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Engine Simulator for ECMs Diagnosis

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Abstract: Currently, the number of companies that provide diagnosis, repair and maintenance services to the electronic control modules – ECMs of the vehicles is very limited. Even though the demand of the service is still unsatisfied, the possibility of expansion of the existing companies is limited by the need of an engine simulator to semi-automate the ECMs diagnosis process. To fulfill this requirement, the present paper describes the design, implementation and testing of an electronic device that simulates the electrical signals generated by the sensors and transducers commonly installed on engines. The device was programmed to simulate different models of commercial engines and to perform automatically the standard procedures followed to identify the most common failures of the ECMs.

This device incorporates systems to guarantee the safety of the information gathered during the diagnosis process and the physical integrity of the ECMs being diagnosed.

1. INTRODUCTION

Currently 100% of the commercial vehicles have electronic control modules – ECMs to control and optimize the vehicle performance. These ECMs receive the information generated by the sensors and transductors installed around the vehicle. The variables monitored in a vehicle are essentially the same regardless of the manufacturer. Most of them are related to the engine operation. ECMs use the information coming from sensors to [1]:

- Display to the driver the operational conditions of the vehicle such as speed, fuel level, oil levels, etc.
- Regulate the vehicle operation by controlling its different actuators, as for example: fuel injectors, fuel pump, etc.
- Diagnose and display the vehicle functional problems

Although the ECMs were designed to stand the adverse conditions of operation to which a vehicle is typically exposed to, the cases of faulty ECMs have become more frequent.

Vehicles manufacturers recommend replacing faulty ECMs by new ones. Nevertheless, this solution is not reasonable for the case of heavy duty vehicles where in addition to the replacement cost, the high opportunity cost of keeping a vehicle in standby during the delivery and calibration time needed by a new ECM must be taken into account. Some companies have been created in response to this business opportunity.

The diagnosis process is carry out connecting the ECM to an engine testing cell and a laptop with a specialized software, as illustrated in figure 1. Then, a standard procedure is followed where the engine is operated under different working regimes.

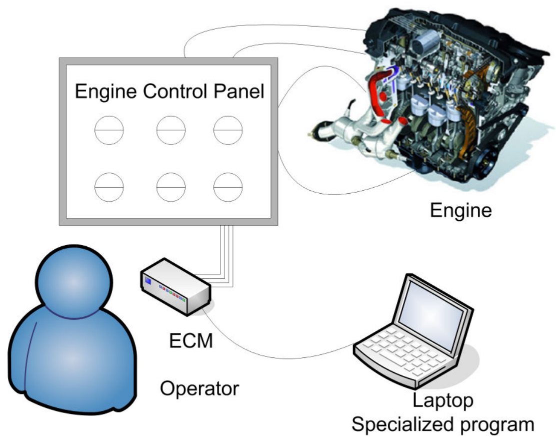

Fig. 1. Setup currently used to diagnose ECMs problems

This procedure requires to have available an engine of the same specifications of the one for which the ECM was originally designed and programmed. Consequently, these companies have been forced to count with a representative sample of the engine models most used in the region where they are located. In practice, these companies must acquire an engine whenever a new model is launch to the market.

Finally, after the failure is identified, staff with specialized knowledge repair the ECM and perform the physical tests required to guarantee the quality of the service. These know how is the main barrier to the incoming of new competitors in the market. The high cost of the required infrastructure and the need of preserving its “know how” have limited the expansion of these companies. As an alternative, the companies have proposed to semi-automate the diagnosis process so that it could be performed in several subsidiaries and to concentrate the repair process in the company headquarters.

Considering that for the diagnosis purposes the engine testing cell is simply a source of electrical signals, here it is proposed to use hardware in loop – HiL [2] to simulate those electrical signals that come from the engine to the ECM, as illustrated in figure 2. This paper describes the design and implementation of an engine simulator to diagnose ECMs failures.

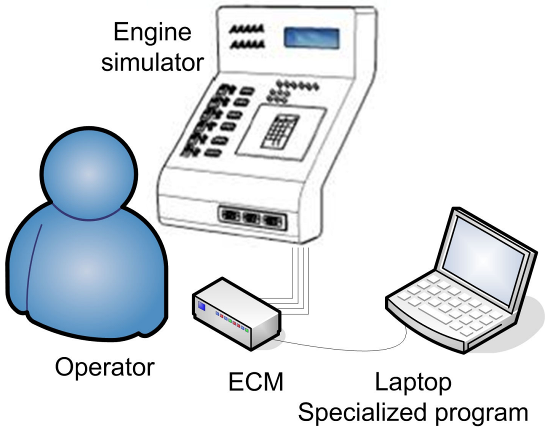

Fig. 2. HiL proposed to test and diagnose problems in ECMs

2. ENGINE SIMULATOR

The engine simulator should be a device that generates in their respective operational ranges and signal nature, the electrical signals that the sensors and transducers installed on the engine produce at different working regimes. The design of the simulator should take into account the following parameters:

2.1 Engine simulator design parameters

Besides to generate the signals that simulate the engine at different working regimes, the engine simulator must fulfill the following characteristics:

- Real time operation.
- Display the value or state of each variable that controls and monitors the performance of the engine. It must report the physical value of the measured variable instead of the representative electrical signal generated by the sensor. Table 1 lists the main variables to be considered [3,4].
- Include protective systems to avoid electrical overloads to the ECM.
- Include a self-diagnosis system to verify the correct operation of the simulator
- Allow its reconfiguration to simulate different engine models.
- Generate the typical values that are commonly reported by the sensors installed in the engine when it operates at low, medium and high load under steady state conditions. This involves, for example, the simulation of the engine temperature that typically is reported by this sensor when the engine operates at low, medium and high load.
- Allow the manual variation of the most important variables. This allows users to simulate arbitrary work conditions of the engine and to induce, on purpose, errors in the sensors and transducers.
- Include a multipurpose data registration system. It could be used for example, to save results of a diagnosis process made with the simulator. It should contain the operator identification, date, ECM model, type of tests performed, ECM error codes, etc.
- Include a security system to restrict the use by non-authorized users.
- Operate under the adverse environmental conditions of temperature, humidity, vibration and shocks that typically can be found in vehicle repair workshops.
- Easy to operate since it will be manipulated by technician without special training.

Table 1. Variables that usually are monitored in an engine [3,4]

No	Variables	Type	Range (V)	Range (Physical units)
1	Engine speed	Pulse train	[-3…12]	(0-3000) rpm
2	Accelerator angle	Analog	[0...5]	(0-100) %
3	Engine position	Pulse train	[0...12]	0°-360°
4	Intake pressure	Analog	[0...5]	(0-65,15) in Hg
5	Barometric pressure	Analog	[0...5]	(0-30,54) in Hg
6	Coolant temperature	Analog	[0…5]	(0-100) °C
7	Intake manifold temperature	Analog	[0...5]	(0-100) °C
8	Oil temperature	Analog	[0…5]	(0-100) °C
9	Oil pressure	Analog	[0...5]	(0-689,5) kPa
10	Clutch switch	Switch	[0…12]	ON/OFF
11	Brake switch	Switch	[0...12]	ON/OFF
12	Test signal for diagnosis	Switch	[0…12]	ON/OFF
13	Cruise control signal Set/Resume	Switch	[0...12]	ON/OFF
14	Cruise control signal On/Off	Switch	[0…12]	ON/OFF
15	Engine break - On/Off	Switch	[0...12]	ON/OFF
16	Idle speed – Increase/Decrement	Switch	[0...12]	ON/OFF
17	Ignition	Switch	[0...12]	ON/OFF
18	Coolant level - High/Low	Switch	[0...12]	ON/OFF
19	Injector 1/2/3/4/5/6	Pulse train	[0...12]	------

2.2 Simulator design

Now days, especially in the automotive industry, hardware in the loop –HiL applications are common. Furthermore, there are some commercial tools available to develop HiL engine simulators [2,5,6,7]. However those tools are essentially software that were created to assist engineers in the development of new or improved components in its design stage, prior to its physical manufacture. They look for simulating the mechanical operation of the engine. Therefore they involve the use of computers and a protected, laboratory likewise, working conditions. To satisfy the previously defined design parameter for the present applications, it is required a robust, stand alone, physical device able to operate with or without any computer.

To address the previous need an industrial prototype of engine simulator was developed. It has the following internal modules: power, communication, control, data storage, user interface, signal conditioning and electrical protections. Figure 3 shows the different subsystems that are included in the simulator. Next, a description of each module is presented.

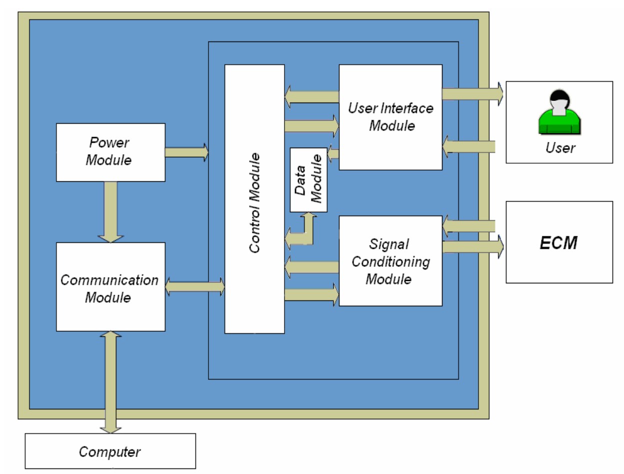

Fig. 3. General configuration of the engine simulator

2.2.1 Power module

It provides the energy that under normal conditions the battery of the vehicle provides to the ECM. Additionally, this module is the power supply for each one of the electronic devices included within the simulator. For its operation, the power module requires a 120V AC connection. The module has a capacity of 200Watts distributed on voltage outputs of ± 12V and ± 5V. [3,4,8].

2.2.2 Communication module

It is designed to control the serial communication with any computer under RS232 protocol. It also includes a software developed in Java [9] to download the information stored in the simulator through a user interface.

Since the engine simulator is an stand alone device designed to provide the electrical signal of the sensor and transducer of the engine and to display those signals in the user interface, it does not require to have, internally o externally, the same standard communisation protocol used in vehicles such as CAN, LIN, J1850, and J1959. All the internal communications are made under the I2C protocol.

2.2.3 Control module

It is the main module of the simulator. It includes a commercial microprocessor. It sends instructions and information to the other modules using a data bus under the I2C protocol. This module contains the information related to the calibration curves of sensors and transducers and the routines for the self-diagnosis of the simulator, ECM errors report and data storage.

2.2.4 Data module

The main components of this module are a real time clock and a serial memory EEPROM of 2kbit which are controlled by the control module. Its main function is to acquire and store the information gathered during the diagnosis process. The stored information is used to evaluate the performance of the simulator. In the near future the historic information stored in the simulators will also be used to design new test procedures to identify ECMs problems.

2.2.5 User interface module

This module includes 3 commercially available microcontrollers [10] used to control the input and output elements included in the user interface.

Figure 4 illustrates the user interface developed for the engine simulator. As input elements this module has a matrix 4 by 4 keyboard. This element allows the user to enter passwords, values or to choose the test to be made. Additionally, there are switches and knobs to allow users, in an independent way, to control the ignition module and the value of each variable. As output elements this module has indicators leds, 7-segments displays and a liquid crystal display - LCD. These devices allow the operator to know the state or value of the different variables that are being simulated.

The user interface module make possible the interaction with the user to change the configuration of the engine simulator, select between manual o automatic operation, carry out standard test, perform a self-diagnosis test, modify the calibration curves of sensor and transducers, display the information stored in memory, include new users and create and change passwords. Different security passwords are handled to protect the different levels of information and operation of the engine simulator.

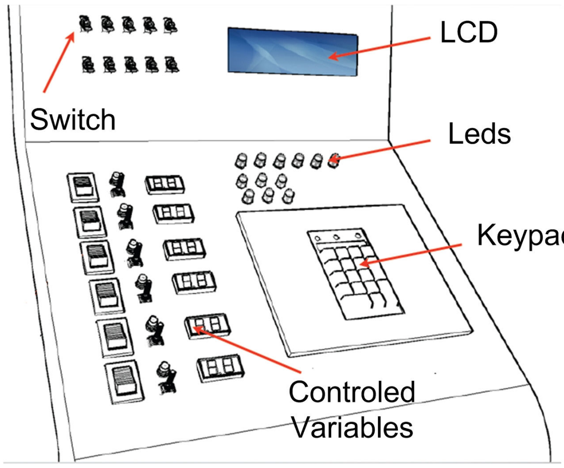

Fig. 4. User interface of the engine simulator

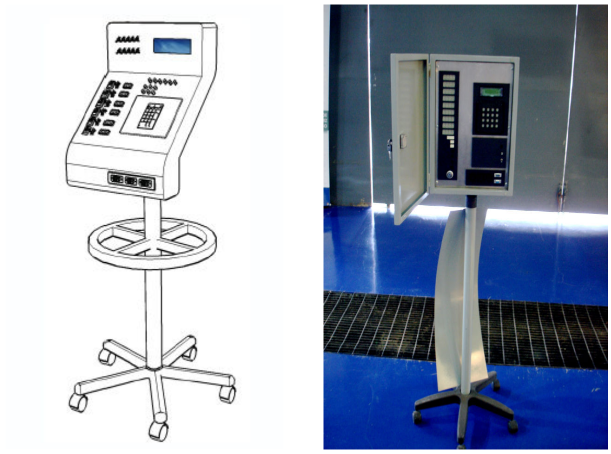

Fig. 5. Engine simulator manufactured to diagnose ECMs problems

2.2.6 Signal conditioning and electrical protections module

This module generates the electrical signals that simulate each of the sensor and transducer of the engine. In most of the cases, the sensors generate analogous signals [3,4,8]. To simulate these signals, 8-bit digital potentiometers controlled through I2C data networks were used. The speed sensor and the crankshaft position sensor generate signals that have the form of a square wave. For these cases, the PWM modules of a microcontroller of the same family than the mentioned before were used to simulate them. The variables that are controlled through switches do not require any additional type of control within the engine simulator.

3. IMPLEMENTATION AND OPERATIONAL TEST

Electrical circuits were designed to perform the operations described before. In all the cases commercial components with state of the art technology were used. Additionally, it was designed and manufactured a chassis to keep the electrical circuits and to place the user interface components described previously. Figure 5 shows the first prototype of engine simulator manufactured.

Currently, a set of operational tests are been performed on the engine simulator prototype to evaluate its performance. In addition, a set of physical endurance tests are been performed to verify its resistance to adverse conditions of vibrations, temperature and humidity.

As future work it is been considered to use the information stored in the data module to strengthen the current standard tests and to design new standard tests to diagnose the most frequent ECMs problems.

4. CONCLUSIONS

An engine simulator was designed and manufactured to semi-automate the diagnosis process of ECMs problems. This device integrates the state of the art technology to process, condition, transmit and store information. The device simulates the nature and intensity of the electrical signals generated by the sensors and transducers commonly installed on commercial engines. It can simulate different models of commercial engines. The device was programmed to carry out in an automatic way a set of standard tests to identify the most common ECMs failures. It incorporates systems to guarantee the integrity and safety of the information gathered during the diagnosis process and the physical integrity of the ECMs being diagnosed.

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