INVESTIGATION OF CAR ENGINES EMISSION CONTROL

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ABSTRACT

Automobile exhaust gases significantly pollute the environment. Pollution decreases the modern electronic engine management system. Exhaust gas emissions due to correct the engine management system work. Management system failures identify the diagnostic aid. Automobile diagnostics is one of the main subjects in training cars service specialists in Vilnius College of Technologies and Design. 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 bloc. 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, exhaust gas, oxygen sensor, electric signal.

1. INTRODUCTION

Automobile mechatronic systems are recently the most developing automobiles field. New generation automobiles electronic control's units (ECU) are now controlling many systems and mechanisms, such as engines, gear boxes, brakes systems and so on. Various types of engines and others mechanisms management systems work and their faults are investigated in the laboratory. The main equipment consists of mechanism's 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 ECU about trouble codes' and display working parameters. However we can only see real sensors' signals by having direct contact. Students must measuring mechanism's management signals in the laboratory by using an data acquisition device "E-Biol". 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 wo:k of automobile diagnosis.

2. OVERALL EQUIPMENT AND SOFTWARE REQUIREMENTS

For the investigation of the operation of engine management's system is used Toyota engine 2NZ-FE simulator (see Figure 1).

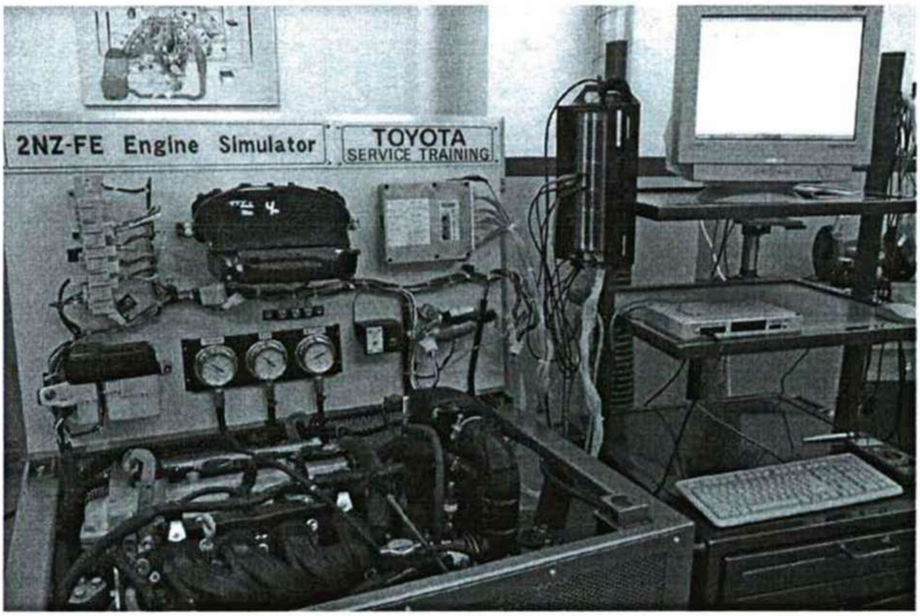

Figure 1. Engine 2NZ-FE simulator

Engine control system uses an ECU with a built-in microprocessor (see Figure 2).

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 Figure 3).

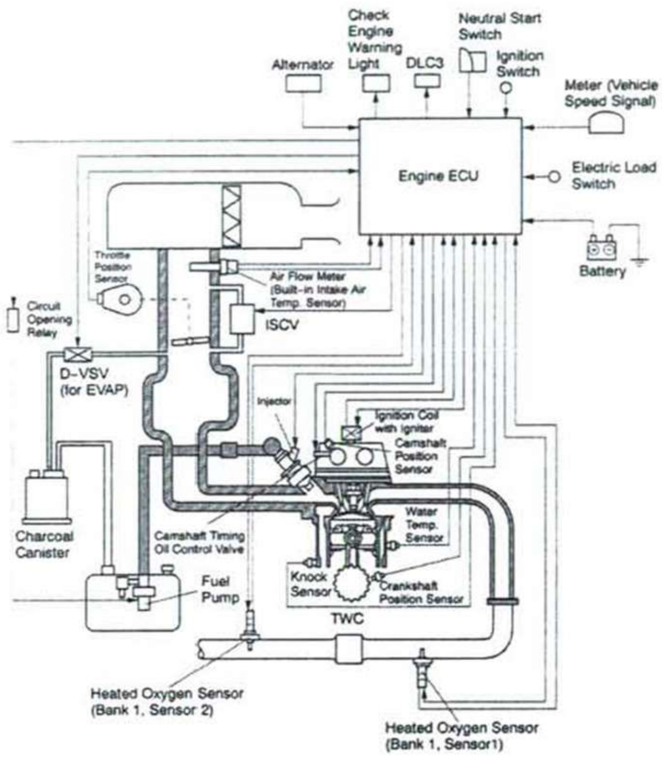

Figure 2. Engine 2NZ-FE computer controlled system diagram

1. EFI (Electronic Fuel Injection)
2. ESA (Electronic Spark Advance)
3. ISC (Idle Speed Control)
4. VVT-i (Variable Valve Timing-intelligent)
5. FUEL PUMP CONTROL
6. OXYGEN SENSOR HEATER CONTROL
7. EVAPORATIVE EMISSION CONTROL
8. ENGINE IMMOBILIZER
9. DIAGNOSIS
10. FAIL-SAFE

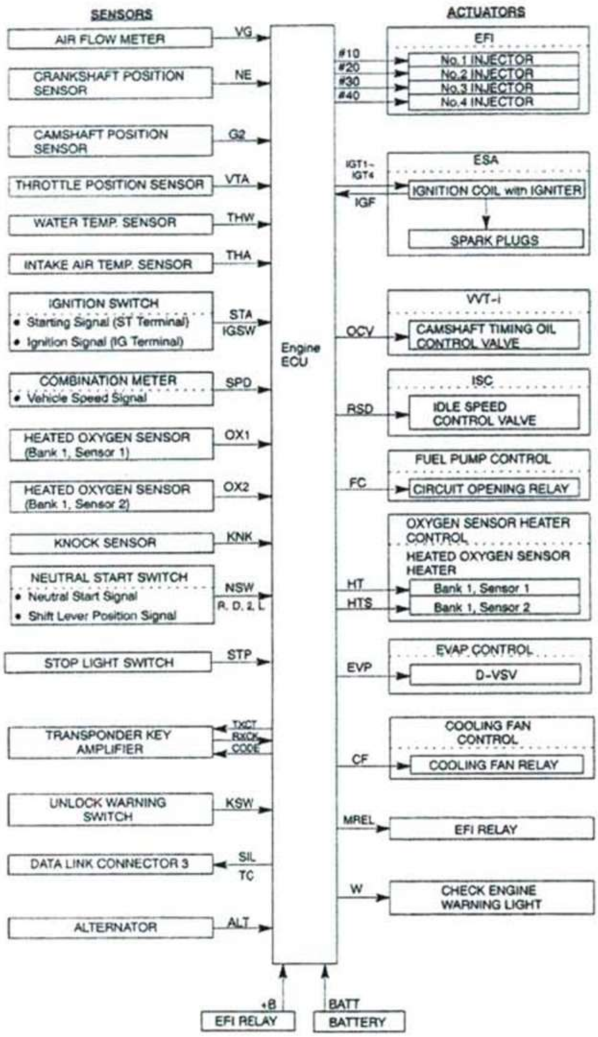

Figure 3. The configuration of the engine control system

With the break-out box (Figure 4) 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.

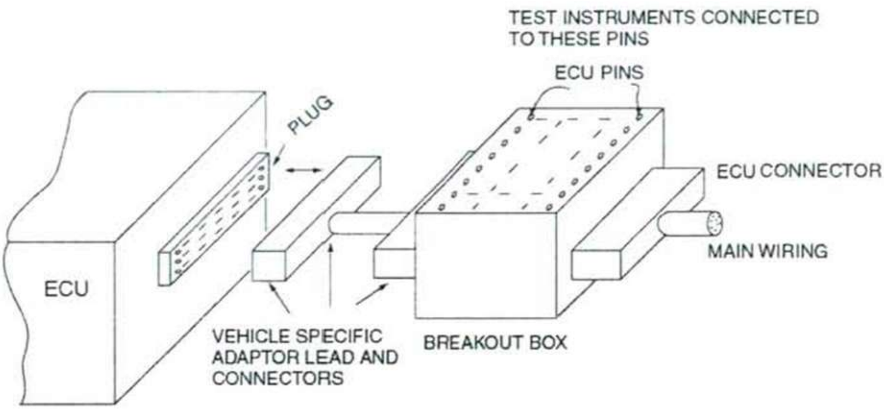

Figure 4. A breakout box

3. INVESTIGATION OF OXYGEN SENSORS' SIGNALS

To obtain a high purification rate for the CO, HC and NO_x components of the exhaust gas, a three-way catalytic converter is used:

$$2CO + O_2 \rightarrow 2CO_2$$
$$2NO + 2CO \rightarrow N_2 + 2CO_2$$
$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

For the most efficient use of the three-way catalytic converter (see Figure 5), the air-fuel ratio must be precisely controlled so that it is always close to the stoichiometric air-fuel ratio ($\lambda = 1$).

$$\lambda = \frac{actual\ air - fuel\ ratio}{cemiclly\ correct\ air - fuel\ ratio\ (14{,}7:1)}$$

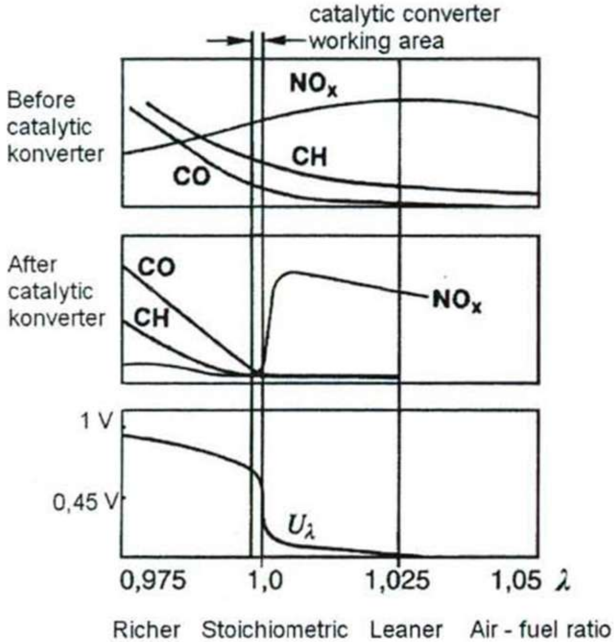

Figure 5. Catalytic converter work efficiently

The oxygen sensor has the characteristic whereby its output voltage changes suddenly in the vicinity of the stoichiometric air-fuel ratio. 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: $U_{\lambda} < 0.45$ 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: $U_{\lambda} > 0.45$ 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 (see Figure 6). 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.

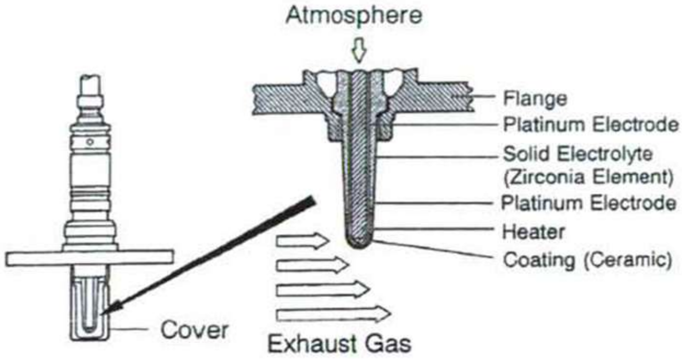

Figure 6. Oxygen sensor

When the system is operating correctly the oxygen sensor OX1 (before catalytic converter) output varies between approximately 0,1 V and 0,9 V, and the frequency of change for the sensor signal is around 1-3 Hz.

If catalytic converter is working, it consumes oxygen. So after catalytic converter, the oxygen sensor OX2 must generate voltage about 0,6…0,8 V (see Figure7).

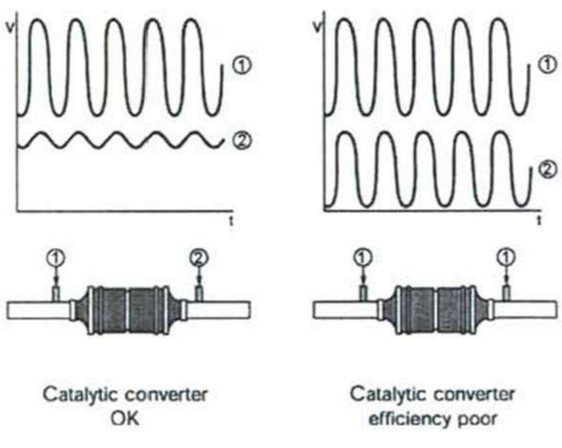

Figure 7. The voltage traces from the upstream and downstream oxygen sensors

4. SIGNAL MEASUREMENT PROCEDURE

Connect the first inlet canal of data acquisition device "E-Biol" to oxygen sensor contact OX1 (positive) and E2 (earth) (Figure 8). Connect the second inlet canal of data acquisition device "E-Biol" to oxygen sensor contact OX2 (positive) and E2 (earth).

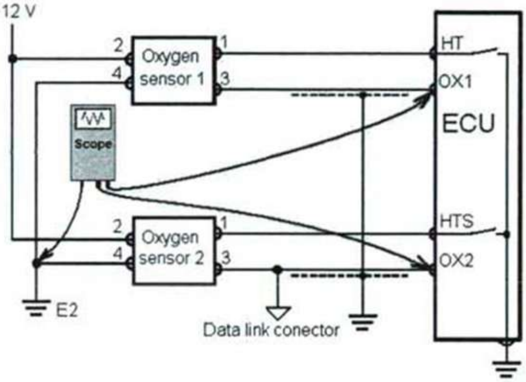

Figure 8. Engine (2NZ-FE) oxygen sensors OX1 and OX2 connection diagram

Start up engine simulator. The throttle valve must bee partly open. Engine rate: 2000…2500 rpm (revolutions per minute). Electric signals from oxygen sensors OX1 and OX2 are transmitting in engine ECU (Figures 9; 10; 11). Record signals from oxygen sensors OX1 and OX2.

Figure 9 shows the diagram of the voltage signal that derivable at the output of oxygen sensor 1 and oxygen sensor 2 when oxygen sensors and three-way catalytic converter are cold.

Figure 10 shows the diagram of the voltage signal that derivable at the output of oxygen sensor 1 and oxygen sensor 2 when oxygen sensors are hot but three-way catalytic converter is warm.

Figure 11 shows the diagram of the voltage signal that derivable at the output of oxygen sensor 1 and oxygen sensor 2 when oxygen sensors and three-way catalytic converter are hot.

This pattern shows the oxygen sensors control's signal when the engine winding is medium.

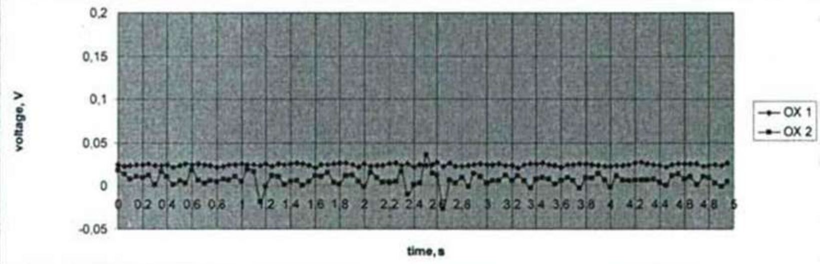

Figure 9. Signals from heated oxygen sensor 1 and oxygen sensor 2 (oxygen sensors and three-way catalytic converter are cold and does not function). a – OX1 signal; b – OX2 signal

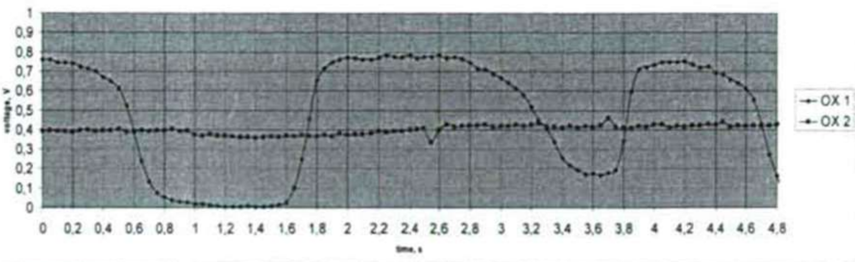

Figure 10. Signals from heated oxygen sensor 1 and oxygen sensor 2 (oxygen sensors and three-way catalytic converter are warm and functions partly). a – OX1 signal; b – OX2 signal

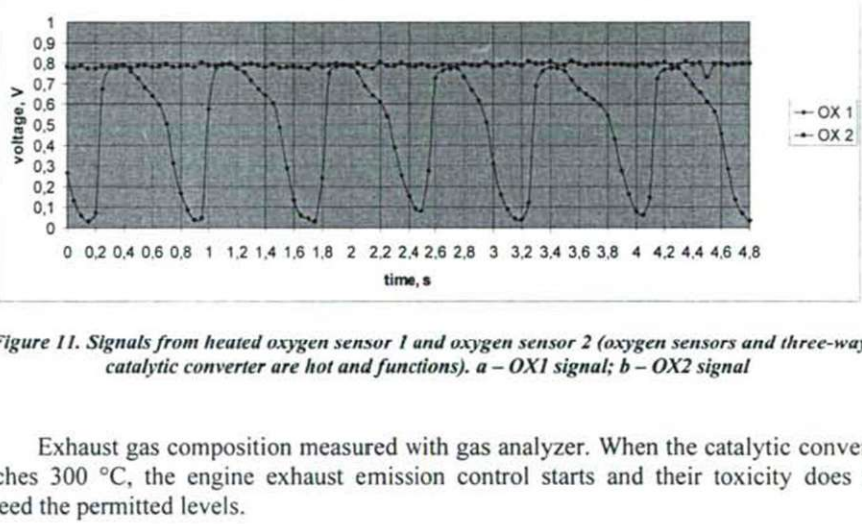

Figure 11. Signals from heated oxygen sensor 1 and oxygen sensor 2 (oxygen sensors and three-way catalytic converter are hot and functions). a – OX1 signal; b – OX2 signal

Exhaust gas composition measured with gas analyzer. When the catalytic converter reaches 300 °C, the engine exhaust emission control starts and their toxicity does not exceed the permitted levels.

4. CONCLUSIONS

1. Oxygen sensor starts to function reliably when the temperature reaches approximately 300...350°C. An ideal temperature for operate is around 600°...800°C.
2. The electrical signal's diagram from oxygen sensors OX1 are stand within the pale 0,1...0,9 V.
3. The frequency of change for the sensor signal is around 1...3 Hz, depending on an engine's speed, a temperature and other factors.
4. The action of a catalytic converter, OX2 has generated voltage about 0,6...0,8 V.
5. The action of oxygen sensor and catalytic converter, exhaust gas toxicity is minimal.
6. 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.

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