This requires measuring the current consumption of the ECUs as a function of software states – this is the only way to attain the required energy efficiency.

The research conducted by the advanced development and production development departments of automotive OEMs and suppliers show that much work is clearly being done on electrically powered vehicles and related mobility concepts. Some products have already advanced beyond the experimental stage, while many others are prepared to follow shortly. This has put systematic testing of vehicle electronics into focus in accountable testing departments. During initial conceptual and prototype phases, existing components from conventional vehicles are often used, while the focus was on the electrical powertrain and innovative functions. However, in production development of initial electric and hybrid vehicles, it is now necessary to transfer important findings of the past decades related to E/E architecture validation to the new electric vehicles.

What is different in testing vehicle electronics in electrically powered vehicles? How do established test strategies need to be changed, supplemented or even replaced?

New Challenges in e-Vehicles
The most noticeable change in on-board electronics is the new ECUs for the electrical drive components and the battery (Figure 1). In a fully electric vehicle, the engine controller is replaced by a controller for electric drives. The transmission ECU has been eliminated, but a new battery management system handles all aspects related to the battery cells, and an on-board battery charger enables “refueling”. The testing departments can transfer existing test methods to these ECUs. For the batteries and electric motors in particular, suitable environment simulations must be integrated in the test benches. On closer examination, this turns out to be a great challenge, because the high voltages used in the electrical powertrain have a tremendous influence on the test bench equipment. The primary challenge is to attain the same testing depth and the same degree of test automation for the new systems under these conditions as for known electronic components.
With electric charging, a new communication interface is also assuming an important place in the vehicle: the communication between the charging station and the vehicle. Just a few simple electrical signals suffice if communication is limited to control and verification of the actual charging process. However, complex communication is needed for more extensive functions. Such functions include automatic billing for charging and integration of the vehicle in a “smart grid” – i.e. cost-benefit optimized charging for the vehicle that is temporarily connected to the infrastructure.

All around the globe, various development groups and standardization committees are addressing these issues. Clearly assuming a central role here is ISO 15118, which describes intelligent charging with AC power. Communication is conducted over the power line (Power Line Communication), utilizes the Internet Protocol (IP) and is based on typical Internet technologies (TCP/UDP, DHCP, XML, JSON, to name just a few). These technologies are indeed widely used – every PC handles most of them – but implementation with the limited resources of an automotive ECU is new. The testers are faced with new challenges as well; they now need to analyze these protocols and set up suitable test environments.

Another aspect: While communication in the vehicle previously ran between known ECUs, now there is complex communication between the vehicle and a variable infrastructure. To assure troublefree operation in the field, a broad-based test of the vehicle interface is necessary. The same applies to the charging stations. In the future, uniform test content might be arranged (key word: Conformance Test). Certainly, some aspects are still in flux with regard to standardization; however, adequate tests must still be developed for ongoing vehicle projects.

Power-saving technologies play a central role in the development of electrically powered vehicles. In the conflicting priorities between range, available battery technologies and system costs, electrical energy is an extremely scarce resource. One might say fine, but energy-saving systems are under consideration for vehicles with internal combustion engines as well – the drivers here are goals and commitments to reduce CO₂ emissions. Each vehicle should therefore consume as little energy as possible on the ECU and network levels.

**Energy Saving in the ECU Network**

In the development of ECUs and networks, various ideas are currently being pursued. Not all of these approaches are new, but recently they are being addressed with high priority and are making their way into standardization (notably in AUTOSAR).

- **In Partial Networking**, logical networks are formed which must conform to the physical networks. The energy-saving sleep states are defined on the logical partial networks. They can be implemented more effectively in this way, because fewer ECUs need to leave the sleep state in many operating states.
- **In Pretended Networking**, individual ECUs are constructed so that they appear to one another as active on the communication network, but they can essentially go into a sleep mode internally. This is used whenever the actual ECU functionality is not needed. Extensions in the ECU hardware ensure that periodic messages continue to be sent, and the ECU core is awakened under certain conditions.
- **The key word ECU Degradation covers all measures in which unnecessary parts of the ECU are deactivated.** This ranges from simple switching off of electrical driver stages to fine-granular control of chip-internal logic units. GPS signals (optional).
- **Merging of different functions into just a few ECUs not only reduces overall energy requirements, but also offers savings potential in hardware costs. AUTOSAR methodology already supports this approach in its distinct functional perspective.**

High-performance multi-core proces-
the savings potential consists of many individual optimizations, the tester must test very precisely whether the current consumption meets expectations in the individual ECU states. The same applies to development: The developer must be able to evaluate the current consumption in reference to the momentary software state.

High-performance test systems such as the VT System (Figure 2) from Vector therefore enable precise acquisition of the current consumption of the ECUs under test and permit correlations to system states. The modular VT System test hardware simulates the sensors and loads, stimulates the inputs and measures the output signals, generates electrical faults such as short circuits and line breaks, and permits toggling between internally simulated and externally connected sensors and loads. Moreover, the VT System controls the supply voltage and measures the consumed current. Fast, automatic range switching ensures that very high currents while operating under load, as well as minimal currents in power-saving and sleep modes, can be measured with high resolution.

With the VT System, CANoe handles automation of these tests. This software simultaneously permits simulation of the rest of the network nodes (remaining bus simulation) and services software accesses to the ECU. Furthermore, it contains comprehensive analysis functionalities, so that developers can use the system for testing and debugging.

The refined techniques designed to attain energy savings increase the complexity of ECUs and networks. That is why systematic tests introduced early in development phases are more important than ever.

**Testing Current Consumption in a Differentiated Way**

The current consumption of ECUs plays a key role in testing. Previously, current consumption was acquired as a mean total value, or it depended on relatively static operating modes, e.g. the key word Sleep Mode. In consumption-optimized systems, however, it must be determined dynamically in relation to the ECU’s software states. Since the savings potential consists of many individual optimizations, the tester must test very precisely whether the current consumption meets expectations in the individual ECU states. The same applies to development: The developer must be able to evaluate the current consumption in reference to the momentary software state.

High-performance test systems such as the VT System (Figure 2) from Vector therefore enable precise acquisition of the current consumption of the ECUs under test and permit correlations to system states. The modular VT System test hardware simulates the sensors and loads, stimulates the inputs and measures the output signals, generates electrical faults such as short circuits and line breaks, and permits toggling between internally simulated and externally connected sensors and loads. Moreover, the VT System controls the supply voltage and measures the consumed current. Fast, automatic range switching ensures that very high currents while operating under load, as well as minimal currents in power-saving and sleep modes, can be measured with high resolution.

With the VT System, CANoe handles automation of these tests. This software simultaneously permits simulation of the rest of the network nodes (remaining bus simulation) and services software accesses to the ECU. Furthermore, it contains comprehensive analysis functionalities, so that developers can use the system for testing and debugging. CANoe was specially developed for analysis, simulation and testing of ECUs and networks, and therefore it is able to act as a communication partner for the various charging station interfaces. In testing a charging ECU, the charging station is simulated – and vice versa.

Testing and analysis require that various signals be used to determine the system states of ECUs and networks. They may be bus signals, hardware signals or information that is...
read out from the ECU via diagnostic or calibration interfaces. For example, a value on the internal state of the ECU read via XCP could provide information in the ECU’s internal state. What is important here is that all values are available directly and with the same time base, as in CANoe. Suitable tool support makes it easy to evaluate ECU behavior (Figure 3). This is particularly necessary in the development phases and during debugging. Using the same basic approach, it is also easy to formulate test programs and automate the tests. Even in E-vehicles, testing departments can thereby attain the same high level of automation that has proven to be a key component of validation strategies in recent years.

Translation of a German publication in: Automobil Elektronik, August/2011

Image rights:
Vector Informatik GmbH

Links:
Homepage Vector: www.vector.com
Product Information VT System: www.vector.com/vtsystem

Dr. Stefan Krauß
is a group leader at Vector Informatik GmbH in Stuttgart. As Product Manager he is responsible for the VT System.