Investigation of signals in diagnostics car engines electronic control

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Abstract – Automobile diagnostics is one of the main subjects in training cars service specialists. The diagnostics subject consists of theoretical and practical training. Various types of engine management systems work and their faults are investigated in the laboratory. The main equipment consists of engine simulators. The development of using microprocessing technologies in automobile control requires more sophisticated diagnostics equipment. Most developing diagnostics equipment are systemic testers which take the information from the electronic control unit (ECU) about trouble codes’ and display working parameters. However we can only see real sensors’ signals by having direct contact. Students are measuring engine management signals in the laboratory by using an electricity signals input block. On the screen of the PC we can see the electronic management signals graphics image. The signals are analyzed and that is how the faults are diagnosed. Experience of automobile electronic management signals research is necessary for the students in their practical work of automobile diagnosis.

Keywords – Automobile diagnosis, engine simulator, electric signal, electronic control unit (ECU).

1. INTRODUCTION

Vilnius Technical College prepares automobiles technical exploitation’s specialists. Studies last for three years. Studies program consist of general and special subjects. Students are learning general subjects are such as mathematics, physics, mechanics, electrotechnics. The students also study subjects according to them speciality: construction of automobile, technical exploitation, automobiles technical equipment diagnostics and etc. They also have practical training by learning in the laboratories in car technical service stations. The main aim of the studies is to give practical and theoretical knowledge in organizing automobiles technical exploitation.

Automobile electronic control’s systems are recently the most developing automobiles field. New generation automobiles electronic control’s blocks are now controlling many systems and mechanisms, such as engines, gear boxes, brakes systems and so on. The students have to understand really good system working fundamentals. Only then they can do electronics control systems diagnostics and repairing. Students study electronic control fundamentals at the third years during the course “Automobile Electronic Control Systems” (80 hours).

Various systems of automobiles simulators that have electronic control systems used in the laboratories for the training. Data acquisition device “E-Biol” that is used for recording electronic control signals helps in researching work. This apparatus firstly was used in the collage five years ago according Leonardo da Vinci project “ComLab-SciTech” (Computerized laboratory in science and technology teaching). The new TOYOTA-TEP center opened in college in 2006. This center gave us possibility to use Toyota engines simulator 2NZ-FE. This equipment let us to improve quality of studies

2. THE LABORATORY EXERCISES FOR INVESTIGATION OF THE SIGNALS OF CAR ENGINES ELECTRONIC CONTROL

For the investigation of the operation of engine management’s system we use Toyota engine 2NZ-FE simulator (see Fig. 1). Engine control system uses an ECU (Electronic Control Unit) with a built-in microprocessor (see Fig. 2). Stored inside the ECU is the data for fuel injection duration, ignition timing, idle speed, etc., which are matched with the various engine conditions as well as programs for calculation. The ECU utilizes these data and signals from the various sensors in the vehicle and makes calculations with the stored programs to determine fuel injection duration, ignition timing, idle speed, etc., and outputs control signals to the respective actuators which control operation (see Fig. 3).

Fig. 1. Engine 2NZ-FE simulator.

With the break-out box installed on the simulator it is possible to pass electronic signals to inputs of data acquisition block “E-Biol”. The break-out box consists primarily of male and female connectors that connect to the engine ECU terminals and the terminal measuring probe. The terminals for inserting the probes of an electrical tester “E-Biol” are provided on the break-out box in order to measure voltage or resistance.
As a result of investigation of signals used for engines electronic control students explains the system work and can diagnoses the faults.

### 2.1. Investigation of throttle position sensor’s signal

On throttle position sensor, a DC of 5V is applied to its VC terminal from the engine ECU [7]. As the contact slides along the resistor in accordance with the throttle valve opening angle, a voltage is applied to the VTA terminal in proportion to this angle (see Fig. 4).

The state of the throttle valve, from fully closed (idling) to fully open, is monitored by reading the changes in the VTA terminal voltage.

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**Fig. 4. Throttle position sensor.**

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An example of a signal registered from the throttle position sensor is shown in Fig. 6 a. In experiment the throttle valve runs from fully closed (idling) to partly open back and forth.

### 2.2. Investigation of air flow meter's signal

This compact and lightweight plug-in type air flow meter allows a portion of the intake air to flow through the detection area (see Fig. 5) [7]. By directly measuring the mass and the flow rate (see Fig.6 b) of the intake air, the detection precision is improved and the intake air resistance is reduced. This air flow meter has a built-in intake air temperature sensor.

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**Fig. 5. Air flow meter.**
2.3. Investigation of crankshaft and camshaft position sensor’s signals

The timing rotor of the crankshaft consists of 34 teeth, with 2 teeth missing (see Fig. 7) [7]. The crankshaft position sensor outputs a crankshaft rotation signal every 10°, and the missing teeth are used to determine the top-dead-center.

To detect the camshaft position, a timing rotor on the intake camshaft is used to generate 3 pulses for every 2 revolutions of the crankshaft (see Fig. 8).

To obtain a high purification rate for the CO, HC and NOx components of the exhaust gas, a three-way catalytic converter is used, but for the most efficient use of the three-way catalytic converter, the air-fuel ratio must be precisely controlled so that it is always close to the stoichiometric air-fuel ratio [7].

The oxygen sensor has the characteristic whereby its output voltage changes suddenly in the vicinity of the stoichiometric air-fuel ratio (see Fig. 10). This is used to detect the oxygen concentration in the exhaust gas and provide feedback to the computer for control of the air-fuel ratio. When the air-fuel ratio becomes LEAN, the oxygen concentration in the exhaust increases and the oxygen sensor informs the engine ECU of the LEAN condition (small electromotive force: < 0.45 V).

When the air-fuel ratio is RICHER than the stoichiometric air-fuel ratio the oxygen concentration in the exhaust gas is reduced and the oxygen sensor informs the engine ECU of the RICH condition (large electromotive force: > 0.45 V). The engine ECU judges by the electromotive force from the oxygen sensor whether the air-fuel ratio is RICH or LEAN and controls the injection time accordingly. However, if a malfunction of the oxygen sensor causes an output of abnormal electromotive force, the engine ECU is unable to perform accurate air-fuel ratio control.

The main heated oxygen sensors include a heater which heats the zirconia element. The heater is controlled by the engine ECU. When the intake air volume is low (the temperature of the exhaust gas is low) current flows to the heater to heat the sensor for accurate oxygen concentration detection.
The oxygen sensor must generate voltage about 0.6-0.8 V (see Fig. 11).

An example of a signal from the oxygen sensor 1 (a) and the oxygen sensor 2 (b) is shown in Fig. 12.

2.5. Investigation of electronic fuel injection’s signal

An L-type EFI system directly detects the intake air mass with a hot wire type air flow meter [7].

An independent injection system (in which fuel is injected once into each cylinder for each two revolutions of the crankshaft) is used.

Also, when the engine is starting, a group injection (in which fuel is injected once into two cylinders for each revolution of the crankshaft) is effected. It changes to an independent injection when the engine’s speed or the water’s temperature becomes higher than a prescribed value.

The ECU contains the power transistors that are used to switch injector electrical circuits on and off (see Fig. 13) [1].

An example of a signal in petrol injector is shown in Fig. 15. We can see time of injection.

2.6. Investigation of ignition coil’s operating signal

A DIS (Direct Ignition System) is used in engine 2NZ-FE (see Fig. 14) [7]. The DIS improves the ignition timing accuracy, reduces high-voltage loss, and enhances the overall reliability of the ignition system by eliminating the distributor.

The DIS is a 1-cylinder ignition system which ignites one cylinder with one ignition coil. In the 1-cylinder ignition system, one spark plug is connected to the end of the secondary winding. High voltage generated in the secondary winding is applied directly to the spark plug. The spark of the spark plug passes from the center electrode to the ground electrode.

The engine ECU determines ignition timing and outputs of the ignition signals (IGT) for each cylinder. Based on IGT signals, the power transistors in the igniter cut off the current to the primary coil in the ignition coil, which is supplied to the spark plugs that are connected to the end of the secondary coil. At the same time, the igniter also sends an ignition confirmation signal (IGF) as a fail-safe measure to the engine ECU.

A knocking control system is used in order to constantly realize optimal ignition timing.
In fig. 15b is shown an example of a signal in ignition coil from ECU. We can compare petrol injection moment with ignition moment.

Fig. 15. Signals in petrol injector and in ignition coil with igniter.

3. CONCLUSION

The investigation of signals used for car engines electronic control is an effective way to improve understanding materials of the “Automobile electronic control systems” course. The data acquisition device “E-Biol” are measuring electric signals from sensors too electronic control unit (ECU) and from ECU to actuators. On the screen of the PC we can see the electronic management signals graphics image. At the same time, structure and sensors and actuators functioning are analyzed. This information enables students more precisely understand the electric signals used for systems control and faults possible causality.

These laboratory exercises are applied for teaching the students and garage workers. Gained knowledge can be used for the diagnostic of cars electronic control’s systems. Moreover, the data acquisition device “E-Biol” can be fitted for diagnostic of a real car.

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