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CAN-BOX – OBD II Interface – or how to simplify mechanoscopic examination of electronic vehicle components

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Abstract

This article describes a project designed and developed at the Forensic Laboratory of the Voivodeship Police Headquarters in Łódź, which facilitates the mechanoscopic examination of electronic vehicle modules. It describes the basic theory of data transmission using vehicle buses and demonstrates the possibility of its application in research.

Key words: device, controller, vehicle module, electronics, CAN bus, interface, OBD II connector, diagnostic tester, black box, mechanoscopy, road accidents

Introduction

In today's world, it is difficult to imagine a new car without any electronic systems. Cars whose only electronic system is the direction indicator relay module have been registered as vintage vehicles a long time ago. We live in times where the development of electronics has led to a situation in which the driver is no longer the most important 'element' governing the behaviour of the vehicle in unexpected road situations; we could even go as far as to say that the driver is becoming a passenger in his own car. Ten to twenty years ago, the directors of science fiction films predicted the future of modern vehicles and visualised cars without drivers, where the passenger entered the vehicle and simply said where he wanted to go, while the virtual driver drove him safely to his destination and – to tell the truth – we are already living in such times.

Many leading car manufacturers are introducing new solutions intended to eliminate any driver errors, while new regulations are even forcing car manufacturers to introduce them into serial production. The problems with autonomous vehicles are related to legal regulations in the event of a road accident – who is responsible for such an accident if there is no driver and is it possible to penalize a car? This problem will not be discussed further in this article, although it does stand in the way of implementing these technologies in practice.

The rapid development of new technologies and electronic components enables the implementation of faster data transmission and faultless transmission protocols, which leads to the creation of increasingly safe cars, equipped with the latest technology. As late as at the beginning of the 21st century, an on-board computer that calculated values such as average fuel consumption was reserved only for the most lavishly equipped car models. The ongoing technological advance resulted in the creation of electric systems that enable car diagnostics via an OBD II type connector that was first introduced in 1996 in cars manufactured in the United States. Nowadays, in the times of highly advanced electronics, a car's on-board system can be equipped with several independent transmission buses responsible for safety while driving. In new cars, data is most commonly transmitted via a CAN (Controller Area Network) bus. A huge number of installed sensors requires the use of fast, reliable data transmission buses and their mutual communication. The use of data transmission buses that transmit data from all sensors installed in a vehicle has also enabled the cars to self-diagnose. CAN buses responsible for issues such as engine functioning, the comfort or safety systems, are connected to an external interface that can be connected to a diagnostic tool to enable the real-time monitoring of data sent by the sensors and electronic modules and to decode operational errors recorded in this data. Buses are connected with each other via a controller known as the GateWay, which is terminated with a 16-pin OBD II diagnostic connector (On-Board Diagnostic level 2) – see figure 1.

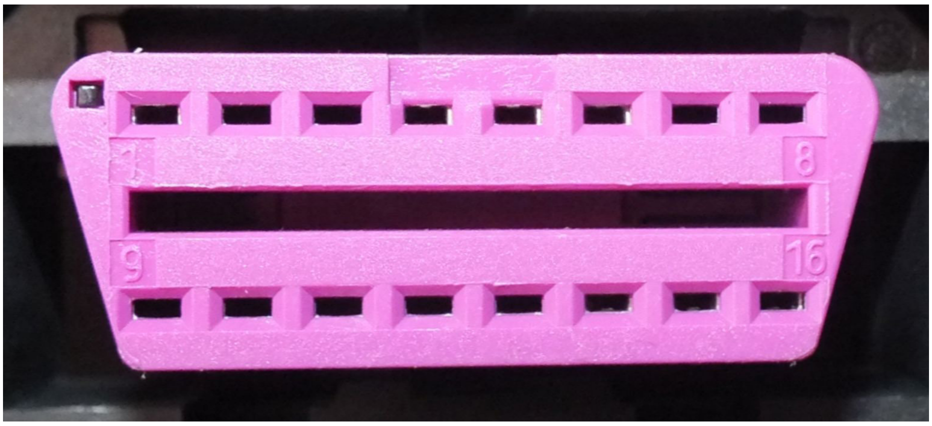


Fig. 1. An OBD II connector installed in passenger cars

One of the most important advantages of a CAN bus is that all electronic modules and sensors in a given subnet are connected in parallel to a twisted pair, which reduces the weight and cost of an electric system. A simplified diagram of the topology of a CAN bus has been shown in figure 2.

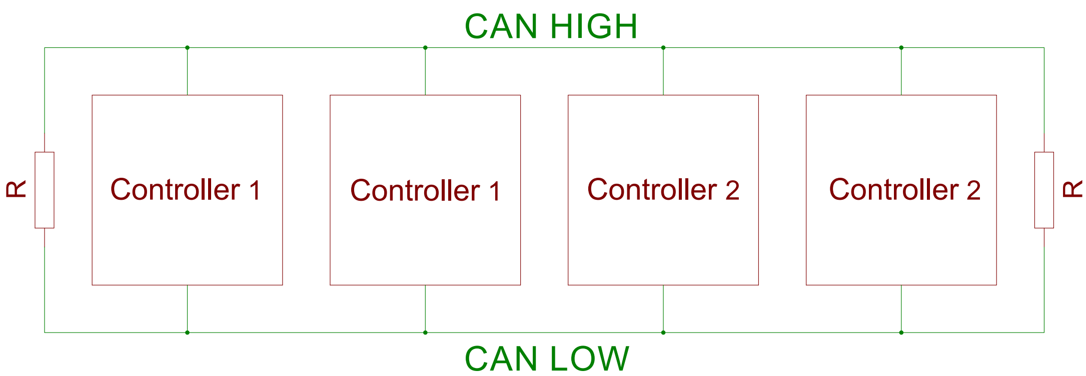


Fig. 2. The topology of a CAN bus

Data in a twisted pair is transmitted using a differential signal, which makes it very resistant to external electromagnetic interference and reliable in car safety systems. In order to eliminate signal interference, terminating resistors of the values of approx. 120 ohms are installed on both ends of the bus. The resistance value depends, among others, on the type of the installed twisted pair. A CAN line includes two conductors known as 'CAN HIGH' and 'CAN LOW'. When no information is transmitted through the bus (recessive state), the voltage on both lines is 2.5 V each, during transmission (dominant state) the values change into 1.5 V for the Low line and 3.5 V for the High line – see figure 3.

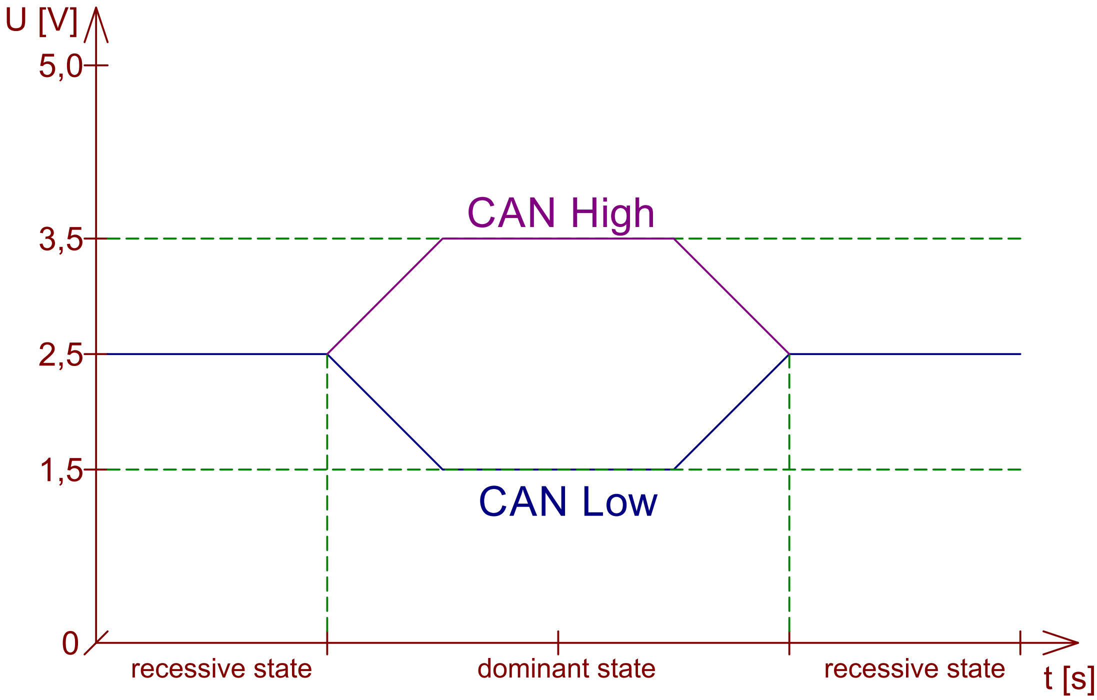


Fig. 3. Voltage levels on CAN High and CAN Low lines

The knowledge of basic information on the transmission of data in a CAN bus, such as voltage level values, can be useful, because it allows us to easily determine whether data is being currently transmitted using a standard voltage meter. The theory related to CAN buses is very extensive and would require a separate article, therefore all the relevant details on data buses can be found in literature and on the internet.

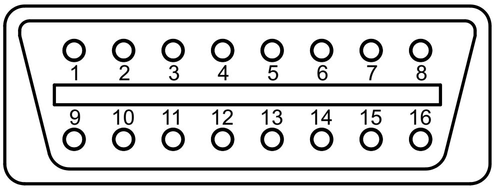
Interfejs CAN-BOX project

Due to the increase in car theft and consequently the growing influence of recommended mechanoscopic examination of electronic components in cars, in 2017 a CAN-BOX Interface was developed at the workshop of the Forensic Laboratory of the Voivodeship Police Headquarters in Łódź, which facilitates the connection of a diagnostic tool to pin connectors of electronic modules installed in cars. The interface enables the easy, non-invasive connection of a diagnostic tool to an examined electronic module and the extraction of data recorded in its memory. Of note is the fact that car manufacturers record data, such as vehicle VIN numbers and module serial numbers, in an increasing number of components, such as engine controllers, dashboard indicators, air bag controllers, BSI modules and even in parking support modules. VIN vehicle numbers recorded by car manufacturers in electronic components represent their individual identification features and can be accessed only using specialist equipment. The interface can also be used to decode 'black boxes', which since July 2022 are an obligatory element in all new cars, while this kind of examination is being implemented in tests carried out at the Road Accident Reconstruction laboratory. We must bear in mind that if a vehicle has been dismantled or damaged in an accident in a way that prevents the connection to a diagnostic connector, only the possibility of decoding such a black box or electronic module will allow a laboratory to examine the box recovered from the vehicle wreck.

The CAN-BOX interface is a simple external interface for the OBD II connector that provides easy access to the CAN bus and to other transmission lines used by car manufacturers. The OBD II connector is usually situated under the steering wheel (see figure 4) in all cars manufactured after 2003.

Fig. 4. Location of the OBD II connector in new cars

Figure 5 shows a table which describes the pinout of the OBD II diagnostic connector (socket). Pins designated as options are pins that can be used by car manufacturers for their own communication protocols.



1	Option	9	Option
2	J1850 BUS +	10	J1850 BUS -
3	Option	11	Option
4	Chassis GND	12	Option
5	Signal GND	13	Option
6	CAN High	14	CAN Low
7	ISO9141 K-Line	15	ISO9141 L-Line
8	Option	16	Power

Fig. 5. The pinout of an OBD II connector

The analysis of signals directly from the connector is very inconvenient due to its location. CAN-BOX provides easy access to the 16 pins of the OBD II connector. It enables the connection of all kinds of diagnostic equipment, CAN bus data analysers, oscilloscopes or diagnostic tools to more accessible connectors, which allows the user to easily diagnose signals sent from a vehicle's electronic modules. An illustrative diagram of connection with a vehicle has been shown in figure 6, while its practical application in a vehicle – in figure 7.

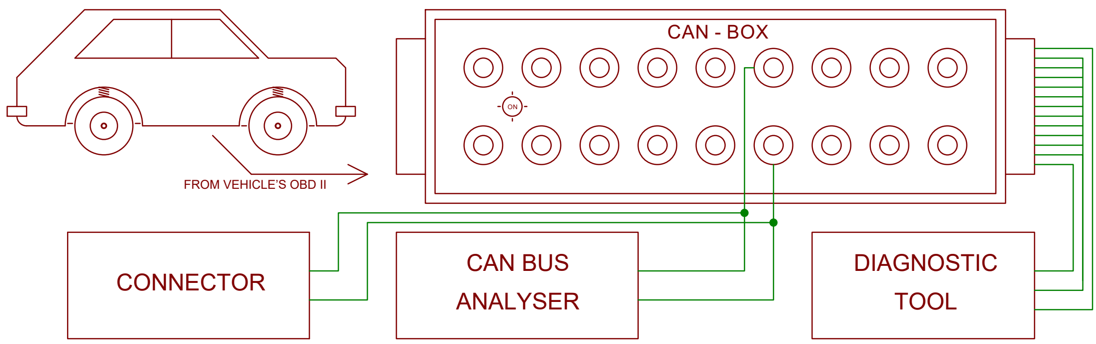


Fig. 6. An illustrative diagram of the connection of interface with vehicle's diagnostic connector

Fig. 7. The practical application of CAN-BOX in a vehicle together with a diagnostic tool

CAN-BOX also enables the easy connection of an electronic module removed from a vehicle and its examination out of the vehicle, as shown in diagram in figure 8. Figure 9 shows an engine controller connected via cables to the CAN-BOX, in order to extract data recorded in its memory.

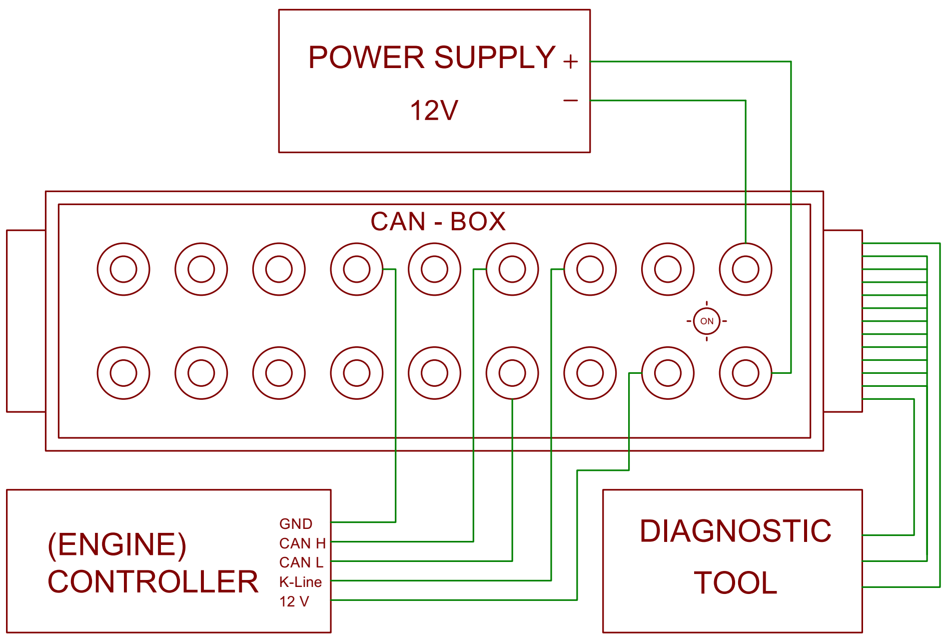


Fig. 8. An illustrative diagram of the connection of controller removed from vehicle

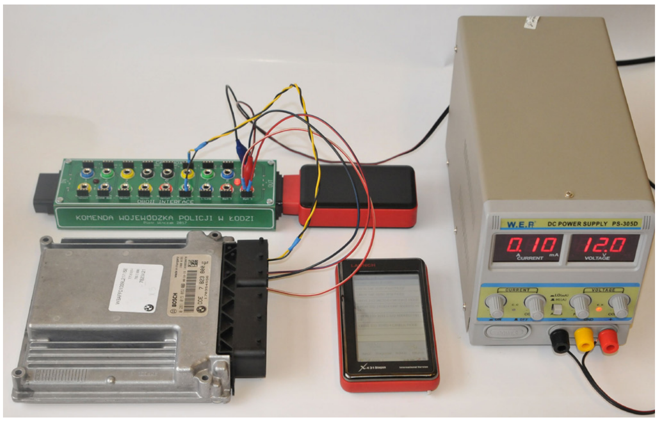


Fig. 9. The practical connection of an engine controller with the CAN-BOX interface in order to extract data from its memory

The CAN-BOX can be powered in two ways – via the OBD II diagnostic connector or via a laboratory power supply unit. Both power supply lines are secured using rectifier diodes that protect the connected diagnostic equipment against reverse polarity of the supply voltage. A schematic diagram of the project has been shown in figure 10.

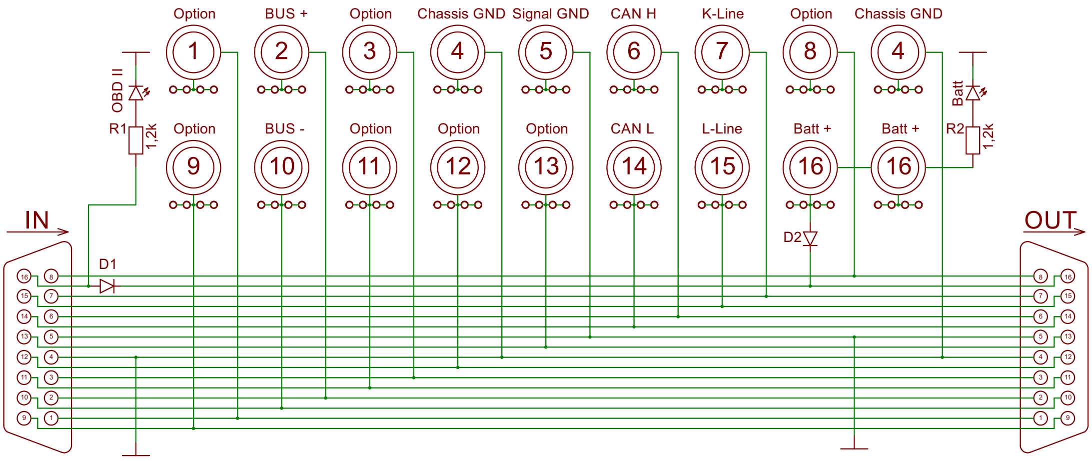


Figure 10. A schematic diagram of the CAN-BOX interface

The CAN-BOX interface is clearly an electronically simple device. It could even be classified as an electric device, because apart from four electronic elements in the form of LED diodes and rectifier diodes, it only consists of electrical connections. Therefore we will not discuss the principle of operation of this device. It is useful to know the purpose of the LED diodes and the rectifier diodes. Diode D1 protects the diagnostic tool connected to the OBD II connector, indicated as 'OUT' in the schematic diagram, against reverse polarity that may be present on the vehicle's OBD II connector (this situation may occur in the event of interference with the connector to prevent a thief from starting the car). Diode 2 meanwhile protects the diagnostic tool connected to the OBD II connector, indicated as 'OUT' in the schematic diagram, against reverse connection of the external power supply to banana connectors indicated as 'Batt+' and 'GND'. Two LED diodes have been used in the project. The LED diode indicated as 'OBD II' signals the presence of voltage at pins 16 (power supply plus) and 4 (housing ground) at the moment of connection of CAN-BOX to the vehicle's OBD II connector, while the LED diode indicated as 'Batt' signals the presence of internal voltage connected to pins 4 and 16.

Conclusions

Having used the project for the examination of vehicle components at the Forensic Laboratory of the Voivodeship Police Headquarters in Łódź for many years, we can confirm that it has significantly accelerated the identification tests of electronic components of cars and the constantly updated connection diagram database of the FAVI police application further extends the possibilities of its application.

Source of figures: author