CHAPTER 13

EFI fuel systems

- Petrol as a fuel
- Air–fuel ratio
- Types of EFI systems
- Basic multipoint EFI system
- Multipoint fuel systems
- Fuel-supply system components
- Air intake system components
- Electronic control components
- Basic direct fuel injection
- Checks and precautions
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The engine gets its power by burning a mixture of air and fuel in the combustion chamber. This chapter will show how that occurs in an electronic fuel-injection (EFI) system. There are basically two ways that the fuel (petrol) enters the cylinder: injection into the intake manifold and injection directly into the combustion chamber.

The chapter also covers the fuel storage and supply parts of the fuel system – from the fuel tank to the injectors.

Reference: EFI systems are covered in more detail in Volume 2. Diesel fuel systems are also covered in Volume 2, while information on carburettors and gas fuel systems can be accessed online through *Connect*.

Petrol as a fuel

Petrol (also called gasoline in some countries) is a chemical compound. It is a hydrocarbon, which means that it consists mainly of hydrogen and carbon atoms. Petrol cannot be used in the engine in liquid form, and must be mixed with air to obtain oxygen to form a combustible mixture. The liquid fuel has to be *atomised* so that each little droplet of fuel can be surrounded by air with enough oxygen to completely burn the fuel (Figure 13.1).

With an ideal mixture of air and fuel and complete combustion taking place, full power would be obtained from the fuel. The engine's exhaust would be clean, and pollution of the atmosphere would be reduced.

Reference: Refer to Chapter 30: Fuels, fluids and lubricants for more information.

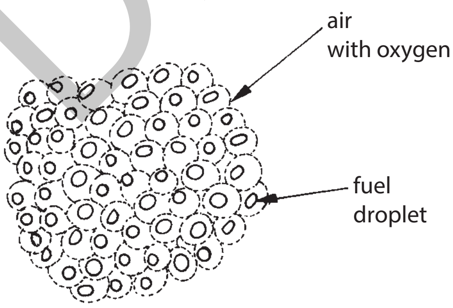

Figure 13.1 In a fuel charge, each fuel droplet is surrounded by its own supply of air with oxygen

Air–fuel ratio

For a petrol engine, the most suitable ratio of air to fuel is approximately 15:1, by mass – that is 15 kg of air to 1 kg of petrol (Figure 13.2). An EFI system (or a carburettor) must supply a mixture with this ratio, although the ratio is varied for certain engine conditions, such as starting, accelerating and operating under heavy load. The air–fuel ratio for complete combustion is known as the *stoichiometric ratio*, and is actually 14.7:1 (by mass).

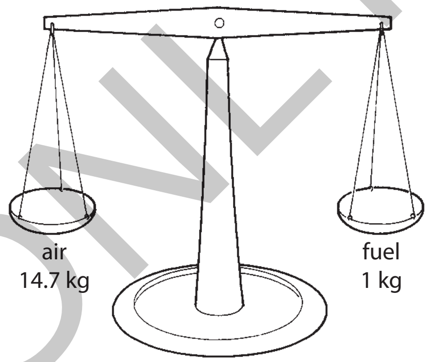

Figure 13.2 The ratio of air to fuel in the mixture, for complete combustion, is 14.7:1 by mass

If there is too much fuel for the air in the engine's cylinders then there will be a *rich mixture*. Combustion will not be complete and some fuel will remain unburnt. This will be exhausted into the atmosphere as gas and will cause air pollution. If the mixture is very rich there could be black smoke from the exhaust.

If there is not enough fuel for the air in the cylinders, there will be a *weak mixture*. This could cause hard starting, poor combustion and loss of power.

The chemical composition of the gases in the engine's exhaust system will vary according to how well the fuel has burnt. This can be checked with an exhaust-gas analyser. A sampling tube is placed in the end of the exhaust pipe and readings of the exhaust emissions are shown on the gauges (Figure 13.3). A high reading could indicate an incorrect air–fuel ratio – this could be caused by incorrect supply of fuel to the engine, or by poor fuel combustion.

Handy hint: Poor combustion might not be a fuel problem, but could be the result of poor ignition.

Figure 13.3 An exhaust-gas analyser takes a sample of the exhaust gas and analyses it for emissions

Mixing of fuel within the engine

Petrol is very volatile. This means that it will vaporise easily, or change its state readily from a liquid to a gas (Figure 13.4).

Fuel from an EFI system is delivered to the engine by the injectors as a fine spray. The fuel is then vaporised by the air flowing through the intake manifold into the engine, also by the heat of the cylinder head.

Inside the engine, piston movement and the shape of the combustion chamber keep the air and fuel mixed. This prevents fuel from settling on the surfaces of the combustion chambers and cylinder walls.

Fuel in liquid form will only burn on its surface, so every effort is made to keep the air and fuel mixed so that each particle of the fuel has its own supply of oxygen to enable the fuel to be fully burnt.

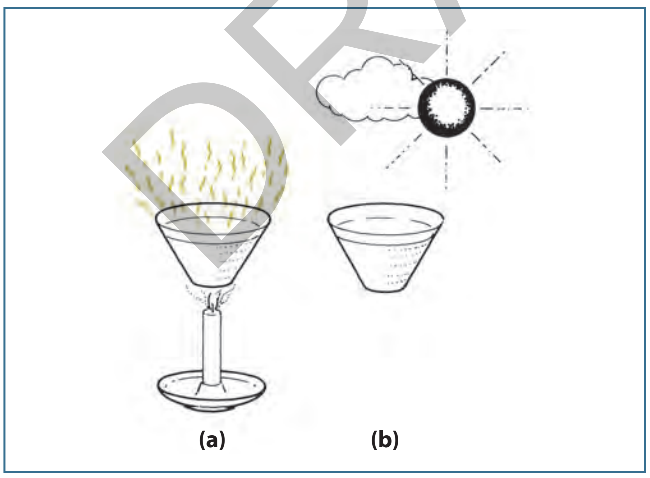

Figure 13.4 Vaporisation, or evaporation, of a liquid **(a)** increased evaporation by applying heat **(b)** evaporation by natural means – in an engine, vaporisation is assisted by the heat of the cylinder head

Types of EFI systems

EFI systems use injectors to spray the fuel. There are two different systems: multipoint injection and throttle-body injection (also called single-point injection). In both systems, the injectors are electronically controlled.

Multipoint injection is the most commonly used and is further divided into *indirect* and *direct* injection. Both systems have an injector for each cylinder. Indirect injection sprays fuel into the intake valve port, while direct injection sprays fuel directly into the combustion chamber.

Throttle-body injection acts like an electronic carburettor. It has one or two injectors, depending on the size of the engine, which spray fuel into the air passing through the throttle body into the intake manifold.

Reference: Only basic multipoint injection will be covered here. Throttle-body and multipoint injuction are covered in more detail in Volume 2.

Basic multipoint EFI system

Figure 13.5 shows the arrangement of a basic multipoint fuel-injection system. Some parts supply fuel to the engine and other parts supply air. These are:

1. *Fuel tank* – to store the fuel.
2. *Fuel pump* – to provide pressure for the system.
3. *Filter* – to protect the injectors.
4. *Fuel rail* – to supply the injectors with fuel.
5. *Injectors* – to spray fuel into the intake valve ports.
6. *Pressure regulator* – to provide a regulated pressure in the system.
7. *Air cleaner and ducting* – to provide clean air and carry it to the intake manifold.
8. *Throttle body* – to control the flow of air to the engine by means of a throttle valve.
9. *Airflow meter* – to measure air entering the engine.
10. *Plenum, or air, chamber* – to dampen the flow of air.
11. *Intake manifold* – to carry the air to the cylinders.

In addition to the parts listed above, there is an electronic control unit (ECU). This is a micro-computer that receives signals from a number of sensors, processes them and uses the results to operate the injectors.

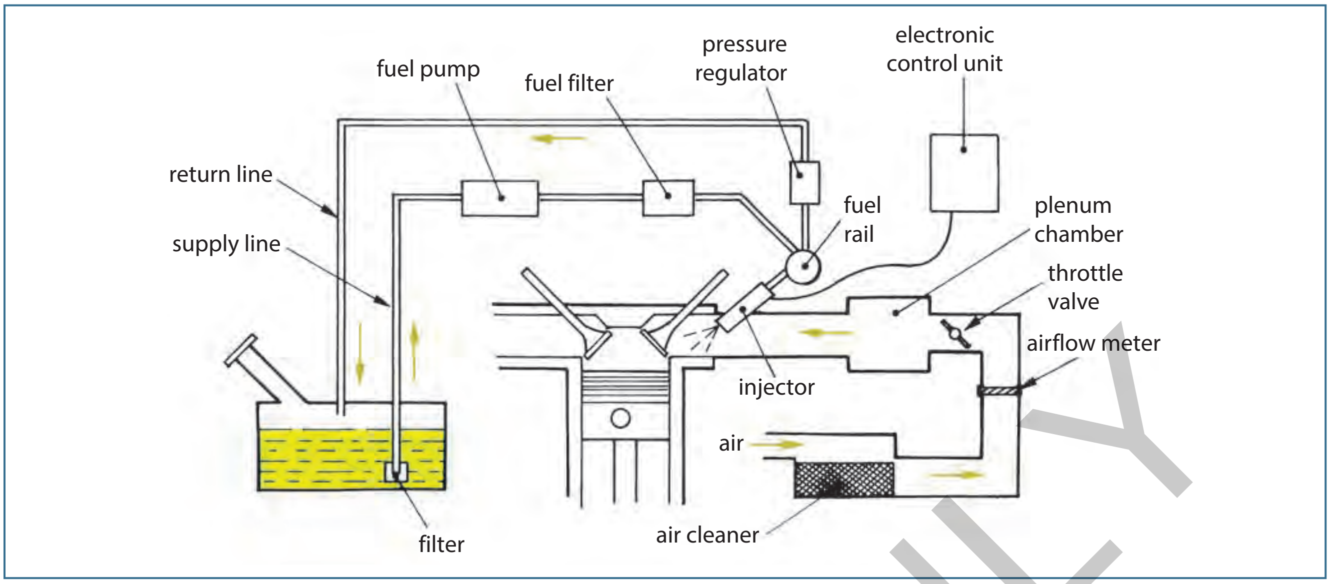

Figure 13.5 Arrangement of a basic multipoint EFI system

Multipoint fuel systems

An EFI system can be considered as having three subsystems, each of which has a number of components. These subsystems are:

1. fuel supply system
2. air intake system
3. electronic control system.

Fuel supply system

The location of the various parts of a fuel supply system are shown in Figure 13.6.

The high-pressure pump, located in the fuel tank, pumps fuel through the supply line to the fuel filter, then from the filter to the fuel rail, where it is held under pressure.

The fuel pressure regulator at the end of the fuel rail maintains pressure in the system. It does this by holding sufficient fuel in the fuel rail to create the pressure required and passing excess fuel through the return line to the fuel tank.

The injectors are connected into the fuel rail and spray fuel directly into the intake ports of the engine. The amount of fuel delivered by the injectors and their timing are controlled by the electronic control unit.

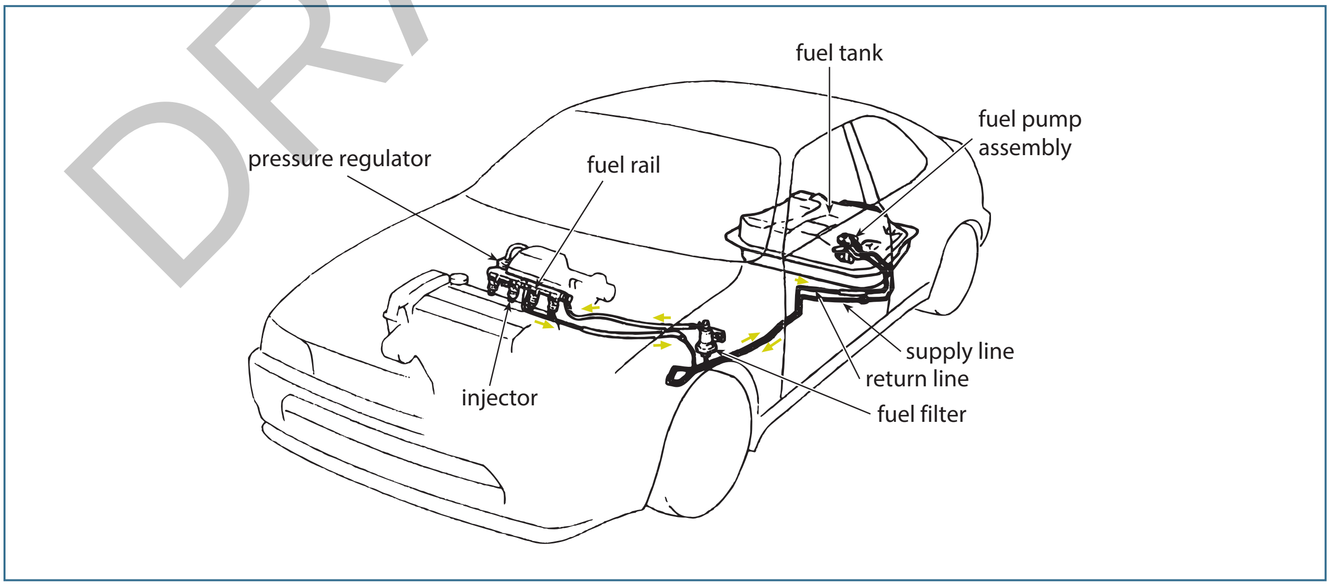

Figure 13.6 Parts of an EFI fuel-supply system TOYOTA

Air intake system

The air intake system is shown in Figure 13.7. Air is drawn in through the air intake and then through the air filter before reaching the throttle body assembly.

A butterfly valve in the throttle body is connected to the accelerator pedal of the vehicle and this controls the air that passes through to the plenum chamber and the intake manifold.

The plenum chamber dampens out the pulsations in the air in the intake system before it enters the intake manifold. Fuel sprayed from the injectors into the intake valve ports is carried into the cylinders with a direct flow of air.

The amount of air that passes through the throttle body, and the fuel that it carries from the injectors into the engine, determine the power and speed of the engine. Depressing the accelerator pedal will open the throttle valve to admit more air. The injectors will be told (electronically) to supply more fuel and the power delivered by the engine will increase.

Depending on the load that is on the engine, the speed could also increase. Releasing the accelerator pedal has the opposite effect.

The resonator chamber that is fitted to some air intake systems is used to reduce the air noise and to provide a more even flow of air.

Electronic control unit

The electronic control system consists of an electronic control unit (ECU), a number of different sensors and their interconnecting wiring. An example of where sensors are located is shown in Figure 13.8.

The ECU is the 'brains' of the system; it is a microprocessor, or mini-computer. It can receive information (inputs) and send signals (outputs) to other components. Its main function in the fuel system is to tell the injectors when they should spray and how long they should remain open. The length of time that the injectors are open determines the amount of fuel that is sprayed into the engine.

The ECU receives signals from the various sensors, processes them and adjusts the amount of fuel that is delivered from the injectors. This enables the air–fuel ratio to be adjusted to suit many different operating conditions.

Figure 13.9 shows inputs to and outputs from the ECU for a typical EFI system.

Fuel-supply system components

Following are some of the main components of a fuel system in more detail.

Fuel (petrol) tanks

Petrol tanks for passenger cars are made of steel or from a special plastic material. Fuel tanks for commercial vehicles are made from steel or aluminium.

Steel tanks are made from tin-coated steel that is pressed to shape. The tank is made in two parts, joined by a continuous weld around the flanges where the parts fit together.

Internal baffles strengthen the tank and prevent surging of the fuel. Surging could affect the float of some fuel gauge sender units and upset the fuel gauge reading.

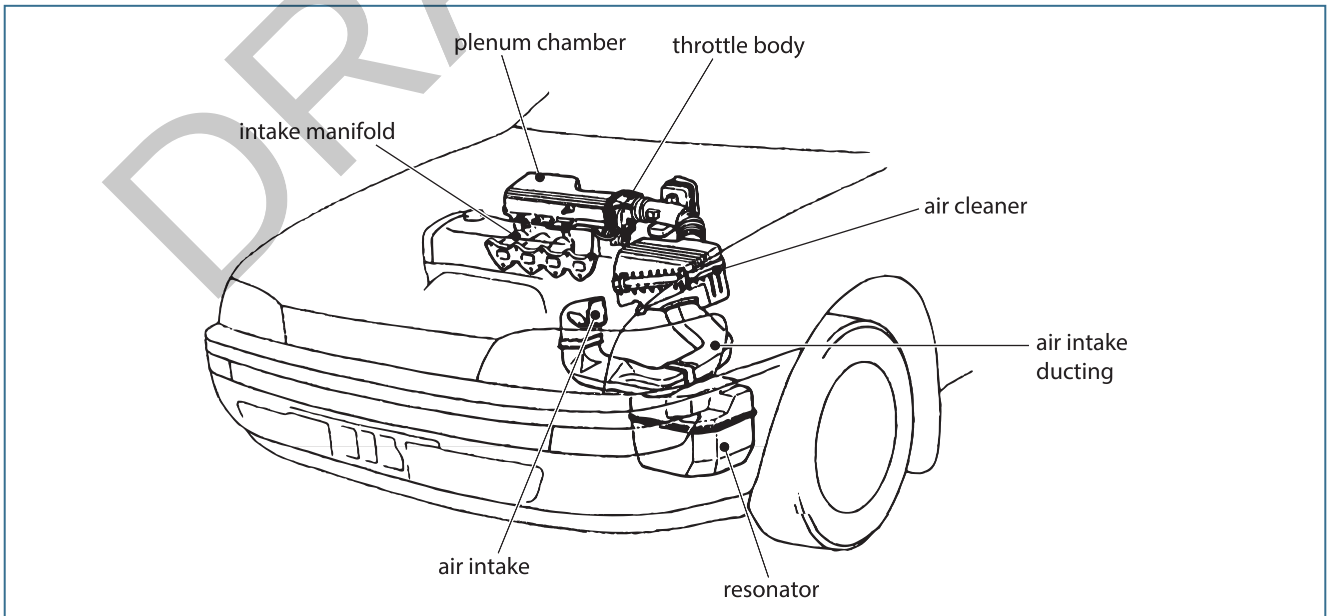

Figure 13.7 Air intake system for an EFI engine TOYOTA

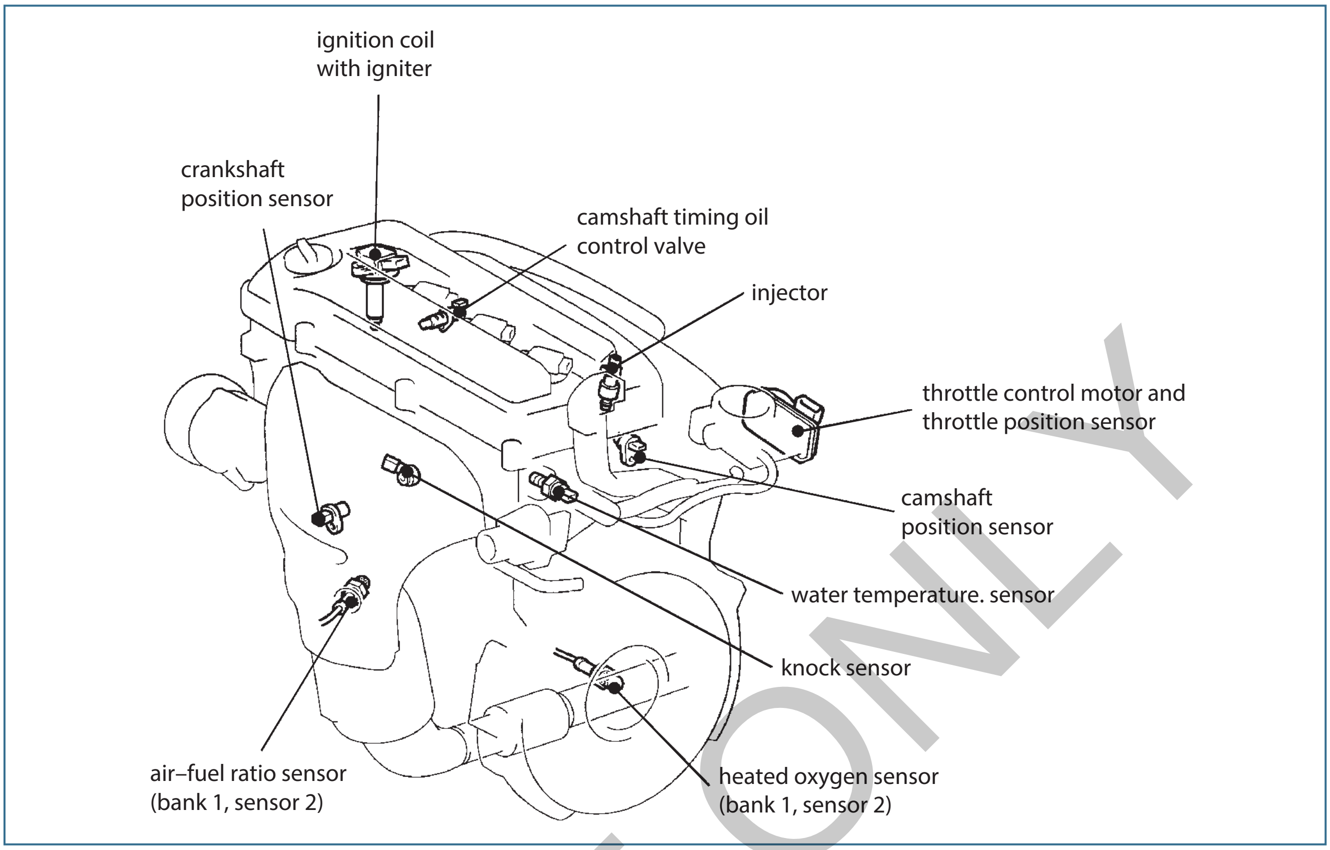

Figure 13.8 Components of an electronic control system TOYOTA

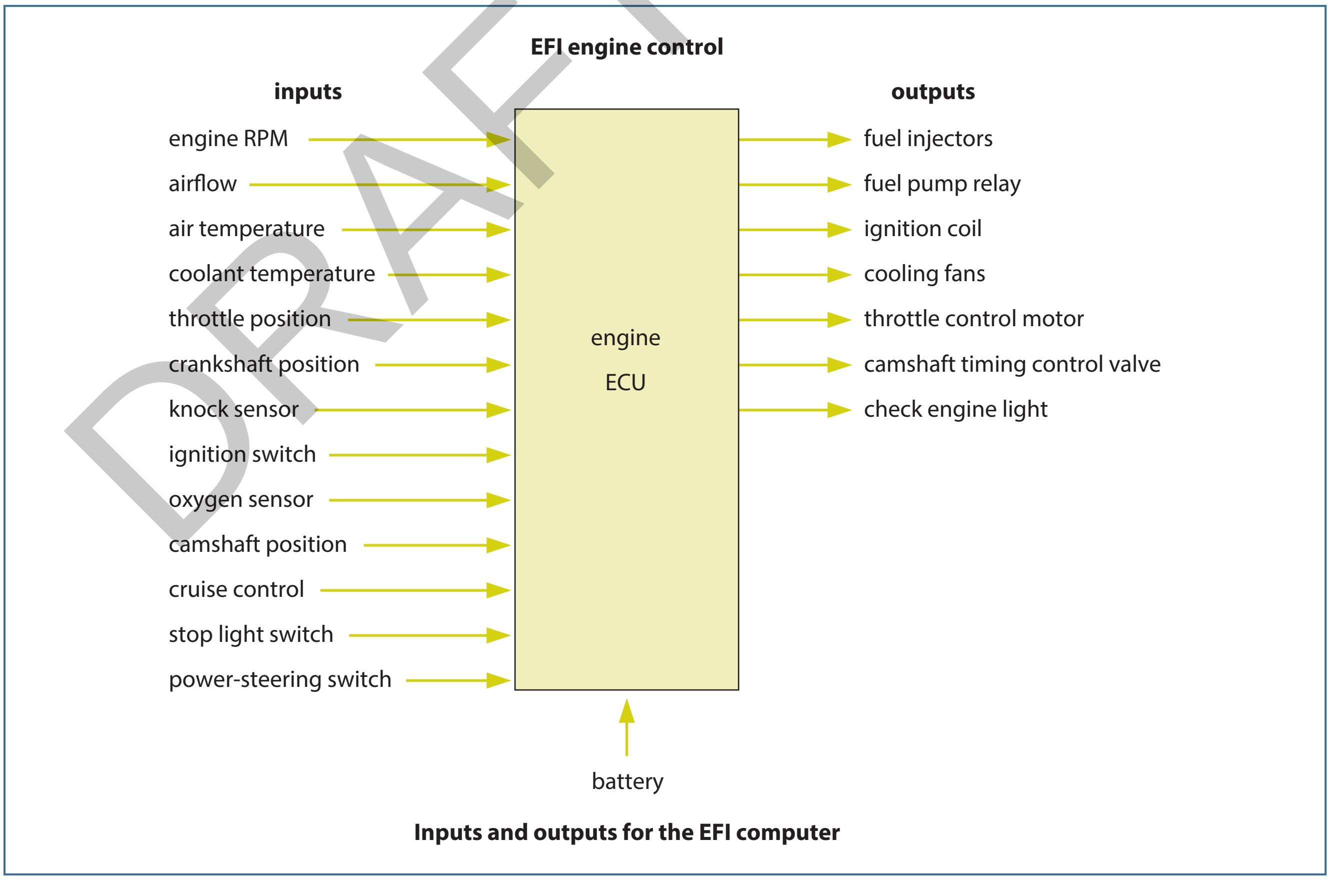

Figure 13.9 Inputs to and outputs from the ECU for a typical EFI system

It could also cause a temporary shortage of fuel at the suction pipe or pump, particularly if the fuel in the tank is low.

Plastic fuel tanks are moulded to shape from fuel-resistant material. This type of manufacture enables tanks to be designed to fit the shape of the bodywork of the vehicle (Figure 13.10).

Location of fuel tanks

The fuel tanks are usually located under the rear of the vehicle, although some light commercial vehicles have their tanks mounted to one side.

Most tanks are removed from underneath the vehicle. Figure 13.11 shows a vehicle that has been raised above the floor to enable the fuel tank to be removed. The tank is bolted by its flange to the underside of the body of the vehicle. Some tanks, particularly plastic ones, like the one in Figure 13.10, are retained by straps that are fitted underneath the tank.

Filler neck and cap

The filler neck is a large diameter pipe that extends above the fuel tank and allows the tank to be filled. To prevent the wrong fuel from being put into an unleaded fuel tank, the filler necks of tanks for unleaded petrol (ULP) have a baffle with a smaller hole than those for lead-replacement petrol (LRP).

Service station petrol pumps that dispense ULP have a hose with a smaller-diameter nozzle than those that dispense LRP. The small nozzle fits the hole in the filler neck of vehicles that use unleaded petrol, but the larger nozzles of lead replacement petrol do not.

Fuel tank cap

The fuel tank cap (Figure 13.12) seals off the filler neck to prevent petrol vapour from escaping into the atmosphere. Caps have a vacuum (negative pressure) valve which allows air into the tank to replace fuel that is used. The valve also allows air into the tank if the pressure

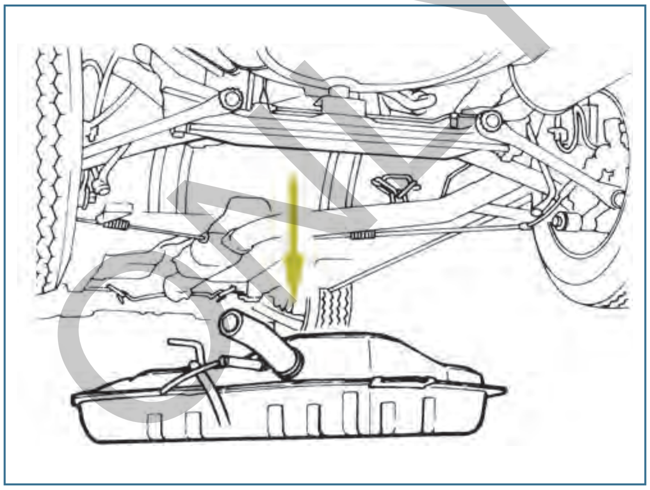

Figure 13.11 A fuel tank removed from underneath the vehicle FORD

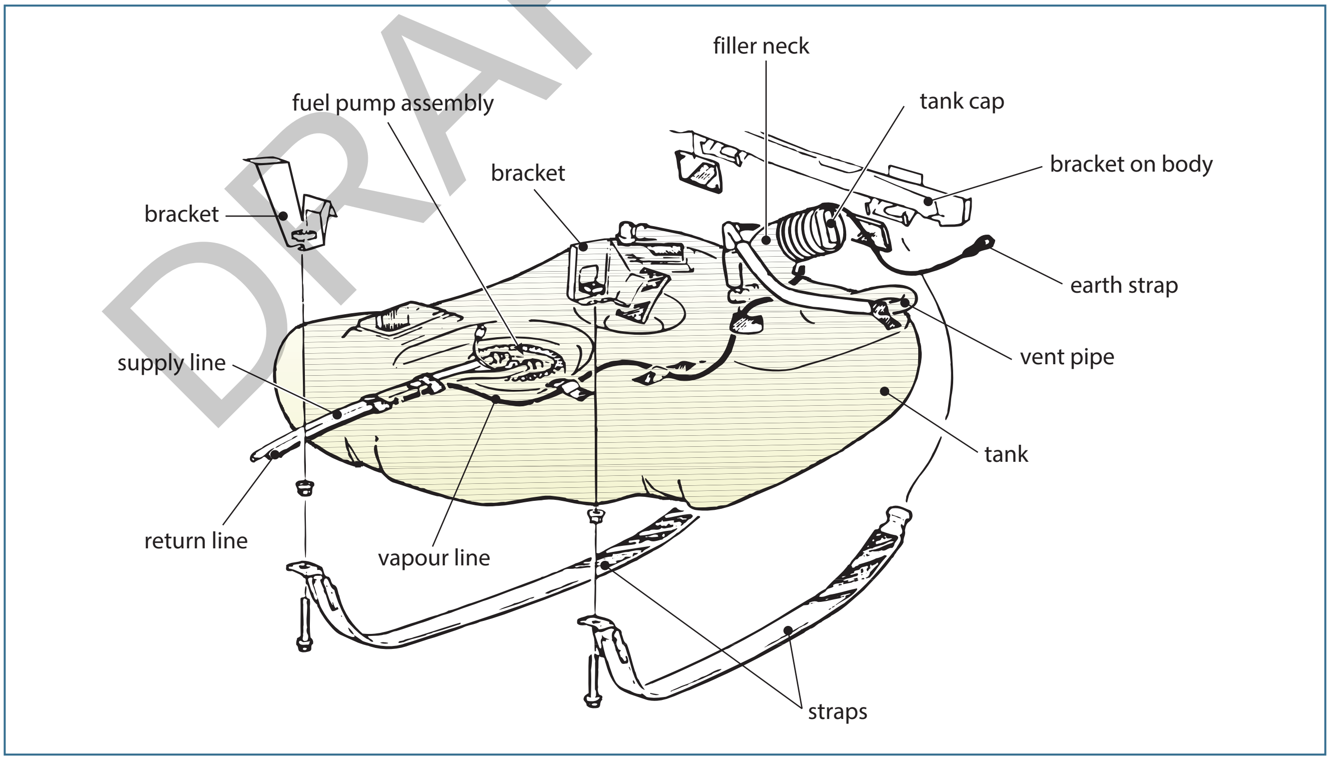

Figure 13.10 Moulded fuel tank shaped to fit under the floor of the vehicle FORD

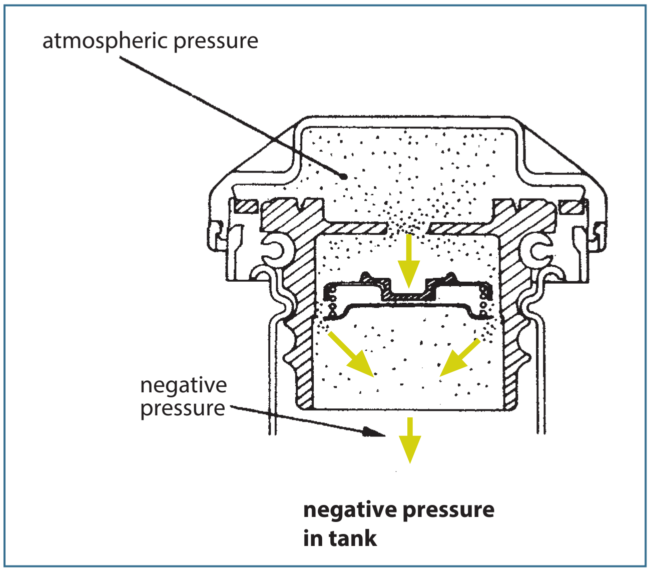

Figure 13.12 Fuel tank filler cap HYUNDAI

Safety: Fuel tank caps are not generally interchangeable and if a replacement cap is fitted, it must be the same design as the original.

inside the tank drops due to a change in temperature. This is a one-way valve – air can enter but fuel vapour cannot escape.

Fuel tank venting (evaporative control)

Fuel tanks have to be vented to allow them to *breathe*. This provides for expansion and contraction of the fuel that is caused by changes in temperature.

Emission-control regulations prevent fuel tanks from being vented directly to the atmosphere where the fuel vapour would cause air pollution, so they are vented through evaporative controls.

Figure 13.13 shows a simplified evaporative-control system. The vapours from the tank are carried by a vapour line (pipe) to a canister, which is located in the engine compartment, or sometimes under the vehicle. The canister is filled with granulated charcoal which absorbs the petrol vapours. The top of the canister is connected by a pipe to the air intake system of the engine.

While the engine is stopped, vapour from the fuel tank can pass through the vent pipe to the charcoal inside the canister. Once the engine is started and running, the canister is *purged* and fuel vapour from the canister is carried into the engine to be burnt.

Purging of the canister is controlled by a solenoid valve that is opened and closed by the engine's electronic control unit. This is opened only when purging would not upset the air–fuel mixture and is not opened when the engine is idling.

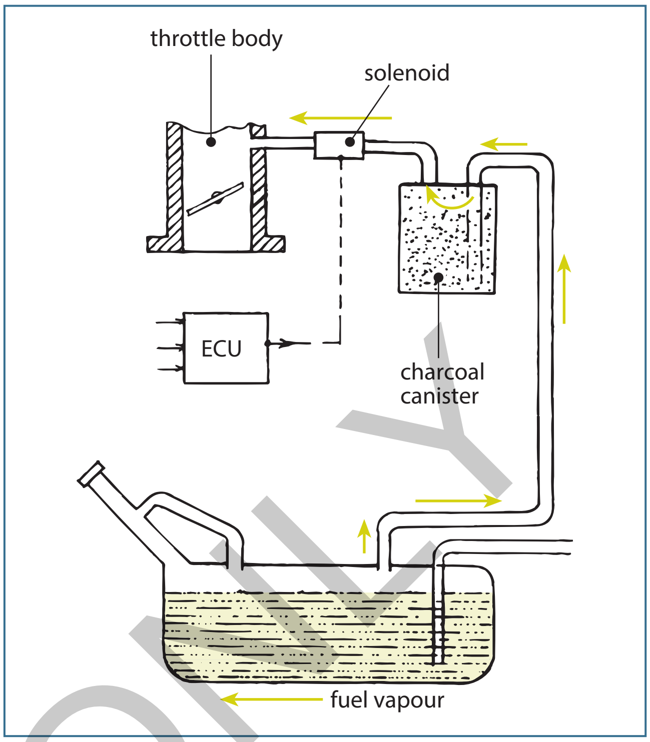

Figure 13.13 Basic evaporative-control system

Reference: Evaporative controls are covered in more detail in the chapter on emission controls in Volume 2.

Fuel gauge

The fuel gauge has a sender unit in the tank, connected electrically to a fuel gauge unit in the instrument panel. A basic sender unit consists of a float that follows the fuel level and a rheostat that is operated by the float (Figure 13.14).

The position of the float determines the resistance of the rheostat. This, in turn, controls the voltage at the fuel gauge so that it shows the appropriate fuel-level reading.

The sender unit in the tank is often part of an assembly which can include the fuel lines, vapour line, a fine filter and the fuel pump.

Fuel lines

There are three pipes (or lines) between the fuel tank and the engine compartment although some systems can have only two. These are:

1. The fuel supply line, also called delivery line, which carries fuel to the engine.
2. The fuel return line, which returns surplus fuel to the tank.
3. The vapour line, which vents the fuel tank to the charcoal canister.

Other pipes within the engine compartment connect various components of the fuel system to the engine.

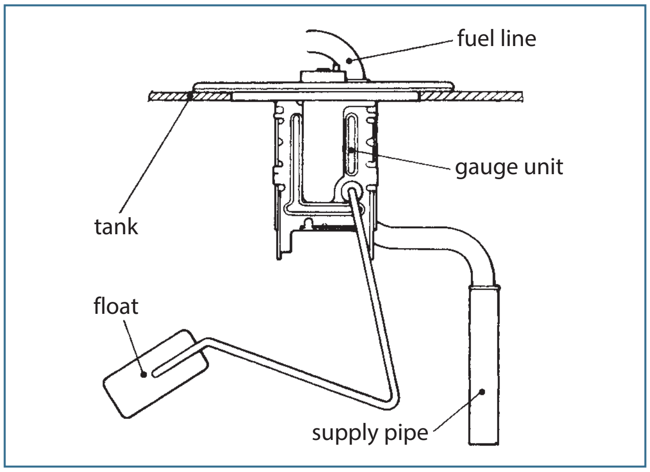

Figure 13.14 Fuel tank sender unit for a fuel gauge

Most systems have a return fuel line, which keeps the fuel circulating so that it is at tank temperature and not being heated in the engine compartment. However, there are systems that do not have an external fuel return line. With these systems, the pressure regulator is located within the fuel tank as part of the fuel pump assembly and it regulates the pressure in the supply line (see Figure 13.18).

> **Information:** Where there is no return line, the fuel in the supply line is at regulated pressure right from the tank through to the fuel rail and injectors.

Inline fuel pump

Figure 13.15 shows an inline electric pump. This is a rotary pump that consists of an electric motor and a pumping element in a common housing.

Electric pumps are used with EFI because the system has to be pressurised before the engine can be started. The injectors do not pressurise the fuel – they spray fuel from the system which has been pressurised by the electric pump.

A high pressure is required in the system – an electric pump operates at a pressure over 200 kPa, but is capable of producing up to 600 kPa.

Inline pump construction

The pump is connected directly into the fuel supply line, with an inlet connection at one end and an outlet connection at the other. Fuel from the tank is taken into one end of the pump and discharged from the other under pressure. The pump is always full of fuel, which both lubricates and cools the pump motor.

Figure 13.15 shows a section through the complete assembly. A permanent-magnet type electric motor is used and the pump element is attached to the rear end of its armature. Fuel under pressure from the pump element flows around the armature to the front of the pump and through a non-return valve to the pump outlet. A relief valve at the rear of the pump limits the maximum pump pressure.

Pump element

A diagram of the pump element is shown in Figure 13.16. This is referred to as a *roller-cell pump*. It has a rotor that is spun in its housing by the electric motor. The rotor is offset in the housing and carries rollers in metal slots.

As the rotor spins, the rollers are moved outwards by centrifugal force and form a seal between the rotor and the housing. Fuel taken in through the inlet is carried

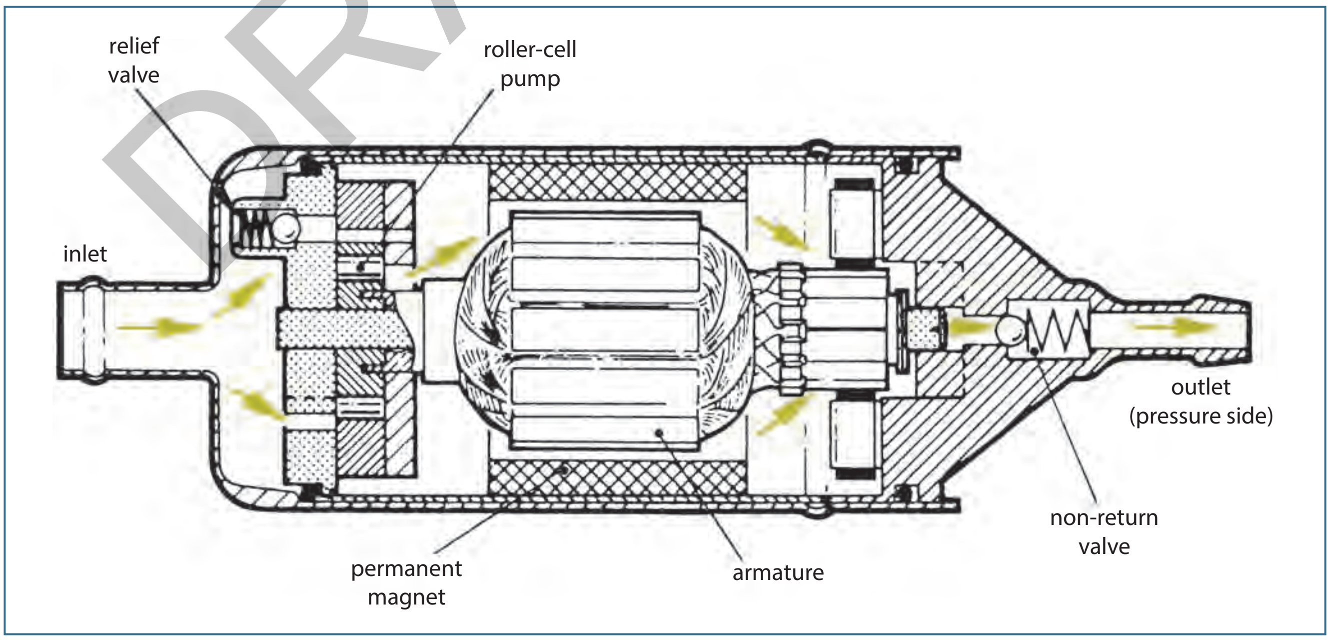

Figure 13.15 Rotary-type electric fuel pump used with an EFI system FORD

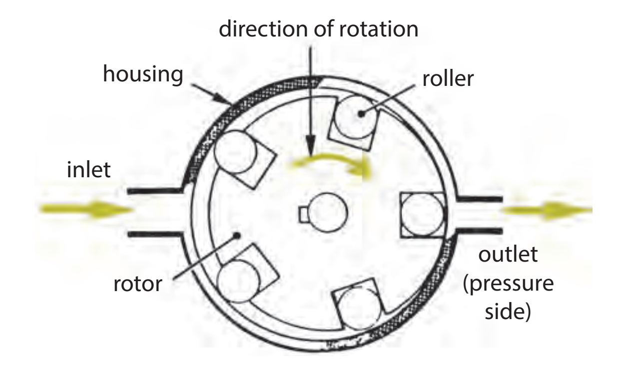

Figure 13.16 Roller-cell pump element for an EFI fuel pump FORD

around between the rollers and is discharged through the outlet.

Submersible fuel pump

The pump, fuel gauge sender unit, fuel line connections and a filter are combined to form an assembly (Figure 13.17). This is installed through an opening in the top of the fuel tank.

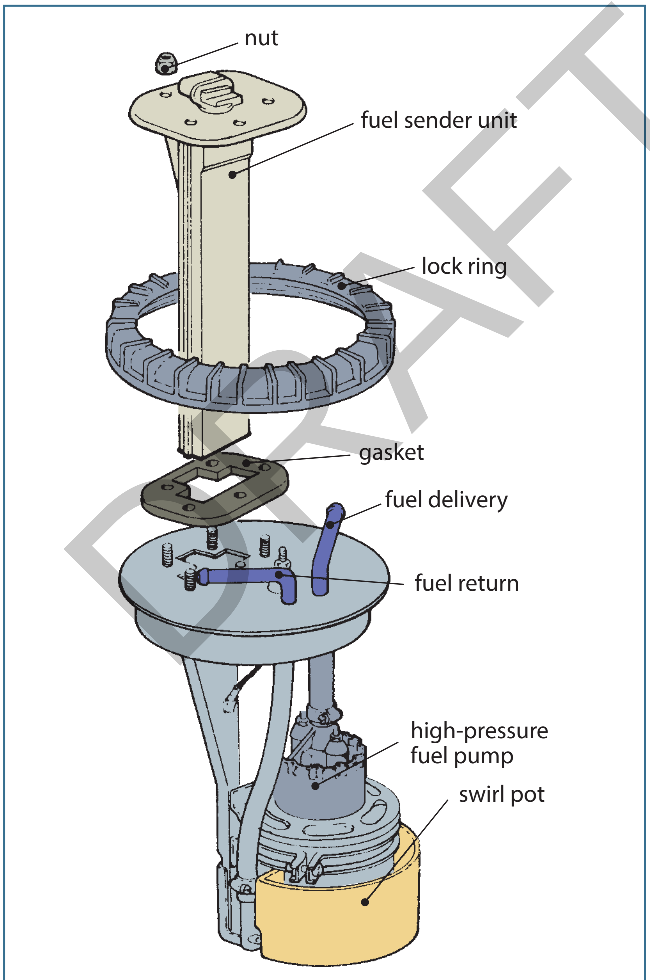

Figure 13.17 Rotary electric-pump assembly for installation in the fuel tank FORD

This type of pump is mounted inside the fuel tank and submerged in the fuel. The pumping element is capable of producing a high pressure but has little suction, which is why the pump has to be close to the fuel – this keeps the pump primed. The intake end of the pump in the illustration is fitted into a swirl pot, which holds fuel at the pump intake under all vehicle-operating conditions.

Figure 13.18 shows another arrangement of a submersible fuel-pump assembly. The fuel pressure regulator is also part of the assembly. There is a supply line, but no fuel return line in this system.

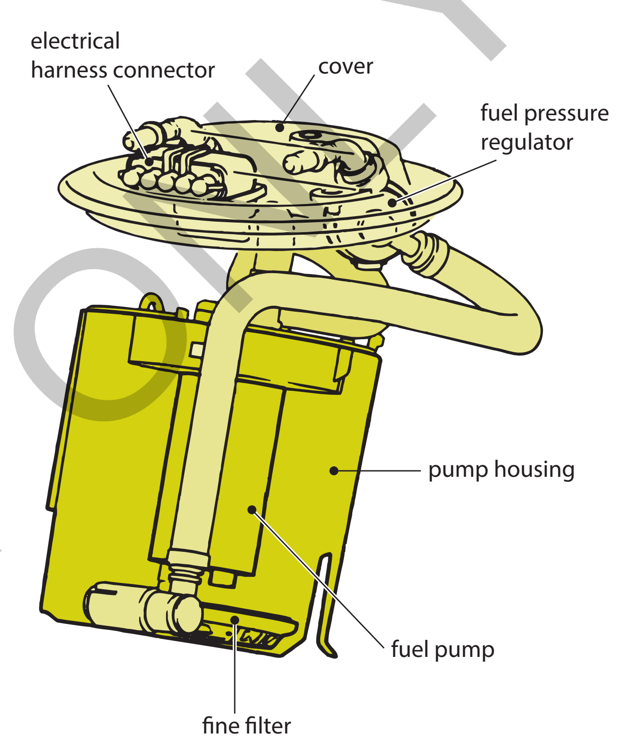

Figure 13.18 Submersible fuel-pump assembly that includes the pressure regulator HOLDEN LTD

> **Information:** Some systems have a high-pressure pump mounted externally and a low-pressure pump in the tank that is used to prime and supply the high-pressure pump.

Fuel filters

The main fuel filter is located on the pressure side of the fuel pump. It consists of a metal container with an inner paper filter element (Figure 13.19). Some filters are located in the engine compartment; others are on the underside of the vehicle. They cannot be cleaned and have to be replaced if they become restricted.

As well as the main filter in the system, there is a filter on the suction side of a submersible pump. This is made of fine nylon mesh.

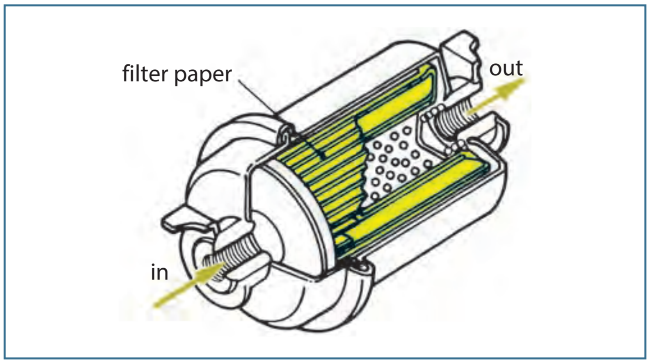

Figure 13.19 EFI line fuel filter DAIHATSU

The parts of a dismantled pump assembly are shown in Figure 13.20. Some pumps cannot be dismantled for repair and the complete pump assembly has to be replaced if it is faulty.

Fuel rail and injectors

The injectors are fitted into the fuel rail with the nozzle (spray) end projecting into the intake manifold. Figure 13.21 shows how this is arranged for a four-cylinder engine. There is an O-ring and a rubber grommet to provide a fuel seal at the fuel rail end of the injector, and an insulator at the manifold end.

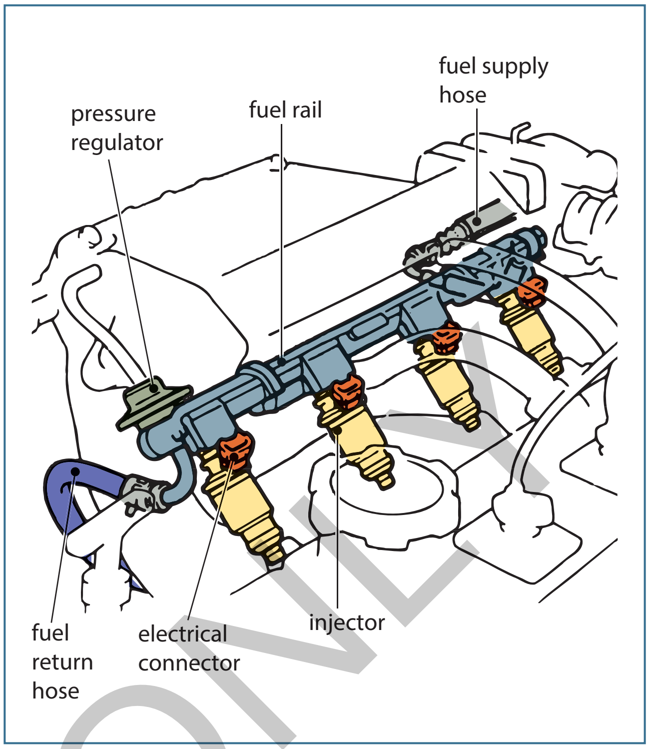

Figure 13.21 Fuel rail and injectors for a four-cylinder engine TOYOTA

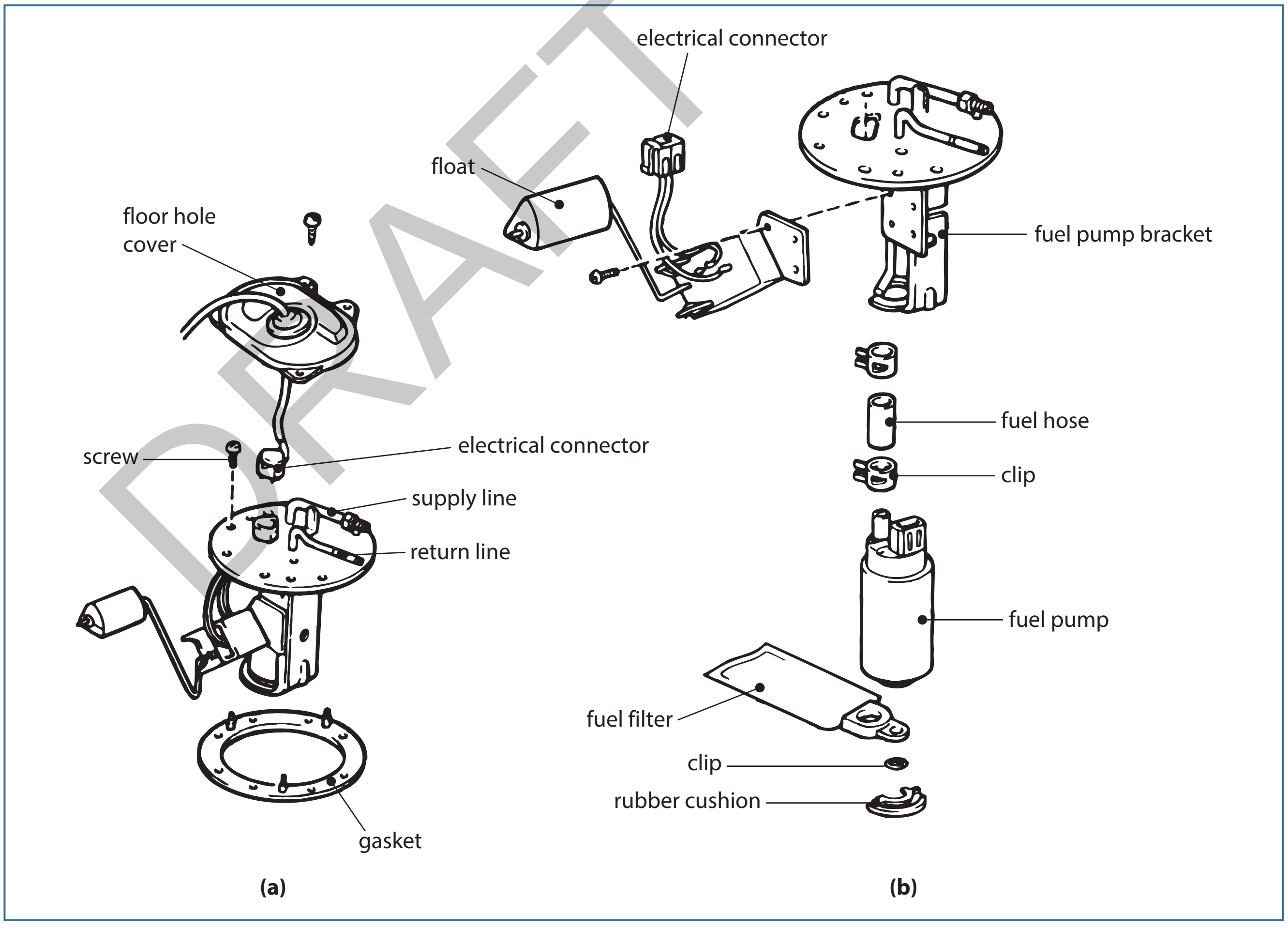

Figure 13.20 Submersible fuel pump and sender unit assembly **(a)** assembled **(b)** dismantled TOYOTA

The pressure regulator on the end of the fuel rail maintains regulated fuel pressure in the fuel rail and in the injectors.

There is an electrical connector on the injector for the wiring which connects it to the ECU. The injector is basically a mechanical valve that is operated by an electromagnet – it is a type of electrical solenoid. Voltage signals from the ECU energise the electromagnet in the injector and this opens the valve to spray fuel into the intake manifold.

Air intake system components

Parts of an air intake system are shown in Figure 13.22. There are various designs of air systems and they vary in shape and size for different models of engines.

Filtered air from the air cleaner passes through, ducting to the throttle body and then to the plenum chamber. The plenum chamber is connected to the intake manifold (not shown in the illustration). Some intake manifolds have long curved branches, others are much shorter. Manifolds for V-type engines are of a different design to those for inline engines.

Throttle body assembly

A throttle body is shown in Figure 13.23. The power and speed of the engine is controlled by the throttle valve. This is a disc-type valve, mounted on a spindle, which is rotated to open or close the bore of the throttle body.

The throttle valve is opened by the accelerator pedal to increase engine power or speed, and closed to decrease power or speed.

Airflow meter

An airflow meter at the throttle body measures the amount of air that passes through the throttle body. It provides this information to the electronic control unit (ECU), which determines the quantity of fuel that needs to be injected to maintain the correct air–fuel ratio.

The airflow meter provides a continuous check of the air flowing through the induction system, so that any

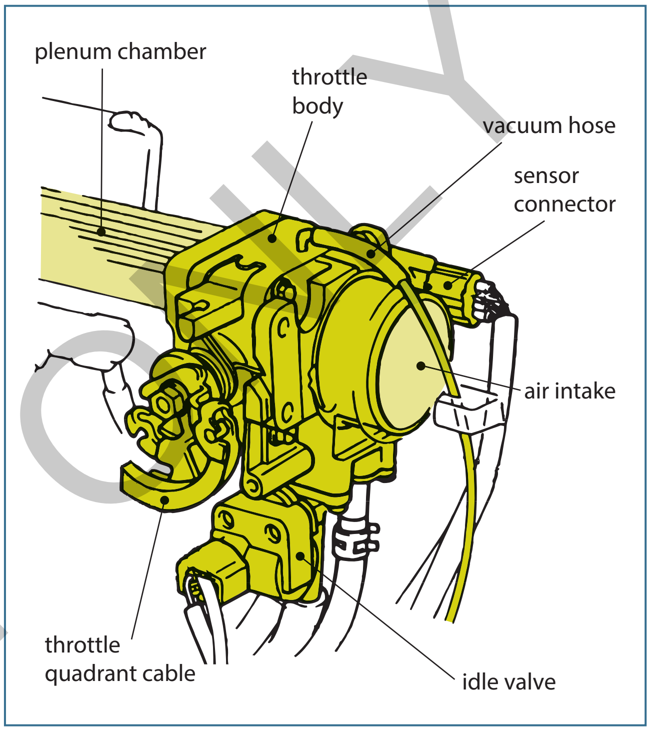

Figure 13.23 Throttle body assembly for an EFI system TOYOTA

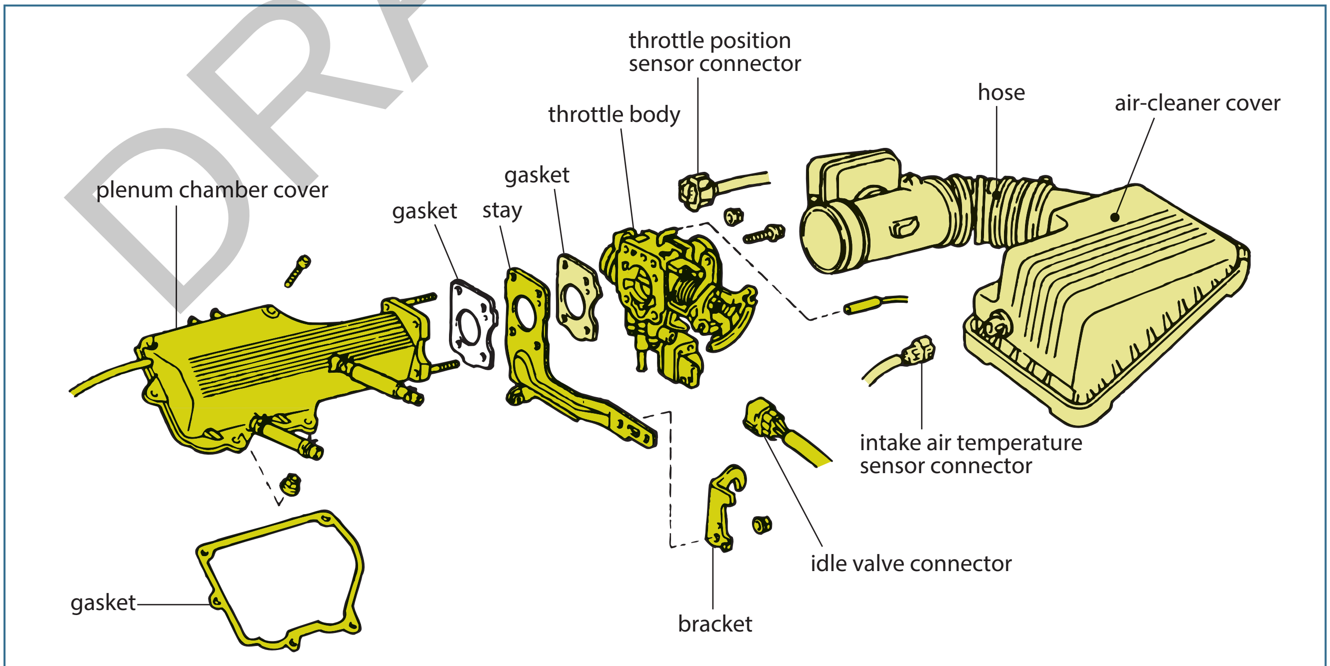

Figure 13.22 Components of an air intake system TOYOTA

movement of the accelerator pedal to open or close the throttle valve will be signalled to the electronic control unit.

The system has an idle speed control, which ensures that some air will pass the throttle valve in the closed position to allow the engine to run at idle.

Electronic control components

As well as controlling fuel injection, the ECU is responsible for a number of other operations, such as ignition timing. The engine electronic control unit (ECU) is given different names by the vehicle and component manufacturers. It is also referred to as an engine control module (ECM), or as a power control module (PCM).

Information: Electronic control units are not confined to electronic fuel injection – they can be programmed to perform various engine, transmission and other functions.

Sensors

A number of sensors that send signals to the ECU are shown in Figure 13.24. The number and type of sensors will depend on the particular vehicle and system. Some sensors that relate to an EFI system are:

1. *Intake air temperature sensor*. The density of air varies with temperature, so changes in temperature could affect the ratio of air to fuel (remember, this is a ratio by mass). A sensor in the air intake senses the temperature of the air entering the engine.
2. *Atmospheric pressure sensor*. The mass of air varies with altitude, and also to some extent with weather conditions. Signals sent to the ECU allow it to adjust the fuel quantity to suit the density of air.
3. *Coolant temperature sensor*. The engine needs a richer mixture when starting and when cold. Signals from this sensor allow the ECU to make suitable adjustments.
4. *Engine RPM sensor*. This sends the engine speed to the ECU. Changes in engine speed indicate changes in engine load and the ECU can make adjustments for this. It can provide a slightly richer mixture when the engine is under load, or a slightly leaner one with reduced engine load.

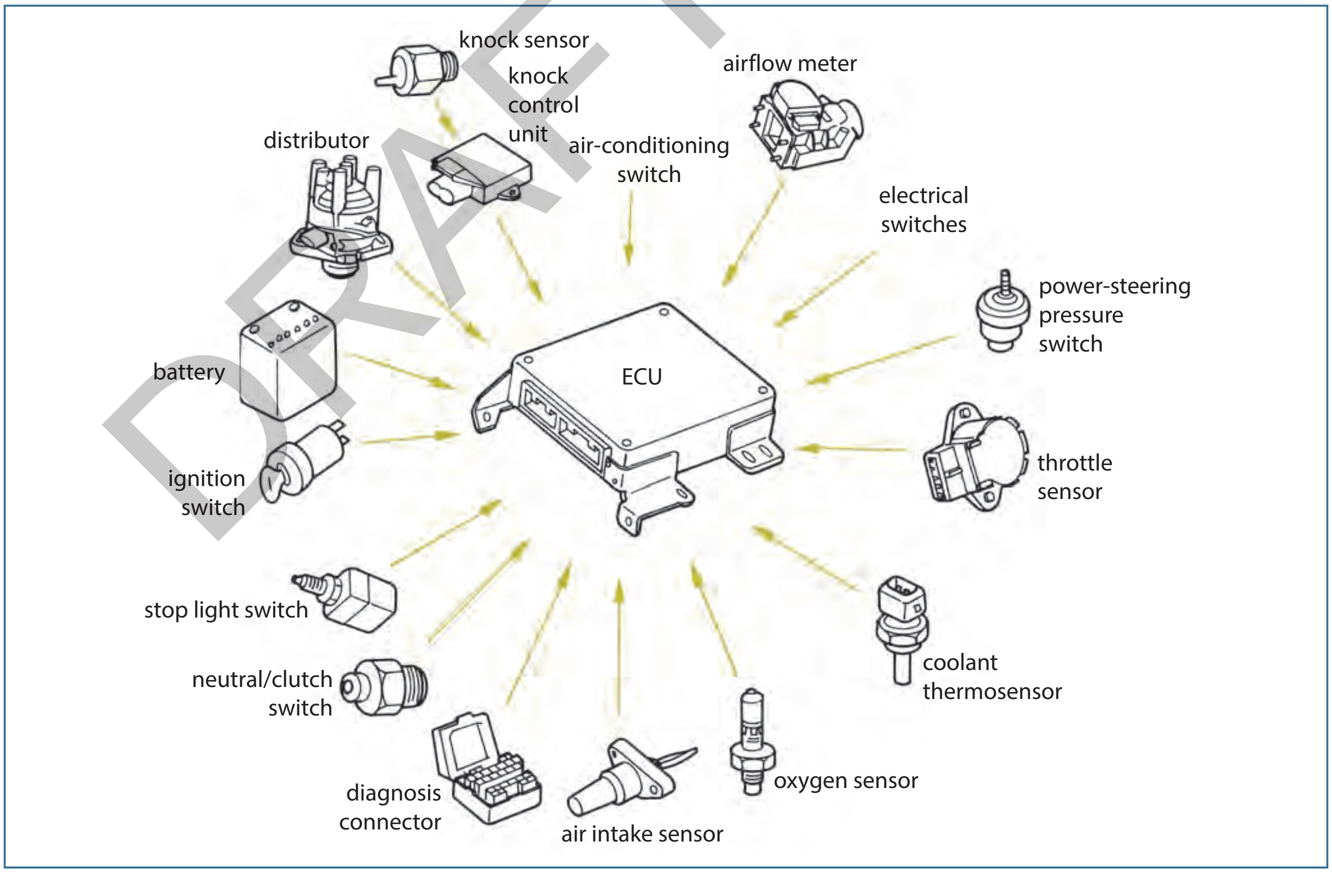

Figure 13.24 ECU inputs

The ECU also adjusts the ignition timing to suit the engine speed.

5 *Knock sensor*. Engine detonation is picked up by this sensor, which is attached to the engine block. Under certain operating conditions irregular combustion within the combustion chamber can produce detonation, or knocking, which is harmful to the engine. If detonation is sensed, the ECU acts to prevent this by retarding the ignition and/or providing a richer fuel mixture.

6 *Vacuum sensor*. This is used in the intake system to sense manifold pressure.

7 *Oxygen sensor*. Located in the exhaust manifold, this sensor detects oxygen in the exhaust gases. If the air–fuel mixture is correct, there will be good combustion in the cylinders and there will be little or no oxygen present in the exhaust gases. With poor combustion, oxygen will be present.

The oxygen sensor is part of a closed-loop system, with the exhaust gases being continuously monitored. Information is provided to the ECU, which makes frequent adjustments to the fuel mixture or to the spark as required. The result is improved engine performance and fuel economy.

Basic direct fuel injection

Direct fuel injection is also known as gasoline direct injection (GDI). The two main advantages of direct injection are improved fuel economy and reduced emissions. These can be achieved by accurately varying the quantity and time of fuel injection to suit the engine's needs. The major components are show in figure 13.25.

Information: The fuel and air supply systems for direct injection are similar to other multipoint EFI systems.

Fuel injector

The fuel injector atomises and meters the fuel directly into the combustion chamber of the engine. The injector must be able to cope with the high temperature and pressure of combustion and so is different in construction from the indirect injector. Figure 13.26 shows a high-pressure injector in cross-section.

Operation

High-pressure fuel enters the injector through the inlet filter (1) from the fuel rail and fills the injector. When a high-voltage signal (60 volts) is received at the input terminal (2) from the ECU, the high-current solenoid winding (4) is energised. This attracts the armature and plunger needle (6) off its seat. Fuel is then sprayed out through the directional outlet hole (8).

When the solenoid is de-energised, fuel pressure and the return spring (3) will force the plunger back onto its seat.

The quantity of fuel delivered is determined by two factors: fuel rail pressure and time the plunger remains open.

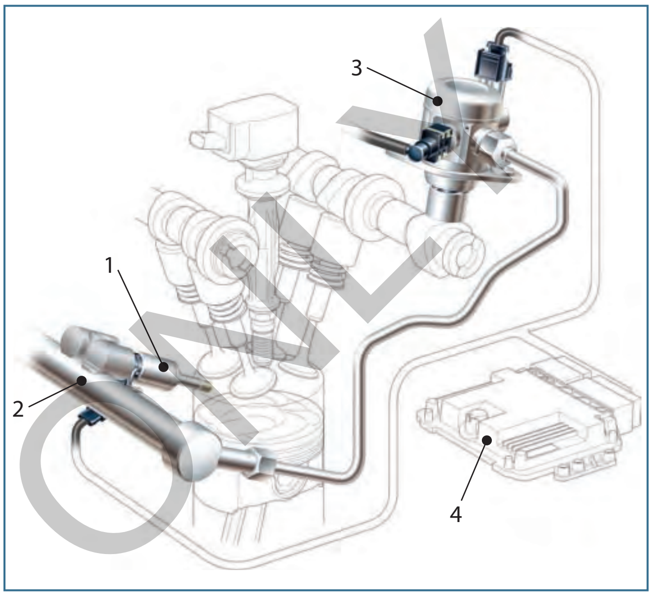

Figure 13.25 Main components of a direct fuel-injection system
1 Fuel injector **2** Fuel rail **3** High-pressure fuel pump **4** Engine management computer VOLVO

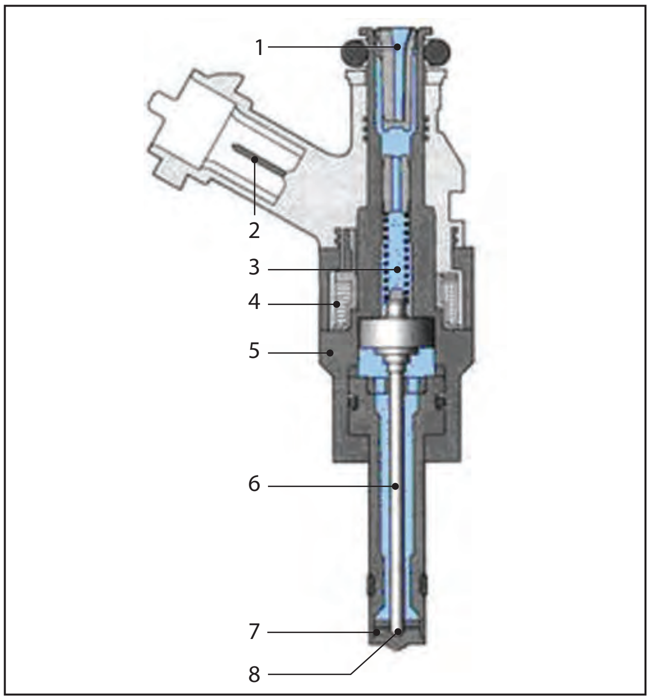

Figure 13.26 Direct petrol injection
1 fuel inlet filter **2** high voltage terminal **3** plunger return spring **4** high current solenoid winding **5** body **6** plunger needle **7** pintle **8** directional outlet hole BOSCH

High-pressure fuel pump

The high-pressure fuel pump is a single-plunger driven by the camshaft pump. It is flange of mounted on the cylinder head and has a separate three-lobe cam to maintain a constant fuel supply. The pump also contains a fuel-supply control valve, variable pressure attenuator and high-pressure limiting valve (Figure 13.27).

Operation

Fuel enters the pump on the low-pressure side at supply pump pressure of approximately 0.4 MPa (400 KPa). As the plunger (5) moves down on the intake stroke, fuel moves past the inlet valve (not shown), filling the space above the plunger. When one of the cam lobes forces the plunger up, fuel is pressurised to 12–20 MPa.

The fuel supply control valve (8) acts as a metering device. Fuel above the plunger is not pressurised until the fuel supply valve closes. The ECU can vary the quantity and pressure of fuel injected by closing the valve earlier or later on the pressure stroke.

Maximum pressure in the fuel rail is controlled by the pressure limiting valve (2). Excess fuel is returned to the inlet side of the pump. The gas-filled attenuator (1) acts like a pulsation damper to even out pressure changes in the pump. Excess fuel not required by the injectors is directed into the upper chamber compressing the diaphragm. The attenuator assists in a rapid filling of the pump on the intake stroke when the pressure is released.

High-pressure fuel sensor

The sensor is screwed into the fuel rail and monitors the pressure for the ECU. The ECU can then make adjustments to the pressure by changing the time the fuel supply valve in the high-pressure pump remains closed.

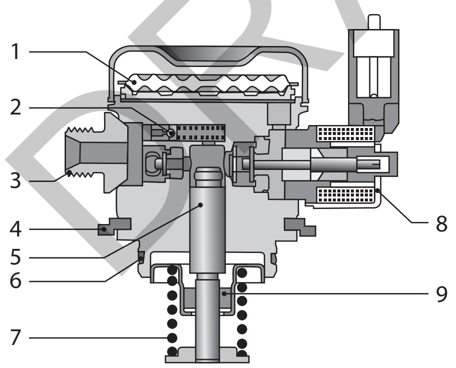

Figure 13.27 Single-plunger fuel pump
1 Variable pressure attenuator MMD **2** Pressure limiting valve **3** High pressure connection **4** Mounting flange **5** Delivery plunger **6** O-ring **7** Plunger spring **8** MSV5 fuel-supply control valve **9** Plunger seal Robert Bosch (Australia) Pty Ltd, Automotive Aftermarket: www.boschautoparts.com.au.

Checks and precautions

Following are some basic checks that can be carried out and precautions that need to be taken with EFI systems.

EFI systems have a self-diagnosis function built into the ECU that identifies faults and stores the information in its memory. These are referred to as diagnostic trouble codes (DTCs). In some early systems, the faults are indicated by light-emitting diodes on the ECU, which use a flashing sequence as codes. In other systems, information is obtained from the ECU by using the engine check light in the instrument cluster to flash codes.

Systems that have a diagnostics data link connector (DLCs) can have fault codes extracted using a compatible scan tool or computer. Manufacturers provide a list of the codes and explain what they represent, as well as diagnostic information.

Relieving system pressure

An EFI system is under pressure. Even when the engine is not running, the pressure is held in the system by the pressure relief valve.

As a safety precaution, to prevent petrol spray, the pressure must be relieved before hoses are removed or components disconnected. (For example, this applies when removing a fuel filter.) (See Figure 13.28.) Direct injection systems require a scan tool connected to the DLC to pulse the injectors and thus relieve the pressure in the fuel rail.

Alternatively, remove the electrical connection from the pump and run the engine to use up the fuel in the system.

Checking fuel pumps

Fuel pumps can be checked for pressure and delivery. A quick check for pressure can be made by squeezing the hose of the supply line as shown in Figure 13.29. An actual

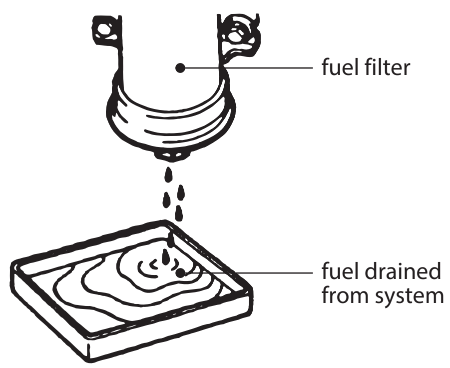

Figure 13.28 The pressure in the fuel system must be relieved before disconnecting components TOYOTA

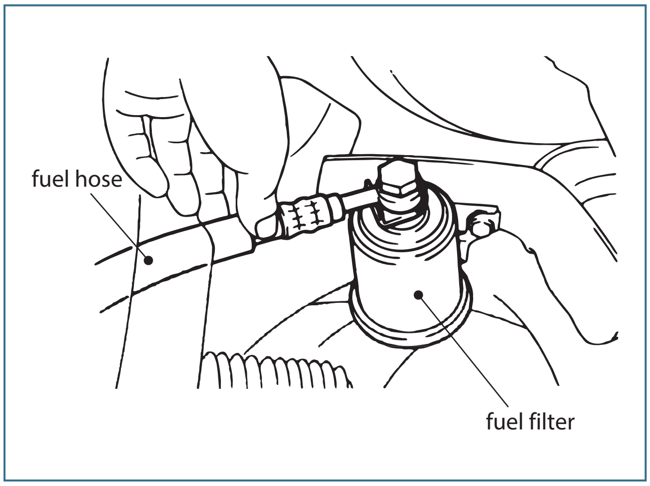

Figure 13.29 Pinching the hose of the fuel supply line to feel for pressure TOYOTA

pressure test is done by inserting a T-piece into the fuel delivery line and attaching a pressure gauge. These are high-pressure pumps that will produce a pressure of 200 kPa at idle speed.

The volume of fuel can be checked by removing the supply line at a convenient connection and directing the fuel into a graduated container. Approximately 1 litre of fuel should be delivered in 30 seconds. If the volume is low, the filter and fuel line should be checked for restrictions.

Information: Volume checks are not carried out on direct injection high-pressure pumps.

Checking injector operation

A basic check of the injectors can be made with them in place on the engine. This is done by feel and by sound (Figure 13.30). With the engine at idle, place a finger on each injector in turn. It should be possible to feel the injector operating. A good injector will have regular pulses.

Using a stethoscope, the operation of an injector can be checked by its sound. The probe of a stethoscope placed against the injector will pick up its operation. This enables the operator to determine whether the injector is good or faulty.

There are more detailed tests for injectors. An *ohmmeter* can be used to check its resistance, and other checks can be done with the injector removed from the engine.

The power supply to the injector from the ECU can be checked easily by removing the socket to the injector and inserting a special noid light, as in Figure 13.31. If the

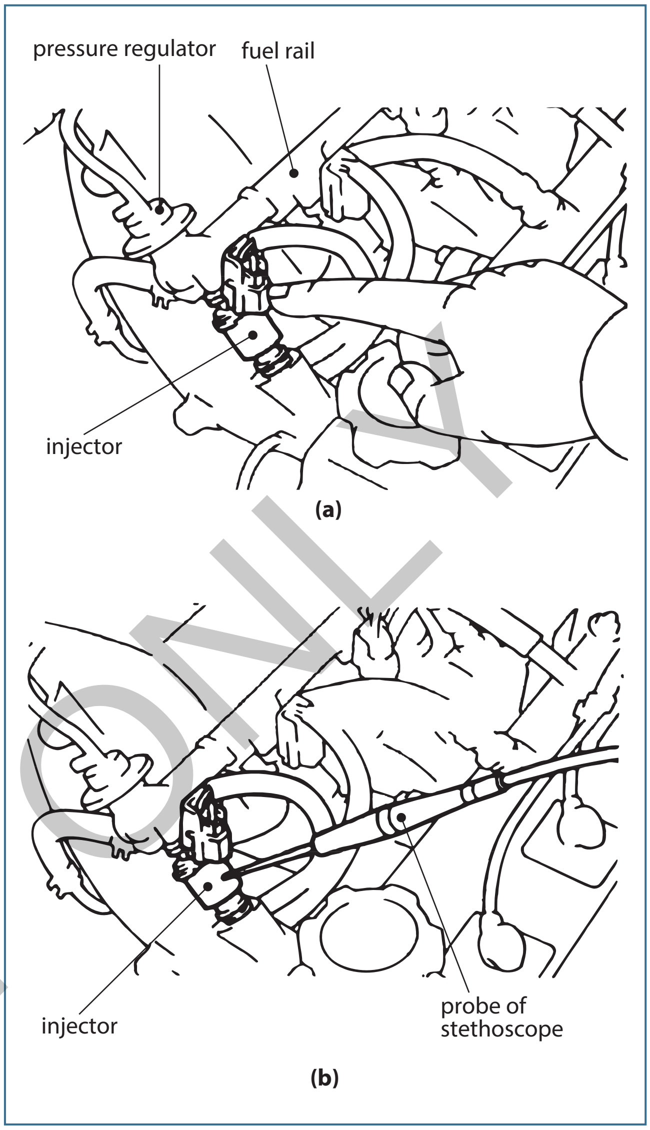

Figure 13.30 Checks for injector operation
(a) feeling for injector pulses **(b)** using a stethoscope TOYOTA

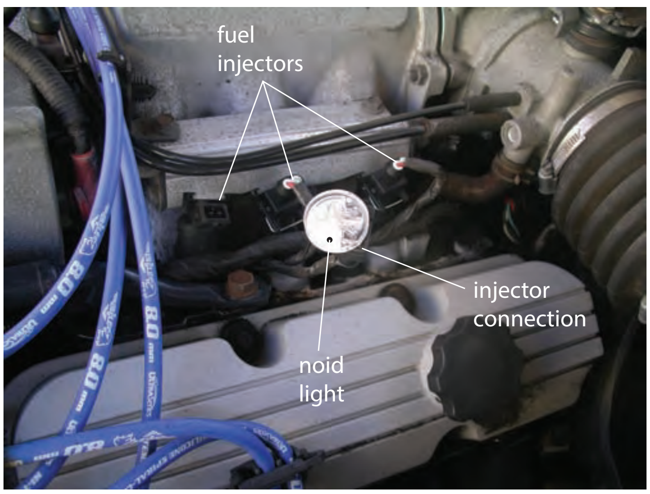

Figure 13.31 A noid light fitted to the injector socket

light doesn't pulse when the engine is cranking there is no power to the injectors.

Isolating the battery

Remove the negative battery terminal to isolate the battery before commencing work on any of the electrical components (Figure 13.32). This is a safety precaution to prevent sparks or damage to components. In some instances, the diagnosis code or information in the memory of the ECU should be checked before disconnecting the battery, otherwise information could be lost when power is removed from the system.

Checking electrical connections

There are a number of electrical connections associated with electronic fuel injection. Many are multipin connectors and these should be clean and fit tightly together. One type of connector is shown in Figure 13.33.

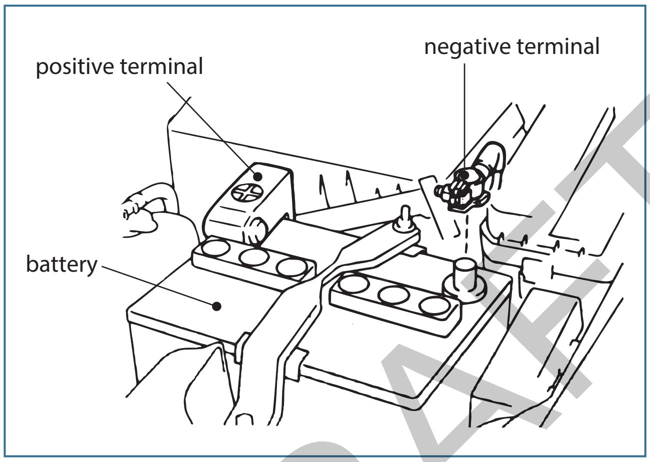

Figure 13.32 The negative battery terminal should be disconnected before working on EFI components TOYOTA

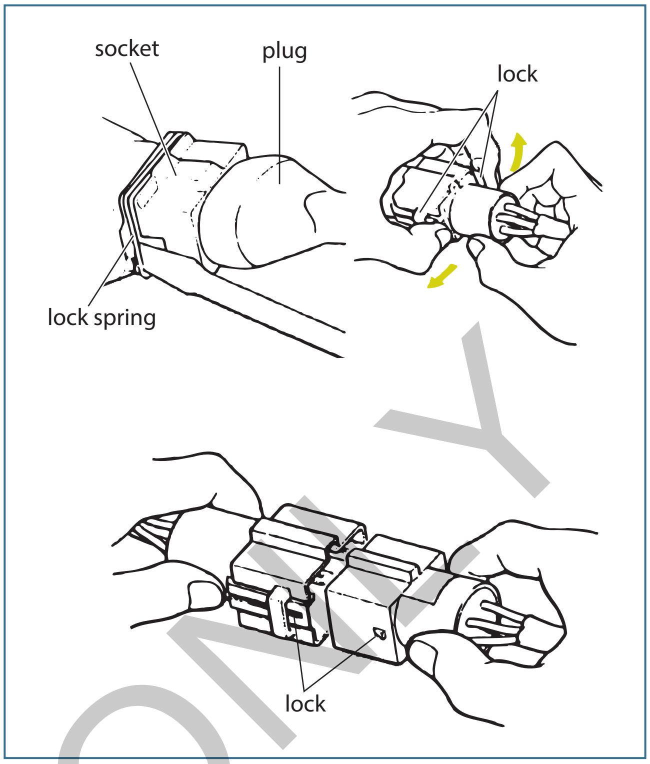

Figure 13.33 Some of the electrical connectors used with EFI systems TOYOTA

Service requirements

Injectors may need cleaning and testing after the vehicle has travelled a large number of kilometres. The injectors have to be removed and special equipment is used for cleaning.

Cleaning additives are available and these can be added to the fuel tank periodically. This helps to keep the injectors clean while the engine is running.

Fuel filters cannot be cleaned, and if considered faulty will have to be replaced. Some in-tank filters are replaced or cleaned after extended periods of operation.

Technical terms

Electronic, electronic fuel injection, EFI, diesel, petrol, distillate, gasoline, hydrocarbon, oxygen, combustion, combustible, polluted, air–fuel ratio, stoichiometric ratio, rich mixture, weak mixture, power, exhaust gas analyser, chemical composition, volatile, vaporise, throttle body, pressure regulator, plenum chamber, fuel rail, micro-computer, electronic control unit, ECU, surging, lead replacement petrol, vacuum, negative pressure, evaporation, evaporative control, canister, granulated charcoal, purge, sender unit, inline, armature, roller cell, centrifugal force, primed, swirl pot, submersible, self-diagnosis, graduated, stethoscope, diagnostic trouble codes (DTCs), diagnostics data link connector (DLCs), noid light.

Review questions

1. Name the different types of fuel systems used for motor vehicles.
2. What are the two main chemicals in petrol?
3. What is meant by combustion?
4. Why does the engine need a mixture of air and fuel?
5. What is air–fuel ratio and why is it important?
6. What is a rich mixture? What is a lean mixture?
7. What would an exhaust-gas analyser be used for?
8. In an EFI fuel system, how does the fuel get into the engine?
9. Name the main parts of a multipoint EFI system.
10. What is the ECU?
11. What is the purpose of the ECU in an EFI system?
12. An EFI system can be considered as having three subsystems. What are these?
13. What is the function of the throttle body?
14. Why does the system need a plenum chamber?
15. Where are the injectors located in an EFI system?
16. What controls the operation of the injectors?
17. How is the pressure controlled in the fuel system?
18. What are fuel tanks made of?
19. Why is a fuel tank cap fitted with a valve?
20. How are fuel tanks vented?
21. What lines or pipes connect the engine to the fuel tank?
22. What are submersible fuel pumps?
23. Explain briefly what occurs in the EFI system when the vehicle is being driven and the driver presses down the accelerator.
24. What is the function of the oxygen sensor?
25. Why would a coolant temperature sensor be fitted?
26. What are the two main advantages of direct petrol injection?
27. How is pump pressure regulated in the high-pressure part of the system?
28. Which valve regulates the volume of fuel pumped by the high-pressure pump?
29. State the two factors that determine the volume of fuel injected.
30. What precautions should be taken before disconnecting or removing a component of an EFI system?
31. What are the basic checks for injector operation?