Automotive Tutorials

Emissions-Related Components and Actuators

In this tutorial we look at the actuators and components that affect the vehicles exhaust emissions when the electronically controlled fuel injection system is found to be over fuelling.

There are predominantly two reasons for excessive fuelling: increased fuel pressure and extended injector duration.

The fuel pressure should be tested using an accurate pressure testing kit and the results compared against the manufacturer's specification. The system pressure on the majority of multi-point injection systems is usually around 2.0 bar, increasing to 2.5 bar under acceleration conditions. The fuel pressure regulator (Figure 1.0) is separated into two halves by a diaphragm.

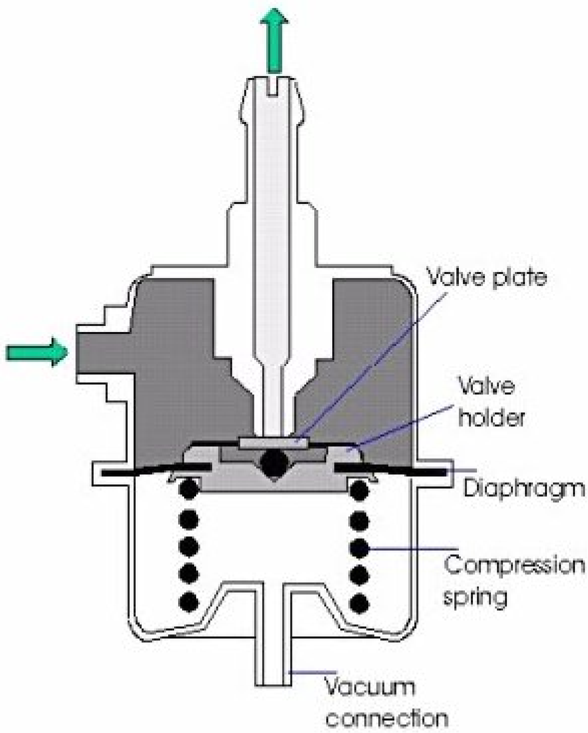

Figure 1.0

The lower part has an internal spring and a vacuum take off point; the upper half receives the fuel from the fuel rail. When the fuel pressure overcomes the spring tension, the diaphragm is depressed and the excess pressure escapes back to the fuel tank via the return pipe. If the spring inside the pressure regulator becomes weakened, the pressure reduces accordingly.

The vacuum hose that is connected to the lower chamber allows the effective pressure exerted onto the diaphragm to change with different engine loads. Excessive fuelling will occur if the rubber diaphragm inside the pressure regulator is perforated as this will allow fuel to pass into the inlet manifold via the vacuum pipe.

The emissions produced by the combustion process have never before been under more scrutiny from both ecological movements and government legislation; it is therefore important that the vehicle runs efficiently, helping to minimise harmful emissions from the exhaust tail pipe. An engine can, in theory, run at such a point where the emissions produced will be no more than harmless oxygen, carbon dioxide, nitrogen and water. The theory may be correct, but with the combination of moving parts, varying engine speed, changing temperature, and different timing and fuel mapping, the final output is often less than perfect.

At a certain Air / Fuel Ratio (AFR) the emissions from the exhaust are minimised and, with the introduction of the catalytic converter and lambda sensor, the outputs can be reduced to satisfy the current construction and use regulations. If the engine should suffer from an ignition misfire or an electronic component failure the combustion process will be greatly compromised, causing both an unacceptable increase in exhaust emissions and the possibility of damage to the catalytic converter. Most vehicles registered after 1992 are equipped with a three way catalytic converter and, more often than not, have 'closed loop' control.

'Closed loop' means that when the expended exhaust gases pass through the exhaust pipe, the lambda (or oxygen) sensor reports the condition of the mixture to the Electronic Control Module (ECM) which can adjust the fuelling accordingly. A sensor that is switching correctly will alter the fuelling about once per second and the speed of this switching can be seen on an oscilloscope. An ideal air/fuel ratio from complete combustion allows the lambda sensor to 'fine tune' the fuelling.

Assuming that the fuel pressure is correct, the excess fuel must therefore be due to an increase in injector duration. This can be caused by any of the following sensors and actuators.

- Coolant temperature sensor
- Mass airflow meter
- MAP sensor
- Throttle position sensor
- Weak or ‘dribbling’ injector
- Air temperature sensor
- Lambda sensor
- ECM fault

Coolant Temperature Sensor

The sensor alters its resistance with engine temperature change. The majority of sensors have a Negative Temperature Coefficient (NTC) which results in the resistance of the component decreasing as the temperature increases. The resistance change therefore alters the voltage seen at the sensor and can be monitored for any discrepancies across its operational range. Select a time scale of 500 seconds, then connect the oscilloscope to the sensor and observe the output voltage. Start the engine and in the majority of cases the voltage will start in the region of 3 to 4 volts; however, this voltage will depend on the temperature of the engine — as the temperature increases the resistance decreases and the voltage will also drop. If the resistance of the sensor is higher than anticipated this will fool the ECM into thinking that the engine is colder than it actually is, thus giving additional fuelling. The same effect will be seen if there is a poor conductivity at either the sensor's two pin connector or at the ECM. This will give the equivalent of another resistance in series, increasing the overall resistance.

Mass Airflow Meter (Air Vane)

The voltage output from the internal track of the Air Flow Meter (AFM) should be proportional to flap movement; this can be measured on an oscilloscope and should look similar to the example shown in Figure 1.1.

The waveform should show approximately 1.0 volt when the engine is at idle; this voltage will rise as the engine is accelerated and produces an initial peak. This peak is due to the inertia of the air vane and drops momentarily before the voltage rises again to a peak of approximately 4.0 to 4.5 volts. The initial voltage seen at idle will vary between motor manufacturers and should therefore be compared against the relevant data.

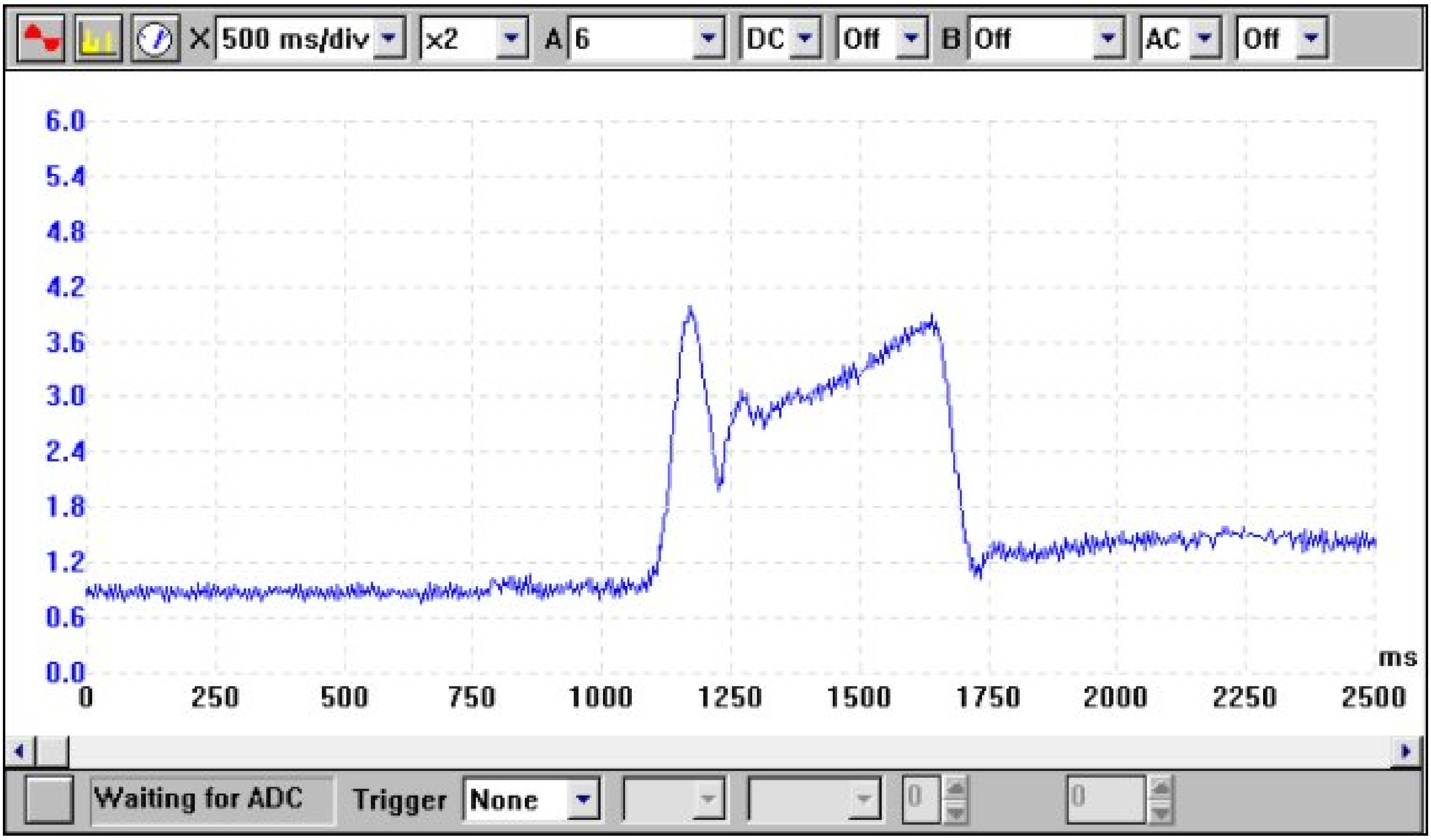

Figure 1.1

Mass Airflow Meter (Hot Wire)

This form of air flow meter is, in many ways, superior to the conventional air vane meter as it offers very little resistance to the flow of incoming air. The mass air flow is measured by the cooling effect on a heated wire that is suspended in the air passage, and it is the air flow's cooling effect on the wire that signals to the ECM the quantity of incoming air.

Inside the component are two wires, one of which is used to convey the temperature of the incoming air, the other heated to a high temperature (approximately 120 °C) by passing a small current through it. As the air flows across the heated wire, it has a cooling effect on it causing a temperature change; a small circuit inside the component increases the current passing through the wire to maintain the temperature, and it is this current that signals to the ECM the mass air flow. The current supplied to the heated wire alters proportionally to the air flow.

Any wire that is constantly heated will form an oxide coating. To clean the wire after each journey, a current is passed through the wire heating it to approximately 1000 °C, burning off any build up, and ensuring a clean wire for the next time the vehicle is started.

MAP Sensor (Analogue)

This component can be either an integral part of the electronic control unit or an individual component. The output from the analogue version shows a rise and fall voltage depending upon the vacuum seen. When the engine is stationary or the throttle is wide open, zero vacuum is recorded and a voltage approaching 5 volts will be seen, and as a vacuum is applied the voltage will reduce. With this particular form of engine load recognition, the condition of the vacuum pipes and connections is vital as any air leak will fool the ECM into over fuelling.

MAP Sensor (Digital)

A digital MAP sensor produces a square wave signal to the engine management ECM; this square wave changes frequency with varying engine vacuum readings. This output waveform can also be monitored on an oscilloscope, or the frequency measured on a certain multimeters that have the appropriate setting (Hz). The frequency seen at idle should match the frequency seen in the manufacturer's data. Air leaks also affect this digital form of monitoring the engine's vacuum.

With both forms of MAP sensor, the engine's fuelling will increase if the exhaust system has a restriction that impedes the flow of the spent gases.

Throttle Position Sensors

This throttle potentiometer (Figure 1.2) indicates to the ECM the exact amount of throttle opening. A throttle switch is unable to give precise positions of opening, but a throttle pot can give precise openings due to its linear output. The majority of modern engine management systems employ this particular sensor, and like the throttle position switch it is located on the butterfly spindle.

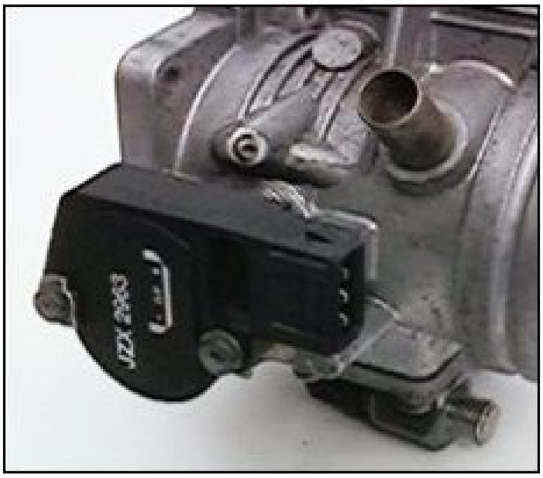

Figure 1.2

This is also a three-wire device employing a 5 volt supply, an earth connection and a variable output from the centre pin. Some TPS's are attached to the throttle body via elongated locating holes; if this is the case, an initial voltage setting must be made as too high an initial voltage will suggest an open throttle and the ECM will over-fuel.

Weak or ‘Dribbling’ Injectors

The injector consists of a solenoid-operated valve which is held in the closed position by a spring until the ECM completes the earth circuit. When the electromagnetic field lifts the pintle off its seat, fuel is delivered to the engine. The total lift on the pintle is approximately 0.15 mm (6 thou) and it has a reaction time around 1 millisecond. Any dirt ingress around the pintle seating area will cause the injector to not seat properly, allowing fuel to escape into the inlet manifold. The same consequences will also occur if the internal spring is damaged or broken.

Figure 1.3

The injectors can be tested for flow rate, reaction time and leakage in a specialised test unit. The leakage test can however be performed by removing the fuel rail, pressurising the system and observing the injectors for any leakage. Any faulty injector should of course be replaced with another injector with a comparable flow rate. An example injector can be seen in Figure 1.3.

Air Temperature Sensor

With the air temperature sensor contributing only 20% of the temperature compensation, the sensor would have any discernible effect only if it was open circuit.

Lambda Sensor

The most popular lambda sensor used on European vehicles is the Zirconia type. This sensor is essentially two porous platinum electrodes. The outer electrode surface is exposed to the exhaust gases and is coated in a porous ceramic with the inner coated surface exposed to fresh air. The sensor then produces a voltage when there is a difference in oxygen content between the two electrodes. This signal is then sent to the ECM which adjusts the mixture accordingly. The voltage range is normally 0.2 volts when lean to 0.8 volts when rich.

A constant high voltage output from the sensor shows that the engine is running constantly rich and is outside the ECM's adjusting range.

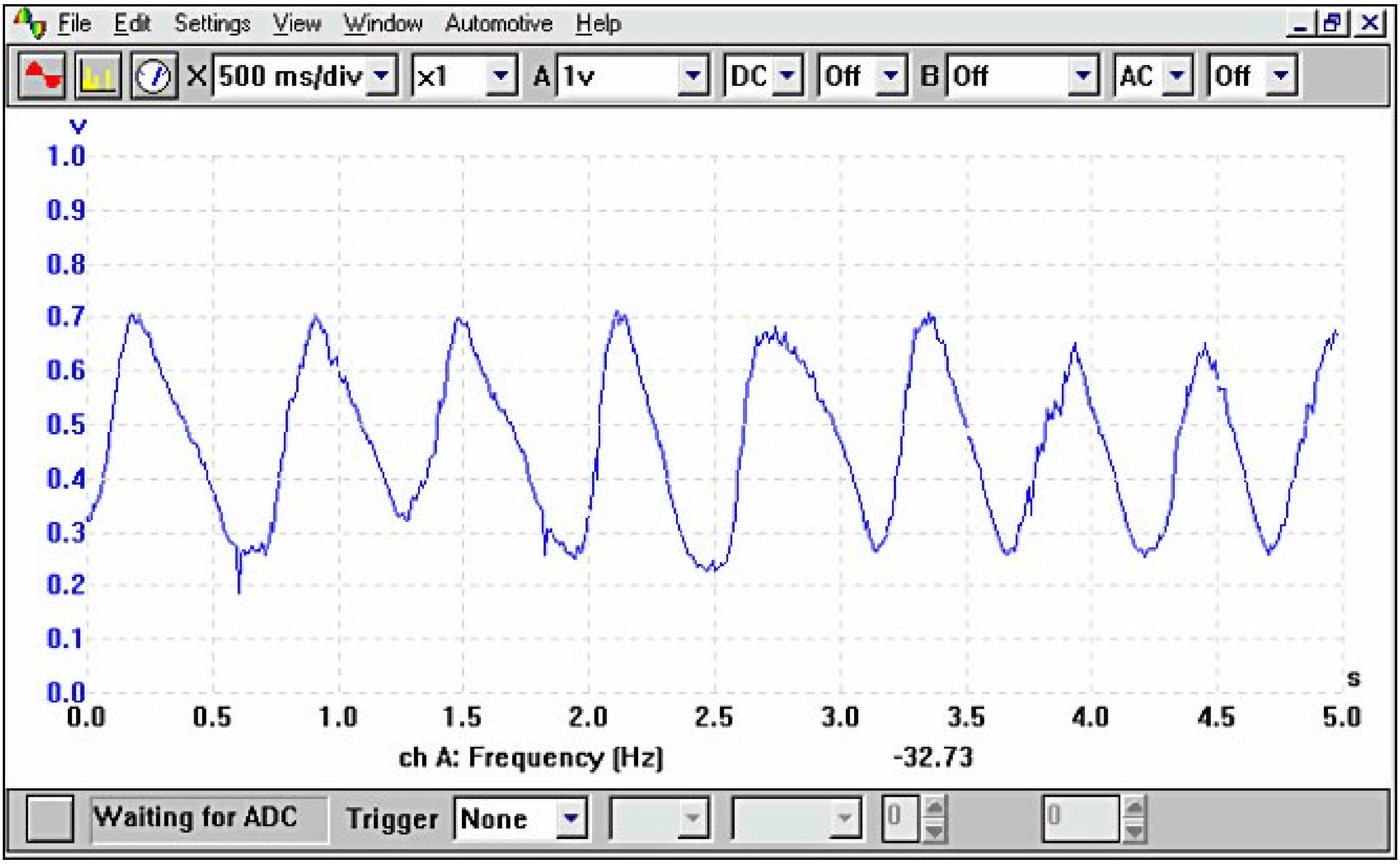

Figure 1.4

Lambda sensors, when working correctly, switch approximately once per second (1 Hz) and only start to switch when at normal operating temperature. This switching can be monitored on an oscilloscope with the waveform looking similar to the one in Figure 1.4.

A conventional Zirconia sensor will display a high voltage while the engine is running with an excess of fuel, with a low voltage while running lean. The same principle also applies to the Titania variant but this time at a higher voltage of 0 to 5 volts.

ECM Fault

The ECM fitted to today's modern engine management system is responsible for the 'mapping' of the ignition timing and the fuel delivery. In order for the ECM to calculate the required ignition and fuelling parameters, it must be fed with input signals from the engine's sensors. The ECM is pre-programmed with data that ensures that the engine's performance and efficiency are maintained throughout the operational rev range and can be trimmed using a knock sensor to finely adjust the ignition timing and a lambda sensor to control the fuelling when in closed loop.

The majority of ECM's have a self-diagnosis facility which is able to detect any problems from signals outside their normal operating range. Another facility that the ECM has is its ability to operate in 'limp home' or LOS mode (Limited Operation Strategy). This allows the ECM to operate from preset parameters when the system encounters a failure, often illuminating the engine warning light. If a faulty ECM is suspected, it can be tested to assess its condition before a substitute unit is fitted.

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