AUTOMOTIVE FIELDBUS TECHNOLOGY: DEVELOPMENT TOOLS AND ELECTRONIC EQUIPMENT FOR LABORATORY PRACTICES

S. OTERO, F. POZA, M. A. DOMÍNGUEZ AND P. MARIÑO
Electronic Technology Department. University of Vigo. Spain
jsotero@uvigo.es, fpoza@uvigo.es, mdgomez@uvigo.es, pmarino@uvigo.es

The increase of the electronic equipment in the automotive market has been very important in the last years. There are amount of Electronic Control Units (ECUs) and a reliable and real-time communication between them is essential. The use of industrial communication networks or fieldbuses becomes necessary. Thus, it is important to train professionals with knowledge in the fieldbuses that are used in vehicles. This paper presents a course about fieldbuses with application in automotive industry and the laboratory implementation for the development of the practices.

Keywords: CAN, ECUS, fieldbuses, education.

1. Introduction

Nowadays, automobiles are more and more equipped with electronic devices that make it easier to drive the vehicle and improve their security and comfort. These electronic devices are applied to functions such as Electronic Stability Program (ESP), braking help system (ABS: Antilock-Braking System), gear control, light control, climate control, seats control, navigation and guide (based on GPS: Global Positioning System and GIS: Geographic Information System), etc. These functions require the use of reliable and real time exchange of information between the different control systems and the sensors and actuators.

The ever increasing diverse population of number and complexity of electronic systems included in the automobiles, made impossible to implement this exchange of information through point-to-point links because it would suppose a disproportionate length of cable, a rising cost and production time, reliability problems and other drawbacks. Thus, it becomes necessary the use of an industrial communication network or fieldbus [1],[2],[3].

At the beginnings of 1980s the engineers of the automobile manufacturers assessed the existing fieldbuses systems for their using in vehicles. They came to the conclusion that any of these protocols fulfilled completely their requirements. It supposes the beginning of the development of new fieldbus protocols [4]. Each manufacturer has bet for a particular solution. For example, Bosch developed the CAN (Controller Area Network) protocol, Volkswagen implemented the A-BUS (Automobile Bitserielle Universal-Schnittstelle), Renault and the PSA Consortium used the VAN (Vehicle Area Network) protocol, BMW tried it with the M-BUS and Honda with the DLCS. The majority of these automobile manufacturers evolved and adopted for the general purpose communication the CAN standard [5], [6], [7], [8].

For other functionalities, such as low speed smart sensors, multimedia, high speed and safety applications, the manufacturers are adopting other protocols in the last years. For example, the Firewire (IEEE 1394), MOST (Media Oriented System Transport) [9], [10], D2B optical and D2B Smartwirex are used for high speed multimedia applications; TTP, Byteflight and FlexRay for high speed and safety

applications; and LIN (Local Interconnect Network) for low speed smart sensor communication [11], [12], [13].

Table 1. Contents of the course

Name	Topics	Hours	Type
State of the art of the automotive fieldbuses	Beginning, applications, standards	1	Theory
Design of automotive fieldbuses: the CAN protocol	Introduction to CAN, characteristics, specification CAN 2.0, history, applications, physical layer, data link layer	1	Theory
Other automotive fieldbuses: LIN and MOST	Consortiums, physical layer, frames, main features	1	Theory
Analysis tools for CAN	CANoe, CANALYZER, USB-MUX-DIAG	1	Theory
Simulation of a CAN network	Design and simulation of a CAN network using CANoe tool	1	Practice
Real CAN traffic monitoring in a simulated environment	Prototype with ACTIA ECUs, configuration of CANoe tool	1	Practice
Real CAN traffic monitoring in a vehicle	OBD connector, CANoe analyser, identifiers	1	Practice

It is necessary to train professionals with good knowledge in these fieldbuses [14], [15]. A course about fieldbuses is described in the next sections of this paper. It is part of a Master in technologies and processes in the automotive industry which first edition was given this academic year (2008-2009) in the Industrial Engineers School of Vigo (Spain). The aim of the Master is to train recently graduates and offer new professionals to the automotive sector. The Master has 60 ECTS (European Credit Transfer System) and has duration of 10 month (October to July).

2. Design of the course

This course about fieldbuses used in the embedded automotive networks, is part of a specialization module of the Master about technologies in the automotive industry (electric and electronic systems). It is a 7 hours course and the contents are summarized in Table I.

The aim of this course is to explain the main protocols that are used currently in the automotive networks embedded in commercial vehicles [16], [17]. Thus, the core is the CAN protocol that is the most important fieldbus for the general purpose functionalities of the automobiles. There are functionalities that do not need high data rates and can be resolved with low cost nodes, and another ones that need high bandwidth (multimedia applications). Thus, the automotive communication networks have a hierarchical architecture, with networks of low data rate (up to 20 Kbps) and for multimedia application (up to 25 Mbps). The course presents the basic features of two protocols that are introducing in the vehicles for these applications that are LIN and MOST.
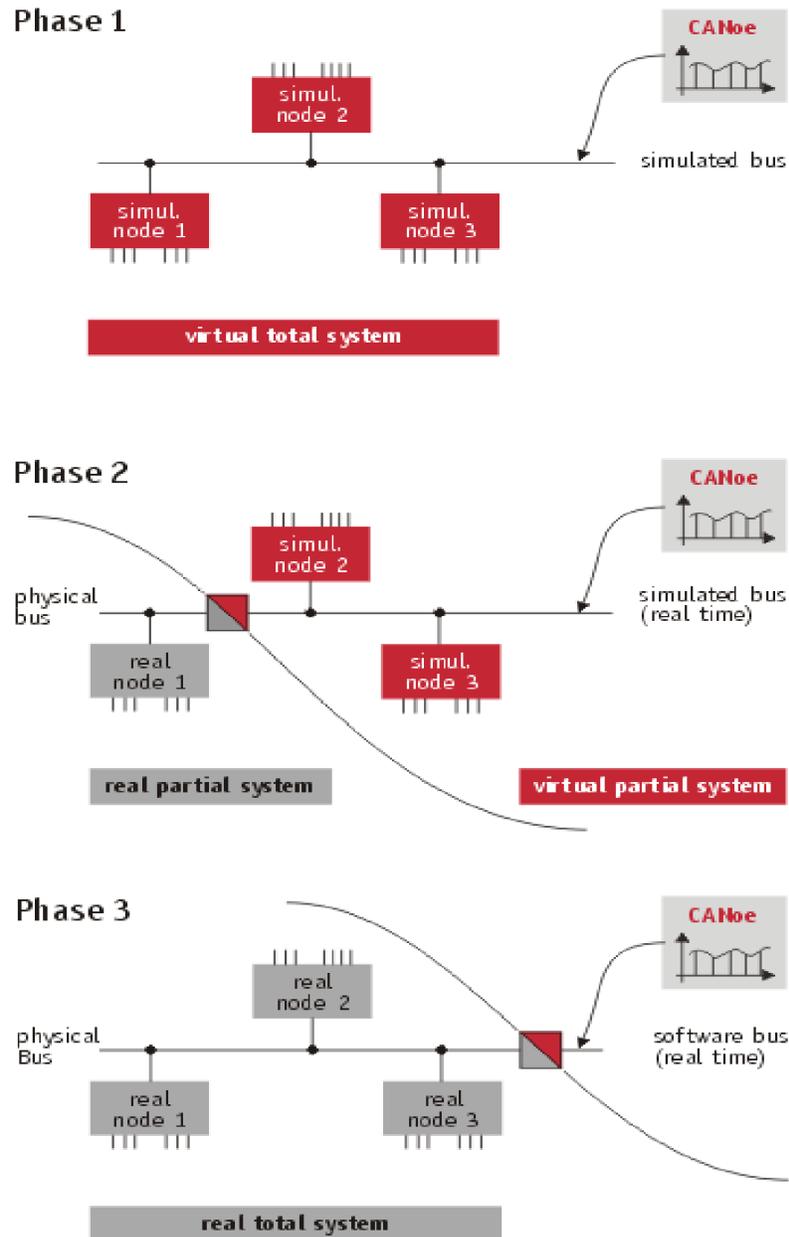
Figure 1. Phases in CANoe development process.

3. Laboratory for training on automotive networks

The authors have implemented a laboratory to give an adequate training about automotive networks. This laboratory is the most interesting of the course because let to the students check the work of CAN networks, and see the frames sent by the ECUs in a real vehicle and in a prototype of automotive network. Below the practices implemented in the present course are described with the hardware and software elements that were used.

3.1. Practice about design software of CAN networks

The first practice introduces a software tool for designing a CAN network. The software tool chosen for this purpose is CANoe from the VECTOR company [18].

CANoe is a development, analysis and test environment for systems based in CAN networks. The CANoe development process differentiates three development stages (Figure 1):

1) The first phase defines the whole virtual system, distributing the overall functionality among different CAN network nodes, defining messages, signals, bus baud rate, etc. The user must define the behaviour of each network node using a procedural language and an event-driven model. This behaviour definition must specify what frames must be sent and received and when. Also the input and output signals to/from each network nodes are described using environment variables. The results of the simulation obtained in this phase serve to validate the design and can be used later for testing the implementation.

2) This phase covers the design and implementation of individual physical nodes, usually performed in parallel and independently, using the specific software tools from the ECUs manufacturer. The behaviour of each physical network node can be tested, using the models for the other network nodes to simulate the remainder of the bus. For this purpose a CAN interface to the real bus is required.

3) In this phase the integration of the overall system is made. All physical network nodes are connected to the CAN bus step-by-step at the time the same virtual nodes are disconnected one-by-one from the models bus. CANoe can be used to observe the message traffic between the real network nodes on the bus and to compare the results obtained against the specified requirements.
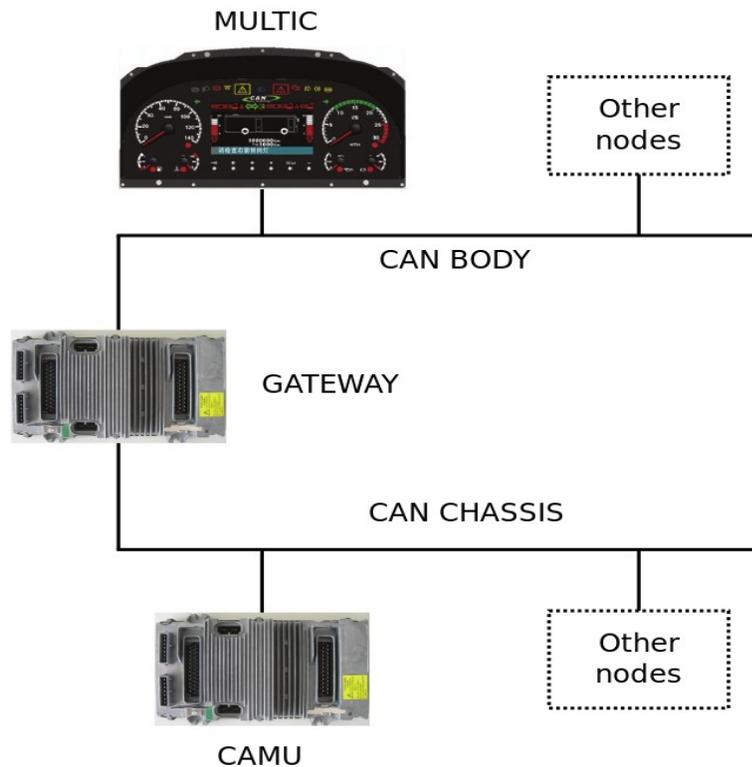

Figure 2. CAN networks and nodes modelled

In this practice two CAN buses and three nodes have been modelled (Figure 2). The required functionality of the system is quite simple and the operation of each network node is described below.

The CAMU (Central ACTIGRAF Management Unit) node is in the chassis network and has connected to it a position light, a DC motor and a potentiometer, simulating the operation of a gas pedal. This node receives two frames from GATEWAY node and sends one to it. The first frame received named GAT_CAMU_dig is used for the operation of the position light. The second named GAT_CAMU_ana is used for controlling the RPMs of the DC motor. The frame CAMU_GAT_ana is sent to GATEWAY with the position of the accelerator pedal.

The GATEWAY node serves as gateway between the two CAN networks and has connected a switch and another potentiometer. The switch is used to operate the position light and the potentiometer to control the RPMs of the DC motor. This node sends two frames to MULTIC node. One is GAT_MULTIC_dig to inform about the position of the switch. The other is GAT_MULTIC_ana with the same information as CAMU_GAT_ana.

Finally the MULTIC (MultiBUS Instrument Cluster) node is in the body network and is a dashboard with some gauges and lights. One light glows when the switch at GATEWAY is operated and one gauge is used to show the vehicle speed simulated with the potentiometer at CAMU. Figure 3 summarizes the frames interchanged in the system and the elements connected to each node.
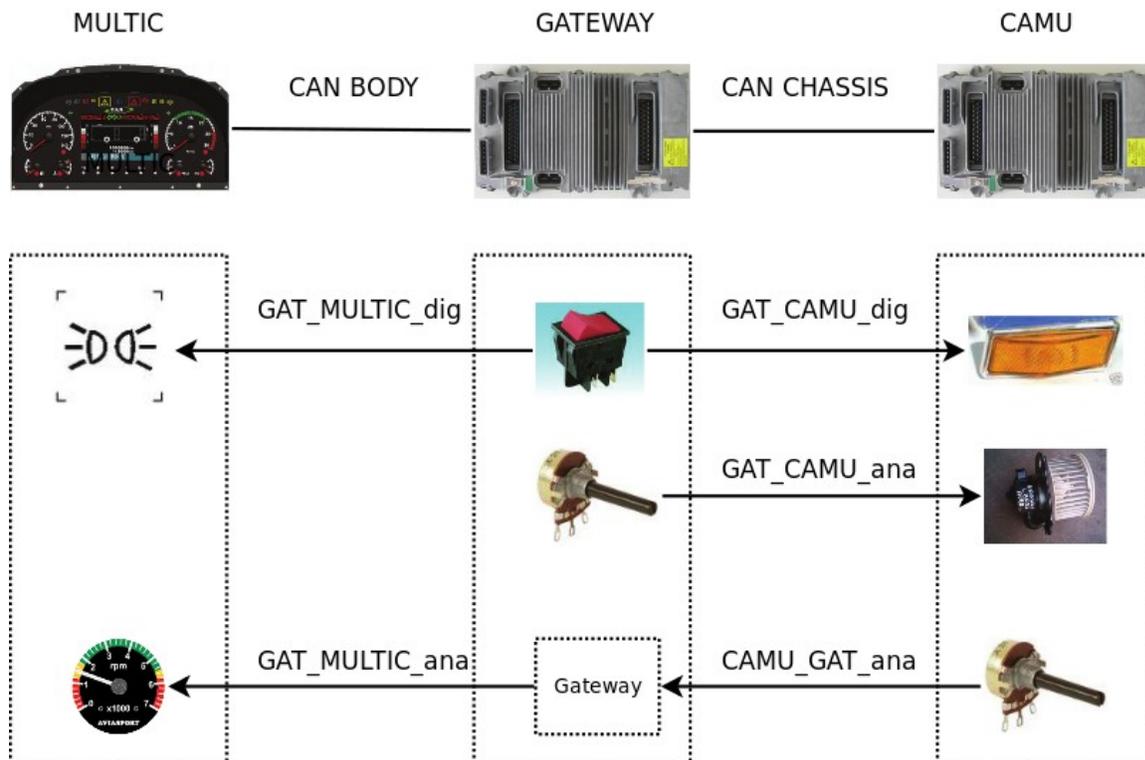
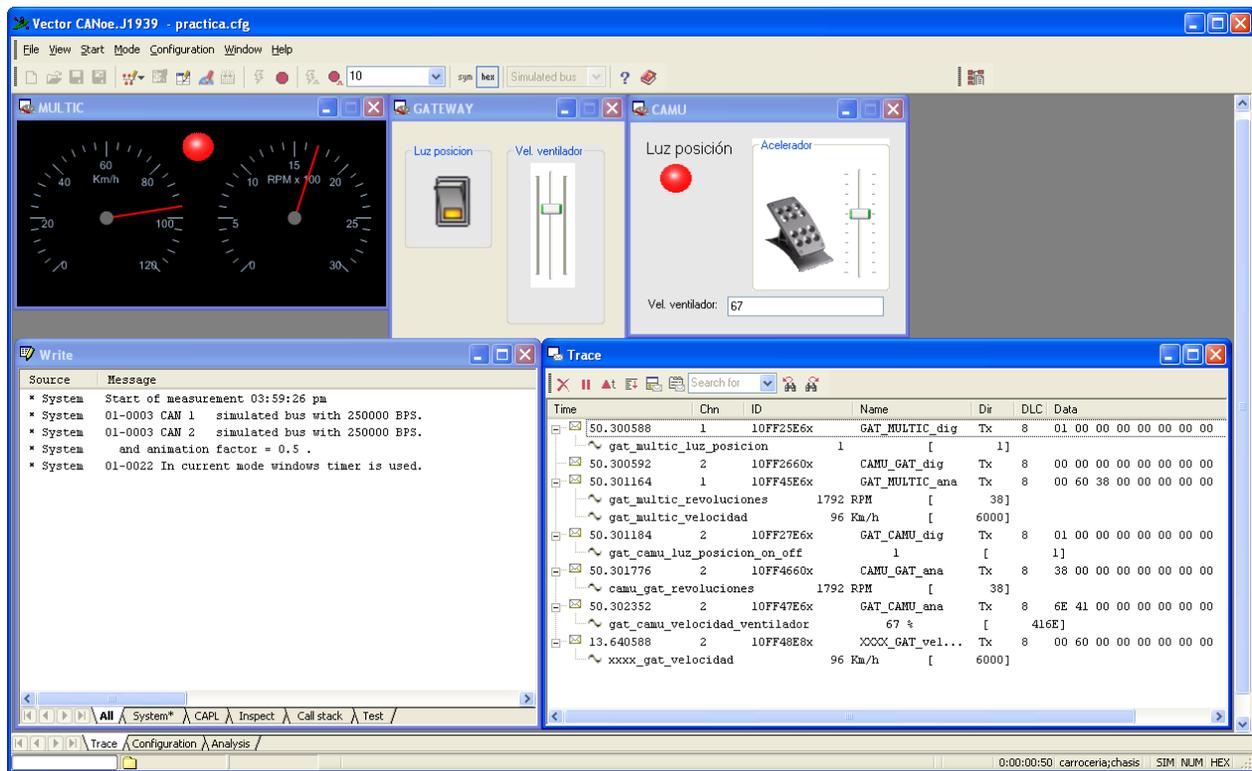

**Figure 3.** Frames interchanged and node elements.

Figure 4. CANoe main window with panels and frames.

Using CANdb++ software, included in CANoe tools, a database is created for each CAN network. In these databases network nodes, messages, signals and environment variables are defined. Then CANoe software is used for the simulation of the complete system. This can be done using CAPL language and using graphical panels that make possible to the user interact with network nodes. Figure 4 shows the CANoe window where the panels developed and the messages in the CAN networks can be seen.

3.2. Practice about control of ECUs in a prototype

Once designed the CAN network, the software tool can be connected to a real CAN network to check the good working of the design. The ECUs in the design are replaced for a real unit in a progressive way and the corresponding functionality checked. For this purpose a model has been designed using a dashboard and CAN units from the ACTIA manufacturer.

The figure 5 shows the implemented laboratory model for the real CAN network practice where the two CAMU units and the MULTIC dashboard are connected through two different CAN networks. The elements connected to both CAMUs are those described and simulated in the previous section: one light, one potentiometer and one fan motor in the CAMU; and one switch and one potentiometer in the CAMU gateway. The CAMUs and the MULTIC dashboard have been programmed using the manufacturer development tools named ActiGRAF and ISaGRAF whose knowledge is beyond the scope of this course.
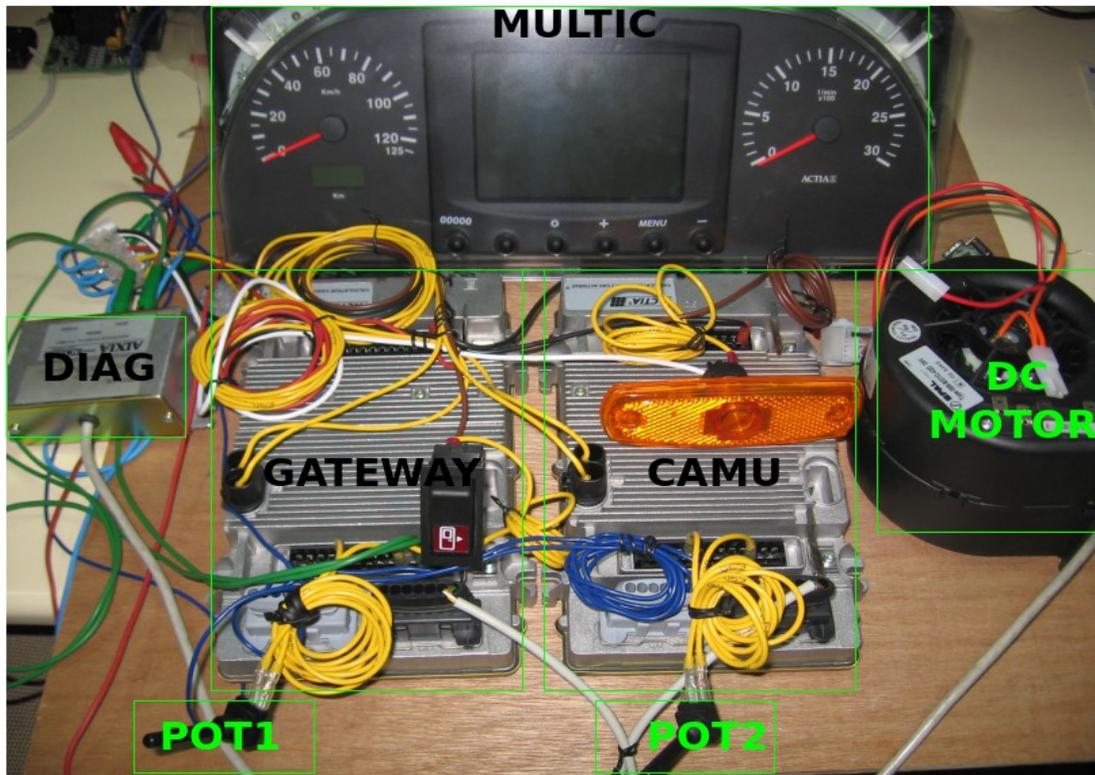
Figure 5. Real CAN network laboratory

With this laboratory model and the CANoe tool the students can check and review the working of the full system and also of each part following the steps 2 and 3 mentioned in the previous section:

• Test of individual physical nodes (step 2). Each physical node is validated using a simulation of the remaining nodes. For example, for the validation of the GATEWAY node, the CAMU and the MULTIC are simulated with the CANoe while the real ones are disconnected. The inputs and outputs of the simulated nodes are accomplished using the configurable panels available in the CANoe as seen in the upper part of the figure 4.

• Test of full system (step 3). Once all the physical nodes of the system were successfully tested in the previous step, the last step is to verify the right operation of the full system. This is accomplished monitoring the CAN networks (lower part of the figure 4) while operating with the real system, and at the same time comparing the data with the obtained in the simulation process.

3.3. Practice in a real vehicle

Finally, the students can check how the traffic (frames circulating by the communication network) of a real vehicle can be analysed using the CANoe software tool. A commercial vehicle such as a Citroen C2 is used for this purpose. The structure of the communication network of this vehicle is shown in figure 6. The following networks are present in this vehicle:

• A CAN network for motor ECUs (500 Kbps)
• A CAN network for the body units (125 Kbps)
• A CAN network for the comfort functionalities (125 Kbps)
• A CAN network for diagnosis (500 Kbps)
• A LIN network for fuel additive (19,200 bps)
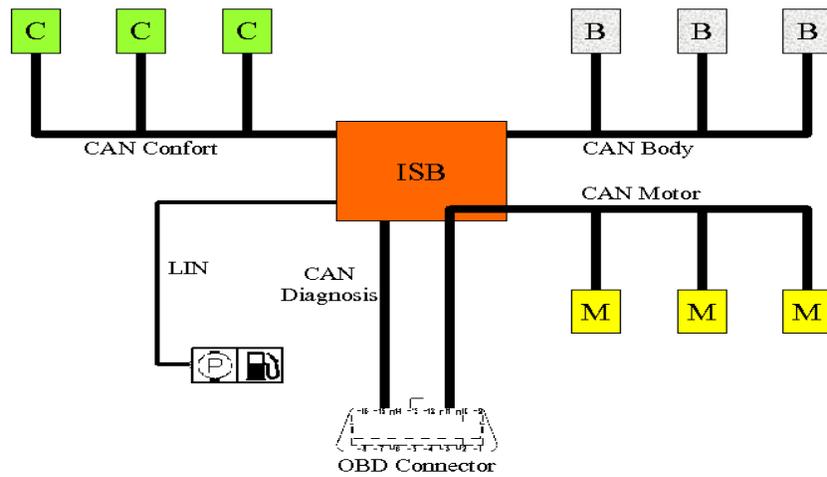
Figure 6. Citroen C2 communication structure

The ISB (Intelligent Service Box) manages the communication and the power of ECUs. The OBD (On Board Diagnosis) connector allows to connect an external tool to the vehicle, and then to communicate with all the ECUs of the automobile. It can be used for diagnosis and ECUs programming. It is a 16 pins connector.

In this practice, the students can connect the CANoe software tool to the OBD connector of the vehicle through an USB port in a laptop (Fig. 7). Thus they can see all the messages sent by the CAN networks and associate the identifiers with the signals presents in the automobile. For example, the evolution of the RPM (Revolution Per Minute) and speed can be observed such as it is shown in figure 8.

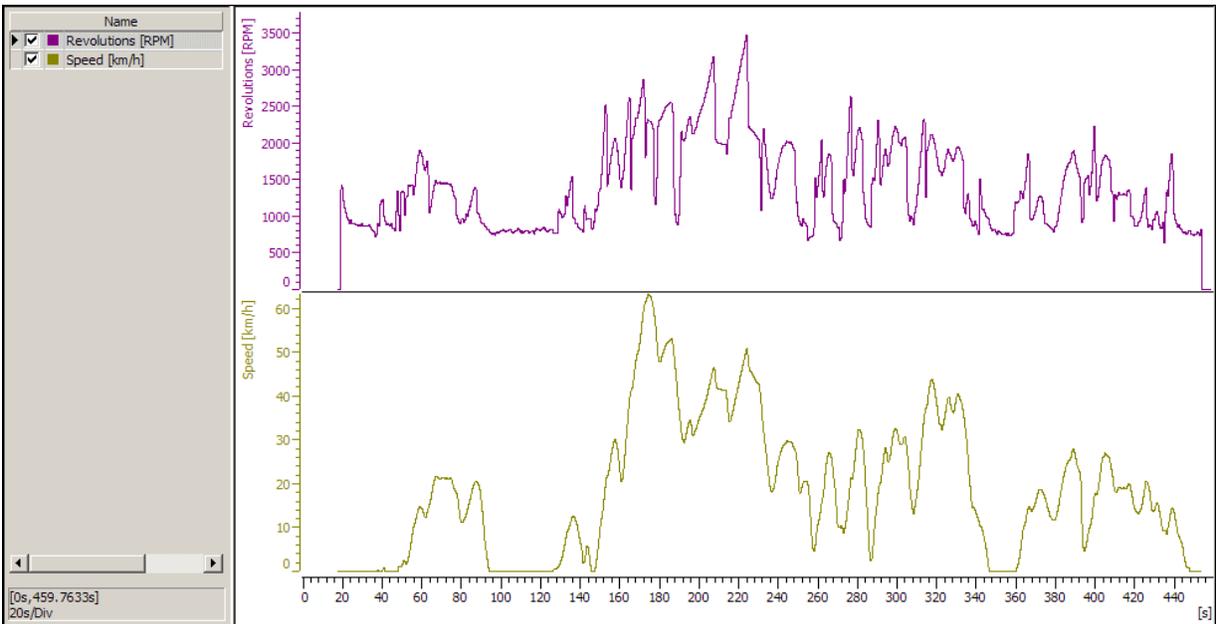Figure 7. Analyzer software tool connected to the OBD connector in a
Citroen C2

Figure 8. Window of CANoe with the evolution of RPM and speed.

4. Conclusion

The technologies and processes in the automotive industry are very important in the present days. Thus, it is necessary to offer an adequate specific education to obtain professionals with knowledge in these topics. The communications in the automobiles to integrate the control and management of the ECUs is essential, and the design of a set of practices about the communication networks embedded in vehicles is significant.

The authors present in this paper a laboratory test bench for training on communication networks, intended for a master in automotive technologies and processes, where the students must get a lot of knowledge in few hours. The laboratory is designed to make practices about CAN networks because it is the most important protocol used in the nowadays automotive industry.

This laboratory allows to design a CAN network and simulate the functionalities of the ECUs, using a prototype based on modules and a dashboard from the ACTIA company. Also practices in a real vehicle can be made.

The hardware and software used in this laboratory and the designed practices, allow that the students of the Master can be acquainted on communication networks in the vehicles and their role in the automotive industry, in few hours. Thus, the aim of this laboratory is achieved.

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