CENTRAL COMMUNICATION UNIT FOR VEHICLES WITH DIESEL ENGINE

Dragan Taranović[1], Radivoje Pešić, Aleksandar Davinić, Andrija Savčić

UDC: a) 629.3.054
b) 629.113.5 : 681.587.7

INTRODUCTION

Motor vehicle, as a complex system, has several subsystems (engine, brakes, suspension, steering, active and passive safety systems, signalization, diagnostics ...). Each subsystem has corresponding electronic control unit. The same information is frequently required for operation of different electronic control units, so the information exchange is necessary. Also, synchronization of operation of all subsystems is necessary. Information exchange is conducted by using a serial communication network between the subsystems' control units. A special central communication unit, which directs and filters information gained by data exchange between subsystems' control units, is used to synchronize the subsystems.

Some subsystems (for example, engine, ABS, air bags ...) with their control units may be used on several vehicle models of the same or different producers. Particularity of each vehicle model manifests itself through Central communication unit, which integrates all subsystems in a whole, providing necessary information for operation of all subsystems and meeting specific demands of vehicle model.

Factory "Zastava Automobiles" has built a diesel engine DV4DT (made by Peugeot factory), which acquires some of information necessary for normal engine operation with the help of communication network based on CAN protocol, on Zastava Florida vehicle in order to modernize the vehicle and broaden a model range. Also, part of information on engine operation that is being transferred for operation of the instruments and signal bulbs on the dashboard may have been acquired only through communication network. In vehicles made by Peugeot, it is achieved through a special central communication unit, CCU, (Peugeot factory calls it BSI) that cannot be used in Zastava Florida vehicle. Thus, it has been necessary to develop a specific Central Communication Unit for Zastava Florida vehicle with a diesel engine. A small budget for development and potential small series of vehicles did not allow the engagement of some specialized firm like Bosch in development of the Central communication unit.

TECHNICAL DEMANDS FOR REALIZATION OF THE CENTRAL COMMUNICATION UNIT

The Central Communication Unit (CCU) exists in every modern vehicle that meets strict ecological and safety regulations. The control part of the unit is realized with the help of

[1] Corresponding author e-mail: tara@kg.ac.rs, Faculty of Mechanical Engineering from Kragujevac, Sestre Janjić 6, 34000 Kragujevac, Serbia

microprocessor in which the software is placed in EEPROM memory and may be updated if there is a need to replace the model in production or if software error is observed in exploitation.

Vehicle models produced in large series have Central communication units developed specially for those vehicles.

Vehicle models produced in small series use standard hardware units and software is developed and adjusted to the vehicle model for which it is used for. There are a few producers specialized for adoption of software of standard hardware communication units to the vehicle and the leader in this field is Bosch.

Software in control units, as well as the used algorithms, based on which the software is written, represent producer's business secret and they are not presented in public. One part of the information that is being exchanged through communication network is public and its form is prescribed by corresponding regulations (OBD for example), while the rest of the information is not documented and thus it is unavailable for public use.

Depending on the number of the subsystems built in the vehicle, there may be a swamp during information flow, so some information may lose their relevancy after some time, if only one communication network is used. In order to prevent a swamp of communication networks, the Central communication unit may be connected with two or more communication networks. Using of several communication networks demands the networks to be divided according to priority and communication speed through them.

By analysis of communication demands in Zastava Florida vehicle with diesel engine, conclusions are reached that the communication unit should have one communication channel for data exchange between engine Electronic Control Unit (ECU) and the Central communication unit and that additional electronic control units of some vehicle subsystems like ABS or airbags that have not been implemented at the start of the production, may be later connected to communication bus.

Concept of communications in Zastava Florida vehicle with diesel engine is shown in figure 1.

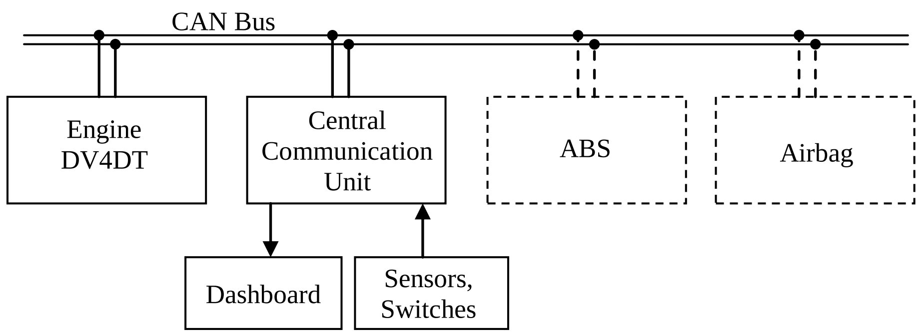

Figure 1: *Concept of communications in Zastava Florida vehicle*

The central communication unit acquires and processes information necessary for operation of diesel engine and dashboard. Accuracy of the information is checked by algorithms and, when their accuracy is established, they are coded and transformed in numeric binary form in order to send them through CAN bus to diesel engine's ECU.

The total travelled distance of the vehicle calculated on the basis of information on vehicle speed acquired from the engine's ECU is transferred to the engine's ECU as numeric information. The total travelled distance is permanently memorized in the CCU and it is needed by the ECU for forming of OBD information. If some information is not reliable or accurate, the engine's ECU is also informed by corresponding message.

The Central communication unit sends the following information as binary information to the ECU:

- brake switch state,
- inertial switch state,
- air-conditioning switch state and
- fuel level in reservoir.

A result of algorithmic check is sent with each of this information.

Based on numeric information separated from the engine's ECU messages, CCU extracts information necessary for operation of signal bulbs and instruments on the dashboard and for operation of some devices on the vehicle.

CCU on the dashboard controls operation of the following signal bulbs:

- diagnostic bulb (MIL),
- exceeding of the engine's maximum temperature,
- occurrence of water in diesel fuel,
- overheating of the diesel engine and
- proper function of the CCU.

Based on numeric information from the engine, analogue signals necessary for operation of the following instruments are generated in the CCU:

- speedometer,
- engine speed,
- engine temperature.

As an answer to air-conditioning turnign on, the engine's ECU sends information when it is permited to turn on the air-conditioning and, based on that information, the CCU engages the relays that turn on the air-conditioning.

HARDWARE AND SOFTWARE REALIZATION OF THE CENTRAL COMMUNICATION UNIT

A prototype of the Central communication unit for Zastava Florida vehicle with diesel engine type DV4DT, made by Peugeot, is made with microprocessor that has a communication module with CAN protocol and RAM and EEPROM memory on it.

Industrial prototype is made with double-sided printed circuit-board with SMD components chosen in such a way that it may work in broad temperature range from -40°C to 85°C as demanded from electronic components that are to be mounted on motor vehicles. The printed circuit-board with electronic components and a connector is placed in a metal box which decreases electro-magnetic disturbances that may unfavourably influence the operation of electronic devices. Connecting the prototype to vehicle's electric installation is done by 25-pins connector. Complete prototype of the CCU is placed under the steering wheel in immediate vicinity of the dashboard in order to reduce the length of the cables connecting the dashboard and the CCU.

A view of CCU prototype with printed circuit-board partially pulled out is shown in figure 2.

Figure 2: *Prototype of the central communication unit*

Functional zones, marked in figure 3 on , may be seen on the printed circuit-board of the CCU.

In figure 3, zone 1, there is a microcontroller with an oscillator that operates on frequency of 24 MHz. In zone 2, there are output drivers for switching on and off of the bulbs on the dashboard and of the relays for switching on the air-conditioning. Output drivers have overload protection and self check if output section is in a short circuit and cut-off and they transfer that information to the microcontroller. In zone 3, there are analogue outputs for starting the instrument for engine temperature measurement and pulse generators for operation of the instrument for vehicle and engine speed measurement. Zone 4 contains components for conditioning and multiplexing of input signals from the switch.

Conditioning and multiplexing is realized with the help of a special integrated circuit that has voltage overload protections built in. In zone 5, there are drivers for CAN bus access with filters for prevention of electro-magnetic disturbances that appear during passing of impulse signals through electric installation. Zone 6 is a connector. In zone 7, there is a voltage stabilizer that provides 5V voltage for microcontroller operation. Connector for input and update of software from microcontroller is placed in zone 8.

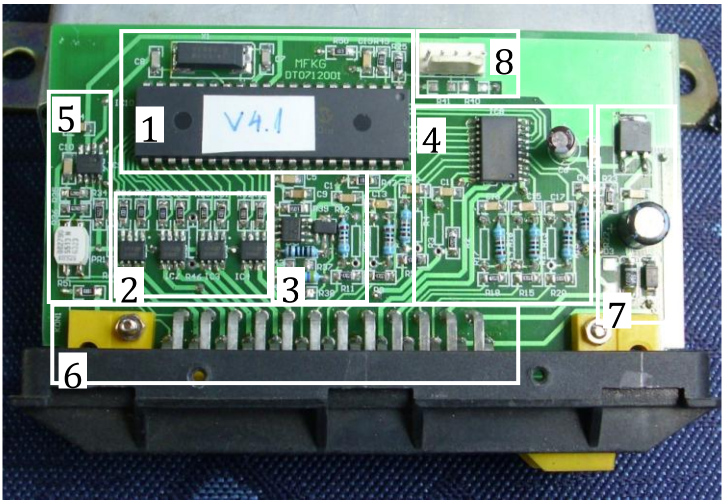

Figure 3: *Functional zones of the Central communication unit*

Electric circuit layout for connecting the Central communication unit to the electric installation of vehicle is shown in figure 4. Wires that are used for connecting to the CAN bus are realized as twisted pairs in order to eliminate electromagnetic disturbances.

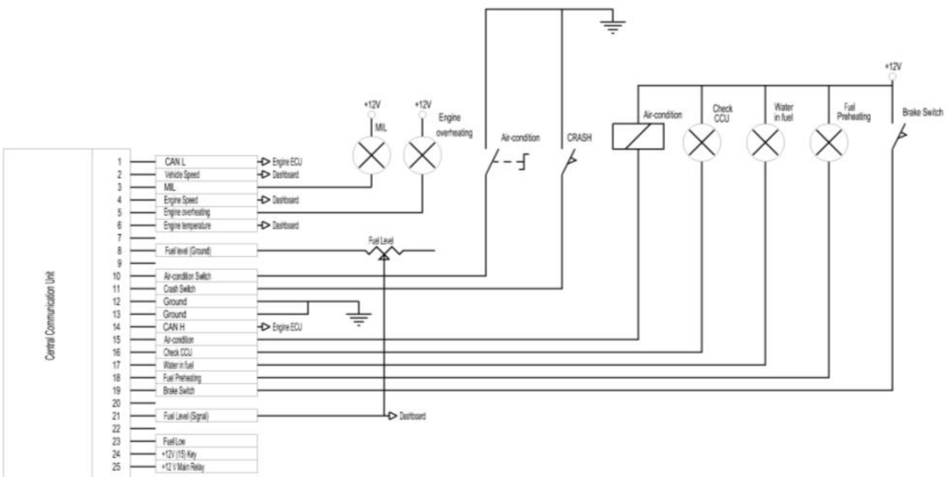

Figure 4: *Electric circut layout of the Central communication unit*

Programming code is placed in microcontroller's EEPROM memory and written in assembler in order to achieve maximal operation speed, in order words that CCU may perform control in real time. Operation in real time is necessary for mathematical transformation of numeric information gained for the engine's ECU into impulse train for sensor of vehicle and engine speed and into analogue voltage for temperature indicator.

Algorithms used in the programming code are formed on the basis of own experiences and information available from literature. Numeric information acquired from the engine's ECU, logically crossed with information acquired at the CCU's input, is used in algorithms for checking the accuracy of information generated by CCU.

Electric circuit diagram and algorithm for checking if output driver is functioning and if really desired activity, e.g. switch on the bulb, is realized (figure 5). Testing of the proper functioning is especially important for reliable determination of proper indication or malfunction of MIL bulb.

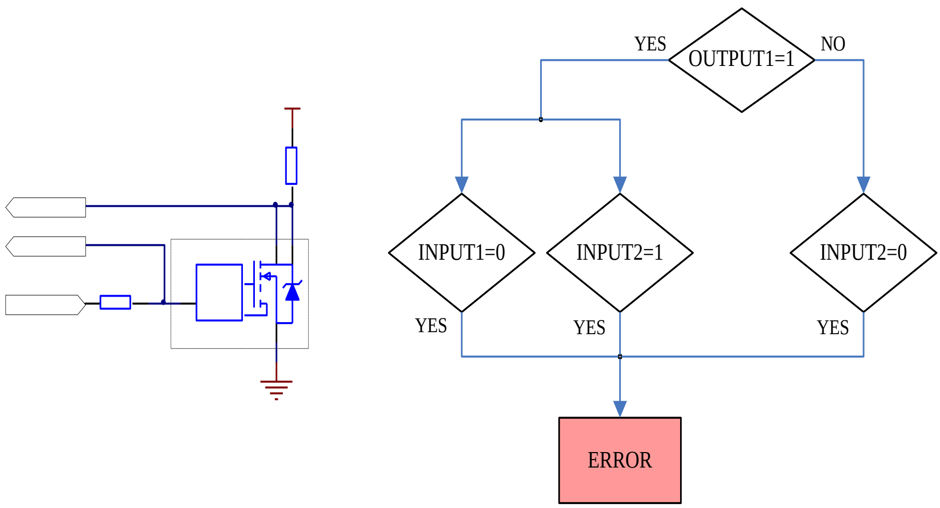

Figure 5: *Algorithmic test of proper function of CCU's output drivers*

Turning on of the bulbs and relays is realised simply by supplying the voltage of the logical unit to the input of the output driver, OUTPUT1. Algorithmic testing if load, Rp, that may be a bulb, a relay or some other resistance actuator, is really switched on, demands the use of two inputs of microcontroller, INPUT1 and INPUT2. With INPUT1, checking if the load's state is adequate to desired is performed and with INPUT2 testing of the driver itself (if it is in short circuit, overheated ...) is performed based on driver's self test.

In the case when there is less than minimum fuel in the reservoir, the engine's ECU switches to a special regime of operation. In order to test if fuel sensor is functioning properly and to determine the fuel low level, fuel gauge must be used which equivalent scheme is shown in figure 6. Algorithm for testing of fuel gauge proper function is presented in the same figure. Since the signal from the fuel gauge is analogue, analogue to digital conversion of this signal is necessary. Based on values obtained by that conversion, it may be determined if the gauge is cut off (CODE 11) or if it has connection to the ground (CODE 01).

Fuel level gauge is cut off if analogue signal measure by microcontroller is higher than:

$$V_{\max} = \frac{\mathrm{POT} + \mathrm{R2}}{\mathrm{POT} + \mathrm{R1} + \mathrm{R2}} \mathrm{VCC} \qquad (1)$$

where POT is total resistance of the fuel gauge.

Fuel gauge is connected to ground if analogue signal measured by microcontroller is less than:

$$V_{\min} = \frac{\mathrm{R1}}{\mathrm{POT} + \mathrm{R1} + \mathrm{R2}} \mathrm{VCC} \qquad (2)$$

Limit value of fuel minimum is experimantally determined.

Example of the applied algorithms, where engine ECU's information is used, is control of proper function of the brake switch (if information that the brake is pressed is correct), given in figure 7.

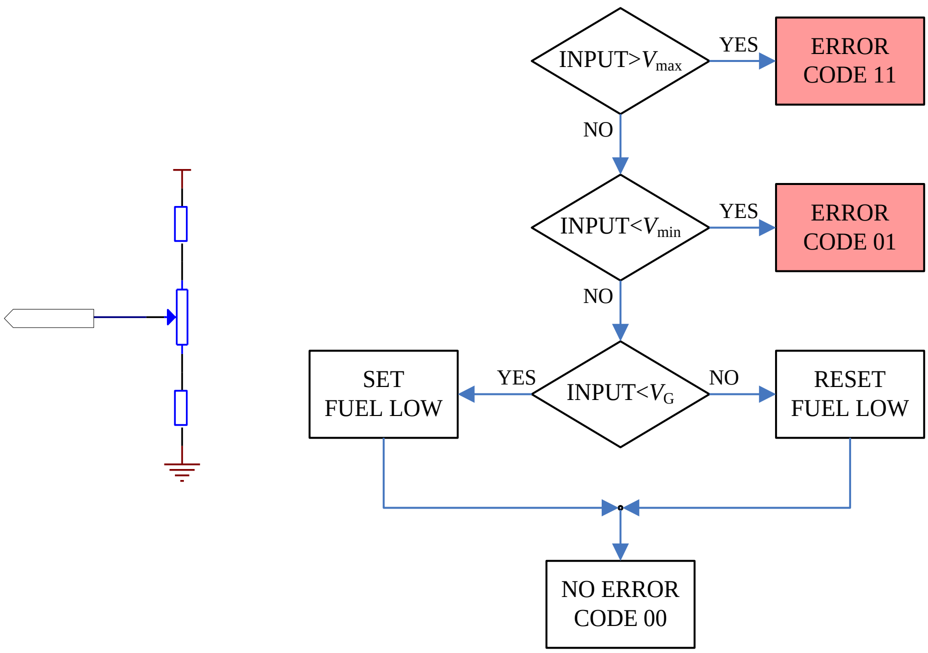

Figure 6: *Algorithmic checkihg of fuel gauge*

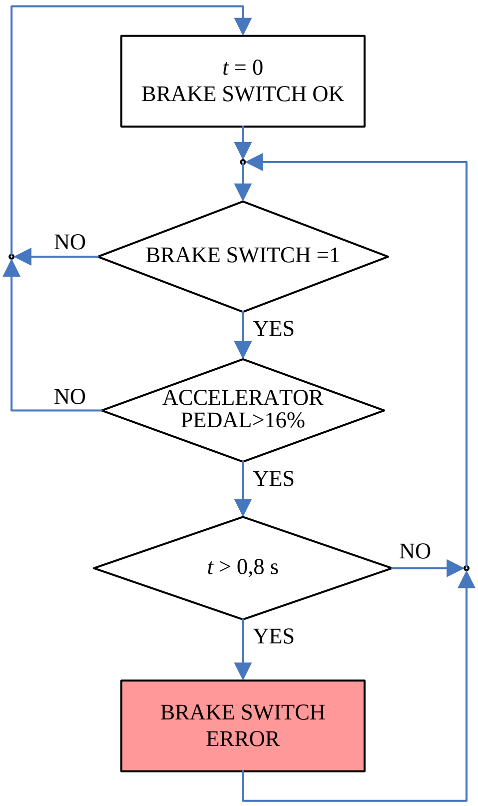

Figure 7: *Algorithmic checking of break switch proper function*

It is considered that the brake switch is defective algorithmically if:

- the brake switch is activated,
- the gas pedal is in position 16% higher than at full throttle,
- previous two conditions exist longer than 0,8 s.

Gas pedal position is obtained in numeric form from the engine's ECU through communication network and it is followed by information if this information is correct. If information is not correct, testing of the proper function of the brake switch is not performed and the CCU sends information that information on brake switch state is not correct.

Malfunctioning of the Central communication unit is signalled to the driver by especial bulb at the dashboard. Conditions for the CCU failure are non existing communication on a CAN bus, malfunction of output drivers (cutting off, short circuit or overload) and algorithmically determined failures of the input parameters.

CONCLUSIONS

Central communication unit for Zastava Florida vehicle with diesel engine is successfully both hardware and software realized. During realization, it has been shown that, in addition to functional characteristics of the device, it is necessary to take care of reliability and accuracy of information transferred to other subsystems. Specific algorithms developed for specific purpose during realization are built into software for testing the accuracy of information and for checking if output organs have properly done what has been to them. They are very often more complex and program demanding than realization of control goals.

ACKNOWLEDGMENTS

The paper is the result of the research within the project financed by the Ministry of Science and Technological Development of the Republic of Serbia.

REFERENCES

[1] Etschberger K.: “Controller Area Network: Basics, Protocols, Chips and Application”, Ixxat press 2001, ISBN 3-00-007376-0

[2] Jovanović S., Taranović D., Savčić A., Đorđević M., Marković Z.: “CAN-bus in automotive application”, International congress Motor vehicles/Motors, CD, paper MVM20080039, Kragujevac, 2008. ISBN 978-86-86663-39-9

[3] Kiencke U., Nielsen L.: “Automotive Control Systems”, Springer-Verlag Berlin Heidelberg 2005, ISBN 3-540-23139-0

[4] Robert Bosch GmbH: "CAN Specification Version 2.0", 1991, Germany

[5] Taranović D., Grujović A.: “Standardization of network protocols in vehicle electric interconnection”, Mobility & Vechicle Mechanics, Vol. 27, Number 3&4, September-December 2001, p. 19-26.

[6] Taranović D., Radulović J., Jovanović S., Savčić A.: “Basic Communication Protocols in Vehicle Electronic Systems”, ICEST 2005 - XL international scientific conference on information, communication and energy systems and technologies, Proceedings of Papers and CD, page 561-564, Niš, 2005