Modern approaches in car diagnostics

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Abstract: Modern vehicles such as agricuture tractor with ECU controlled engine has many electronic parts (sensors, actuators). This parts are usually connected to an ECU. Sensor converts physical quantity to an electrical signal. This signals are used with ECU to manage the operation of the engine with help of actuators. Every signal can be measured with modern diagnostics equipment to verify the functionality of the ECU system. Modern motormanagement systems are supported by serial diagnostics (diagnostics equipment from the manufacturer) but there are still problems that serial diagnostic is not able to solve. Hence, the modern diagnostics techniques should be supported by parallel diagnostics. This article is focused on parallel diagnostics of engine.

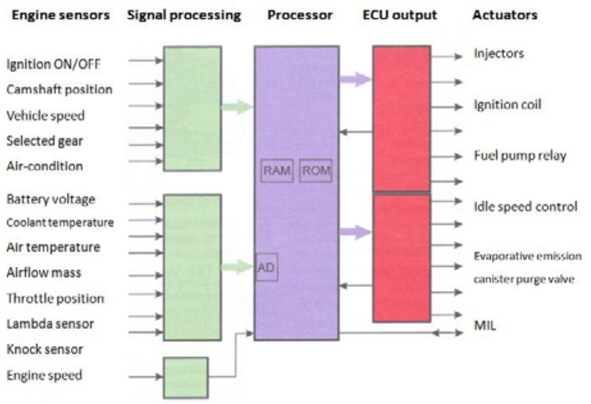
Key-Words: oscilloscope, waveform, sensor, parallel diagnostics

Introduction

The engine management system can be viewed as a closed control loop. In the system there is a control unit that is responsible for managing the operation of the engine. Because the combustion engine is operated in different modes, the controller has to be able to adapt the engine run to these conditions. An example of such a system may be, for example, running the engine shortly after cranking. If it will be a cold start, it is necessary to adjust the fuel injection that enable the smooth start. Said simply, the engine control unit needs to know what the conditions are in the engine, then this state evaluate and set the output parameters of the actuators. Actuators carry out the orders they have received from the control unit. Engine sensors are used to find out input parameters for the control unit. The sensors convert the input parameters such as speed, pressure and temperature into an electrical signal. These signals are then processed in the control unit with input circuits.

As is evident from Fig.1 the control unit has to be connected to a large number of sensors, which differ only its purpose (speed sensing, throttle position sensing, pressure sensing, etc.). They are also different in their output parameters. Many sensors have voltage outputs - eg temperature sensors. The voltage on the sensor then corresponds to a specific temperature (coolant, oil, air, etc.). Each of such sensor has characteristic waveform in the workshop manual or in the datasheet. This waveform can describe the dependence of sensor's resistance on temperature (coolant temperature sensor), or the dependence of generated voltage on engine speed (inductive crankshaft position sensor). These values should be used for the first diagnostics of this component. The basic diagnostic of such sensor can be made using an ohmmeter.

Fig. 1 ECU inputs and outputs [7]



With the increasing complexity of engine management systems also its internal diagnostic is beeing improoved. A milestone in the field of internal diagnostics was the establishment of standards OBD (On Board Diagnostic), respectively OBD-2. The European form of the system is known as the E-OBD [1]. The purpose of introducing these independently operating programs was prevention of excess pollution produced from internal combustion engines. In such a motor management system run tests of individual components which are emission-relevant. Tests of emission-relevant components occur after meeting predetermined conditions, such as coolant temperature, engine speed, vehicle speed, etc. All runs independently of the driver's will. The aim of these tests is to check all components and create the Readiness code. This code is in binary form and every individual position represents the component of the drive unit, for example catalytic convertor etc. [2, 3] This allows find out what test has not been executed.

For repairs and fault detection is important fault memory. The fault memory keeps written faults and after reading with the diagnostic equipment is supposed to help with repair process. The control unit can show what type of problem has occurred (for example exceeding upper voltage limits, lower voltage limits, or open circuit). With this information is operator able to focus on the origin of defects and speed up the return of the machine to its normal condition. For the OBD-2 standard respectively E-OBD is typical that with any written fault the Freeze Frames are recorded. The Freeze Frames includes specific information about failure issue – e.g. engine speed, coolant temperature, vehicle speed, etc.

Material and Methods

Characteristics of Parallel Diagnostics

Parallel diagnostic consists of control of the basic properties of the component. In other words, it is an independent checking of component whether his behavior is correct. Tests can be performed on all elements, which are connected to the control unit. The control unit (ECU) is an essential element of motor management system. There are a microprocessor and memory in which characteristics (essential to engine running) are stored. According to the data stored in these characteristics ECU controls its outputs – injectors, fuel pump, relays.
A suitable instrument for parallel diagnostics of such components is a digital oscilloscope. The oscilloscope displays the captured signal in time. Then this signal can be analyzed. The big advantage of digital oscilloscope is the ability of recording the signal for later analysis. The kit of the oscilloscope designed for automotive diagnostic is in Fig.2.

Fig. 2 Pico Technology USB oscilloscope

The oscilloscope is able to display only the voltage waveforms. To view the current waveform it has to be connected a current clamp to the oscilloscope. The current clamp converts the magnitude of the current to voltage. In the previous figure (Fig. 2) is also showed other accessories required for oscilloscope in the automotive industry. This equipment includes the already mentioned current clamp, back pinning probes, test leads, attenuators, etc.

Oscilloscope in Automotive Diagnostics

The oscilloscope also finds utilization by checking other devices in the car. An example might be checking the work of the alternator, maximum current of starter, battery informative test, CAN-BUS signal checking or losses in the wiring. You can also control the actuators that have a feedback signal. To check the alternator work is necessary to focus on voltage or current checking. Externally the problem in the alternator may show a gradual reduction of the battery capacity due to insufficient charging or glowing charging indicator. The voltage checking can be done with a voltmeter but the voltage may be within the normal range of alternator regulated voltage even with faulty diode of rectifier. The consequence of faulty diode in the rectifier bridge can be seen just on the oscilloscope in the voltage or current waveform.

Components testing (sensors and actuators) that are connected to the control unit must be adapted according to the type of component. It was mentioned that sensors vary in their output (voltage / current, analog / digital). If we are focused on a petrol engine with fuel injection, the entire engine management system can be checked by using an oscilloscope. The following table shows components suitable for testing with oscilloscope.

Table 1 Tested parameters of sensors / actuators

Sensor / Actuator Type	Parameter
Inductive sensors	voltage
Injector	voltage, current
MAP sensor	voltage
Oxygen sensor	votage
MAF sensor	votage
Fuel pump	current
Ignition	voltage, current

Results and Discussion

Position sensor testing (crankshaft, camshaft)

Test consists of checking: peak to peak voltage, frequency, interference of signal (Fig. 3). Frequency and amplitude of the signal depends on the speed of the pulse wheel. The pulse wheel has teeth and gaps on its perimeter (Fig. 4), which change the magnetic flux in the coil of the sensor. The output voltage of the sensor can be described with help of the Equation 1, where can be seen that induced voltage is directly proportional to the change of the magnetic flux in time. [6]

Equation 1: Equation of induced voltage

$$U_i = n.\frac{d\phi}{dt} \quad [V],$$

where: U_i – induced voltage,
n – number of winding,
dϕ - magnetic flux change,
dt – time change.

Fig. 3 Crankshaft position sensor (red), camshaft position sensor (yellow)

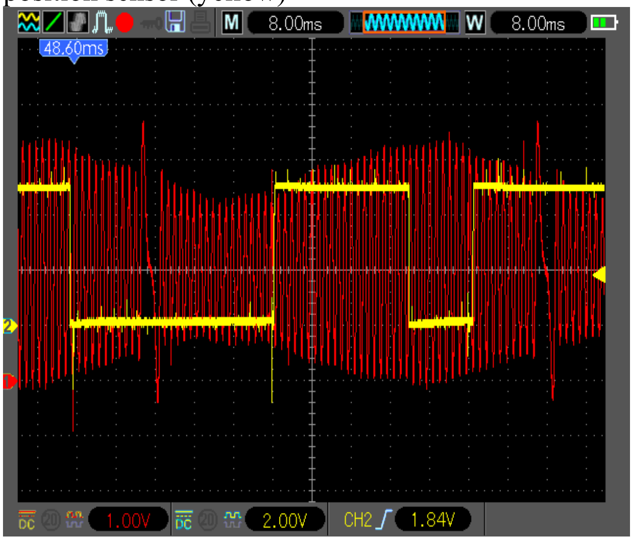
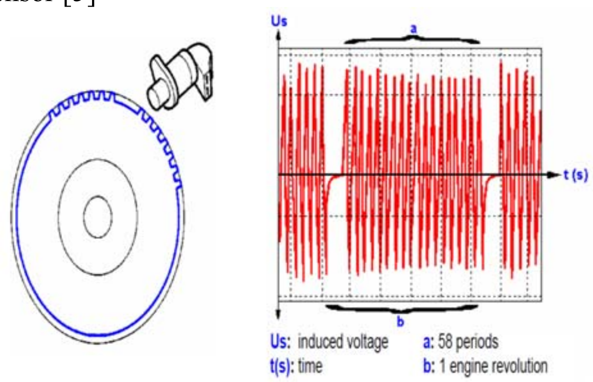


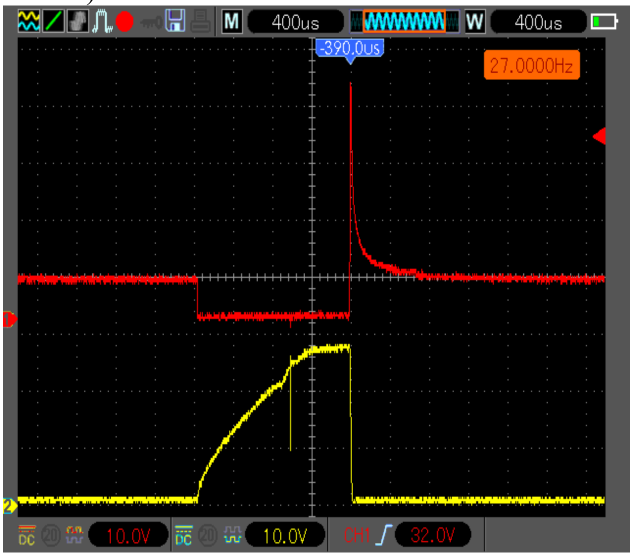
Fig. 4 Pulse wheel and typical waveform of position sensor [5]



Injection testing

On the injectors waveform could be seen the function of injectors or injector needle lift. Injectors can be compared with each other if are measured on another channel (Fig. 5).

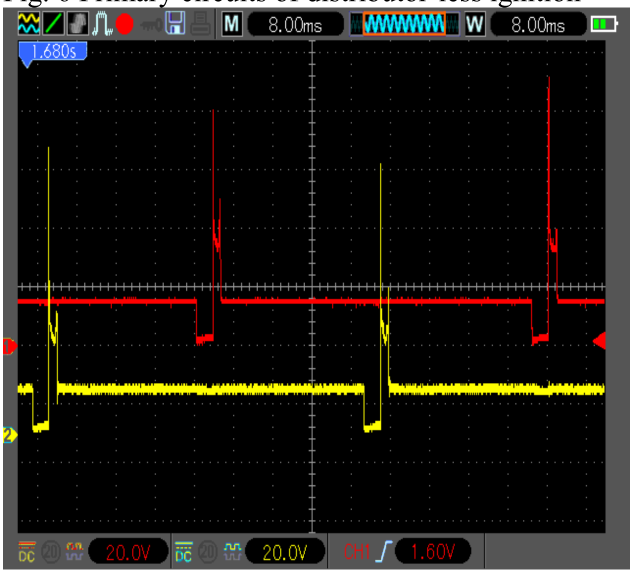
Fig. 5 Injector waveform (red – voltage, yellow-current)



Ignition testing

It exists many ways how to test the ignition. First of all it has to be obvious what type of ignition will be tested (ignition with distributor / distributor-less ignition / COP ignition). In Fig.6 there are showed primary circuits of modern distributor-less ignition.

Fig. 6 Primary circuits of distributor-less ignition



Oxygen sensor testing

Oxygen sensor is tested at changing acceleration and deceleration. In the Fig.7 is shown zirconia oxygen sensor at idle speed.

Fig. 7 Zirconia oxygen sensor at idle speed

Fuel pump current testing

Typical fuel pump is an actuator which is controlled by multifunciton relay. In Fig. 8 is shown good fuel pump current waveform. In wrong waveform would be characteristic decreases of current (see Fig. 9).

Fig. 8 Fuel pump current

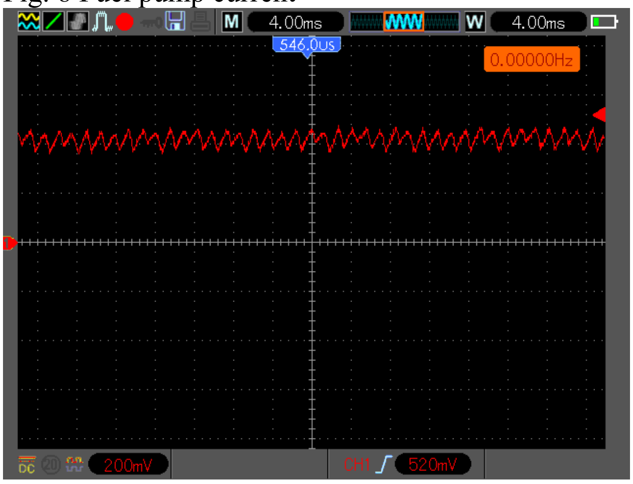
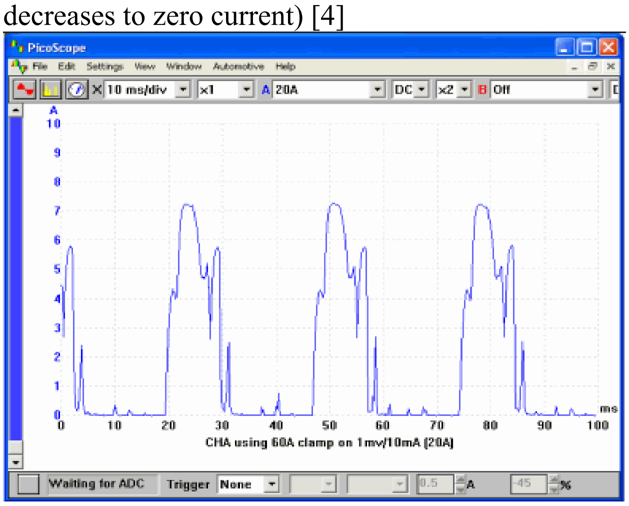


Fig. 9 Wrong waveform of fuel pump current (large decreases to zero current) [4]



Alternator testing

To the objective detection of a problem it is necessary to measure the voltage using an oscilloscope or current using a current clamp. Fig. 10 and Fig. 11 show the voltage and current at the faulty alternator. The alternator current waveform shows current declines to zero. The right waveform is just characterized by sharply defined half-waves of voltage or current.

To remove the DC component of the voltage the first channel was coupled with AC. The CH1 shows voltage at terminal B+ and CH2 shows the alternator current.

Fig. 10 Wrong waveform of alternator current (CH2) and voltage (AC coupled CH1)

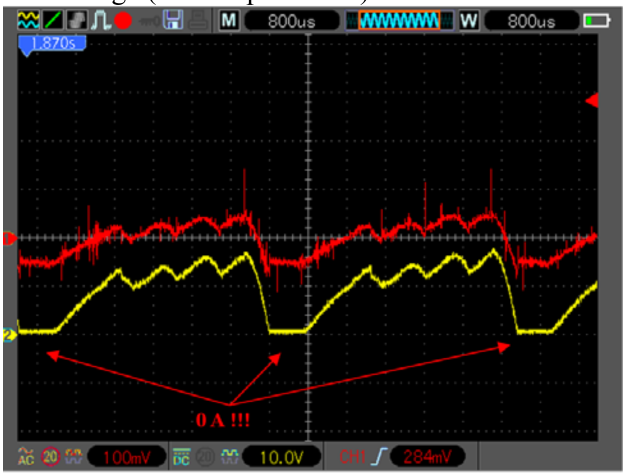
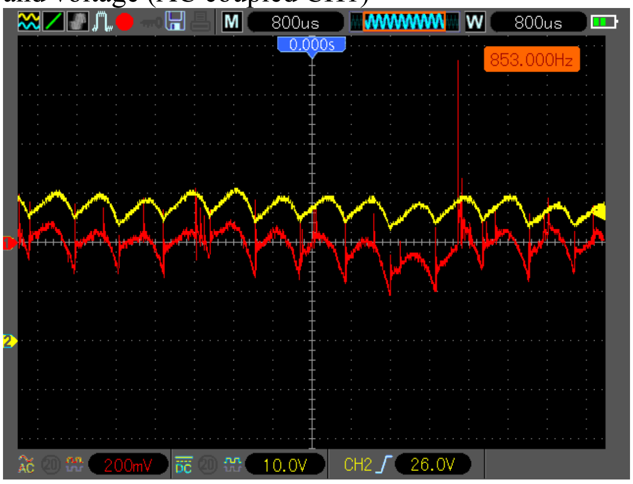


Fig. 11 Correct waveform of alternator current (CH2) and voltage (AC coupled CH1)



Conclusion

This article shows a brief overview of parallel diagnostic of sensors and actuators of motor management system. To verify the functionality of the component is important to assess the shape of curve. In other cases the voltage value or frequency is assessed. Parallel diagnostic with an oscilloscope requires a certain amount of the operator experience. To the detection of defects on the sensor or actuator is not enough to measure the waveform, but it is important to assess it. Equally important is the knowledge of the engine control system. If the service network is connected to direct support from the manufacturer, it is possible to search for properties of sensors and their outputs in datasheet. The overview shows the measurements with help of 2-CH oscilloscope. Modern oscilloscopes used in the car repair services can be equipped with 4, 8 or more channels. The number of channels is crucial in the cases where random faults appear. If it is possible to observe more channels you can see the connections that occur for example during the engine misfiring and see the fault. Today, the essential properties of a digital oscilloscope are ability of waveform recording. Records are then re-used to locate faults and this feature can help to speed up the diagnostic process.

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