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Current Trends For Vehicle System Monitoring – Development Of Second Generation On-Board Diagnostics.

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Abstract. The objective of the article is to show the development of the second generation vehicle on-board diagnostics and its application for monitoring harmful emissions mainly emitted by the internal combustion engines. Since the end of the last century, car manufacturers have begun to integrate a range of electronic control units into vehicles. This integration is aimed at increasing fuel economy and reducing vehicle emissions. Monitoring is primarily achieved through signals sent by internal combustion engine-mounted sensors that record and send electronic signals to electronic control units about the processes occurring inside and outside the engines' cylinders. Electronic signals are collected and processed in these electronic control units via a CAN controller, where they can be read in real time by diagnostic tools using communication protocols. In order to achieve the monitoring of mass vehicle systems, it is necessary to use common standards for data exchange and their reading by universal diagnostic tools. The International Organization for Standardization (ISO) and the Society of Automotive Engineers (SAE) have issued CAN standards for data exchange in vehicle systems.

INTRODUCTION

Since 1996, car manufacturers have begun to integrate a range of electronic control units into vehicles. The main goal was to increase fuel economy and reduce emissions released by the vehicle through electrical signals sent by the receivers. The additional advantage of electronic control units is car diagnostics, which became applicable at a later stage, and the recording of data for technical evaluation of vehicles. Vehicle diagnostics, also known as on-board diagnostics, is connected via a data connector to the vehicle. The data is sent by the electronic engine control units [1, 12]. In order for on-board diagnostics to be compatible with all vehicles, it is necessary to use a common standard interface. For data transmission between the different control blocks, communication protocols that have become industrial standards are used, with the only difference being the placement of communication pins [5, 6].

These electronic control units are interconnected and participate in the construction of the car's on-board network via a CAN controller. In its structure, the on-board network of the vehicle represents interconnected sources of electricity and their on-board consumers, which together create an on-board electrical network. The main elements of this network are connecting wires, overload protection, switching means (switches) and various connecting and switching devices. Automotive electrical networks are DC 12V and 24V networks [15].

To establish a standard, the International Organization for Standardization (ISO) and the Society of Automotive Engineers (SAE) have issued CAN standards for data exchange in vehicle systems.

For low speed data transmission up to 125 kbit/s: ISO 11519-2 and 11898-2. With high speed higher than 125 kbit/s: ISO 11 898-2 and SAEJ 22 584 or SAEJ 1 939. An ISO standard for diagnostics over CAN is also published as ISO 15 765. Standardization makes it possible for components from different manufacturers to function together. No adaptations required.

Communication with the vehicle is carried out through the CAN controller network when performing diagnostics with a diagnostic tool. Several communication systems are used, corresponding to different communication layers. The ISO 9141 system uses a single K-line for communication, while the new CAN bus

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system uses twisted pair cables with a differential signal. CAN is significantly faster than ISO 9141 reaching a data transmission rate of 500 kbps instead of 10.4 kbps. New hardware and new software are required to be able to run diagnostics on cars that use CAN for diagnostics. CAN is a serial standard for connecting electronic control units, also known as nodes. The complexity of the node can vary from a simple I / O (Input / output) with a built-in computer with a CAN interface and complex software. A node can be a gateway, allowing a computer to communicate via a USB or Ethernet port to devices on the CAN network. All nodes are interconnected by a two-wire bus [15].

High-speed CAN bus (CAN-C) is defined in ISO standard 11898-2 and operates at a data transmission rate of 125 kbits/s to 1 Mbit/s. They are used to connect the following systems in a network: Engine control system, electronic transmission control, vehicle stabilization systems; Instrument cluster.

Low-speed CAN bus (CAN-B) is defined in ISO standard 11898-3 and operates at a data transmission rate of 5 to 125 kbit/s. They are used to control: Climate system; seat adjustment; electric glasses; mirror adjuster; lighting system; navigation system control.

Both CAN buses perform real-time data transmission. CAN buses are increasingly used in vehicle diagnostics. The control unit is connected directly to the CAN bus and thus real-time diagnosis of the vehicle is performed.

CAN can be defined as a serial communication protocol that effectively supports real-time distributed control with a very high level of security [3, 9].

High-speed CAN signaling actuates the CAN high wire to 5V and the low CAN wire to 0V when transmitting dominant (0), and does not actuate either wire when transmitting recessive (1). Setting "0" as dominant gives nodes with lower IDs priority on the bus. The dominant differential voltage is nominally 2V. The dominant voltage in common mode should be generally from 1.5 to 3.5 V [15].

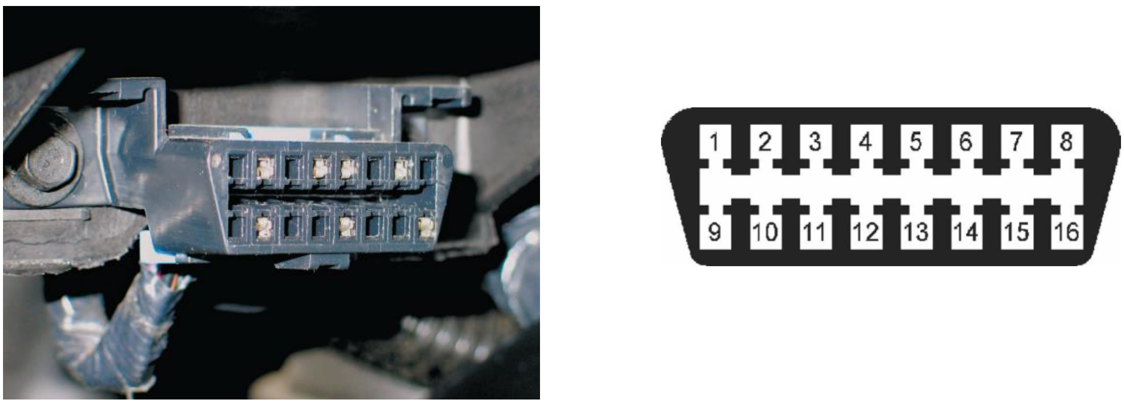
Types of CAN buses used in practice. CAN bus of the power unit (fast bus), allowing the transmission of information at a speed of 500 kbps. It serves to connect the engine line control units and the transmission. Bus "Comfort" CAN system (slow bus), allowing the transmission of information at a speed of 100 kbps. It serves to connect the control units entering the "comfort" system. CAN data bus of the information and command system (Slow bus), allowing data transmission at a speed of 100 kbps. It serves to connect different service systems: radio system, communication system, etc. [15].

On-board diagnostics technology is used to monitor engine performance and the operating status of the exhaust gas recirculation system. On-board diagnostics has become one of the necessary devices in vehicles. On-board diagnostics integrates the vehicle's exhaust gas monitoring system into the engine control system and can continuously monitor the operating status of the components affected by the exhaust gases [11]. Scanners and code readers are used to read the information generated by the computer systems for vehicle operation control [10].

The monitoring of the operations carried out in the vehicle engine is the subject of research, which includes effective monitoring, understanding and even improving their use [2, 4].

MATERIAL AND METHOD

The arrangement of the connector pins for connecting to the on-board diagnostics is shown on (Figure 1) [10]. Typically, the connector location is no more than a meter around the vehicle's steering wheel. The connector must be easily and conveniently accessible for connection to the diagnostic tool. Almost all scanners will automatically configure and read whatever protocol the vehicle uses to send data to the scanner. Table 1 shows the connector pins or terminals and their meaning.



(a) (b)

FIGURE 1. Standard 16-pin diagnostic connector to connect to second generation on-board diagnostics [9]: (a)- location of the on-board diagnostics connector; (b)- arrangement of the connector pins.

Computers and their receivers and all vehicle components that consume electricity are connected to each other through wires called "twisted pair". This twisted pair used by the CAN system to communicate within the computer system is called a BUS, which is nothing more than a communication network. This BUS communication network allows all information from the electronic components operating in this network to be available at any time, since digital messages are sent from each computer or controller in the system and are received by all computers connected to the network [10].

The remaining officially assigned pins of the on-board diagnostic connector can be accessed and used by anyone with a diagnostic tool as follows:

- most European and almost all Asian vehicles use pins 4, 5, 7, 15 and 16 (ISO-9141) for their communication protocols;
- Ford, Mazda, Jaguar use pins 2, 4, 5, 10 and 16 (SAE J-1850) for their communication protocols;
- DaimlerChrysler and most General Motors vehicles use pins 2, 4, 5, and 16 (SAE J-1850 VPM) for the same function;
-since 2003 a limited number of manufacturers including Ford, JM, Mazda, Saab use pins 4, 5, 7, 15 for their respective communication protocol. A trend towards using dedicated pins continued until 2008 when it became mandatory for all manufacturers to use dedicated CAN bus pins on the connector.

The diagnostic tools read the diagnostic trouble codes in the vehicle systems shown on Figure 2. As shown on Figure 2, the code consists of numbers and letters describing the exact fault in the vehicle systems. Each diagnostic tool uses a huge library to describe malfunctions by displaying codes similar to the one shown on Figure 2. The powertrain control module processes a large number of diagnostic trouble codes. Over 4,000 common diagnostic codes are known for the powertrain alone. This number does not include the rest of the vehicle [10].

TABLE 1. Connector pins or terminals to connect to the on-board diagnostics [10]

Terminal. No.	**Assignment**
1	Vehicle manufacturer special
2	Data bus (+) – SAE J1850
3	Vehicle manufacturer special
4	Chassis ground (grounding)
5	Signal ground (grounding)
6	CAN data bus, High – ISO 15765 – 4
7	K – line – ISO 9141 – 2/ ISO 14230 – 4
8	Vehicle manufacturer special
9	Vehicle manufacturer special
10	Data bus (-) – SAE J1850
11	Vehicle manufacturer special
12	Vehicle manufacturer special
13	Vehicle manufacturer special
14	CAN data bus, Low – ISO 15765 – 4
15	L – line – ISO 9141 – 2 / ISO 14230 – 4
16	Battery voltage

There are numerous types of fault codes consisting of five digits [13, 14, 15].

First digit shown on Figure. 2:

- P – Powertrain. Engine and transmission functioning;
- B – Body. Body systems functioning;
- C – Chassis. Chassis functioning;
- U – Network. Bus for data exchange among the electronic units.

Second digit shown on Figure 2:

- 0 – Generic second generation on-board diagnostic code;
- 1 – Manufacturer code;
- 2 – Manufacturer code;
- 3 – Reserve.

Third digit shown on Figure 2:

- 0 – Fuel, air and emission controls;
- 1 – Fuel or air;
- 2 – Fuel or air;

- 3 – Ignition system;
- 4 – Emission controls;
- 5 – Vehicle speed, idle control or aux emissions;
- 6 – Computer or aux outputs;
- 7, 8, 9 – Transmission;
- A, B C – Hybrid propulsion;
- D, E, F – For future development;

Fourth and fifth digits shown on Figure 2 give the specific fault.

These two digits define the general fault.Communication protocols for data transmission in vehicle on-board diagnostics. Although the on-board diagnostics standard is fairly well defined, there are many different protocols or formats in which the data stream is represented through the connector. The methodology by which the electronic control unit communicates with the outside world or other modules is known as communication protocols. As already mentioned, second-generation on-board diagnostics supports various communication protocols that have been constantly developed over time. These protocols include [7, 8]:

- SAE J1850 VPW and SAE J1850 PWM with protocol characteristics shown in Table 2;
- ISO 9141-2 with protocol characteristics shown in Table 3;
- ISO 14230 KWP2000 with protocol characteristics shown in Table 4;
- ISO 15765 CAN with protocol characteristics shown in Table 5.

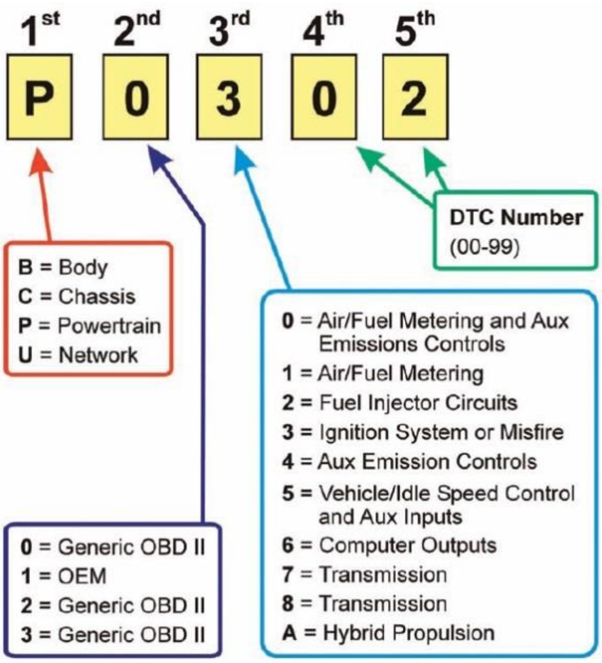


FIGURE 2. Standardized diagnostic fault codes [10].

TABLE 2. Characteristics of communication protocols SAE J1850 VPW and SAE J1850 PWM [7, 8, 13]

Characteristics	Communication protocols	
	SAE J1850 PWM Protocol (Ford)	**SAE J1850 VPW Protocol (General Morots)**
Data transmission pins	Pin 2: low speed of bus data transmission, Pin 10: high speed of bus data transfer Pin 16: +12V Pin 4 and Pin 5: grounding of the automobile systems (including chassis)	Pin 2: High speed of bus data transmission Pin 16: +12V Pin 4 and Pin 5: grounding of the automobile systems (including chassis)
Logic voltage	+5v	+3.5V (max +7v)
Transmission rate	41.6 kilobauds	10.4/41.6 kilobauds
Message length	12 bytes	12 bytes

TABLE 3. Characteristics of communication protocol ISO 9141-2 PWM Protocol [7, 12, 13]

Characteristics	Communication protocols *ISO 9141-2 PWM Protocol*
Data transmission pins	Pin 7: K-line, Pin 15: K-line (optional) Pin 16: +12V Pin 4 and Pin 5: grounding of the automobile systems (including chassis)
Logic voltage	+5v
Transmission rate	10.4 kilobaud
Message length	12 bytes

TABLE 4. Characteristics of communication protocols ISO 14230 KWP2000 Communications Protocol [7, 12, 13]

Characteristics	Communication protocols *ISO 14230 KWP2000 Communications Protocol*
Data transmission pins	Pin 7: K-line, Pin 15: L-line (optional) Pin 16: +12V Pin 4 and Pin 5: grounding of the automobile systems (including chassis)
Logic voltage	+5v
Transmission rate	1.2 to 10.4 kilobauds
Message length	Up to 255 bytes

TABLE 5. Characteristics of communication protocol ISO 15765 CAN Protocol [7, 12, 13]

Characteristics	Communication protocols *ISO 15765 CAN Protocol*
Data transmission pins	Pin 6: CAN high, Pin 14: CAN low Pin 16: +12V Pin 4 and Pin 5: grounding of the automobile systems (including chassis)
Logic voltage	2v difference between high and low
Transmission rate	250 or 500 kbit/sec
Message length	Up to 4095 bytes

RESULTS AND DISCUSSION

Connecting a diagnostic tool to the vehicle on-board diagnostics and systems is shown in Figure 3. Upon successful connection with the THINKTOOL READER diagnostic tool to the vehicle interface OPEL / VAUXHALL model VECTRA C with VIN - W0L0ZCF6981124995, it is possible to proceed to analysis of the engine, suspension, comfort, chassis (body) and safety systems.

The diagnostic tool allows all data from the sensors shows to a graphic (oscillogram) or a tabular appearance in real time. As the number of sensors increasing the connecting mechanisms and connection diagrams in the respective car, the automotive asciloscope is instrument that diagnoses irregularities quickly and easily, and accordingly gives guidance for the next steps to solve the problems that have arisen. Diagnostic Instruments give the direction of diagnosing and detecting irregularities in vehicle systems. True work is done in the next stages. Checking the integrity of the cables and if necessary replacement with new ones, checking the sensor and the output from it, and if necessary replacement with a new one.

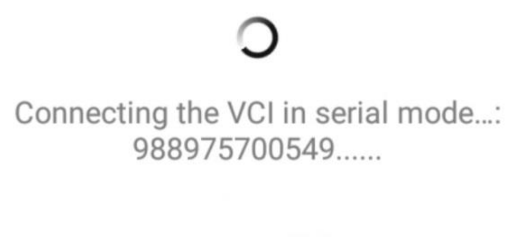


FIGURE 3. Connecting a diagnostic tool with the vehicle on-board diagnostics

CONCLUSIONS

Current trends in vehicle tracking primarily through physical connection to the vehicle's on-board diagnostics connector have been reviewed. Second generation on-board diagnostic communication protocols for data transmission between modules in vehicle systems have been reviewed. The method of connecting a diagnostic tool to the vehicle interface and data reading has been discussed.

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