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Communication Error Detection of Automotive ECUs

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Abstract: *CAN (Controller Area Network) and LIN (Local Area Network) communication protocols are widely used in the field of automotive technology. To communicate with the ECUs after the vehicles are constructed, the manufacturers use the UDS (Unified Diagnostic Services) communication protocol over one of the vehicle's CAN buses. It can be used for reading and writing the vehicle internal parameters. In this article I present a test, which main function is the testing of the LIN communication channels error detection, with the help of monitoring the status of the internal trouble codes. These trouble codes are called DTCs (Diagnostic Trouble Code) and they are used for storing informations about the occurred malfunctions. If an error occurs, technicians in the service station can read the codes, and get informations about the malfunctions with the usage of the UDS protocol.*

Keywords: *e embedded software testing, integration test, error detection in automotive ECUs, Diagnostic Trouble Code*

I. INTRODUCTION

Such systems are called security critic systems, which may endanger human lives in the case of breakdown; and may cause serious damages in the environment and economy as well.

In security critic systems the smallest error may also fatal consequences concerning users and therefore developers, too.

In such systems the appropriate quantity and quality of testing are indispensable. The passenger car is a security critic system, because its breakdown may also endanger human lives.

In many cases also occurred that the manufacturer the whole sold substance of a series, because during the operation such errors came to light, which despite the thorough testing could avoid the attention of testers and developers. Such an action may rather awkwardly touch manufacturers, because they have to spend a lot of money on repairing the defective cars.

According to industrial surveys the costs of calling back is the hundredfold of costs arising during the manufacturing and tenfold the costs of errors coming to light in final products [1].

Experts working in services shall know all errors taken place before in the car. The user can also perceive some errors accompanied with lighting up signal light or sound. However, a lot of error may occur during the operation in the car, which the user does not perceive. Such information has an extraordinary importance for maintainers.

In technical life testing is the indispensable step of the development. In the case of smaller works developers and testers carry out testing on themselves, but for realizing greater projects the work of the developers' team is supported by a testers' team.

The article presents a procedure elaborated testing ECU (Electrical Control Unit) used in motor industry, by means of which the ECU can be analyzed through CAN (Controller Area Network) and LIN (Local Interconnect Network) network buses.

The goal of the development is the elaboration of a testing system, with which can be controlled, if Diagnostic Trouble Code (DTC) are really activated.

II. LIN MONITORING TEST

Hardware and software elements used for testing the products of Vector Informatik GmbH. The main profile of the company is the development of hardware and software elements, by means of which the message turnover of any communication system (e.g.: LIN, CAN, FlexRay) or influence it.

The tools can cooperate with software developed by Vector (CANoe, CANape etc.), easing thus the testing the electronic control unit by simulating its planned environment.

For the tests hardware and software elements of Vector are used. In the configuration built-up before a VN1640 is attached to the network of BCM 1 CAN and 3 LIN.

2. Complete modeling of networks

For beginning the testing firstly the model of the network to be examined in CANoe under the window „Simulation Setup”. The CANoe can automatically construct the network using the DBC and LDF databases assigned to it (if our system consists only of LIN and CAN networks). The DBC database describes a CAN network, while the LDF describes a LIN network. The two databases contain all features of all messages of all ECUs. In the knowledge of all important attributes of messages the CANoe can simulate the network turnover of the given network. If the constructed network consists only of simulated units and no CAPL program code influencing its function is assigned to any simulated ECU, only the cyclic messages to be read from the database will appear with the values of Signals.

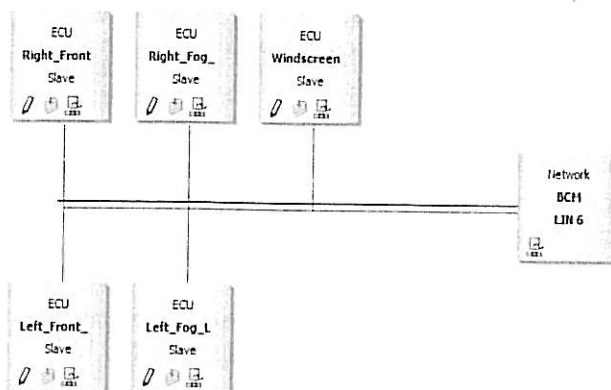


Figure 5. CANoe Simulation Setup.

3. Simulation of the other parts of the network to available physical units

In a simulated network the CANoe promotes the selection of ECUs, which we do not want to simulate. The reason of this may be that the given unit is also physically available and we would like to incorporate this into the network. In this case the CANoe simulates the other parts of the network according to the databases and CAPL [9] program assigned to them, while the physical unit can function according to the program incorporated to it and running on it.

In the configuration adjusted for carrying out the test The Body Computer Module is present as a real physical unit. The 4 LIN and 1 CAN network connected to it are simulated by the CANoe.

4. Diagnostic operations

The CANoe offers a lot of possibilities to carry out diagnostic operations on the examined ECU. In the test two functions are used: Diagnostics Console and Fault Memory windows. Through the Diagnostics Console diagnostic messages can be manually sent to the ECU. In the Fault Memory window all parameters of the activated DTC can be read.

5. Test software

In the CANoe the test software can be assigned to the examined network in the following manners:

- CAPL Test Node
- XML Test Module
- .NET Test Module

In the case of use of CAPL Test Node and XML Test Module the program is written in CAPL language, while in the case of use of .NET Test Module the CANoe assures that the software can be written in C# or Visual Basic language. The main difference between CAPL Test Node and XML Test Module lies in that for this latter the test construction shall be written in XML language as a first step. In the implemented test, the XML Test Module is used.

IV. PROCESS OF TESTING

By means of a ReadDTCInformation function the state of a DTC can be polled. The 0.bit of the state indicates the condition of the DTC, which can be either active (logic 1) or passive (logic 0). If the function represented by the DTC indicates insufficiency, the value of the condition bit will be 1, i.e. it will be active. If the function is sufficient, the value of the condition bit will be 0, i.e. it will be passive. The test software written before examines the changes of the value of the conditions bit.

The DTCs to be tested have three special features concerning the time of the examination of conditions of the activation or deactivation of a DTC. These are as follows:

- 1) During the test the appropriate function of error codes belonging to the units connected to the LIN communication channel are tested. The Body Computer Module shall perceive that a given Node is really connected to the bus, because the conditions of the activation of the DTC of a Node are only examined in this case. This is completely logical, because it is possible that surplus components are later incorporated into the car (e.g. an air conditioner). In this case a parameter of BCM shall be reset in the service through diagnostic, which indicates that the unit installed later has been connected to the bus system since this time.
- 2) The conditions for modifying the state of a DTC can only be examined in the case of the fulfillment of a previous condition (Randbedingung). In the case of failure of the fulfillment of this previous condition the state of the DTC can not changed independently from that the error represented by it exists or not.
- 3) DTCs are assigned to LIN Nodes in 4 different priority levels (1 is the highest). All DTCs are ranged to one priority level and their function is influenced by the state of DTC ranged to higher priority levels. If a DTC state belonging to a higher priority level is active, the DTC state belonging to lower priority level must not change at all.

Hardware elements: The testing environment can be divided to 4 blocks, which are connected to each other on the following way.

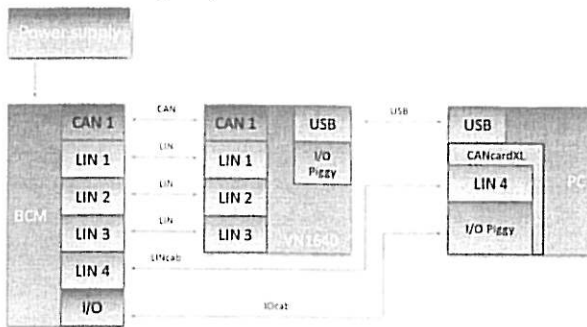


Figure 1. Hardware elements of the testing environment.

1. Body Computer Module (BCM)

The Body Computer Module (BCM) is a central part of the car. This part is responsible among others for interior and exterior lights, heating, windscreen wiper and alarming device besides comfort services. It is connected to other ECUs through CAN and LIN buses. This plays the role the LIN Master operating the communication in LIN channels. It also functions as a gateway between CAN and LIN channels and so e.g. in the service the unit connected to the LIN channel can be easily reached by experts working in the service being connected to the CAN network.

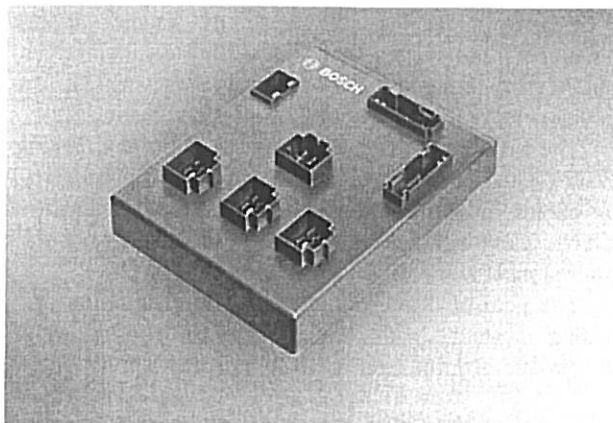


Figure 2: Body Computer Module [7].

2. VN1640

The VN1640 is the most developed member of the VN1600 family [2]. The VN1640 functions as an interface between the computer and networks to be analyzed. It can communicate with the PC through a USB 2.0. It can be connected to four LIN/CAN channels depending on the transceiver being used. Perceivers can be incorporated into the device in any combination. The possible highest baudrate is 2Mbit/s through the CAN bus and 330 Kbit/s through the LIN bus [3] [4]. The connection to networks is possible by means of conventional D-SUB 9 interface



Figure 3. VN1630 (below) and VN1640 (above)[3].

3. CANcardXL

The CANcardXL is a two-channel card, which shall be inserted into the reader of the PC PCMCIA card. One of its channels can function as an I/O control unit, while the other channel can handle CAN, LIN or J1708 networks. There is an incorporated transceiver in the card and therefore the function of the transceiver is assured by special exterior cables (LINcab, CANcab, J1708cab and IOcab). The card shall be directly connected to the networks to be analyzed and I/O lines.



Figure 4. CANcardXL and IOcab [8].

4. CANcardXL and IOcab

The I/O channel of the CANcardXL I/O is connected to some digital stands of the Body Computer Module through IOcab, which shall be directly controlled during the test (e.g. lighting switch). The other channel of the card is connected to one of LIN networks of the BCM by means of a LINcab.

III. SOFTWARE ELEMENTS

1. CANoe

The CANoe is a many-sided tool used for Electrical Control Unit development, examination and analyze. In the following some of its generally used function are presented:

- Complete modeling of networks
- Simulation of available physical units to the other parts of the network
- Diagnostic operations
- Writing of test software for a network

All three above-mentioned conditions shall be fulfilled so that the examination of the conditions of influencing a DTC state [6]:

- Nodes shall be coded.
- The previous condition (Randbedingung) shall be fulfilled.
- No DTC ranged to a higher priority level must not be active.

The state of a DTC can be activated, if the conditions enumerated before exist and the events necessary for activation take place and exist for a previously determined time.

The state of a DTC can get passive, if the conditions enumerated before exist and the events necessary for deactivation take place and exist for a previously determined time. The events of the deactivation are usually contraries of those of activation.

The first step of the process is the diagnostic contact with the Body Computer Module. In the framework of this step the operation mode of the ECU shall be set to a state, in which the coding of Nodes is allowed. For coding we shall login towards the BCM by means of the GetSecurityAccess diagnostic message. Beside these all notes belonging to DTC are deleted from the memory of the BCM.

After the successful carrying out of the first preparatory step the testing of DTC read through from the database is started. As the first step of the testing the Node belonging to the DTC to be controlled shall be coded. If this fails for any reason, the test will not interrupted, because in this case the state of the DTC to be tested could not change either and the developer could assume that the function of the software is not appropriate.

If the coding of the Node successfully took place, the test will try to set the parameters contained by the previous condition (Randbedingung). If it fails, the test will be continued with the examination of the next DTC. If the previous condition (Randbedingungen) is fulfilled, the test will verify in the next step if a DTC of a higher priority level is assigned to the DTC to be tested. If this condition fails to be fulfilled, the test will carry out the DTC activation test step presented before.

If there is a DTC ranged to a higher priority level, the testing program will carry out the testing, if the DTC of higher priority is inactive and then, when it is active. At the end of the test Randbedingungen is intentionally broken and then the test carries out the DTC activation test steps.

Event to be evaluated are as follows [10]:

- 1) Can all activation procedures can activate the DTC in lack of a DTC of higher priority?
- 2) Can be the DTC to be examined be activated with any activation procedure, if the DTC to be tested has a DTC of higher priority?
- 3) Can be the DTC to be examined be activated with any activation procedure, if the DTC to be tested has a DTC of higher priority in its passive state?

- 4) Can the DTC be activated, if Randbedingungen conditions are not fulfilled?

In the first and third case we have a positive result in the case of the activation of the DTC. In the second and fourth case we will have a positive result, if the DTC is not activated.

III. CONCLUSIONS

The prepared test can be an important tool for software developing engineers. The manual testing of DTC being the centre of testing is a rather uncomfortable and time-consuming task. However, due to the test we have an automated test system easy to treat. In the case of necessity the test can also be extended very easily, because the algorithm is given and only new activation procedures need to be implemented into the testing function, for which the CAPL offers a lot of incorporated functions. I tried to form the functions written in the test on myself so that later they can also be used for other tests.

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