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DIAGNOSTICS TODAY

Nothing is possible in modern vehicles without diagnostics: From engineering through manufacturing right into the repair shop, diagnostics is the prerequisite for being able to read out information and states. For example internal variables and error memory entries from more than 100 Electronic Control Units (ECUs). At least with close-to-production ECUs, diagnostics is the only possibility.

In engineering, for example, it is necessary to monitor states at test benches and query variables to verify functions. With diagnostics, both of these are simple. Furthermore, the identification (for example software version) of the installed ECUs can be read out during the test drive.

In manufacturing, the functioning of mechatronic systems is often verified on component test benches. Along the line, diagnostics is usually used in a number of line sections. This is the only way it is possible to ensure the currently applicable assembly status: Are all contacts connected correctly, is the current feed okay, etc.

Ultimately, it is simply impossible to carry out a repair in the repair shop today without an expert system. Errors often have to be isolated using vague symptoms and then localized to reveal the precise repair required and then ultimately verify it.

In all the cases described, a further important application case is being dealt with using the diagnostic communication methods: New software versions are installed on the ECUs using flash programming. This is not least why diagnostics is a process topic: It is actually developed together with the actual control functions in the ECU, but the function is not actually used until later process steps and always has to be kept consistent using corresponding releases.

Paradigm Shift Enhances the Quality of Diagnostics

Trends such as electrified and autonomous driving are leading to paradigm shifts in the E/E architecture. This and the increasing number of variants of electronic control units is leading to new challenges in vehicle diagnostics. As Softing Automotive describes, at the same time this development opens up opportunities for improving the quality of diagnostics and increased efficiency: There will be new ways of diagnostics with even cloud-based systems.

TAKING A LOOK UNDER THE HOOD

The starting point for diagnostics is always the individual ECU. Routines which permanently monitor input and output variables as well as internal states run on the ECUs. In the same way, attention is paid on the communication channels as to whether all necessary messages are available. As soon as what is referred to as On-board Diagnostics (OBD) detects any irregularities, entries are made in the error memories.

Now an external tester can be connected via a VCI (Vehicle Communication Interface) at the vehicle using the OBD jack and information read out from individual ECUs – error memory but also internal variables. This information is then aggregated in the external tester and translated into an error map – the actual diagnostics. This then enables specific steps to be defined to remedy the problem.

Today, the external diagnostics procedure has no alternative because among other reasons ECUs come from different manufacturers, levels of release in the field vary and ECUs can be installed optionally – the diversity among the variants is extremely high and no change is to be expected.

THE CHALLENGE OF NEW MOBILITY

There are currently two topics that are dominating the development of electronics in the vehicle: (semi-) electric driving and autonomous driving. Initially, electric driving is intended to improve the emission balance both in terms of exhaust emissions as well as in terms of noise reduction. The introduction of batteries as energy stores, however, also leads to a greater need to control energy users so as not to have any negative influences on the operating range. As this takes place centrally, it is sensible to integrate a greater number of functions in one ECU. Simultaneously, however, a reverse trend is also apparent: Functions are distributed to several ECUs. “Braking” for example is a procedure which, in an electric vehicle, is shared between the electric motor, the battery, and the mechanical brake.

Autonomous driving, the second megatrend, focuses, on the one hand, on the comfort of not having to drive and, on the other, on the expected increase in safety by cutting out “man” as a source of error. This is offset by the essential massive increase in computing capacity to be able to process the additional sensors, such as radar, video and lidar, with their high data volume at sufficient speed. Furthermore, the vehicle communicates with external infrastructure, such as other vehicles, traffic lights and building control systems, as would be found in parking lots, **FIGURE 1**.

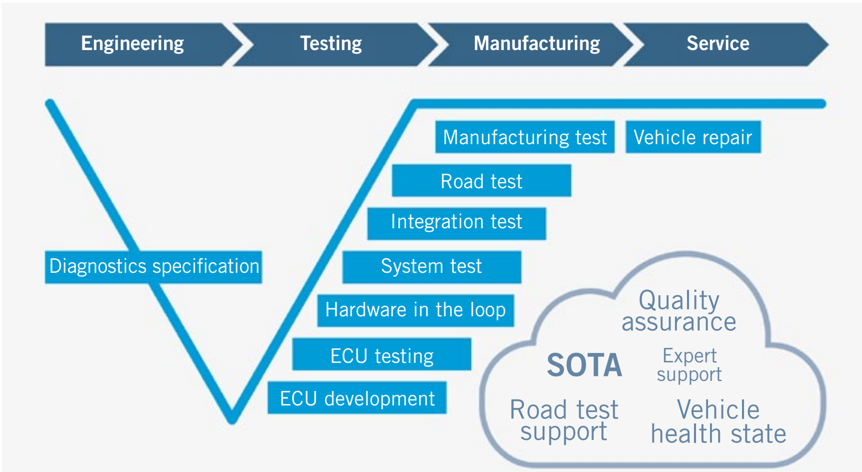

FIGURE 1 Use cases and extensions over Diagnostics 4.0 (© Softing Automotive)

DIAGNOSTICS IN A STRESS FIELD

All this has an incredible influence on the functional safety of the vehicle, directly or indirectly, but also on vehicle diagnostics. Particularly in tests compliant with ISO 26262, diagnostics often makes it relatively simple to make sense of the variables. But diagnostics is also relevant while driving: Distributed functions such as braking, as mentioned above, have to be tested constantly by a central unit (diagnosis master) using several ECUs to enable comprehensive statements to be made on the functioning.

Opening up the vehicle to the outside via radio links also opens up new application cases for diagnostics. Along with updating the ECU Software Over the Air (SOTA), genuine diagnostic applications also become possible. An example of this is the ISO 20078 (Extended Vehicle) which allows interested third parties to gain access to vehicle data via cloud applications when this has been cleared by the vehicle owner. Examples of third parties may be legislators (OBD), insurance companies or manufacturers of diagnostic testers. The prerequisite for such scenarios is the mastering of the security requirements in terms of applications (in the vehicle, but also outside), data and connecting routes.

DIAGNOSTIC STANDARDS

To facilitate the collaboration between OEMs and ECU suppliers as well as tool manufacturers, fundamental communication mechanisms have today been standardized. This all started out with communication protocols where the original manufacturer-specific protocols were replaced in favor of standardized ones more than 20 years ago. Today, CAN-Bus UDS is used for cars and Diagnostic-over-IP (DoIP) and Ethernet for higher bandwidth requirements. Furthermore, it has been proved that ever more extensive diagnostic specifications cause additional difficulties. This is why a standard diagnostic system has won through today in terms of the architecture, **FIGURE 2**.

The file formats are the basis. The data is stored in XML files and can thus be processed directly by the computer or converted into readable formats ("executable specification"). ODX (Open Diagnostic Data Exchange) describes the communication between the tester and the ECU, typically consisting of a request and the respective response. These include conversion rules from the machine format ("hex") to physical variables ("symbolic"). With OTX (Open Test Sequence Exchange) several such communication cycles can be combined to form closed diagnostic tasks and can then be used in different testers without any additional effort. Examples include a flash programming sequence or a vehicle quick test.

Various Application Programming Interfaces (APIs) are available for integration in test systems: The D-PDU API is used to integrate VCIs as varying form factors are usually required in the lab, on test benches, production lines and in the repair shop. The MCD-3D makes it possible to run individual diagnostic services

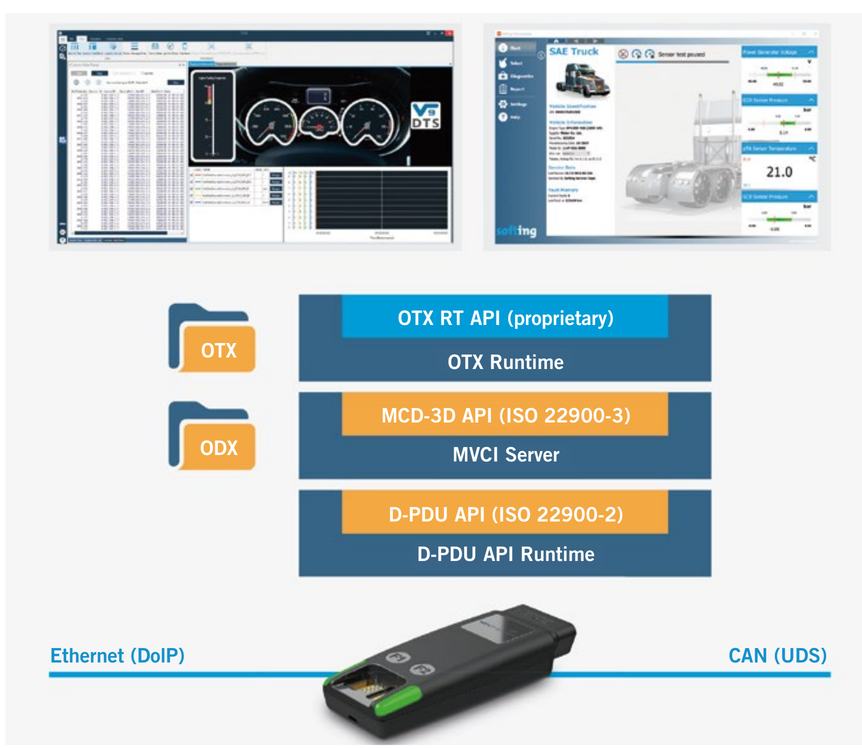

FIGURE 2 Standardized diagnostic runtime system (© Softing Automotive)

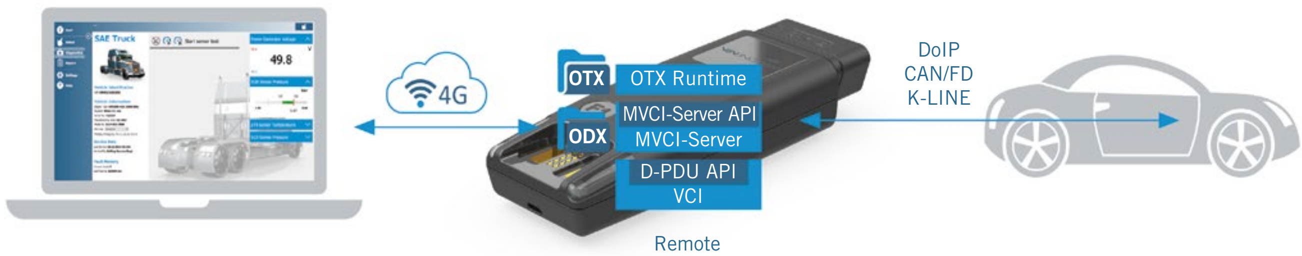

FIGURE 3 It is possible to call in a diagnostic expert from a distance during engineering to run in-depth analyses to decrease cost (© Softing Automotive)

whereby both the parameterization and the results are human-readable ("measurement value reading (engine speed)" as "1900 rpm"). Both APIs are standardized in ISO 22900. OTX sequences are accessed using proprietary APIs because only the exchange format was specified in ISO 13209.

Systems constructed this way can generally be separated at all interfaces, meaning that specific parts can work independently of one another, whereby the relevant basic conditions must be heeded in terms of bandwidth, latency and transmission reliability.

NEW DIAGNOSTIC PATHS

The named basic conditions particularly have an effect in remote and cloud applications (Diagnostics 4.0). Suitable architectures must be selected depending on the quality and availability of the data connection (infrastructure) and on the requirements resulting from the application cases such as:

- vehicle is in the repair shop
- driving the test circuit or on the roads
- is standing at the customer's.

Basically this results in completely new possibilities. Software for example can be updated on an ECU without having to visit the repair shop. This saves the customer a trip to the repair shop and saves the manufacturer the associated costs. It is, however, also possible to carry a diagnostic system around in the vehicle, regularly run diagnostic sequences and to store the data in the cloud at an appropriate moment. This results in a pool of historic data which can be used in many ways in quality assurance but which can also be used for predictive maintenance. Vehicle availability is thus significantly increased.

A further valuable application case is expert support. This makes it possible to call in a diagnostic expert from a distance during engineering on test benches or in a test drive, or even in the repair shop, and run more in-depth analyses. There is a corresponding decrease in costs in both cases, **FIGURE 3**.

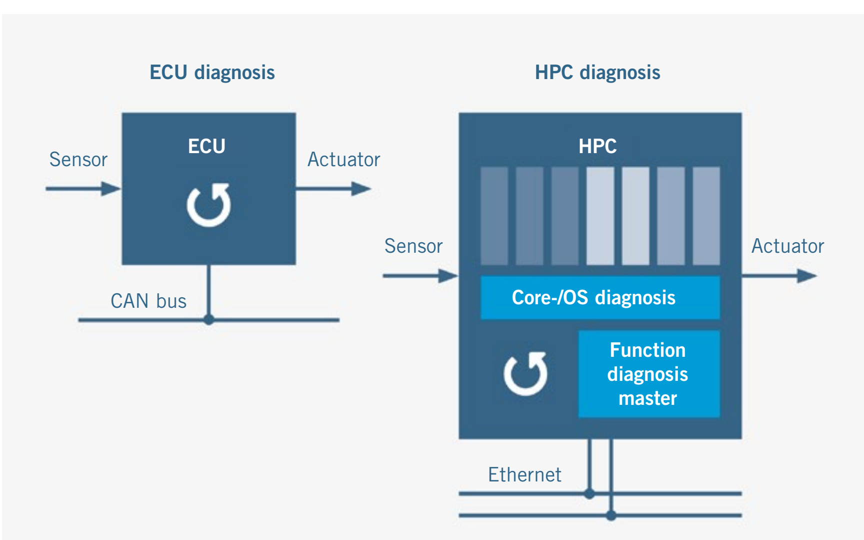

FIGURE 4 Comparison ECU diagnosis versus HPC diagnosis (© Softing Automotive)

AUTONOMOUS DRIVING AND DIAGNOSTICS

The requirements of autonomous driving lead to completely new E/E architectures in which several High-performance Computers (HPC) take over central control tasks and today's ECUs only control decentral sensors and actuators. The HPCs have connections to high bandwidths and can also facilitate external networking (WiFi/4G/5G). In many cases they are multi-core systems with up to twelve computation cores on which different operating systems can be used for different tasks, such as Autosar parallel to Linux, **FIGURE 4**.

As far as diagnostics is concerned, HPCs will initially have the same tasks as today's ECUs. In addition, they must provide the master functionality for distributed functions and for the mentioned example of the brake to ensure that battery management, recuperation over the electro motor and mechanical brake work both individually and in the entire system. In addition, the described requirements of Multi-Core and Multi-OS (Operating System) require diagnostics of the HPC states in terms of the distribution of functions and the CPU utilization. Only then can the reliable functioning of different applications from different manufacturers be ensured with changing states.

STEP-BY-STEP MIGRATION

Adjustments to E/E architectures will not be executed in a revolutionary way, simply for cost reasons. This means the first HPCs will often be domain controllers with additional tasks. Parallel to this, diagnostics will also introduce new mechanisms. Luckily, existing architectures already allow extensive scaling, new approaches can be based on current methods or even integrated in tried and tested implementations.