

Electronic Fuel Injection (Part 1)

In this tutorial we will be looking at the Electronic Fuel Injection system, with particular focus upon the sensors and actuators, and their inputs and outputs to and from the vehicle's ECM. The tutorial looks at the multi-point injection system, with single-point being covered in a later tutorial.

Overview

Both the multi-point and the single-point systems operate in a very similar fashion, having an electromechanically operated injector or injectors opening for a predetermined length of time called the injector pulse width. The pulse width is determined by the engine's Electronic Control Module (ECM) and depends on the engine temperature, the engine load and the information from the oxygen (lambda) sensor. The fuel is delivered from the tank through a filter, and a regulator determines its operating pressure. The fuel is delivered to the engine in precise quantities and in most cases is injected into the inlet manifold to await the valve's opening, then drawn into the combustion chamber by the incoming air.

The Fuel Tank

This is the obvious place to start in any full system explanation. Unlike the tanks on early carburettor-equipped vehicles, it is a sealed unit that allows the natural gassing of the fuel to aid delivery to the pump by slightly pressurising the system. When the filler cap is removed, pressure is heard to escape because the fuel filler caps are no longer vented.

The Fuel Pump

This type of high-pressure fuel pump (Fig 1.0) is called a roller cell pump, with the fuel entering the pump and being compressed by rotating cells which force it through the pump at a high pressure. The pump can produce a pressure of 8 bar (120 psi) with a delivery rate of approximately 4 to 5 litres per minute. Within the pump is a pressure relief valve that lifts off its seat at 8 bar to arrest the pressure if a blockage in the filter or fuel lines or elsewhere causes it to become obstructed. The other end of the pump (output) is home to a non-return valve which, when the voltage to the pump is removed, closes the return to the tank and maintains pressure within the system. The normal operating pressure within this system is approximately 2 bar (30 psi), at which the current draw on the pump is 3 to 5 amps. Fuel passing across the fuel pump's armature is subjected to sparks and arcing; this sounds quite dangerous, but the absence of oxygen means that there will not be an explosion!

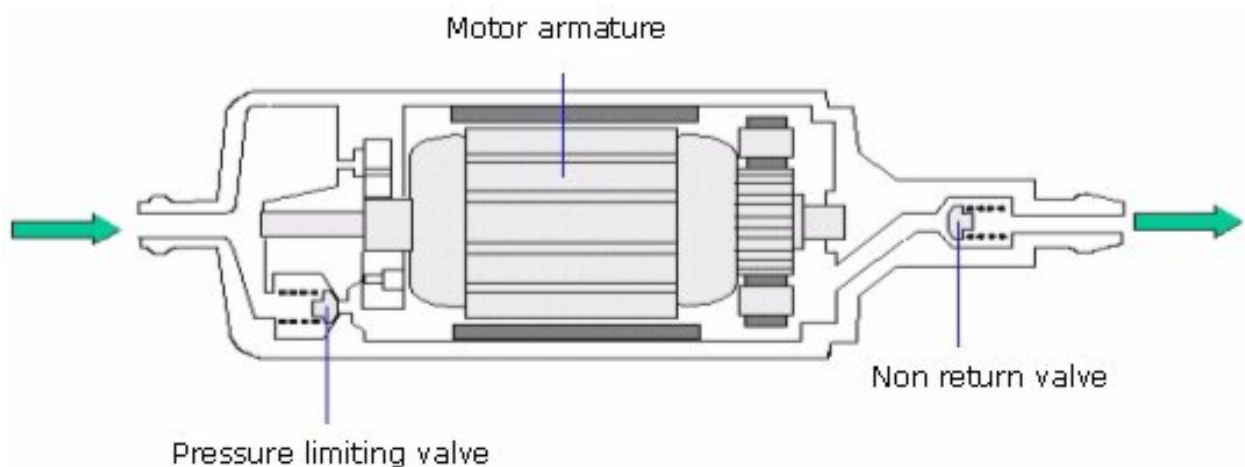


Figure 1.0

The majority of fuel pumps fitted to today's motor vehicles are fitted within the vehicle's petrol tank and are referred to as 'submerged' fuel pumps. The pump is invariably been located with the fuel sender unit and both units can sometimes be accessed through an inspection hole either in the boot floor or under the rear seat. Mounted vertically, the pump comprises an inner and outer gear assembly that is called the 'gerotor'. The combined assembly is secured in the tank using screws and sealed with a rubber gasket, or a bayonet-type locking ring. On some models, there are two fuel pumps, the submerged pump acting as a 'lift' pump to the external roller cell pump.

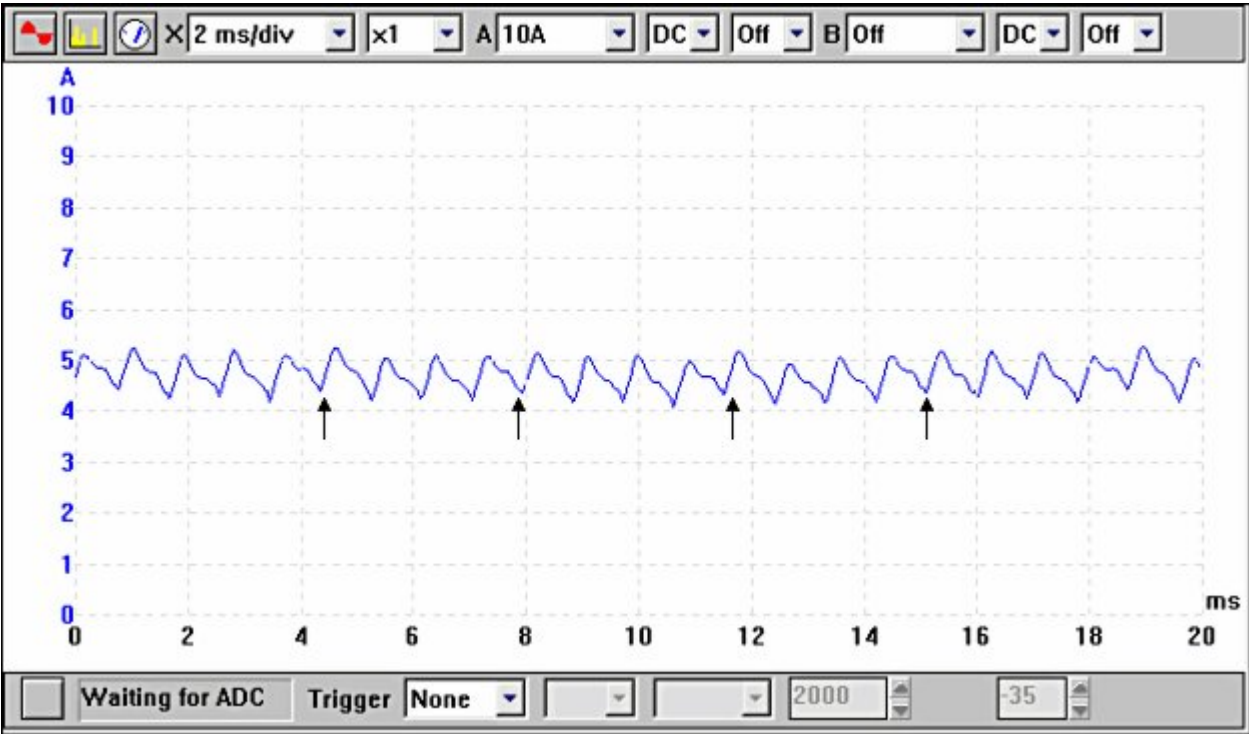


Figure 1.1

The waveform illustrated in Fig 1.1 shows the current for each sector of the commutator. The majority of fuel pumps have 6 to 8 sectors, and a repetitive point on the waveform can indicate wear and an impending failure. In the illustration waveform it can be seen that there is a lower current draw on one sector and this is repeated when the pump has rotated through 720°. This example has 8 sectors per rotation.



Figure 1.2

Fig 1.2 shows typical access to the fuel-submerged pump to measure current draw.

The current drawn by the fuel pump depends upon the fuel pressure but should be no more than 8 amps, as found on the Bosch K-Jetronic mechanical fuel injection which has a system pressure of 75 psi.

Fuel Supply

A conventional 'flow and return' system has a supply of fuel delivered to the fuel rail, and the unwanted fuel is passed through the pressure regulator back to the tank. It is the restriction in the fuel line created by the pressure regulator that provides the system operational pressure.

Returnless Fuel Systems

Have been adopted by several motor manufacturers and differ from the conventional by having a delivery pipe only to the fuel rail with no return flow back to the tank.

The returnless systems, both the mechanical and the electronic versions, were necessitated by emissions laws. The absence of heated petrol returning to the fuel tank reduces the amount of evaporative emissions, while the fuel lines are kept short, thus reducing build costs.

Mechanical Returnless Fuel Systems

The 'returnless' system differs from the norm by having the pressure regulator inside the fuel tank. When the fuel pump is activated, fuel flows into the system until the required pressure is obtained; at this point 'excess' fuel is bled past the pressure regulator and back into the tank.

The 'flow and return' system has a vacuum supply to the pressure regulator: this enables the fuel pressure to be increased whenever the manifold vacuum drops, providing fuel enrichment under acceleration.

The 'returnless' system has no mechanical compensation affecting the fuel pressure, which remains at a higher than usual 44 to 50 psi. By increasing the delivery pressure, the ECM (Electronic Control Module) can alter the injection pulse width to give the precise delivery, regardless of the engine load and without fuel pressure compensation.

Electronic Returnless Fuel Systems

This version has all the required components fitted within the one unit of the submersible fuel pump. It contains a small particle filter (in addition to the strainer), pump, electronic pressure regulator, fuel level sensor and a sound isolation system. The electronic pressure regulator allows the pressure to be increased under acceleration conditions, and the pump's output can be adjusted to suit the engine's fuel demand. This prolongs the pump's life as it is no longer providing a larger than required output delivery.

The Electronic Control Module (ECM) supplies the required pressure information, while the fuel pump's output signal is supplied in the form of a digital square wave. Altering the square wave's duty cycle affects the pump's delivery output.

To compensate for the changing viscosity of the fuel with changing fuel temperature, a fuel rail temperature sensor is installed. A pulsation damper may also be fitted ahead of or inside the fuel rail.

Injectors

The injector is an electromechanical device, which is fed by a 12 volt supply from either the fuel injection relay or the ECM. The voltage is present only when the engine is cranking or running, because it is controlled by a tachometric relay. The injector is supplied with fuel from a common fuel rail. The injector pulse width depends on the input signals seen by the ECM from its various engine sensors, and varies to compensate for cold engine starting and warm-up periods, the initial wide pulse getting narrower as the engine warms to operating temperature. The pulse width also expands under acceleration and contracts under light load conditions.

The injector has constant voltage supply while the engine is running and the earth path is switched via the ECM. An example of a typical waveform is shown below in Fig 1.3.

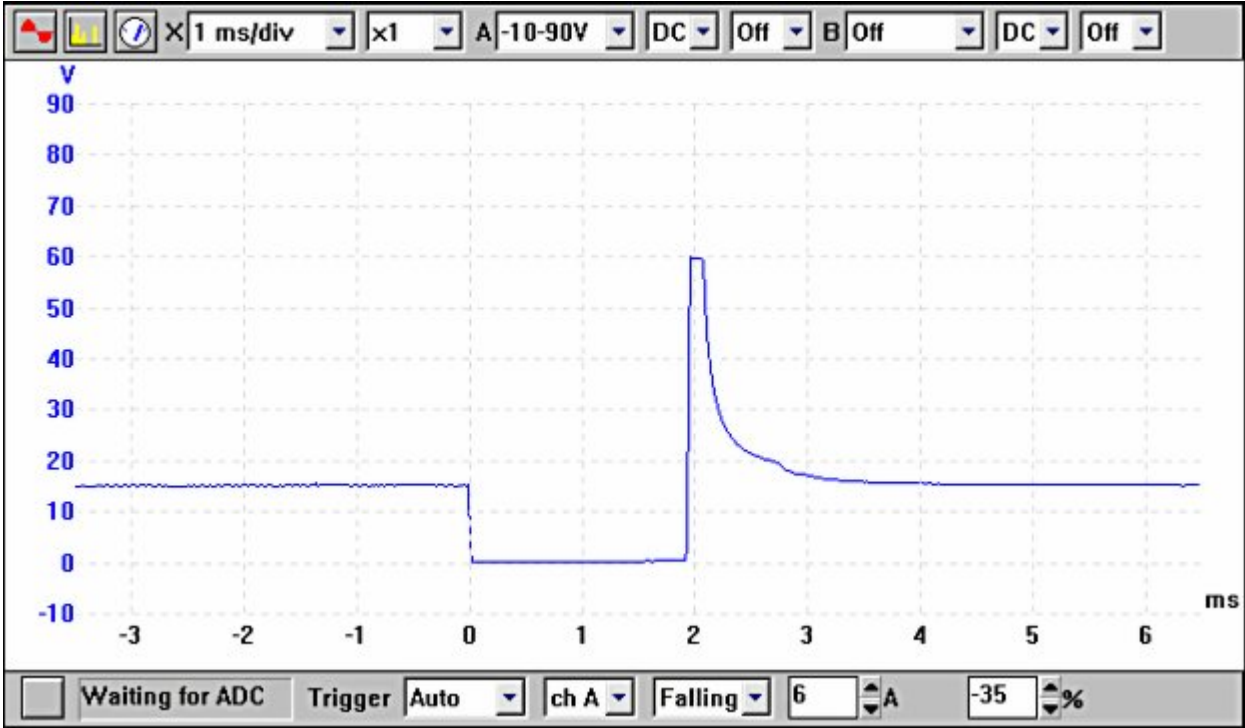


Figure 1.3

Multi-point injection may be either sequential or simultaneous. A simultaneous system fires all 4 injectors at the same time with each cylinder receiving 2 injection pulses per cycle (720° crankshaft rotation). A sequential system receives just 1 injection pulse per cycle, timed to coincide with the opening of the inlet valve. As a very rough guide the injector pulse widths for an engine at normal operating temperature at idle speed are around 2.5 ms for simultaneous and 3.5 ms for sequential.

An electromechanical injector of course takes a short time to react, as it requires a level of magnetism to build before the pintle is lifted off its seat. This time is called the 'solenoid reaction time'. This delay is important to monitor and can sometimes occupy a third of the total pulse width. A good example of the delay in opening can be seen in the example waveform shown below in Fig 1.4.

The waveform is 'split' into two clearly defined areas. The first part of the waveform is responsible for the electromagnetic force lifting the pintle, in this example taking approximately 0.6 ms. At this point the current can be seen to level off before rising again as the pintle is held open. With this level off it can be seen that the amount of time that the injector is held open is not necessarily the same as the time measured. It is not however possible to calculate the time taken for the injector's spring to fully close the injector and cut off the fuel flow.

This test is ideal for identifying an injector with an unacceptably slow solenoid reaction time. Such an injector would not deliver the required amount of fuel and the cylinder in question would run lean.



Figure 1.4

Fig 1.5 shows both the injector voltage and current displayed simultaneously.

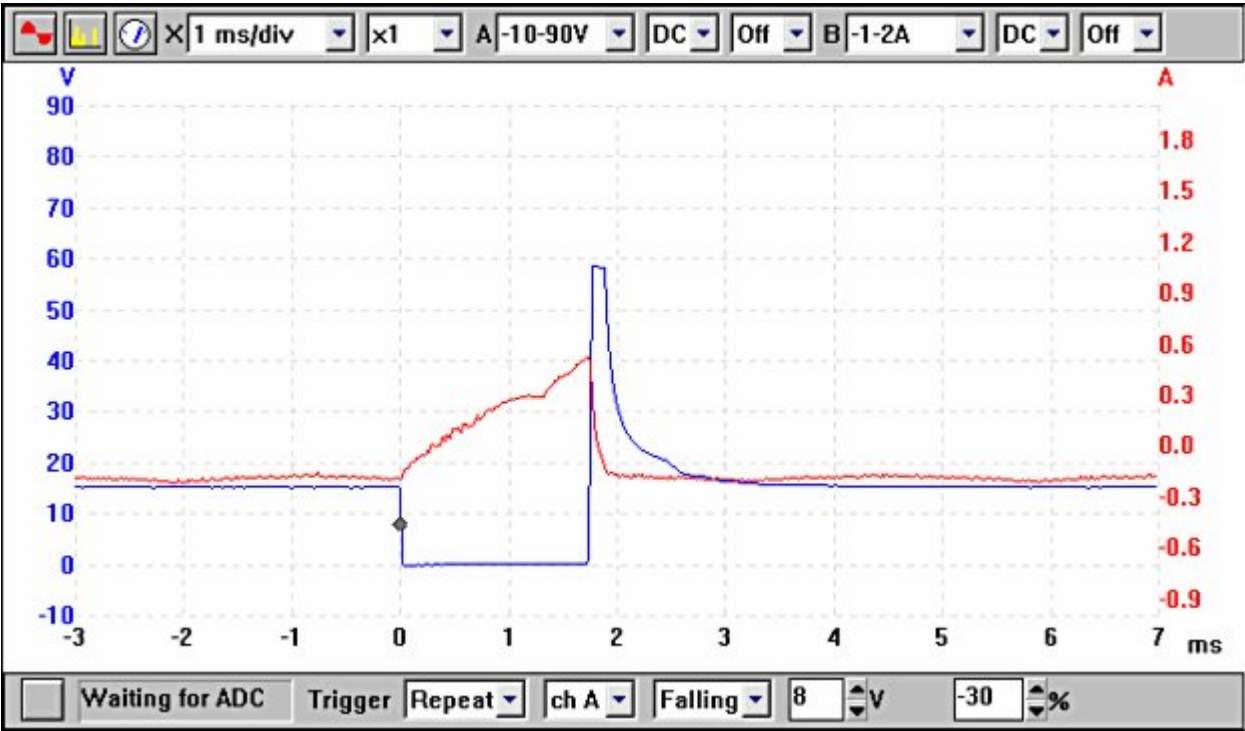


Figure 1.5



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