Testing environment for heterogeneous electrical/electronic vehicle topologies

Networking test in an interconnected system for ACN FD, LIN, Flexray and automotive Ethernet

Introduction

The marked heterogeneity and the increasing complexity of modern electrical/electronic vehicle architectures provide new challenges for testing equipment. In order to guarantee the reliability and safety of the vehicle's electrical system despite complex transmission protocols, high data volumes and a multitude of new technologies, existing test cases and test systems need to be adapted or new ones developed. The networking test focuses on both established bus systems and modern transmission technologies.

To date, the CAN bus has proved itself to be an efficient and robust communication technology in the networking of electrical automotive components. The "FD – Flexible Data Rate" upgrade provides it with optimisations in terms of bandwidth and net data rate, and it is therefore equipped for the requirements of modern vehicle architectures. Previously used throughout vehicles, the application of this bus technology is now concentrated in individual vehicle areas or is used as the backbone when introducing new transmission technologies.
The FlexRay bus has established itself as the complement to tried-and-tested CAN networking. This bus system is distinguished among other things by deterministic transmission behaviour and a comparatively high gross data rate. Currently, it is used in particular for networking the electrical components in the drive train.
The low-frequency LIN bus offers a cost-effective alternative for implementing sub-buses. Following the master–slave principle, it allows less complex ECUs to be networked as well as sensors and actuators, for example in the seat and door controls.

The Ethernet, technology that is familiar from consumer electronics, is now finding its way into German cars with the IEEE standards 100Base-T1 and 1000Base-T1. The automotive Ethernet plays a special role amongst the established automotive communications technologies as this is the first time it is not a bus system in the conventional sense. It features point-to-point connections between the subscribers and a switch-based network topology, which also changes the nature of the physical test access to the Ethernet segments in the vehicle. Relatively high-frequency signals are transmitted via the communication medium by means of ternary pulse amplitude modulation. Combined with high bitrates, this allows large data volumes to be transmitted as they arise between modern high-performance computers from individual vehicle domains.

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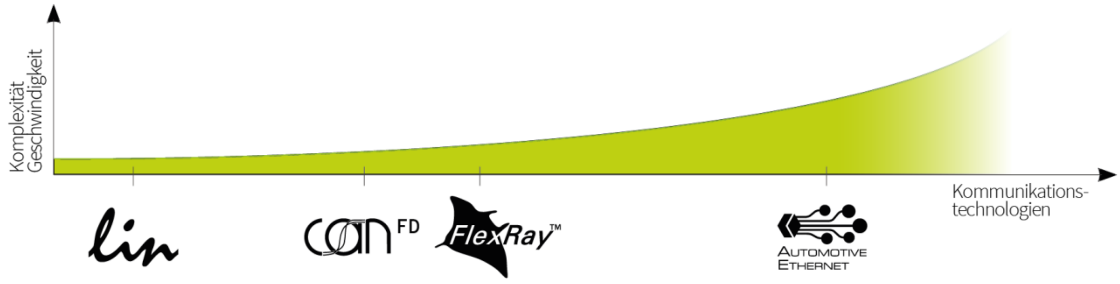

Figure 1: Increasing speed and complexity of communications technologies

Multi-level networking test

The desired behaviour of the bus subscribers is defined in the technical specifications of OEMs. Associated testing standards specify methods for testing the network functions. They describe the desired behaviour of the individual ECUs or of a group of multiple ECUs.

During the networking test on the vehicle as a whole, the bus communication is analysed with a primarily passive test system. The test objectives are split into four categories. Errors can be detected and eliminated early on in an iterative process, thus avoiding potential consequential errors. The components of this multi-stage test method are explained below.

1. Plausibility test

A plausible and consistent data basis is crucial for a meaningful test. The heterogeneous vehicle environment and the different trim levels are depicted by tailored description files (test basis). They are an extension to the data definition and are already being used in the individual control unit test for coordination with the ECU suppliers and those responsible for ECUs. A test basis documents deviations from the data definition and also includes information relating to the transmission behaviour, the physical interfaces and the diagnosis of a control unit.
Figure 2 shows a simplified hierarchy of test bases for describing an ECU group with two buses (segments), three control units and four physical interfaces.
In order for misconfigurations to be detected early on in the test, a plausibility check is performed on the description files. An extendible control installation checks, amongst other things, the correct parametrisation of the individual files, the plausibility of transmitting and receiving relationships and the consistency between the test bases.

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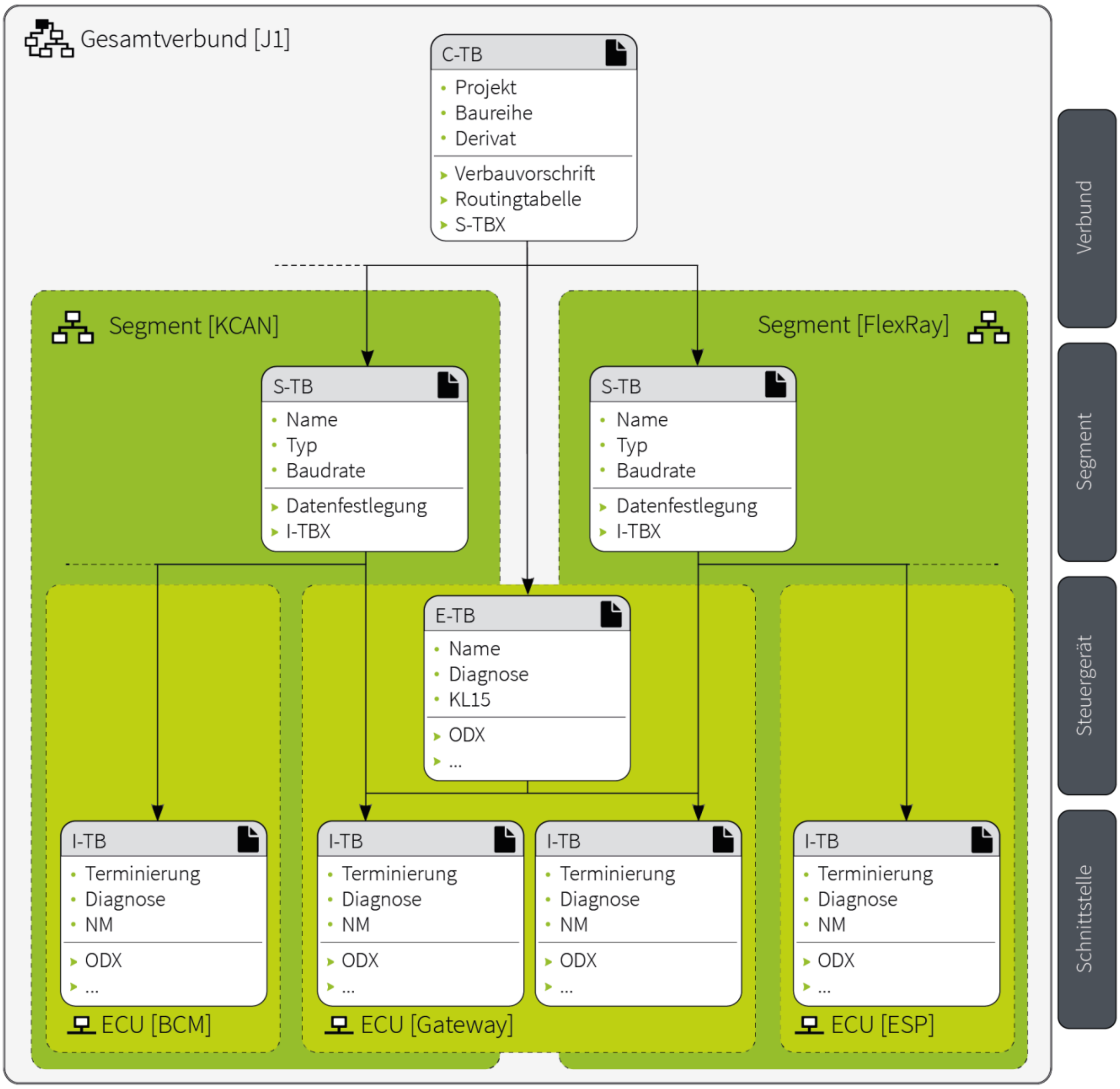

Figure 2: Hierarchy of test bases (TB) for describing an ECU group

2. Acceptance test

Limited availability of laboratory vehicles and unexpected configurations of prototypes in practice repeatedly lead to difficulty in validating the ECU group. An acceptance test therefore checks basic electrical properties of the ECU network and its ability to communicate in advance.

In addition to measurement of the bus terminating resistor and the freedom from defects of the segments, the acceptance test also involves a test for the correct distribution of the terminal information (e.g. ignition on/off) in the ECU network, since without this information some ECU functions are not carried out or are only carried out with restrictions.

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An algorithm also checks the assignment of the segments in the ECU group to the interfaces of the test system. The test system detects the connected segments based on bus communication and optionally responds flexibly to changes in wiring in new test vehicles.
Finally, the diagnostic capability of all group subscribers must be proven. This is an essential prerequisite for a variety of subsequent test cases.

3. Subscriber configuration

The correctness of the SW and HW version, parts number, data status and coding of all installed ECUs are prerequisites for an ECU group to be free from defects. The test system uses diagnostics to determine the corresponding data of the diagnosable subscribers and checks their responses based on installation specifications for the specific vehicle project.
The entries in the error memory of an ECU are also of great significance. They provide information about any potential configuration or ECU errors. In an ECU group that is close to production, the error memory of an ECU should not contain any entries that relate to communication.

4. Group test

Significant test cases in this test complex relate to the *start-up and sleep behaviour* of the ECU group. All subscribers must start the transmission process to the transmission process within a specified period (e.g. after the ignition is switched on) and discontinue sending on the bus once again at a later time (e.g. after switching off the ignition) and maintain this state of bus inactivity. Figure 3 shows the start of the bus communication of all bus segments in a group after switching on the ignition (KL15). The start of transmission for each ECU within a specified time is an important testing criterion and an essential condition for the correct functioning of the vehicle as a whole.

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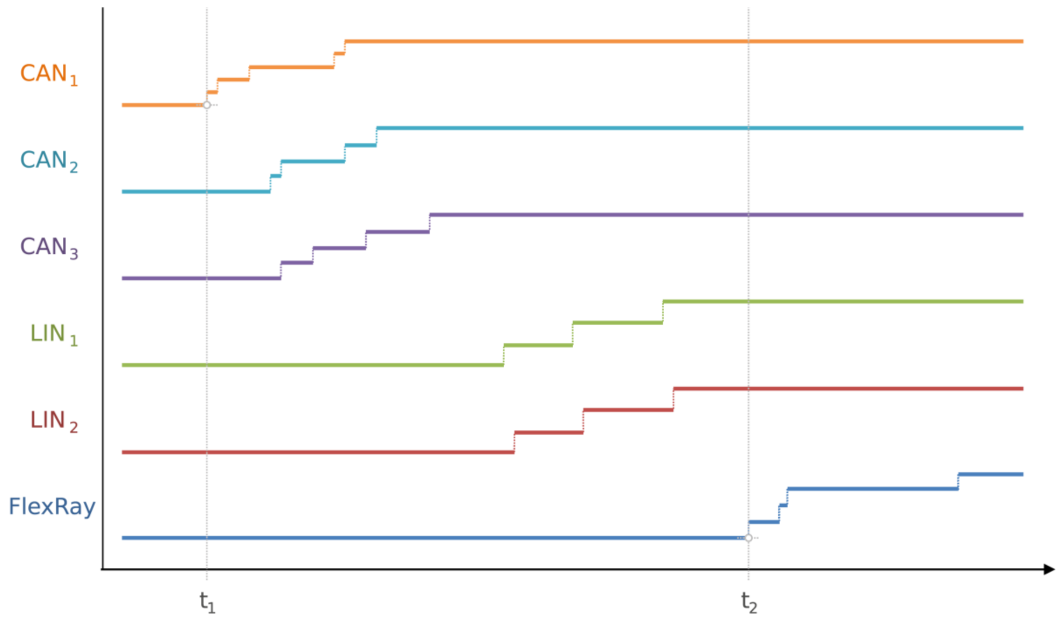

Figure 3:
Illustration of the transmission start time for all ECUs per bus segment after KL15 is switched on.
The stages correspond to the time of the first transmission activity of an ECU.
The first bus segment starts at the time t1 and the last bus segment starts at the time t2.

ECUs in a function cluster that can be put into standby early on as part of sub-network operation if the function cluster is no longer required play a separate role in this test complex.
An error in these major operational states of an ECU can result in undesirable error memory entries in ECUs as well as increased quiescent current consumption of the overall group.
To increase the testing depth further, it is useful to perform additional *stress tests*. The time between the group entering sleep mode and being re-awoken by the test system is iteratively reduced in order to verify the stability of the ECU behaviour. Often, such tests require real-time, cross-bus mechanisms which, when one segment enters sleep mode (e.g. an Ethernet links), trigger active awakening on another segment (e.g. a CAN bus). The realisation of an event/action concept such as this within a test system for an ECU group is shown in Figure 4.

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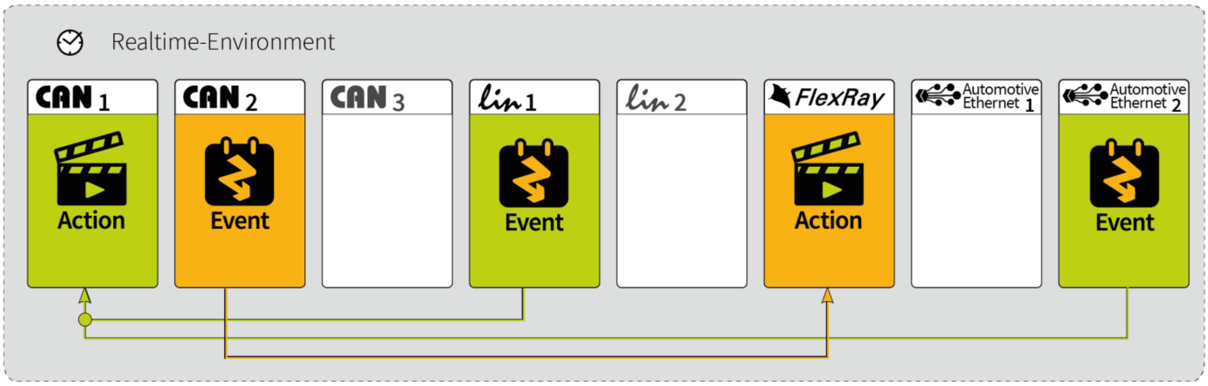

Figure 4: Real-time, cross-bus mechanism
An event is followed by actions with a parametrisable delay

The *transmission behaviour of the ECUs in the group, which is in line with the specifications,* must be checked under various operating conditions between the start-up and sleep process.
The communication during and after normal, undervoltage, overvoltage and various voltage pulses are test scenarios whose significance is equal to that of the communication after physical line errors and faults that are introduced by the test system and that need to be detected by the bus subscribers.
The data sent from the ECUs is checked according to the information from the data definition when evaluating the bus communication. Amongst other things, this includes maintaining the cycle time and the data length at the message or PDU level, as well as correctly calculating counters and checksums in the corresponding signals. The parallel recording of the bus segments and bus-independent test tools allow the use of uniform test routines on different bus technologies. Due to the common time base of the records, further tests can be performed relating to wake-up forwarding or PDU/signal routing for gateway controllers.

Another important section of important tests concerns *network management* of the bus subscribers. This includes state transitions, wake-up causes and maintenance of the bus inactivity. A stress test is useful in this context, too, in order to validate the stability of the network management state machine.

The *tests for self-diagnosis* of ECUs include all operating areas of the group. Basically, tests for checking the relevant diagnostic services of all diagnosable control units via CAN and Ethernet vehicle diagnostic access.
The test complex of the diagnostic tests contains, for example, correct filling of the error memory following undervoltage or overvoltage, voltage dips, line faults and message failure.

Hardware

Göpel electronic GmbH has various test systems for detecting communication in the ECU group using measurement technology.

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Compact systems

The mobile test system magicCAR compact represents efficient testing of functions/applications in the automotive sector. The new device series boasts a compact design, which combines all the necessary resources (power supply, relay matrix, communication interfaces, current measurement and possibly analysis/trigger modules). The device is based on an internal Ethernet architecture and can be extended with external Ethernet-enabled devices, such as oscilloscopes and multimeters. The internal use of GÖPEL standard products for CAN-FD, LIN, Flexray, automotive Ethernet and LVDS is an essential element.
As part of networking tests, the magicCAR compact .NET can be used both for single interface tests as well as group tests on a board assembly or real vehicles.

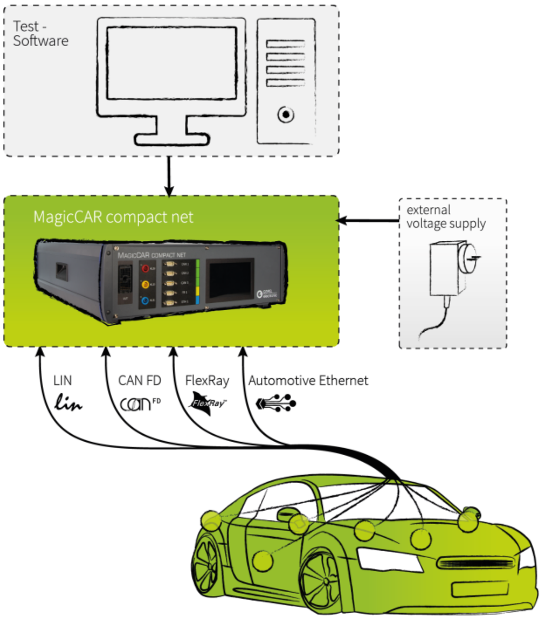

Figure 5: magicCAR compact .NET on the entire vehicle

Network testing systems

In the laboratory, the powerful 19" network testing systems provide detailed checking of physical properties of bus interfaces their communication behaviour and also the simulation of transmission errors on the ECUs both individually and in a group.

The network testing systems from GÖPEL electronic are modular, OEM-independent and can be used across all buses. All available resources (power supply, oscilloscope, multimeter, communication

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interfaces, current and voltage measurement and possibly analysis/trigger modules) can be connected to each other via a versatile relay matrix.

Figure 6: Examples of CAN/FD, LIN, Flexray, Ethernet network test systems

Summary

The testing of modern electrical/electronic vehicle architectures poses various challenges for testing equipment. A plausibility-checked and coordinated data basis and a multi-stage testing process help avoid consequential errors. By using uniform testing mechanisms, heterogeneous vehicle networks can be tested efficiently. Detailed tests to ascertain whether the behaviour of the ECUs in the group is in line with the specifications can be implemented flexibly based on the scalable GÖPEL testing environment. GÖPEL excels in this area thanks to its many years of experience in working with OEMs and suppliers and thanks to its customer focus and flexibility.

About the author:

M. Sc. Christopher Manthey studied practical computer science at the University of Cooperative Education in the German town of Gera. In 2017, he completed his master's degree in the field of computer science at the Friedrich Schiller University in Jena. Since 2010, he has worked as an applications engineer in the "Automotive Test Solutions" division, developing customer-specific solutions for the testing and simulation of communication interfaces in vehicles.