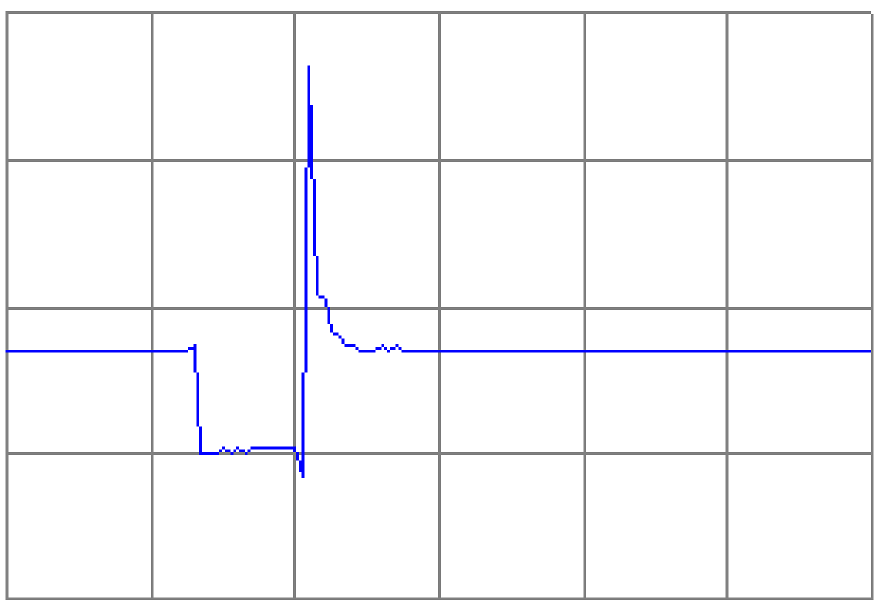
ENGINE MANAGEMENT SYSTEMS

Student Workbook



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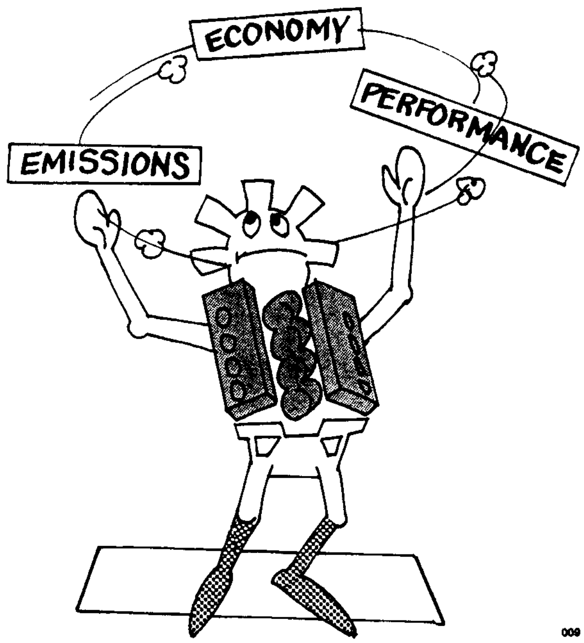
INTRODUCTION

Overview
Modern engine management systems allow powertrain designers to maintain the critical balance between performance, fuel economy, and emissions. As government regulations concerning emissions and fuel economy become more demanding, the need for advanced fuel delivery technologies and operational strategies that can meet these exacting standards becomes greater.

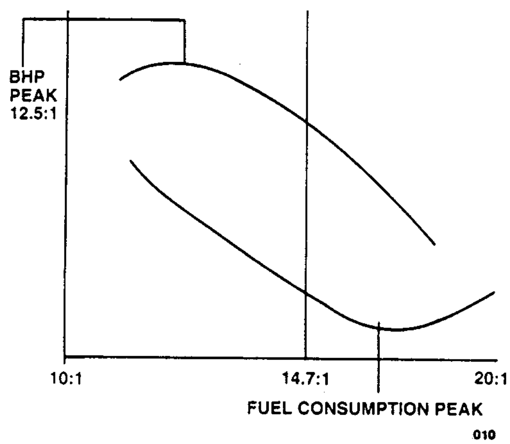


Balancing Operating Priorities

To assist technicians servicing today's engine control systems, the Society of Automotive Engineers (SAE) has developed standards that apply to all vehicle manufacturers. Topics covered include diagnostic trouble codes (Standard J2012) diagnostic connector form and location (J1962) and even automotive terms and acronyms (J1930). These terms and standards, used throughout this book, can help build a bridge between your knowledge of basic vehicle operating systems and specific Land Rover applications.

THEORY

It has long been known that the key to efficient combustion is maintaining the proper relationship between air and fuel. The point at which fuel burns most efficiently is known as the stoichiometric ratio. With gasoline engines, the stoichiometric ratio is approximately 14.7 (air) to 1 (fuel). Keeping this relationship constant is a challenge, as the engine must operate under continually changing conditions and loads.



Stoichiometric Ratio

Once the stoichiometric ratio has been achieved, igniting the air/fuel mixture at the appropriate time presents the next big challenge. Although it seems to occur instantaneously, combustion takes time.

And while combustion time remains relatively constant, the environment in which it occurs (an automotive cylinder with a moving piston) changes dramatically depending on engine speed. The appropriate spark timing at idle will not be the most effective point of ignition at 4,000 rpm. The key is not to compromise, but to provide the best point of ignition for every operating condition.

A modern engine needs a system to manage the complex collection of inputs and outputs and correctly interpret the ways they relate to each other. This course is about the sophisticated systems that have been developed to control the supply of air and fuel, and to control the exact moment at which this mixture is ignited.

Incorrect application of any of these three inputs (air/fuel/ignition) can lead to unsatisfactory performance, poor fuel economy, and/or excessive exhaust emissions.

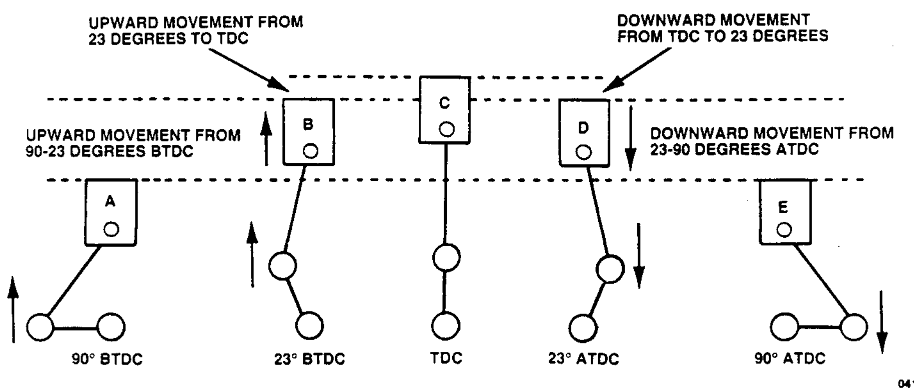
IGNITION SYSTEMS

Introduction

Providing the proper air/fuel mixture is an important factor in promoting efficient engine operation. However, once the air/fuel mixture is introduced into the cylinder, it must be burned efficiently. The combustion process on a gasoline engine can't begin until a spark is introduced. Accurate timing of the spark in relation to piston position and can provide the difference between peak performance and inefficient operation.

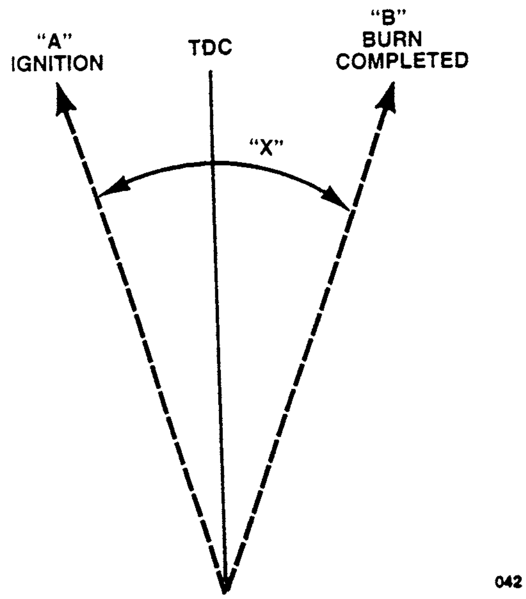
When a spark is introduced to the air/fuel mixture in the cylinder, a flame front is generated. With proper ignition timing, the flame front exerts force on the piston just as it begins its downward movement. To allow time for the force to reach the piston, ignition occurs before the piston reaches Top Dead Center (TDC). However, if ignition occurs too soon, the force of combustion contacts the piston on its way up. This produces engine knock. If ignition takes place too late, engine performance lags.

The natural rotation of the crankshaft keeps the piston at or near TDC for approximately 46° of its rotation (23° Before TDC to 23° After TDC). The crankshaft rotates at a constant speed, but the piston moves very little at this point. Once past 23° ATDC, the piston begins to move very rapidly. For best results, the burn should be completed as close to 23° ATDC as possible.



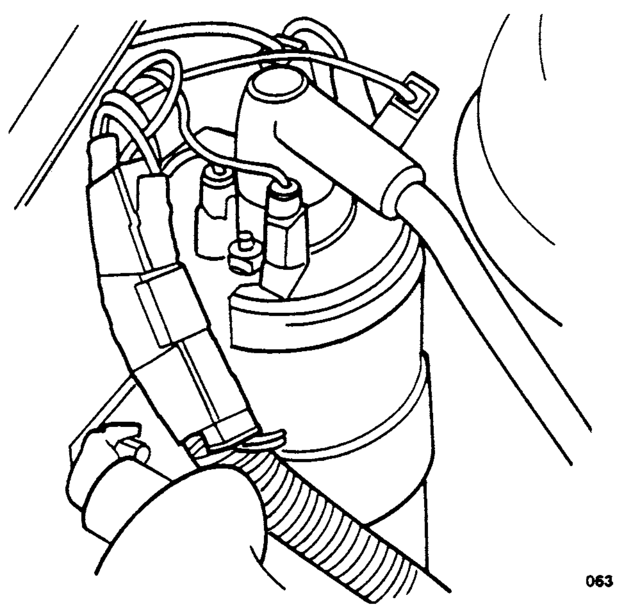
Piston Position at Top of Stroke

As engine speed increases, spark must be further ahead of TDC to allow adequate time for the air/fuel mixture to burn completely. Because of this, increasingly sophisticated methods of advancing and retarding ignition have been implemented.



Spark Timing Window

The high voltage required for ignition is generated in the vehicle's ignition coil. It contains two sets of windings, primary and secondary, that allow battery voltage to be stepped up to approximately 30,000 volts.



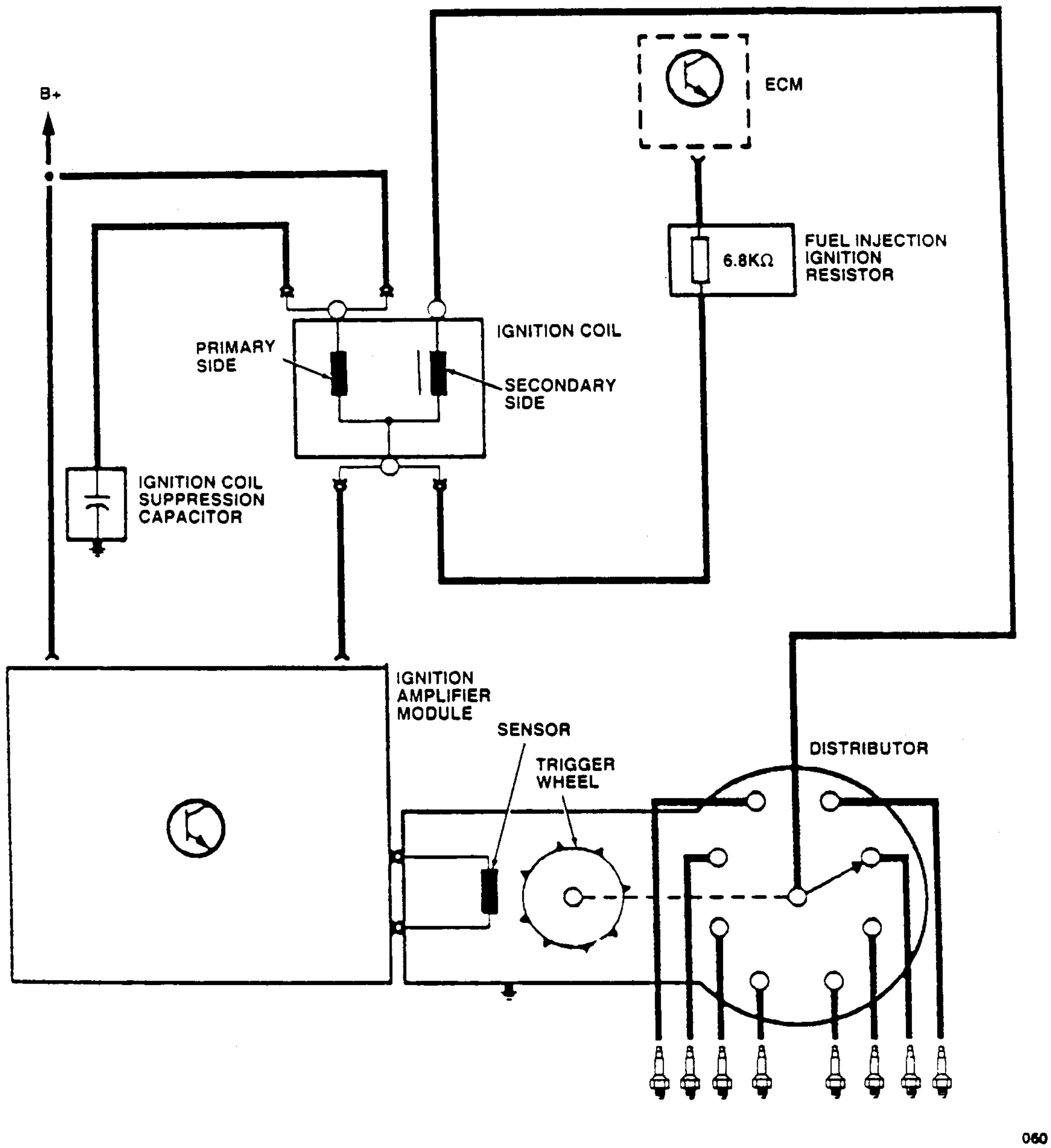
Ignition Coil

ELECTRONIC IGNITION SYSTEMS

Early electronic ignition systems used a single coil with a distributor to fire the cylinders in the correct sequence. The spark was triggered by a pickup within the distributor. The main timing control was a mechanical advance geared to the crankshaft rotational speed, additional advance at part throttle was provided by a vacuum servo mounted on the distributor body.

A sensor (pickup) mounted in the distributor generates pulses as a trigger wheel mounted to the distributor shaft passes it. Later models have the ignition control module mounted to the ignition coil bracket.

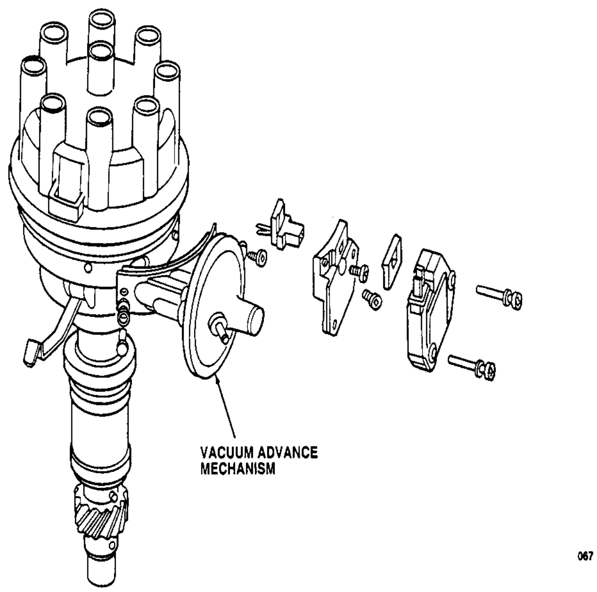
Land Rover vehicles discontinued use of this system in 1996.



Solid State Ignition System

Two methods are used to advance ignition timing. A centrifugal mechanism mounted internally in the distributor advances timing as rotational speed of the engine (and distributor shaft) increases.

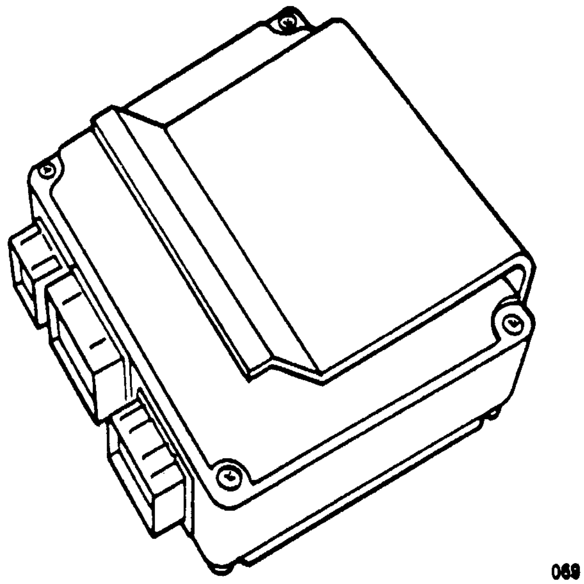
A vacuum advance mechanism is mounted externally on the distributor body. This helps provide advance over and above that provided by the centrifugal mechanism when operating at part throttle.



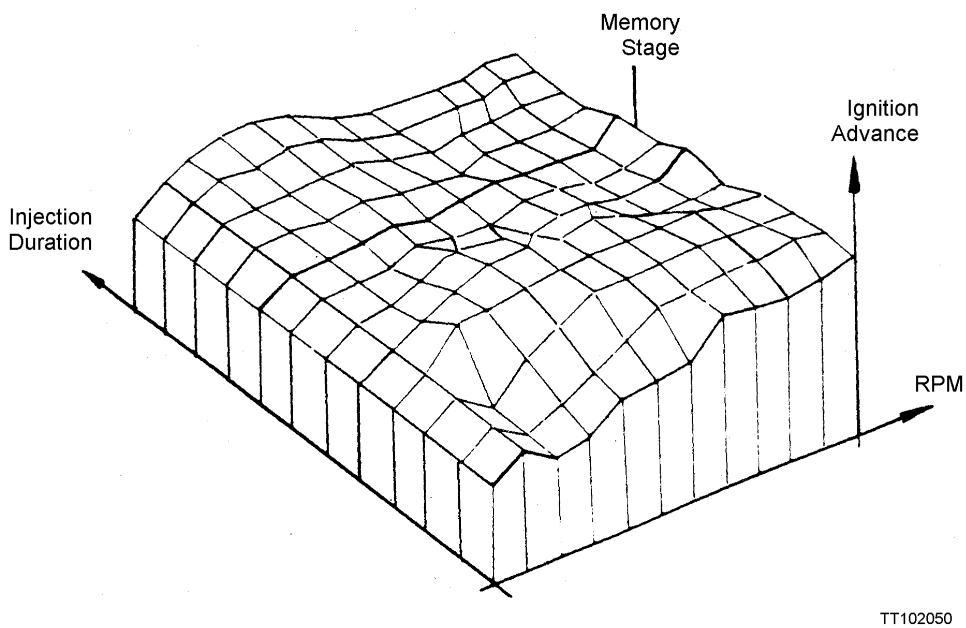
Distributor

DIRECT IGNITION SYSTEM

To more accurately control engine operation and emissions, most modern systems use a Direct Ignition System (DIS). The ignition system is controlled by the Engine Control Module (ECM) which receives inputs from a variety of sensors. This information is then processed to provide the optimum spark advance for every operating condition.



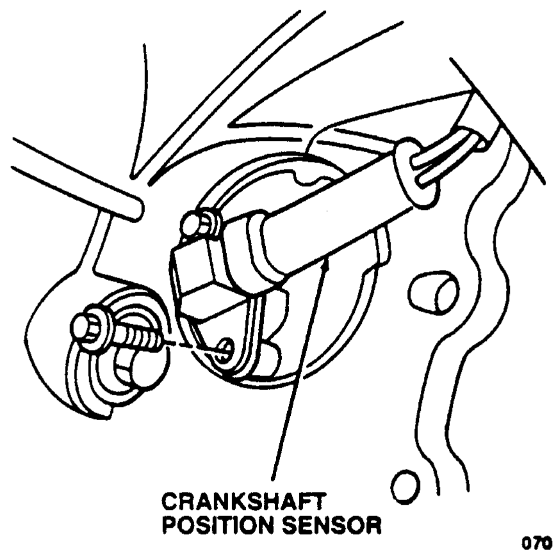
Engine Control Module



Typical ECM Ignition Control Map

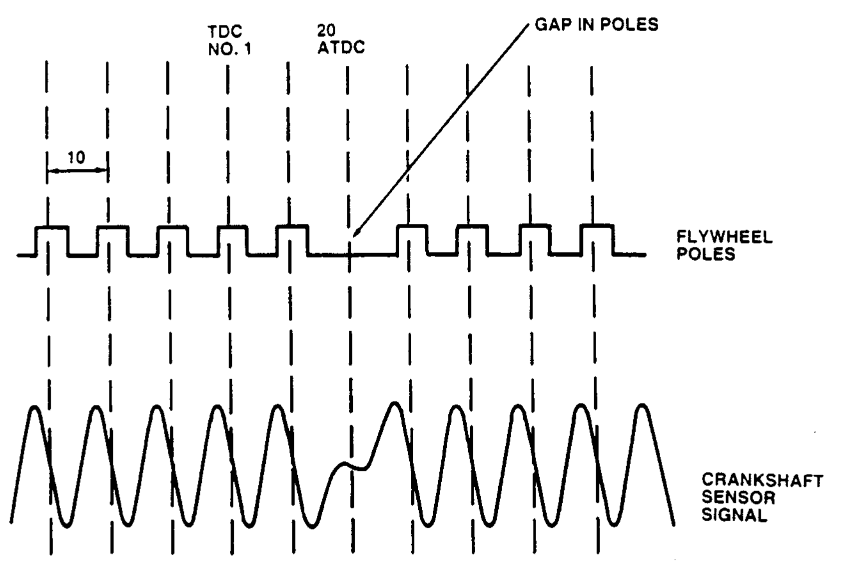
INPUTS

Crankshaft Position Sensor (CPS)
Basic engine timing is controlled by the ECM using input from the crankshaft position sensor. It is mounted on the flywheel housing, opposite the starter motor.



Crankshaft Position Sensor

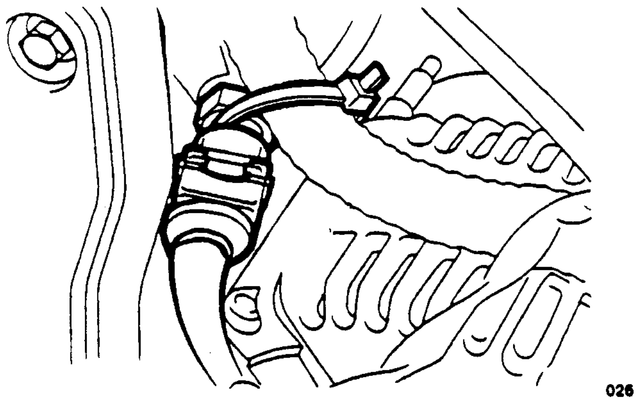
The sensor reacts to reluctor teeth placed on the flywheel at precise intervals, with some means of identifying the TDC position of the #1 piston. In the example pattern shown, the teeth are spaced at 10º intervals, and one missing reluctor tooth identifies the T.D.C. position of the #1 piston. The electrical signal produced by the crankshaft position sensor as the teeth pass it provides a constant update of engine speed and crankshaft position to the ECM.



Typical Crankshaft Position Sensor Signal

Engine Coolant Temperature Sensor

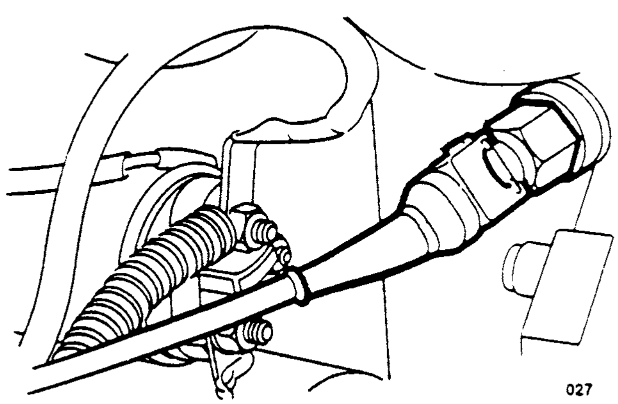
Variations in engine operating temperature require variations in ignition timing to maintain the optimum balance between driveability and emissions. The ECM advances ignition timing when the engine is cold and retards it as the engine warms up. The coolant temperature sensor provides the ECM with data on which to base these timing decisions.



Coolant Temperature Sensor

Knock Sensors

A pair of knock sensors monitors engine noise and vibration for the ECM. Engine knock is often caused by detonation or pre-ignition which can damage pistons and valves. The ECM is able to identify the characteristics of engine knock and retard ignition timing when knock is present. The ability to sense engine knock allows the ECM to operate the engine close to its limits of ignition advance. This is the most efficient ignition timing for maximum performance and fuel economy.



Knock Sensor

The sensors are mounted in the cylinder block located between cylinders 3 and 5 and between cylinders 4 and 6. Positioning a sensor in each bank of cylinders allows the ECM to precisely identify which of the eight cylinders is knocking.

OUTPUTS

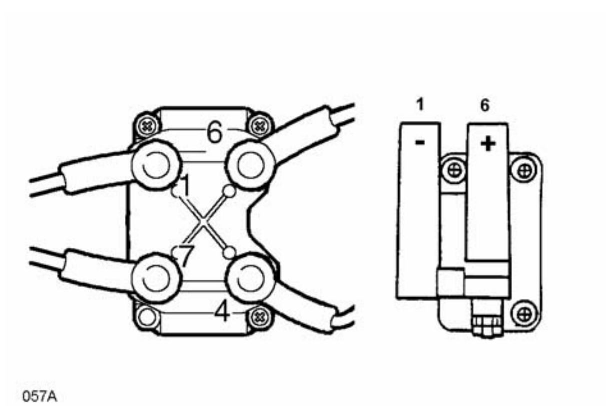
Coils

Spark distribution is achieved by a pack of coils mounted at the rear of the engine compartment. Coil operation is controlled by the ECM. A single coil is used to fire two plugs simultaneously - one on the compression stroke and the other on the exhaust stroke. The circuit for each coil is completed by switching within the ECM.

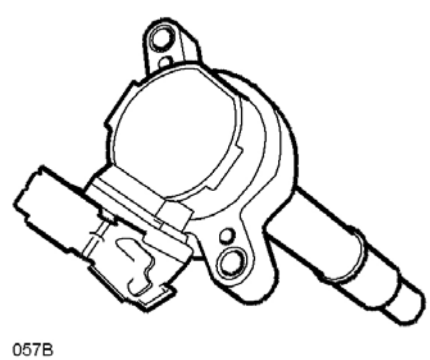
The spark on the exhaust stroke is said to be wasted hence, the term “wasted” or “lost” spark ignition system. Actually, little in the way of voltage is wasted on the spark in the cylinder on the exhaust stroke. The cylinder containing the air/fuel mixture (compression stroke) conducts the electrical charge far more efficiently than the cylinder containing exhaust gasses. Most of the voltage takes this path of least resistance to ground.

Performance is also improved. By using more than one coil (as opposed to the traditional single coil system) each coil is allowed more time to charge between firings.

Other DI systems may use a separate coil for each cylinder, mounted directly on the plug (COP) or connected via a short high voltage lead. Each coil is controlled directly by the ECM.



Multiple Ignition Coil Packs- Bosch (left), GEMS (right)



Coil On Plug

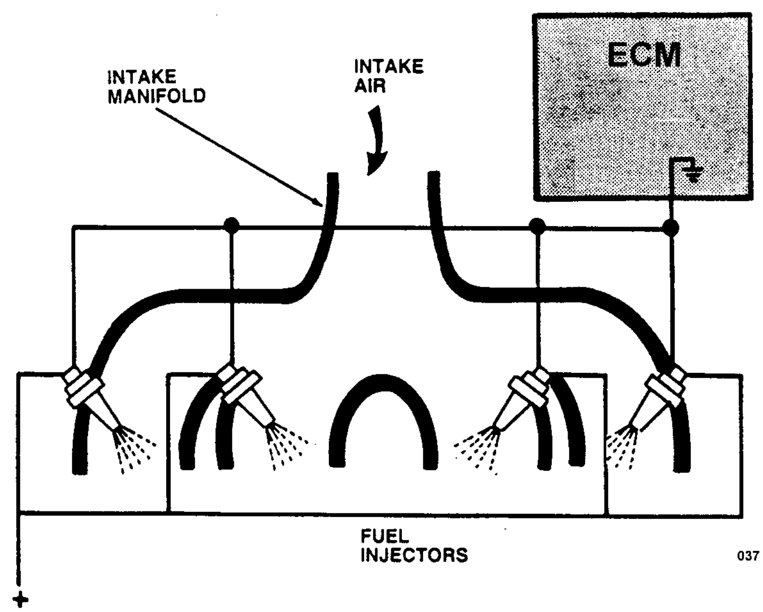
FUEL INJECTION SYSTEMS

Recent years have seen the process of automotive fuel delivery evolve from carburetors to fuel injection. Current Land Rover vehicles use one of two types of electronically controlled fuel injection systems: Multiport Fuel Injection (MFI) or Sequential Multiport Fuel Injection (SMPI).

MULTIPORT FUEL INJECTION (MFI)
Multiport fuel injection systems utilize an injector for each engine cylinder. These injectors are mounted above the cylinder's intake valve in the intake manifold. The injectors for each bank of cylinders open twice during the four-stroke engine cycle - once each during the intake and exhaust strokes.

Since the injectors spray fuel into the manifold on the back face of each intake valve, there is no need for injection to be precisely timed to valve operation or combustion stroke.

Fuel is injected twice per stroke because two small portions of fuel are more easily atomized than a single large quantity. The atomized fuel is then drawn into the cylinder intake for combustion. MFI allows for precise fuel control for each bank of cylinders.

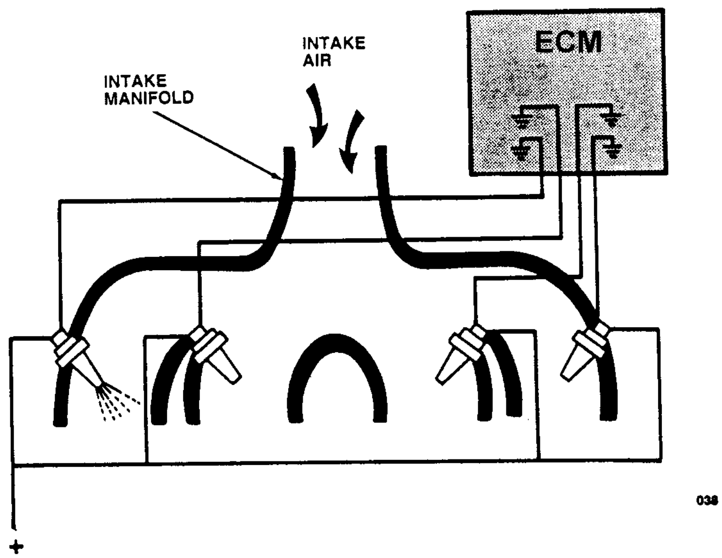


Multiport Fuel Injection

SEQUENTIAL MULTIPORT FUEL INJECTION (SFI)
Sequential multiport injection goes a step further in fuel delivery precision. By providing separate ECM ground controls for each injector, SFI provides control of individual injectors. This differs from MFI systems which control operation of the injector banks.

The SFI system allows the supply of fuel to be matched to the specific needs of each individual cylinder. It also requires that injector operation be precisely timed to valve operation. The ECM in an SFI system uses additional inputs, over and above those found in an MFI system, to control injector operation.

Because an equal amount of fuel is injected into each cylinder, engines equipped with port fuel injection systems must ensure that equal amounts of air enter each cylinder. This is achieved by providing equal length intake tracts connected to a common chamber or plenum.



Sequential Multiport Fuel Injection

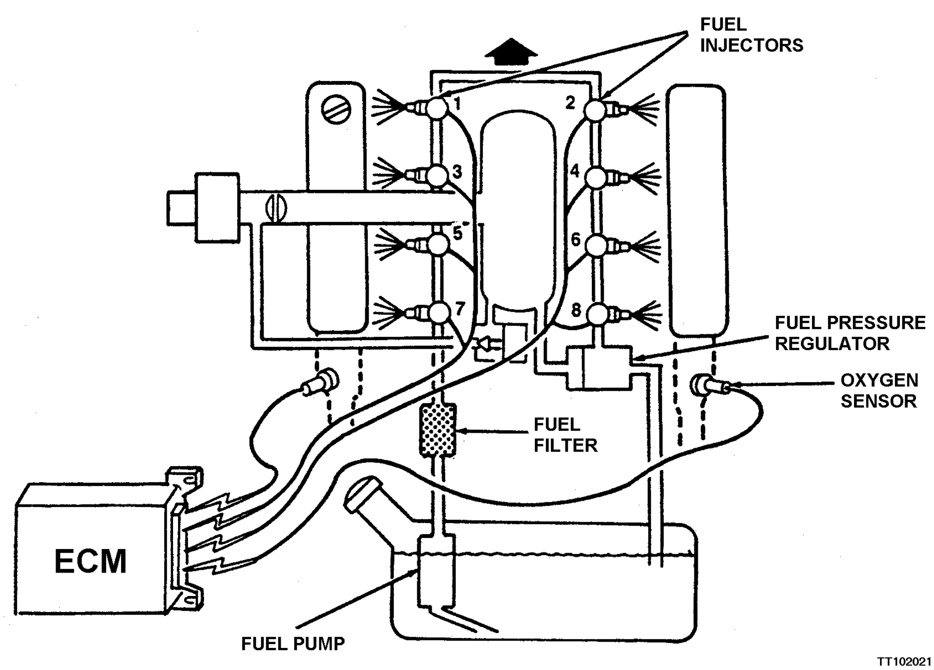
FUEL SYSTEM COMPONENTS

The following components are included in a basic fuel injection system:

- Engine Control Module (ECM)
- Oxygen Sensor (HO2S)
- Fuel Pump
- Fuel Filter
- Fuel Pressure Regulator
- Fuel Injectors

Additional components are used to monitor and control the “air” portion of the air/fuel mixture. These are listed below:

- Mass Air Flow Sensor (MAFS)
- Throttle Butterfly
- Throttle Position Sensor (TPS)
- Idle Air Control (IAC)

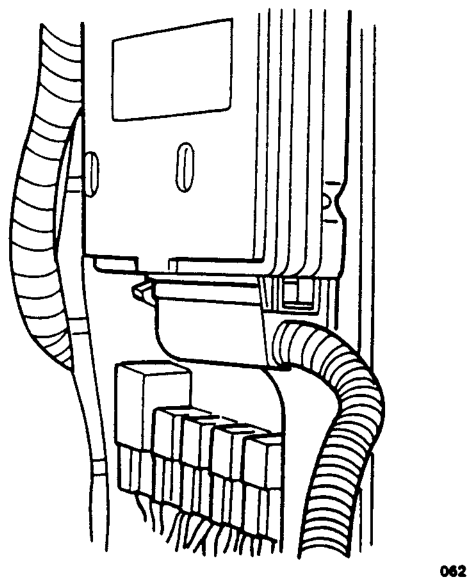


Basic Fuel Injection System

Engine Control Module (ECM)

The Engine Control Module (ECM) is the heart of the vehicle's fuel delivery system. It monitors information from several inputs to determine the fuel delivery strategy required to produce efficient operation. As the sophistication of the fuel injection system increases, the amount of information processed by the ECM also increases. Additional strategies to cover fueling requirements for situations such as cold starting, hot starting, and wide-open throttle acceleration may also be added to the ECM software.

Newer generations of engine management systems include additional ECM memory to allow such features as adaptive sensor mapping strategies, cylinder knock control, active ignition timing, and extended fault diagnostics.



Engine Control Module (ECM)

FUEL SYSTEM OUTPUTS

Fuel Pump

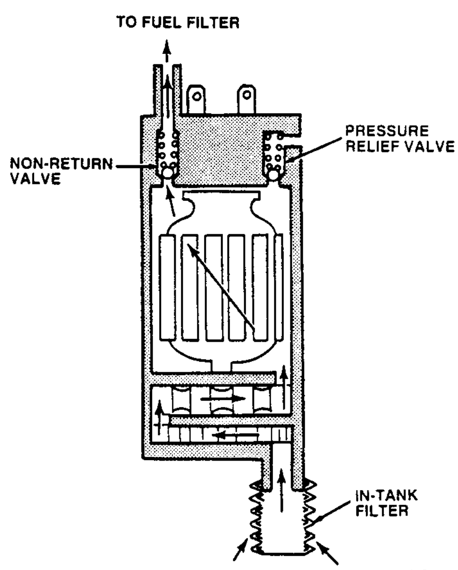
Fuel is supplied to the engine via a tank-mounted electric pump. In the case of a system that uses an external fuel filter, an additional filter may also be used on the pump inlet to protect the fuel pump itself.

The pump is usually mounted inside the fuel tank. The advantage of mounting the pump in the fuel tank is that the pump armature and bearings are cooled by the surrounding fuel. The tank also helps isolate any noise produced by pump operation. The pump is capable of delivering more fuel volume and pressure than required by the engine. A non-return valve in the pump prevents fuel from the injector supply pipe from draining back into the tank when the pump is not running.

There are two general types of fuel supply strategies in use- the Fuel Return type, and the Non-Return type.

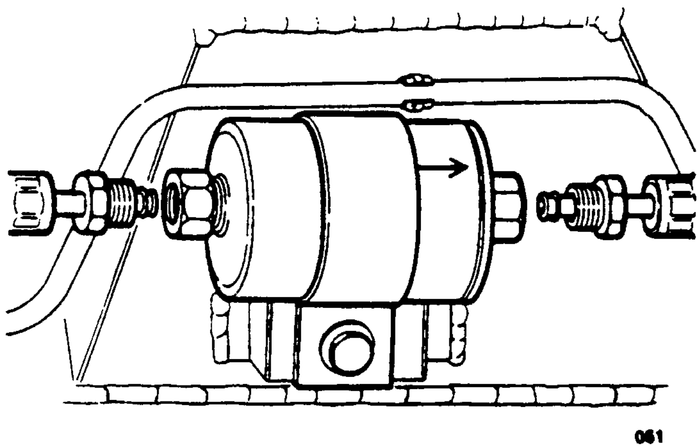
In the return type, most of the fuel circulates through the fuel rail and is returned to the fuel tank. This constant supply of relatively cool fuel through the system helps prevent vapor lock. This type of system uses a pressure regulator mounted on or near the fuel rail. The regulator senses engine manifold pressure and adjusts the quantity of fuel returned to the fuel tank. On the fuel pump itself, there is a pressure relief valve to prevent over-pressure in the event of a system blockage.

In the Non-Return type, the fuel rail has no means to return fuel to the tank. In this type of system the pressure at the fuel rail is typically higher than in the return type system, and regulation is integral with the pump. Excess fuel can be returned to the tank, but it is done via the relief valve inside the pump.



Fuel Pump

Fuel Filter
Because of the close internal tolerances of the injectors, thorough filtration of fuel is required. The filter element is able to trap particles down to 20 microns in size.



Fuel Filter

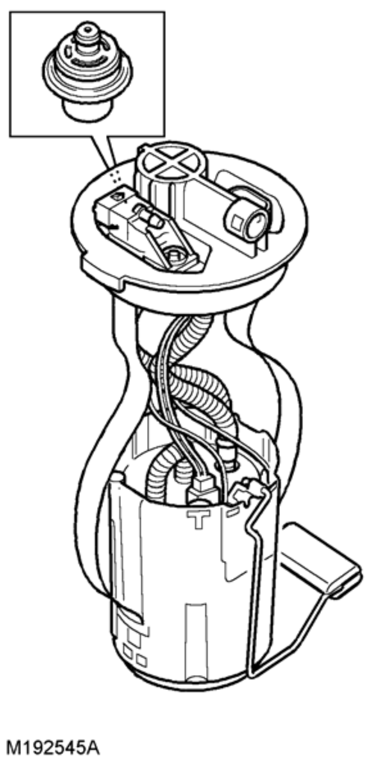
Most modern engine management systems use a filter that is mounted on the fuel pump, and inside the fuel tank. Some systems however (typically the Return type), use an externally mounted filter.

The fuel filter is a simple component that is commonly overlooked as a source of fuel system concerns. Check for proper system pressure at the fuel rail before disassembling the fuel rail or injectors in search of an obstruction.

Fuel Pressure Regulator
A constant pressure to the fuel injectors must be maintained during all engine operating conditions to ensure correct fuel metering and emission levels. As previously mentioned, return type systems use an external regulator, while non-return type systems use a regulator mounted inside the fuel tank, on the fuel pump.

Non-return type Systems
This type of fuel pressure regulator is located in the fuel pump assembly, and maintains a constant fuel pressure relative to atmospheric pressure. The supply pressure at each injector must be sufficient to provide adequate fuel flow during high demand such as acceleration under load, and wide open throttle. There must also be sufficient pressure to keep the injectors seated during periods of high intake vaccum, such as during deceleration.

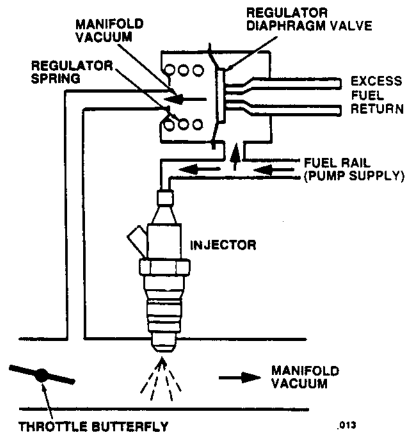
Since fuel pressure is regulated well before the fuel rail assembly, proper engine fuelling with this type of supply system is slightly more sensitive to restrictions in the supply pipes than in a return type system. Typically, a fuel pressure test port is provided on the fuel rail to verify adequate pressure at the injectors.



Typical Non-Return Type System Pressure Regulator

Return type systems
A constant fuel pressure relative to, and above intake manifold pressure, is controlled by a regulator valve mounted at the end of the fuel injector rail. The fuel pressure regulator contains two chambers separated by a spring-loaded diaphragm. One chamber contains fuel from the supply line. The other chamber is linked to the engine side of the throttle butterfly to sense manifold vacuum (negative pressure).

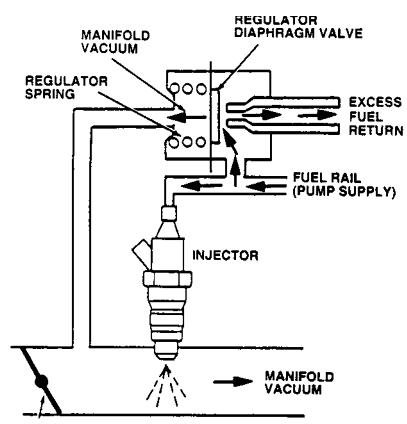
When fuel pressure and manifold vacuum are low (full throttle), spring pressure holds the diaphragm valve against the fuel return pipe. This assures a higher level of fuel pressure to satisfy the fuel needs of the injectors. Fuel pressure must exceed a calibrated amount before the spring is compressed and fuel is allowed to enter the return line.



Regulator Closed

When manifold vacuum is high (idle and coast-down), the combination of fuel pressure and vacuum is able to overcome the pressure of the regulator spring. The fuel return line opens at much lower fuel pressures when vacuum assist is present. This reduces the tendency of manifold vacuum to draw excess fuel from the injector nozzle and ensures that the amount of fuel actually delivered matches the level desired by the ECM.

The fuel pressure regulator is pre-set during manufacture. No service adjustments are provided.

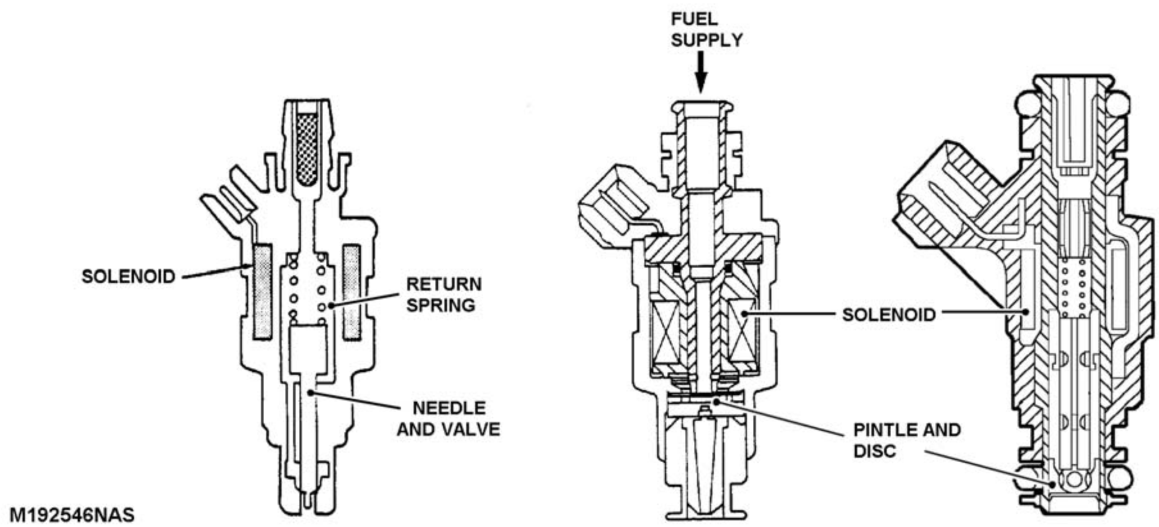


Regulator Open

Fuel Injectors

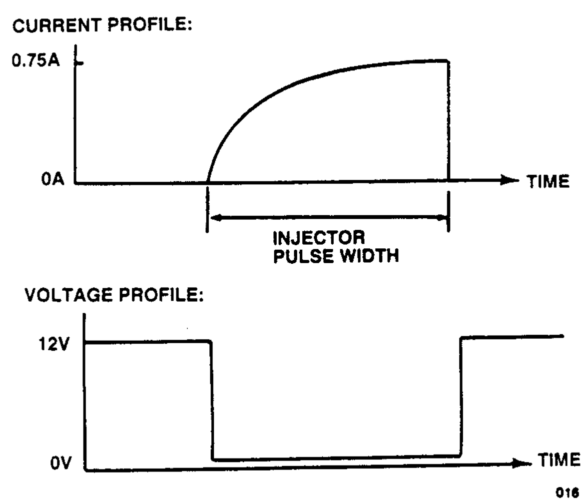
The electronically operated fuel injector provides a simple and effective way of metering the fuel provided for combustion.

Each injector contains a precisely machined needle valve or a pintle and sealing valve held in position by a spring. When the injector solenoid is energized, the needle or pintle is lifted, allowing fuel to pass. When the solenoid is de-energized, the needle or pintle snaps shut under spring pressure, cutting off fuel flow.



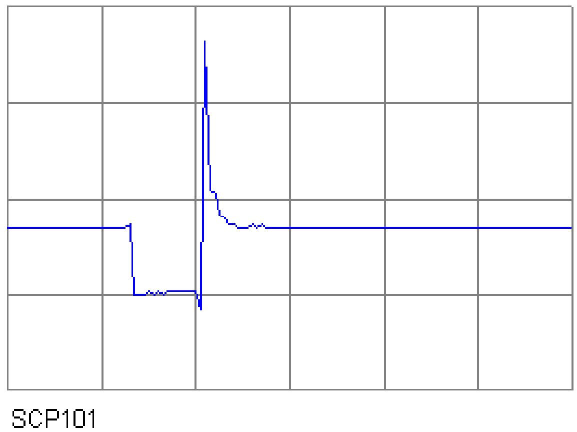
Fuel Injector Types

The length of time the injector is energized and delivering fuel is referred to as injector "pulse width." This varies between 1.5 to 10 milliseconds, depending on operating conditions. The longer the injector is energized, the greater the volume of fuel delivered. The ECM uses the duration of its ON signal to the injector (where it provides a ground for the circuit) to control fuel delivery to the cylinder.

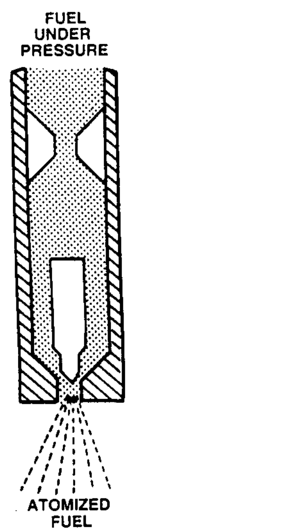


Injector Pulse Width

When looking at injector operation using an oscilloscope, an additional ‘spike’ will be observed along with the ‘on-time’, or pulse width. This spike is the result of voltage build-up, current flow and limiting, and collapse in the injector solenoid winding.



To further enhance the combustion process, the tip of the injector's needle valve is precision ground to a shape that produces a fine atomized fuel spray. This enables the fuel to vaporize faster and more completely than fuel introduced by a carburetor. The result is more complete and efficient combustion.



Atomized Fuel

As long as the supply of fuel to the injector is sufficient, the volume of fuel delivered can be precisely controlled by the length of time the injector needle valve is open. The valve remains open as long as a path to ground is provided by the ECM.

Idle Air Control (IAC)

To ensure a smooth and constant idle speed, a port allows a measured amount of air to bypass the throttle plate and enter the plenum chamber. Generally the system allows this bypass when the following conditions are present:

- Low or No road speed
- Throttle closed
- Engine above cranking speed rpm

The amount of air flowing through an orifice is controlled by the ECM. This orifice and its control mechanism is called an Idle Air Control Valve (IACV). The IACV can be a tapered valve mounted in the by-pass port, or a slotted disc or drum rotating into the bypass air flow. In either case, the precise movement of this variable restriction is controlled by the ECM, usually using an electric motor.

NOTE: Electronic throttle control systems do not use an IACV as they are able to control the throttle plate directly.

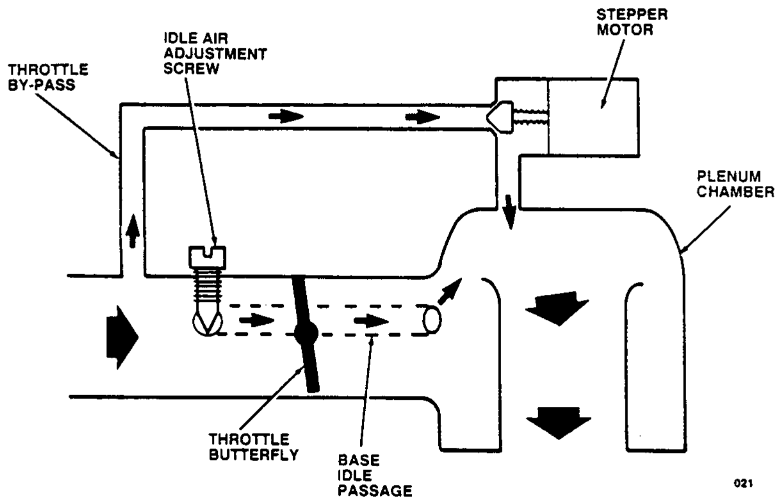
The ECM makes idle air control adjustments based on sensor inputs (ambient temperature, engine load produced by accessories such as air conditioning or defrosters) to keep idle speed sufficient for the situation.

If a tapered valve type of IACV is used, the motor uses multiple windings that are powered in sequence to allow small ‘steps’ of motor movement. Thus, this type of motor is called a ‘stepper’ motor.

If a disc or drum type of IACV is used, the position of the disc or drum is controlled by a motor with two opposing windings. The power to the windings is alternated between the two by varying the amount of time each recieves current. In this way, the disc or drum can be precisely positioned.

Failure of the stepper motor can result in either a high or low idle speed, engine stall or no-start.

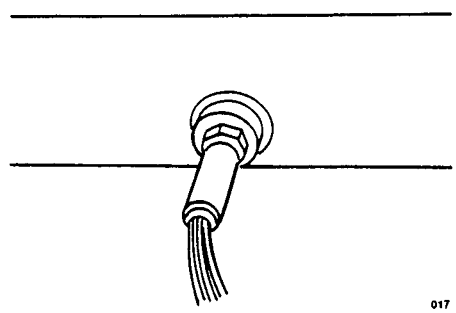
"Base" idle is controlled through a separate bypass port located in the housing for the throttle butterfly. The volume of air allowed to bypass the throttle butterfly is controlled by an adjustment screw. The size of this orifice does not vary during engine operation.



Stepper type Idle Air Control

FUEL SYSTEM INPUTS

Heated Oxygen Sensor (HO2S)
The oxygen (Lambda) sensor mounted in the exhaust downpipe serves as the key input in an electronic fuel injection system. The sensor is used by the ECM to determine the amount of oxygen present in the exhaust gas. The ECM uses this information to increase or decrease injector open time to bring the air/fuel ratio as close to Stoichiometric as possible.



Heated Oxygen Sensor

Oxygen sensors operate efficiently only when warm. Sensors include heaters to help them reach operating temperatures quickly. This allows the sensors to provide accurate information to the ECM soon after start-up and allows the system to enter closed loop operation (based on sensor inputs) sooner. Closed loop operation helps provide an efficient fuel mixture and controls emissions when the engine is cold. Closed loop also guards against catalytic converter overheating from the introduction of too much fuel.

“Closed loop” simply means that the ECM is controlling fuel to the engine based on the oxygen sensor “feedback”, rather than using a programmed mixture based solely on engine temperature, speed, and load. Closed loop operation helps provide an efficient fuel mixture and controls emissions when the engine is cold. Closed loop also guards against catalytic converter overheating from the introduction of too much fuel.

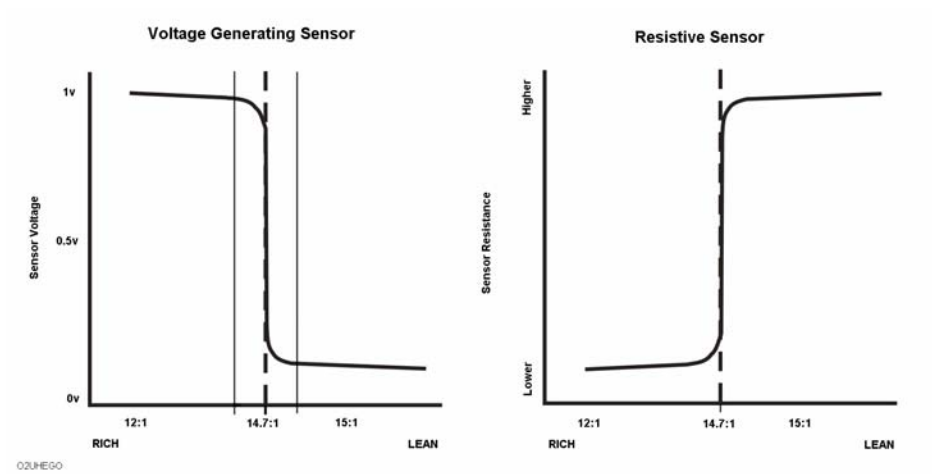
There are three general types of Oxygen Sensors:

- Those that change resistance in the presence of oxygen in the exhaust
- Those that generate a voltage based on the absence of oxygen in the exhaust
- “Wide Band” sensors that change a current flow signal in a reference circuit, based on the air/fuel content of the exhaust gas. These are also sometimes referred to as “Air/Fuel ratio”, or A/F sensors

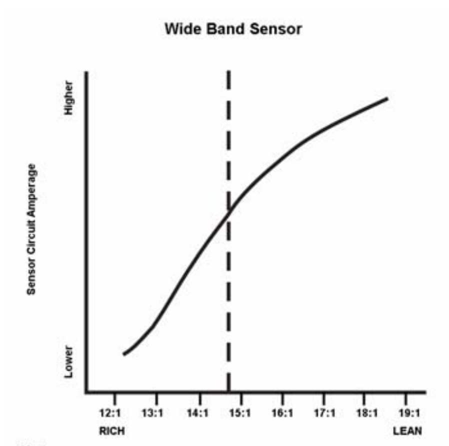
The first two types of oxygen sensors are referred to as “Heated Exhaust Gas Oxygen-Sensor” (HEGO) and their signals are continually "switching" between rich and lean as the exhaust gas content changes. The engine management system is programmed to understand that a stoichiometric air/fuel ratio is roughly mid-way between the low and high signal values from the sensor, and constantly corrects the fuel mixture to maintain an average mid-point reading.

It is best to measure HEGO operation through the ECM with a diagnostic tester, although it is possible to measure them directly at the sensor or wire harness connections.

"Wide Band" sensors are referred to as "Universal Heated Exhaust Gas Oxygen-Sensor" (UHEGO) and are able to provide the system with a much more accurate air/fuel ratio reading. Their signals change in direct proportion to the changes in air/fuel ratio, and consequently change more slowly. The signals from these sensors cannot be easilly measured at the sensor, and must be measured through the ECM via a diagnostic tester such as T4/WDS.



Typical HEGO sensor operating ranges



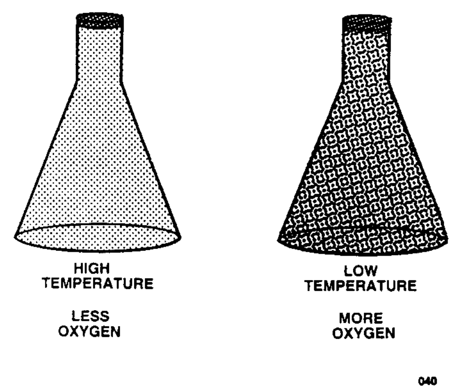
Typical "Wide Band" or UHEGO sensor operating range

On systems with more than one sensor, the ECM monitors each sensor separately. Fuel trim adjustments are made independently to each cylinder bank, or individual cylinder, depending on the fuel system. Sensors located downstream of the catalyst are used to verify proper catalytic converter operation.

In their operating environment, oxygen sensors are quite durable. However, they are easily damaged if dropped, exposed to excessive heat, or contaminated. Care should be taken when handling oxygen sensors. Avoid overtightenig or jarring the sensor. Contamination of the sensor body can lead to premature failure. The sensor threads must be sealed with the material provided to ensure there are no oxygen leaks. Do not use silicone sealants for this purpose as they will contaminate the sensor.

Mass Air Flow Sensor (MAFS)
The Mass Air Flow Sensor (MAFS) is an electronic device mounted between the air filter and the plenum chamber. It serves as a key ECM input, performing two functions: indicating the volume and temperature of air being drawn into the engine. These two factors allow the ECM to adjust the fuel supply accordingly.

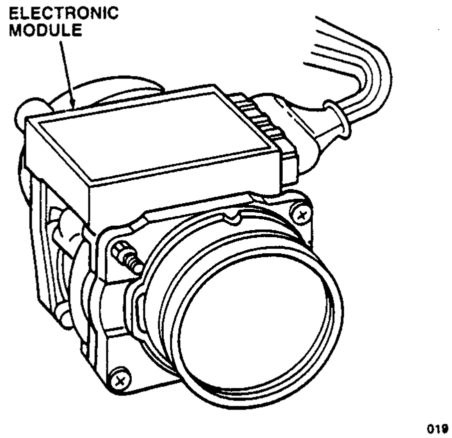
Air density varies with temperature and altitude. Cold air is denser and contains more of the oxygen required for combustion. At higher temperatures and altitudes, more air must enter the engine to deliver the same amount of oxygen.



Air Density

The “Hot Wire” type of MAF sensor contains two wires with current passing through them. Both are connected to the module mounted on the MAF unit. One wire, which is unheated, reacts to intake air temperature. The second wire is heated to a known fixed temperature value above the unheated wire. As air flow increases, the current required to maintain this difference in temperature increases. The electronic module monitors this wire's current requirements to determine the amount of air entering the intake manifold. It then provides a signal to the ECM that corresponds to the air flow. While air temperature is also a factor that affects the current requirements of the wire, a separate sensor for air temperature is commonly used.

Another type of MAF sensor contains two elements made of a film material, that behave similar to the wires in the hot-wire type.



Mass Air Flow Sensor

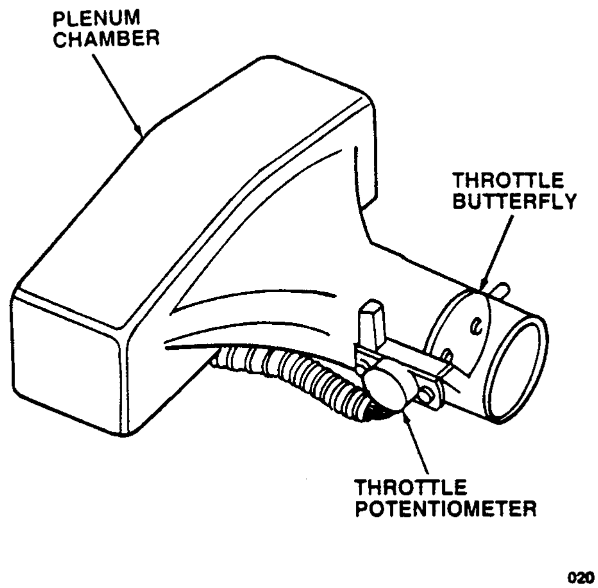
Throttle Butterfly

The throttle butterfly is located between the plenum chamber and the MAF sensor. The throttle butterfly controls the volume of air entering the plenum chamber and is either linked directly to the accelerator pedal or is controlled by the ECM via a motor. As the accelerator pedal is depressed, the throttle butterfly opens. This allows a greater volume of air to enter the plenum chamber.

Throttle Position Sensor (TPS)

A potentiometer mounted at the throttle butterfly converts throttle position into an electrical signal used by the ECM (along with data from the air flow meter) to determine the volume of air entering the intake manifold.

The ECM also monitors the throttle position sensor for the rate of throttle application. During periods of hard acceleration, the ECM will enhance the fuel mixture to prevent a lag in engine response.



Throttle Position Sensor

Electronic throttles ("drive by wire" systems) use 2 potentiometers. One potentiometer is mounted on the throttle pedal, and monitors driver demand. The second potentiometer is mounted at the throttle butterfly to monitor the actual butterfly position.

Electronic throttle systems provide the ECM with accurate and consistent feedback of the throttle position and allow the system to adapt to variations caused by throttle stop wear and component differences. These ECM adaptions must be reset if throttle components are replaced of disturbed.

CLOSED LOOP OPERATION

During closed loop, or feedback operation, the ECM controls fuel system operation based on information provided by the various vehicle inputs. Because these inputs represent actual operating conditions, the system is most able to meet performance and efficiency targets when operating in closed loop.

The primary input during closed loop operation is the oxygen sensor since it indicates the result of the combustion process, regardless of the engine speed and load.

The primary output during closed loop operation is the fuel injector timing and duration.

All other sensors generally serve to help the ECM ‘trim’ or anticipate the operation of the engine to meet a particular oxygen sensor value or known tailpipe emission condition.

OPEN LOOP OPERATION

At times (start-up, full throttle) engine operating requirements may fall outside the bounds of that suggested by the ECM inputs. Some sensors do not operate at peak efficiently until warm. At these times, the ECM substitutes a pre-programmed set of reference inputs that are most likely to produce desired engine operation. This is referred to as open loop operation.

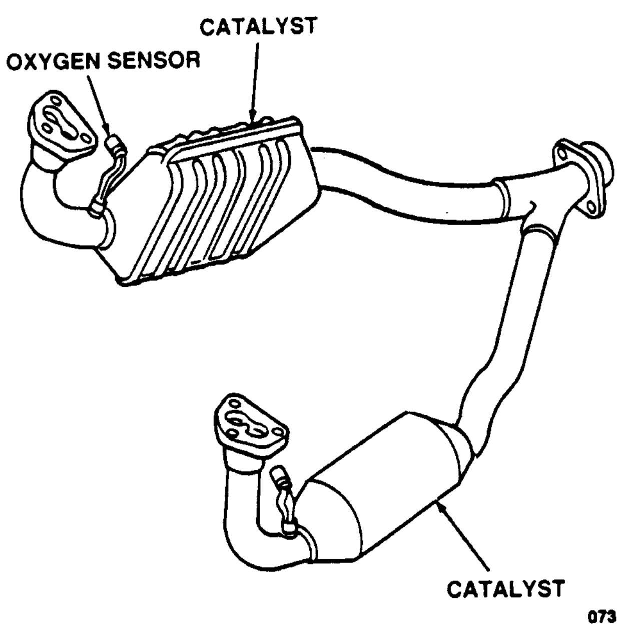
The system may also default to open loop operation when component failure provides an input signal outside the range of known parameters recognized by the ECM. The ECM will substitute a signal value that allows the vehicle to continue to operate. The Malfunction Indicator Lamp (CHECK ENGINE) on the instrument panel is illuminated at this time to indicate the failure of an emissions-related component.

EMISSION CONTROLS

Introduction
Emissions control systems on Land Rover vehicles work closely with fuel system controls to reduce airborne pollutants. Improper operation of these systems can lead to increased emissions and poor engine performance. The catalytic converter is used to clean up tailpipe emissions. Crankcase ventilation and evaporative purge address a different concern - the evaporative emissions produced by the vehicle.

CATALYTIC CONVERTER
Even when operating at peak efficiency, engines produce undesirable emissions as a result of the combustion process. A three-way catalytic converter, located in the vehicle's exhaust system, is able to reduce the three greatest sources of concern - Hydrocarbons (HC) Carbon Monoxide (CO) and a variety of Nitrous Oxides (NOx) - from tailpipe emissions.

To operate properly, a catalytic converter must reach very high temperatures (approximately 760° C or 1400° F). That is why it is mounted directly downstream from the exhaust manifold



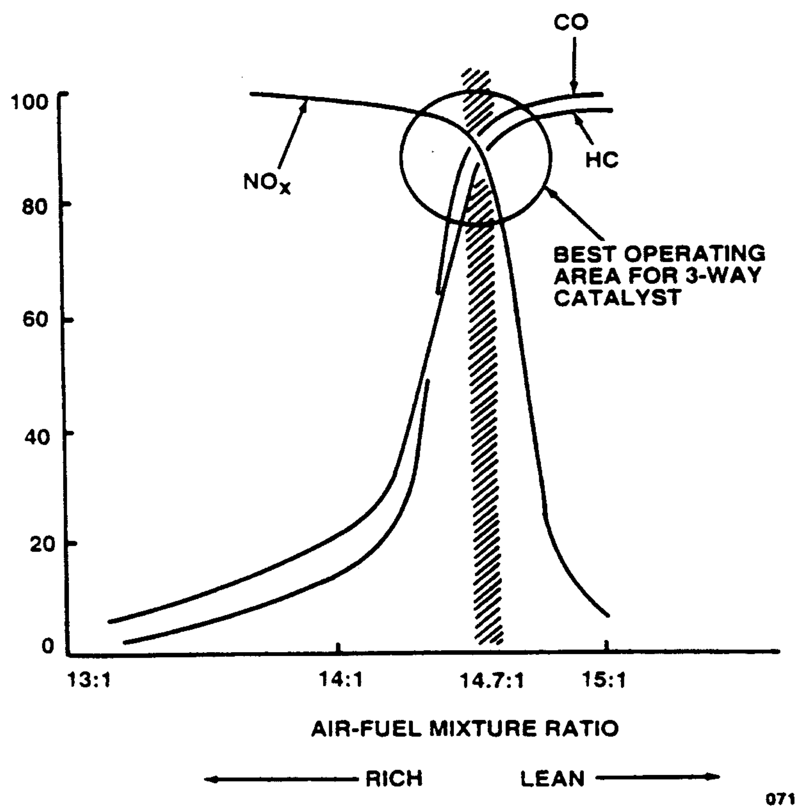
Catalytic Converter

Exhaust gasses pass through and heat the converter core which contains a mixture of platinum and rhodium. The combination of materials in the core and extreme temperature promotes chemical reactions that reduce the HC, CO and NOx to harmless Carbon Dioxide (CO_2) Nitrogen (N_2) and water (H_2O). (Three way catalyst.)

Precise control of the air/fuel ratio is critical for effective catalyst operation. The chart below shows that once the mixture moves away from stoichiometric, catalyst efficiency suffers.

The two greatest enemies of catalyst life are leaded fuels and overheating. The use of leaded fuels will cause deposits to form in the converter core and reduce its ability to produce the desired chemical reactions.

Excessive core temperatures are produced during misfire situations when raw gas in the exhaust ignites in the catalyst core. This can cause the core to fuse into a solid mass that exhaust gasses cannot pass through. Because of this, the desired chemical reactions cannot take place. Poor engine performance due to high backpressure is often a result of this situation.



Catalyst Operating Efficiency

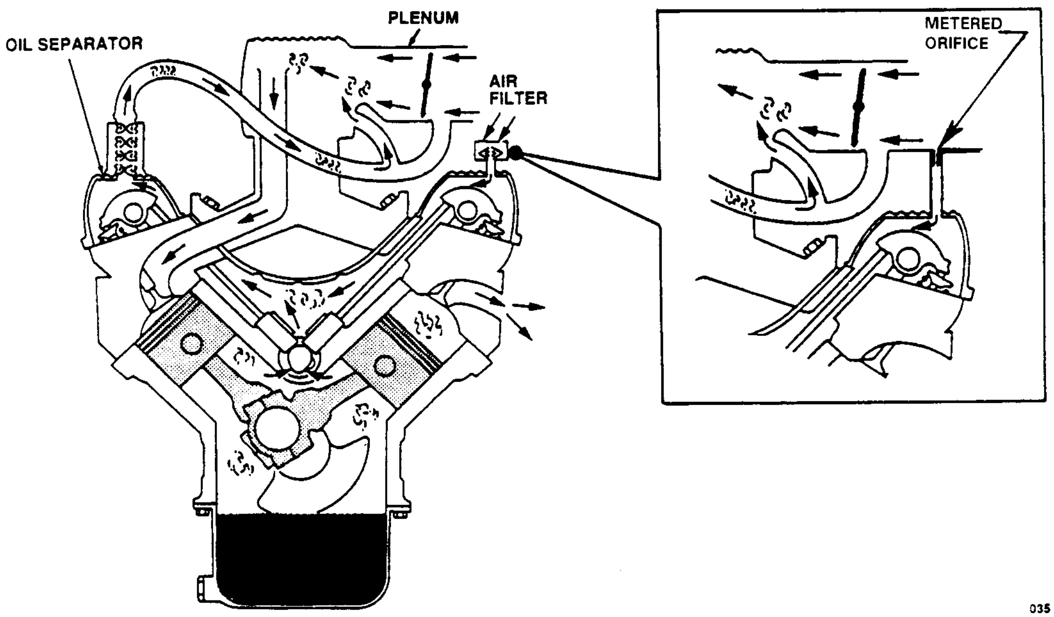
CRANKCASE VENTILATION

During engine operation, noxious gasses are produced in the engine's crankcase. The crankcase ventilation system allows these gasses to be burned along with the air/fuel mixture. As an additional source of air to the engine's plenum chamber, the crankcase ventilation system could be considered an integral part the vehicle's air intake system.

Manifold vacuum (negative pressure) draws oil laden vapor in the crankcase through an oil separator on the valve cover. The separator prevents engine oil from being drawn into the plenum.

The remaining gasses flow through a line where they are mixed with fresh air and directed to the plenum. Here the gasses become part of the air/fuel mixture and are burned during normal engine combustion.

The air intake on the valve cover of the opposing cylinder head prevents excessive crankcase vacuum or pressure from developing during engine operation. It is fitted with a filter to prevent contaminants from entering the crankcase. On some models, the filter has been replaced by a hose supplying air that has already passed through the engine's air filter.



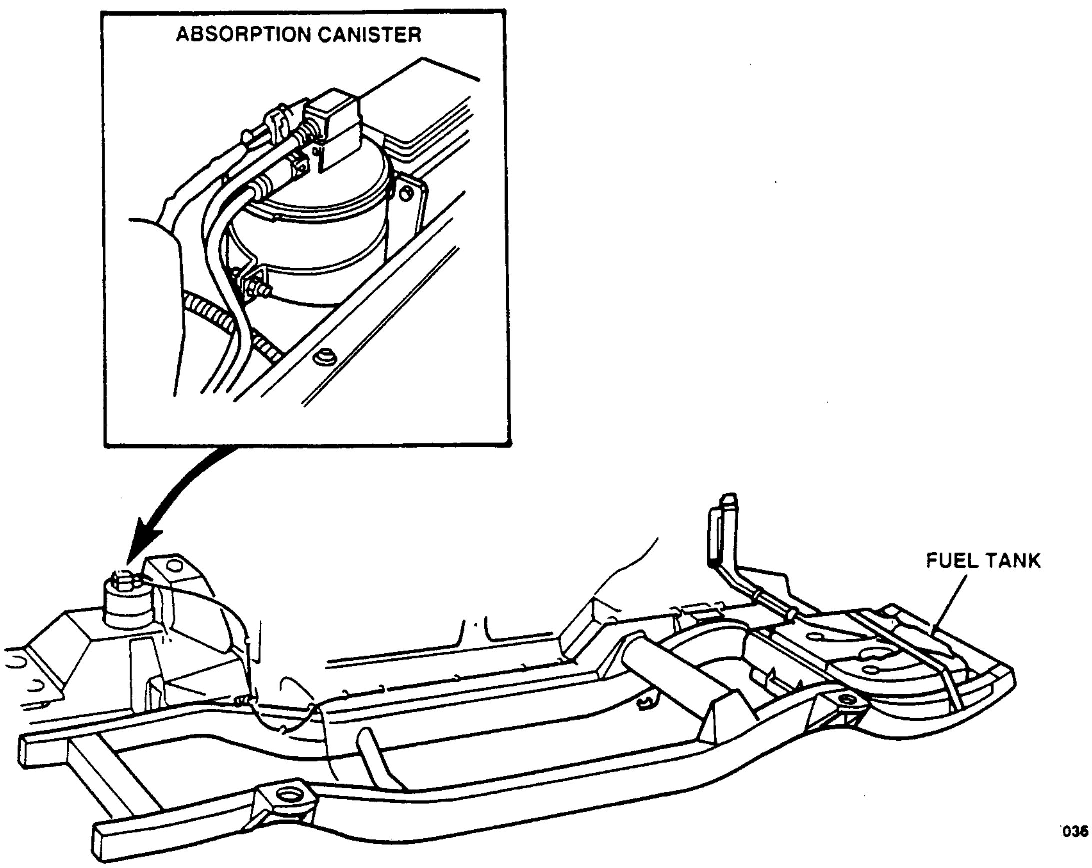
Crankcase Ventilation

Evaporative Emission Control System (EVAP)

EVAPORATIVE PURGE

As gasoline from the fuel tank is pumped to the engine, air must enter the system to prevent a vacuum from developing. However, harmful hydrocarbon vapors form in the fuel tank as gasoline evaporates. Venting the fuel tank directly to the atmosphere would allow these vapors to escape.

To prevent this from occurring, fuel system vapors are routed to a charcoal canister which absorbs and stores fuel vapor from the tank when the engine is not running. Once the engine is started, the vapor is purged from the canister by fresh air drawn through an orifice at the base of the canister and the vacuum introduced at the top.



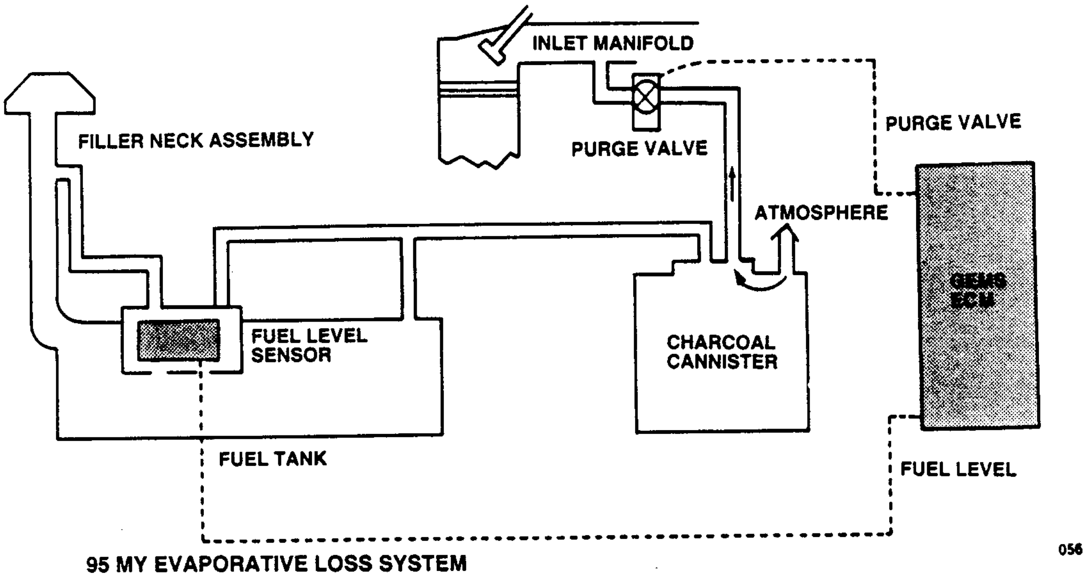
Evaporative Purge System Components

On 1989 and later vehicles, purge operation is controlled by the ECM through a solenoid valve. When the valve is opened, the vapor is drawn into the plenum to be added to the air/fuel mixture. Control of evaporative purge operation is an important ECM function for effective emission control.

When operating, purge flow into the plenum is not accounted for in the ECM's air/fuel calculations. Because of this, purge operation is saved for those times when the additional vapor is least likely to affect emissions. Typically, this is when the engine is warm and operating well above idle speed.

The ECM controls the flow rate by opening, closing, or pulsing the solenoid valve. The ECM monitors purge flow by looking for signs from the oxygen sensors that the fuel mixture has been enriched when the solenoid valve is opened. When this no longer occurs, the ECM interprets this to mean that no more vapor is present. Purge operation is discontinued at this time.

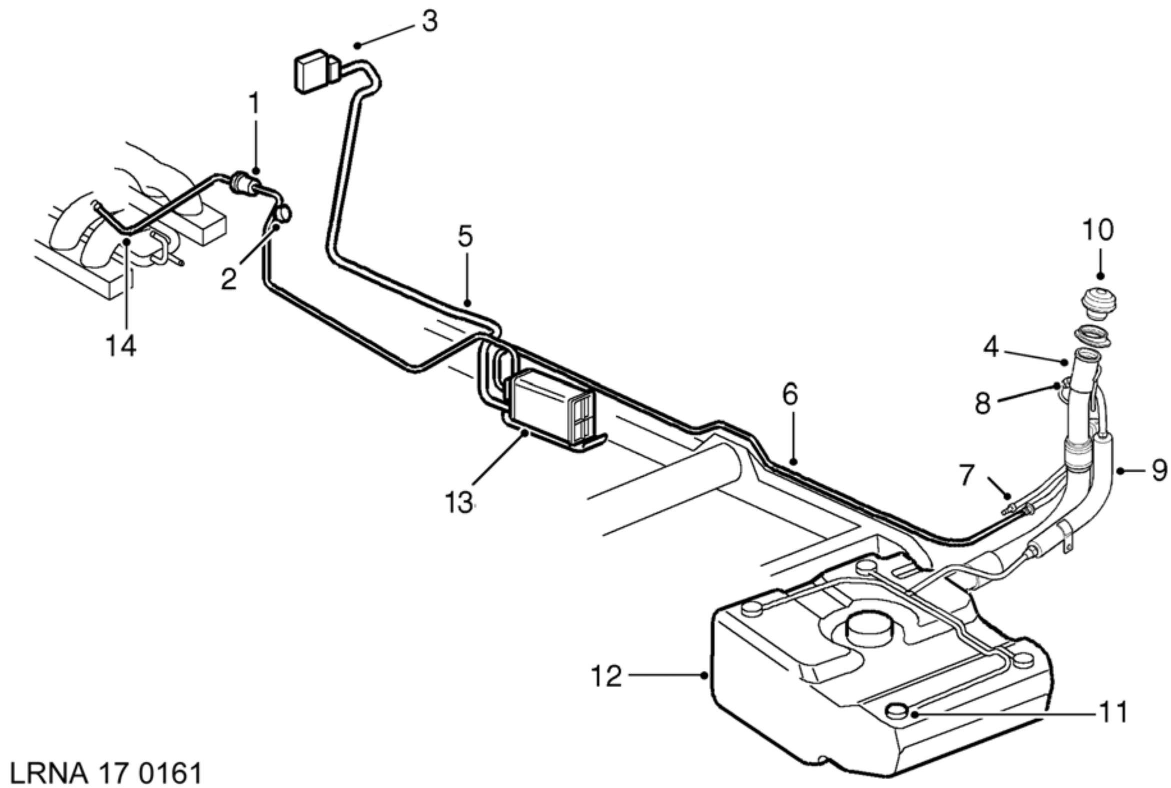
It is important that purge occur only as long as vapor is present. This reduces the time period in which unmetered air is introduced into the plenum. A purge solenoid stuck in the open position will increase vehicle emissions and affect driveability, especially at idle.



Purge Operation

EVAP With Leak Detection

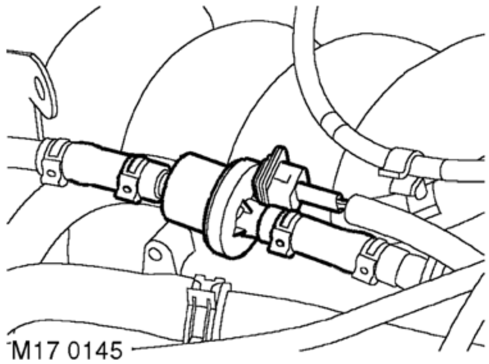
OBDII Legislation requires that the ECM must indicate the occurrence of a fault to the driver, if a leak in the fuel system allows hydrocarbons to escape to atmosphere. It will do this whenever it detects leakage greater than a predetermined rate. This rate was initially based upon the amount permitted to escape through a 1 mm (0. 04”) diameter hole, and for later models, a 0.5mm (0.02”) diameter hole.



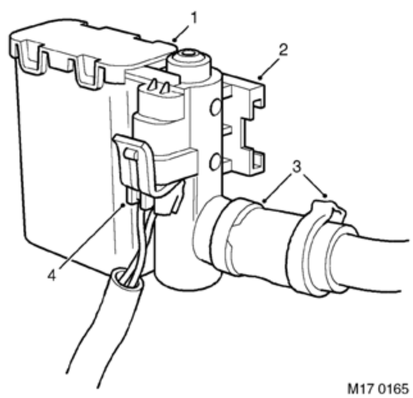
1	Purge valve	8	Anti-trickle valve
2	Service port	9	Liquid vapor separator
3	Canister Vent Solenoid (CVS) unit	10	Fuel filler cap
4	Filler neck	11	Roll over valves (ROV's)
5	Charcoal canister breather tube	12	Fuel tank assembly
6	Vent pipe to charcoal canister	13	Charcoal canister
7	Pipe connection to OBD sensor in fuel pump	14	Purge line connection to engine manifold

The ECM uses the purge system and a fuel tank pressure sensor to check the integrity of the fuel system. The ECM purges the charcoal canister of vapor and then closes the charcoal canister vent valve. This action produces a vacuum within the fuel tank. At a predetermined vacuum, the purge valve is closed. This action seals the fuel system. The ECM then monitors the rate at which the pressure within the fuel tank climbs to atmospheric pressure. The rate at which the pressure equalises is assessed against a ‘model’ (i.e. a pre-programmed map) of fuel evaporation. If a leak exists, then the pressure will equalize rapidly.

The ECM completes the purge test only while the vehicle is stationary and the engine is at idle. The test compensates for the natural evaporation of gasoline, which occurs when it is exposed to a slight vacuum. If any condition is detected that would produce an excessive level of natural evaporation levels (e.g. excessive air temperatures or a large degree of movement of fuel within the fuel tank), the diagnostic is cancelled.

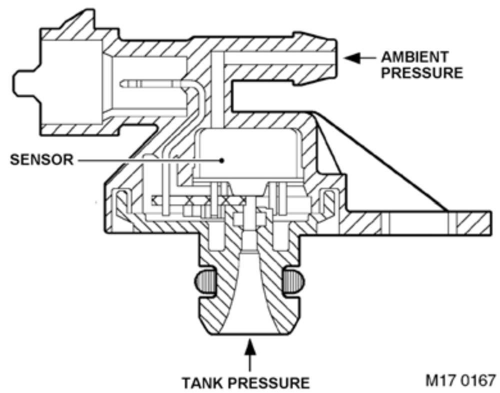


Canister Vent Solenoid Assy.



Purge Control Valve

If the ECM detects a leak in the fuel system (i.e. it has an air leak greater than 1 mm (0. 04”) in it), it will record a fault code. A loose fuel filler cap can cause the ECM to incorrectly diagnose an excessive air leak, so always ensure that the fuel filler cap is tight if the ECM has logged a present fault with the EVAP system. If the ECM records a fault code, the engine speed, engine coolant temperature and battery voltage is also recorded when the fault is first recognized. If the ECM detects a fault within the EVAP system on two consecutive ‘journeys’, then it will illuminate the MIL lamp.



Fuel Tank Pressure Sensor

Secondary Air Injection (SAI)

The secondary air injection system is used to limit the emission of carbon monoxide (CO) and hydrocarbons (HCs) that are prevalent in the exhaust during cold starting of a spark ignition engine. The concentration of hydrocarbons experienced during cold starting at low temperatures are particularly high until the engine and catalytic converter reach normal operating temperature. The lower the cold start temperature, the greater the prevalence of hydrocarbons emitted from the engine.

There are several reasons for the increase of HC emissions at low cold start temperatures, including the tendency for fuel to be deposited on the cylinder walls, which is then displaced during the piston cycle and expunged during the exhaust stroke. As the engine warms up through operation, the cylinder walls no longer retain a film of fuel and most of the hydrocarbons will be burned off during the combustion process.

The secondary air injection (SAI) system uses the following components:

- Secondary air injection pump
- SAI vacuum solenoid valve
- SAI control valves (2 valves, 1 for each bank of cylinders)
- SAI pump relay
- Vacuum reservoir
- Vacuum harness and pipes

The SAI pump is used to provide a supply of air into the exhaust ports in the cylinder head, onto the back of the exhaust valves, during the cold start period. The hot unburned fuel particles leaving the combustion chamber mix with the air injected into the exhaust ports and immediately combust. This subsequent combustion of the unburned and partially burned CO and HC particles help to reduce the emission of these pollutants from the exhaust system. The additional heat generated in the exhaust manifold also provides rapid heating of the exhaust system catalytic converters. The additional oxygen which is delivered to the catalytic converters also generate an exothermic reaction which causes the catalytic converters to ’light off’ quickly.

The catalytic converters only start to provide effective treatment of emission pollutants when they reach an operating temperature of approximately 250° C (482° F) and need to be between temperatures of 400° C (752° F) and 800° C (1472º F) for optimum efficiency. Consequently, the heat produced by the secondary air injection “afterburning”, reduces the time delay before the catalysts reach an efficient operating temperature.

The engine control module (ECM) checks the engine coolant temperature when the engine is started, and if it is below 55° C (131° F), the SAI pump is started. Secondary air injection will remain operational for a period controlled by the ECM and is dependent on the starting temperature of the engine. This varies from approximately 95 seconds for a start temperature of 8° C (46° F) to 30 seconds for a start temperature of 55° C (131° F). The SAI pump operation can be cut short due to excessive engine speed or load.

Air from the SAI pump is supplied to the SAI control valves via pipe work and an intermediate T-piece which splits the air flow evenly to each bank.

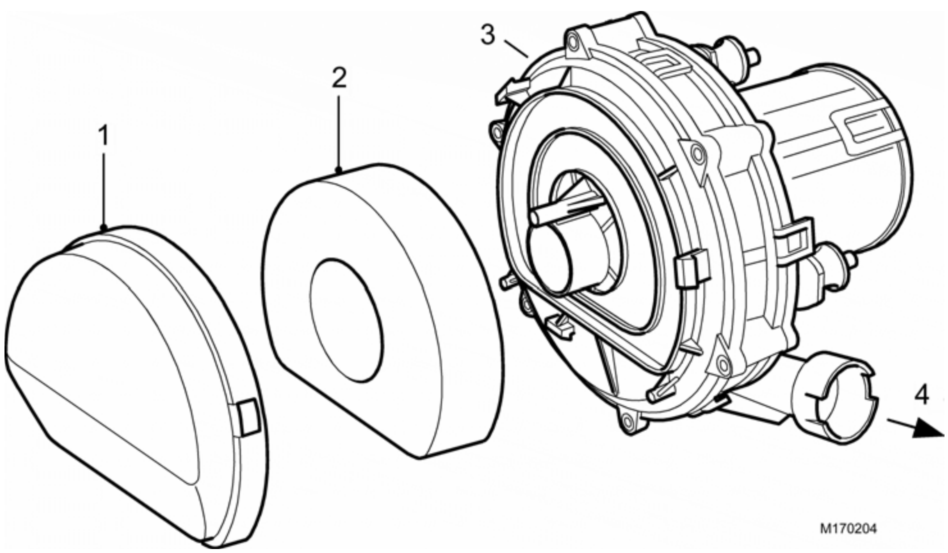
At the same time the secondary air pump is started, the ECM operates a SAI vacuum solenoid valve, which opens to allow vacuum from the reservoir to be applied to the vacuum operated SAI control valves on each side of the engine.

When the vacuum is applied to the SAI control valves, they open simultaneously to allow the air from the SAI pump through to the exhaust ports. Secondary air is injected into the inner most exhaust ports on each bank.

When the ECM breaks the ground circuit to de-energize the SAI vacuum solenoid valve, the vacuum supply to the SAI control valves is cut off and the valves close to prevent further air being injected into the exhaust manifold. At the same time as the SAI vacuum solenoid valve is closed, the ECM opens the ground circuit to the SAI pump relay, to stop the SAI pump.

A vacuum reservoir is included in the vacuum line between the intake manifold and the SAI vacuum solenoid valve. This prevents changes in vacuum pressure from the intake manifold being passed on to cause fluctuations of the secondary air injection solenoid valve. The vacuum reservoir contains a one way valve and ensures a constant vacuum is available for the SAI vacuum solenoid valve operation. This is particularly important when the vehicle is at high altitude.

Secondary air injection (SAI) pump



1	SAI pump cover	3	SAI pump
2	Foam filter	4	Pressurized air to exhaust manifolds

The SAI pump is attached to a bracket at the rear RH side of the engine compartment and is fixed to the bracket by three studs and nuts. The pump is electrically powered from a 12V battery supply via a dedicated relay and supplies approximately 35kg/hr of air when the vehicle is at idle in Neutral/Park on a start from 20C (68F).

Air is drawn into the pump through vents in its front cover and is then passed through a foam filter to remove particulates before air injection. The air is delivered to the exhaust manifold on each side of the engine through a combination of plastic and metal pipes.

The air delivery pipe is a flexible plastic type, and is connected to the air pump outlet via a plastic quick-fit connector.

The other end of the flexible plastic pipe connects to the fixed metal pipe work via a short rubber hose. The part of the flexible plastic pipe which is most vulnerable to engine generated heat is protected by a heat reflective sleeve. The metal delivery pipe has a fabricated T-piece included where the pressurized air is split for delivery to each exhaust manifold via the SAI control valves.

The pipes from the T-piece to each of the SAI control valves are approximately the same length, so that the pressure and mass of the air delivered to each bank will be equal. The ends of the pipes are connected to the inlet port of each SAI control valve through short rubber hose connections.

The T-piece is mounted at the rear of the engine (by the ignition coils) and features a welded mounting bracket which is fixed to the engine by two studs and nuts.

The foam filter in the air intake of the SAI pump provides noise reduction and protects the pump from damage due to particulate contamination. In addition, the pump is mounted on rubber mountings to help prevent noise which is generated by pump operation from being transmitted through the vehicle body into the passenger compartment.

The SAI pump has an integral thermal cut-out switch, to stop pump operation when the pump overheats. The pump automatically enters a 'soak period' between operations, to allow the pump motor a cooling off period.

If the secondary air injection pump malfunctions, the following fault codes may be stored in the ECM diagnostic memory, which can be retrieved using 'Testbook':

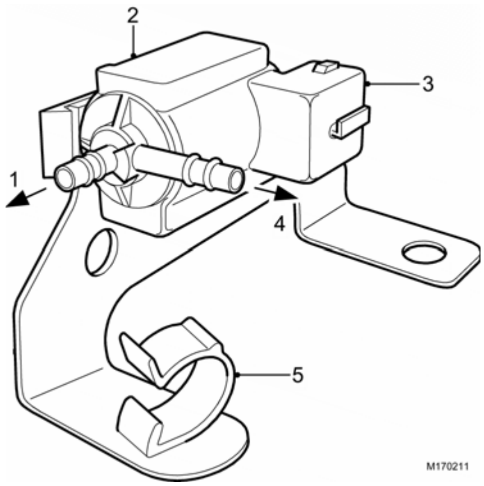
P-code	Description
P0418	Secondary air injection pump power stage fault (e.g. - SAI pump relay fault / SAI pump or relay not connected / open circuit / harness damage).

Secondary air injection (SAI) pump relay

The secondary air injection pump relay is located in the engine compartment fuse box. The engine control module (ECM) is used to control the operation of the SAI pump via the SAI pump relay. Power to the coil of the relay is supplied from the vehicle battery via the main relay and the ground connection to the coil is via the ECM.

Power to the SAI pump relay contacts is via fusible link FL2 which is located in the engine compartment fuse box.

Secondary air injection (SAI) vacuum solenoid valve



1 Vacuum port to intake manifold (via vacuum reservoir)

2 SAI vacuum solenoid valve

3 Electrical connector

4 Vacuum port to vacuum operated SAI control valves

5 Purge valve clip

The SAI vacuum solenoid valve is located at the rear LH side of the engine and is electrically operated under the control of the ECM. The SAI vacuum solenoid valve is mounted on a bracket together with the EVAP system purge valve.

Vacuum to the SAI vacuum solenoid valve is provided from the intake manifold depression via a vacuum reservoir. A small bore vacuum hose with rubber elbow connections at each end provides the vacuum route between the vacuum reservoir and SAI vacuum solenoid valve. A further small bore vacuum hose with a larger size elbow connector is used to connect the SAI vacuum solenoid valve to the SAI control valves on each side of the engine via an intermediate connection. The SAI vacuum solenoid valve port to the SAI control valves is located at a right angle to the port to the vacuum reservoir.

The intermediate connection in the vacuum supply line is used to split the vacuum equally between the two SAI control valves. The vacuum hose intermediate connection is located midpoint in front of the inlet manifold. All vacuum hose lines are protected by flexible plastic sleeves.

Electrical connection to the SAI vacuum solenoid valve is via a 2–pin connector. A 12V electrical power supply to the SAI vacuum solenoid valve is provided via the Main relay and Fuse 2 in the engine compartment fuse box. The ground connection is via the ECM which controls the SAI vacuum solenoid valve operation.

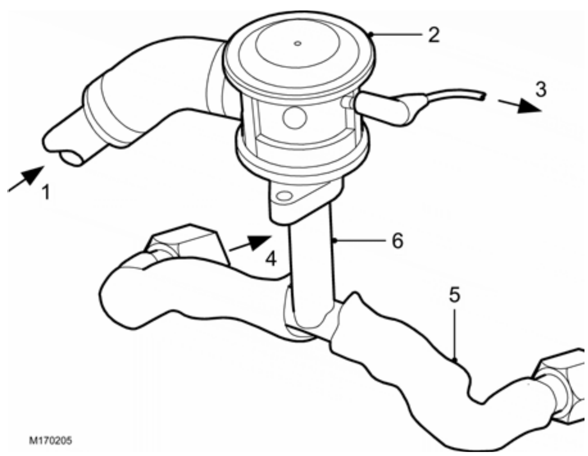
NOTE: The harness connector to the SAI solenoid valve is grey, and must not be confused with the harness connector to the EVAP system purge valve which is black.

The ECM switches on the SAI vacuum solenoid valve at the same time as initiating SAI pump operation. When the SAI vacuum solenoid valve is open, a steady vacuum supply is allowed through to open the two vacuum operated SAI control valves. When the ECM breaks the earth path to the SAI vacuum solenoid valve, the valve closes and immediately shuts off the vacuum supply to the two SAI control valves at the same time as the SAI pump operation is terminated.

If the SAI vacuum solenoid valve malfunctions, the following fault codes may be stored in the ECM diagnostic memory, which can be retrieved using ’Testbook’:

P-code	Description
P0413	SAI vacuum solenoid valve not connected, open circuit
P0414	SAI vacuum solenoid valve short circuit to ground
P0412	SAI vacuum solenoid valve power stage fault - harness damage, short circuit to battery supply voltage

SAI control valves



1	Pressurized air from SAI pump	4	Pressurized air to exhaust manifold
2	Vacuum operated SAI control valve	5	Protective heat sleeve
3	Vacuum hose from SAI vacuum solenoid valve	6	Air delivery pipe to exhaust manifold

The SAI control valves are located on brackets at each side of the engine.

The air injection supply pipes connect to a large bore port on the side of each SAI control valve via a short rubber connection hose. A small bore vacuum port is located on each SAI control valve at the opposite side to the air injection supply port. The vacuum supply to each vacuum operated SAI control valve is through small bore nylon hoses from the SAI vacuum solenoid valve. An intermediate connector is included in the vacuum supply line to split the vacuum applied to each vacuum operated valve, so that both valves open and close simultaneously.

When a vacuum is applied to the SAI control valves, the valve opens to allow the pressurized air from the SAI pump through to the exhaust manifolds. The injection air is output from each SAI control valve through a port in the bottom of each unit. A metal pipe connects between the output port of each SAI control valve and each exhaust manifold via an intermediate T-piece. The T-piece splits the pressurized air delivered to ports at the outer side of the two center exhaust ports on each cylinder head. The pipes between the T-piece and the exhaust manifold are enclosed in thermal sleeves to protect the surrounding components from the very high heat of the exhaust gas, particularly at high engine speeds and loads.

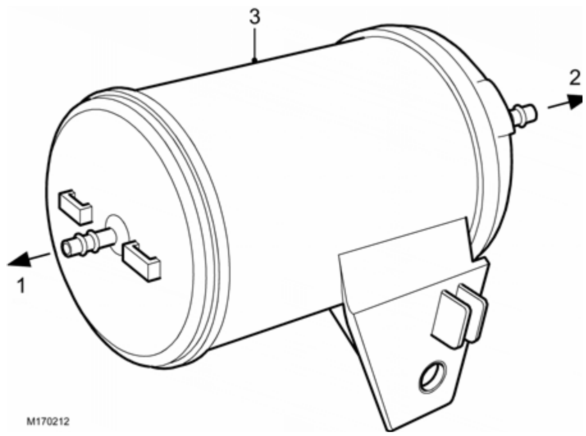
When the SAI vacuum solenoid valve is de-energized, the vacuum supply line opens to atmosphere, this causes the vacuum operated valves to close automatically and completely to prevent further air injection.

If the vacuum operated SAI control valves malfunction, the following fault codes may be stored in the ECM diagnostic memory, which can be retrieved using ’Testbook’:

P-code	Description
P1412	SAI system fault (LH side) - air delivery not reaching catalysts
P1414	SAI system fault (LH side) - air delivery not reaching catalysts
P1413	SAI system fault (LH side) - air delivery not reaching catalysts
P1415	SAI system fault (RH side) - air delivery not reaching catalysts
P1417	SAI system fault (RH side) - air delivery not reaching catalysts
P1416	SAI system fault (RH side) - air delivery not reaching catalysts

The above system faults could be attributable to anything which might prevent air delivery to the exhaust manifolds (e.g. disconnected or blocked SAI delivery pipe, disconnected or blocked vacuum pipe etc.)

Vacuum reservoir



1 Vacuum port to SAI vacuum solenoid valve

2 Vacuum port to intake manifold (one-way valve end)

3 Vacuum reservoir

A vacuum reservoir is included in the vacuum supply line between the intake manifold and the SAI vacuum solenoid valve. The vacuum reservoir contains a one-way valve, to stop vacuum from leaking back towards the intake manifold side. The reservoir holds a constant vacuum so that the SAI control valves open instantaneously as soon as the SAI solenoid valve is energized.

The vacuum reservoir is a plastic canister construction located on a bracket at the LH side of the engine compartment.

It is important to ensure the reservoir is installed in the correct orientation, and the correct vacuum hoses are attached to their corresponding ports. The one-way valve end of the vacuum reservoir (cap end, to inlet manifold) is installed towards the rear of the vehicle.

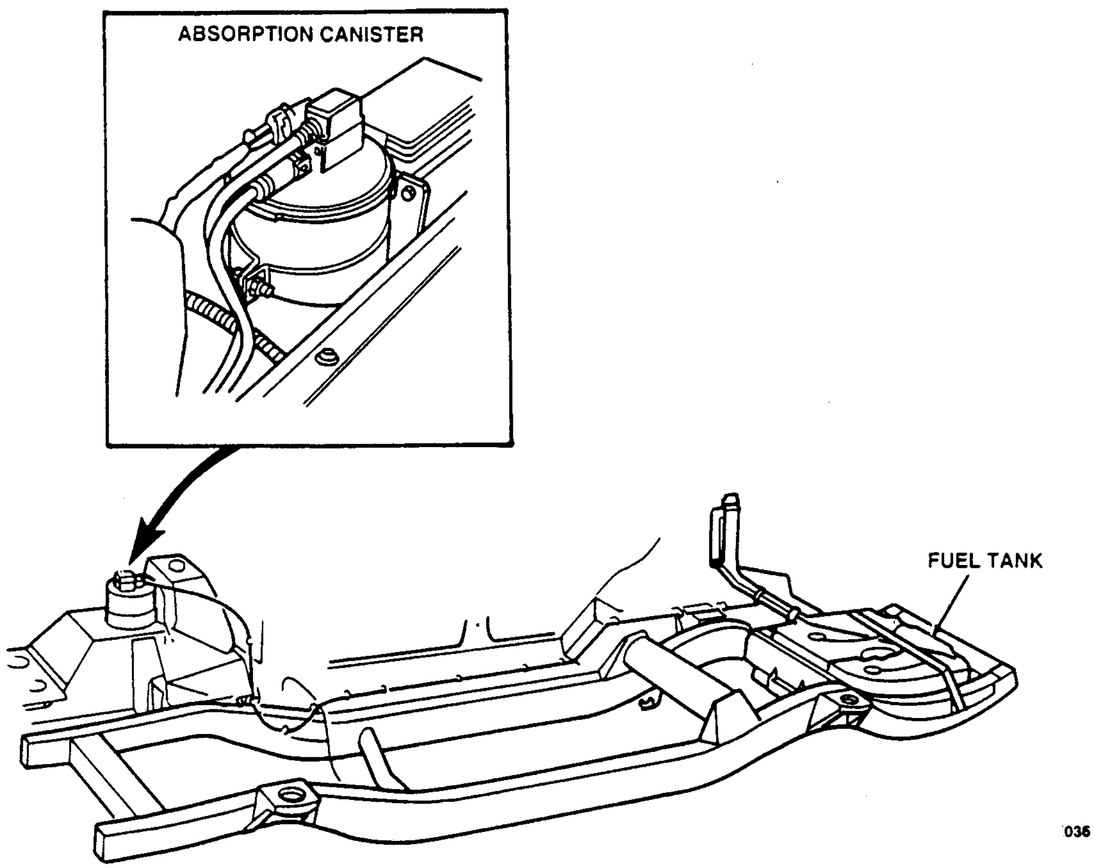
A small bore nylon hose is used to connect the one-way valve end of the vacuum reservoir to a port on the RH side of the inlet manifold. A further hose connects between the other port on the vacuum reservoir and a port on the front of the SAI vacuum solenoid valve.

EVAPORATIVE EMISSION CONTROL SYSTEM (EVAP)

EVAPORATIVE PURGE

As gasoline from the fuel tank is pumped to the engine, air must enter the system to prevent a vacuum from developing. However, harmful hydrocarbon vapors form in the fuel tank as gasoline evaporates.   Venting the fuel tank directly to the atmosphere would allow these vapors to escape.

To prevent this from occurring, fuel system vapors are routed to a charcoal canister which absorbs and stores fuel vapor from the tank when the engine is not running. Once the engine is started, the vapor is purged from the canister by fresh air drawn through an orifice at the base of the canister and the vacuum introduced at the top.



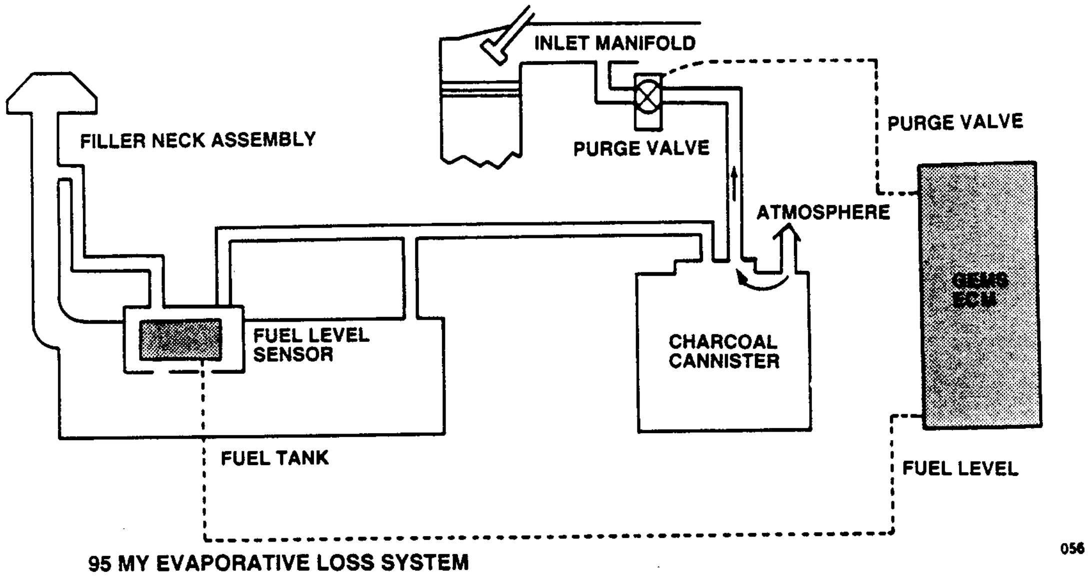
Evaporative Purge System Components

On 1989 and later vehicles, purge operation is controlled by the ECM through a solenoid valve. When the valve is opened, the vapor is drawn into the plenum to be added to the air/fuel mixture. Control of evaporative purge operation is an important ECM function for effective emission control.

When operating, purge flow into the plenum is not accounted for in the ECM's air/fuel calculations. Because of this, purge operation is saved for those times when the additional vapor is least likely to affect emissions. Typically, this is when the engine is warm and operating well above idle speed.

The ECM controls the flow rate by opening, closing, or pulsing the solenoid valve. The ECM monitors purge flow by looking for signs from the oxygen sensors that the fuel mixture has been enriched when the solenoid valve is opened. When this no longer occurs, the ECM interprets this to mean that no more vapor is present. Purge operation is discontinued at this time.

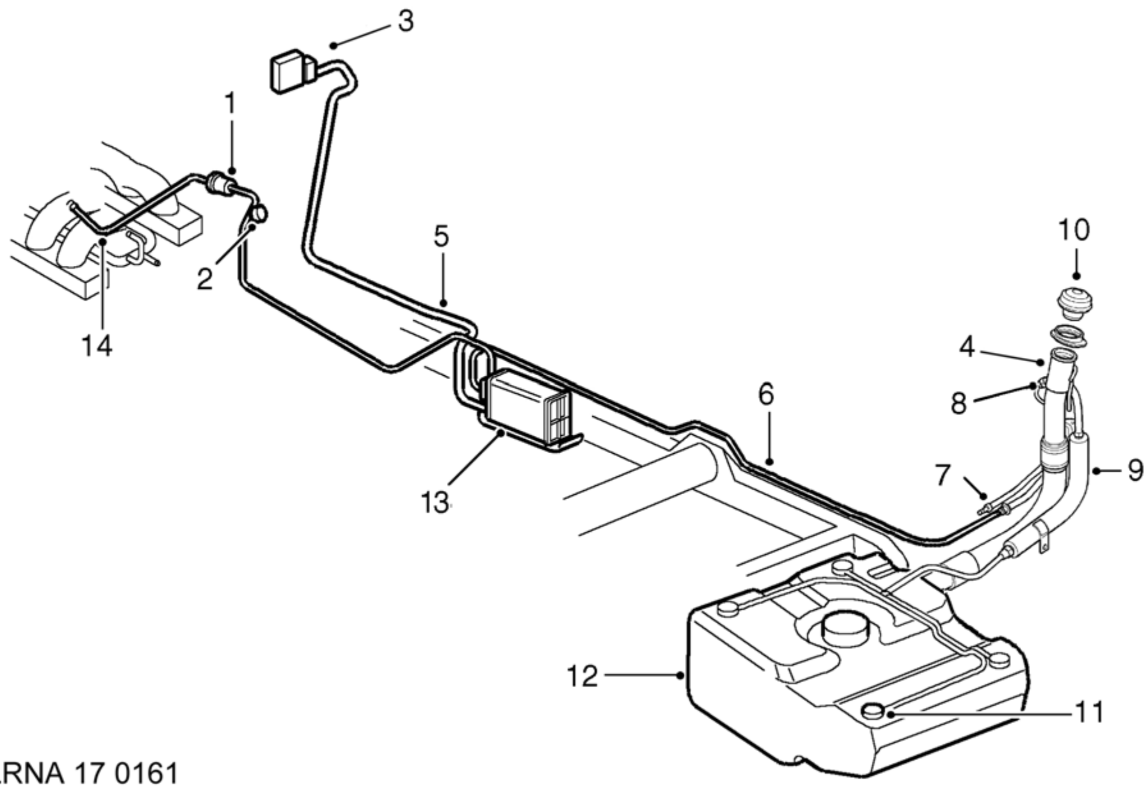
It is important that purge occur only as long as vapor is present. This reduces the time period in which unmetered air is introduced into the plenum. A purge solenoid stuck in the open position will increase vehicle emissions and affect driveability, especially at idle.



Purge Operation

EVAP With Leak Detection

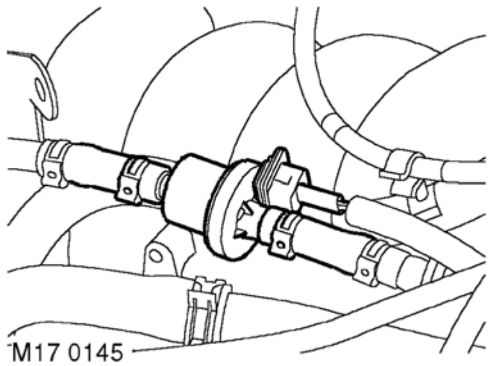
OBDII Legislation requires that the ECM must indicate the occurrence of a fault to the driver, if a leak in the fuel system allows hydrocarbons to escape to atmosphere. It will do this whenever it detects leakage greater than a predetermined rate. This rate was initially based upon the amount permitted to escape through a 1 mm (0. 04”) diameter hole, and for later models, a 0.5mm (0.02”) diameter hole.



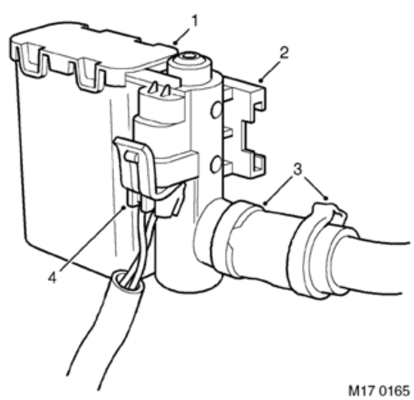
1	Purge valve	8	Anti-trickle valve
2	Service port	9	Liquid vapor separator
3	Canister Vent Solenoid (CVS) unit	10	Fuel filler cap
4	Filler neck	11	Roll over valves (ROV's)
5	Charcoal canister breather tube	12	Fuel tank assembly
6	Vent pipe to charcoal canister	13	Charcoal canister
7	Pipe connection to OBD sensor in fuel pump	14	Purge line connection to engine manifold

The ECM uses the purge system and a fuel tank pressure sensor to check the integrity of the fuel system. The ECM purges the charcoal canister of vapor and then closes the charcoal canister vent valve. This action produces a vacuum within the fuel tank. At a predetermined vacuum, the purge valve is closed. This action seals the fuel system. The ECM then monitors the rate at which the pressure within the fuel tank climbs to atmospheric pressure. The rate at which the pressure equalises is assessed against a ‘model’ (i.e. a pre-programmed map) of fuel evaporation. If a leak exists, then the pressure will equalize rapidly.

The ECM completes the purge test only while the vehicle is stationary and the engine is at idle. The test compensates for the natural evaporation of gasoline, which occurs when it is exposed to a slight vacuum. If any condition is detected that would produce an excessive level of natural evaporation levels (e.g. excessive air temperatures or a large degree of movement of fuel within the fuel tank), the diagnostic is cancelled.

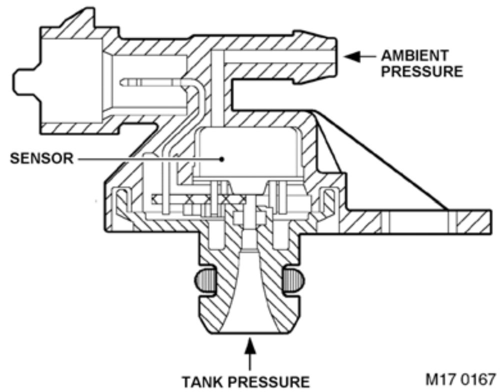


Canister Vent Solenoid Assy.



Purge Control Valve

If the ECM detects a leak in the fuel system (i.e. it has an air leak greater than 1 mm (0. 04”) in it), it will record a fault code. A loose fuel filler cap can cause the ECM to incorrectly diagnose an excessive air leak, so always ensure that the fuel filler cap is tight if the ECM has logged a present fault with the EVAP system. If the ECM records a fault code, the engine speed, engine coolant temperature and battery voltage is also recorded when the fault is first recognized. If the ECM detects a fault within the EVAP system on two consecutive ‘journeys’, then it will illuminate the MIL lamp.



Fuel Tank Pressure Sensor

ON-BOARD DIAGNOSTICS

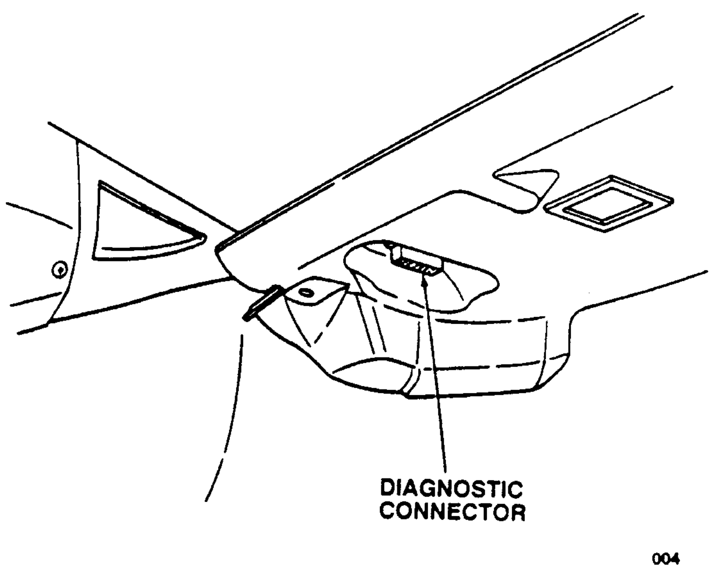
The development and adoption of legislation calling for more stringent automotive emission requirements, initiated by the California Air Resources Board (CARB), is now part of the Federal Clean Air Act. This legislation is an extension and enhancement of previous requirements (OBD) and is known as On-Board Diagnostics II (OBD II). Federal law requires that by the 1996 model year, vehicles sold in the United States meet common standards for emission control and diagnostic capability. GEMS allows Land Rover products to meet these operating standards.

Monitoring Emissions Performance

The original OBD required that vehicles monitor operation of key components such as oxygen sensors, fuel delivery system, and the module controlling the system's powertrain. Failure of components in these systems is indicated by MIL illumination and generation of a Diagnostic Trouble Code (DTC).

OBD II takes this monitoring a step further by not only checking the operation of emission components, but their performance. While the difference between monitoring operation and performance may sound small, the changes to ECM operating strategies required to accomplish this are enormous.

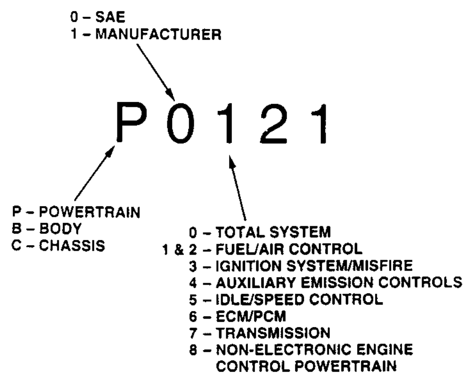
OBD II regulations require the vehicle's MIL to be illuminated and a DTC generated when system operating conditions are such that vehicle emissions will exceed 15% of the original emissions specification. DTCs are retrieved using the TestBook or any diagnostic scan tool. All vehicles meeting OBD II standards use a standardized 16-pin connector for engine management system diagnostics. The Diagnostic connector on the Range Rover is located in the front passenger's footwell, near the center console.



16-Pin Connector

Diagnostic Trouble Codes (DTC)

OBD II requires that diagnostic trouble codes for common components are provided by all manufacturers. These codes must follow the format developed in the Society of Automotive Engineer's (SAE) standard J2012. This five-digit code consists of four numbers preceded by a single letter.

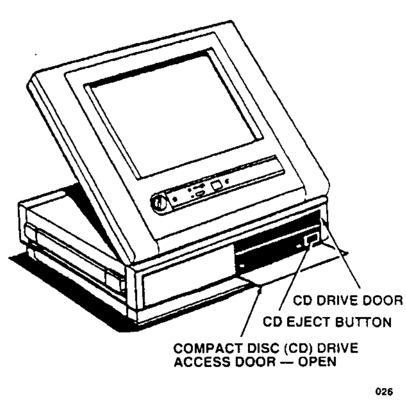


Five-Digit DTC

The initial letter designates the vehicle system to which the code refers. All powertrain codes begin with the letter P. The first number indicates who was responsible for the DTC definition. The number “0” indicates an SAE defined code required under OBD II while “1” indicates that this code definition is manufacturer-specific (in this case, Land Rover). The “1” codes allow manufacturers to develop diagnostic capabilities over and above those required by OBD II.

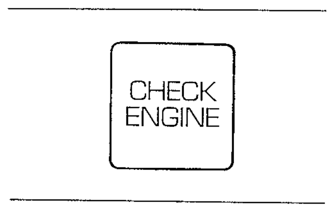
The third digit (second number) of the powertrain DTC ranges from 0 through 8 and indicates the specific system subgroup. The fourth and fifth places indicate the specific concern the DTC addresses.

The number of diagnostic codes that can be produced by the ECM has increased substantially with the introduction of OBD II. A complete list of P-codes is included at the end of this chapter. The good news is that these codes are far more specific than those previously available. This helps technician's pinpoint the cause of a customer concern more quickly than in the past. All DTCs can be retrieved with a hand held scan tool or T4/WDS.



TestBook

Diagnostic System Manager
OBD II requires that more components be monitored for a wider range of “failures” that previously may have gone unnoticed. Because of this, you can expect the MIL to illuminate more often than in the past.



Malfunction Indicator Lamp (MIL)

The ECM does, however, contain a special diagnostic strategy or Diagnostic System Manager (DSM) to help prevent unnecessary MIL illumination. The DSM delays vehicle self-tests, known as OBD II monitors, until the appropriate operating conditions for the test (engine temperature, rpm, engine load conditions) are present. This provides the best indicator of fuel system and emissions control operation under real driving conditions.

The designers of OBD II also recognize that unique operating conditions can produce emissions that, for a brief period, exceed allowable levels even though engine systems are operating properly. To prevent these infrequent glitches from triggering the MIL, in most cases the DSM requires that the system exceed allowable levels on two consecutive test sequences (known as trips) before the MIL is illuminated.

The DSM software also runs the tests in a specific order. This minimizes the production of misleading DTCs. If a component or system should fail, there is no sense in performing additional tests on systems or components which rely on the failed component. They'll fail too! The GEMS diagnostic strategy doesn't bother to run tests dependent on failed components/ systems until they are operating properly.

OBDII Monitoring
The OBD II system test strategy performs self-diagnostics on related systems (known as Monitors) as required by federal regulations. These OBD II Monitors are listed below. They will be covered in greater detail later in the lesson.

- Misfire Monitor
- Comprehensive Component Monitor
- Fuel System Monitor
- Catalyst Efficiency Monitor

Warm-up Cycle
A term used in discussing OBD II diagnostic strategy is warm-up cycle. The ECM uses the number of warm-up cycles as a counting device. After a specified number of warm-up cycles (typically 40) DTCs that are no longer relevant to the engine operating condition are automatically erased from the ECM’s memory.

This is important from a technician's standpoint because DTCs and information from a concern that illuminated a customer's MIL at one time may no longer be in the ECM's memory. If the source of the concern is no longer present (bad gasoline) and the customer has waited a long time before coming in - you won't find information to work with. On the other hand, old and irrelevant information isn't likely to be present to mislead you when searching for current concerns.

The definition of a warm-up cycle is very specific. It includes engine operation, after an engine OFF period, where engine coolant temperature rises at least 22° C (40° F) and reaches at least 71° C (160° F). It then must cool down below 71° C (160° F).

OBD II Trip
Another important concept is that of the OBD II Trip. This is defined as engine operation after an engine OFF period, where OBD II components are tested and the following monitors are completed:

- Misfire
- Comprehensive Component
- Fuel System

The completion of an OBD II Trip is required for most of the new diagnostic strategies that can produce MIL illumination.

OBDII Monitors
The ECM performs a battery of tests on specific vehicle systems to determine if they are operating within the parameters set by OBD II. The Diagnostic System Manager software ensures that the tests are performed at specific times and in the correct sequence in order to produce valid results. Testing the vehicle while cold, or in unusual operating conditions (such as during evaporative purge) could produce false readings that would illuminate the vehicle's MIL unnecessarily .

Comprehensive Component Monitor
ECM inputs and outputs are checked frequently during engine operation. As in the original OBD application, these components and their circuits are checked for operation. Tests for shorts and opens are performed. Some tests require system or component actuation so a change of state can be observed. DTCs and MIL illumination occur when a fault is recorded.

OBD II requires even more careful review of these input and output components by not only determining if they are operating, but also by performing rationality checks. By comparing the readings from other sensors, the GEMS can determine if a sensor reading is appropriate for the current operating conditions. An example of this is a throttle position sensor signal indicating the throttle is half open when other inputs and outputs (rpm, IACV) suggest the engine is at idle.

A specific DTC is stored as soon as a fault is detected. The system must fail the test on two consecutive drive cycles before the MIL is illuminated.

The GEMS will continue testing failed or out of range components, even after the MIL is illuminated. Should the system pass the test on three consecutive trips, the MIL will turn off. The DTC will remain stored however, for 40 more warm-up cycles.

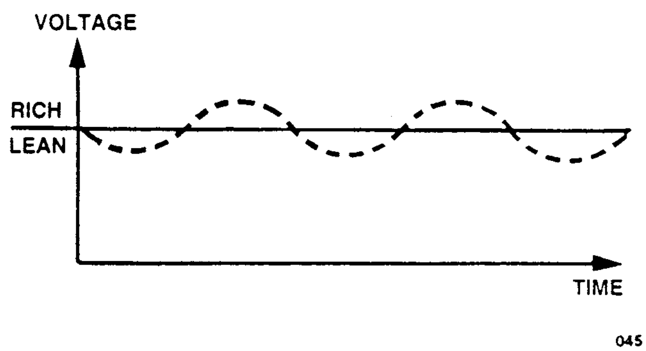
Fuel System Monitor
The ECM continually adjusts fuel trim when in closed loop operation. If a system malfunction occurs, requiring an amount of fuel trim compensation that exceeds standards set in the GEMS program, a DTC will be stored. The ECM monitors the fuel system continuously once it is operating in closed loop.

Should fuel trim requirements fall outside of the acceptable parameters on a second consecutive trip, the MIL will be illuminated. If the system concern does not repeat itself for three consecutive trips, the MIL will turn off. The DTC will remain stored for 40 more warm-up cycles.

NOTE: It is important to understand that two consecutive trips is not the same as two warm-up cycles. Two consecutive trips could occur two weeks apart, with dozens of warm-up cycles in between.

Catalyst Efficiency Monitor

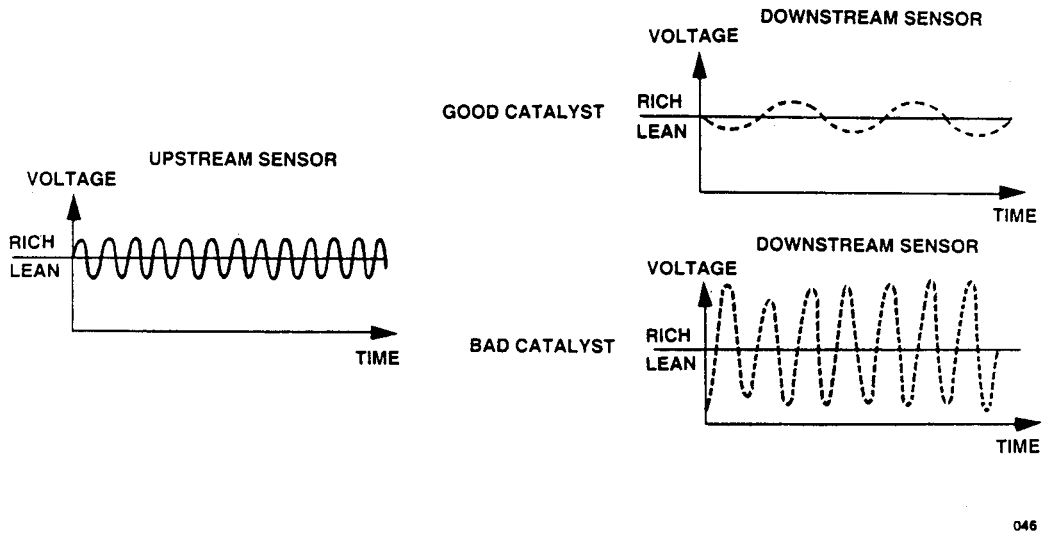
The Three-Way Catalyst (TWC) or catalytic converter, is a central device in the vehicle's emissions control system. Over time, deterioration of a catalyst's operating efficiency can lead to an increase in hydrocarbon emissions. OBD II requires that the ECM monitor operation of the vehicle's TWCs to ensure that they are operating within specification. This is accomplished by monitoring signals produced by oxygen sensors mounted ahead of (upstream) and below (downstream) of each TWC.



Catalyst Signal

A properly functioning three-way catalyst stores oxygen during lean engine operation and gives up that stored oxygen during rich engine operation to consume unburned hydrocarbons. Catalyst efficiency is estimated by monitoring the oxygen storage capacity of the catalyst during closed-loop operation.

The GEMS monitors the switching frequency of the downstream HO2S during the test. Because the sensor switches in the presence of oxygen, it should have a significantly lower switching frequency than the sensor mounted ahead of the catalyst.



Rear Catalyst Monitor

A frequency approaching that of the upstream sensor would indicate that the TWC is not storing oxygen during lean operation. This lack of stored oxygen renders the TWC incapable of burning off excess hydrocarbons produced during the rich cycle. The result is excessive hydrocarbon emissions.

Catalyst efficiency is tested once each drive cycle. The first time the system fails a self-test, the ECM will store a DTC. The system must fail the test on two consecutive drive cycles before the MIL is illuminated.

The Diagnostic System Manager will continue testing for catalyst efficiency once each drive cycle, even after the MIL is illuminated. Should the system pass the test on three consecutive drive trips, the MIL will turn off. The DTC will remain stored, however, for 40 more warm-up cycles.

Misfire Monitor

Cylinder misfire poses a serious threat to the vehicle's emissions system. Misfires produce concerns ranging from open ignition circuits to fouled spark plugs. As a cylinder misfires, the raw hydrocarbons (HC) that should have been consumed during ignition are forced out of the exhaust manifold. Obviously, this adversely affects vehicle emissions. Worse however, is what happens after these raw HCs leave the engine and enter the three-way catalyst (TWC).

As these raw hydrocarbons move into the catalyst, the internal temperature of the converter increases. Continued operation can cause the catalytic honeycomb to melt into a solid mass, destroying the catalyst's ability to function. Eventually, the TWC may cause so much restriction that the excessive backpressure prevents the engine from running. Obviously, detecting and preventing engine operation under misfire conditions is a high priority of an emissions control system.

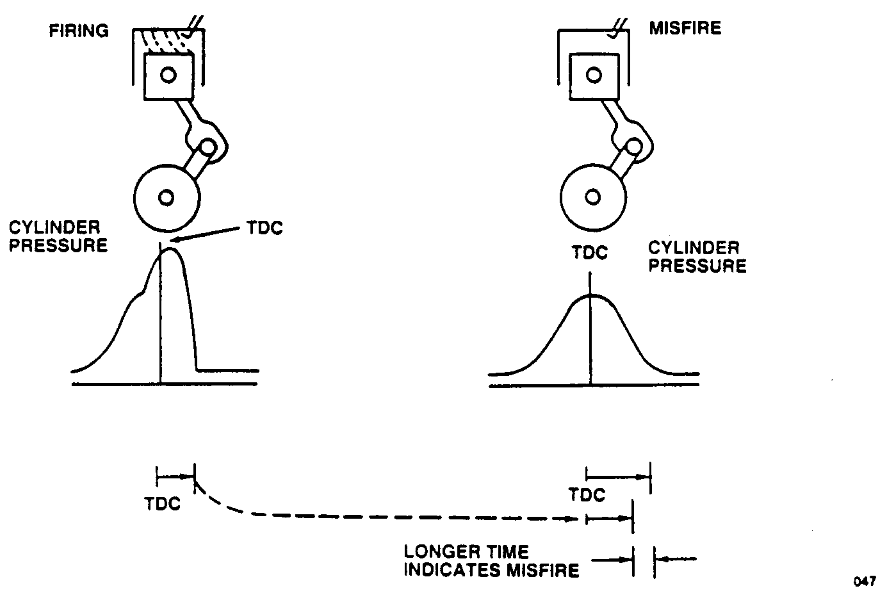
The ECM detects engine misfire by measuring the contribution each cylinder makes to engine performance. This is calculated from measurements of crankshaft acceleration for each cylinder provided by the crankshaft position sensor.

The acceleration for each cylinder is determined from the crankshaft rotation velocity. The GEMS performs a series of calculations to determine the acceleration rates of the individual cylinders. When a cylinder's acceleration falls outside of a predetermined range, the GEMS takes a closer look at the signal.

For example, operating conditions such as rough roads or high rpm/light load operation can provide misfire-like changes in crankshaft acceleration. Internal programming in the GEMS is designed to filter out these look-alike signals and focus on real misfire. The GEMS separates misfire into two classifications, and has a different response for each.

Type A Misfire:
This is a serious misfire situation where raw fuel entering the TWC can cause excessive catalyst temperatures. This could quickly cause permanent damage to the TWC. In this situation, the MIL lamp illuminates immediately and flashes to attract the driver's attention. Continued operation at this point will damage the TWC.

Type B Misfire:
A second type of response occurs when the GEMS detects a low-level misfire. At lower levels, misfire will not significantly raise TWC temperature but will produce excessive vehicle emissions. In this situation, the GEMS records a DTC. The GEMS will illuminate the MIL if this failure is repeated during a second consecutive drive cycle where operating conditions (engine warm-up, rpm and load) are approximately the same. Should the misfire not reappear under these conditions on three consecutive trips, the MIL will turn off.



Crankshaft Acceleration Signal

Freeze Frame

OBD II provides a special diagnostic screen known as freeze frame, to help technicians determine the exact conditions that caused a MIL to be illuminated. Freeze frame traps the following data the moment a monitor fails:

- DTC
- Fuel System Status (Open/Closed Loop)
- Engine Load*
- Coolant Temperature
- Short Term Fuel Trim (Bank 1)**
- Long Term Fuel Trim (Bank 1)**
- Short Term Fuel Trim (Bank 2)***
- Long Term Fuel Trim (Bank 2)***
- RPM
- Vehicle Speed
- Intake Air Temperature
- Throttle Position

Accessing this data can help you determine the nature of the concern and the steps required to solve the problem.

* Engine load is represented by a "Calculated load value" which refers to an indication of the current airflow divided by peak airflow, where peak airflow is corrected for altitude, if available. This definition provides a unitless number that is not engine specific, and provides the service technician with an indication of the percent engine capacity that is being used (with wide open throttle as 100%).

$$CLV = \frac{\text{Current Airflow}}{\text{•Peak airflow (@ sea level)}} \times \frac{\text{Atm Pressure (@ sea level)}}{\text{•Barometric pressure}}$$

** Also known as Bank “A”, Odd bank, or left bank

*** Also known as Bank “B”, Even bank, or right bank

Service Drive Cycles

While each of the OBD II monitors is often completed during the course of normal driving, there is a way to be sure they run in a single driving session. This is called the Service Drive Cycle, and is of value to technicians diagnosing OBD II concerns.

Plan a test route that will allow you to accomplish the tasks listed. Obey posted speeds and all traffic laws.

1. Allow vehicle to cold soak until coolant temperature is less than 60° C (140° F).
2. Start engine.
3. Idle for approximately 8 minutes. Diagnostics for misfire, sensors and actuators will run and produce an outcome. An additional test requiring the engine to run for a total of 15 minutes is present. Idling is the most efficient way to achieve this.
4. Shift to Drive. Accelerate up an incline at wide open throttle to maintain a high engine load for approximately 10 seconds. This allows Neutral/Drive switch and Road Speed diagnostics to take place.
5. Drive on and off the throttle so that a total of 40 gear changes take place. (Shifts from Park to Drive or Drive to Neutral don't count toward this total).
6. Accelerate to 35-45 mph and maintain this speed at a steady load for approximately three minutes. This allows fuel trim adaptations and catalyst monitoring to take place.
7. Slow to idle and place the transmission in Park.
8. Bring the engine to 1500-2000 rpm for approximately one minute.
9. Idle for two minutes, then turn ignition to OFF.

LAND ROVER FUEL INJECTION SYSTEMS

INTRODUCTION

Land Rover vehicles use one of two types of electronically controlled fuel injection systems: Multiport Fuel Injection (MFI) or Sequential Multiport Fuel Injection (SFI).

MULTIPORT FUEL INJECTION (MFI)

Multiport Fuel Injection (MFI) is found on Land Rover models using the Lucas 13 CU, 14 CU, and 14 CUX engine management systems.

Applications:

- 13CU
  1987-1988 Range Rover Classic
- 14CU
  1989 Range Rover Classic
- 14CUX
  1990-1995 Range Rover Classic
  1994-1995 Discovery
  1993 Defender 110
  1994-1995 Defender 90

SEQUENTIAL MULTIPORT FUEL INJECTION (SFI)

Sequential Multiport Injection (SFI) is used on vehicles equipped with the Sagem/Lucas Generic Engine Management System (GEMS), and the Bosch Motronic M5.2.1 engine management system.

Applications:

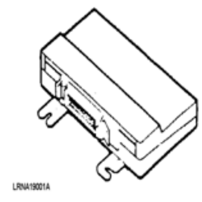
- GEMS
  1995-early 1999 Range Rover
  1996-early 1999 Discovery
  1997 Defender 90
- Bosch Motronic 5.2.1
  1999- Range Rover
  1999- Discovery Series II

LAND ROVER FUEL SYSTEM COMPONENTS

The following section will provide an overview and comparison of Land Rover fuel system components in use since 1987. These components will be discussed in the order of Engine Control Module, System Outputs, and System Inputs.

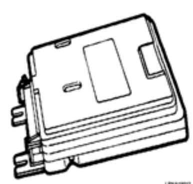
Engine Control Module (ECM)

13CU



- Used 1987 & 1988
- Limited on-board self-diagnostics
- Adaptive short term fuelling offsets for each bank
- Volatile fault memory
- Diagnostics with Land Rover/Lucas Hand-Held Tester or TestBook
- Mounted under the passenger seat

14CU/14CUX

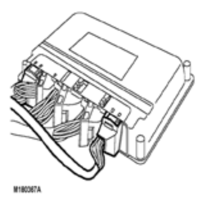


- 14CU used 1989, 14CUX used 1990-1995
- 14CU supports adaptive TPS and ISC
- EVAP purge control
- 14CUX has extended memory & supports on-board diagnostics compliant with OBD 1
- Volatile fault memory
- Replaceable PROM chips
- Mounted under the passenger seat on 1989-1994 Range Rover Classic and 1995 Defender; Right side kick panel 1995 Range Rover Classic and Discovery; Under right side dash 1993 Defender 110 and 1994 Defender 90.
- Diagnostics via On-board display or with Land Rover/Lucas Hand-Held Tester or TestBook

GEMS

- Used (Range Rover) 1995 to early 1999, (Discovery) 1996- early 1999, (Defender) 1997
- Both short term and long term fuelling offsets
- Ignition timing control integration
- Engine immobilization
- OBDII compliant on-board diagnostics
- Non-Volatile fault memory
- Replaceable PROM chips
- Diagnostics with SAE J1962/J1979 compatible tester or TestBook
- Mounted in engine compartment

Bosch Motronic 5.2.1

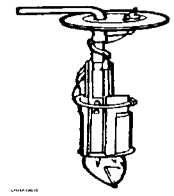


- Used 1999 - present
- Additional memory, faster processor/data bus refresh speed
- OBDII compliant on-board diagnostics and additional advanced diagnostic capability
- Both volatile and non-volatile (LEV) fault memory
- EEPROM programmable via data link
- Diagnostics with SAE J1962/J1979 compatible tester or TestBook

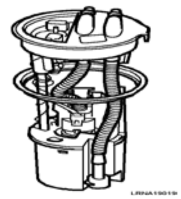
FUEL SYSTEM OUTPUTS

Fuel Pump

Fuel Return Type Systems -1987 to 1990

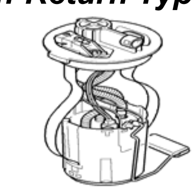


1991-1999



- Used 1987- early 1999
- Integral fuel level sending unit beginning 1991
- In-tank with external fuel filter
- 2.4-2.6 bar (34-37 psi) operating pressure
- Key off pressure drop from 2.3-2.6 bar (36-38 psi)- less than 0.7 bar (10 psi) in one minute
- Integral Advanced EVAP sensor from October 1996

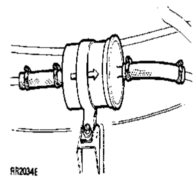
Non-Return Type System

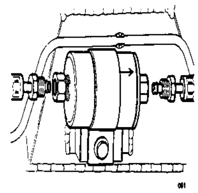


- Used with Bosch EMS 1999- present
- Integral fuel pressure regulator
- 3.5 bar (50.75 psi) operating pressure
- Integral advanced EVAP sensor 1999-present (Except LEV Phase II vehicles)

Fuel Filter

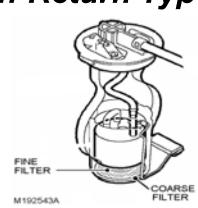
Return Type Systems





- External 1987-1999
- Mounted on the chassis, near the passenger-side rear wheel arch. An arrow on the filter body indicates the direction of fuel flow.
- Worm clamps 1987-1990
- O-Ring and Fitting 1991- early 1999

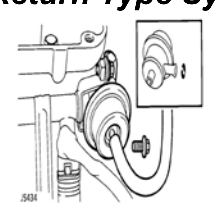
Non-Return Type System



- 1999- present (Bosch EMS)
- Integral with fuel pump
- Coarse gauze filter in swirl pot
- Fine paper filter around pump inlet

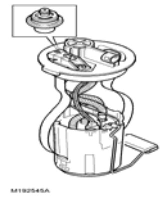
Fuel Pressure Regulator

Return Type Systems



- Mounted on fuel rail
- No service adjustments
- Adjusts pressure relative to intake manifold pressure

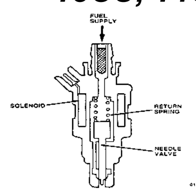
NON-RETURN TYPE SYSTEM



- Mounted on fuel pump
- No service adjustments
- Adjusts pressure relative to atmospheric pressure

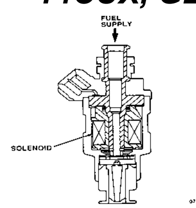
Fuel Injectors

13CU, 14CU



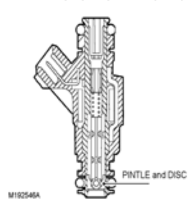
- Machined Needle Valve type.
- Approx. 16W resistance per injector
- Flow rate = 180-195cc (using gasoline) minimum at 2.5 bar (36 psi) at 20°C (68°F)

14CUX, GEMS



- Moveable Disc and Rod type.
- 16.2W ±0.5W resistance per injector at 20°C (68°F)
- Flow rate = 180-195cc (using gasoline) minimum at 2.5 bar (36 psi) at 20°C (68°F)

Motronic 5.2.1



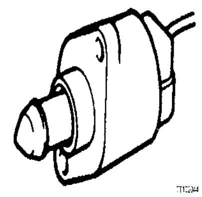
- Fixed Disc and Ball-ended pintle type.
- 14.5W ±0.7W resistance per injector at 20°C (68°F)

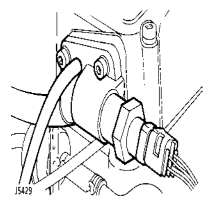
NOTE: Injector Testing Note:The preferred method for testing all Land Rover fuel injectors is using the procedure outlined in TIB 19/02/97/NAS. This method checks for nozzle leakage, and also specifies that the fuel pressure drop the injectors. Each injector should be within ±13.8

kpa (2 psi) of all the other injectors when pulsed for 500ms with the test equipment.

Idle Air Control Valve (IACV)

13CU, 14CU, 14CUX



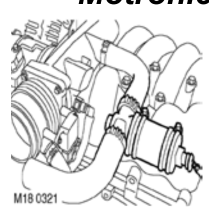


- Bipolar stepper motor controlling a screw-mounted tapered valve
- Active when: Road speed less than 3 mph; Throttle closed; Engine above 50 rpm
- Air valve open = 0 steps
  Air valve closed = 180 steps
- Base idle is controlled through a separate bypass port located in the housing for the throttle butterfly.

GEMS

- Similar in operation as 13/14CU, 14CUX
- Air valve open = 200 steps (180 steps for vehicles up to 97MY)
  Air valve closed = 0 steps
- Base idle is controlled through a separate bypass port located in the housing for the throttle butterfly.

Motronic

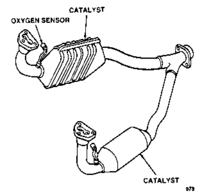


- Pulse Width Modulated 2-winding motor, controlling a rotary valve within an idle air flow passage
- No base idle adjustments

FUEL SYSTEM INPUTS

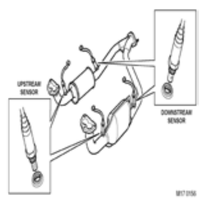
Heated Oxygen Sensor (HO2S)

13CU, 14CU,14CUX



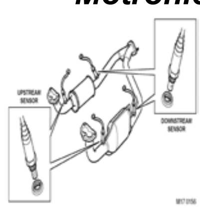
- One heated sensor for each bank, located upstream of the catalysts
- 3-wire resistive titanium sensor element
  Sensor power supplied from heater element
- Constant voltage supply to heater elements

GEMS



- Two heated sensors per bank, one pre-catalyst, one post-catalyst. Post-catalyst sensor used only to monitor catalyst efficiency.
- 4-wire resistive titanium sensor element
  5v supply from ECM
- Pulse Width Modulated voltage supply to heater elements

Motronic



- Two heated sensors per bank, one pre-catalyst, one post-catalyst. Post-catalyst sensor used only to monitor catalyst efficiency.
- 4-wire voltage generating Zirconium sensor element
- Pulse Width Modulated voltage supply to heater elements
- Front and Rear sensors are different

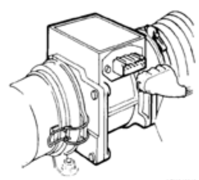
Sensor Operation Notes

Resistive Sensors-
- Uses a voltage supply through the sensor element
- Resistance increases under lean conditions
  Resistance decreases under rich conditions

Voltage Generating Sensors-
- Generates voltage (up to 1.1 v) under rich conditions - high voltage measured at sensor
  Low or No voltage generated under lean conditions - low voltage measured at sensor

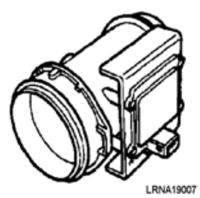
Mass Air Flow Sensor (MAFS)

13CU, 14CU, 14CUX



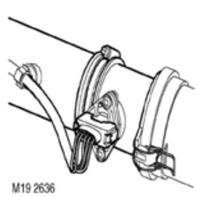
- Hot Wire type
- No additional intake air temperature sensor used

GEMS



- Hot Wire type
- Uses additional intake air temperature sensor

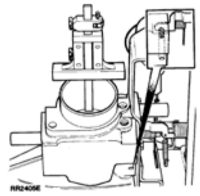
Motronic

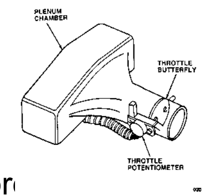


- Hot Film type
- Uses additional intake air temperature sensor

Throttle Butterfly

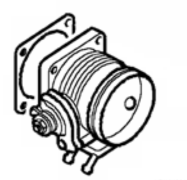
13CU, 14CU, 14CUX, GEMS





- Must be perpendicular within the bore
- Close tolerence between plate and bore- particular attention should be paid to deposit build-ups
- Coolant-fed pre-heating passage underneath housing/plate area
- Cable slack is adjustable
- Linkage and stop screw wear may allow plate to ‘flip backwards’ slightly in bore
- Adjustment must be made using a depth gauge
- 1987 Models have adjustment screw mounted on throttle lever, all others have screw mounted in housing as shown

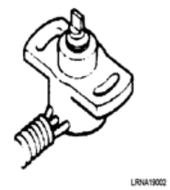
Motronic



- No plate adjustment normally needed
- Cable slack is adjustable
- Coolant-fed pre-heating passage underneath housing/plate area

Throttle Position Sensor (TPS)

13CU



- Adjustable- ECM DOES NOT adapt
- Voltage Range 0.29-0.36v throttle closed
  4.2-4.8v throttle open

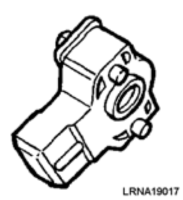
14CU

- Non-Adjustable- ECM is adaptive
- Voltage Range 0.085-0.545v throttle closed
  4.2-4.9v throttle open

14CUX

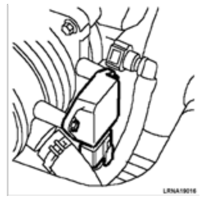
- Non-Adjustable- ECM is adaptive
- Voltage Range 0.083-0.547v throttle closed
  4.7-4.9v throttle open

GEMS



- Non-Adjustable- ECM is adaptive
- Voltage Range approx. 0.6v throttle closed
  approx. 4.5v throttle open

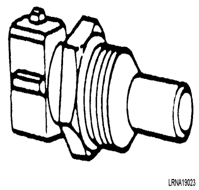
Motronic



- Non-Adjustable- ECM is adaptive
- Voltage Range 0.29-0.36v throttle closed
  4.2-4.9v throttle open

Engine Coolant Temperature Sensor (ECT)

13CU/14CU/14CUX



- NTC type sensor
- Resistance range = approx. 9200W at -10°C (-22°F) to 175W at 100°C (212°F). Approx. 300W at 80°C (176°F).
- ECM fault default value = 36°C (96.8°F).
- Located at the top front of the engine, to the right of the alternator and in front of the plenum chamber.

GEMS

- NTC type sensor
- Output = Approx. 4.7v at -30°C (-22°F) to 0.25v at 130°C (302°F). Approx. 0.7v at 85°C (185°F)
- ECM fault default value = dependant on value of air temperature sensor
- Located at the top front of the engine, to the right of the alternator and in front of the plenum chamber.

Motronic

- NTC type sensor
- Sensor contains two elements, only one is used on Discovery, on Range Rover one is also used for the instrument temperature gauge.
- Output = Approx. 4.9v at -50°C (-58°F) to 0.75v at 130°C (266°F). Approx. 1.8v at 70°C (158°F)
- ECM fault default value = dependant on software map up to 60°C (140°F), after which

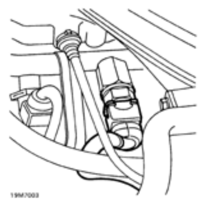
defaults to 85°C (185°F)
- Located at the top front of the engine, to the right of the alternator and in front of the plenum chamber.

Engine Fuel Temperature Sensor (EFT)

13CU/14CU/14CUX

- NTC type sensor
- Range = 9.1k-W at -10 °C (14°F) to 150W at 100°C (212°F). Approx. 1.2 k-W at 40°C (104°F)
- Located on the fuel rail forward of the intake housing, between left and right injector banks

GEMS



- NTC type sensor
- Range = 23k-W at -30 °C (-22°F) to 290W at 80°C (176°F). Approx. 1.1 k-W at 40°C (104°F)
- Located on the fuel rail by cylinders 3 and 5

Motronic

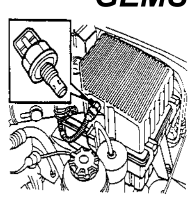
- None used

Intake Air Temperature Sensor (IAT)

13CU/14CU/14CUX

- None used

GEMS



- NTC type sensor
- Retards ignition timing above 55°C (131°F)
- Range = 23k-W at -30 °C (-22°F) to 290W at 80°C (176°F)
- Located in air cleaner housing

Motronic

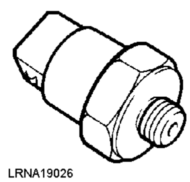
- NTC type sensor
- Range = 4.75v at -40 °C (-40°F) to .25v at 130°C (266°F)
- Default fault value = 45°C (113°F)
- Integral with Mass Air Flow Sensor

Knock Sensor

13CU/14CU/14CUX

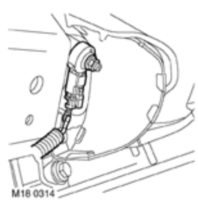
- None used

GEMS



- Two used- mounted on the cylinder block between the two center cylinders of each bank
- Voltage output increases with severity of knock detected

Motronic



- Same location and operation as GEMS

OPEN AND CLOSED LOOP OPERATION

CLOSED LOOP OPERATION

During closed loop, or feedback operation, the ECM controls fuel system operation based on information provided by the various vehicle inputs. Because these inputs represent actual operating conditions, the system is most able to meet performance and efficiency targets when operating in closed loop.

The primary input during closed loop operation is the oxygen sensor since it indicates the result of the combustion process, regardless of the engine speed and load.

The primary output during closed loop operation is the fuel injector timing and duration.

All other sensors generally serve to help the ECM ‘trim’ or anticipate the operation of the engine to meet a particular oxygen sensor value or known tailpipe emission condition.

OPEN LOOP OPERATION

At times (start-up, full throttle) engine operating requirements may fall outside the bounds of that suggested by the ECM inputs. Some sensors do not operate at peak efficiently until warm. At these times, the ECM substitutes a pre-programmed set of reference inputs that are most likely to produce desired engine operation. This is referred to as open loop operation.

The system may also default to open loop operation when component failure provides an input signal outside the range of known parameters recognized by the ECM. The ECM will substitute a signal value that allows the vehicle to continue to operate. The Malfunction Indicator Lamp (CHECK ENGINE) on the instrument panel is illuminated at this time to indicate the failure of an emissions-related component.

13/14CU AND 14CUX SYSTEMS

Introduction
Three variations of similar Lucas engine management systems have been used on Land Rover vehicles from 1987 to selected 1995 models. Operation of each of these systems is fundamentally the same, the differences between each being enhancements to self diagnostics, improved adaptability to operating conditions, and additional input/output capability. All of these systems utilize a Engine Control Module, and all are tied to vehicle inputs and outputs through a similar 40 pin connector.

The systems used are:

- 13 CU (1987-88)
- 14 CU (1989)
- 14 CUX (1990-95)

The system control modules are mounted under the passenger seat on 1987-1994 vehicles. The module is moved to a position just behind the glove box on 1995 models.

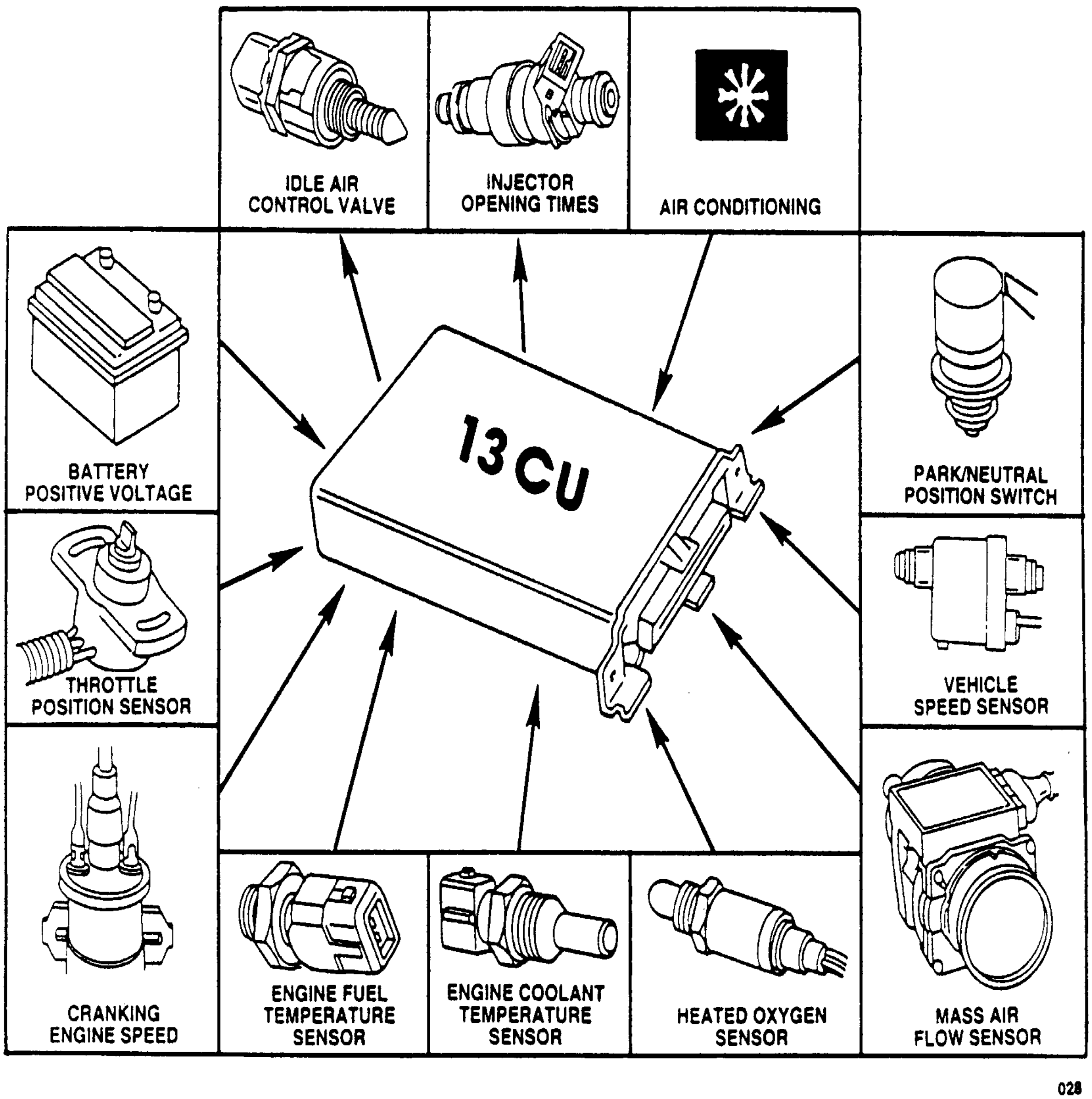
The ECM works with system inputs and outputs to deliver the best possible combination of engine performance and economy while minimizing vehicle emissions.

13 CU
The 13 CU module receives the following inputs:

- Key on
- Battery voltage
- Throttle Position Sensor (TPS)
- Engine speed
- Engine Fuel Temperature (EFT) sensor
- Engine Coolant Temperature Sensor (ECT)
- Heated Oxygen Sensor (HO2S)
- Mass Air Flow Sensor (MAF)
- Vehicle Speed Sensor (VSS)
- Park/Neutral Position Switch (PNPS)
- Air Conditioning Fan and Mode Switch
- Heated Rear screen load (1987 only)

The following are 13 CU outputs:

- Fuel Injectors
- Idle Air Control Valve (IACV)
- Malfunction Indicator Lamp (MIL)
- Fuel Pump/ Oxygen Sensor Heaters Relay
- Main relay



13CU System Inputs and Outputs

14CU and 14CUX

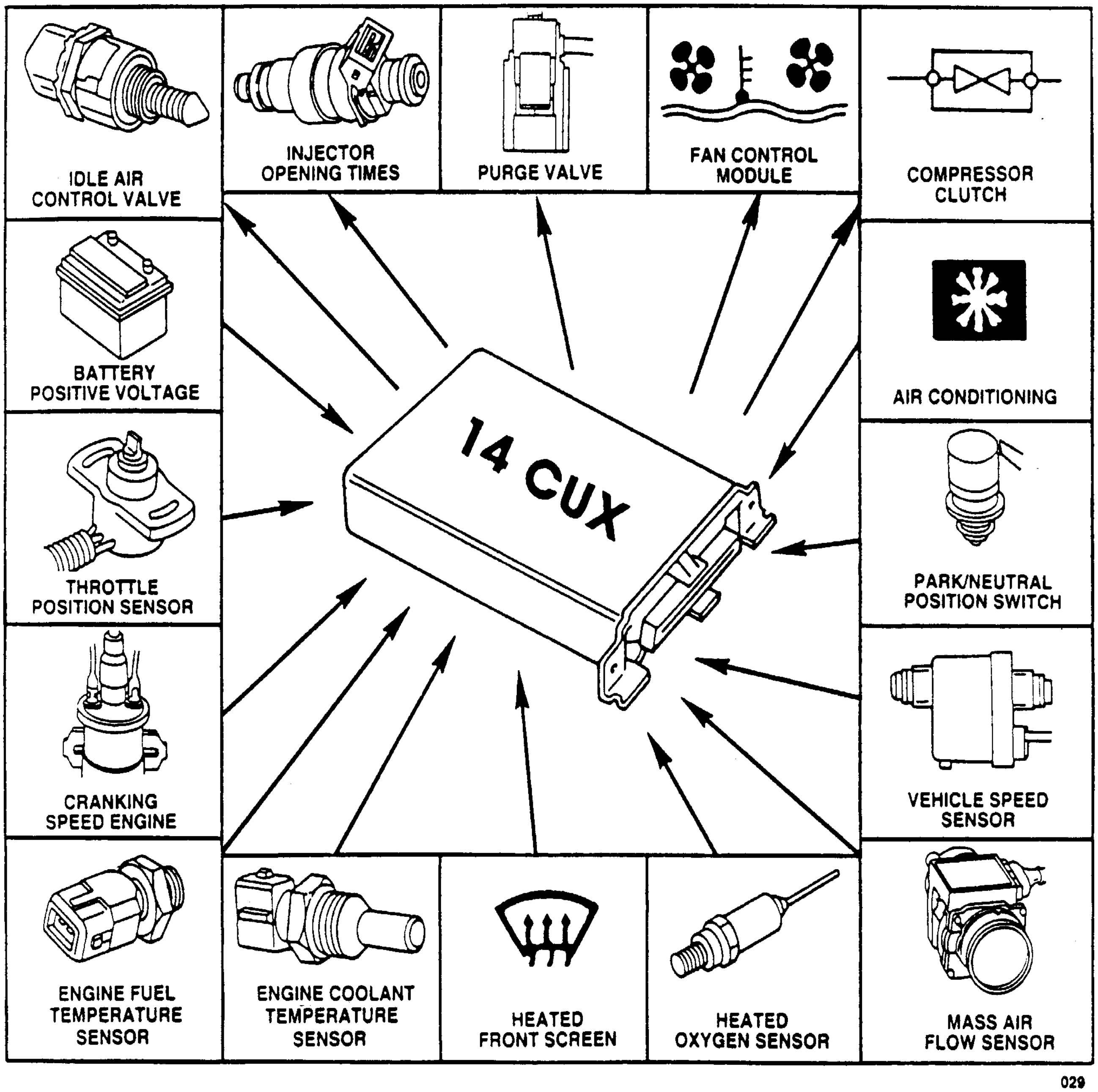
The 14CU and 14CUX modules include additional inputs and output controls for more precise control of the air-fuel mixture and enhanced self-diagnostic capabilities.

The following are ECM inputs:

- Key on
- Battery voltage
- Throttle Position Sensor (TPS)
- Engine speed
- Engine Fuel Temperature (EFT) sensor
- Engine Coolant Temperature Sensor (ECT)
- Heated Front Screen
- Heated Oxygen Sensor (HO2S)
- Mass Air Flow Sensor (MAF)
- Vehicle Speed Sensor (VSS)
- Park/Neutral Position Switch (PNPS)
- Air Conditioning Fan Switch (14CU only)
- Air Conditioning Thermostat

The ECM outputs are as follows:

- Fuel Injectors
- Idle Air Control Valve (IACV)
- Purge Valve (CANPV)
- A/C Compressor Clutch
- A/C Condenser Fan Control Module (FCM)
- Malfunction Indicator Lamp (MIL)
- Fuel Pump/ Oxygen Sensor Heaters Relay
- Main relay
- Fault Code Display Unit (14CUX only)



14CUX Inputs and Outputs

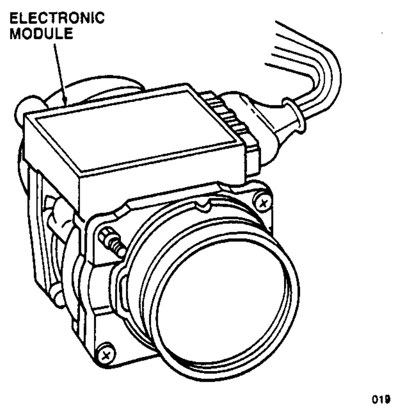
SYSTEM INPUTS

Mass Air Flow Sensor (MAF)

The Mass Air Flow (MAF) sensor is a hot-wire type. It contains two wires, one heated to a known value of 100° C (212° F) above the other. As air flow increases, the current required to maintain this difference in temperature increases. The air flow meter's circuitry converts this current requirement into a signal the ECM uses to determine the amount of air entering the intake manifold.

Typical MAF output voltage at idle is between 1.3 and 1.5 VDC. A diagnostic trouble code (12) is produced if MAF voltage is:

- less than 122 mV with RPM in excess of crank speed.
- greater than 4.96 V with RPM less than 976 for more than 160 milliseconds.



Mass Air Flow Sensor

Throttle Position Sensor (TPS)

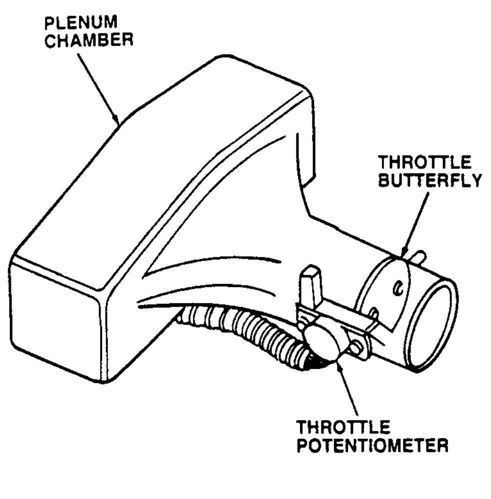
This potentiometer is mechanically linked to the throttle butterfly and provides an output voltage proportional to the butterfly position. This information allows the ECM to determine throttle position and is used for ECM strategies like the following:

- Acceleration Enhancement - The ECM increases the amount of fuel normally provided for a given throttle position during periods of peak acceleration. This allows the system to anticipate fuel needs.
- Deceleration Fuel Shut-off - During throttle closed deceleration, the ECM does not activate fuel injectors (zero pulse-width) to prevent unneeded fuel from entering the cylinders. This strategy protects against catalytic converter overheating and reduces fuel consumption.

13 CU throttle position sensors must be set to an initial output reading of 290-360 mV when installed. Gradual loosening of the TPS or damage to the throttle stop could cause the sensor to move out of range.

14 CU and CUX throttle circuitry is adaptable within a range of 80 to 500 mV. Within this range, the PCM will adapt to the initial setting and use it as a reference. There is no need to adjust the TPS following installation on these models. If the TPS should fail, the ECM will use a default value of 576 mV and the MIL will be illuminated.

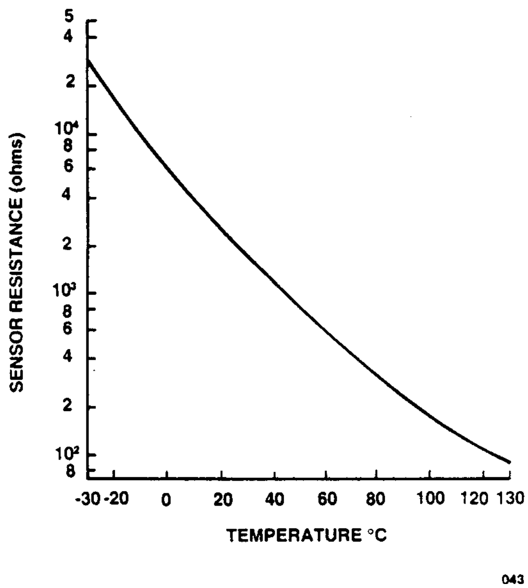
A diagnostic trouble code (17) is set when sensor output is less than 78 mV for longer than 160 milliseconds.



Throttle Position Sensor

Engine Coolant Temperature Sensor (ECTS)
The ECTS is a resistor based sensor. As coolant temperature increases, sensor resistance decreases. The ECM uses this information for hot- and cold-start strategies that require additional fuel delivery. It also uses this information to help determine when to enter closed loop operation.

A diagnostic trouble code (14) is stored when the signal is out of range (0.15V to 4.9V) for longer than 160 milliseconds. The MIL will illuminate and the ECM will substitute a default value of 36° C (97° F).

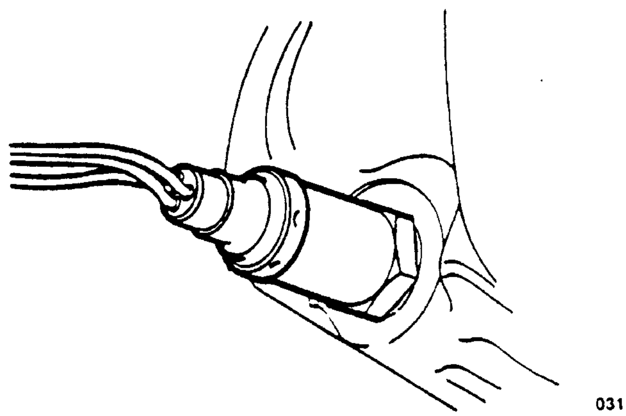


Coolant Temerature Sensor Response

Engine Fuel Temperature Sensor (EFTS)
The fuel temperature sensor, mounted on the fuel rail, operates in the same manner as the ECTS. When the ECM receives a high fuel temperature input, it increases injector pulse during hot restarts. When fuel is hot, vaporization occurs in the fuel rail and bubbles may be found in the injectors. This can lead to hard starting. Increasing injector pulse time flushes the bubbles away and cools the fuel rail with fresh fuel from the tank. Since 1989, the EFTS has also been used by ECM to trigger operation of the radiator fans when under-hood temperatures become extreme.

As with the engine coolant temperature sensor, a diagnostic trouble code (15 [14CUX only]) is stored when the signal is out of range (0.08V to 4.9V) for longer than 160 milliseconds. No default value is provided by the ECM, however the MIL will illuminate.

Heated Oxygen Sensor (HO2S)
The heated oxygen sensor is mounted in each exhaust downpipe and is used by the ECM to determine whether the engine is operating rich or lean. The ECM uses this information to increase or decrease injector pulse width to bring the air/fuel ratio as close to Stoichiometric as possible. The ECM monitors each sensor separately and makes fuel trim adjustments to each cylinder bank independent of the other.



Typical Heated Oxygen Sensor

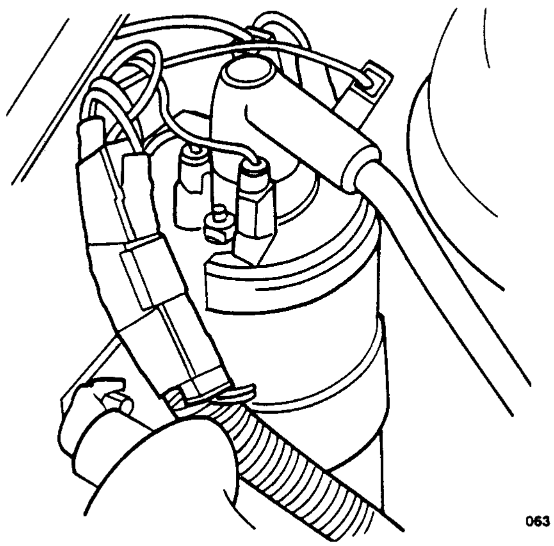
Oxygen sensors operate efficiently only when warm. Heated sensors reach operating temperatures quickly to provide accurate information to the ECM soon after start-up and allow closed loop operation to occur sooner. This helps provide an efficient fuel mixture during engine warm-up and guards against catalytic converter overheating.

The sensors operate in a range of 0 to 1.1 VDC. To avoid the possibility of interference in this narrow range of operation, each input wire is shielded against RF interference.

Diagnostic trouble codes (44/45) are produced if either HO2S will not switch after the ECM has radically altered fueling on that bank of injectors. The test is performed when the engine is at normal operating temperature, TPS input is above 2 volts, and a road speed input is received.

Park/Neutral Position Switch (PNPS)
The ECM uses this information on transmission gear selection to determine correct positioning of the Idle Air Control (IACV) valve. A diagnostic trouble code (69 [14CUX only]) is set when sensor voltage is 5 V during cranking or 0 V with RPM above 2663 and MAFS voltage above 3 V.

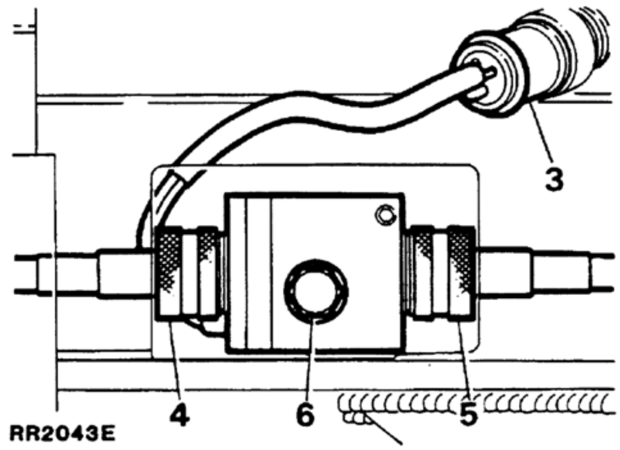
Engine Speed
The ECM determines engine speed from data received through the negative coil lead. A dropper resistor (6800 ohms) reduces the voltage at the ECM to approximately 7 volts. The ECM requires a pulse from the ignition system before energizing injectors.



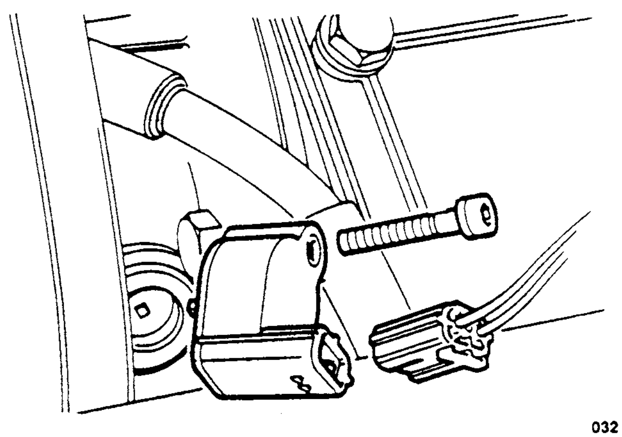
Coil Leads

Vehicle Speed Sensor (VSS)

The Vehicle Speed Sensor is located on the left hand side of the frame on early models, and on the left hand side of the transfer case on later models. It informs the ECM when vehicle speed is above or below 3 mph. This information is used by the ECM to ensure that the idle air control valve (IACV) is moved to a position to prevent a stall when the vehicle comes to a stop. DTC 68 will be displayed if the MAF is greater than 3V at 2000-3000 RPM's



Vehicle Speed Sensor 1987-1995



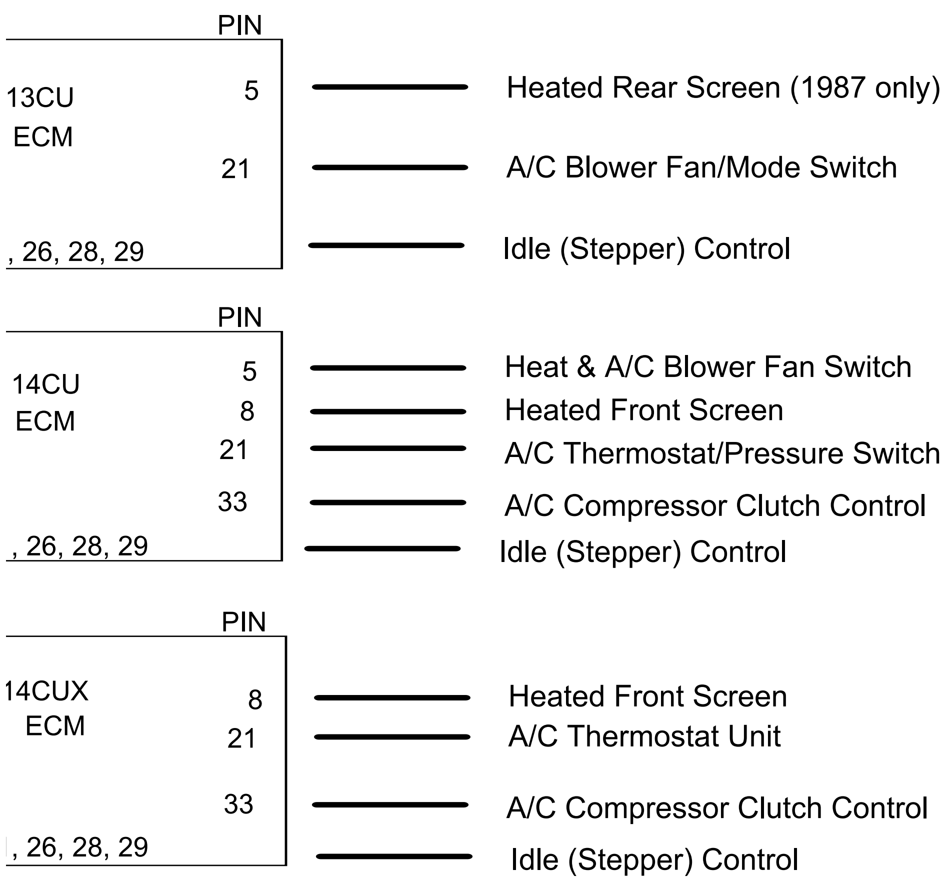
Vehicle Speed Sensor 1995- Onward

A/C Fan Switch Input (13CU and 14CU only)
This indicates that heater or A/C blower motor operation has been requested via the dash control panel. On 13CU systems, this is the only Air Conditioning system input signal. The ECM will compensate for the additional engine load and adjust idle speed accordingly. On 14CU systems, this signal is used in combination with the A/C thermostat input signal.

A/C Thermostat Input (14CU and 14CUX only)
By indicating when the A/C compressor is operating, the ECM can compensate for the additional engine load and adjust idle speed accordingly. On 14CU systems this signal comes from the A/C thermostat, through the A/C high pressure switch. On 14CUX, this signal comes from the A/C thermostat control unit.

Heated Rear Screen (1987 M.Y. 13 CU only)
By indicating when the heated rear screen is in use, the ECM can compensate for the additional load the generator produces on the engine by adjusting the idle speed.

Heated Front Screen (14 CU and 14 CUX only)
By indicating when the heated front screen is in use, the ECM can compensate for the additional load the generator produces on the engine. The ECM will then adjust the idle speed accordingly.



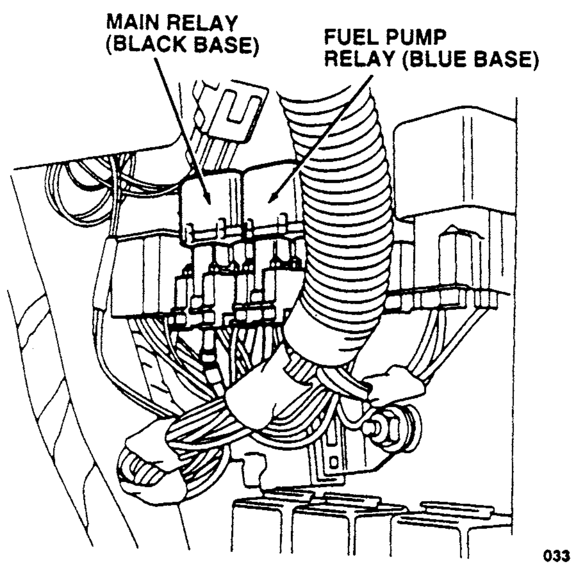
OUTPUTS

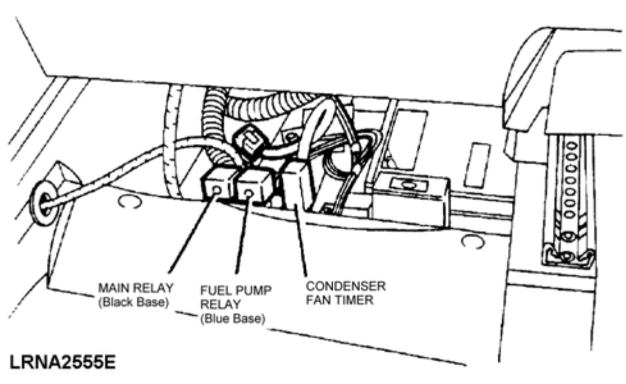
Main relay

The ECM provides power to both fuel injector banks, MAFS, the fan module, and fault display via the main relay. The relay is located under the passenger seat on most models. For 1995, the relay has been moved to the engine compartment where it is mounted on the passenger side fender wall. On Defender, the relay is mounted on the passenger side of the bulkhead.

Fuel Pump Relay

The fuel pump relay is located next to the main relay. The ECM provides power to the fuel pump, HO2S heaters and purge valve through the fuel pump relay. The ECM operates the fuel pump for one second at key on and then when it senses a crank/run signal from the ignition system.





Relay Locations 1987-1995Relay Locations 1995

Fuel Injectors
The ECM provides ground side switching to both A (pin 13) and B (pin 11) injector banks. Banks are operated alternately except at start-up when simultaneous operation is used to provide additional fuel to the system. Injectors are shut off during deceleration.

The ECM controls fuel volume through injector pulse width. Pulse width varies between approximately 2.4 milliseconds at idle to a maximum of approximately 9.0 milliseconds at full load. Each injector has a resistance of 16 ohms. Resistance value of the complete injector circuit (wired in parallel) will be approximately 4 ohms.

Idle Air Control Valve (IACV)
The idle air control "stepper motor" operates through a range of 180 steps with the 0 position completely open and the 180 position fully closed. The further open the valve is positioned, the higher the idle speed will be. Idle position on a vehicle at normal operating temperature with no engine load is approximately 160. The ECM opens the valve a fixed number of steps in response to input signals from load producing items such as the air conditioning compressor, front defroster, and transmission shifting out of Park/Neutral. Resistance in the IACV coils ranges from 40-60 ohms at room temperature and up to 70 ohms when hot.

Malfunction Indicator Lamp (MIL)
Formerly known as the CHECK ENGINE lamp, the MIL illuminates when the ECM determines an emissions-related component has failed. The MIL also illuminates at key-on and vehicle start-up to test bulb operation.

Purge Valve (CAN PV) 14 CU, 14 CUX only
Land Rover vehicles contain an evaporative emission system designed to capture vapors produced by the vehicle's fuel system. Evaporative emissions from the fuel tank are trapped in a carbon filled canister before they can reach the atmosphere. These vapors are then vented to the plenum chamber through a purge valve during engine operation. The ECM pulses the valve open for short periods below 1700 RPM and holds it open at higher speeds once the engine has achieved operating temperature and is in closed loop. Operating temperature is defined as engine coolant temperature above 54° C (130° F).

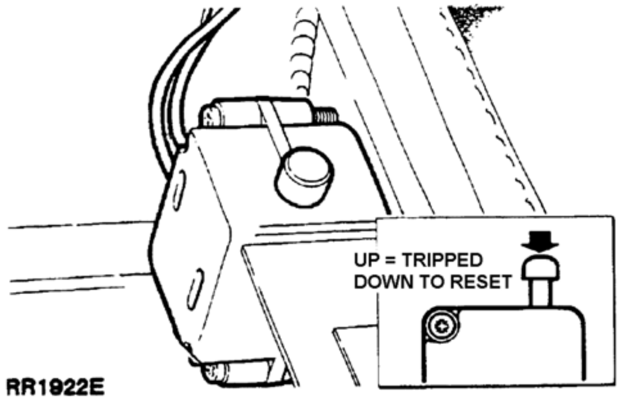
The ECM monitors the need for canister purge by looking at HO2S response when the valve is opened. No change in HO2S response with the valve open indicates that the canister has been purged of fuel vapor and continued valve operation is no longer necessary. Operation of the purge function when no longer required can negatively impact vehicle emissions.

A/C Compressor Relay
The ECM controls operation of the electronic A/C clutch through this relay. The ECM provides a ground path for the relay circuit when it receives a request for A/C operation from the A/C control panel.

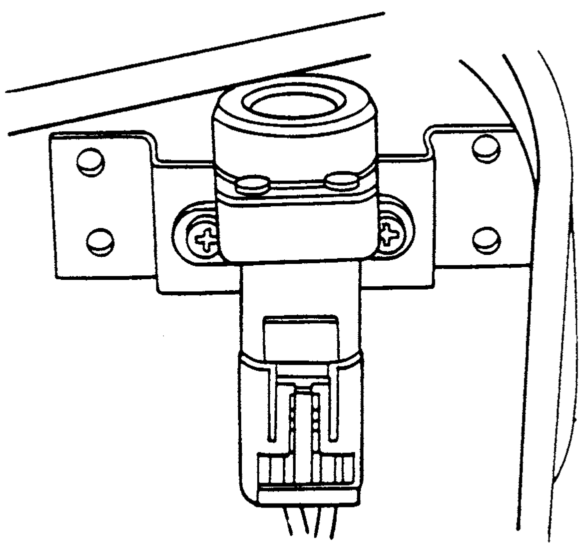
Fan Control Module (FCM)
The ECM remains powered for approximately five seconds after the ignition is switched to OFF. During this time, it monitors under-hood temperature through the engine fuel temperature sensor. If measured temperatures exceed 70° C (150° F), the ECM grounds the fan control module, allowing the condenser fans to run for ten minutes.

Inertia Switch

The inertia switch isolates the power supply to fuel pump in the event of extreme deceleration like that which would occur in a collision. The inertia switch is located under the left front seat on 1987-1994 vehicles, and on the bulkhead at the back of the engine compartment from 1995. It can be reset by pressing the button at the top of the switch.



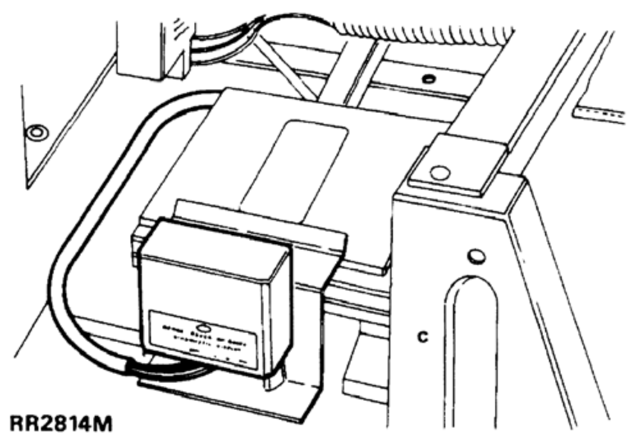
Inertia Switch 1987-1994



Inertia Switch 1995

Engine On-Board Diagnostic (OBD) System
Much of the new technology introduced on these engine control systems is directed toward improving the quality of exhaust gas emissions and reducing air pollution. Much of this has been mandated by legislation that originated with the California Air Resources Board (CARB). Control system self-diagnostics, or On-Board Diagnostics (OBD) for vehicle emissions are included in the 14 CUX engine control system.

OBD regulations produced by CARB require that vehicles monitor operation of key emissions components such as the oxygen sensor, fuel delivery system, and ECM. Failure of components in these systems is indicated by the illumination of a CHECK ENGINE or Malfunction Indicator Lamp (MIL) on the instrument cluster.



On-board Fault Display Unit

Diagnostic Trouble Codes (DTCs) are provided to help direct the technician to the source of the concern. They can be retrieved with the TestBook or the Lucas HHT.

Codes are also displayed on 1990-1995 models, via the on-board fault display. No additional diagnostic equipment is required and if a system fault exists, it is displayed any time the ignition switch is in the 'on' position. Any additional faults are displayed in order of system priority, but only one at a time.

The following procedure displays the codes, and clears the fault memory:

1 Switch On ignition.
2 Disconnect serial link mating plug, wait 5 seconds, reconnect.
3 Switch OFF ignition, wait for main relay to drop out.
4 Switch ON ignition. The display should now reset. If no other faults exist, and the original fault has been rectified, the display will be blank.
5 If multiple faults exist repeat Steps 1 to 4. As each fault is cleared the code will change, until all faults are cleared. The display will now be blank.

System Fault Codes

13CU and 14CU systems have a limited number of self-diagnostic fault codes, however all of the basic system areas such as Oxygen Sensors, Throttle Potentiometer, Air Flow Sensor, and Coolant Sensor are monitored.

14CUX sytems are OBD (I) compliant, and will display the following faults, which are listed in order of display priority:

Code	Description
02	ECM Power Disconnected (displays only until first key on/key off cycle)
29	ECM Memory Check
44	Lambda Sensor A
45	Lambda Sensor B
25	Ignition Misfire
40	Misfire Bank A
50	Misfire Bank B
12	Airflow Meter
21	ECM Tune Select
34	Injector Bank A
36	Injector Bank B
14	Coolant temperature Sensor
17	Throttle Potentiometer
18	Throttle Potentiometer high while Airflow Meter low
19	Throttle Potentiometer low while Airflow Meter high
88	Purge Valve
28	Intake System Air Leak
23	Fuel Supply
48	Stepper Motor
68	Road Speed Sensor
69	Automatic Transmission Gear Switch
59	Fuel Supply or Air Leak Group fault
15	Fuel Temperature Sensor

SYSTEM DIAGNOSTICS

A technician's approach to diagnostics of any vehicle system should include the following steps:

- Verify the customer concern
- Determine related symptoms
- Isolate the source of the concern
- Perform the required repair
- Verify system operation

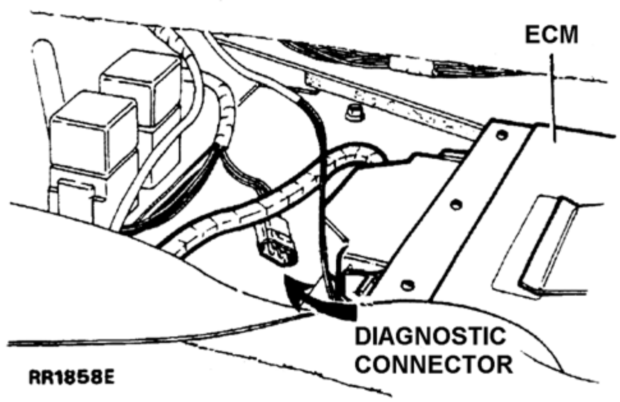
As indicated, the first step in vehicle diagnosis is verification of the customer's concern. This can eliminate time spent unnecessarily searching for the cause of a normal operating condition. An example of this might be changes in engine idle during times of high accessory load.

The next step in diagnosing the concern is to determine related symptoms and narrow them down to a specific vehicle system. Retrieving diagnostic trouble codes (DTCs) is recommended at this stage of diagnosis. Vehicles using the 13 through 14 CUX series controllers allow limited self-diagnostics, including code retrieval, using the TestBook or Hand Held Tester.

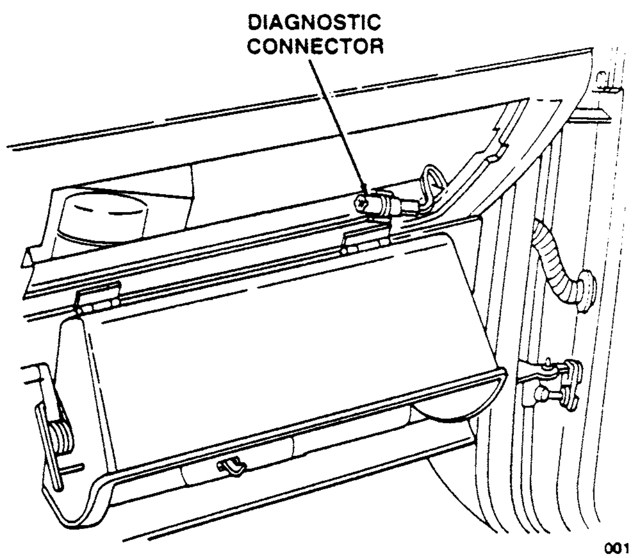
Diagnostic Connector

The 14 CUX communicates with diagnostic test equipment (TestBook) through connector pins 18 and 9. These pins can be accessed through a harness located under the passenger seat on most models. For the 1995 model year, the harness is located behind the glove box. Search for the harness carefully as it may be tucked in among other wiring.

Using this diagnostic connector allows you to perform system diagnostics without removing the harness connector from the ECM and clear codes without diagnostic equipment.



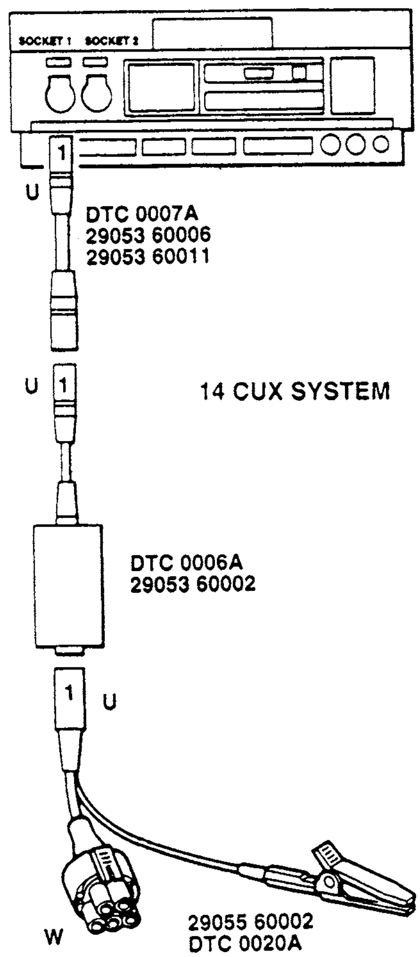
Diagnostic Connector Locations



TestBook Connections

Selecting the correct accessory cables is critical when using the TestBook for system diagnosis. Cables can vary for each application.

Once you have selected the proper cables, ensure that they are securely connected and plugged into Socket 1 at the back of the TestBook unit. Next, connect the clip on the power lead to the positive (B+) post of the vehicle's battery. You are now ready to enter TestBook diagnostics.



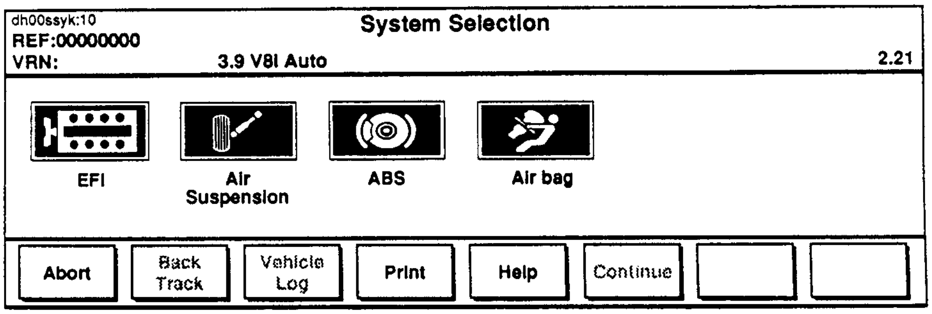
TestBook Diagnostic Connector Hook-up

Once past the main menu, TestBook offers a selection of vehicle systems that can be tested. These include:

- EFI
- Air Suspension
- ABS
- Airbag

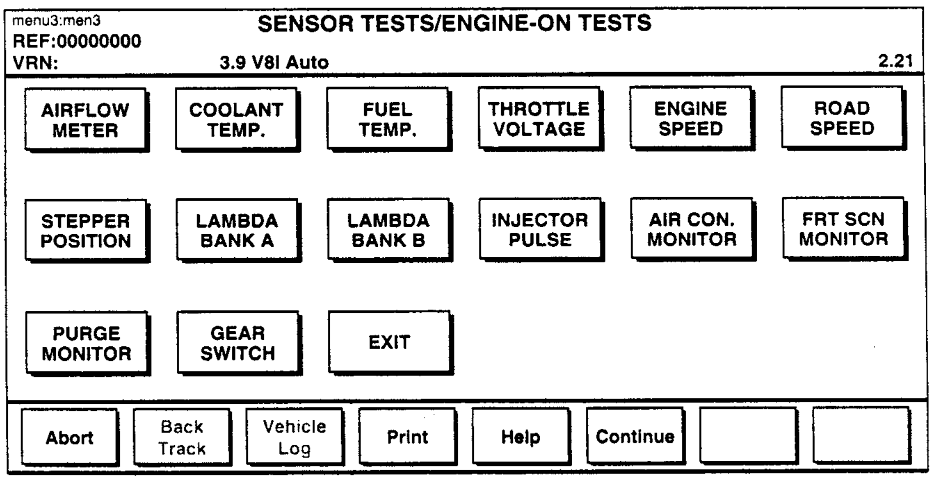
The air suspension selection is available only on Range Rover Classic.

Touch the system icon to move on to the next selection screen.



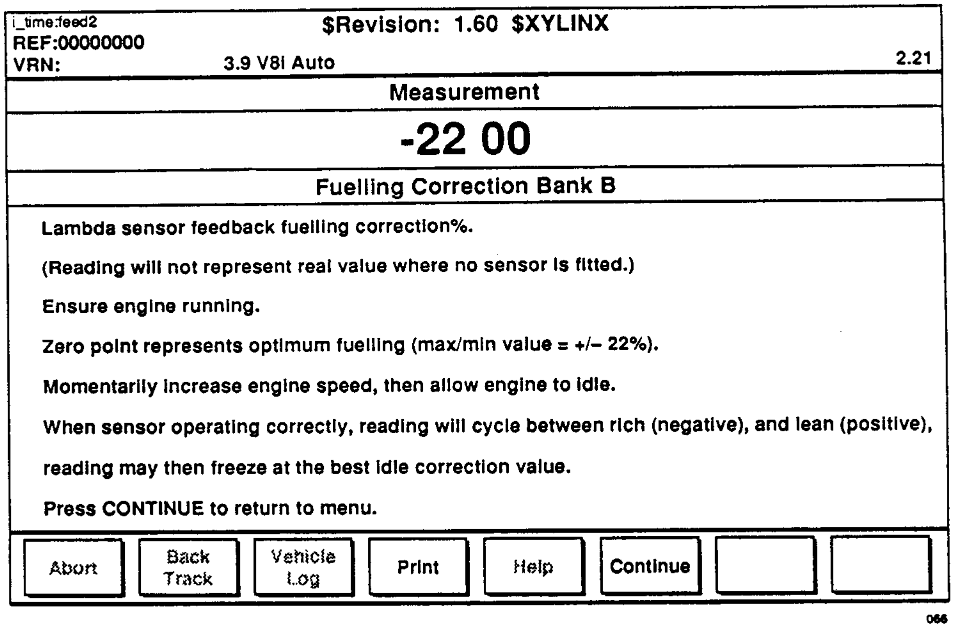
064

TestBook provides you with the opportunity to monitor the function of the system inputs listed on the screen below.



065

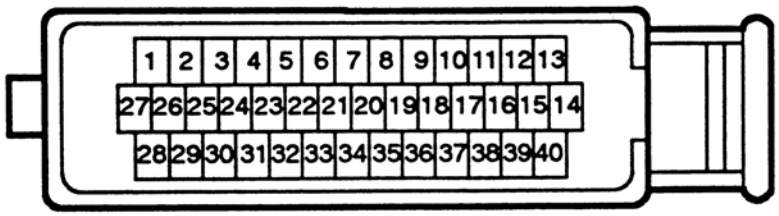
The screen below provides you with an example of the information available under the icon LAMBDA BANK B. (Lambda is another term for oxygen sensor.) This is an example of how TestBook allows you to monitor sensor operation as the engine is operating.



Information is provided on the screen to help you determine if the component is operating within specified parameters. This screen is also helpful in verifying operation following a repair.

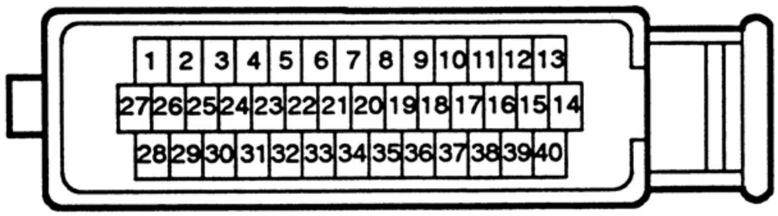
13/14CU and 14CUX ECM Connector Pin-Outs

1987-88 Lucas 13 CU ECM



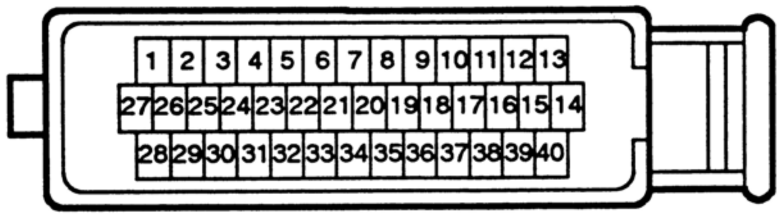
PIN	WIRE COLOR	FUNCTION	PIN	WIRE COL-OR	FUNCTION
1	RG	Stepper "D"	21	YU	A/C clutch input
2	NO	Battery + Main Relay	22	UR	AFM Idle trim
3	Y	TPS Reference voltage	23	U	Lambda Bank "A"
4	B	Lambda ground	24	U	Lambda Bank "B"
5	NP	(1987) Rear Screen input (1988) N.C.	25	RB	Sensor "VE"
6	Y	Vehicle Speed input	26	GW	Stepper "C"
7	GU	Water Temperature input	27	BS	Signal Ground
8	-		28	US	Stepper "B"
9	WLG	Serial Link	29	O	Stepper "A"
10	BY	"EFI" Light (MIL)	30	-	
11	YW	Bank "B" injector ground	31	-	
12	UR	Main Relay Request	32	SW	Fuel Temperature input
13	YU	Bank "A" injector ground	33	-	
14	B	ECM Ground	34	OB	Park/Neutral input
15	N	Battery +	35	UG	AFM input
16	UP	Fuel Pump Relay Request	36	-	
17	-		37	WY	Serial Link
18	WK	Serial Link	38	-	
19	WS	Ignition "ON" input	39	WB	Tachometer input
20	R	TPS input	40	B	ECM ground

1989 Lucas 14 CU ECM



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	RG	Stepper “D”	21	YB	A/C clutch input
2	NO	Battery + Main Relay	22	UR	AFM Idle trim
3	Y	TPS Reference voltage	23	U	Lambda Bank “A”
4	B	Lambda ground	24	U	Lambda Bank “B”
5	BW	A/C Fan Switch Input	25	RB	Sensor Signal Ground
6	Y	Vehicle Speed input	26	GW	Stepper “C”
7	GU	Water Temperature input	27	BS	Ground
8	PY	Heated Front Screen input	28	US	Stepper “B”
9	WLG	Serial Link	29	O	Stepper “A”
10	BY	“EFI” Light (MIL)	30	-	
11	YW	Bank “B” injector ground	31	-	
12	UR	Main Relay Request	32	SW	Fuel Temperature input
13	YU	Bank “A” injector ground	33	BS	A/C clutch output
14	B	ECM Ground	34	OB	Park/Neutral input
15	N	Battery +	35	UG	AFM input
16	UP	Fuel Pump Relay Request	36	BG	Fan Timer Request
17	SY	Purge Control	37	WY	Serial Link
18	WK	Serial Link	38	-	
19	WS	Ignition “ON” input	39	WB	Tachometer input
20	R	TPS input	40	B	ECM ground

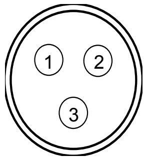
1990-95 Lucas 14 CUX ECM



C243

PIN	WIRE COLOR	FUNCTION	PIN	WIRE COL-OR	FUNCTION
1	RG	Stepper “D”	21	YB	A/C clutch input
2	NO	Battery + Main Relay	22	UR	AFM Idle trim
3	Y	TPS Reference voltage	23	U	Lambda Bank “A”
4	B	Lambda ground	24	U	Lambda Bank “B”
5	BW	Tune Resistor (1990 only)	25	RB	Sensor “VE”
6	Y	Vehicle Speed input	26	GW	Stepper “C”
7	GU	Water Temperature input	27	BS	Signal Ground
8	PY	Heated Front Screen input	28	US	Stepper “B”
9	WLG	Serial Link	29	O	Stepper “A”
10	BY	“Check Engine” Light (MIL)	30	K	Fault Display output
11	YW	Bank “B” injector ground	31	BG	Diagnostic Reset
12	UR	Main Relay Request	32	SW	Fuel Temperature input
13	YU	Bank “A” injector ground	33	BS	A/C Clutch output
14	B	ECM Ground	34	OB	Park/Neutral input
15	N	Battery +	35	UG	AFM input
16	UP	Fuel Pump Relay Request	36	BG	Fan Timer Request
17	SY	Purge control	37	-	
18	WK	Serial Link	38	NK	Fault Clock output
19	WS	Ignition “ON” input	39	WB	Tachometer input
20	R	TPS input	40	B	ECM ground

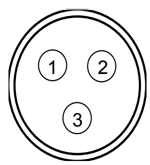
Heated Oxygen Sensor X139, X160



3way-Black

PIN	WIRE COL-OR	FUNCTION
1.00	WO	Heater Power Supply- 12v
2.00	U	Sensor Signal- 0.1v to 1.1v
3.00	B	Ground

Throttle Position Sensor X171



3way-Black

PIN	WIRE COL-OR	FUNCTION
1.00	RB	Signal Ground
2.00	R	Sensor Signal
3.00	Y	TPS Reference voltage- 5v

14CUX ECM Tune Summary

Tune	ACpplication
R3652	3.9 litre ‘93-‘95 MY Range Rover Classic 3.9 litre ‘93-‘95 MY Discovery
R3653	4.2 litre ‘93-‘95 MY Range Rover Classic
R3654	3.9 litre ‘94-‘95 MY Defender 90 3.9 litre ‘93 MY Defender 110
R3362	3.9 litre ‘89-‘92 MY Range Rover Classic Low compression

Note:When using Tune # R3652, R3653, or R3654 to correct cold start complaints, the entire “Cold Start Enhancement” package must also be used (except Defender 110)

See reverse for complete tune listing.

Model	Tune #	Description
Range Rover Classic 3.9 Low CR	R2103	Initial production tune
Range Rover Classic 3.9 Low CR	R2161	Desensitized OBD, IAC refinements
Range Rover Classic 3.9 Low CR	R2306	Fixed A/C glitch @ 65 mph (2250rpm); eliminated tune resistor (Code 21)
Range Rover Classic 3.9 Low CR	R2419	Desensitized OBD, , prinarily Code 48; Service Actioon (Recall CA)
Range Rover Classic 3.9 Low CR	R2665	Improved IAC control, new strategy for IAC OBD; further OBD desensitization
Range Rover Classic 3.9 High CR	R2813	Initial production tune
Range Rover Classic 4.2 High CR	R2926 B	Initial production tune
Defender 3.9 High CR	R3038	Initial production tune
Range Rover Classic 3.9 High CR	R3100	Low Reed Vapor Pressure fuel tune
Range Rover Classic 4.2 High CR	R3102	Low Reed Vapor Pressure fuel tune
Range Rover Classic 3.9 High CR	R3315	MIL on no code fix (interim)
Range Rover Classic 4.2 Low CR	R3316	MIL on no code fix (interim)
Range Rover Classic 3.9 Low CR	R3326	Low Reed Vapor Pressure fuel tune (interim)
Range Rover Classic 3.9 Low CR	R3339	MIL on no code fix (interim)
Defender 3.9 High CR	R3340	MIL on no code fix (interim)
Defender 3.9 High CR	R3341	Low Reed Vapor Pressure fuel tune (interim)
Range Rover Classic 3.9 High CR	R3342 A	MIL on no code fix (interim)
Range Rover Classic 4.2 High CR	R3343 A	MIL on no code fix (interim)
Range Rover Classic/ Discovery 3.9 High CR	R3360	Desensitized OBD 95 MY Tune (‘94 Discovery)
Range Rover Classic 4.2	R3361	Desensitized OBD 95 MY Tune
Range Rover Classic 3.9 Low CR	R3362	Desensitized OBD 95 MY Tune; improvements for Low CR

Defender 3.9 High CR	R3365	Desensitized OBD 95 MY Tune
Range Rover Classic 4.2	R3507	Part # PRM3361A; Interim improved Cold Start, fueling below -22âC (- 10âF)
Range Rover Classic/Discovery 3.9 High CR	R3526	Part # PRM3360A; Note: LR Part numbers are different from Tune numbers
Defender 3.9 High CR	R3529	Part # PRM3365A
Range Rover Classic/Discovery 3.9 High CR	R3652	Operation Pride Tune Current tune with final improved Cold Start fueling below -22âC (-10âF).
Range Rover Classic 4.2 High CR	R3653	Operation Pride Tune Current tune with final improved Cold Start fueling below -22âC (-10âF).
Defender 3.9 High CR	R3654	Operation Pride Tune Current tune with final improved Cold Start fueling below -22âC (-10âF).

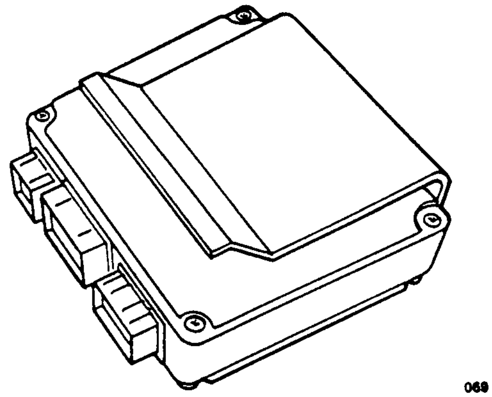
GENERIC ENGINE MANAGEMENT SYSTEM (GEMS)

Land Rover moves into the next level of sophistication in engine management with the Generic Engine Management System (GEMS). GEMS incorporates the function of the distributor into the ECM to provide a computer-controlled Distributorless Ignition System (DIS).

GEMS also provides more precise fuel delivery through the use of adaptive operating software and Sequential Multiport Fuel Injection. More sophisticated OBD II diagnostic capabilities are also included as part of the package.

New default strategies have been incorporated into the GEMS to allow the vehicle to continue running in the event of sensor failure - sometimes without any apparent symptoms other than an illuminated MIL. When this is occurring, however, there is a reduction in vehicle performance, economy, or emissions system operation.

ELECTRONIC CONTROL MODULE (ECM)



GEMS Electronic Control Module

System Inputs
The ECM is mounted in the engine compartment. The expanded list of ECM inputs is as follows:

- Crankshaft Position (CKP) Sensor
- Ignition Signal (Key on signal)
- Camshaft Position (CMP) Sensor
- Knock Sensor (KS)
- Intake Air Temperature Sensor
- Engine Coolant Temperature (ECT) Sensor
- Engine Fuel Temperature (EFT) Sensor
- Throttle Position Sensor (TPS)
- Mass Air Flow Sensor (MAFS)
- Park/Neutral Position Switch (PNPS)
- Heated Oxygen Sensors (4)
- Fuel Level Sensor
- Heated Front Screen
- Road speed (Range Rover)
- Air Conditioning request
- Battery Voltage
- Cooling fan request
- Security link
- ABS link

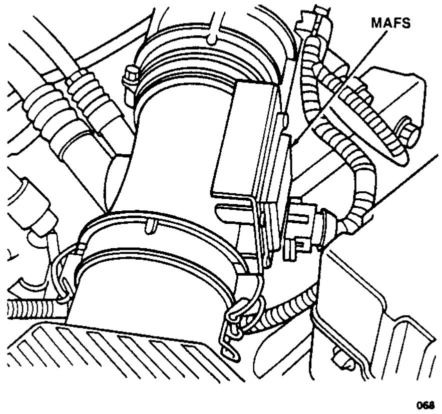
Several of these inputs (road speed, A/C request) originate in the ABS Module and are received via the Body Control Module.

System Outputs
System outputs are as follows:

- A/C Compressor Clutch
- Fan Control
- Fuel Injectors
- Idle Air Control
- Purge Valve
- Malfunction Indicator Lamp (MIL)
- Fuel Pump Relay
- Main Relay
- Coil Driver

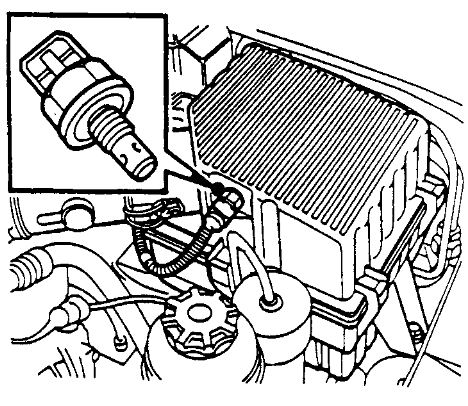
NEW COMPONENTS
Many system inputs and outputs remain similar previous models. There are, however, several important exceptions:

Mass Air Flow Sensor (MAFS)
GEMS controlled vehicles use a MAFS with somewhat less responsibility than the sensor used on previous models. The MAFS sensor contains a single heated wire that is used, as on previous models, to measure air flow. The second wire, used to determine intake air temperature, is remotely mounted on GEMS vehicles and is no longer a part of the MAFS function.



Mass Air Flow Sensor

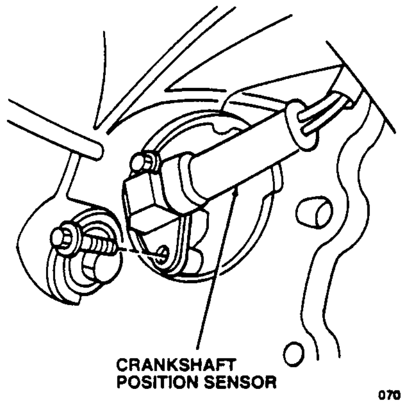
Intake Air Temperature Sensor
A dedicated sensor, mounted on the air cleaner housing, measures intake air temperature.



Intake Air Temperature Sensor

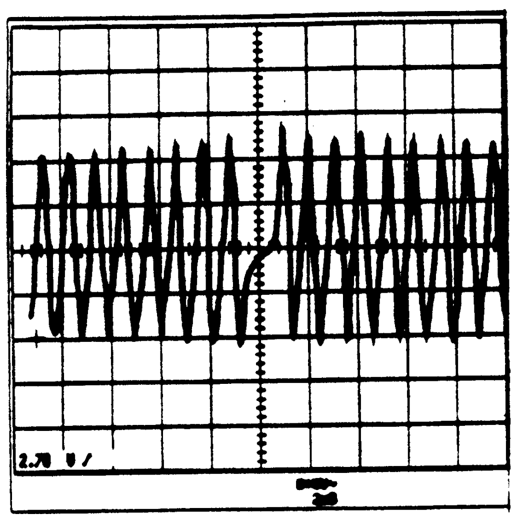
Crankshaft Position (CKP) Sensor
Basic engine timing is controlled by the ECM using input from the crankshaft position sensor. The sensor's signal is also used by the ECM in its engine knock and cylinder misfire operating strategies. There are no back-up strategies for the Crankshaft Position Sensor. The engine will not start or continue to run in the event of a Crankshaft Position Sensor failure.

The sensor is mounted on the flywheel housing.



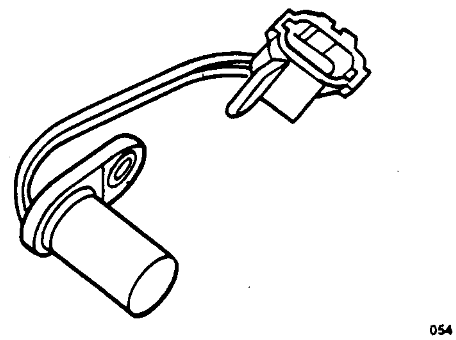
Crankshaft Position Sensor

A detailed description of the Crankshaft Position Sensor's signal is provided in the Ignition System section of this book.



Crankshaft Position Sensor Scope Pattern

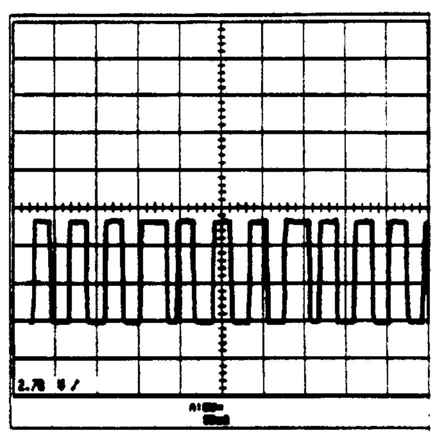
Camshaft Position (CMP) Sensor
Camshaft position input is provided to the GEMS by a Hall Effect sensor located on the engine's front cover. Electronic pulses are produced as lobes on the cam chain wheel pass the sensor tip. Four pulses are produced for every two engine revolutions.



Camshaft Position Sensor

The camshaft position signal is used by the ECM to precisely time fuel injector operation. This is especially important with SFI. The signal is also used, along with the crankshaft position sensor, as part of the engine knock control strategy.

A camshaft position sensor was not used on pre-GEMS systems.

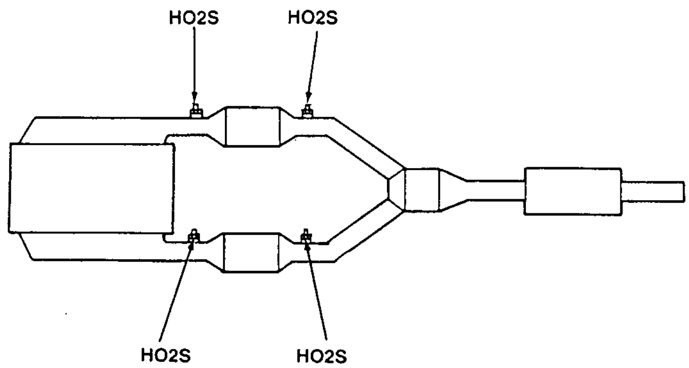


Camshaft Position Sensor Scope Pattern

Rear HO2S Sensors

Additional oxygen sensors are mounted in the exhaust system, downstream from each of the vehicle's catalytic converters. Data from these new sensors is compared with the signal produced by the front sensor on each bank. This information is used by the GEMS to monitor performance of the Three-Way Catalyst (TWC).

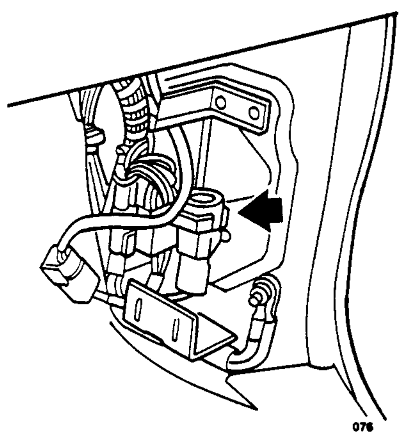
The rear sensors are also part of the ECM's fuel system back-up strategy. Should the signal from the front HO2S fail, the signal from the corresponding rear sensor will be used so that the vehicle can remain in closed-loop operation.



Oxygen Sensor Circuit

Inertia Switch

The inertia switch on GEMS equipped vehicles has been relocated to the passenger compartment, behind a trim panel on the right side footwell. Operation is identical to that of previous models.



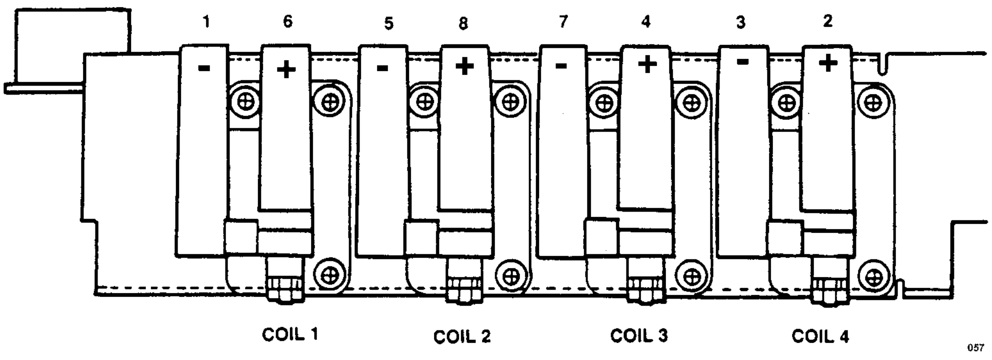
Inertia Switch

Ignition Coils

New ignition coils are used as part of the GEMS controlled Distributorless Ignition System (DIS). Four double-ended coils are mounted on a bracket at the rear of the engine compartment.

The circuit for each coil is completed by switching within the ECM. This produces sparks in two cylinders simultaneously, one cylinder on the compression stroke and one on the exhaust stroke. The spark on the exhaust stroke is the "wasted" spark described in the Ignition section of this book.

The ECM provides precise coil operation and ignition timing based on inputs including cam and crank position, coolant temperature, engine knock and load.



Range Rover SE Ignition Coils

Relays
The GEMS engine management system uses four relays:

- Main Relay
- Ignition Relay
- Starter Motor Relay
- Fuel Pump Relay

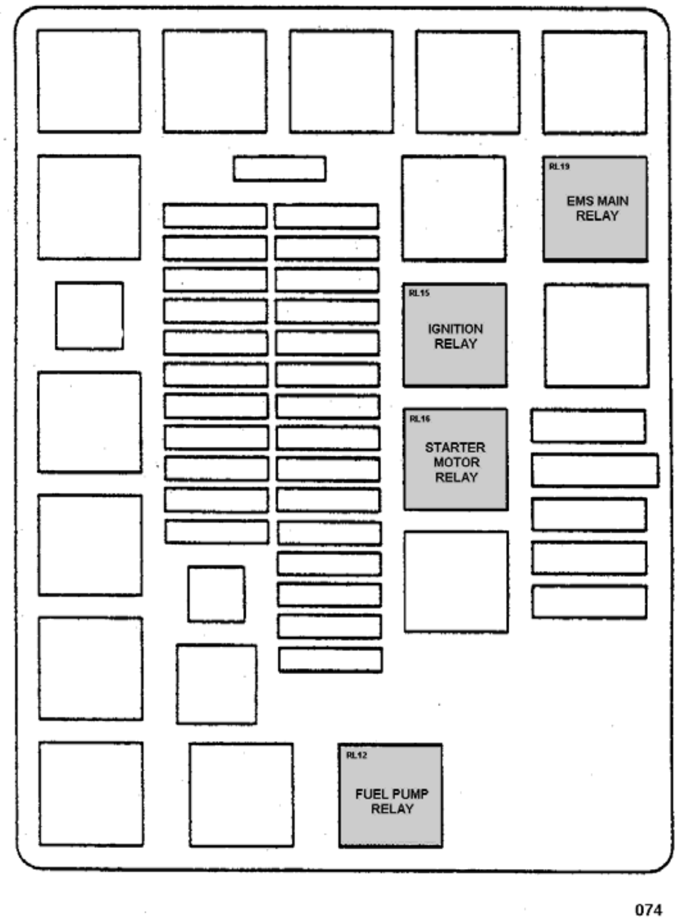
Each of these relays is located in a fuse box mounted in the engine compartment.

The main relay supplies power to the ECM, fuel injectors, mass air flow meter and purge valve. Failure of this relay will prevent the engine from starting.

The ignition relay supplies power to the coils, fuel pump relay and heated oxygen sensors. This relay is immediately de-energized when the ignition key is turned to the OFF position.

The starter relay provides the power feed to the starter motor. Operation of this relay is controlled by the ignition key.

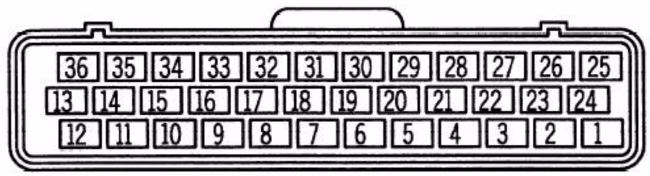
The fuel pump relay is powered through the ignition relay and controlled by the ECM. The relay is first activated briefly with the key in the ON position to prime the fuel system. The relay remains activated during cranking and while the engine is running.



Relay Location in Fuse Box

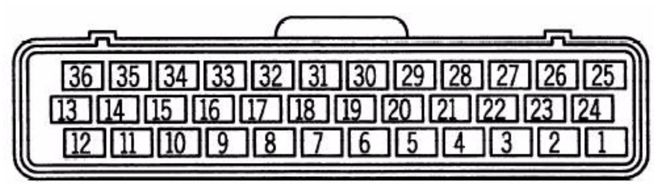
GEMS CONNECTOR PINOUTS

Range Rover 4.0/4.6
C505 (36way-Black)



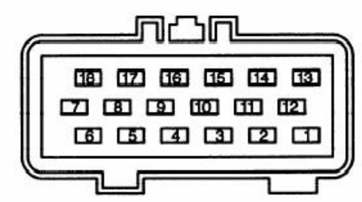
PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	BG	A/C Clutch Control via HEVAC ECU	19	SY	Purge Control Valve Control
2	GU	Fuel Consumption output to computer	20	-	
3	P	Cooling Fan Relay	21	WO	HO2S Upstream Heater Control
4	-		22	BY	MIL control via BeCM
5	-		23	S	Engine speed output to BeCM
6	-		24	UP	Fuel Pump Relay Control
7	-		25	-	
8	-		26	-	
9	-		27	YO	Throttle Angle Output to TCU
10	-		28	WU	HO2S Downstream Heater Control
11	YB	Cylinder #3 Injector Control	29	SP	Engine Torque Output to TCU
12	-		30	YN	Cylinder #4 Injector Control
13	YU	Cylinder #1 Injector Control	31	-	
14	-		32	YR	Cylinder #7 Injector Control
15	US	IACV-D	33	YG	Cylinder #5 Injector Control
16	RG	IACV-B	34	GW	IACV-C
17	YS	Cylinder #6 Injector Control	35	OR	IACV-A
18	YK	Cylinder #8 Injector Control	36	YW	Cylinder #2 Injector Control

Range Rover 4.0/4.6
C507 (36way-Red)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	YK	ABS Rough Road input (96MY)	19	-	
2	SU	Cam Position Sensor	20	-	Data Link (non-NAS)
3	-		21	PG	Heated Front Screen input
4	ULG	T-Box Low Range input (96MY)	22	-	
5	-		23	KR	Data Link (NAS)
6	-		24	-	
7	GB	Fuel Level Input	25	-	
8	G	Right Downstream HO2S input	26	B	BeCM Engine Immobilization input
9	-		27	Y	Road speed input from ABS ECU
10	RB	Knock Sensor Common (0 volt)	28	BS	A/C Request from HEVAC input
11	KW	LH Knock Sensor input	29	YB	Cooling Fan Request input
12	KB	RH Knock Sensor input	30	-	
13	SLG	Air Temperature input	31	SR	Auto Gearbox Ignition retard
14	G	Coolant Temperature Sensor input	32	RB	HO2S Common
15	YLG	Throttle Position Sensor input	33	U	Right Upstream HO2S input
16	UG	Mass Air Flow Sensor input	34	O	Left Upstream HO2S input
17	Y	Left Downstream HO2S input	35	SW	Fuel Temperature Sensor input
18	BO	Park/Neutral Switch input	36	RB	Sensor common

Range Rover 4.0/4.6
C509 (18way-Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	WK	Coil Driver Cylinders 5 & 8	10	B	Earth E529
2	-		11	BY	Crank Sensor Negative
3	-		12	KB	Crank Sensor Positive
4	R	TPS 5 volt supply	13	WU	Coil Drivers Cylinders 2&3
5	B	Earth E529	14	WB	Coil Drivers Cylinders 1&6
6	-		15	WY	Coil Drivers Cylinders 4&7
7	NO	Power Supply from Main Relay	16	B	Earth E529
8	W	“ON” input from Ignition Relay	17	UR	Main Relay Control - Low output
9	B	Earth E 529	18	-	

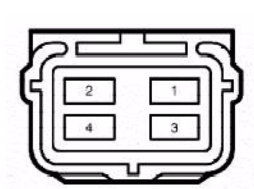
Heated Oxygen Sensors (HO2S)
C521 Left Upstream

C526 Right Upstream

C535 Left Downstream

C536 Right Downstream

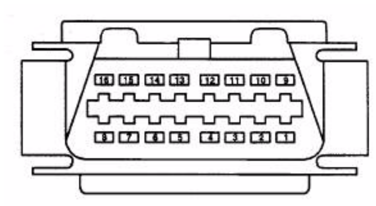
(4-way, Black)



PIN	Wire Color				Description
	C521 Left Up-stream	C526 Right Up-stream	C535 Left Downstream	C536 Right Downstream	
1	O	U	Y	G	HO2S 5 Volt Reference
2	RB	RB	RB	RB	HO2S Signal Ground

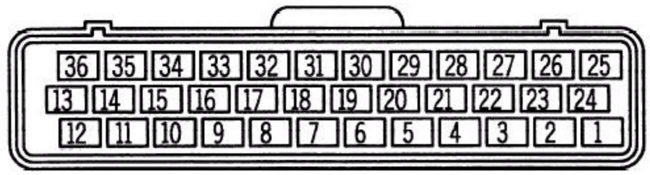
3	W	W	W	W	Heater Power supply
4	WO	WO	WU	WU	Heater Control

Data Link Connector (X-318)
C231 (16-way, Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	SR	Air Suspension Reset	9	-	
2	-		10	-	
3	-		11	WLG	“K”-Air Suspension
4	B	Battery Negative	12	WK	“L”-Air Suspension
5	BP	Chassis Negative	13	YK	“K”-SRS
6	-		14	YG	“L”-SRS
7	KR	“K”-GEMS,BeCM,HVAC,ABS	15	LGR	“L”-GEMS,BeCM,HVAC,ABS
8	-		16	N	Battery Positive(F33-Underhood)

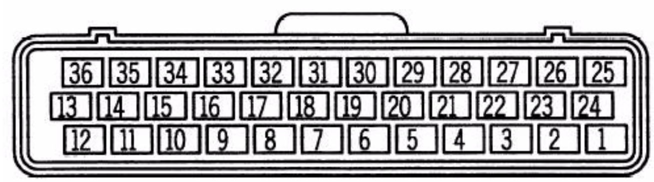
Discovery without EVAPS [pre 97MY]
C1032 (36way-Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	BS	A/C Clutch Relay Control	19	SY	Purge Control Valve Control
2	-		20	-	
3	GW	Cooling Fan Relay Control	21	WO	HO2S Upstream Heater Control
4	-		22	RS	MIL control
5	-		23	-	
6	-		24	UP	Fuel Pump Relay Control
7	-		25	-	
8	-		26	-	
9	-		27	-	
10	-		28	WU	HO2S Downstream Heater Control
11	YB	Cylinder #3 Injector Control	29	-	
12	-		30	YN	Cylinder #4 Injector Control
13	YU	Cylinder #1 Injector Control	31	-	
14	-		32	YR	Cylinder #7 Injector Control
15	US	IACV-D	33	YG	Cylinder #5 Injector Control
16	RG	IACV-B	34	GW	IACV-C
17	YS	Cylinder #6 Injector Control	35	OR	IACV-A
18	YK	Cylinder #8 Injector Control	36	YW	Cylinder #2 Injector Control

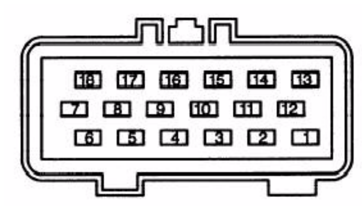
Discovery without EVAPS [pre-97MY]

C1017 (36way-Red)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	YK	ABS Rough Road input (96MY)	19	-	
2	SU	Cam Position Sensor	20	WK	Data Link (non-NAS)
3	-		21	-	
4	-		22	-	
5	-		23	WLG	Data Link (NAS)
6	-		24	-	
7	GB	Fuel Level Input	25	-	
8	R	Right Downstream HO2S input	26	B	10AS Engine Immobilization input
9	-		27	YK	Road speed input from ABS ECU
10	RB	Knock Sensor Common (0 volt)	28	YB	A/C Request input
11	O	LH Knock Sensor input	29	PB	Cooling Fan Request input
12	Y	RH Knock Sensor input	30	-	
13	SLG	Air Temperature input	31	-	
14	G	Coolant Temperature Sensor input	32	RB	HO2S Common
15	YLG	Throttle Position Sensor input	33	OG	Right Upstream HO2S input
16	UG	Mass Air Flow Sensor input	34	GR	Left Upstream HO2S input
17	GW	Left Downstream HO2S input	35	SW	Fuel Temperature Sensor input
18	OB	Park/Neutral Switch input	36	RB	Sensor common

Discovery without EVAPS [pre-97MY]
C1033 (18way-Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	WK	Coil Driver Cylinders 5 & 8	10	B	Earth E529
2	-		11	G	Crank Sensor Negative
3	-		12	N	Crank Sensor Positive
4	R	TPS 5 volt supply	13	WU	Coil Drivers Cylinders 2&3
5	B	Earth E529	14	WB	Coil Drivers Cylinders 1&6
6	-		15	WY	Coil Drivers Cylinders 4&7
7	NO	Power Supply from Main Relay	16	B	Earth E529
8	G	“ON” input from Ignition Relay	17	UR	Main Relay Control - Low output
9	B	Earth E 529	18	-	

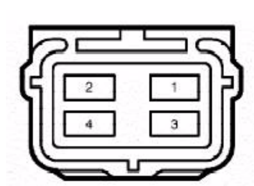
Heated Oxygen Sensors (HO2S)
C112 Left Upstream

C113 Right Upstream

C1019 Left Downstream

C1020 Right Downstream

(4-way, Black)

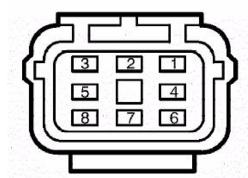


PIN	Wire Color				Description
	C112 Left Upstream	C113 Right Upstream	C1019 Left Downstream	C1020 Right Downstream	
1	UY/GR	OG	GW	R	HO2S 5 Volt Reference
2	UW/NU	YB	NW	U	HO2S Signal Ground
3	B/WG	WG	WG	WG	Heater Power supply

4	NU/WO	WO	WU	WU	Heater Control

MULTI-FUNCTION RELAY UNIT CONNECTORS

Discovery (without EVAPS) C1029 (8way-Black)

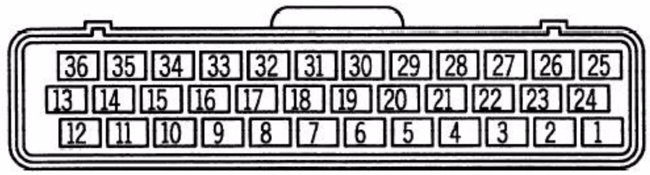


PIN	WIRE COLOR	FUNCTION
1	-	
2	-	
3	NO	Load Relay power out to ECM, Injectors, CANPV, MAFS, CMP
4	WP	Fuel Pump Power out
5	-	
6	NLG	Battery power to Load relay from Fuse F7
7	PW	Battery power to Fuel Pump Relay Fuse F6
8	NO	Load Relay power out common with pin 3

Discovery (without EVAPS) C1030 (6way-Black)

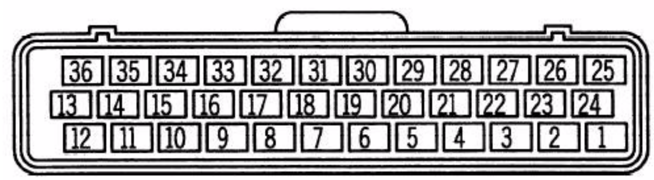
PIN	WIRE COLOR	FUNCTION
1	UP	Fuel Pump Relay control from ECM
2	WG	Key on power Fuel Pump Relay control from Fuse F3
3	UR	Main Relay control from ECM
4	-	
5	-	
6	-	

Discovery with EVAPS [97-99½ MY]
C1032 (36way-Black)



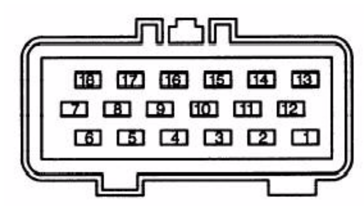
PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	BS	A/C Clutch Relay Control	19	SY	Purge Control Valve Control
2	-		20	-	
3	GW	Cooling Fan Relay Control	21	WO	HO2S Upstream Heater Control
4	-		22	RS	MIL control
5	-		23	-	
6	NR	Canister Vent Seal Valve control	24	UP	Fuel Pump Relay Control
7	-		25	-	
8	-		26	-	
9	-		27	-	
10	-		28	WU	HO2S Downstream Heater Control
11	YB	Cylinder #3 Injector Control	29	-	
12	-		30	YN	Cylinder #4 Injector Control
13	YU	Cylinder #1 Injector Control	31	-	
14	-		32	YR	Cylinder #7 Injector Control
15	US	IACV-D	33	YG	Cylinder #5 Injector Control
16	RG	IACV-B	34	GW	IACV-C
17	YS	Cylinder #6 Injector Control	35	OR	IACV-A
18	YK	Cylinder #8 Injector Control	36	YW	Cylinder #2 Injector Control

Discovery with EVAPS [97-99½ MY]
C1017 (36way-Red)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	YK	ABS Rough Road input (96MY)	19	-	
2	SU	Cam Position Sensor	20	WK	Data Link (non-NAS)
3	-		21	-	
4	-		22	-	
5	-		23	WLG	Data Link (NAS)
6	-		24	-	
7	GB	Fuel Level Input	25	-	
8	R	Right Downstream HO2S input	26	B	10AS Engine Immobilization input
9	-		27	YK	Road speed input from ABS ECU
10	RB	Knock Sensor Common (0 volt)	28	YB	A/C Request input
11	O	LH Knock Sensor input	29	PB	Cooling Fan Request input
12	Y	RH Knock Sensor input	30	GK	Fuel Tank Pressure input
13	SLG	Air Temperature input	31	-	
14	G	Coolant Temperature Sensor input	32	RB	HO2S Common
15	YLG	Throttle Position Sensor input	33	OG	Right Upstream HO2S input
16	UG	Mass Air Flow Sensor input	34	GR	Left Upstream HO2S input
17	GW	Left Downstream HO2S input	35	SW	Fuel Temperature Sensor input
18	OB	Park/Neutral Switch input	36	RB	Sensor common

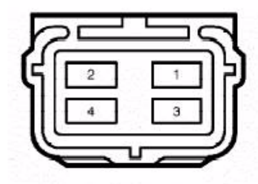
Discovery with EVAPS [97-99½ MY]
C1033 (18way-Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	WK	Coil Driver Cylinders 5 & 8	10	B	Earth E529
2	-		11	G	Crank Sensor Negative
3	-		12	N	Crank Sensor Positive
4	R	TPS 5 volt supply	13	WU	Coil Drivers Cylinders 2&3
5	B	Earth E529	14	WB	Coil Drivers Cylinders 1&6
6	-		15	WY	Coil Drivers Cylinders 4&7
7	NO	Power Supply from Main Relay	16	B	Earth E529
8	G	“ON” input from Ignition Relay	17	UR	Main Relay Control - Low output
9	B	Earth E 529	18	-	

Heated Oxygen Sensors (HO2S)
C112 Left Upstream
C113 Right Upstream

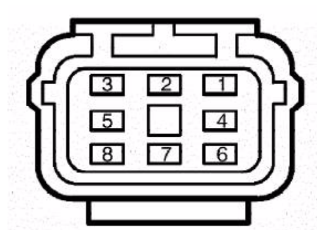
C1019 Left Downstream
C1020 Right Downstream
(4-way, Black)



PIN	Wire Color				Description
	C112 Left Up-stream	C113 Right Upstream	C1019 Left Downstream	C1020 Right Downstream	
1	UY/GR	OG	GW	R	HO2S 5 Volt Reference
2	UW/NU	YB	NW	U	HO2S Signal Ground
3	B/WG	WG	WG	WG	Heater Power supply
4	NU/WO	WO	WU	WU	Heater Control

MULTI-FUNCTION RELAY UNIT CONNECTORS
Discovery (with EVAPS)[97-99½ MY]

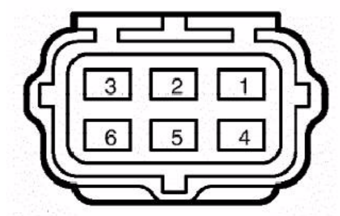
C1029 (8way-Black)



PIN	WIRE COLOR	FUNCTION
1	-	
2	-	
3	NO	Load Relay power out to ECM, Injectors, CANPV, MAFS, CMP
4	WP	Fuel Pump Power out
5	-	
6	NLG	Battery power to Load relay from Fuse F7
7	PW	Battery power to Fuel Pump Relay Fuse F6
8	NO	Load Relay power out common with pin 3

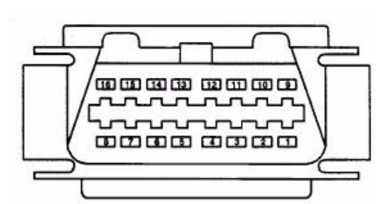
Discovery (with EVAPS)[97-99½ MY]

C1030 (6way-Black)



PIN	WIRE COLOR	FUNCTION
1	UP	Fuel Pump Relay control from ECM
2	WG	Key on power Fuel Pump Relay control from Fuse F3
3	UR	Main Relay control from ECM
4	-	
5	-	
6	-	

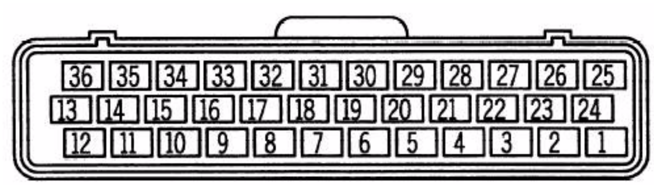
Data Link Connector (X-318)
Discovery (All with GEMS) C2083 (16-way, Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	-		9	-	
2	-		10	-	
3	-		11	-	
4	B	Battery Negative	12	-	
5	B	Chassis Negative	13	YK	“K”-SRS
6	-		14		
7	WLG	“K”-GEMS,,ABS	15	WK	“L”-GEMS, ABS
8	KB	“K”-10AS	16	WR	Battery Positive (F3-Satellite Box2)

1997 Defender 90

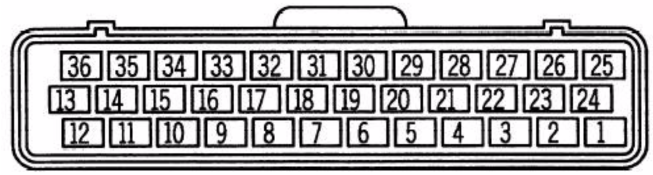
C634 (36way-Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	BS	A/C Clutch Relay enable (-)	19	SY	Purge Control Valve enable (-)
2	-		20	-	
3	GW	Cooling Fan Relay enable (-)	21	WO	HO2S Upstream Heater Control
4	-		22	RS	MIL bulb and Immob. ECU (Output)
5	-		23	-	
6	-		24	UP	Fuel Pump Relay Control (+)
7	-		25	-	
8	-		26	-	
9	-		27	-	
10	-		28	WU	HO2S Downstream Heater Control
11	YB	Cylinder #3 Injector Control	29	-	
12	-		30	YN	Cylinder #4 Injector Control
13	YU	Cylinder #1 Injector Control	31	-	
14	-		32	YR	Cylinder #7 Injector Control
15	US	IACV-D	33	YG	Cylinder #5 Injector Control
16	RG	IACV-B	34	GW	IACV-C
17	YS	Cylinder #6 Injector Control	35	OR	IACV-A
18	YK	Cylinder #8 Injector Control	36	YW	Cylinder #2 Injector Control

GEMS CONNECTOR PINOUTS

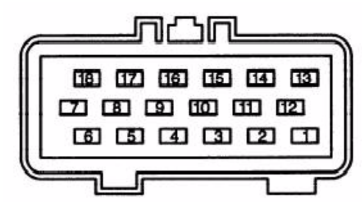
1997 Defender 90
C636 (36way-Red)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	YR	ROUGH ROAD DET. ECU	19		
2	SU	CMP SENSOR INPUT	20	WK	ROUGH ROAD DET. ECU
3			21		
4			22		
5			23	WLG	ROUGH ROAD DET. ECU
6			24		
7	GB	FUEL LEVEL INPUT	25		
8	R	R.R. O2 SENSOR INPUT	26	B	Immobilization Unit Input
9			27	YK	
10	RB	KNOCK SENSOR GROUND	28	YB	A.C. COMPRESSOR REQUEST (TRINARY SWITCH -HIGH/LOW PRESS.)
11	O	L. KNOCK SENSOR	29	PB	A.C. CONDSER FAN REQUEST (A.C. TRINARY SWITCH -MED. PRESS.)
12	Y	R. KNOCK SENSOR INPUT	30		
13	SLG	AIR TEMP SENSOR INPUT	31		
14	G	ECT SENSOR INPUT	32	RB	O2 SENSOR GROUND
15	YLG	TP SENSOR INPUT	33	OG	R.F. O2 SENSOR INPUT
16	UG	MAF SENSOR INPUT	34	GR	L.F. O2 SENSOR INPUT
17	GW	L.R. O2 SENSOR INPUT	35	SW	FUEL TEMP SENSOR INPUT
18	OB	STARTER RELAY GROUND	36	RB	MULT.* SENSOR GROUND

* Multiple Sensor Ground= TP, ECT, MAF, CMP, Fuel Temp., Air Temp.

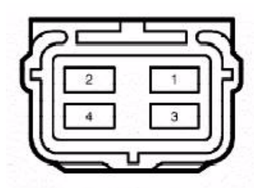
1997 Defender 90
C635 (18way-Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	WK	Coil Driver Cylinders 5 & 8	10	B	Earth C560
2	-		11	G	Crank Sensor Negative
3	-		12	N	Crank Sensor Positive
4	R	TPS 5 volt supply	13	WU	Coil Drivers Cylinders 2&3
5	B	Earth C560	14	WB	Coil Drivers Cylinders 1&6
6	-		15	WY	Coil Drivers Cylinders 4&7
7	NO	Power Supply from Main Relay	16	B	Earth C560
8	WG	Fuel Pump Relay enable (-)	17	UR	Main Relay Control - enable (-)
9	B	Earth C560	18	-	

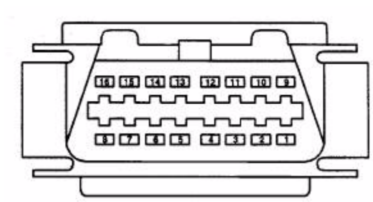
Heated Oxygen Sensors (HO2S)
C644 Left Upstream
C645 Right Upstream

C643 Left Downstream
C642 Right Downstream
(4-way, Black)



PIN	Wire Color				Description
	C644 Left Up-stream	C645 Right Up-stream	C643 Left Downstream	C642 Right Downstream	
1	O	U	Y	G	HO2S 5 Volt Reference
2	RB	RB	RB	RB	HO2S Signal Ground
3	W	W	W	W	Heater Power supply
4	WO	WO	WU	WU	Heater Control

Data Link Connector (X-318)
C040 (16-way, Black)



PIN	WIRE COLOR	FUNCTION	PIN	WIRE COLOR	FUNCTION
1	-		9	-	
2	-		10	-	
3	-		11	-	
4	B	Chassis Negative (Header C286, C550)	12	-	
5	B	Chassis Negative (Header C286, C550)	13	-	
6	-		14	-	
7	WLG	"K"-GEMS, Rough Road Det. ECU	15	WK	"L"-GEMS, Rough Road Det. ECU
8	OLG		16	P	Battery Positive(Fuse 3-Passenger Compartment)

GEMS ECM TUNE SUMMARY

NOTE: Any of the following tune levels may be valid for the year/model listed. ECM tunes should only be changed according to published service documentation or at the direction of the Technical Help desk, and only due to verified complaint or symptoms. Should a replacement be necessary, only 'Final Service Fix' PROM's should be used unless otherwise directed by Techline.

Model	Tune #	Description
95MY RR	9612	Production Tune, POE installed.
	9613	Production Tune, Line Build.
	9638	“Final" Service fix
96MY RR	9618	Original Production Tune
	9622	Service Fix for ABS/T-box Link Faults (P1317/1703)
	9636	“Final" Service fix
97MY RR	9635	POE fix for Oxy period fix on 4.6L
	9639	“Final" Service fix
98MY RR	9648	Original Production Tune (Contains all RR final service fixes)
99MY RR	9648	Original Production Tune (same as 98 MY)
99MY Calloway	9659	Available only with complete ECM
96MY Discovery	9621	Orignial Production Tune - phase 1
	9623	Orignial Production Tune - phase 2
	9631	Service Fix for ABS Link P1317 and Warm up timer P0125 (both phase 1&2)
	9637	“Final" Service fix - Auto trans
	9630	“Final" Service fix - Man trans
97MY Discovery	9624	Original Production Tune - Auto trans
	9629	Original Production Tune - Man trans
	9662	“Final" Service fix - Auto trans
	9644	“Final" Service fix - Man trans
97.5MY Discovery w/ EVAP Leak Detection	9633	Original Production Tune - Auto trans
	9634	Original Production Tune - Man trans
	9640	Running change, fix for Idle Surge and Fuel Level Fault P0461
	9641	Running change, fix for Idle Surge and Fuel Level Fault P0461
	9652	“Final" Service fix - Auto trans
	9653	“Final" Service fix - Man trans
98MY Discovery	9652	Original Production Tune - Auto trans (Contains all 97 Discovery final service fixes)
	9655	“Final" Service fix - Auto trans
99MYDisco	9655	Original Production Tune - Auto trans (same as 98 MY)
97MY Def 90	9632	Original Production Tune
	9661	“Final" Service fix
Range Rover “Final" Service fix tunes will include: Oxy period resolution to driver induced faults, Idle speed improvement preventing cold hesitation, and Engine Speed Fault (Gbox 21). Improved torque map to prevent Torque Reduction Fault (Gbox 23).		
Discovery “Final" Service fix tunes will include: Oxy period resolution to driver induced faults, Trailing Throttle Misfire, Idle speed improvement preventing cold hesitation, Idle speed fluctuation on decel, Fuel Level Fault P0461.		

Interim Service Tunes

The following is a list of unreleased tunes that were sent out by the GEMS Helpline on a case by case basis to correct individual problems.

Each one contains elements of the final service fix, but does not provide the full benefit of a final service fix tune.

Model	Tune #	Description
95 MY RR	4000	Increased Idle speed, Oxy Period fix (P0130/0150)
96 MY RR	4001	Increased Idle speed, Oxy Period fix (P0130/0150)
97 MY RR	4002	Increased Idle speed, Oxy Period fix (P0130/0150)
96 MY Discovery	8173	Increased Idle speed.
96 MY Discovery	568_563	Misfire trailing throttle and Oxy period fix (P0130/0150)

Other Tunes

The following is a list of tunes that may be encountered in a vehicle, but are not appropriate for the year/model listed.

Model	Tune #	Description
95MY RR	9601	Original Production Tune - never sold
97MY RR	9626	Original Production Tune (All reworked to 9635)
98MY Discovery	9653	Original Production Tune - Man trans (no NAS Man trans built)

BOSCH 5.2.1 ENGINE MANAGEMENT SYSTEM

Introduction

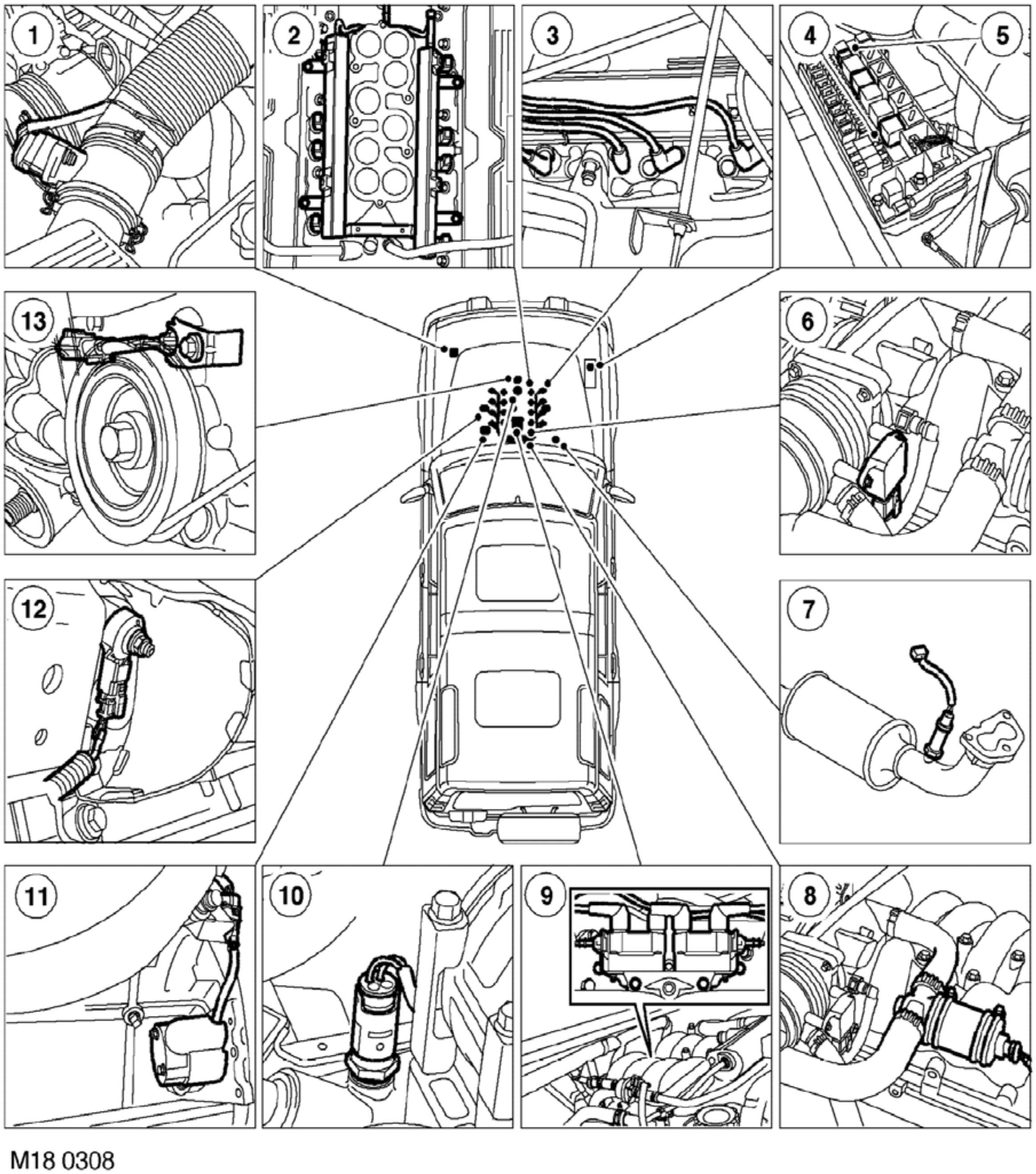
Bosch supplies the engine management system used on Discovery Series II and Range Rover beginning mid 1999 model year. It is referred to as the Bosch Motronic 5.2.1 system. The system supports sequential fuel injection and waste spark ignition. The system is designed to optimize the performance and efficiency of the engine.

The key functions of the Bosch 5.2.1 engine management system are:

- To control the amount of fuel supplied to each cylinder
- To calculate and control the exact point of fuel injection
- To calculate and control the exact point of ignition on each cylinder
- To optimize adjustment of the injection and ignition timings to deliver the maximum engine performance throughout all engine speed and load conditions
- To calculate and maintain the desired air/fuel ratio, to ensure the 3 way catalysts operate at their maximum efficiency
- To maintain full idle speed control of the engine
- To ensure the vehicle adheres to the emission standards
- To ensure the vehicle meets with the fault handling requirements, as detailed in the 'On-board diagnostic II' (OBDII) legislation
- To provide an interface with other electrical systems on the vehicle

To deliver these key functions, the Bosch 5.2.1 engine management system relies upon a number of inputs and controls a number of outputs. As with all electronic control units, the ECM needs information regarding the current operating conditions of the engine and other related systems before it can make calculations, which determine the appropriate outputs.

System Components



1. Mass Airflow & Temperature Sensor
2. Fuel Injectors
3. Spark Plugs/High Tension Leads
4. Fuel Pump Relay
5. A/C Compressor Clutch & Cooling Fan Relay
6. Throttle Position Sensor
7. Heated Oxygen Sensor
8. Idle Air Control Valve
9. Ignition Coils
10. Engine Coolant Temperature Sensor
11. Crankshaft Speed and Position Sensor
12. Knock Sensor
13. Camshaft Position Sensor

System Inputs
The Bosch 5.2.1 system optimizes engine performance by interpreting signals from numerous vehicle sensors and other inputs. Some of these signals are produced by the actions of the driver, some are supplied by sensors located on and around the engine and some are supplied by other vehicle systems.

The inputs are as follows:

- Ignition switch (position II)
- Throttle position sensor (TPS)
- Crankshaft position sensor (CKP)
- Camshaft position sensor (CMP)
- Engine coolant temperature sensor (ECT)
- Knock sensors (KS)
- Air mass flow and temperature sensor (MAF)
- Heated Oxygen sensors (HO2)
- Immobilization signal
- Fuel level signal
- Vehicle speed sensor (VSS)
- Rough road detection signal
- Automatic temperature control (ATC) system request
- Automatic gearbox information
- Fuel tank pressure sensor

Engine control module
The engine control module (ECM) is secured to a pressed steel bracket located at dash level on the right hand ‘A’ post. It features five separate electrical connectors. Each connector groups associated pin-outs together.

The five connectors interlock when connected to the ECM. Therefore, they must be connected to the ECM in a specific order. Connector 1 must be used first, connector 2 second, connector 3 third, and so on. The connectors can be disconnected only in the reverse order of this. It is not possible to remove the connectors from the ECM in any other order, the way in which the connectors interlock prevents this.

The main functions of the groups of pin outs incorporated into each connector are detailed in the following table.

Connector number	Connector color	Main functions
1	Black	Main power supply and ground connections
2	Black	Oxygen sensor inputs and Oxygen sensor
3	Black	All sensor inputs and outputs

4	Black	Most related vehicle system communications.
5	Black	Ignition coil control

The ECM is programmed during manufacture by writing the program and the engine ‘tune’ into the Flash EPROM (erasable programmable read only memory). This Flash EPROM can be reprogrammed in service, using TestBook. In certain circumstances, it is possible to alter the ‘tune’ or functionality of the ECM using this process.

The engine management system (EMS) now used on Discovery Series II , is an improvement over existing systems. The new EMS now improves the capability with respect to the monitoring, evaluating, diagnosing and correcting of many engine mechanical irregularities. It also has improved capability for monitoring and adapting its own operation to ensure that any mechanical variations do not affect the performance or the exhaust emissions of the engine.

The ECM has advanced fault-handling capabilities. It can detect the type and severity of faults, store relevant engine operating conditions at the time a fault occurs and also store the time the fault occurred. The individual fault handling procedures the ECM completes will be explained throughout the section. The ECM stores fault codes, referred to as ‘P’ codes. It is this ‘P’ code that Land Rover has to make available to third party scanning tools. The ‘P’ codes are defined within the OBDII legislation. Three environment variables are stored for each fault, in addition to Freeze Frame data. Once recorded, details of a fault will stay in the ECM’s memory for 40 ‘trips’.

A ‘trip’ is defined precisely by the on board diagnostic (OBD) legislation. It is a predetermined routine through which the engine or vehicle must pass before the ECM will attempt to ‘validate’ a previously faulty signal. There are a number of OBD set routines. They are all grouped into one of several inspection/maintenance flags (IMF). These are:

- Catalytic converter efficiency
- Purge (all markets) / evaporative emission leak detection diagnostic.
- Oxygen sensor diagnostics
- Oxygen sensor heater diagnostics

The above diagnostics all demand very strict engine conditions be met before they will run. By following the appropriate driving cycle, the IMF flags will indicate when the diagnostic completes. Most of the other diagnostics will operate within the first 30 seconds after engine starts. Refer to the appropriate service literature for details on drive cycle, trip, and journey details for any given sensor/system.

TestBook can be used to view the diagnostic routines performed by the ECM, which need to be set before the relevant IMF becomes set. When a fault code is stored, it will indicate, via TestBook, the IMF required to ensure that successful repair can been verified.

When certain fault conditions prevail, the EMS stores data relating to the value of certain engine inputs. These values, when stored, are known as ‘freeze frame data’. Freeze frame data is not the same as the three environmental variables stored when a fault is detected. Environmental variables are stored along with each fault (three variable conditions for each ‘P’ code), whereas freeze frame data is stored for the highest priority fault (different faults have different priorities, according to their likely impact on exhaust gas emissions).

Freeze frame data always records:

- Engine speed
- Engine load
- ‘P’ code
- Short term fuelling trim A / B
- Long term fuelling trim A / B
- Fuelling status A / B
- Coolant temp
- Road speed

The ECM will illuminate the malfunction indicator lamp (MIL) on detection of a fault, providing the fault has occurred on two consecutive driving cycles. This strategy ‘validates’ the fault, ensuring that the MIL does not illuminate needlessly. There is one exception to this, this being the ECM detecting that a catalyst-damaging misfire is currently occurring. In this case, the ECM will flash the MIL immediately the fault is detected. If the fault rectifies itself, the ECM will stop flashing the MIL, changing it to continuously ‘on’.

The MIL is illuminated by a bulb check facility when the ignition is switched to position II, a “MIL event fault”, or if the automatic gearbox requests it.

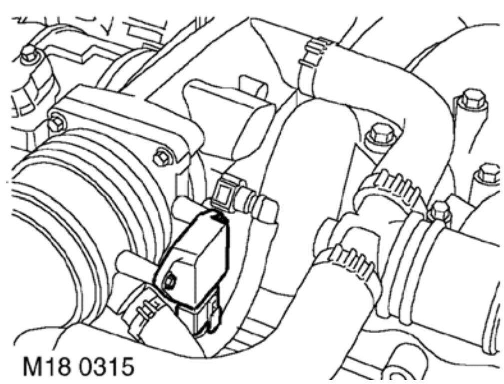
Ignition switch

The ignition switch supplies a signal to the ECM whenever it is turned to position II (‘ignition on’). Using this signal, the ECM is able to detect when the ignition switch is turned ‘on’ and when it is turned ‘off’. The ECM will initiate its ‘power-up’ sequence whenever the ignition is turned ‘on’. At this time it will energize the main relay (which, amongst other things, supplies the main feed to the ECM), energize the fuel pump relay and initiate a ‘self-check’ on the EMS system.

When it detects the ignition switch has been turned ‘off’, the ECM will stop the engine (if it was running) and record all the relevant information within its internal memory to enable the quick-start functions to operate correctly. It will then initiate its ‘power-down’ sequence, which involves de-energizing the main relay.

Throttle position sensor

The throttle position sensor (TPS) is connected to the throttle valve shaft, located on the throttle body portion of the plenum chamber (see figure 50). It monitors the position and the rate of movement of the throttle valve, which is controlled by the driver via the throttle pedal and accelerator cable.



The throttle position sensor is a potentiometer. It receives a 5 volt supply from the ECM whenever the ignition switch is turned ‘on’. It then returns a proportion of the supplied voltage to the ECM to indicate its position and rate of movement. The actual position of the throttle valve, the direction in which it is moving (if it is moving) and, if so, the rate at which it is moving will determine the value of the voltage returned. The returned voltage will be in the range of 0.1 volts (throttle fully closed) to 4.8 volts (throttle fully open). The ECM will supply 5 volts on the signal wire when the throttle potentiometer is disconnected. This voltage is used in the diagnostics of the wiring harness. The sensor has gold plated terminals to reduce the environmental impact. Care must be taken not to scratch the gold coating, particularly when using a multimeter connected directly to the sensor.

In addition to using the signal supplied by the throttle position sensor to determine the driver’s requirements, the ECM also uses the signal to check the plausibility of the signal supplied by the air flow meter. In circumstances where the signal supplied by the air flow meter indicates that only a small quantity of air is entering the engine, and the signal supplied by the throttle position sensor indicates a large throttle angle (i.e. throttle open), the ECM will store a ‘ratio fault’ indicating the throttle position and airflow have not matched.

The TPS sensor does not require any type of adjustment or calibration process. The Bosch 5.2.1 ECM is able to ‘learn’ the closed throttle position using the signal it supplies. If the ECM detects a sensor failure, or the signal supplied by the throttle position sensor is deemed implausible, then it will introduce a substitute signal. The actual value of the substitute signal will be dependent upon a variety of signals received from other sensors located on and around the engine. Engine performance will be affected in these circumstances and the driver will notice the following:

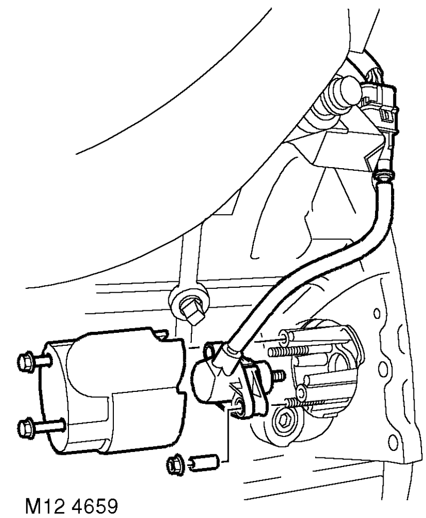
- The engine will idle poorly
- The vehicle will default to 3rd / 4th gear (limp home strategy automatic vehicles only)
- The engine will run poorly and respond poorly to throttle pedal movement
- The gearbox will not kickdown (automatic vehicles only)
- Altitude adaptations will be incorrect (engine performance affected even more when the vehicle is operated at high altitudes

Expected Values

Throttle Angle	Max/Min Value	Nominal Value	Diagnostic Fault Value	Nominal Resistance
Closed	0.811 mV	0.894 mV	0.960 mV	1.013kW
Fully Open	0.162 mV	0.096 mV	0.040 mV	2.575kW

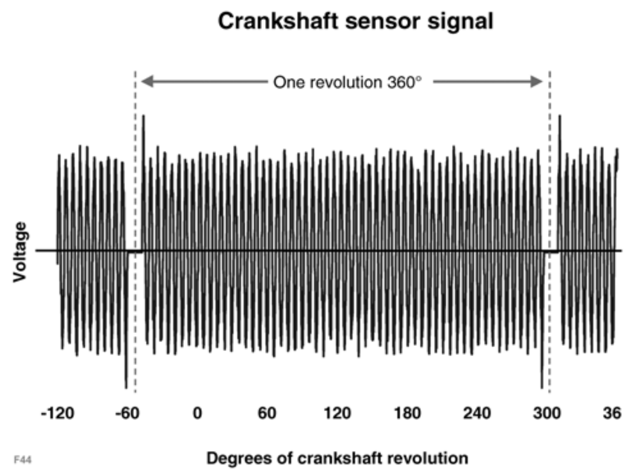
TestBook will retrieve the fault code and perform the necessary diagnostics. The sensor can also be probed directly, providing the care point mentioned above is adhered to. TestBook also has the capability of displaying the value of the TPS signal received by the ECM. It displays this on the ‘live reading’ screen. It will also display the altitude adaptive value currently being used on this screen.

Crankshaft position sensor


M12 4659

The crankshaft position sensor is located in the engine block, just below number 7 cylinder (see figure 51). It protrudes through the cylinder block and is positioned adjacent to the face of the flywheel or flex plate. The sensor reacts to a 'drilled reluctor' incorporated into the flex plate to ascertain engine speed and position information. The sensor is located on a spacer and is secured in position by a single bolt. The spacer is 18 mm (0.709 in) thick on vehicles used with automatic transmission. The thickness of the spacer determines how far the sensor protrudes through the cylinder block and, therefore, sets the position of the sensor in relation to the flywheel or flex plate. The sensor and the spacer are covered by a protective heat shield. The sensor has three wires attached to it; one signal wire, one ground wire connected to the ECM and one ground wire connected to vehicle ground. This last wire acts as a shield to earth any stray electromagnetic radiation produced from the crankshaft signal.

The crankshaft sensor is an inductive type sensor which produces a sinusoidal output voltage signal. The following illustration shows a typical crankshaft signal over a 480° crankshaft revolution. This voltage is induced by the proximity of the moving toothed reluctor, which excites the magnetic flux around the tip of the sensor when each tooth passes. This output voltage will increase in magnitude and frequency as the engine rpm rises and the speed at which the reluctor passes the sensor increases. The signal voltage will peak at approximately 6.5 volts if connected to the ECM (further increases in engine speed will not result in greater magnitude). The ECM neither specifically monitors nor reacts to the output voltage (unless it is very small or very large) but does measure the time intervals between each pulse (i.e. signal frequency). The signal is determined by the number of teeth passing the sensor, and the speed at which they pass. The teeth are spaced at 6° intervals, with two teeth missing at 60° BTDC to give the ECM a hardware point of reference, so there is a total of 58 teeth.



The ECM outputs an engine speed signal to the automatic gearbox, the SLABS ECU, the instrument pack and the ACE ECU. The signal to the automatic gearbox TCM and the SLABS ECU are supplied via the CAN link, while the signals to the ACE ECU and the instrument pack are carried via a frequency dependent digital signal.

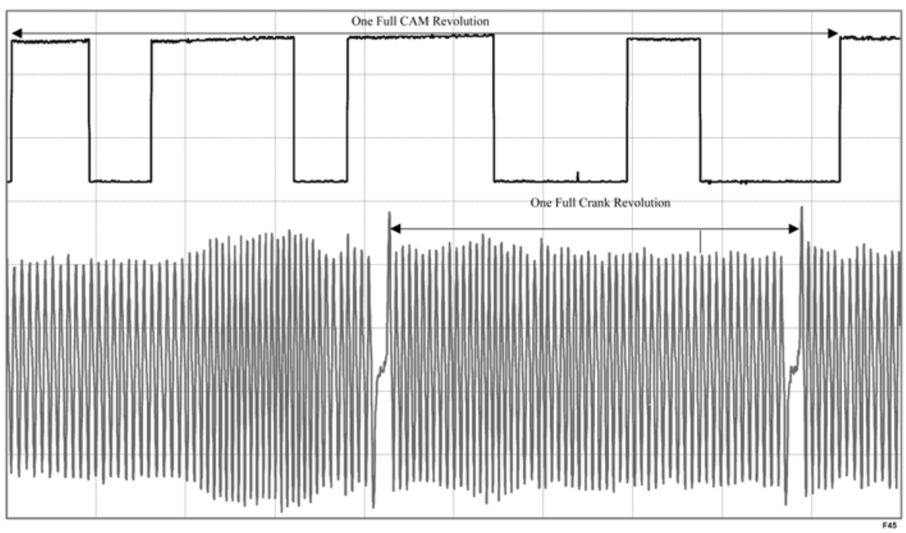
The signal produced by the crankshaft position sensor is critical to engine running. There is no backup strategy for this sensor and failure of the signal will result in the engine stalling and/or failing to start. If the sensor fails when the engine is running, then the engine will stall, a fault code will be stored and details captured, of the battery voltage, coolant temperature and air temperature at the time of the failure. If the signal fails when the engine is cranking, then the engine will not start and no fault will be stored, as the ECM will not detect that an attempt had been made to start the engine. In both cases the tachometer will also cease to function immediately and the MIL lamp will not extinguish.

During the power-down procedure, which occurs when the ignition is switched ‘off’, the ECM stores details of the position of the crankshaft. This enables the ECM to operate the injectors appropriately to aid quick engine start, which serves to reduce emissions when the engine is cold.

Camshaft position sensor

The camshaft position sensor is located in the timing cover and the tip of the sensor is positioned in close proximity to the camshaft gear. The camshaft gear incorporates four teeth. The camshaft position sensor is a hall-effect sensor which switches a battery fed supply 'on' and 'off'. The supply is switched when the teeth machined onto the camshaft gear pass by the tip of the sensor. The four teeth are of differing shapes, so the ECM can determine the exact position of the camshaft at any time. Using this signal in conjunction with the signal supplied by the crankshaft position sensor, the ECM is able to detect the firing position of the engine (i.e. the exact position and stroke of each piston). Care must be taken to avoid fitting an incorrect camshaft gear, as the gear used on engines equipped with GEMS EMS looks similar, but if this gear is used in place of the correct gear, a fault will be stored, as the two gears have a different tooth spacing pattern.

Unlike an inductive type sensor, a hall-effect sensor does not produce a sinusoidal output voltage (sine wave).



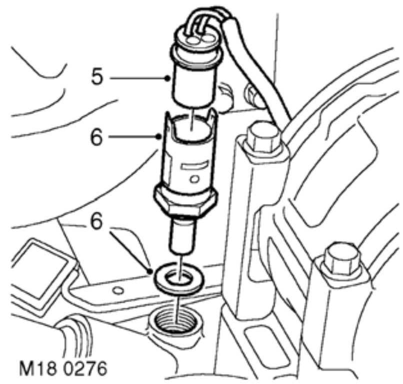
Camshaft/Crankshaft Signal Output

Instead it produces a 'square wave' output. The edges are very 'crisp', rising very sharply and falling very sharply, giving the ECM a defined edge on which to base its calculations. An implausible signal will result in the following:

- The MIL lamp illuminated after 'validating' the fault)
- Loss of performance, due to the corrective ignition strategy being disabled. A default ignition map is used which retards the timing to a safe position
- Injector operation possibly 360° out of phase, i.e. fuel injected during compression stroke rather than during exhaust stroke
- Quick crank/cam synchronization on start-up feature disabled
- Some Oxygen sensor diagnostics disabled

In addition, the ECM will store a relevant fault code and capture the input signal supplied by the engine coolant temperature sensor, and the engine load calculation and the engine rpm at the time of failure. TestBook will display the live readings from the camshaft sensor.

Engine coolant temperature sensor



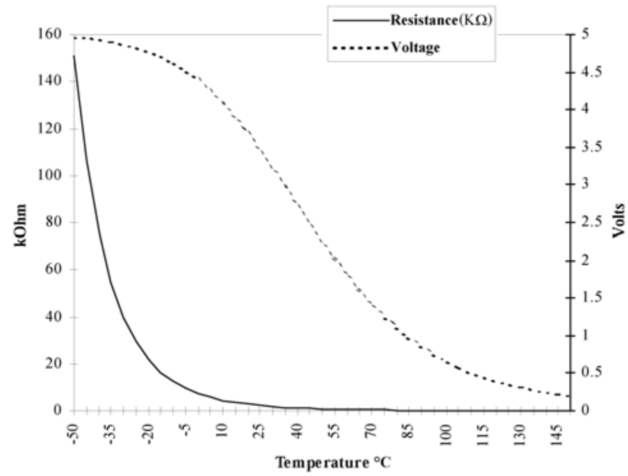
The engine coolant temperature sensor is located near the top of the engine, adjacent to the coolant outlet pipe. The sensor features four electrical connections; two are used on Discovery Series II applications and all four are used in 1999 MY Range Rover applications. The sensor conforms to the conventional negative temperature coefficient (NTC) electrical characteristics.

The signal supplied by the engine coolant temperature sensor is critical to many fuel and ignition control strategies. Therefore, the Bosch 5.2.1 system incorporates a complex engine coolant temperature sensor default strategy, which it implements in the event of failure. The ECM uses several alternative inputs to determine the specific default value selected in these circumstances. The amount of time the engine has been running and the temperature of the air entering the engine are the primary inputs used to determine the default value. The software model of the temperature increasing will finish when it reaches a value of 150°F (65°C). This value is then used until the engine is switched off.

The following symptoms may be noticeable in the event of an engine coolant temperature sensor failure:

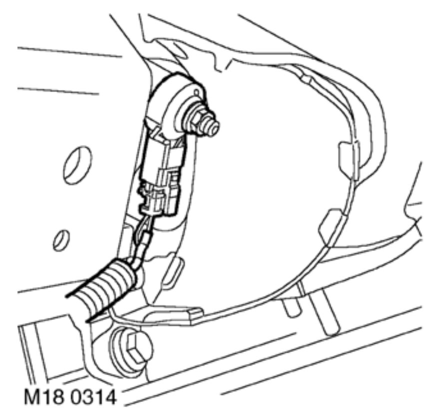
- The MIL lamp illuminated (after ‘validating’ the fault)
- Poor engine hot and cold start
- Overheat warning lamp (incorporated within the Instrument pack) is illuminated
- Excessively hot or cold needle reading on the temperature gauge

The ECM will also store details of the engine speed, engine load and air temperature in its memory. This information is stored to aid diagnosis of the fault



Coolant Sensor Operational Values

Knock sensors



There are two knock sensors on the V-8 engine, both located directly on the cylinder block, one on each side. The knock sensors produce a voltage signal in proportion to the amount of mechanical vibration generated at each ignition point. Each sensor monitors the four cylinders in one bank.

The knock sensors incorporate a piezoceramic crystal. This crystal produces a voltage whenever an outside force tries to deflect it, (i.e. exerts a mechanical load onto it). When the engine is running, the compression waves in the material of the cylinder block, caused by the violent combustion of the fuel/air mixture within the cylinders, deflect the crystal. As described above, these forces acting on the crystals cause them to produce an output voltage signal. These signals are supplied to the ECM and compared with sample ‘mapped’ signals stored within its memory. From this, the ECM can identify when the ignition is too far advanced and causing pre-ignition problems.

Care must be taken at all times to avoid damaging the knock sensors, but particularly during removal and installation procedures. The recommendations regarding to torque and surface preparation must be adhered to. The torque applied to the sensor and the quality of the surface preparation both have an influence over the transfer of mechanical noise from the cylinder block to the crystal.

The ECM uses the signals supplied by the knock sensors in conjunction with the camshaft sensor signal, to determine the optimum ignition point for each cylinder. The ignition point is set according to pre-programmed ignition maps stored within the ECM. In this case, the ECM is programmed to use ignition maps for 95 RON premium specification fuel. It will also function on 91 RON regular specification fuel but without adaptations. If the only fuel available is of poor quality, or the customer switches to a lower grade of fuel after using a high grade for a period of time, the engine may suffer slight pre-ignition for a short period. This amount of pre-ignition will not damage the engine. This situation will be evident while the ECM learns and then modifies its internal mapping to compensate for the variation in fuel quality. This feature is called 'adaptations'. The ECM has the capability of adapting its fuel and ignition control outputs in response to several sensor inputs.

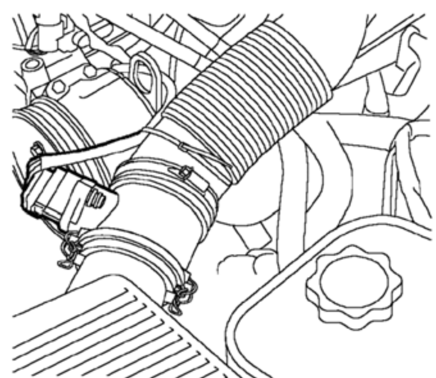
Unlike previous Land Rover engine management systems, the Bosch 5.2.1 system is capable of advancing the ignition timing for improved power and economy, as well as retarding it.

The ECM will cancel 'closed loop' control of the ignition system if the signal received from either knock sensor becomes implausible, or the signal from the camshaft sensor is corrupted at any time. In these circumstances, the ECM will default to a safe ignition map. This measure ensures the engine will not become damaged if low quality fuel is used. The MIL lamp will not illuminate at this time (in any market), although the driver may notice that the engine 'knocks' in some driving conditions and displays a slight drop in performance and smoothness.

When a knock sensor fault is stored, the ECM will also store details of the engine speed, engine load and the coolant temperature.

Mass Air Flow and Intake Air Temperature sensor

The mass air flow (MAF) sensor is located in the air intake ducting, between the air filter housing and the plenum chamber. The MAF sensor returns a signal to the ECM to indicate how much air is entering the engine. The amount of air entering the engine is calculated from two functions:



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1 The sensor incorporates a hot film element. This film is heated by the circuitry in the MAF sensor. A proportion of the air flowing into the engine flows past the film and acts to cool it. The greater the air flow, the greater the cooling effect. The output voltage varies in accordance with the amount of electrical power being consumed by the mass air flow meter to keep the film at a predetermined temperature.

2 The MAF sensor also incorporates an intake air temperature (IAT) sensor. This sensor is an NTC type of sensor. It informs the ECM of the temperature of the air entering the engine. The temperature of the air entering the engine will affect its density. The density of the air entering the engine will affect its ability to support combustion. The signal supplied by the temperature sensor is used to calculate the cooling effect on the hot film from a given mass of air, along with several other fuelling calculations.

The MAF sensor is sensitive to sudden shocks and changes in its orientation. It should, therefore, be handled carefully. It is also important that the intake ducting between the air filter housing and the engine plenum chamber is not altered in diameter or modified in any way. The air mass flow meter contains electronic circuitry, so never attempt to supply it directly from the battery. The terminals have a silver coating to provide a superior quality of connection over many years. If, at any time, a probe is used to measure the output directly from the sensor, then care must be taken to ensure this coating is not damaged.

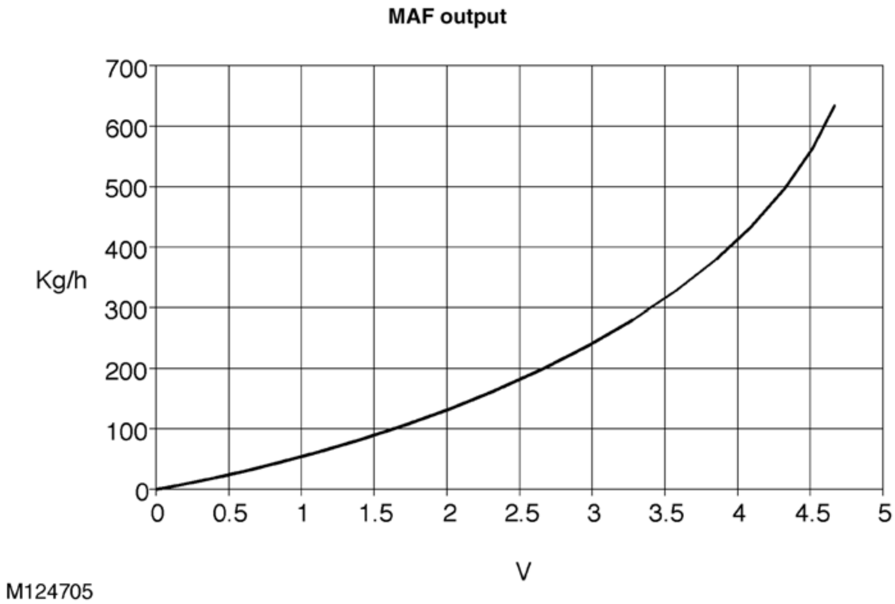
If the MAF sensor signal fails then the ECM will adopt a default strategy. This strategy will cause the ECM to assume that a certain quantity of air is entering the engine. The exact quantity will be based upon the signals received relating to throttle position, engine speed and air temperature. The following engine symptoms will be noticeable:

- The MIL lamp will be illuminated after the fault has been ‘validated’
- The engine speed might ‘dip’ before the default strategy enables continued running
- The engine may be difficult to start and prone to stalling
- The overall performance of the engine will be adversely affected (throttle response in particular)
- Exhaust emissions will be out of tolerance, because the air/fuel ratio value is now assumed, not calculated; no closed loop fuelling
- Idle speed control disabled, leading to rough idle and possible engine stall

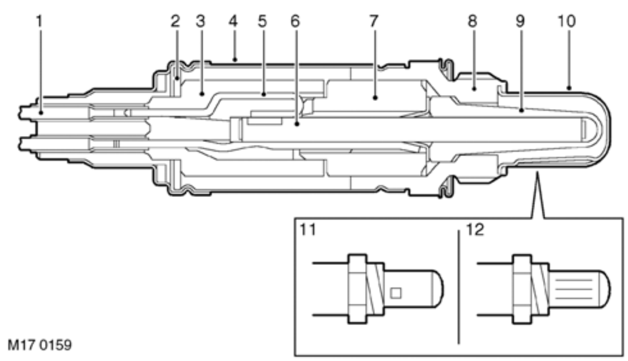
At the time of failure, the ECM will store details of the engine speed, coolant temperature and throttle angle.

If the signal from the air temperature sensor fails, the ECM will assume a default value of 112°F (45°C). This default value is then used within all the calculations involving intake air temperature. The effect on the vehicle of a failed air temperature signal will not be so noticeable to the driver, who may notice a reduction in engine performance when operating the vehicle at high altitudes or in hot ambient temperatures. The occurrence of this fault will also disable fuelling adaptations and the catalyst monitoring function of the ECM.

The ECM will store details of the engine speed, engine load and battery voltage when this fault is first detected.



Oxygen sensors
There are four Oxygen sensors used on the V-8 Discovery Series II. Two of the sensors are located in each downpipe.



11- "Downstream" Sensor tip   12- "Upstream" Sensor tip

One sensor is used upstream of the catalyst, i.e. between the catalyst and the engine, and one is used immediately downstream of the catalyst. The two sensors used upstream of the catalyst are referred to as 'pre-catalyst' sensors (12), while the two sensors used downstream are referred to as 'post-catalyst' sensors (11). It should be noted that the 'pre-catalyst' Oxygen sensors are not interchangeable with the 'post' catalyst Oxygen sensors. The pre and post sensors can be identified by the shape of the vents on their protective metal tip shell., as shown below.

The Oxygen sensors are very sensitive devices. They must be handled carefully at all times. Failure to handle correctly will result in a very short service life, or non-operation.

Oxygen sensors are pre-coated with an anti-seize compound prior to installation. Care should be taken to avoid getting this compound on the sensor tip.

If the sensor needs to be removed and reinstalled, a small amount of anti-seize compound should be applied (see workshop manual for details).

The Oxygen sensors use ‘Zirconium technology’. The sensors feature a Galvanic cell (6), which is surrounded by a gas permeable ceramic material (9) enclosed by a protective metal shell (10). This allows exhaust gas to come into contact with one side of the sensor. The other side of the sensor is exposed to the atmosphere. Due to its construction, the sensor produces a voltage. The precise value of the voltage produced is dependent upon the ratio of Oxygen in the atmosphere compared to the Oxygen in the exhaust gas. The voltage produced for an exhaust gas with Lambda 1 (i.e. stoichiometric air, fuel ratio of 14.7:1) is 0.45 - 0.5 volts (450 – 500 mv). The voltage will fall in value to approximately 0.1 volts (900 mv), or Lambda 0.8, when the Oxygen in the exhaust gas rises (lean mixture - too much air in relation to fuel). The voltage will rise in value to approximately 0.9 volts when the Oxygen level in the exhaust gas falls to approximately Lambda 1.2 (rich mixture - too much fuel in relation to air).

The voltage from the Oxygen sensor is communicated to the ECM via the Oxygen sensor signal wires (1, 5). The ECM monitors the effect of altering the injector pulse widths uses the information supplied by the Oxygen sensors. Injector pulse width is the length of time the injector is energized, which determines how much fuel is injected. The response time is such that under certain driving conditions, the ECM can assess individual cylinder contributions to the total exhaust emissions. This enables the ECM to adapt the fuelling strategy on a cylinder by cylinder basis, i.e. inject the precise amount of fuel required by each individual cylinder at any given time.

The ECM continuously checks the signals supplied by the Oxygen sensors for plausibility. If it detects an implausible signal, then it will store a relevant fault code. On the second concurrent ‘journey’ that a fault is recognized, the ECM will illuminate the MIL lamp and store details of engine speed, engine load and the Oxygen sensor voltage. The ECM requires the Oxygen sensor signals to set most of its adaptations. Failure of an Oxygen sensor will result in most of these adaptations resetting to their default values. This, in turn, will result in the engine losing its ‘finesse’. The engine may exhibit poor idle characteristics and emit a strong smell of rotten eggs from the exhaust (H_2S).

The efficiency of the Oxygen sensors slowly deteriorates over many kilometers/miles (unless contamination such as excessive oil or lead has occurred causing sudden damage/ failure). The ECM is able to detect this steady deterioration using the feedback signals. When a signal from a sensor deteriorates beyond a predetermined threshold, the ECM will illuminate the MIL lamp and store a fault code. At the same time, the ECM will capture details of the engine speed, engine load and battery voltage. The sensor response time will normally deteriorate over its life, however the engine management system monitors performance, and will illuminate the MIL when a sensor requires replacement.

The ECM also monitors the efficiency of the catalysts. The ECM uses the signal received from the two post-catalyst Oxygen sensors to do this. The state of each catalyst is assessed in line with its ability to 'hold' Oxygen. In a serviceable unit the 'excess' Oxygen in the exhaust gas is held on the surface of the precious metal coating of the ceramic blocks within the catalyst. This Oxygen is used to convert the harmful elements produced by incomplete combustion (particularly during acceleration and conditions where the engine requires a rich air/fuel ratio) into Carbon Dioxide, Nitrogen and water. By comparing the signals received from the pre-catalyst sensors with those received from the post-catalyst sensors, the ECM can calculate how much Oxygen is retained by each catalyst and can, therefore, determine their condition. If the ECM determines that one or both catalysts require replacement, then it will illuminate the MIL (after validating the fault) and store the relevant fault code. At the same time, the ECM will record details of the engine speed, engine load and air temperature.

Zirconium Oxygen sensors need high operating temperatures to work effectively. To ensure a suitable operating temperature is reached as soon as possible, each sensor incorporates a heating element inside the ceramic tip. This element heats the Oxygen sensor to a temperature greater than 670°F (350°C). The heating rate (the speed at which the temperature rises) is carefully controlled by the ECM to prevent thermal shock to the ceramic material. By way of a PWM voltage supply to the heater elements, the ECM controls.

The rate at which the element temperature is increased. The sensors are heated during engine warm-up and again after a period of engine idle.

The ECM monitors the state of the heating elements by calculating the amount of current supplied to each sensor during operation. If the ECM identifies that the resistance of either heating element is too high or too low, it will store a fault code, the engine speed, coolant temperature and the battery voltage. When the fault is logged twice on consecutive 'journeys', the MIL lamp will illuminate.

Immobilisation signal

The BCU sends a coded signal to the ECM before it activates the starter motor. If the ECM accepts the immobilization signal (i.e. the code is correct), the engine will be permitted to start and will continue to run normally. If the immobilization signal is corrupted (i.e. not sent, or incorrect), then the ECM will allow the engine to start, but will then stop it immediately.

If the BCU is replaced during the service life of the vehicle, the immobilization code will need to be relearned. If an attempt to start the engine is made with a new ECM installed on the vehicle (an ECM not yet programmed with any immobilization code), the ECM will not allow the engine to start and will store a fault code. This fault code must be cleared and the immobilization code learned before the ECM will allow the engine to run.

The immobilization code must also be relearned in cases where an ECM from one vehicle is used on another.

If the ECM detects an incorrect immobilization code it will store a fault code. Simultaneously, the ECM will record the engine speed, battery voltage and the number of occurrences (the number of times the incorrect code has been detected).

Fuel level signal
This signal is supplied to the ECM by the instrument pack. It is used to alter the fault code strategy adopted by the ECM when a misfire is detected (see misfire detection) or if the ECM detects that the Oxygen signal is unexpectedly recording a weak air/fuel ratio. It will not stop a fault being logged but will modify the fault code to indicate the likely cause of the misfire.

Vehicle speed sensor signal
The ECM uses this signal within its calculations for idle control. The ECM also forwards the vehicle speed signal to the automatic gearbox TCM via the CAN bus. The vehicle speed signal is produced by the SLABS ECU. The signal is calculated from the road speed signals of all four wheel speed sensors.

Rough road signal
This signal is also produced by the SLABS ECU. It is derived from the variations between each signal received from the four wheel speed sensors (see section on ABS for full description).

The ECM alters its misfire detection strategy whenever a rough road signal is received. The ECM will not store details of a misfire fault at this time (see misfire detection strategy).

Automatic temperature control system request
A signal is supplied to the ECM whenever the ATC system requires the compressor clutch and/ or condenser fans to function. The ECM integrates the control of these components with the engine management system. This ensures effective engine preparation for any sudden increase in the engine load.

The ECM will turn off the ATC compressor clutch if the engine coolant temperature exceeds 255°F (124°C). The ECM will turn on the condenser fans if the engine coolant temperature exceeds 212°F (100°C). See section on ATC for more details on the exact operation of the compressor clutch and condenser fans.

The ECM will store engine speed, battery voltage and engine load details whenever it detects a fault originating from the ATC circuit. It will store engine speed, intake air temperature and details of the battery voltage if the fault relates to the compressor clutch or condenser fan operation.

Automatic gearbox information
Information sent to and from the automatic gearbox TCM is transmitted on the CAN bus. Full details of this information are in the section on automatic gearbox.

The ECM requires information on gear position to calculate the likely engine load during acceleration and deceleration conditions. The ECM also disables the misfire detection function whenever low range is selected. Information regarding range selection is supplied by the TCU.

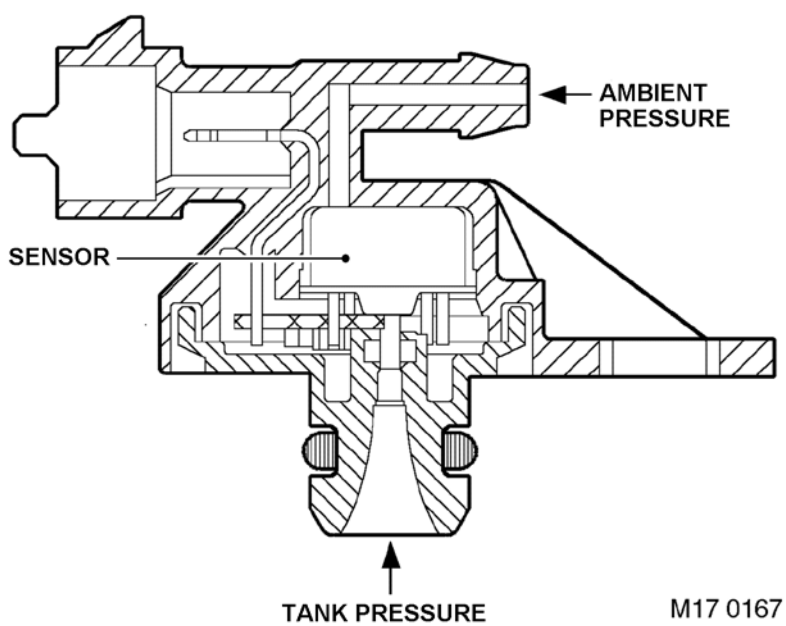
There are several possible fault codes associated with the CAN bus and the validity of information sent to and from the ECM from the TCU. In most cases, the ECM will store engine speed, engine coolant temperature and details of the battery voltage at the time when the fault is detected.

The automatic transmission TCM is able to request the illumination of the MIL lamp if it detects a fault within its systems that might lead to the vehicle emitting excessive levels of pollutants. It is good practice to check both ECM and the automatic gearbox TCM for faults when the MIL lamp is illuminated, or a MIL event is logged in the ECM.

Fuel tank pressure sensor

The fuel tank pressure sender is located in the fuel tank. This unit supplies a signal to the ECM related to the amount of fuel vapor pressure within the fuel tank. It is used as a feedback device within the ECM’s evaporative emission control (EVAP) leak test. This test is detailed later in the section.

If a fault is present, the ECM will store a relevant fault code and the engine speed value, battery voltage and details of the engine coolant temperature. If the fault happen on the next ‘journey’, the ECM will illuminate the MIL lamp.



System Outputs
The ECM receives and processes the input information previously described and modifies the fuelling and the ignition points for each cylinder accordingly. The ECM will also supply output information to other vehicle system ECUs.

The ECM drives the following components:

- Fuel injectors
- Ignition coils
- Idle speed actuator
- Main relay and fuel pump relay
- Purge valve

The ECM provides other systems with information regarding the -

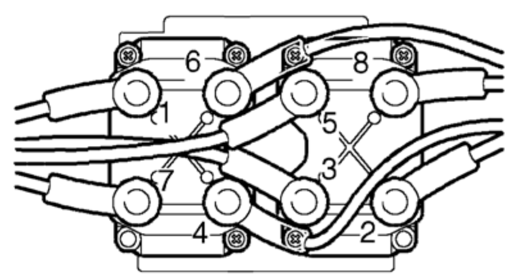
- Engine speed
- Driver demand
- Grant signals ATC
- Grant signals Automatic Transmission

Ignition coils
The V-8 gasoline engine in Discovery Series II uses two twin-ignition coils (total of four coils). The two coils are located behind the plenum chamber at the rear of the engine (see figure 57). Each coil contains two primary windings and two secondary windings. There is a three-pin connector on each coil. Pin two connects both primary windings to an ignition supply. There is one suppression capacitor connected to each supply. This helps eliminate the effect of the magnetic radiation created by the sudden demands for power as each coil recharges.

The system employs waste spark technology to produce a powerful and precise spark. The cylinders are paired according to the table below.

Coil Set	Coil 1	Coil 2	Coil 3	Coil 4
Cylinders	1 & 6	7 & 4	5 & 8	3 & 2

The ECM provides a path to ground whenever a spark is required. To ensure a sustained magnetic field collapse, the ECM carefully controls the rate of discharge from each coil at this time. This control also limits the amount of heat created during this process and reduces the total power consumed by each coil. Any faults detected within the primary and HT circuits will result in the ECM storing an appropriate misfire fault, but not a fault directly related to the spark creation and delivery.



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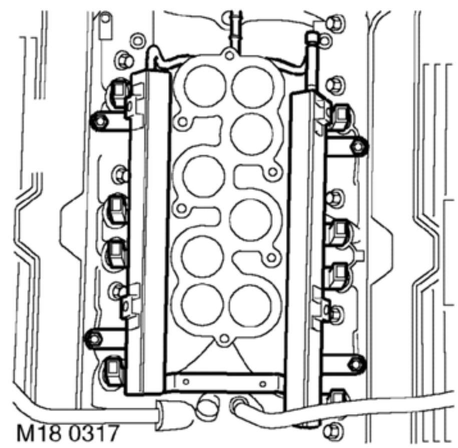
Fuel injectors



There are eight injectors (one per cylinder) used on the V-8 gasoline engine. The ECM controls the injectors directly, and individually. It opens an injector by providing a path to ground for a voltage supplied by a common fuse. The injectors are fed fuel under pressure from a common fuel rail. A fuel pressure relief valve, incorporated into the lift pump assembly located inside the fuel tank, controls the pressure in the fuel rail. In this case, the pressure is controlled to a fixed value of 51 psi (3.5 Bar). As indicated, the fuel pressure is fixed and the relief valve provides no compensation for increases or decreases in manifold vacuum. The ECM alters injector duration to accommodate such changes.

Connecting an appropriate gauge to the Schrader valve on the fuel rail provides a method of checking the fuel pressure. The valve is located to the rear of injector no. 7. Considerable care must be taken whenever making this connection.

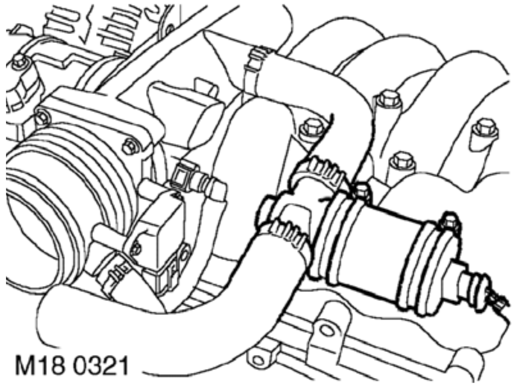
Each injector is sealed with two ‘O’ rings. These ‘O’ rings should be renewed whenever an injector is reinstalled on an engine. A small amount of engine oil can be applied to the ‘O’ rings to aid installation. No other form of lubrication should be used.

Measuring the electrical resistance of the injectors internal coil enables an assessment to be made of the serviceability of an injector. An injector in a serviceable condition should possess a resistance of 14.5 ohms at 68°F (20°C) with a tolerance of ± 0.7 ohms.

The ECM can detect electrical inconsistencies within each injector. It can also detect, via feedback from the Oxygen sensors, mechanical faults such as blockage or leakage. The ECM will store a relevant fault code in these circumstances. The ECM will also store the engine speed, engine load and details of one of the following: battery voltage, engine coolant temperature or intake air temperature. The precise details stored depend on the exact nature of the fault detected.

TestBook will also display data regarding injector operation via its live readings. Care must be taken when analyzing this data, as the precise timings will vary considerably. Individual timings will be affected by any current engine load.

Idle speed actuator



The idle speed control actuator is located behind the throttle body on the intake manifold. It is connected to the intake manifold by two hoses. One hose connects upstream and the other connects downstream of the throttle valve. Therefore, the idle speed actuator effect provides an air bypass for the throttle valve.

The ECM controls the engine idle speed via the idle speed actuator. It does this by allowing a measured quantity of air into the engine when the throttle valve is closed. The idle speed actuator comprises a rotary valve and two electrical coil windings. The ECM alters the position of the idle speed actuator and, therefore, the amount of air bypassing the closed throttle valve by providing a PWM voltage to the two opposing coils inside the actuator. These coils control the position of the rotary valve by producing opposing magnetic fields. When the ECM identifies a need for a higher idle speed it enables a greater quantity of air to bypass the throttle valve. It does this by altering the PWM voltage supplied to both coils. This provides an imbalance in magnetic fields inside the actuator and, in turn, alters the amount of air bypassing the throttle valve.

The ECM controls the position of the rotary valve within the idle speed actuator to maintain a stable idle speed in all conditions. It will alter the position to obtain a pre-set target speed. The precise pre-set idle speed will vary according to the operating conditions of the engine and the transmission gear that is selected. These pre-set speeds are detailed in the table below.

Condition	Air conditioning status	Target idle speed (rpm) high range	Target idle speed (rpm) low range
First 20 seconds after a cold start	N/A	1200	1200
Low battery voltage detected	N/A	850	850
Drive selected	On	740	580
Park/ neutral selected	On	740	580
Drive selected	Off	660	580
Park/ neutral selected	Off	660	580

For 20 seconds immediately following cold start, the idle speed will be raised to 1200 rpm. At the same time the ECM will retard the ignition timing. These actions ensure the engine and the catalysts reach their operating temperatures as quickly as possible.

The ECM can identify faults with the circuitry used to control the position of the idle speed actuator. In circumstances where it detects a fault with one coil it will de-energise the other coil. This action prevents the idle speed control valve being driven to a fully open or fully closed position. The idle speed control actuator contains two permanent magnets inside the body. These magnets will determine the position of the valve at this time. In this position the engine will idle at approximately 1200 rpm. This state should not be confused with the target idle speed initiated by the ECM for the first 20 seconds immediately following cold engine start.

The ECM will store fault codes relating to the electrical properties of the idle speed actuator and to associated failures, such as poor engine response to movement of the rotary valve. The associated data stored will depend upon which fault is detected, such as battery voltage, engine coolant temperature and throttle angle for faults related to the circuitry; or engine speed, engine coolant temperature and intake air temperature for ‘poor response’ fault codes.

If ECM control of the idle speed actuator is suspended, (i.e. fault stored), then the driver may notice the following symptoms relating to engine performance:

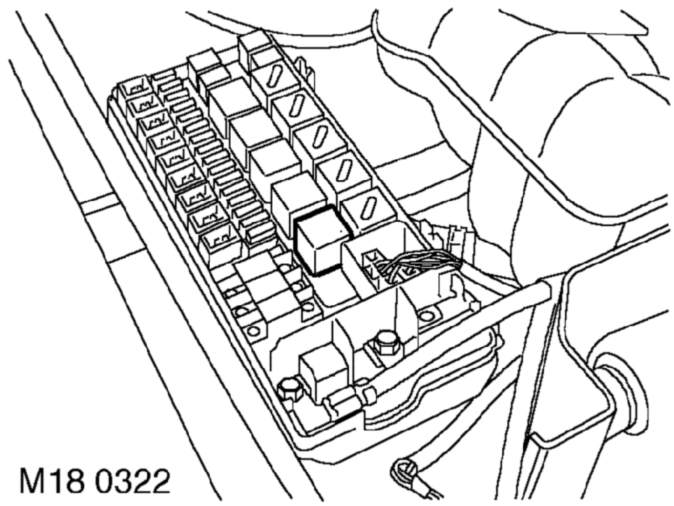
- The engine will exhibit poor idle stability
- The engine will exhibit a high idle speed
- The engine will be prone to stalling
- The engine will be difficult to start

Main relay and fuel pump relay

The ECM controls the main relay and the fuel pump relay. They are both located in the under-hood fuse box.

The ECM energizes the fuel pump relay when the ignition is first turned to position II. It also energises it during engine cranking and when the engine is running.

The ECM controls its own power supply, via the main relay. When the ignition is turned to position II, the ECM provides a ground to the relay coil winding. This, in turn, connects the main power feed to the ECM. The ECM controls the main relay and therefore its own power, so that when the ignition is turned off it can follow the previously described power-down sequence, during which it records values from various sensors and writes adaptations into its memory, etc. The last action the ECM carries out before completing its power-down sequence is to turn off the main relay. This will occur approximately 15 seconds after the ignition has been switched off, as long as the coolant temperature is not rising.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The ECM monitors the state of the wiring to the coil winding within the fuel pump relay. The ECM will store relevant fault codes if the ECM detects a problem. The ECM is not able to assess the state of the fuel pump circuit because it is isolated by the function of the relay. However, if the fuel pump circuit fails, or the pump fails to deliver sufficient fuel (while the fuel level is above its minimum), the ECM will store adaptive faults as it tries to increase the air/fuel ratio by increasing the duration (pulse width) of the injectors.

Failure of the main relay will result in engine non-start. The engine will cease to operate if the main relay fails while the engine is running.

Failure of the fuel pump relay will result in engine non-start. If the fuel pump fails while the engine is running, the symptoms will be engine hesitation and engine misfire. These symptoms will worsen progressively until the engine stops. The ECM will store several fault codes under this condition.

Purge valve

The purge valve is located on the right hand side of the engine (when viewed from the front of the vehicle) forms part of the evaporative emission control system (EVAP) and is situated in the line between the charcoal canister and the manifold. The purge valve controls the amount of air/fuel vapor drawn from the canister into the engine. The other components incorporated into the EVAP system are:

- The charcoal canister, which is located on the right hand inner chassis rail by the hand

brake drum
- The fuel tank pressure sensor, located in the fuel sender unit
- The intake manifold

The ECM controls the amount of vapor drawn from the charcoal canister by controlling the length of time the purge valve is open. It controls the length of time it is open by supplying the purge valve with a PWM voltage. Control is used to maintain the required level of emissions, as a hydrocarbon vapor level of 1% can affect the air/fuel ratio by as much as 20%.

The ECM can diagnose faults with the purge valve and the rest of the EVAP system. The ECM will store the relative fault codes, along with details of the engine speed, battery voltage and air temperature. The driver may notice the following effects in circumstances where the EVAP system has failed:

- The engine may stall periodically when returning to idle
- The engine may suffer from poor idle quality

OTHER ECM OUTPUTS

Engine speed
The engine speed signal is supplied from the ECM to the automatic gearbox TCM via the CAN bus. All other systems requiring the engine speed input receive a frequency dependent square wave supplied by the ECM.

Driver demand
The ECM receives and processes the signal supplied by the throttle position sensor. It then digitises this information, which enables it to supply a driver demand signal, via the CAN bus, to the automatic gearbox TCM or, by a PWM signal, to any other system requiring this information.

ATC grant signal
The ECM supplies a signal to the ATC Compressor relay to activate the compressor.

Torque reduction grant signal
The ECM also informs the automatic gearbox TCM if its torque reduction request has been granted.

ECM Adaptations

The ECM, as previously mentioned, has the ability to adapt the values it uses to control certain outputs. This capability ensures the EMS can meet emissions legislation and improve the refinement of the engine throughout its operating range.

The components which have adaptations associated with them are:

- The idle speed control (ISC) valve
- The throttle position sensor (TPS)
- The Heated Oxygen sensors (HO2S)
- The airflow sensor (MAF)
- The crankshaft sensor (CKP)

Idle speed control valve

Over a period of time, the ECM adapts the position it sets the idle speed control valve. The adaptations are made relative to engine coolant temperature and engine load. When a new idle speed control valve or a replacement ECM is used, this adaptation should be reset. Subsequently, the ECM will make further adaptations to suit the particular characteristics of the new or replacement components. Failure to reset the original adaptation may result in a prolonged period of poor idling. During this time the ECM slowly adapts the original, ‘incorrect’ value stored in its memory.

TestBook will display the adaptation currently being applied against the model programmed into its memory. This can be used to indicate the possible cause of problems relating to the amount of air entering the engine, such as air blockages or air leaks within the induction system.

Throttle position sensor

The ECM ‘learns’ the closed position of the throttle position sensor. The closed voltage value supplied by the sensor is stored by the ECM and can be read using TestBook (see TPS sensor for information regarding the likely readings and signal tolerance band). If the sensor is replaced, the new closed throttle position will be learned by the ECM during the IMF cycle for the TPS.

The signal from the TPS sensor is used in conjunction with the air mass flow meter to calculate the altitude adaptations. This adaptation affects the amount of fuel entering the engine and the ignition timing. Details of the value of this adaptation are supplied to the automatic gearbox TCM. Using this information, it will adapt its gear change control maps. The altitude adaptation is continuously changing and indicates current driving conditions. Details of the altitude adaptation are stored within the ECM’s memory when the ignition is switched off. This enables the ECM to provide correct fuelling on the next engine start.

Oxygen sensors & air flow meter

There are several adaptive maps associated with the fuelling strategy. Within the fuelling strategy the ECM calculates short-term adaptations and long term adaptations. The ECM will monitor the deterioration of the Oxygen sensors over a period of time. It will also monitor the current correction associated with the sensors.

The ECM will store a fault code in circumstances where an adaptation is forced to exceed its operating parameters. At the same time, the ECM will record the engine speed, engine load and intake air temperature.

Crankshaft position sensor

The characteristics of the signal supplied by the crankshaft position sensor are learned by the ECM. This enables the ECM to set an adaptation and support the engine misfire detection function. Due to the small variation between different flywheels and different crankshaft sensors, the adaptation must be reset if either component is renewed, or removed and replaced. It is also necessary to reset the flywheel adaptation if the ECM is renewed or replaced.

The ECM supports four flywheel adaptations for the crankshaft position sensor. Each adaptation relates to a specific engine speed range. The engine speed ranges are detailed in the table below.

Engine speed range	Adaptation
1800 – 3000	1.00
3001 – 3800	2.00
3801 – 4600	3.00
4601 - 5400	4.00

To set the flywheel adaptations, follow the procedure detailed below. This procedure should be carried out in an appropriate area off the public highway. TestBook must be connected throughout this procedure. The adaptive speed settings must be read from TestBook while the vehicle is moving at speed.

1. Use TestBook to clear any adaptations currently set.
2. With the engine warm >187°F (86°C) select 2nd gear high range
3. Accelerate the vehicle until the engine speed reaches the rpm limiter
4. Release the throttle and allow the vehicle to decelerate until the engine idle speed is reached
5. Check that one of the speed range adaptations has been set (read this from TestBook)
6. Repeat the above procedure until all four adaptations are set

When all four adaptations have been set, check that the ECM has not recorded any misfire detection faults. If it has, then clear the memory of the fault codes.

It may not be possible to reset adaptation number 4 if the ECM has already been programmed with a value. Due to the nature of the procedure and the self learn capacity of the ECM, if adaptation number 4 does not reset, it is permissible to leave this adaptation and let the ECM learn it.

Misfire detection
Legislation requires that the ECM must be able to detect the presence of an engine misfire. It must be able to detect misfires at two separate levels. The first level is a misfire that could lead to the vehicle emissions exceeding 1.5 times the allowable levels for this engine. The second level is a misfire that may cause catalyst damage.

The ECM monitors the number of misfire occurrences within two engine speed ranges. If the ECM detects more than a predetermined number of misfire occurrences within either of these two ranges, over two consecutive ‘journeys’, the ECM will illuminate the MIL. The ECM will also record details of the engine speed, engine load and engine coolant temperature. In addition, the ECM monitors the number of misfire occurrences that happen in a ‘window’ of 200 engine revolutions. The misfire occurrences are assigned a ‘weighting’ of the likely impact to the catalysts. If the number of misfires exceeds a certain value, the ECM stores catalyst-damaging fault codes, along with the engine rpm, engine load and engine coolant temperature. It will also flash the MIL lamp until the misfires no longer exceed the predetermined number. After the flashing stops, the ECM will continue to illuminate the MIL lamp until the fault is rectified.

The signal from the crankshaft position sensor indicates how fast the poles on the flywheel are passing the sensor tip. A sine wave is generated each time a pole passes the sensor tip. The ECM can detect variations in flywheel speed by monitoring the sine wave signal supplied by the crankshaft position sensor.

By assessing this signal, the ECM can detect the presence of an engine misfire. At this time, the ECM will assess the amount of ‘variation’ in the signal received from the crankshaft position sensor and assigns a ‘roughness’ value to it. This roughness value can be viewed within the real time monitoring feature, using TestBook. The ECM will evaluate the signal against a number of factors and will decide whether to count the occurrence or ignore it. The ECM can assign a roughness and misfire signal for each cylinder, (i.e. identify which cylinder is misfiring).

TestBook Diagnostics

The ECM will, as explained earlier, store fault codes and environmental data. The ECM also records additional data in connection with each fault. The additional data recorded is as follows:

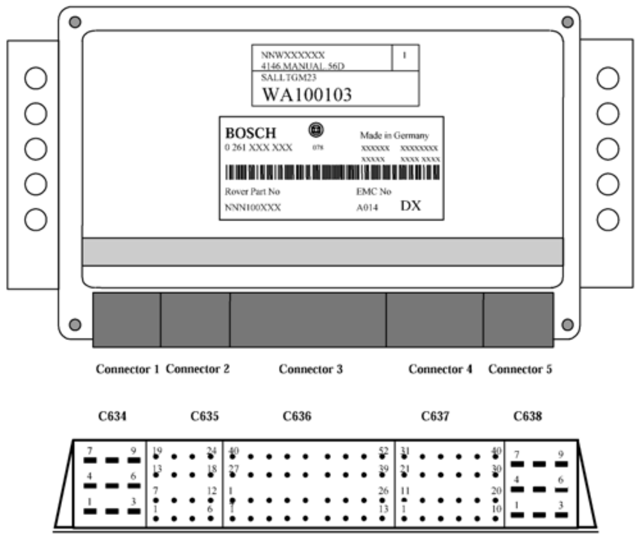
1. The number of occurrences
2. If the fault is currently present
3. If the fault is historic, the number of ‘journeys’ that have elapsed since the fault last occurred.
4. The ‘current time’ stored when the fault occurred. (The time is incremented in hours, hour 0 being the first time the ECM is powered-up, hour 1 being 60 minutes of ignition ‘on’ time, etc.)

This information is displayed for each fault, along with an explanation of the fault code and the stored environmental data. All the above information is stored and displayed to assist with effective fault diagnosis and repair.

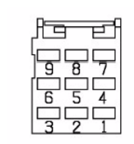
TestBook can also read real time data from each sensor, the adaptive values currently being employed and the current engine fuelling, ignition and idle settings. The live readings are displayed first as a page of readings. To gain more detail press and highlight the reading for which you require more information.

Connector Pinouts

Bosch 5.2.1

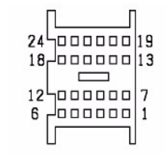


Connector 1
C0634 (9-way, Black)



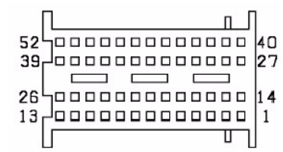
PIN	Wire Color	Description	Voltage Reading
1	W	Ignition sense (position II)	12 V
2	-		
3	-		
4	B	Chassis Earth	0V
5	B	Fuel Injectors Earth	0V
6	B	Power stage Earth	0V
7	PY	Permanent Battery supply	12 V
8	NO	Switched Relay positive	0-12V
9	-		

Connector 2
C0635 (24-way, Black)



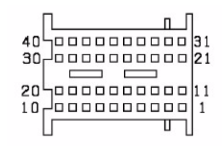
PIN	Wire Color	Description	Signal Range	PIN	Wire Color	Description	Signal Range
1	WU	HO2S Heater Bank B - downstream	12-0V	13	WO	HO2S Heater Bank B -up-stream	12-0V
2	-			14	G	HO2S signal Bank B-down-stream	0-1V
3	-			15	O	HO2S signal Bank A -up-stream	0-1V
4	-			16	U	HO2S signal Bank B -up-stream	0-1V
5		Thermostat Monitoring Thermistor Ground	0V	17	Y	HO2S signal Bank A - downstream	0-1V
6	-			18	UP	Fuel pump relay [PWM]	12-0V
7	WU	HO2S Heater Bank A-downstream	12-0V	19	WO	HO2S Heater Bank A -up-stream	12-0V
8	RB	HO2S Earth Bank B-downstream	0V	20	-		
9	RB	HO2S Earth Bank A -up-stream	0V	21		Thermostat Monitoring Thermistor Signal	0-5V
10	RB	HO2S Earth Bank B -up-stream	0V	22	-		
11	RB	HO2S Earth Bank A-downstream	0V	23	UR	Main Relay Output [Earth]	0V
12	-			24		DMTL Pump Motor	12-0V

Connector 3
C0636 (52-way, Black)



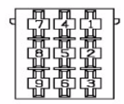
PIN	Wire Color	Description	Signal Range	PIN	Wire Color	Description	Signal Range
1	YW	Injector # 2 driver, sw. -Earth	0V	27	YB	Injector # 3 driver, sw. - Earth	0V
2	YG	Injector # 5 driver, sw. -Earth	0V	28	YK	Injector #8 driver, sw. -Earth	0V
3	NR	Purge valve driver [PWM]	12-0V	29	SP	Hill descent control [PWM]	0-12V
4		SAI Valve solenoid	12-0V	30	SY	Can. vent solenoid, sw. - Earth	0V
5	-			31	GW	Air cond. condenser fan drive	0V
6	RB	Fuel Tank pressure sensor Earth	0V	32	BY	Crankshaft sensor signal	0-300V
7	R	Air flow meter 5V supply	5V	33	-		
8	-			34	SLG	Air temperature signal	0-5V
9	RB	Air flow meter earth	0V	35	W	Knock sensor Bank B Earth	0V
10	R	Throttle Pot 5V Supply	5V	36	KB	Knock sensor Bank B Input	Analog
11	-			37	-		
12	-			38	-		
13	-			39	-		
14	YR	Injector #7 driver / sw - Earth	0V	40	YN	Injector # 4 driver, sw. -Earth	0V
15	YS	Injector #6 driver / sw - Earth		41	YU	Injector # 1 driver, sw. -Earth	0V
16		SAI Pump Relay	12-0V	42	US	Idle speed actuator open	12-0V
17	B	Cam Sensor earth	0V	43	RG	Idle speed actuator close	12-0V
18	-	Low Range Switch(Manual only)	12-0V	44	GU	Coolant Temperature output	0-12V
19	-			45	SCR	CKP shield Ground	0V
20	SU	Camshaft sensor Input signal	0-12V	46	KB	CKP Ground Ref.	0V
21	RB	Coolant sensor Earth	0V	47	-		
22	G	Coolant temperature signal Input	0-5V	48	B	Knock sensor Bank B Earth	0V
23	UG	Air flow meter signal Input	0-5V	49	KW	Knock sensor Bank A Input	Analog
24	YLG	TPS signal	0-5V	50	-		
25	RB	TPS Ground	0V	51	-		
26	-			52	-		

Connector 4
C0637 (40-way, Black)



PIN	Wire Color	Description	Signal Range	PIN	Wire Color	Description	Signal Range
1	-			21	-		
2	-			22	KG	Road speed Signal [PWM]	0-12V
3	-			23	-		
4	-			24	-		
5	-			25	-		
6	RK	T-box Low Range Switch	0V= Low box	26	-		
7	-			27	-		
8	GS	Low Fuel Signal	Active= High	28	-		
9	R	Fuel Tank pressure sensor Vref	5V	29	BS	A/C. compressor “Grant” switch to earth	0V
10	-			30	-		
11	-			31	-		
12		Analogue Fuel Level	0-5V	32	K	Diagnostic K-Line Serial com.	0-12V
13	-			33	LGS	Immobiliser serial W-link	0-12V
14	GK	Fuel Tank pressure signal	0-5V	34	RG	Rough Road signal [PWM]	0-12V
15	-			35	-		
16	YS	A/Conditioning request Input	Active= Low	36	W	CAN bus ‘high’ line Bi-directional comms.	5-2.5V
17	WS	Engine speed output	0-5V	37	Y	CAN bus ‘low’ line Bi-directional comms.	0-2.5V
18	-			38	PW	A/C stand-by Signal	Active= Low
19	-			39	-		
20	RS	MIL ‘on’ Output; “ON” = earth	0V	40	-		

Connector 5
C0638 (9-way, Black)



PIN	Wire Color	Description	Voltage Reading
1	-		
2	U	Ignition driver, Cyl # 2 , 3 Output	Switch to Earth
3	-		
4	-		
5	B	Ignition Coil Ground	0V
6	KB	Ignition driver, Cyl # 1 , 6 Output	Switch to Earth
7	WU	Ignition driver, Cyl # 4 , 7 Output	Switch to Earth
8	R	Ignition driver, Cyl # 5 , 8 Output	Switch to Earth
9	-		

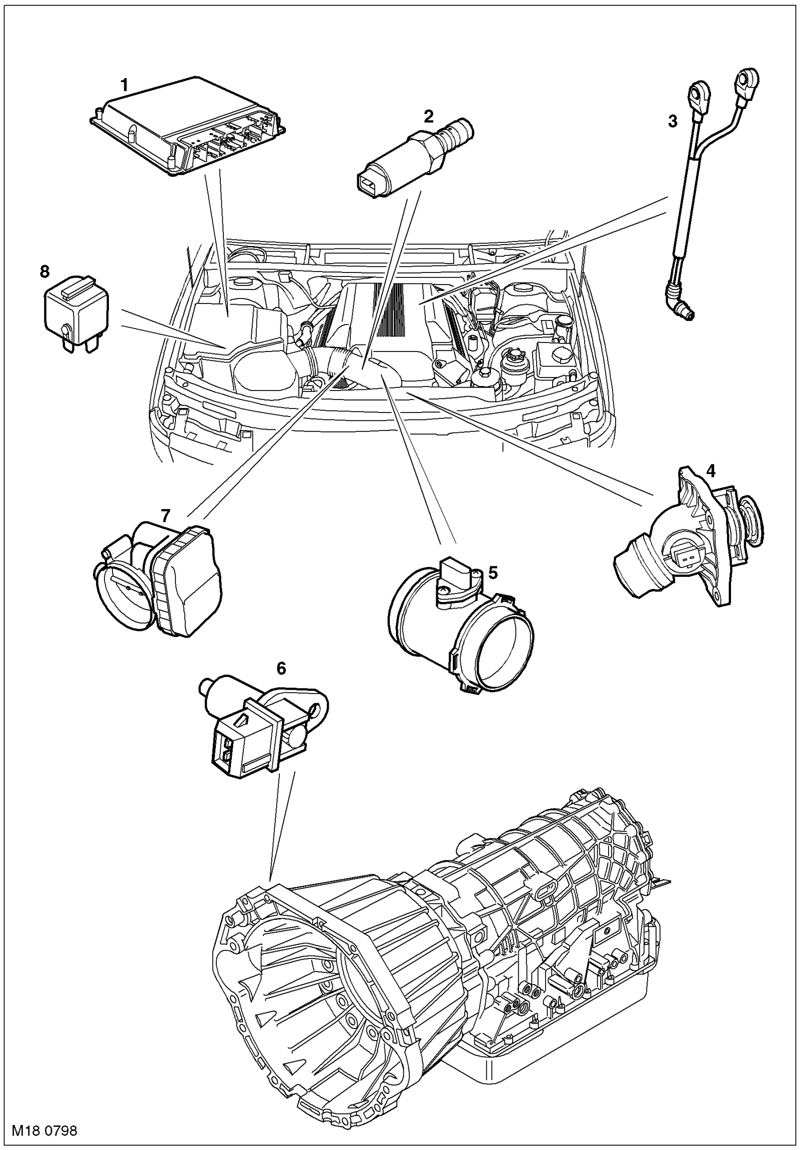
BOSCH ME 7.2 ENGINE MANAGEMENT

Introduction

The Bosch ME 7.2 engine management system (EMS) is similar to the Bosch 5.2.1 system used in previous Land Rover V8 engines. The main difference between the two systems is the "drive by wire" capabilities of the ME 7.2 EMS.

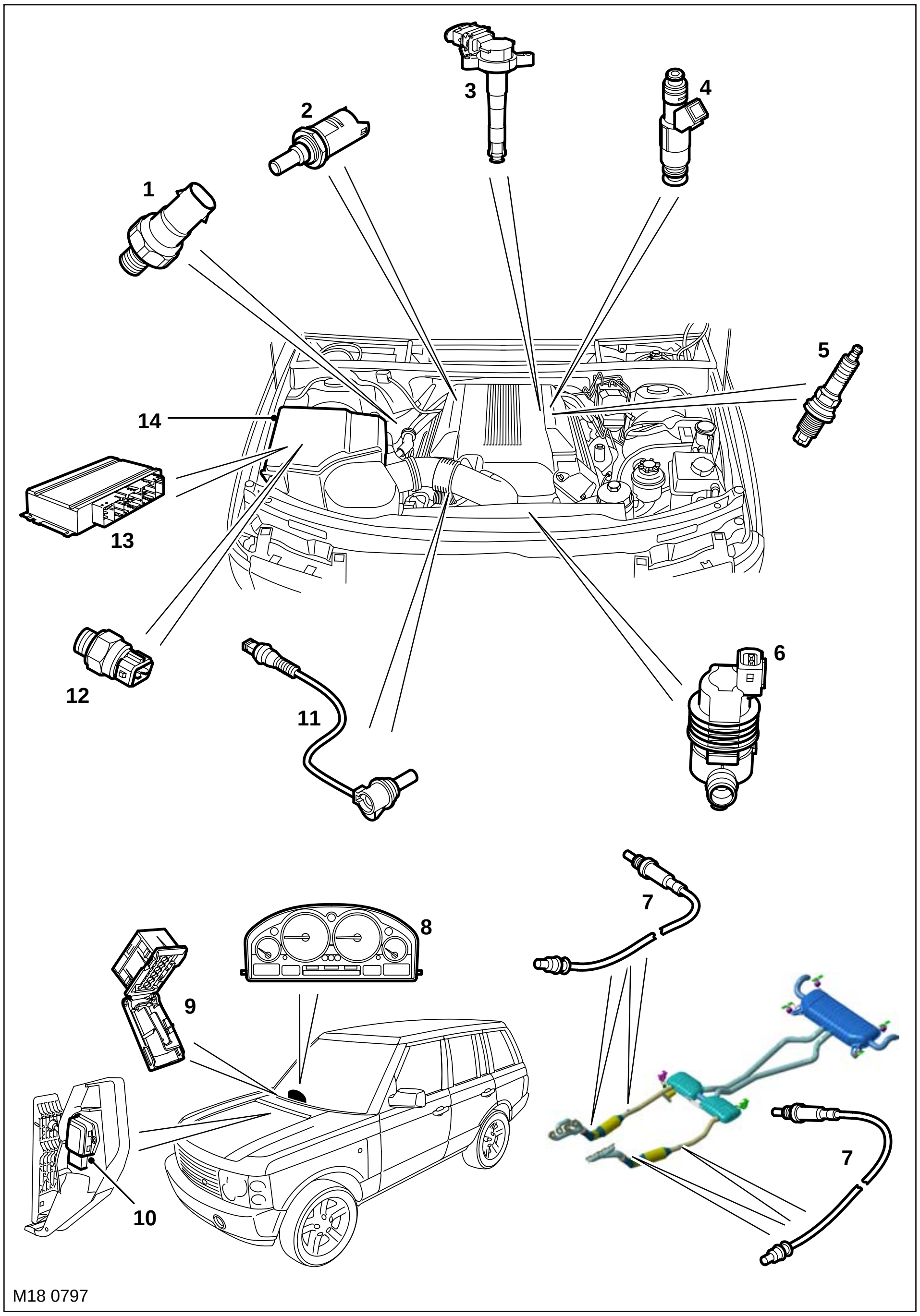
Another main difference between the 5.2.1 system and the ME 7.2 system is that ME 7.2 uses the Keyword protocol 2000* (KWP2000*) which is an ISO 91414 K line compatible version of the Key Word 2000 protocol.

Engine Management Component Location, Sheet 1 of 2



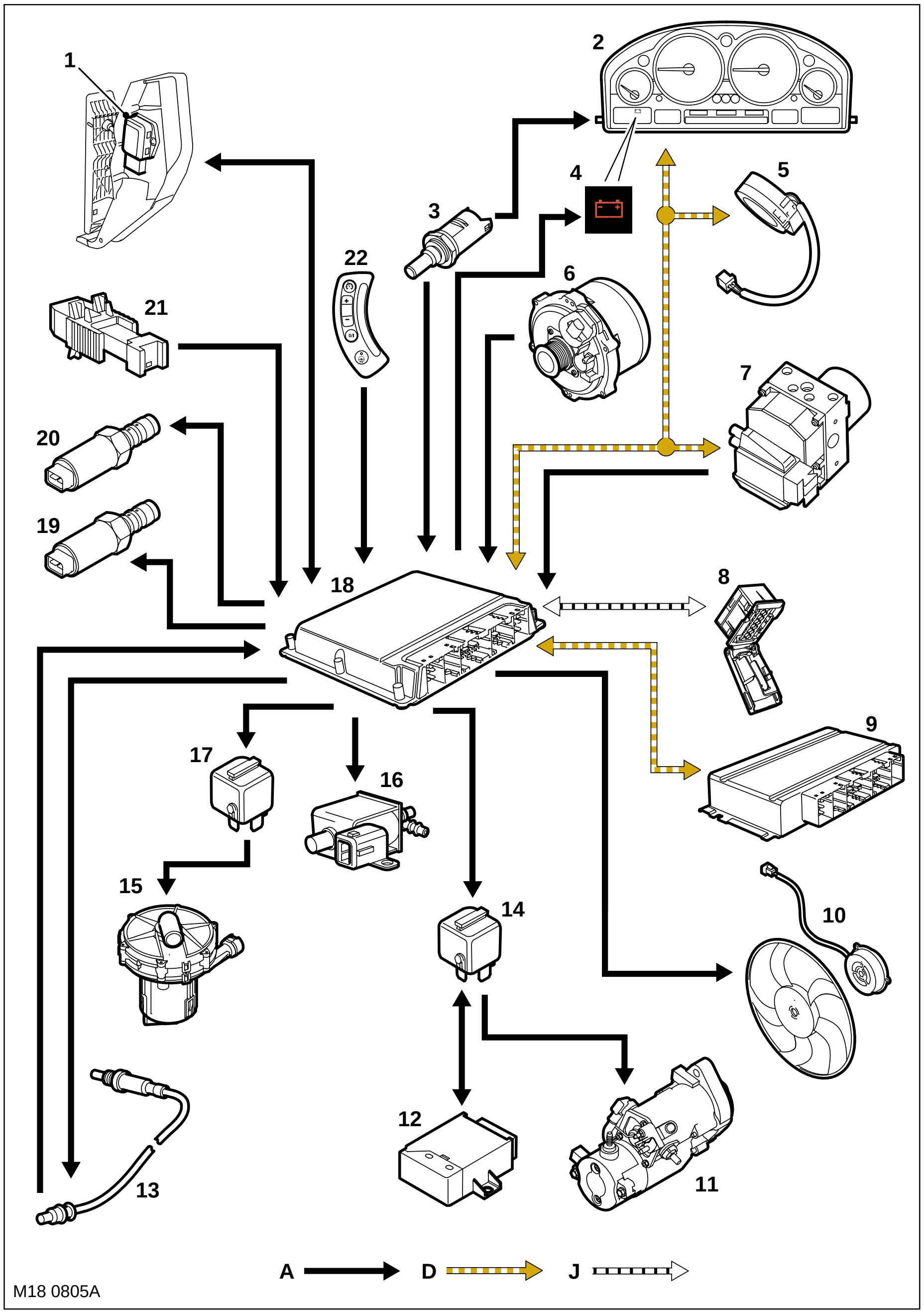
1	ECM	5	Mass Air Flow/Inlet Air Temperature (MAF/IAT) sensor
2	Variable Camshaft Control (VCC) solenoid	6	Crankshaft Position (CKP) sensor
3	Knock sensor (x4)	7	Electric throttle
4	Heated thermostat	8	Main relay

Engine Management Component Location, Sheet 2 of 2



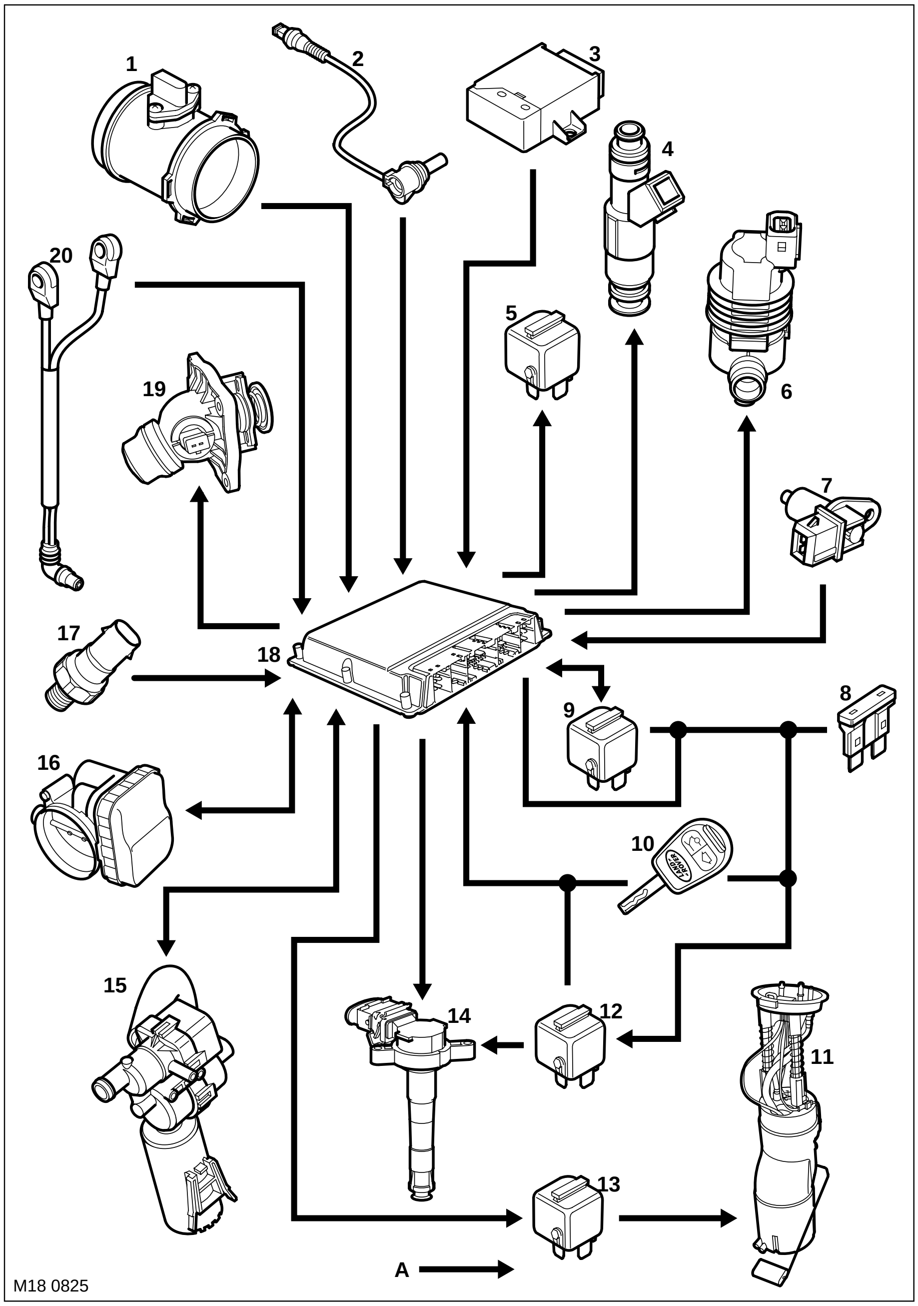
1	Radiator outlet temperature sensor	8	Instrument pack
2	Engine Coolant Temperature (ECT) sensor	9	Diagnostic socket
3	Ignition coil	10	Accelerator Pedal Position (APP) sensor
4	Injector	11	Camshaft Position (CMP) sensor
5	Spark plug	12	E-box temperature sensor
6	Purge valve	13	EAT ECU
7	Oxygen sensors	14	E-box

Engine Management Control Diagram, Sheet 1 of 2



A	Hardwired connections	7	ABS modulator/ECU	16	Vacuum vent valve
D	CAN bus	8	Diagnostic socket	17	SAI pump relay
J	Diagnostic ISO 9141 K line bus	9	EAT ECU	18	ECM
1	APP sensor	10	Electric cooling fan	19	LH bank VCC solenoid
2	Instrument pack	11	Starter motor	20	RH bank VCC solenoid
3	Radiator outlet temperature sensor	12	Immobilisation ECU	21	Brake light switch
4	Ignition warning lamp	13	HO2S (x 4)	22	Cruise control switches
5	Steering angle sensor	14	Comfort start relay		
6	Alternator	15	SAI pump		

Engine Management Control Diagram, Sheet 2 of 2



A	A = Hardwired connection	7	Crankshaft Position (CKP) sensor	14	Ignition coil
1	MAF/IAT sensor	8	Fuse 25	15	Tank leakage detection module
2	Camshaft sensor	9	Main relay	16	Electric throttle
3	Immobilisation ECU	10	Ignition switch	17	Radiator outlet temperature sensor
4	Injector	11	Fuel pump	18	ECM
5	Auxiliary cooling fan relay	12	Ignition coil relay	19	Electrical heated thermostat
6	Purge valve	13	Fuel pump relay	20	Knock sensors

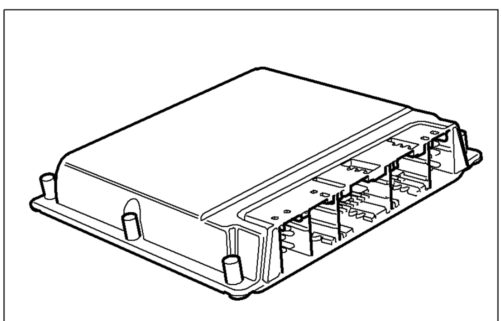
Key Functions

The key functions of the Bosch ME 7.2 engine management system are:

- To control the amount of fuel supplied to each cylinder
- To calculate and control the exact point of fuel injection
- To calculate and control the exact point of ignition in each cylinder
- To optimize adjustment of the injection timing and ignition timing to deliver the maximum engine performance throughout all engine speed and load conditions
- To calculate and maintain the desired air/fuel ratio, to ensure the 3 way catalysts operate at their maximum efficiency
- To maintain full idle speed control of the engine
- To ensure the vehicle adheres to the emission standards (set at the time of homologation)
- To ensure the vehicle meets with the fault handling requirements, as detailed in the European On-Board Diagnostic (EOBD) III legislation
- To provide an interface with other electrical systems on the vehicle
- To facilitate the drive by wire functions
- To control the Variable Camshaft Control (VCC).

To deliver these key functions, the Bosch ME 7.2 Engine Control Module (ECM) relies upon a number of inputs and controls a number of outputs. As with all electronic control units, the ECM needs information regarding the current operating conditions of the engine and other related systems before it can make calculations, which determine the appropriate outputs. A Controller Area Network (CAN) bus is used to exchange information between the ECM and the Electronic Automatic Transmission (EAT) ECU

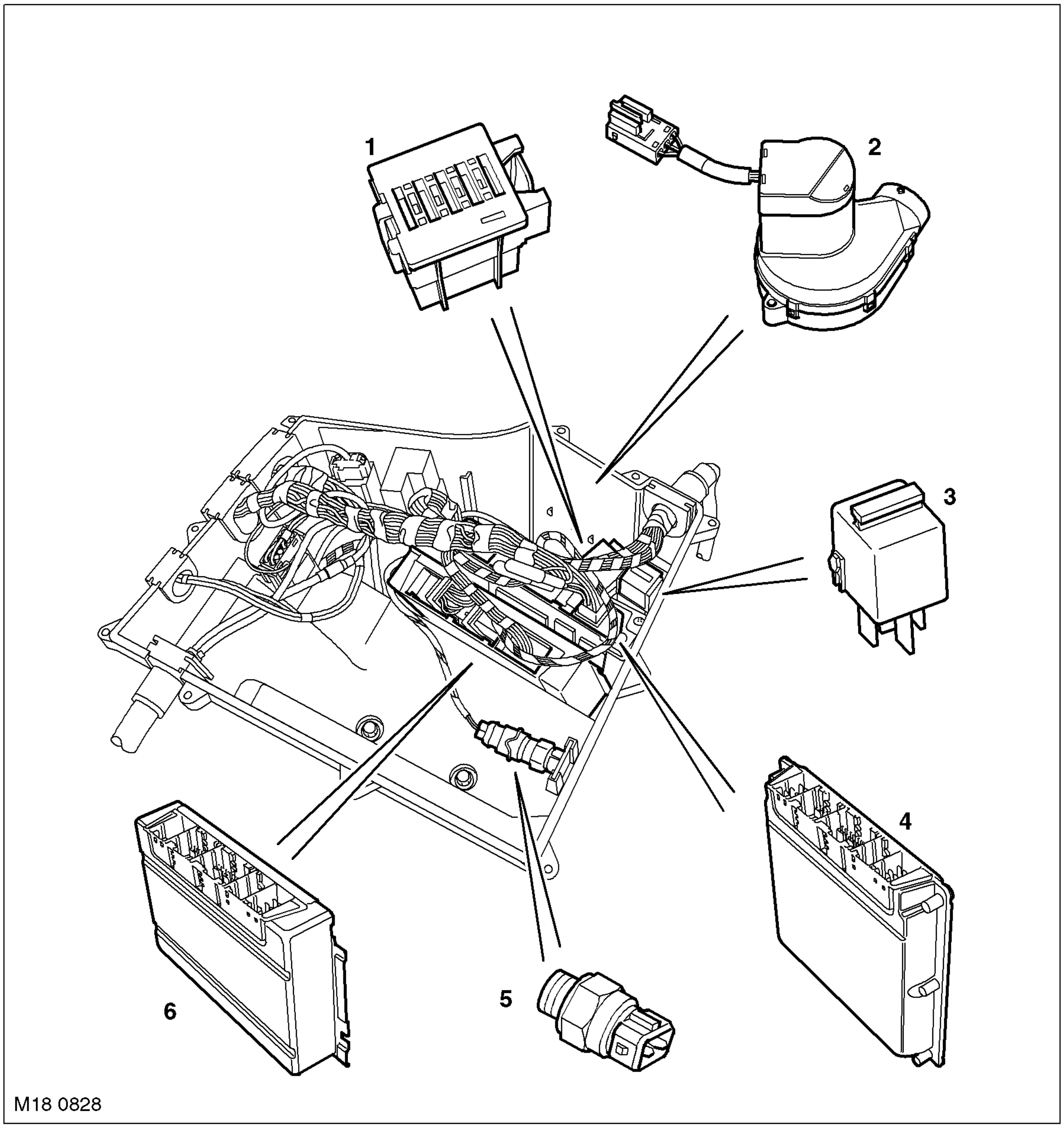
ECM



M18 0827

The ECM is located in the Environmental (E) box, in the front right corner of the engine compartment. The E-box provides a protective environment for the ECM and is cooled by an electric fan. The main relay for the ECM is also located in the E-box.

E-Box



1	Fuse block	4	ECM
2	Cooling fan	5	E Box temperature sensor
3	Main relay	6	EAT ECU

A separate temperature sensor is used to monitor E-box temperature and provides a path to earth to control the electric fan. The sensor turns the fan on when the E-box temperature reaches 35°C (95 °F) and turns the fan off when the temperature drops below 35°C (95 °F). The E-box fan draws air in from the passenger compartment, into the E-box and vents back into the passenger compartment. The fan is also driven for a short period on engine crank, independently of temperature. This is done to ensure the correct function of the fan.

The ECM is programmed during manufacture by writing the program and the engine tune into a Flash Electronic Erasable Programmable Read Only Memory (EEPROM). The EEPROM can be reprogrammed in service using TestBook/T4. In certain circumstances, it is possible to alter the tune or functionality of the ECM using this process.

Advanced fault monitoring is incorporated into the ECM. It can detect the type and severity of faults, store relevant engine operating conditions (environmental and freeze frame data) and time that a fault occurs, suspend the operation of some functions and replace the inputs from faulty sensors with default values. Environmental data is stored for each fault detected, and consists of the inputs from three engine sensors, with the inputs stored depending on the fault. The ECM also records additional data in connection with each fault, as follows:

- The number of occurrences
- If the fault is currently present
- If the fault is historic, the number of drive cycles that have elapsed since the fault last occurred
- The time the fault occurred. Time is incremented in hours, hour 0 being the first time the ECM is powered-up, hour 1 being 60 minutes of ignition 'on' time, etc.

OBD freeze frame data is only stored for emissions related faults. Only one set of freeze frame data can be stored at any one time. Faults are prioritized according to their likely impact on exhaust gas emissions. If more than one emissions related fault occurs, freeze frame data is stored for the fault with the highest priority. Freeze frame data consists of the following:

- Engine speed
- Engine load
- Short term fuelling trim of LH and RH cylinder banks
- Long term fuelling trim of LH and RH cylinder banks
- Fuelling status of LH and RH cylinder banks
- Engine coolant temperature
- Road speed.

Fault information is stored in a volatile Random Access Memory (RAM) in the ECM, so will be deleted if a power failure or battery disconnection occurs.

Five electrical connectors provide the interface between the ECM and the engine/vehicle wiring. The five connectors interlock with each other when installed in the ECM. Adjacent connectors should be disconnected in turn. The installation sequence is the reverse of removal. Each connector groups associated pins together.

System Inputs

The ECM optimizes engine performance by interpreting signals from numerous vehicle sensors and other inputs. Some of these signals are produced by the actions of the driver, some are supplied by sensors located on and around the engine and some are supplied by other vehicle systems. The inputs are as follows:

- Ignition switch
- APP sensor
- Throttle position feedback
- Crankshaft Position (CKP) sensor
- Cruise control signal (from steering wheel switch pack)
- Brake light switch
- Camshaft Position (CMP) sensors
- Engine Coolant Temperature (ECT) sensor
- Knock sensors
- Mass Air Flow/Intake Air Temperature (MAF/IAT) sensor
- Heated Oxygen Sensors (HO2S)
- Immobilisation signal (from immobilisation ECU)
- Fuel level signal (via CAN)
- Vehicle speed signal (from ABS ECU)
- Radiator outlet temperature
- Internal ambient barometric pressure sensor (altitude sensor)
- Electronic Automatic Transmission (EAT) information.

Electric Throttle System

The EMS incorporates an electric throttle control system. This system consists of three main components:

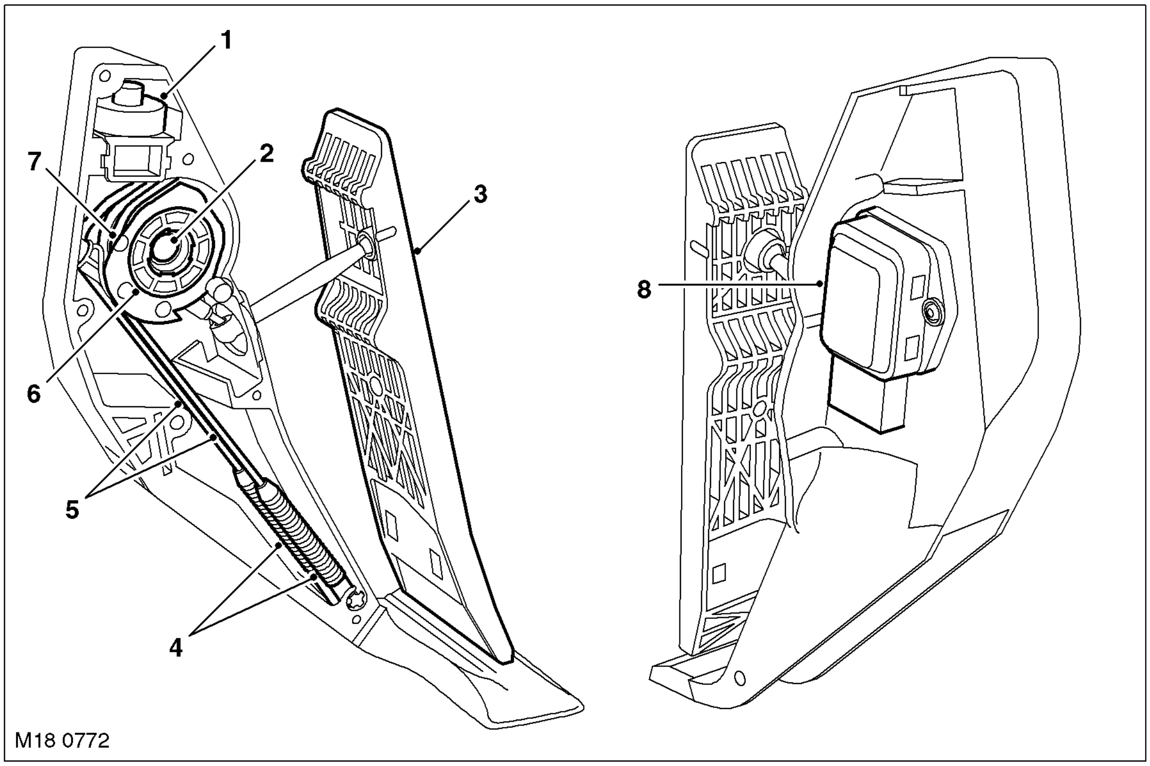
- Electronic throttle control valve
- APP sensor
- ECM.

When the accelerator pedal is depressed the APP sensor provides a change in the monitored signals. The ECM compares this against an electronic “map” and moves the electronic throttle valve via a pulse width modulated control signal which is in proportion to the APP angle signal.

The system is required to:

- Regulate the calculated intake air load based on the accelerator pedal sensor input signals and programmed mapping
- Monitor the drivers input request for cruise control operation
- Automatically position the electronic throttle for accurate cruise control
- Perform all dynamic stability control throttle control interventions
- Monitor and carry out maximum engine and road speed cut out.

Accelerator Pedal Position (APP) Sensor

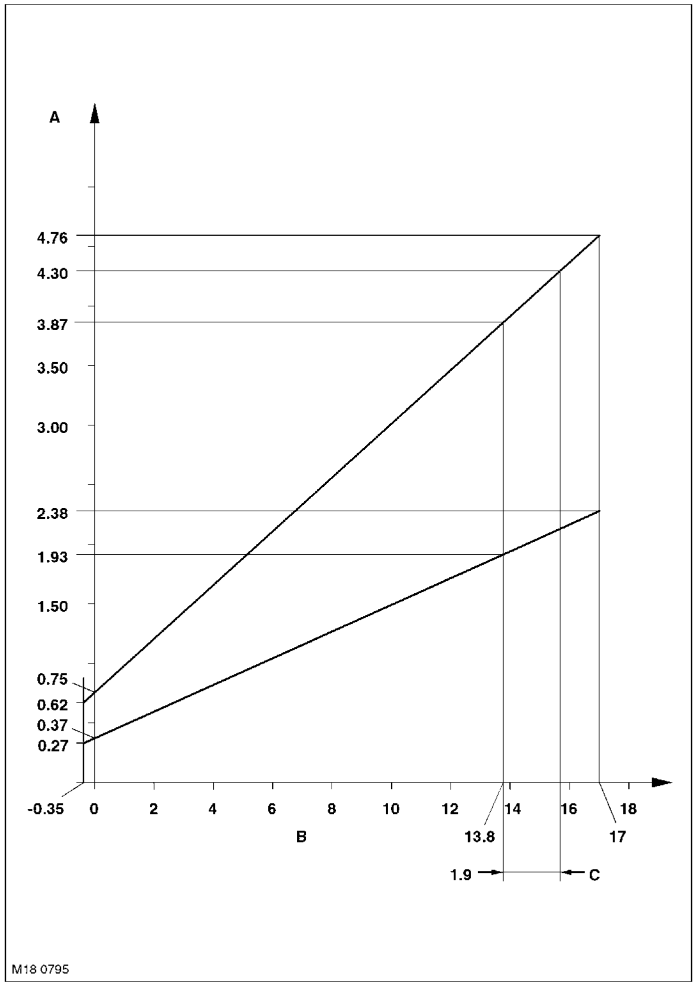


1	Detente mechanism	5	Cables
2	Sensor spigot	6	Bush
3	Pedal	7	Drum
4	Springs	8	APP sensor

The APP sensor is located in a plastic housing which is integral with the throttle pedal. The housing is injection moulded and provides location for the APP sensor. The sensor is mounted externally on the housing and is secured with two Torx screws. The external body of the sensor has a six pin connector which accepts a connector on the vehicle wiring harness.

The sensor has a spigot which protrudes into the housing and provides the pivot point for the pedal mechanism. The spigot has a slot which allows for a pin, which is attached to the sensor potentiometers, to rotate through approximately 90°, which relates to pedal movement. The pedal is connected via a link to a drum, which engages with the sensor pin, changing the linear movement of the pedal into rotary movement of the drum. The drum has two steel cables attached to it. The cables are secured to two tension springs which are secured in the opposite end of the housing. The springs provide 'feel' on the pedal movement and require an effort from the driver similar to that of a cable controlled throttle. A detente mechanism is located at the forward end of the housing and is operated by a ball located on the drum. At near maximum throttle pedal movement, the ball contacts the detente mechanism. A spring in the mechanism is compressed and gives the driver the feeling of depressing a 'kickdown' switch when full pedal travel is achieved.

APP Sensor Output Graph



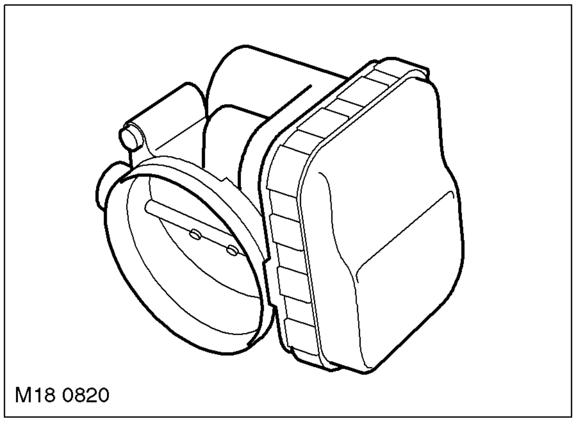
A Voltage B APP sensor angle C Kickdown angle

The APP sensor has two potentiometer tracks which each receive a 5V input voltage from the ECM. Track 1 provides an output of 0.5V with the pedal at rest and 2.0V at 100% full throttle. Track 2 provides an output of 0.5V with the pedal at rest and 4.5V at 100% full throttle. The signals from the two tracks are used by the ECM to determine fuelling for engine operation and also by the ECM and the EAT ECU to initiate a kickdown request for the automatic transmission.

The ECM monitors the outputs from each of the potentiometer tracks and can determine the position, rate of change and direction of movement of the throttle pedal. The 'closed throttle' position signal is used by the ECM to initiate idle speed control and also overrun fuel cut-off.

Electric Throttle

Electric Throttle Control Valve



The Electric Throttle control valve is controlled by the APP sensor via the ECM. The throttle valve plate is positioned by gear reduction DC motor drive. The DC motor is controlled by a proportionally switched high/low PWM signals at a basic frequency of 2000 Hz. Engine idle speed control is a function of the Electric Throttle control valve, therefore a separate idle control valve is not required.

The electric throttle control valve throttle plate position is monitored by two integrated potentiometers. The potentiometers provide DC voltage feedback signals to the ECM for throttle and idle control functions.

Potentiometer one is used as a the primary signal, potentiometer two is used as a plausibility check through the total range of throttle plate movement.

If the ECM detects a plausibility error between Pot 1 and Pot 2 it will calculate the inducted air mass from the air mass (from the air mass sensor) and only utilize the potentiometer signal which closely matches the detected intake air mass. It does this to provide a fail-safe operation by using a 'virtual' potentiometer as a comparative source.

If the ECM cannot calculate a plausible value from the monitored potentiometers (1 and 2) the throttle motor is switched off and the fuel injection cut out is activated.

The electric throttle control valve is continuously monitored during operation. It is also briefly activated when the ignition switch is initially turned to position II. This is done to check the valves mechanical integrity by monitoring the motor control amperage and the reaction speed of the feedback potentiometers.

Should the electronic throttle need replacing the adaption values of the previous unit will need to be cleared from the ECM. This is achieved by the following process:

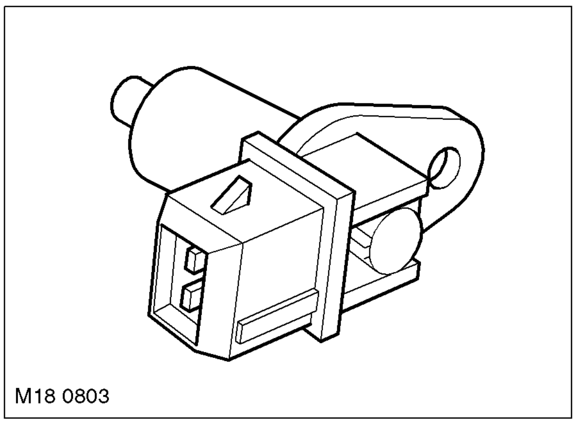
- Using TestBook/T4 clear the adaption values
- Switch the ignition “OFF” for 10 seconds
- Switch the ignition “ON”, for approximately 30 seconds the electric throttle control valve is briefly activated allowing the ECM to learn the new component

This procedure is also necessary after the ECM has been replaced. However the adaption values do not require clearing since they have not yet been established.

Crankshaft Position (CKP) Sensor

The CKP sensor is located in the transmission bell housing adjacent to the edge of the flexplate flywheel. The sensor reacts to a toothed reluctor ring incorporated into the flexplate to ascertain engine speed and position information. The sensor is located on a split spacer and is secured in position by two tube spacers and nuts. The split spacer is 18 mm thick on vehicles fitted with automatic transmission. The thickness of the split spacer determines how far the sensor protrudes through the cylinder block and, therefore, sets the position of the sensor in relation to the reluctor ring. The sensor and the spacer are covered by a protective heat shield. The sensor has three wires attached to it; two signal wires and a screen. The sensor earth screen is connected to chassis earth through the ECM.

CKP Sensor



The CKP sensor is an inductive type sensor which produces a sinusoidal output voltage signal. This voltage is induced by the proximity of the moving reluctor ring, which excites the magnetic flux around the tip of the sensor when each tooth passes. This output voltage will increase in magnitude and frequency as the engine speed rises and the speed at which the teeth on the reluctor ring pass the sensor increases. The signal voltage will peak at approximately 6.5 volts if connected to the ECM (further increases in engine speed will not result in greater magnitude). The ECM neither specifically monitors nor reacts to the output voltage (unless it is very small or very large), instead it measures the time intervals between each pulse (i.e. signal frequency). The signal is determined by the number of teeth passing the sensor, and the speed at which they pass. The reluctor ring has 58 teeth spaced at 6° intervals, with two teeth missing to give the ECM a synchronisation point.

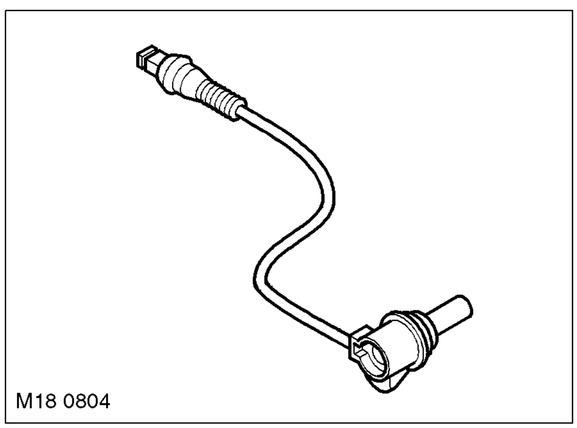
The signal produced by the CKP sensor is critical to engine running. There is no back-up strategy for this sensor and failure of the signal will result in the engine stalling and/or failing to start. If the sensor fails when the engine is running, then the engine will stall, a fault code will be stored and details captured of the battery voltage, engine coolant temperature and intake air temperature at the time of the failure. If the signal fails when the engine is cranking, then the engine will not start and no fault will be stored, as the ECM will not detect that an attempt had been made to start the engine. In both cases the tachometer will also cease to function immediately and the MIL lamp will be permanently illuminated.

During the power-down procedure, which occurs when the ignition is switched off, the ECM stores details of the position of the CKP and CMP sensors. This enables the ECM to operate the injectors in the correct sequence immediately the engine cranks, to produce a quick engine start, which serves to reduce emissions when the engine is cold.

Camshaft Position (CMP) Sensor

There are two CMP sensors which are located on the upper timing case covers. The CMP sensors monitor the position of the camshafts to establish ignition timing order, fuel injection triggering and for accurate Variable Camshaft Control (VCC) camshaft advance-retard timing feedback. The CMP sensor is a Hall-effect sensor which switches a battery fed supply on and off. The supply is switched when the teeth machined onto the camshaft gear pass by the tip of the sensor. The four teeth are of differing shapes, so the ECM can determine the exact position of the camshaft at any time.

CMP Sensor



Unlike an inductive type sensor, a Hall-effect sensor does not produce a sinusoidal output voltage (sine wave). Instead it produces a square wave output. The wave edges are very sharp, giving the ECM a defined edge on which to base its calculations.

An implausible signal from the CMP sensor will result in the following:

- The MIL lamp illuminated after debouncing the fault
- Loss of performance, due to the corrective ignition strategy being disabled. A default ignition map is used which retards the timing to a safe position
- Injector operation possibly 360° out of phase, i.e. fuel injected during exhaust stroke rather

than during compression stroke
- Quick crank/cam synchronisation on start-up feature disabled
- Some Oxygen sensor diagnostics disabled.

In addition, the ECM will store a relevant fault code and capture the input signal supplied by the engine coolant temperature sensor, the engine load calculation and the engine speed at the time of failure. TestBook/T4 will display the live readings from the CMP sensor.

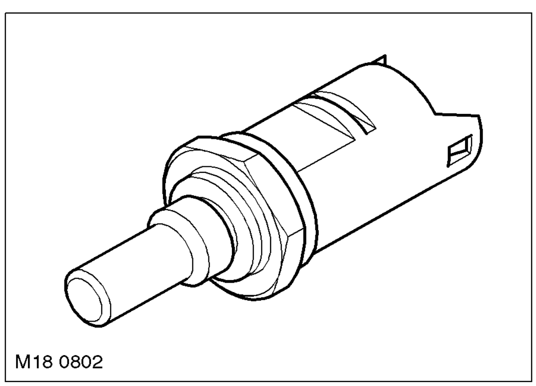
Ambient Barometric Pressure Sensor
The ECM incorporates an integral ambient barometric pressure sensor. This internal sensor is supplied with a 5V feed and returns a linear voltage of between 2.4 and 4.5 Volts. This represents the barometric pressure.

The system monitors barometric pressure for the following reasons:

- The barometric pressure along with the calculated air mass provides additional correction for refining injection “ON” time
- The value provides a base value for the ECM to calculate the air mass being injected into the exhaust system by the secondary air injection system. This correction factor changes the secondary air injection “ON” time which in turn optimizes the necessary air flow into the exhaust system
- The signal is used to recognize down hill driving and to postpone the start of evaporative emission leakage diagnosis.

Engine Coolant Temperature (ECT) Sensor
The ECT sensor is located front of the engine, adjacent to the thermostat housing. The sensor incorporates two Negative Temperature Coefficient (NTC) thermistors and four electrical connections. One set of connections are used by the ECM while the other set are used by the instrument pack temperature gauge.

ECT Sensor



Each thermistor used forms part of a voltage divider circuit operating with a regulated 5 V feed and an earth.

The signal supplied by the ECT sensor is critical to many fuel and ignition control strategies. Therefore, the ECM incorporates a complex ECT sensor default strategy, which it implements in the event of failure. The ECM uses a software model, based on the time the engine has been running and the air intake temperature, to provide a changing default value during the engine warm-up. When the software model calculates the coolant temperature has reached 60 °C (140 °F), a fixed default value of 85 °C (185 °F) is adopted for the remainder of the ignition cycle. The software model also forms part of the sensor diagnostics: if there is too great a difference between the temperatures from the sensor input and the software model, for more than 2.54 seconds, the ECM concludes there is a fault with the sensor input.

The following symptoms may be noticeable in the event of an ECT sensor failure:

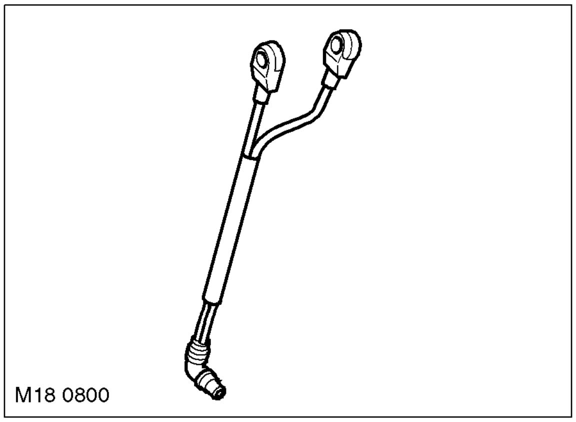
- The MIL lamp illuminated
- Poor engine hot and cold start
- Instrument pack engine overheat warning lamp illuminated
- Excessively hot or cold reading on the temperature gauge.

At the time of a failure, the ECM will also store details of the engine speed, engine load and intake air temperature in its memory. This information is stored to aid diagnosis of the fault.

Knock Sensors

Two knock sensors are located on each cylinder block between the first and second and third and fourth cylinders of each cylinder bank. The knock sensors produce a voltage signal in proportion to the amount of mechanical vibration generated at each ignition point. Each sensor monitors two cylinders in the related cylinder bank.

Knock Sensor



The knock sensors incorporate a piezo-ceramic crystal. This crystal produces a voltage whenever an outside force tries to deflect it, (i.e. exerts a mechanical load on it). When the engine is running, the compression waves in the material of the cylinder block, caused by the combustion of the fuel/air mixture within the cylinders, deflect the crystal and produce an output voltage signal. The signals are supplied to the ECM, which compares them with `mapped' signals stored in memory. From this, the ECM can determine when detonation occurs on individual cylinders. When detonation is detected, the ECM retards the ignition timing on that cylinder for a number of engine cycles, then gradually returns it to the original setting.

Care must be taken at all times to avoid damaging the knock sensors, but particularly during removal and fitting procedures. The recommendations regarding torque and surface preparation must be adhered to. The torque applied to the sensor and the quality of the surface preparation both have an influence over the transfer of mechanical noise from the cylinder block to the crystal.

The ECM uses the signals supplied by the knock sensors, in conjunction with the signal it receives from the camshaft sensor, to determine the optimum ignition point for each cylinder. The ignition point is set according to pre-programmed ignition maps stored within the ECM. The ECM is programmed to use ignition maps for 95 RON premium specification fuel. It will also function on 91 RON regular specification fuel but without adaptions. If the only fuel available is of poor quality, or the customer switches to a lower grade of fuel after using a high grade for a period of time, the engine may suffer slight pre-ignition for a short period. This amount of pre-ignition will not damage the engine. This situation will be evident while the ECM learns and then modifies its internal mapping to compensate for the variation in fuel quality. This feature is called adaption. The ECM has the capability of adapting its fuel and ignition control outputs in response to several sensor inputs.

The ECM will cancel closed loop control of the ignition system if the signal received from either knock sensor becomes implausible. In these circumstances the ECM will default to a safe ignition map. This measure ensures the engine will not become damaged if low quality fuel is used. The MIL lamp will not illuminate, although the driver may notice that the engine 'pinks' in some driving conditions and displays a slight drop in performance and smoothness.

When a knock sensor fault is stored, the ECM will also store details of the engine speed, engine load and the coolant temperature.

Mass Air Flow/Air Intake Temperature (MAF/IAT) Sensor
The MAF/IAT sensor is located in the air intake ducting, between the air cleaner and the throttle body. The sensor outputs intake air flow and temperature signals to the ECM to enable calculation of the mass of the air entering the engine.

In addition to the air flow and temperature outputs, a regulated 5 V feed and an earth are connected between the sensor and the ECM, and the sensor receives a battery power feed from the main relay.

Air flow:

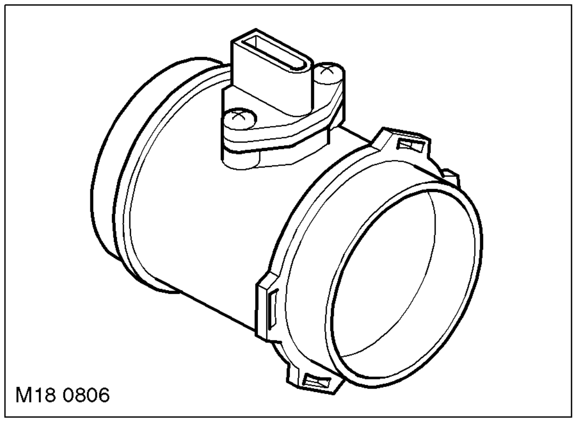
The air flow signal is produced from a hot film element in the sensor. The film is connected between the 5 V feed and the air flow output to the ECM. The film is also heated by the battery power feed and cooled by the air flow into the engine. The greater the air flow, the greater the cooling effect and the lower the electrical resistance across the sensor. So the air flow output voltage varies with changes in air flow and, from voltage/air flow maps stored in memory, the ECM determines the mass of air entering the engine.

Air intake temperature:

The air intake temperature signal is produced by a NTC thermistor connected between the 5 V feed and earth to complete a voltage divider circuit. The ECM monitors the voltage drop across the thermistor and, from voltage/temperature maps stored in memory, determines the temperature of the intake air.

The MAF/IAT sensor is sensitive to sudden shocks and changes in its orientation. It should, therefore, be handled carefully. It is also important that the intake ducting between the air cleaner and the throttle body is not altered in diameter or modified in any way. The air mass flow meter contains electronic circuitry, so never attempt to supply it directly from the battery. The terminals have a silver coating to provide a superior quality of connection over many years. If, at any time, a probe is used to measure the output directly from the sensor, then care must be taken to ensure this coating is not damaged.

MAF/IAT Sensor



If the air flow signal fails the ECM adopts a default value for air flow volume based on throttle position and engine speed. The following engine symptoms will be noticeable:

- The engine speed might 'dip' before the default strategy enables continued running
- The engine may be difficult to start and prone to stalling
- The overall performance of the engine will be adversely affected (throttle response in particular)
- Exhaust emissions will be out of tolerance, because the air/fuel ratio value is now assumed, not calculated; no closed loop fuelling
- Idle speed control disabled, leading to rough idle and possible engine stall.

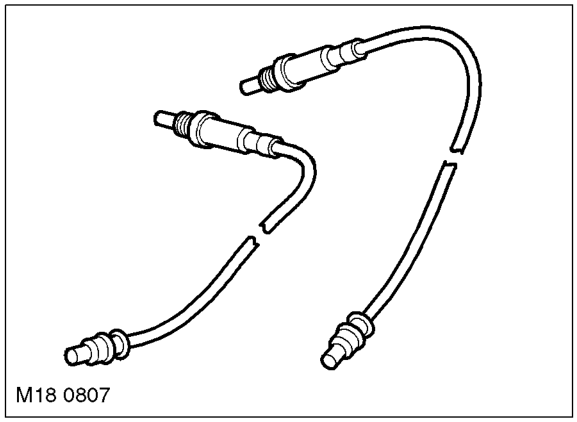
At the time of failure, the ECM will store details of the engine speed, coolant temperature and throttle angle.

If the intake air temperature signal fails, the ECM adopts a default value of 45 °C. This default value is then used within all the calculations involving intake air temperature. The effect on the vehicle of a failed air temperature signal will not be so noticeable to the driver, who may notice a reduction in engine performance when operating the vehicle at high altitudes or in hot ambient temperatures. The occurrence of this fault will also disable fuelling adaptions.

The ECM will store details of the engine speed, engine load and battery voltage when this fault is first detected.

Heated Oxygen Sensors (HO2S)
The HO2S provide feedback signals to the ECM to enable closed loop control of the Air Fuel Ratio (AFR). Four HO2S are installed, one pre-catalyst and one post-catalyst per cylinder bank. Each HO2S produces an output voltage which is inversely proportional to the oxygen content of the exhaust gases.

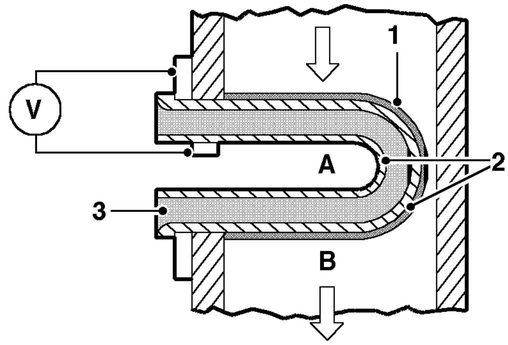
HO2S



Each HO2S consists of a zirconium sensing element with a gas permeable ceramic coating on the outer surface. The outer surface of the sensing element is exposed to the exhaust gas and the inner surface is exposed to ambient air. The difference in the oxygen content of the two gases produces an electrical potential difference across the sensing element. The voltage produced depends on the differential between the two oxygen contents. When the AFR is Lambda 1 (i.e. stoichiometric AFR of 14.7:1 by mass) the voltage produced is approximately 450 mV. With a lean mixture of Lambda 1.2, the higher oxygen content of the exhaust gases results in a voltage of approximately 100 mV. With a rich mixture of Lambda 0.8, the lower oxygen content of the exhaust gases results in a voltage of approximately 900 mV.

The ECM monitors the effect of altering the injector pulse widths using the information supplied by the two HO2S. Injector pulse width is the length of time the injector is energized, which determines how much fuel is injected. The response time is such that under certain driving conditions, the ECM can assess individual cylinder contributions to the total exhaust emissions. This enables the ECM to adapt the fuelling strategy on a cylinder by cylinder basis, i.e. inject the precise amount of fuel required by each individual cylinder at any given time.

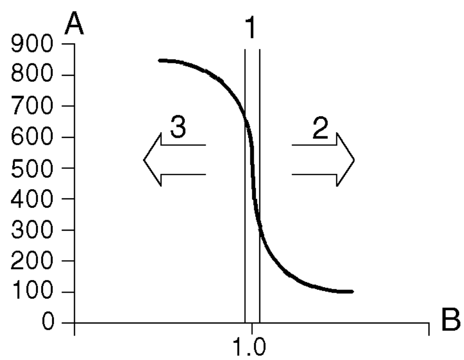
HO2S Principle of Operation



M18 0515

A	Ambient air	2	Electrodes
B	Exhaust gases	3	Zirconium oxide
1	Protective ceramic coating		

HO2S Output



M19 3152

A	Output, mV	2	Lean AFR
B	AFR, lambda	3	Rich AFR
1	Lambda window		

The ECM continuously checks the signals supplied by the HO2S for plausibility. If it detects an implausible signal, the ECM stores a relevant fault code and details of engine speed, engine load and the HO2S signal voltage. The ECM requires the HO2S signals to set most of its adaptions. Failure of an HO2S results in most of these adaptions resetting to their default values. This, in turn, results in loss of engine refinement. The engine may exhibit poor idle characteristics and emit a strong smell of rotten eggs from the exhaust (caused by an increase in hydrogen sulphide).

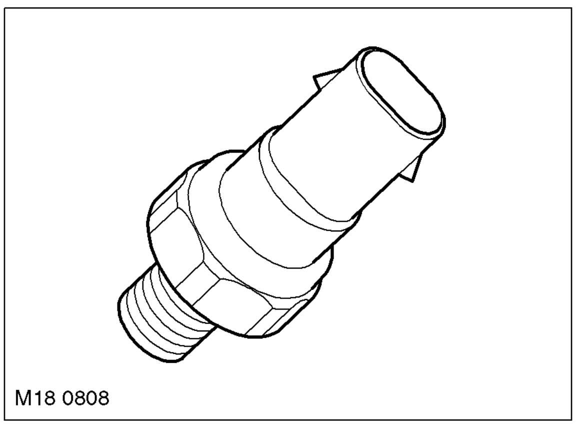
The efficiency of the HO2S slowly deteriorates with use and must be periodically replaced (currently every 120,000 miles, but refer to the maintenance schedules for the latest service replacement period). The ECM is able to detect this steady deterioration from the HO2S signals. If a sensor deteriorates beyond a predetermined threshold, the ECM stores a fault code and captures details of the engine speed, engine load and battery voltage.

The HO2S needs a high operating temperature to work effectively. To ensure a suitable operating temperature is reached as soon as possible, each sensor incorporates a heating element inside the ceramic tip. This element heats the HO2S to a temperature greater than 350 °C (662 °F). The heating rate (the speed at which the temperature rises) is carefully controlled by the ECM to prevent thermal shock to the ceramic material. The ECM supplies a Pulse Width Modulated (PWM) supply to the heater elements to control the rate at which the HO2S temperature is increased. The HO2S are heated during engine warm-up and again after a period of engine idle.

The ECM monitors the state of the heating elements by calculating the amount of current supplied to each sensor during operation. If the ECM identifies that the resistance of either heating element is too high or too low, it will store a fault code, the engine speed, coolant temperature and the battery voltage.

HO2S are very sensitive devices. They must be handled carefully at all times. Failure to handle correctly will result in a very short service life, or non-operation. HO2S are threads coated with an anti-seize compound prior to installation. Care should be taken to avoid getting this compound on the sensor tip. If the sensor needs to be removed and refitted, a small amount of anti-seize compound should be applied (see workshop manual for details).

Radiator Outlet Temperature Sensor



The ECM uses an additional engine coolant temperature sensor located in the radiator outlet. The sensor monitors the temperature of the coolant leaving the radiator for precise activation of the auxiliary fan. The sensor is an NTC thermistor type. The signal is used by the ECM to activate the auxiliary fan when the engine coolant temperature leaving the radiator is in the range of 80 to 104 °C (176 to 219 °F).

Fuel Level Signal

The ECM monitors the contents of the fuel tank as part of the misfire detection strategy. If a misfire occurs while a low fuel level exists, the ECM stores an additional fault code to indicate that fuel starvation resulting from fuel slosh is a possible cause of the misfire. On New Range Rover, the low fuel level signal is internally generated by the ECM, from a CAN signal via the instrument pack.

Vehicle Speed Signal
The ECM receives the vehicle speed signal from the ABS ECU. The ECM uses this signal within its calculations for idle speed control. The signal is transmitted at 8000 pulses/mile and is the average of the road speed signals from all four wheel speed sensors. The ABS ECU outputs the vehicle speed signal to the EAT ECU on the CAN bus.

Rough Road Signal
When the vehicle is travelling over a rough road surface the engine crankshaft is subjected to torsional vibrations caused by mechanical feedback from the road surface through the transmission. To prevent misinterpretation of these torsional vibrations as a misfire, the ECM calculates a rough road level by monitoring individual wheel speeds from the ABS ECU on the CAN bus. The ECM determines the quality of the road surface by monitoring a CAN signal from the ABS ECU, which modulates the duty cycle of the signal in response to variations between ABS sensor inputs. Misfire monitoring is restored when the quality of the road surface improves again.

If there is a fault with the CAN data, the ECM defaults to permanent misfire monitoring.

A/C Request Signals
Because of the loads imposed on the engine when the air conditioning system operates, the ECM is included in the control loop for the compressor and the cooling fans. If it becomes necessary to limit or reduce the load on the engine, the ECM can then prevent or discontinue operation of the air conditioning compressor.

Automatic Gearbox Information
Information sent to and from the EAT ECU is transmitted on the CAN bus.

The ECM requires information on gear position to calculate the likely engine load during acceleration and deceleration conditions. The ECM also disables the misfire detection function whenever low range is selected. The ECM receives this information from the transfer box ECU on the CAN Bus.

There are several possible fault codes associated with the CAN bus and the validity of the messages exchanged between the ECM and the EAT ECU. In most cases, the ECM will store engine speed, engine coolant temperature and details of the battery voltage at the time a CAN fault is detected.

If the EAT ECU detects a gearbox fault, it requests the ECM to illuminate the MIL in the instrument pack and to store freeze frame data.

Ignition Switch
The ignition switch signal enables the ECM to detect if the ignition is on or off. The signal is a power feed that is connected to the ECM while the ignition switch is positions II and III. On the New Range Rover, the power feed comes from the ignition relay in the engine compartment fuse box.

When it first receives the signal, the ECM 'wakes-up' and initiates a power-up sequence to enable engine starting and operation. The power-up sequence includes energising the main relay, which supplies the main power feed to the ECM, energising the fuel pump relay and initiating a self check of the engine management system.

When it detects the ignition has been turned off, the ECM stops activating the fuel injectors and ignition coil, to stop the engine, and de-energizes the fuel pump relay, but keeps the main relay energized while it performs a power down sequence. During the power down sequence the ECM records the engine sensor values required for a quick-start function to operate the next time the engine is cranked. At the end of the power down sequence, the ECM de-energizes the main relay to switch itself off.

System Outputs

The ECM receives and processes the input information previously described and modifies the fuelling and the ignition points for each cylinder accordingly. The ECM will also supply output information to other vehicle systems.

The ECM drives the following components:

- Fuel injectors
- Ignition coils
- Main relay and fuel pump relay
- Tank Leakage Detection (where fitted)
- Secondary Air Injection Pump
- Secondary Air Injection valve
- VCC Valves
- Electrically heated thermostat
- Air conditioning compressor (relay drive).

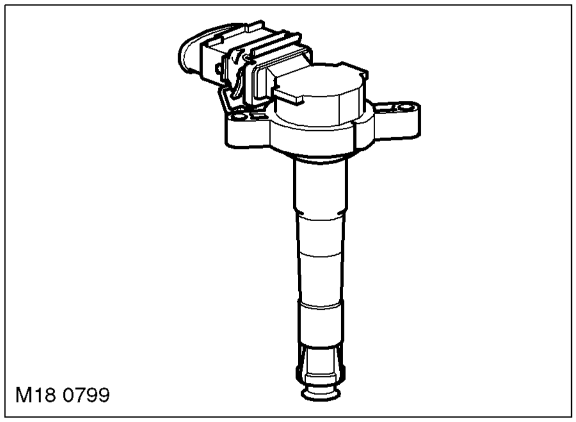
The ECM provides other systems with information regarding the:

- Engine speed
- Driver demand
- ATC request
- Automatic Transmission
- Fuel used
- Auxiliary cooling fan.

Ignition Coils

The ME 7.2 EMS utilizes plug top coils which are mounted directly on top of the spark plug.

Ignition Coils

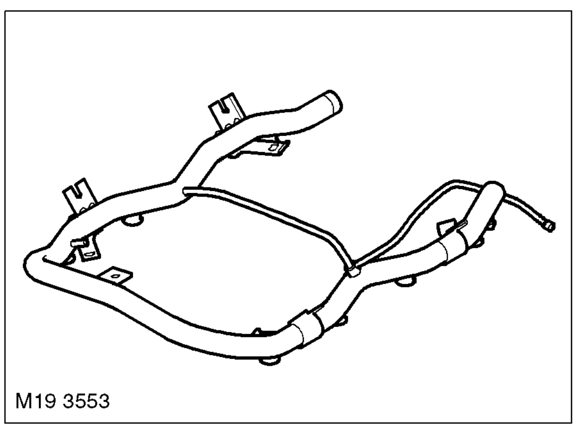


Ignition related faults are indirectly monitored via misfire detection. The are no specific checks of the primary circuits.

Fuel Injectors

An electromagnetic, top feed fuel injector is installed in each cylinder inlet tract of the inlet manifolds. A common fuel rail supplies the injectors with fuel from a returnless fuel delivery system. The fuel in the fuel rail is maintained at 3.5 bar (50.75 lbf.in ^{3}) above inlet manifold pressure by a pressure regulator incorporated into the fuel filter. A Schraeder valve is installed in the fuel rail, to the rear of injector No. 7, to enable the fuel pressure to be checked.

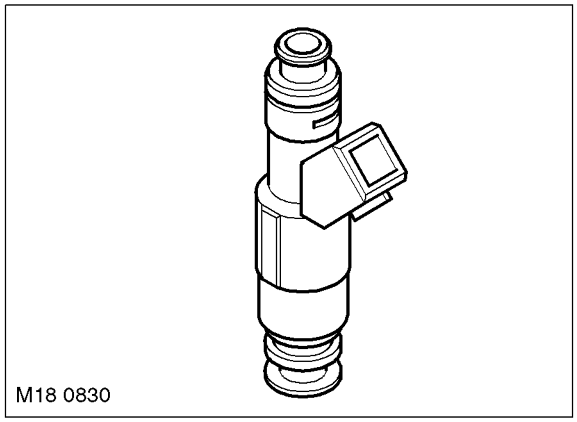
Fuel Rail and Injectors



Each injector contains a solenoid operated needle valve which is closed while the solenoid winding is de-energized. The solenoid winding is connected to a power feed from the main relay and to an earth through the ECM. The ECM switches the earth to control the opening and closing of the needle valve (injector 'firing'). While the needle valve is open, fuel is sprayed into the cylinder inlet tract onto the back of the inlet valves. The ECM meters the amount of fuel injected by adjusting the time that the needle valve is open (injector pulse width).

Each injector is sealed with two 'O' rings, which should be renewed whenever an injector is refitted to an engine. A small amount of engine oil can be applied to the 'O' rings to aid installation. No other form of lubrication should be used.

Fuel Injector



Measuring the electrical resistance of the solenoid winding enables an assessment to be made of the serviceability of an injector. Nominal resistance of the solenoid winding is $14.5 \pm 0.7\ \Omega$ at 20 °C (68 °F).

The ECM can detect electrical inconsistencies within each injector. It can also detect, via feedback from the HO2S, mechanical faults such as blockage or leakage. The ECM will store a relevant fault code in these circumstances. The ECM will also store the engine speed, engine load and details of either the battery voltage, engine coolant temperature or intake air temperature. The precise details stored depend on the exact nature of the fault detected.

TestBook/T4 will also display data regarding injector operation via its live readings. Care must be taken when analysing this data, as the precise timings will vary considerably. Individual timings will be affected by any current engine load.

Main Relay

The ECM controls its own power supply, via the main relay in the engine compartment fusebox. When the ignition is turned to position II, the ECM provides a ground to the main relay coil. The main relay then energizes and connects the main power feed to the ECM. The ECM controls the main relay, and therefore its own power supply, so that when the ignition is turned off it can follow the power-down sequence, during which it records values from various sensors and writes adaptions into its memory, etc. The last action the ECM carries out before completing its power-down sequence is to turn off the main relay. This will occur approximately 7 seconds after the ignition has been switched off, as long as the coolant temperature is not rising. For vehicles with tank module leak detection and under some vehicle system fault conditions, this period could be extended up to 20 minutes.

Failure of the main relay will result in the engine failing to start. The engine will stop immediately if the main relay fails while the engine is running.

Fuel Pump Relay

The ECM controls operation of the fuel pump via the fuel pump relay in the rear fusebox. The ECM switches the relay coil to earth to energize the relay when the ignition is first turned to position II. The relay remains energized during engine cranking and while the engine is running, but will be de-energized after approximately 2 seconds if the ignition switch remains in position II without the engine running.

A fuel cut-off function is incorporated into the ECM to de-energize the fuel pump in a collision. The cut off function is activated by a signal from the SRS DCU in the event of an airbag activation. The ECM receives an airbag activation signal from the SRS DCU on the CAN Bus.

The fuel cut-off function can only be reset by using TestBook/T4.

The ECM monitors the state of the wiring to the coil winding within the fuel pump relay. The ECM will store relevant fault codes if the ECM detects a problem. The ECM is not able to assess the state of the fuel pump circuit because it is isolated by the function of the relay. However, if the fuel pump circuit fails, or the pump fails to deliver sufficient fuel (while the fuel level is above the minimum level), the ECM will store adaptive faults as it tries to increase the air/fuel ratio by increasing the pulse width of the injectors.

Failure of the fuel pump relay will result in the engine failing to start. If the fuel pump fails while the engine is running, the symptoms will be engine hesitation and engine misfire. These symptoms will worsen progressively until the engine stops. The ECM will store several fault codes under this condition.

Electrically Heated Thermostat

The electrically heated thermostat is used to regulate the engine coolant temperature. The thermostat regulates the coolant temperature depending upon engine load and vehicle speed. This allows the engine coolant temperature to be raised when the engine is operating at part load. Raising the coolant temperature while the engine is at part load has a beneficial effect on fuel consumption and emissions.

If a conventional thermostat with higher constant operating temperature is used, poor response when accelerating and in traffic could result.

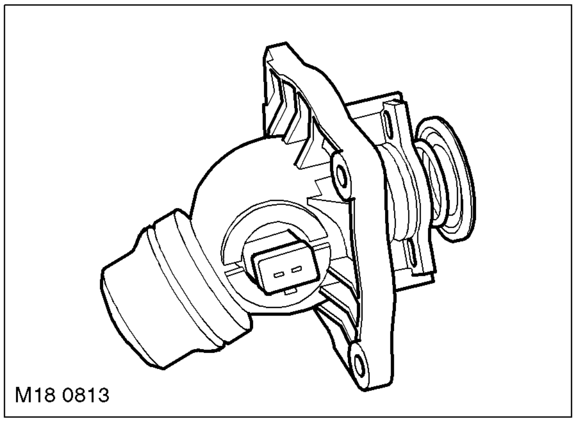
The thermostat is controlled by the ECM is response to engine load against a 'map' stored within the ECM.

The map is based upon the following inputs:

- Engine load
- Engine speed
- Vehicle speed
- Intake air temperature
- Coolant temperature.

The thermostat unit is a one piece construction comprising the thermostat, thermostat housing and heater element. The housing is of a die-cast aluminium. The electrical connection for the heater element is housed in the body. The heater element is an expanding (wax) element.

Heated Thermostat



The thermostat is set to open when the coolant temperature reaches 103 °C (217 °F) at the thermostat. Once the coolant has passed through the engine its temperature is approximately 110 °C (230 °F) at the engine temperature sensor.

If the ECM starts to regulate the system the ECM supplies an earth path for the heater element in the thermostat. This causes the element to expand and increase the opening dimension of the thermostat.

The warmer the element the sooner the thermostat opens and the lower the resulting coolant temperature is. The thermostat regulates the coolant temperature in the range 80 to 103 °C (176 to 217 °F). The expanding element in the thermostat is heated to a higher temperature than the surrounding coolant to generate the correct opening aperture. Should the coolant temperature exceed 113 °C (235 °F) the electrically heated thermostat is activated independently of the prevailing engine parameters.

Should the heated thermostat fail, (fault codes will be stored in the ECM) the EMS will ensure the safe operation of the engine and the thermostat will operate as a conventional unit.

ECM Adaptions

The ECM has the ability to adapt the values it uses to control certain outputs. This capability ensures the EMS can meet emissions legislation and improve the refinement of the engine throughout its operating range.

The components which have adaptions associated with them are:

- The IACV
- The APP sensor
- The HO2S
- The MAF/IAT sensor
- The CKP sensor
- Electric throttle body.

HO2S and MAF/IAT Sensor

There are several adaptive maps associated with the fuelling strategy. Within the fuelling strategy the ECM calculates short-term adaptions and long term adaptions. The ECM will monitor the deterioration of the HO2S over a period of time. It will also monitor the current correction associated with the sensors.

The ECM will store a fault code in circumstances where an adaption is forced to exceed its operating parameters. At the same time, the ECM will record the engine speed, engine load and intake air temperature.

CKP Sensor

The characteristics of the signal supplied by the CKP sensor are learned by the ECM. This enables the ECM to set an adaption and support the engine misfire detection function. Due to the small variation between different flywheels and different CKP sensors, the adaption must be reset if either component is renewed, or removed and refitted. It is also necessary to reset the flywheel adaption if the ECM is renewed or replaced.

The ECM supports four flywheel adaptions for the CKP sensor. Each adaption relates to a specific engine speed range. The engine speed ranges are detailed in the table below:

Adaptation	Engine Speed, rev/ min
1	1800 - 3000
2	3001 - 3800
3	3801 - 4600
4	4601 - 5400

To set the flywheel adaptions, follow the procedure detailed below. This procedure should be carried out in an appropriate area off the public highway. TestBook/T4 must be connected throughout this procedure. The adaptive speed settings must be read from TestBook/T4 while the vehicle is moving at speed.

1. Use TestBook/T4 to clear any adaptions currently set.
2. With the engine warm (> 86 °C (187 °F)), select 2nd gear high range.
3. Accelerate the vehicle until the engine speed reaches the limiter.
4. Release the throttle and allow the vehicle to decelerate until the engine idle speed is reached.
5. Check that one of the speed range adaptions has been set (read this from TestBook/T4).
6. Repeat the above procedure until all four adaptions are set

When all four adaptions have been set, check that the ECM has not recorded any misfire detection faults. If it has, then clear the memory of the misfire fault codes.

It may not be possible to reset adaption number 4 if the ECM has already been programmed with a value. Due to the nature of the procedure and the self learn capacity of the ECM, if adaption number 4 does not reset, it is permissible to leave this adaption and let the ECM learn it during normal vehicle usage.

Misfire Detection

Legislation requires that the ECM must be able to detect the presence of an engine misfire. It must be able to detect misfires at two separate levels. The first level is a misfire that could lead to the vehicle emissions exceeding 1.5 times the Federal Test Procedure (FTP) requirements for the engine. The second level is a misfire that may cause catalyst damage.

The ECM monitors the number of misfire occurrences within two engine speed ranges. If the ECM detects more than a predetermined number of misfire occurrences within either of these two ranges, over two consecutive journeys, the ECM will record a fault code and details of the engine speed, engine load and engine coolant temperature. In addition, the ECM monitors the number of misfire occurrences that happen in a 'window' of 200 engine revolutions. The misfire occurrences are assigned a weighting according to their likely impact on the catalysts. If the number of misfires exceeds a certain value, the ECM stores catalyst-damaging fault codes, along with the engine speed, engine load and engine coolant temperature.

The signal from the crankshaft position sensor indicates how fast the poles on the flywheel are passing the sensor tip. A sine wave is generated each time a pole passes the sensor tip. The ECM can detect variations in flywheel speed by monitoring the sine wave signal supplied by the crankshaft position sensor.

By assessing this signal, the ECM can detect the presence of an engine misfire. At this time, the ECM will assess the amount of variation in the signal received from the crankshaft position sensor and assigns a roughness value to it. This roughness value can be viewed within the real time monitoring feature, using TestBook/T4. The ECM will evaluate the signal against a number of factors and will decide whether to count the occurrence or ignore it. The ECM can assign a roughness and misfire signal for each cylinder, (i.e. identify which cylinder is misfiring).

TestBook/T4 Diagnostics

The ECM stores faults as Diagnostic Trouble Codes (DTC), referred to as 'P' codes. The 'P' codes are defined by OBD legislation and, together with their associated environmental and freeze frame data, can be read using a third party scan tool or TestBook/T4. TestBook/T4 can also read real time data from each sensor, the adaptive values currently being employed and the current fuelling, ignition and idle settings.

Several different drive cycles are defined by OBD legislation for fault diagnosis. Each drive cycle is a precise routine which the engine or vehicle must undergo to produce the conditions that enable the ECM to perform diagnostic routines. TestBook/T4 can be used to view the status and results of the diagnostic routines performed by the ECM. When a fault code is stored, it will indicate, via TestBook/T4, the drive cycle required to verify a repair.

The ECM only records a fault after it has occurred on more than one drive cycle. This fault strategy is referred to as debouncing. When it is first detected, a fault is stored as a temporary fault. If the fault recurs within the next 40 warm-up cycles, the fault is stored as a permanent fault and freeze frame data for the second occurrence is recorded. If the fault does not recur within the next 40 warm-up cycles, the ECM deletes the temporary fault from memory.

The ECM illuminates the MIL when requested to do so by the EAT ECU, to perform a bulb check when the ignition is switched on, and for any emissions related fault. There is no MIL illumination for non emission related engine management faults.

Resetting the adaptions will clear all adaptions from the ECM memory.

Engine Management P Codes

P Code No.	Component/Signal	Fault Description
0010	RH bank CMP sensor	Signal malfunction
0011	RH bank CMP sensor	Timing over-advanced or system performance
0012	RH bank CMP sensor	Timing over-retarded
0020	LH bank CMP sensor	Signal malfunction
0021	LH bank CMP sensor	Timing over-advanced or system performance
0022	LH bank CMP sensor	Timing over-retarded
0030	RH bank front HO2S heater circuit	Circuit intermittent
0031	RH bank front HO2S heater circuit	Short circuit to ground
0032	RH bank front HO2S heater circuit	Short circuit to battery
0036	RH bank rear HO2S heater circuit	Circuit intermittent
0037	RH bank rear HO2S heater circuit	Short circuit to ground
0038	RH bank rear HO2S heater circuit	Short circuit to battery
0050	LH bank front HO2S heater circuit	Circuit intermittent
0051	LH bank front HO2S heater circuit	Short circuit to ground
0052	LH bank front HO2S heater circuit	Short circuit to battery
0056	LH bank rear HO2S heater circuit	Circuit intermittent
0057	LH bank rear HO2S heater circuit	Short circuit to ground
0058	LH bank rear HO2S heater circuits	Short circuit to battery
0102	MAF sensor signal	Short circuit to ground
0103	MAF sensor signal	Short circuit to battery
0106	ECM internal ambient pressure sensor	Performance problem
0107	ECM internal ambient pressure	Short circuit to ground
0108	ECM internal ambient pressure	Open circuit or short circuit to battery
0112	IAT sensor	Short circuit to ground
0113	IAT sensor	Open circuit or short circuit to battery

P Code No.	Component/Signal	Fault Description
0114	Ambient temperature input	Fault data received
0116	ECT sensor	Signal implausible
0117	ECT sensor	Short circuit to ground
0118	ECT sensor	Open circuit or short circuit to battery
0120	APP sensor switch A	Implausible
0121	APP sensor switch A	Range/ Performance problem
0122	APP sensor switch A	Open circuit or short circuit to ground
0123	APP sensor switch A	Short circuit to battery
0125	ECT sensor	Insufficient coolant temperature for closed loop control
0128	Thermostat monitoring sensor	Low coolant temperature ñ thermostat stuck open
0130	RH bank front HO2S signal	Circuit malfunction
0131	RH bank front HO2S signal	Short circuit to ground
0132	RH bank front HO2S signal	Short circuit to battery
0133	RH bank front HO2S signal	Slow response
0134	RH bank front HO2S signal	No activity
0135	RH bank front HO2S heater circuit	Circuit malfunction
0136	RH bank rear HO2S signal	Circuit malfunction
0137	RH bank rear HO2S signal	Short circuit to ground
0138	RH bank rear HO2S signal	Short circuit to battery
0139	RH bank rear HO2S signal	Slow response
0140	RH bank rear HO2S signal	No activity
0141	RH bank rear HO2S heater circuit	Circuit malfunction
0150	LH bank front HO2S signal	Circuit malfunction
0151	LH bank front HO2S signal	Short circuit to ground
0152	LH bank front HO2S signal	Short circuit to battery
0153	LH bank front HO2S signal	Slow response
0154	LH bank front HO2S signal	No activity
0155	LH bank front HO2S heater circuit	Circuit malfunction
0156	LH bank rear HO2S signal	Circuit malfunction
0157	LH bank rear HO2S signal	Short circuit to ground
0158	LH bank rear HO2S signal	Short circuit to battery
0159	LH bank rear HO2S signal	Slow response
0160	LH bank rear HO2S signal	No activity
0161	LH bank rear HO2S heater circuit	Malfunction
0171	RH bank lambda control	Fuelling too lean
0172	RH bank lambda control	Fuelling too rich

P Code No.	Component/Signal	Fault Description
0174	LH bank lambda control	Fuelling too lean
0175	LH bank lambda control	Fuelling too rich
0201	Fuel injector 1	Open circuit
0202	Fuel injector 2	Open circuit
0203	Fuel injector 3	Open circuit
0204	Fuel injector 4	Open circuit
0205	Fuel injector 5	Open circuit
0206	Fuel injector 6	Open circuit
0207	Fuel injector 7	Open circuit
0208	Fuel injector 8	Open circuit
0221	APP sensor switch B	Range/ Performance problem
0222	APP sensor switch B	Open circuit or short circuit to ground
0223	APP sensor switch B	Short circuit to battery
0231	Fuel pump motor drive	Short circuit to ground
0232	Fuel pump motor drive	Short circuit to battery
0233	Fuel pump motor drive	Circuit fault
0261	Fuel injector 1	Short circuit to ground
0262	Fuel injector 1	Short circuit to battery
0264	Fuel injector 2	Short circuit to ground
0265	Fuel injector 2	Short circuit to battery
0267	Fuel injector 3	Short circuit to ground
0268	Fuel injector 3	Short circuit to battery
0270	Fuel injector 4	Short circuit to ground
0271	Fuel injector 4	Short circuit to battery
0273	Fuel injector 5	Short circuit to ground
0274	Fuel injector 5	Short circuit to battery
0276	Fuel injector 6	Short circuit to ground
0277	Fuel injector 6	Short circuit to battery
0279	Fuel injector 7	Short circuit to ground
0280	Fuel injector 7	Short circuit to battery
0282	Fuel injector 8	Short circuit to ground
0283	Fuel injector 8	Short circuit to battery
0300	Misfire detection	Random/Multiple cylinder misfire
0301	Misfire detection	Cylinder 1 misfire
0302	Misfire detection	Cylinder 2 misfire
0303	Misfire detection	Cylinder 3 misfire
0304	Misfire detection	Cylinder 4 misfire
0305	Misfire detection	Cylinder 5 misfire
0306	Misfire detection	Cylinder 6 misfire

P Code No.	Component/Signal	Fault Description
0307	Misfire detection	Cylinder 7 misfire
0308	Misfire detection	Cylinder 8 misfire
0324	Knock sensors	Control system error
0327	RH bank knock sensor 1	Short circuit to ground
0328	RH bank knock sensor 1	Short circuit to battery
0332	LH bank knock sensor 3	Short circuit to ground
0333	LH bank knock sensor 3	Short circuit to battery
0335	CKP sensor	Signal implausible
0340	RH bank CMP sensor	Signal implausible
0342	RH bank CMP sensor	Short circuit to ground
0343	RH bank CMP sensor	Short circuit to battery
0345	LH bank CMP sensor	Signal implausible
0347	LH bank CMP sensor	Short circuit to ground
0348	LH bank CMP sensor	Short circuit to battery
0370	Reference mark detection	Timing reference high resolution signal A
0411	SAI vacuum solenoid valve	Incorrect flow detected
0412	SAI vacuum solenoid valve drive	Circuit malfunction
0413	SAI vacuum solenoid valve drive	Open circuit
0414	SAI vacuum solenoid valve drive	Short circuit
0418	SAI air injection pump relay	Open circuit
0420	RH bank catalytic converter	Efficiency below threshold/light off too long
0430	LH bank catalytic converter	Efficiency below threshold/light off too long
0442	EVAP system	Minor leak (1.0 mm or less)
0443	Purge valve drive	Circuit malfunction
0444	Purge valve drive	Open circuit
0445	Purge valve drive	Short circuit to battery or ground
0455	EVAP system	Major leak (more than 1.0 mm)
0456	EVAP system	Minor leak (0.5 mm or less)
0461	Fuel tank level signal	Range/Performance problem
0462	Fuel tank level signal	Short circuit to ground
0463	Fuel tank level signal	Short circuit to battery
0464	Fuel tank level signal	Circuit intermittent
0491	SAI system	Malfunction on RH bank
0492	SAI system	Malfunction on LH bank
0500	Vehicle speed signal	Signal implausible
0501	Rough road detection vehicle speed signal	Intermittent, erratic or high

P Code No.	Component/Signal	Fault Description
0503	Rough road detection vehicle speed signal	Range/Performance
0512	Comfort start	Request circuit malfunction
0530	A/C refrigerant pressure sensor	Signal fault
0532	A/C refrigerant pressure sensor	Short circuit to ground
0533	A/C refrigerant pressure sensor	Short circuit to battery
0561	Battery voltage monitor	System voltage unstable
0562	Battery voltage monitor	System voltage low
0563	Battery voltage monitor	System voltage high
0571	Brake lights switch	Cruise control/brake switch circuit A
0604	ECM self test	RAM error
0605	ECM self test	ROM error
0606	ECM self test	Processor fault
0615	Comfort start relay drive	Open circuit
0616	Comfort start relay drive	Short circuit to ground
0617	Comfort start relay drive	Short circuit to battery
0634	ECU internal temperature	ECU temperature high
0650	MIL output drive	Open circuit, or short circuit to ground or battery
0660	Manifold valve output drive	Control circuit malfunction
0661	Manifold valve output drive	Open circuit or short circuit to ground
0662	Manifold valve output drive	Short circuit to battery
0691	Engine cooling fan control	Short circuit to ground
0692	Engine cooling fan control	Short circuit to battery
0693	Engine cooling fan control	Circuit intermittent
0704	A/C compressor clutch switch	Input circuit malfunction
1000	DMTL pump motor drive	Intermittent or short circuit to ground or battery
1102	Throttle position to mass air flow plausibility not active	Air mass too small
1103	Throttle position to mass air flow plausibility not active	Air mass too large
1117	Thermostat monitoring sensor	Short circuit to ground
1118	Thermostat monitoring sensor	Open circuit or short circuit to battery
1120	APP sensor	Implausible signals
1121	APP sensor 1	Range/ Performance problem
1122	APP sensor 1	Short circuit to ground
1123	APP sensor 1	Short circuit to battery
1129	HO2S	Swapped sensors (LH to RH)

P Code No.	Component/Signal	Fault Description
1161	RH bank lambda control	Adaption per ignition too small
1162	RH bank lambda control	Adaption per ignition too large
1163	LH bank lambda control	Adaption per ignition too small
1164	LH bank lambda control	Adaption per ignition too large
1170	RH bank front HO2S signal	Fuel trim malfunction
1171	RH bank lambda control	Adaption over time too large
1172	RH bank lambda control	Adaption over time too small
1173	LH bank front HO2S signal	Fuel trim malfunction
1174	LH bank lambda control	Adaption over time too large
1175	LH bank lambda control	Adaption over time too small
1221	APP sensor 2	Range/ Performance problem
1222	APP sensor 2	Short circuit to ground
1223	APP sensor 2	Short circuit to battery
1300	Misfire detection	Catalyst damaging misfire
1301	Misfire detection	Multiple cylinder misfire
1327	RH bank knock sensor 2	Short circuit to ground
1328	RH bank knock sensor 2	Short circuit to battery
1332	LH bank knock sensor 4	Short circuit to ground
1333	LH bank knock sensor 4	Short circuit to battery
1413	SAI air injection pump relay	Short circuit to ground
1414	SAI air injection pump relay	Short circuit to battery
1450	DMTL pump motor	Reference current above limit
1451	DMTL pump motor	Reference current below limit
1452	DMTL pump motor	Reference current unstable
1453	DMTL pump motor	Changeover valve stuck
1454	DMTL changeover valve drive	Short circuit to battery
1455	DMTL changeover valve drive	Short circuit to ground
1456	DMTL changeover valve drive	Open circuit
1481	DMTL heater output drive	Signal intermittent
1482	DMTL heater output drive	Open circuit or short circuit to ground
1483	DMTL heater output drive	Short circuit to battery
1488	DMTL pump motor drive	Open circuit
1489	DMTL pump motor drive	Short circuit to ground
1490	DMTL pump motor drive	Short circuit to battery
1522	Plausibility MSR intervention	No activity
1523	RH bank VCC solenoid valve	Short circuit to ground
1524	RH bank VCC solenoid valve	Short circuit to battery
1525	RH bank VCC solenoid valve	Open circuit
1526	LH bank VCC solenoid valve	Open circuit

P Code No.	Component/Signal	Fault Description
1527	LH bank VCC solenoid valve	Short circuit to ground
1528	LH bank VCC solenoid valve	Short circuit to battery
1614	Electric thermostat heater drive	Open circuit
1615	Electric thermostat heater drive	Short circuit to ground
1616	Electric thermostat heater drive	Short circuit to battery
1619	5V reference voltage	Internal reference voltage error
1620	Comfort start input	Engine crank signal error (request while engine running)
1621	Serial link with immobilisation ECU	Timed out
1623	Serial link with immobilisation ECU	Exchange code in EEPROM failure
1624	Serial link with immobilisation ECU	EEPROM read/write failure
1626	ECM, throttle monitoring/ self test	Engine torque monitoring problem
1630	ECM, throttle monitoring/ self test	Throttle position control deviation
1631	Throttle drive	Motor power stage fault
1632	ECM, throttle monitoring/ self test	'Limp home' position not adapted
1633	ECM, throttle monitoring/ self test	Throttle position control band stuck short
1634	ECM, throttle monitoring/ self test	Throttle position control band stuck long
1635	ECM, throttle monitoring/ self test	Control gain adaption error
1638	ECM, throttle monitoring/ self test	Throttle control range not learned
1639	ECM, throttle monitoring/ self test	Throttle motor spring test failed
1645	CAN bus link with ABS ECU	Timed out
1646	CAN bus link with EAT ECU	Timed out
1647	CAN bus link with instrument pack	Timed out
1651	CAN bus link with transfer box ECU	Timed out
1659	ECM self test	Torque monitor error
1660	ECM self test	Limp home monitor error
1666	Serial link with immobilisation ECU	Message parity bit fault (wrong code)
1672	Serial link with immobilisation ECU	Exchange code implausible
1673	Serial link with immobilisation ECU	No start code programmed
1674	Serial link with immobilisation ECU	Message fault
1693	Serial link with immobilisation ECU	False manipulation of start code by tester interface
1694	Serial link with immobilisation ECU	Start code corrupted
1700	Transfer box ECU	Implausible signal
1709	CAN bus link with transfer box ECU	Message information error

Drive Cycles
TestBook/T4 drive cycles are as follows:

Drive cycle A

7 Switch on the ignition for 30 seconds.

8 Ensure engine coolant temperature is less than 60 °C (140 °F).

9 Start the engine and allow to idle for 2 minutes.

10 Connect TestBook/T4 and check for fault codes.

Drive cycle B

11 Switch ignition on for 30 seconds.

12 Ensure engine coolant temperature is less than 60 °C (140 °F).

13 Start the engine and allow to idle for 2 minutes.

14 Perform 2 light accelerations, i.e. 0 to 35 mph (56 km/h) with light pedal pressure.

15 Perform 2 medium accelerations, i.e. 0 to 45 mph (72 km/h) with moderate pedal pressure.

16 Perform 2 hard accelerations, i.e. 0 to 55 mph (88 km/h) with heavy pedal pressure.

17 Allow engine to idle for 2 minutes.

18 Connect TestBook/T4 and, with the engine still running, check for fault codes.

Drive cycle C

19 Switch ignition on for 30 seconds.

20 Ensure engine coolant temperature is less than 60 °C (140 °F).

21 Start the engine and allow to idle for 2 minutes.

22 Perform 2 light accelerations, i.e. 0 to 35 mph (56 km/h) with light pedal pressure.

23 Perform 2 medium accelerations, i.e. 0 to 45 mph (72 km/h) with moderate pedal pressure.

24 Perform 2 hard accelerations, i.e. 0 to 55 mph (88 km/h) with heavy pedal pressure.

25 Cruise at 60 mph (96 km/h) for 8 minutes.

26 Cruise at 50 mph (80 km/h) for 3 minutes.

27 Allow engine to idle for 3 minutes.

28 Connect TestBook/T4 and, with the engine still running, check for fault codes.

The following areas have an associated readiness test which must be flagged as complete, before a problem resolution can be verified:

- Catalytic converter fault.
- Evaporative loss system fault.
- HO2S fault.
- HO2S heater fault.

When carrying out drive cycle C to determine a fault in any of the above areas, select the readiness test icon to verify that the test has been flagged as complete.

Drive cycle D

29 Switch ignition on for 30 seconds.

30 Ensure engine coolant temperature is less than 35 °C (95 °F).

31 Start the engine and allow to idle for 2 minutes.

32 Perform 2 light accelerations, i.e. 0 to 35 mph (56 km/h) with light pedal pressure.

33 Perform 2 medium accelerations, i.e. 0 to 45 mph (72 km/h) with moderate pedal pressure.

34 Perform 2 hard accelerations, i.e. 0 to 55 mph (88 km/h) with heavy pedal pressure.

35 Cruise at 60 mph (96 km/h) for 5 minutes.

36 Cruise at 50 mph (80 km/h) for 5 minutes.

37 Cruise at 35 mph (56 km/h) for 5 minutes.

38 Allow engine to idle for 2 minutes.

39 Connect TestBook/T4 and check for fault codes.

Drive cycle E

40 Ensure fuel tank is at least a quarter full.

41 Carry out drive cycle A.

42 Switch off ignition.

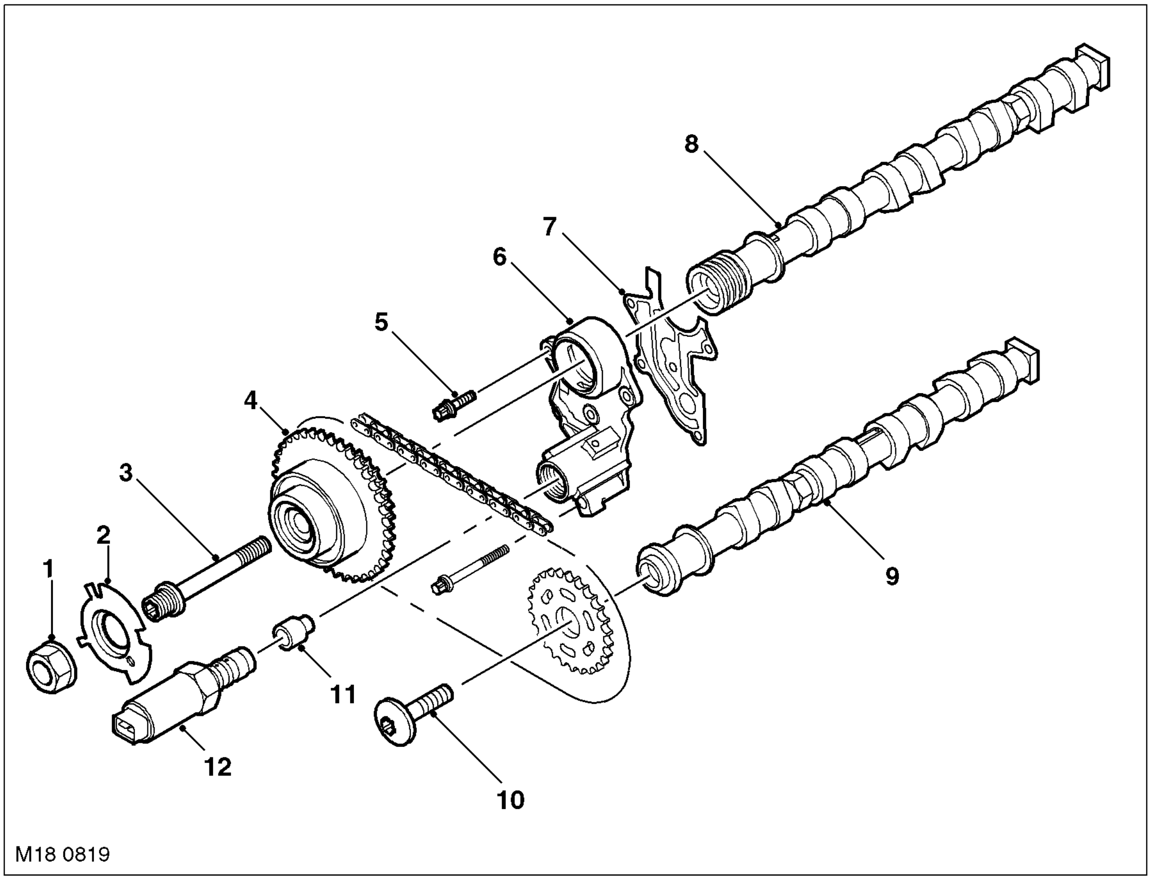
43 Leave vehicle undisturbed for 20 minutes.

44 Switch on ignition.

45 Connect TestBook/T4 and check for fault codes.

VCC System

Variable Camshaft Control Components



1	Locking nut	7	Oil distribution flange gasket
2	Impulse wheel	8	Inlet camshaft
3	Camshaft to sprocket retaining screw	9	Exhaust camshaft
4	VCC transmission unit	10	Drive train gear retaining bolt
5	Bolt	11	Check valve
6	Oil distribution flange	12	VCC solenoid valve

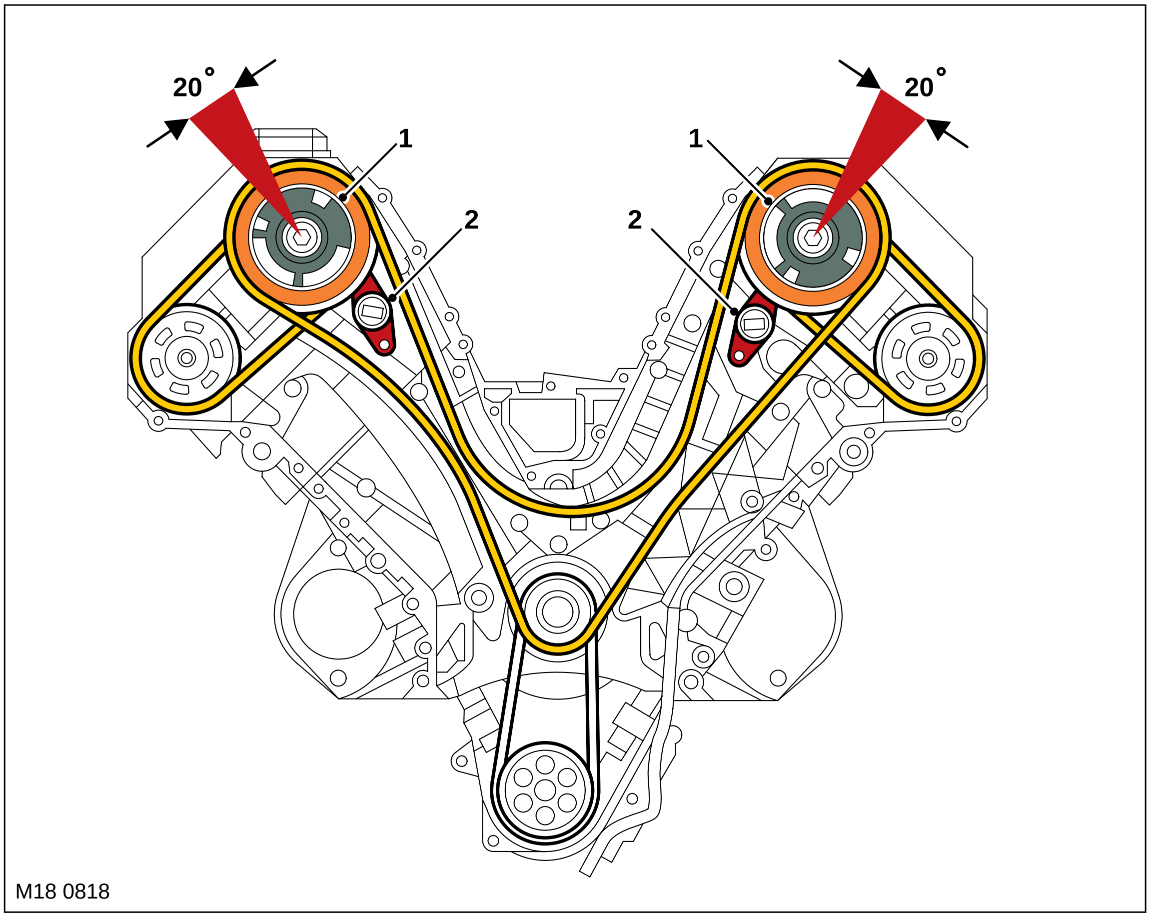
Introduction

The variable intake valve timing system is known as Variable Camshaft Control (VCC).

The VCC system is a new system providing stepless VCC functionality on each intake camshaft. The system is continuously variable within its range of adjustment providing optimized camshaft positioning for all engine operating conditions.

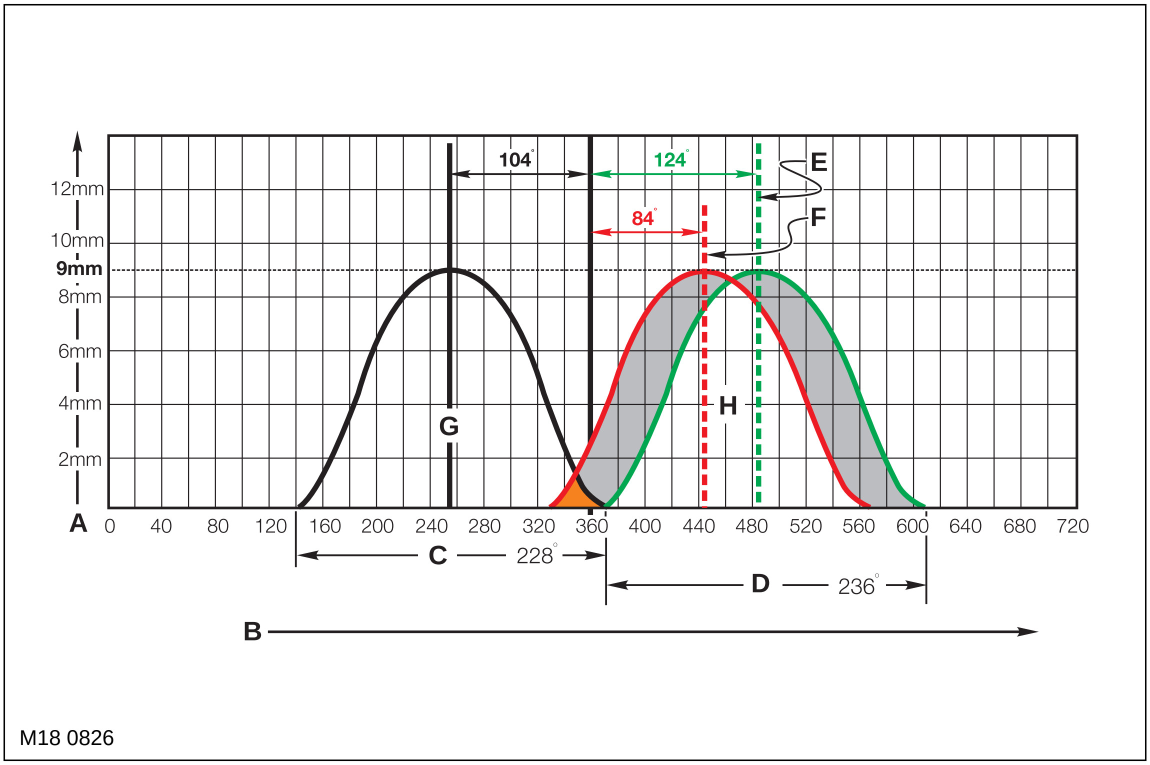
While the engine is running, both intake camshafts are continuously adjusted to their optimum positions. This enhances engine performance and reduces exhaust emissions.

Both camshafts are adjusted simultaneously within 20° (maximum) of the camshafts rotational axis.



1 VCC transmission unit 2 VCC control solenoid valve

This equates to a maximum span of 40° crankshaft rotation. The camshaft spread angles for both banks are as follows.



A	Valve lift	E	Default retard
B	Crankshaft rotation	F	Maximum retard
C	Open duration 228°	G	Exhaust valve
D	Open duration 236°	H	Intake valve

The design of a camshaft for a non adjustable valve timing system is limited to the required overall performance of the engine.

An intake camshaft with an advanced (early) profile will provide a higher performing power curve at a lower engine speed. But at idle speed the advanced position will create a large area of intake/exhaust overlap that causes a rough, unstable idle.

An intake camshaft with a retarded (late) profile will provide a very smooth, stable idle but will lack the cylinder filling dynamics needed for performance characteristics at mid range engine speeds.

The ability to adjust the valve timing improves the engines power dynamics and reduces exhaust emissions by optimizing the camshaft angle for all ranges of engine operation. VCC provides the following benefits:

- Increased torque at lower to mid range engine speeds without a loss of power in the upper range engine speeds
- Increased fuel economy due to optimized valve timing angles
- Reduction of exhaust emissions due to optimized valve overlap
- Smoother idle quality due to optimized valve overlap.

Variable Camshaft Control Electronic Control
The following describes the electronic control of the VCC system.

Electronic Control
The engine control module is responsible for activating a VCC variable position solenoid valve based on EMS program mapping. The activation parameters are influenced by the following input signals:

- Engine speed
- Load (intake air mass)
- Engine temperature
- Camshaft position.

Mechanical Control
The position of the solenoid valve directs the hydraulic flow of engine oil. The controlled oil flow acts on the mechanical components of VCC system to position the camshaft.

The hydraulic engine oil flow is directed through advance or retard activation oil ports by the VCC solenoid. Each port exits into a sealed chamber on the opposite sides of a control piston.

In its default position the oil flow is directed to the rear surface of the piston. This pulls the helical gear forward and maintains the retarded valve timing position.

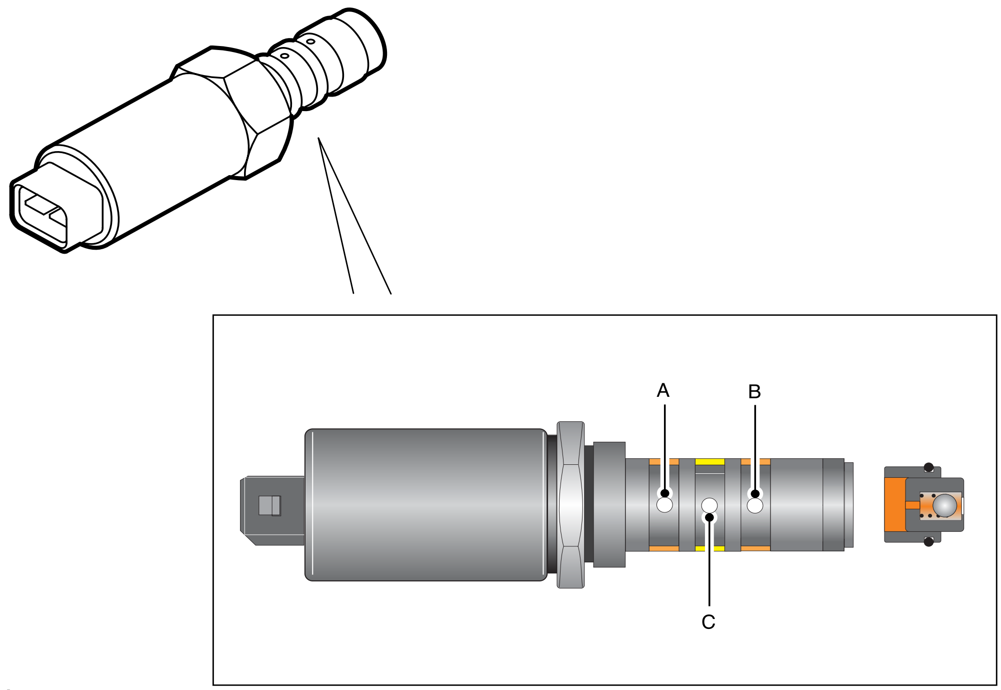
When the oil flow is directed to the front surface of the piston, the oil pushes the helical gear in the opposite direction which rotates the matched helical gearing connected to the camshaft.

The angled teeth of the helical gears cause the pushing movement to be converted into a rotational movement. The rotational movement is added to the turning of the camshaft providing the variable camshaft positioning.

System Components
The VCC components include the following for each cylinder bank:

- Cylinder heads with oil ports for VCC
- VCC transmission with sprockets
- Oil distribution flange
- Oil check valve
- PWM controlled solenoid valve
- Camshaft position impulse wheel.

Control Solenoid and Check Valve



M18 0812

A Advance B Retard C Vent

The VCC solenoid is a two wire, pulse width modulated, oil pressure control valve. The valve has four ports;

A check valve is positioned forward of the solenoid in the cylinder head oil gallery. The check valve maintains an oil supply in the VCC transmission and oil circuits after the engine is turned off. This prevents the possibility of piston movement (noise) within the VCC transmission system on the next engine start.

VCC Transmission

The primary and secondary timing chain sprockets are integrated with the VCC transmission. The transmission is a self contained unit.

The adjustment of the camshaft occurs inside the transmission, controlled oil pressure then moves the piston axially.

The helical gear cut of the piston acts on the helical gears on the inside surface of the transmission and rotates the camshaft to the specific advanced or retarded angle position.

Three electrical pin contacts are located on the front surface to verify the default maximum retard position using an ohmmeter. This is required during assembly and adjustment. (see service notes further on).

Oil Distribution Flanges:

The oil distribution flanges are bolted to the front surface of each cylinder head. They provide a mounting location for the VCC solenoids as well as the advance-retard oil ports from the solenoids to the intake camshafts.

Camshafts
Each intake camshaft has two oil ports separated by three sealing rings on their forward ends.

The ports direct pressurized oil from the oil distribution flange to the inner workings of the VCC transmission.

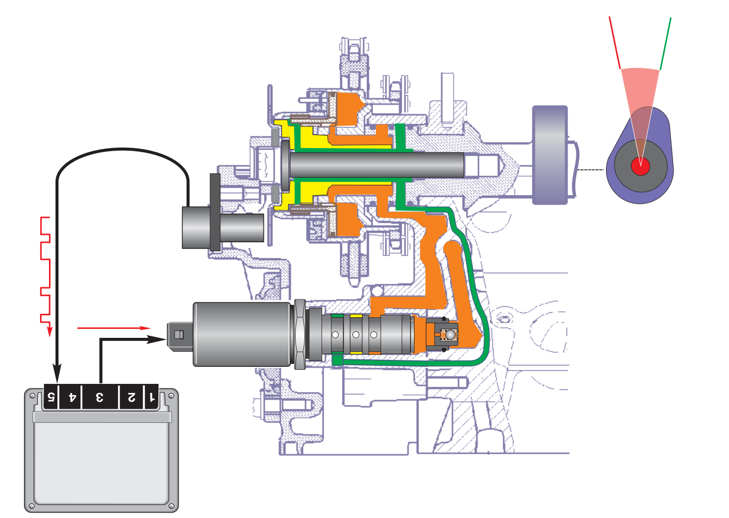
Each camshaft has REVERSE threaded bores in their centres for the attachment of the timing chain sprockets on the exhaust cams and the VCC transmissions for each intake camshaft as shown.

Camshaft Position Impulse Wheels:
The camshaft position impulse wheels provide camshaft position status to the engine control module via the camshaft position sensors. The asymmetrical placement of the sensor wheel pulse plates provides the engine control module with cylinder specific position ID in conjunction with crankshaft position.

VCC Control
As the engine camshafts are rotated by the primary and secondary timing chains, the ECM activates the VCC solenoids via a PWM (pulse width modulated) ground signal based on a program map. The program is influenced by engine speed, load, and engine temperature.

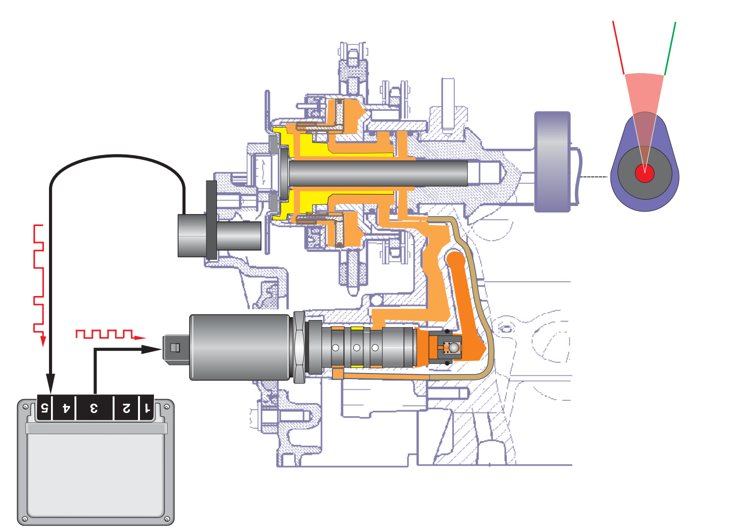
In its inactive or default position, the valves direct 100% engine oil pressure flow to achieve maximum “retard” VCC positioning

Maximum Retard Position


M18 0811

As the Pulse Width Modulation (PWM) increases on the control signal, the valve progressively opens the advance oil port and proportionately closes the retarded oil port.

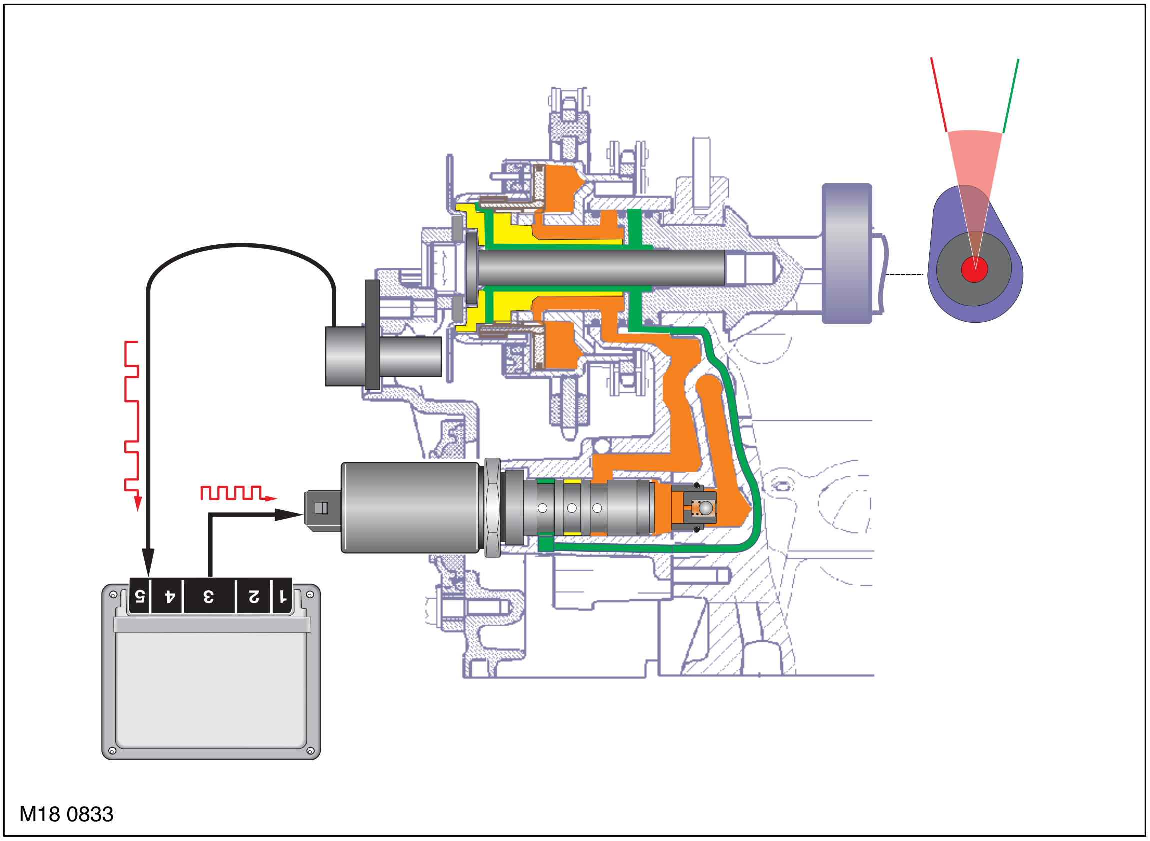
Mid Position


M18 0832

Oil pressure pushes the piston toward the advance position. Simultaneously the oil pressure on the retarded side (rear) of the piston is decreased and directed to the vent port in the solenoid valve and drains into the cylinder head.

At maximum PWM control, 100% oil flow is directed to the front surface of the piston pushing it rearward to maximum advance.

Maximum Advance Position



Varying the pulse width (on time) of the solenoids control signals proportionately regulates the oil pressures on each side of the pistons to achieve the desired VCC advance angle.

VCC Timing Procedures

Always refer to RAVE for complete Valve Timing Procedures. The valve timing adjustment requires the setting of the VCC transmissions to their maximum retard positions with an ohmmeter and attaching the camshaft gears to each camshaft with single reverse threaded bolts.

The process is as follows:

1. After locking the crankshaft at TDC, the camshaft alignment tools are placed on the square blocks on the rear of the camshafts locking them in place
2. The exhaust camshaft sprockets and VCC transmission units with timing chains are placed onto their respective camshafts
3. The exhaust camshaft sprockets and VCC transmissions are secured to the camshafts with their respective single, reverse threaded bolt. Finger tighten only at this point. Install the chain tensioner into the timing chain case and tension the chain
4. Connect an ohmmeter across two of the three pin contacts on the front edge of one of the VCC transmissions. Twist the inner hub of transmission to the left (counter clock- size). Make sure the ohmmeter indicates closed circuit. This verifies that the transmission is in

the default maximum retard position

5 Using an open end wrench on the camshaft to hold it in place, torque the VCC transmission centre bolt to specification.

Camshaft Impulse Wheel Position Tools

The camshaft impulse wheels require a special tool set to position them correctly prior to tightening the retaining nuts.

The impulse wheels are identical for each cylinder bank. The alignment hole in each wheel must align with the tools alignment pin. Therefore the tools are different and must be used specifically for their bank.

The tool rests on the upper edge of the cylinder head and is held in place by the timing case bolts.

Refer to the relevant RAVE section for complete information.

VCC Solenoid Replacement

Refer to the appropriate RAVE section for complete solenoid replacement procedure.

The solenoids are threaded into the oil distribution flanges through a small opening in the upper timing case covers.

VCC Transmission Retard Position Set Up Tools

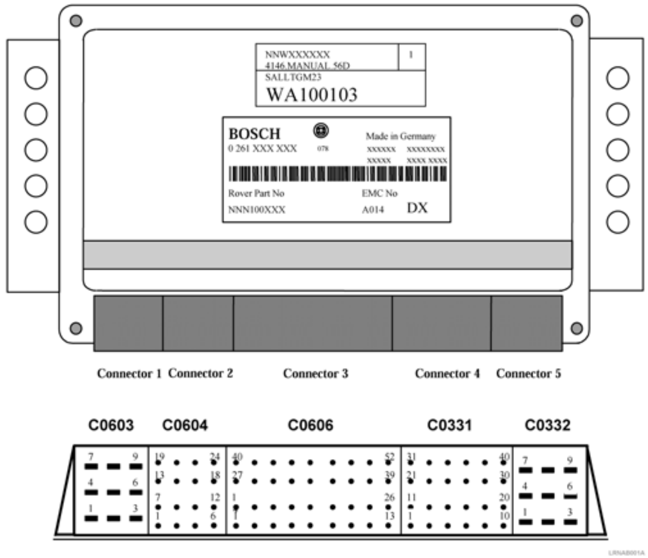
A special tool (see RAVE for correct tool number) is used to rotate the transmission to the full retard position when checking the piston position with an ohmmeter. This tool engages the inner hub of the transmission provides an easy method of twisting it to the left for the ohmmeter test.

Diagnostics

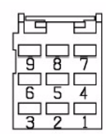
The VCC is fully compatible with the diagnostic software providing specific fault codes and test modules. Additionally, diagnostic requests section provides status of the PWM of the VCC solenoids and camshaft position feedback via the camshaft position sensors. The Service Functions section of the TestBook/T4 also provides a VCC system test.

Connector Pinouts

ME7.2 ECU Pin Out Tables

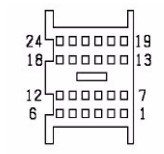


Connector 1
Connector C0603



Pin Number	Wire Color	Circuit Description	Circuit Status
1-01			
1-02			
1-03			
1-04	N	Ground	
1-05	N	Injector ground	
1-06	N	Ground	
1-07	R	Permanent battery supply	
1-08	RU	Switched battery supply (via main relay)	
1-09			

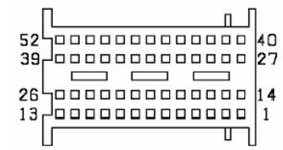
Connector 2
Connector C0604



Pin Number	Wire Color	Circuit Description	Circuit Status
2-01	NW	Rear HO2S heater drive 2	12 – 0V Switching
2-02			
2-03	YN	CAN ‘low’ signal	
2-04	YB	CAN ‘high’ signal	
2-05			
2-06			
2-07	NU	Rear HO2S heater drive 1	12 – 0V Switching
2-08	YW	Rear HO2S signal ground 2	0V
2-09	Y	Front HO2S signal ground 1	0V
2-10	YR	Front HO2S signal ground 2	0V
2-11	YU	Rear HO2S signal ground 1	0V
2-12			
2-13	NR	Front HO2S heater drive 2	12 – 0V Switching
2-14	BW	Rear HO2S signal 2	.2 - .8V Steady *
2-15	B	Front HO2S signal 1	.2 - .8V Switching *
2-16	BR	Front HO2S signal 2	.2 - .8V Switching *
2-17	BU	Rear HO2S signal 1	.2 - .8V Steady *
2-18			
2-19	N	Front HO2S heater drive 1	12 – 0V Switching
2-20			
2-21			
2-22			
2-23	N	Main power relay drive (EMS main relay)	
2-24			

* Note: The signal circuits are held at .5V by ECM when the HO2S's are not switching.

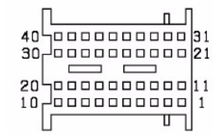
Connector 3
Connector C0606



Pin Number	Wire Color	Circuit Description	Circuit Status
3-01	NY	Cylinder 2 (Injector 8)	
3-02	NG	Cylinder 3 (Injector 6)	
3-03	N	Purge valve drive	
3-04			
3-05			
3-06	N	Ground	
3-07	RG	5V reference supply to HFM	
3-08	NR	Throttle position signal input 2	4.5 - .5V Closed – WOT
3-09	B	Air flow meter signal ground	
3-10	N	Throttle sensor reference voltage supply	
3-11			
3-12	BG	Starter motor feedback	12V Cranking
3-13	U	Generator charge signal	Batt + Charging
3-14	NR	Cylinder 7 (Injector 7)	
3-15	NS	Cylinder 6 (Injector 5)	
3-16	GS	VCC drive 2	12 – 0V Switching
3-17			
3-18			
3-19	W	Camshaft sensor input signal 2	12 – 0V Switching
3-20	Y	Camshaft sensor input signal 1	12 – 0V Switching
3-21	NO	Water temperature signal ground	
3-22	YG	Water temperature signal input	
3-23	Y	Air flow meter signal input	
3-24	P	Throttle position signal input 1	.5 – 4.5 Closed - WOT
3-25	U	Throttle position signal ground	

Pin Number	Wire Color	Circuit Description	Circuit Status
3-26			
3-27	NP	Cylinder 8 (Injector 4)	
3-28	O	Cylinder 5 (Injector 2)	
3-29	GU	VCC drive 1	12 – 0V Switching
3-30			
3-31	NW	Electrically controlled thermostat drive	
3-32	Y	Crankshaft sensor signal input A	
3-33		Electronic ground	
3-34	YU	Air temperature signal input (from HFM)	
3-35	N	Knock sensor ground (cylinders 3 & 4)	
3-36	B	Knock sensor signal (cylinders 3 & 4)	
3-37	B	Knock sensor signal (cylinders 7 & 8)	
3-38	N	Knock sensor ground (cylinders 7 & 8)	
3-39			
3-40	NU	Cylinder 4 (Injector 3)	
3-41	NW	Cylinder 1 (Injector 1)	
3-42	W	Throttle position actuator 1	12 – 0V PWM @ 2K Hz
3-43	R	Throttle position actuator 2	12V
3-44			
3-45	N	Crankshaft sensor signal ground	
3-46	B	Crankshaft sensor signal input B	
3-47			
3-48	N	Knock sensor ground (cylinders 1 & 2)	
3-49	B	Knock sensor signal (cylinders 1 & 2)	
3-50	B	Knock sensor signal (cylinders 5 & 6)	
3-51	N	Knock sensor ground (cylinders 5 & 6)	
3-52	UY	Secondary air valve solenoid drive	

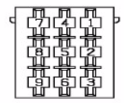
Connector 4
Connector C0331



Pin Number	Wire Color	Circuit Description	Circuit Status
4-01	U	Instrument pack generator warning lamp	
4-02	BG	Instrument pack engine cranking signal	
4-03	NU	Secondary air pump relay drive	
4-04	BG	Condensor fan drive (via power control ECU)	
4-05			
4-06	BY	Ignition switch crank position input	
4-07	NG	Pedal position sensor 1 signal ground	
4-08	W	Pedal position sensor 1 signal input	
4-09	Y	Pedal position sensor 1 reference supply	
4-10	BP	Fuel pump relay drive	
4-11			
4-12	UG	Pedal position sensor 2 signal ground	
4-13	WG	Pedal position sensor 2 signal input	
4-14	YG	Pedal position sensor 2 reference supply	
4-15		Ground	
4-16			
4-17	B	Engine speed signal output (to diagnostic connector)	0 –12V Pulse, engine running
4-18	S	DM-TL heater drive	
4-19	SP	Instrument pack	

Pin Number	Wire Color	Circuit Description	Circuit Status
4-20	BG	DM-TL motor drive	
4-21	SN	Light Control Module	
4-22	YG	Vehicle speed signal input	
4-23			
4-24	UR	Brake pedal sensor input	11V with pedal pressed
4-25			
4-26	GB	Ignition switch position 2 input	
4-27	YB	Steering wheel switches input (cruise switch input)	
4-28	NS	Brake pedal sensor input	12V with pedal pressed
4-29	BG	Air con compressor disengage output (to ATC ECU)	
4-30	NU	DM-TL changeover valve drive	
4-31			
4-32	WPY	K-Diagnostic Line	
4-33	BP	Immobilisation signal	
4-34			
4-35			
4-36	YB	CAN ‘high’ signal	
4-37	YN	CAN ‘low’ signal	
4-38	US	Thermostat monitoring coolant temperature sensor ground	
4-39	BS	Thermostat monitoring coolant temperature sensor signal	
4-40	YN	Starter motor relay drive	Batt + when cranking

Connector 5
Connector C0332



Pin Number	Wire Color	Circuit Description	Circuit Status
5-01	BY	Ignition coil 7 (Cylinder 7)	
5-02	BU	Ignition coil 8 (Cylinder 4)	
5-03	BR	Ignition coil 2 (Cylinder 8)	
5-04	BY	Ignition coil 3 (Cylinder 6)	
5-05	N	Ignition ground	
5-06	BW	Ignition coil 1 (Cylinder 1)	
5-07	BU	Ignition coil 4 (Cylinder 3)	
5-08	BW	Ignition coil 5 (Cylinder 2)	
5-09	BR	Ignition coil 6 (Cylinder 5)	

SIEMENS MS43 ENGINE MANAGEMENT SYSTEM

System Description

The KV6 engine is fitted with a Siemens MS43 Engine Management System (EMS), which is an adaptive system that maintains engine performance at the optimum level throughout the life of the engine.

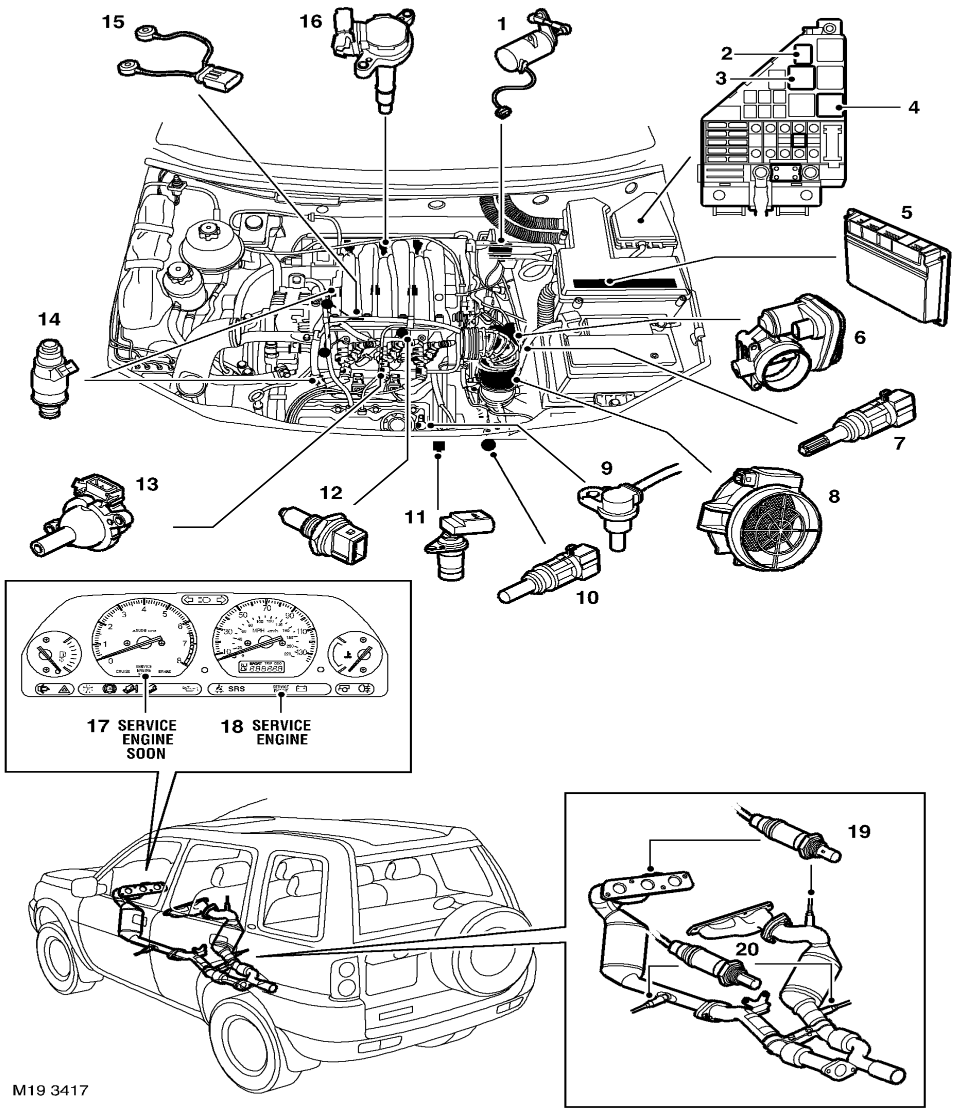
The EMS consists of an Engine Control Module (ECM) that uses inputs from engine sensors and from other vehicle systems to continuously monitor driver demand and the current status of the engine. From the inputs the ECM calculates the Air Fuel Ratio (AFR) and ignition timing required to match engine operation with driver demand, then outputs the necessary control signals to the electric throttle, fuel injectors and ignition coils. The ECM also outputs control signals to operate the:

- Air Conditioning (A/C) compressor.
- Engine cooling fans.
- Evaporative emissions (EVAP) purge valve and Diagnostic Module for Tank Leakage (DMTL).
- Fuel pump.
- Variable Intake System (VIS).

The ECM also interfaces with the:

- Immobilization ECU, for re-mobilization of the engine fuel supply.
- Cruise control interface ECU, to operate cruise control.
- Electronic Automatic Transmission (EAT) ECU, to assist with control of the gearbox.

Engine Management System Component Location



1	Accelerator Pedal Position sensor	11	Crankshaft Position sensor
2	A/C compressor clutch relay	12	Engine Coolant Temperature sensor
3	Main relay	13	LH bank ignition coil (x 3)
4	Fuel pump relay	14	Fuel injector (x 6)
5	ECM	15	Knock sensors
6	Electric throttle	16	RH bank ignition coil (x 3)
7	Intake Air Temperature sensor	17	Malfunction Indicator Lamp (emissions faults)
8	Mass Air Flow sensor	18	Service Engine lamp (non-emissions faults)
9	Camshaft Position sensor	19	Upstream HO2S (x 2)
10	Thermostat monitoring sensor	20	Downstream HO2S (x 2)

Sensor inputs and engine performance are monitored by the ECM, which illuminates the SERVICE ENGINE SOON (MIL) and/or the SERVICE ENGINE warning lamps in the instrument pack if a fault is detected.

As part of the security system's immobilization function, a vehicle specific security code is programmed into the ECM and the immobilization ECU during production. The ECM cannot function unless it is connected to an immobilization ECU with the same code. In service, replacement ECM are supplied uncoded and must be programmed using TestBook/T4 to learn the vehicle security code from the immobilization ECU.

A 'flash' Electronic Erasable Programmable Read Only Memory (EEPROM) allows the ECM to be externally configured, using TestBook/T4, with market specific or new information.

The ECM memorizes the position of the crankshaft and the camshaft when the engine stops. During cranking on the subsequent start the ECM confirms their positions from sensor inputs before initiating fuel injection and ignition.

To achieve optimum performance the ECM is able to 'learn' the individual characteristics of an engine and adjust the fuelling calculations to suit. This capability is known as adaptive fuelling. Adaptive fuelling also allows the ECM to compensate for wear in engine components and to compensate for the tolerance variations of the engine sensors.

If the ECM suffers an internal failure, such as a breakdown of the processor or driver circuits, there is no back up system or limp home capability. If a sensor circuit fails to supply an input, where possible the ECM adopts a substitute or default value, which enables the engine to function, although with reduced performance in some cases.

Engine Starting

When the ignition switch is in position II a power feed is connected from the ignition switch to the ECM. The ECM then initiates 'wake up' routines and energizes the main and fuel pump relays.

When the engine cranks, provided a valid mobilization signal is received from the immobilization ECU, the ECM initiates throttle control, fuelling and ignition to start and maintain control of the engine as necessary to meet driver demand. If no mobilization code is received from the immobilization ECU, or the code is invalid, the ECM inhibits fuel injection and ignition to prevent the engine from starting.

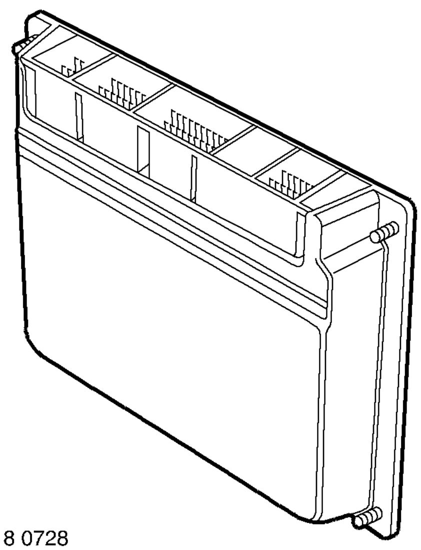
The electrical circuit from the fuel pump relay to the fuel pump is routed through the fuel cut-off inertia switch, located below the E-box in the engine compartment. In the event of a collision the switch breaks the circuit to prevent further fuel being delivered to the engine. The switch is reset by pressing down the centre of the rubber cover on the top of the switch.

During the start sequence, the ECM also illuminates the MIL, as a bulb check. While the ignition switch is in position II the MIL is continuously illuminated. The MIL is extinguished when the ignition switch turns to position III and the engine starts.

Engine Stopping
When the ignition switch is turned to position I, the ECM switches off the ignition coils, injectors and fuel pump to stop the engine. The ECM continues to energize the main relay until the power down functions are completed. Power down functions include the fuel tank leak check (6 minutes maximum), engine cooling (5 minutes maximum) and memorising data for the next start up. If neither a fuel tank lank check nor engine cooling are required, the power down process takes approximately 10 seconds.

When the power down process is completed, the ECM de-energizes the main relay and enters a low power mode. In the low power mode, maximum quiescent drain is 0.5 mA.

ECM



M18 0728

The ECM is located in the engine compartment, in the E-box. Five connectors provide the interface between the ECM and the vehicle wiring.

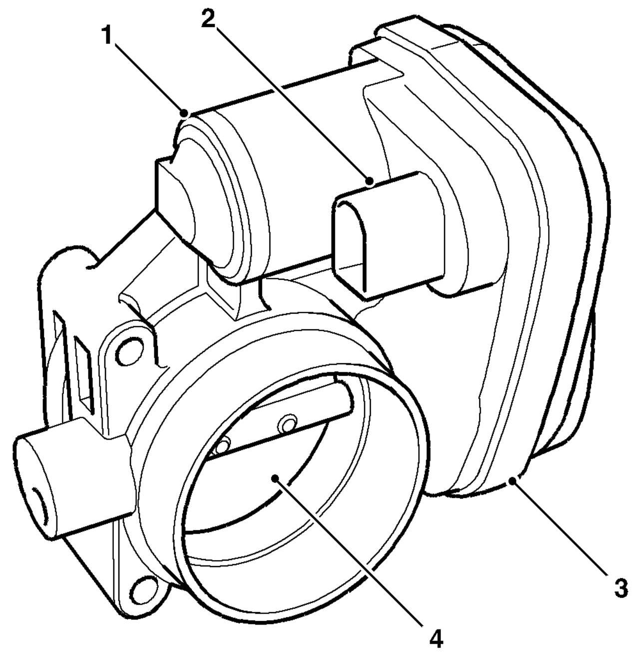
Controller Area Network (CAN) Bus
The ECM is connected to the Anti-lock Braking System (ABS) modulator, EAT ECU and the instrument pack by the CAN bus.

Electric Throttle
The electric throttle controls the air flow into the engine. In addition to the normal engine power control function, the electric throttle allows the cruise control, idle speed control and engine speed limiting functions to be performed without the need for additional hardware.

The electric throttle consists of a throttle body which incorporates a throttle plate driven by a DC motor via reduction gears. A return spring biases the throttle plate in the closed direction. Operation of the DC motor is controlled by the ECM, which outputs two Pulse Width Modulated (PWM) signals to a direction controlled H bridge drive in the motor. To enable closed loop control, the position of the throttle plate is supplied to the ECM by two feedback potentiometers in the throttle body.

The feedback potentiometers have a common 5 volt supply and a common ground connection from the ECM, and produce separate linear signal voltages to the ECM proportional to the position of the throttle plate. The ECM uses the signal from feedback potentiometer 1 as the primary signal of throttle plate position, and the signal from feedback potentiometer 2 for plausibility checks.

- The signal from feedback potentiometer 1 varies between 0.5 volt (0% throttle open) and 4.5 volts (100% throttle open)
- The signal from feedback potentiometer 2 varies between 4.5 volts (0% throttle open) and 0.5 volt (100% throttle open)



M18 0709

1	DC motor	3	Reduction gear/ feedback potentiometer housing
2	Electrical connector	4	Throttle plate

While the ignition is on, the ECM continuously monitors the two feedback potentiometers for short and open circuits and checks the feedback potentiometer signals, against each other and the inputs from the Accelerator Pedal Position (APP) sensor, for plausibility. If a fault is detected in the feedback potentiometer signals or the DC motor, the ECM:

- Stores a related fault code in memory.
- Illuminates the SERVICE ENGINE warning lamp in the instrument pack.
- Adopts a throttle limp home mode or disables throttle control, depending on the nature of the fault.

In the throttle limp home mode the ECM uses the throttle plate to regulate engine speed at 1400 rev/min while the brake pedal is released and idle speed while the brake pedal is pressed. If the ECM disables throttle control, the DC motor is de-energized and the return spring holds the throttle valve closed; the ECM attempts to keep the engine running at idle speed using the ignition timing and fuelling, although the engine is likely to run rough or stall, depending on engine temperature and ambient conditions.

If a plausibility fault between the feedback potentiometer signals is detected, the ECM calculates a virtual throttle plate position from engine mass air flow and compares this to the feedback potentiometer signals:

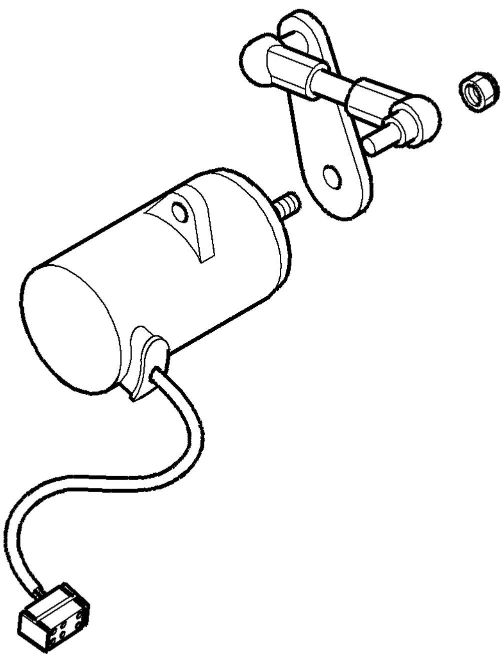
- If one of the feedback potentiometer signals matches the virtual throttle position, the ECM adopts the limp home mode and uses the valid signal to monitor throttle plate position. To ensure safe operation, the ECM continues to use the virtual throttle plate position for plausibility checks with the valid signal.
- If neither of the feedback potentiometer signals is plausible, the ECM disables throttle control.

Engine Sensors

The EMS incorporates the following engine sensors:

- An Accelerator Pedal Position (APP) sensor.
- A Crankshaft Position (CKP) sensor.
- A Camshaft Position (CMP) sensor.
- A Mass Air Flow (MAF) sensor.
- An Intake Air Temperature (IAT) sensor.
- An Engine Coolant Temperature (ECT) sensor.
- A thermostat monitoring sensor.
- Four Heated Oxygen Sensors (HO2S).
- Two knock sensors.

Accelerator Pedal Position (APP) Sensor



M19 3383

The APP sensor enables the ECM to determine the throttle position requested by the driver on the accelerator pedal.

The APP sensor is installed on the pedal box and consists of a twin track potentiometer with wipers driven by a linkage connected to the accelerator pedal. Each potentiometer track has a 5 volt supply and ground connection from the ECM, and produces a linear signal voltage to the ECM proportional to the position of the accelerator pedal. The signal voltage from track 1 of the potentiometer is approximately double that of the signal voltage from track 2.

From the sensor signals, the ECM determines driver demand as a percentage of pedal travel, where 0% is with the pedal released and 100% is with the pedal fully depressed. Driver demand is then used to calculate throttle angle, fuel quantity and ignition timing. The ECM also outputs driver demand on the CAN system, for use by the brake and gearbox control systems.

The ECM stores the signal values that correspond with closed and wide open throttle, and adapts to new values to accommodate component wear or replacement.

The signals from the APP sensor are monitored by the ECM for short and open circuits and plausibility. If a fault is detected, the ECM:

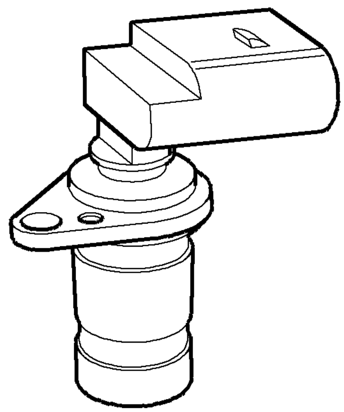
- Stores a related fault code in memory.
- Illuminates the SERVICE ENGINE warning lamp in the instrument pack.
- Inhibits the driver demand message on the CAN bus, which disables the Hill Descent Control (HDC) function of the ABS modulator and reduces the performance of the automatic gearbox (harsh gear changes and loss of kickdown).
- Adopts a sensor limp home mode or the throttle limp home mode (see Electric Throttle,

above), depending on the nature of the fault.

The ECM adopts the sensor limp home mode if a plausibility fault between the two sensor signals is detected. In the sensor limp home mode, the ECM:

- Uses the signal with the lowest throttle demand, which causes a slower throttle response and reduces the maximum throttle position.
- Sets the throttle plate and fuelling to idle when the brake pedal is pressed.

Crankshaft Position Sensor (CKP)



M18 0711

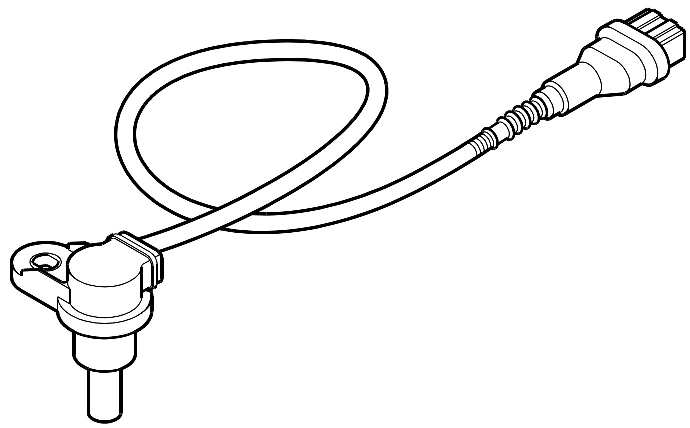
The CKP sensor provides the ECM with a digital signal of the rotational speed and angular position of the crankshaft, for use in ignition timing, fuel injection timing and fuel injection quantity calculations. To determine the exact position of the crankshaft in the engine cycle, the ECM must also use the input from the CMP sensor.

The CKP sensor is mounted on the front of the gearbox housing, in line with the outer circumference of the torque converter. The sensing tip of the CKP sensor is adjacent to a reluctor ring formed in the periphery of the torque converter. The reluctor ring has 58 teeth spaced at 6° intervals. A gap equivalent to two missing teeth, 36° After Top Dead Centre (ATDC) of No. 1 cylinder, provides the ECM with a reference point.

The CKP sensor operates using the Hall effect principle. A permanent magnet inside the sensor applies a magnetic flux to a semiconductor, which receives a power supply from the main relay. The output voltage from the semiconductor is fed to the ECM. As the gaps between the poles of the reluctor ring pass the sensor tip the magnetic flux is interrupted, causing a fluctuation of the output voltage and producing a digital signal.

If the CKP sensor fails the ECM immediately stops the engine.

Camshaft Position Sensor (CMP)



M19 2837A

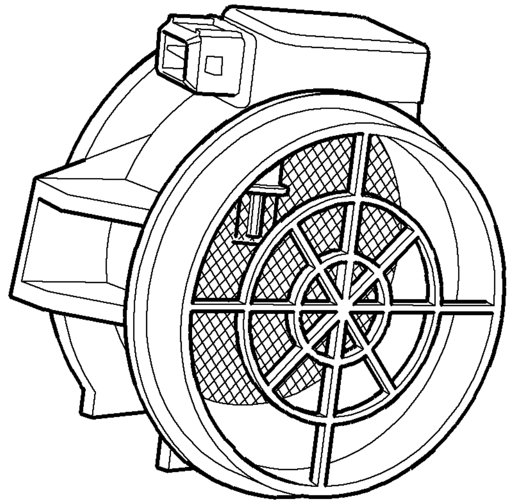
The CMP sensor provides a signal which enables the ECM to determine the position of the camshaft relative to the crankshaft. This allows the ECM to synchronize fuel injection for start and run conditions.

The CMP sensor is located on the camshaft cover of the LH (front) cylinder bank, at the opposite end to the camshaft drive, in line with a 'half moon' reluctor on the exhaust camshaft. The reluctor is a single tooth which extends around 180° of the camshaft circumference.

The CMP sensor operates using the Hall effect principle. A permanent magnet inside the sensor applies a magnetic flux to a semiconductor, which receives a power supply from the main relay. The output voltage from the semiconductor is fed to the ECM. As the gap in the reluctor passes the sensor tip, the magnetic flux is interrupted, causing a fluctuation of the output voltage and producing a digital signal.

If the CMP sensor fails during engine running, the engine will run normally until turned off, but will not restart until the CMP sensor input is restored.

Mass Air Flow Sensor (MAF)



M18 0712

The MAF sensor provides a signal which the ECM uses for engine load calculations.

The MAF sensor is a hot film type, and is located in the intake system between the air filter housing and the throttle body.

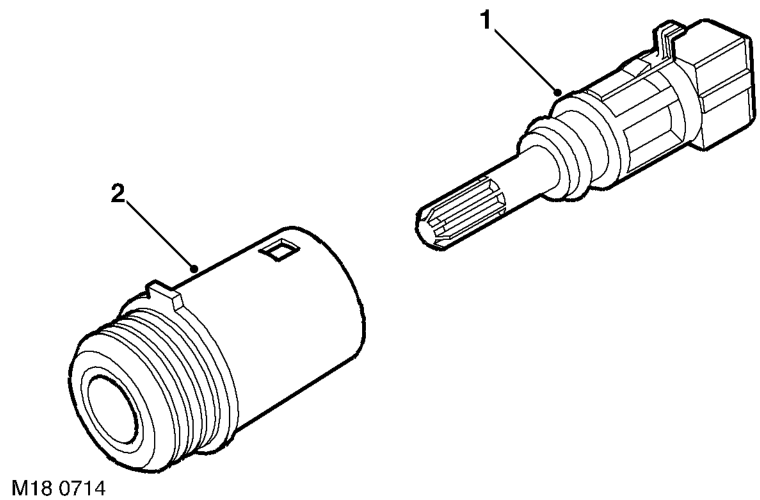
A closed-loop control circuit in the MAF sensor maintains a thick film resistor at a constant 200 °C (392 °F) above ambient temperature. The current required to maintain the temperature of the thick film resistor, against the cooling effect of the air flowing through the sensor, provides a precise, non-linear, measure of the air mass entering the engine.

The MAF sensor receives a battery voltage power supply and generates an output signal to the ECM, between 0 and 5 volts, which is proportional to the air mass drawn into the engine.

In the event of a MAF sensor signal failure, the following symptoms may be apparent:

- During driving engine speed may dip before recovering.
- Difficult starting.
- Engine stalls after starting.
- Delayed throttle response.
- Reduced engine performance.

Intake Air Temperature Sensor (IAT)



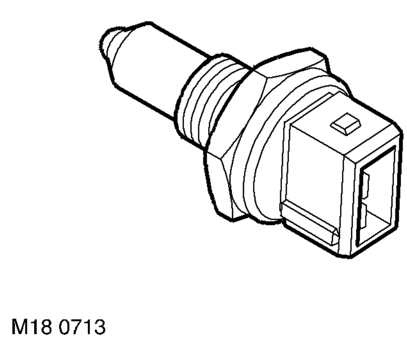
1 Sensor
2 Housing

The IAT sensor provides a signal that enables the ECM to adjust ignition timing and fuelling quantity according to the intake air temperature, thus ensuring optimum performance, driveability and emissions.

The IAT sensor is a Negative Temperature Coefficient (NTC) thermistor located in a plastic housing installed in the intake duct between the MAF sensor and the throttle body. The sensor is a push fit in the housing and sealed by an 'O' ring. A clip is integrated into the sensor to secure it in the housing.

If the input from the IAT sensor fails, the vehicle will continue to run. The ECM will substitute a default value using the information from the speed/load map to run the engine, but adaptive fuelling will be disabled.

Engine Coolant Temperature Sensor (ECT)



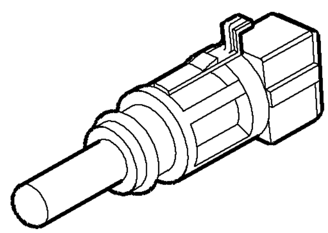
The ECT sensor provides the ECM with a signal voltage that varies with coolant temperature, to enable the ECM to adapt the fuelling quantity and ignition timing with changes of engine temperature.

The ECT sensor is located between the cylinder banks, between cylinders 3 and 6.

The ECT sensor consists of an encapsulated Negative Temperature Coefficient (NTC) thermistor which is in contact with the engine coolant. As the coolant temperature increases the resistance across the sensor decreases and as the coolant temperature decreases the sensor resistance increases. To determine the coolant temperature, the ECM supplies the sensor with a regulated 5 volts power supply and monitors the return signal voltage. The ECM also outputs the coolant temperature on the CAN system, to operate the coolant temperature gauge.

If the ECT signal is missing, or outside the acceptable range, the ECM assumes a default temperature reflecting a part warm engine condition. This enables the engine to function, but with reduced driveability when cold and increased emissions, resulting from an over rich mixture, when the engine reaches normal operating temperature. The ECM will also switch on the cooling fans to prevent the engine and gearbox from overheating.

Thermostat Monitoring Sensor

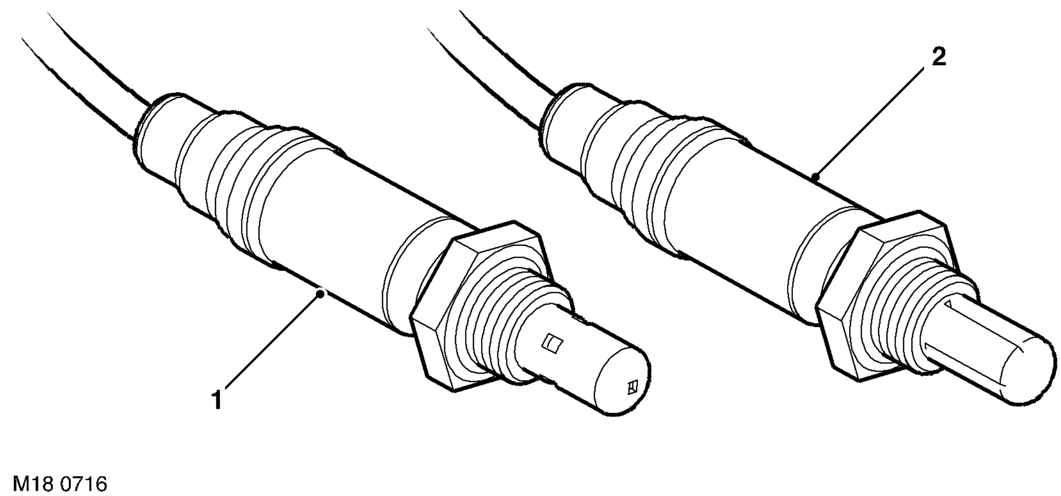


M18 0715

The input from the thermostat monitoring sensor is used by the ECM to monitor the operation of the cooling system thermostat and to control the operation of the engine cooling fans.

The thermostat monitoring sensor is a NTC thermistor installed in a plastic 'T' piece in the radiator bottom hose. The sensor is a push fit in the T piece and sealed by an 'O' ring. A clip is integrated into the sensor to secure it in the T piece.

Heated Oxygen Sensor (HO2S)



1 Downstream HO2S
2 Upstream HO2S

The EMS has four HO2S:

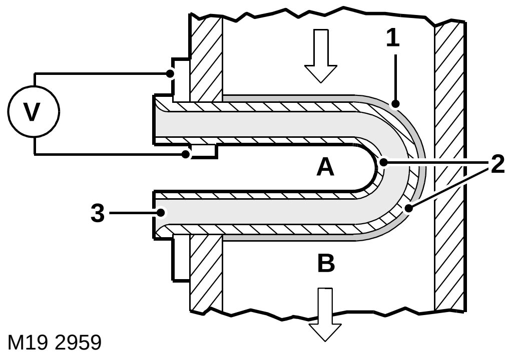
- One upstream of each catalytic converter, identified as LH and RH front HO2S.
- One downstream of each catalytic converter, identified as LH and RH rear HO2S.

The LH and RH front HO2S enable the ECM to determine the AFR of the mixture being burned in each cylinder bank of the engine. The LH and RH rear HO2S enable the ECM to monitor the performance of the catalytic converters and the upstream oxygen sensors, and trim fuel.

Each HO2S consists of a sensing element with a protective ceramic coating on the outer surface. The outer surface of the sensing element is exposed to the exhaust gas, and the inner surface is exposed to ambient air. The difference in the oxygen content of the two gases produces an electrical potential difference across the sensing element. With a rich mixture, the low oxygen content in the exhaust gas results in a higher sensor voltage. With a lean mixture, the high oxygen content in the exhaust gas results in a lower sensor voltage.

During closed loop control, the voltage of the two front HO2S switches from less than 0.3 volt to more than 0.5 volt. The voltage switches between limits every two to three seconds. This switching action indicates that the ECM is varying the AFR within the Lambda window tolerance, to maximize the efficiency of the catalytic converters.

Sectioned View of HO2S



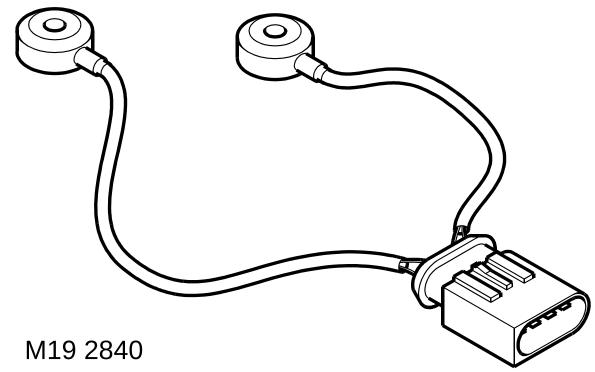
A	Ambient air
B	Exhaust gases
1	Protective ceramic coating
2	Electrodes
3	Zirconium oxide

The material of the sensing element only becomes active at a temperature of approximately 300 °C (570 °F). To shorten the warm up time and minimize the emissions from a cold start and low load conditions, each HO2S contains a heating element powered by a supply from the main relay. The earth paths for the heating elements are controlled by the ECM. On start up, the current supplied to the heating elements is increased gradually to prevent sudden heating from damaging the ceramic coating. After the initial warm up period the ECM modulates the earth of the heating elements, from a map of engine speed against mass air flow, to maintain the HO2S at the optimum operating temperature.

The nominal resistance of the heating elements is 6 Ω at 20 °C (68 °F).

If an HO2S fails, the ECM illuminates the MIL. If a front HO2S fails the ECM also adopts open loop fuelling and catalytic converter monitoring is disabled. If a rear HO2S fails, catalytic converter and upstream HO2S monitoring is disabled.

Knock Sensors



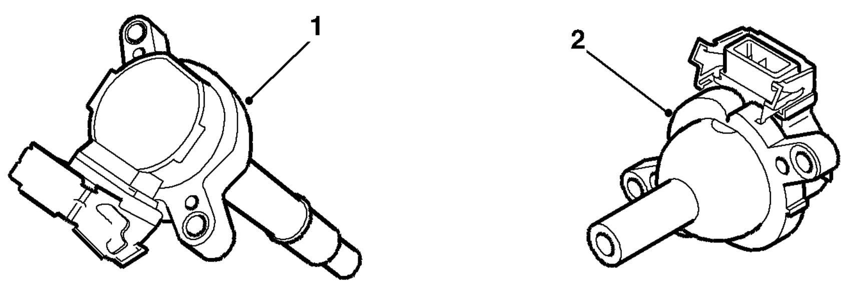
M19 2840

The knock sensors enable the ECM to operate the engine at the limits of ignition advance, for optimum efficiency, without combustion knock damaging the engine. The ECM uses two knock sensors, one for each cylinder bank, located between the cylinder banks on cylinders 3 and 4.

The knock sensors consist of piezo ceramic crystals that oscillate to create a voltage signal. During combustion knock, the frequency of crystal oscillation increases, which alters the signal output to the ECM. The ECM compares the signal to known signal profiles in its memory. If the onset of combustion knock is detected the ECM retards the ignition timing for a number of cycles. When the combustion knock stops, the ignition timing is gradually advanced to the original setting.

The knock sensor leads are of different lengths to prevent incorrect installation.

Ignition Coils



M19 3384

1 RH bank ignition coil

2 LH bank ignition coil

The ECM uses a separate ignition coil for each spark plug. The ignition coils for the LH bank spark plugs are positioned on the forward tracts of the Intake manifold and connected to the spark plugs with High Tension (HT) leads. The ignition coils for the RH bank spark plugs are of the plug top design, secured to the camshaft cover with 2 screws.

Each ignition coil has 3 connections in addition to the spark plug connection; an ignition feed from the main relay, an earth wire for the secondary winding and a primary winding negative (switch) terminal. The switch terminal of each ignition coil is connected to a separate pin on the ECM to allow independent switching. The ignition coils are charged whenever the ECM supplies an earth path to the primary winding negative terminal. The duration of the charge time is held relatively constant by the ECM for all engine speeds. Consequently, the dwell period increases with engine speed. This type of system, referred to as Constant Energy, allows the use of low impedance coils with faster charge times and higher outputs.

The ECM calculates the dwell period using inputs from the following:

- Battery voltage (main relay).
- CKP sensor.
- Ignition coil primary current (internal ECM connection).

The spark is produced when the ECM breaks the primary winding circuit. This causes the magnetic flux around the primary winding to collapse, inducing HT energy in the secondary coil, which can only pass to earth by bridging the air gap of the spark plug.

Ignition related faults are monitored indirectly by the misfire detection function.

Ignition Timing

The ECM calculates ignition timing using inputs from the following sensors:

- CKP sensor.
- MAF sensor.
- Knock sensors.
- TP sensor (idle only).
- ECT sensor.

At start up and idle the ECM sets ignition timing by referencing the ECT and CKP sensors. Once above idle the ignition timing is controlled according to maps stored in the ECM memory and modified according to additional sensor inputs and any adaptive value stored in memory. The maps keep the ignition timing within a narrow band that gives an acceptable compromize between power output and emission control. The ignition timing advance and retard is controlled by the ECM in order to avoid combustion knock.

Knock Control

The ECM uses active knock control to prevent combustion knock damaging the engine. If the knock sensor inputs indicate the onset of combustion knock, the ECM retards the ignition timing for that particular cylinder by 3°. If the combustion knock indication continues, the ECM further retards the ignition timing, in decrements of 3°, for a maximum of 15° from where the onset of combustion knock was first sensed. When the combustion knock indication stops, the ECM restores the original ignition timing in increments of 0.75°.

To reduce the risk of combustion knock at high intake air temperatures, the ECM retards the ignition timing if the intake air temperature exceeds 55 °C (169 °F). The amount of ignition retard increases with increasing air intake temperature.

Idle Speed Control
The ECM controls the engine idle speed using a combination of fuelling, ignition timing and the electric throttle.

When the engine idle speed fluctuates the ECM initially varies the ignition timing, which produces rapid changes of engine speed. If this fails to correct the idle speed, the ECM also adjusts the electric throttle and fuelling.

Misfire Detection
The ECM uses the CKP sensor input to monitor the engine for misfires. As the combustion charge in each cylinder is ignited the crankshaft accelerates, then subsequently decelerates. By monitoring the acceleration/ deceleration pulses of the crankshaft the ECM can detect misfires.

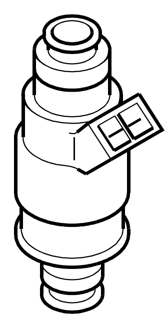
Low fuel level:

When the fuel tank is almost empty there is a risk that air may be drawn into the fuel system, due to fuel 'slosh', causing fuel starvation and misfires. To prevent false misfire faults being logged, the ECM disables misfire detection if it receives a low fuel level message on the CAN bus. Fuel tank content is monitored by the instrument pack, which transmits the low fuel level message if the fuel tank content decreases to less than 15% (8.85 litres; 2.34 US galls).

Rough road disable:

When the vehicle is travelling over a rough road surface the engine crankshaft is subjected to torsional vibrations caused by mechanical feedback from the road surface through the transmission. To prevent misinterpretation of these torsional vibrations as a misfire, the misfire monitor is disabled when a road surface exceeds a roughness limit programmed into the ECM. The roughness of the road is calculated by the ABS modulator, from the four ABS sensor inputs, and transmitted to the ECM on the CAN bus.

Fuel Injectors



M19 2845A

A split stream, air assisted fuel injector is installed for each cylinder. The injectors are located in the Intake manifolds and connected to a common fuel rail assembly.

Each injector contains a pintle type needle valve and a solenoid winding. The needle valve is held closed by a return spring. An integral nozzle shroud contains a ported disc, adjacent to the nozzles. 'O' rings seal the injector in the fuel rail and the Intake manifold.

The solenoid winding of each injector receives a 12 volt supply from the main relay. To inject fuel, the ECM supplies an earth path to the solenoid winding, which energizes and opens the needle valve. When the needle valve opens, the two nozzles direct a spray of atomized fuel onto the back of each Intake valve. Air drawn through the shroud and ported disc improves atomization and directional control of the fuel. The air is supplied from a dedicated port in the intake duct via a plastic tube and tracts formed in the gasket face of the intake manifolds.

Each injector delivers fuel once per engine cycle, during the Intake stroke. The ECM calculates the open time (duty cycle) of the injectors from:

- Engine speed.
- Mass air flow.
- Engine temperature.
- Accelerator pedal position (i.e. driver demand).

The fuel in the fuel rail is maintained at a pressure of 3.5 bar (51 lbf/in^2) by a pressure regulator incorporated into the pump unit in the fuel tank. An accumulator is attached to the fuel rail on the RH Intake manifold to damp out pressure pulses from the pump and ensure that the pressure in the fuel rail is constant (the same component functions as the pressure regulator on vehicles with a return fuel delivery system). The accumulator is connected by a pipe to the Intake manifold from which it receives a vacuum to aid the damping process. A Schraeder valve is installed in the 'fuel return' pipe of the accumulator to allow pressure to be released from the fuel rail and fuel feed pipe prior to maintenance.

The nominal resistance of the injector solenoid winding is 13 - 16 Ω at 20 °C (68 °F).

Evaporative Emissions (EVAP) Purge Valve
The ECM provides a PWM earth path to control the operation of the purge valve. When the ECM is in the open loop fuelling mode the purge valve is kept closed. When the vehicle is moving and in the closed loop fuelling mode the ECM opens the purge valve.

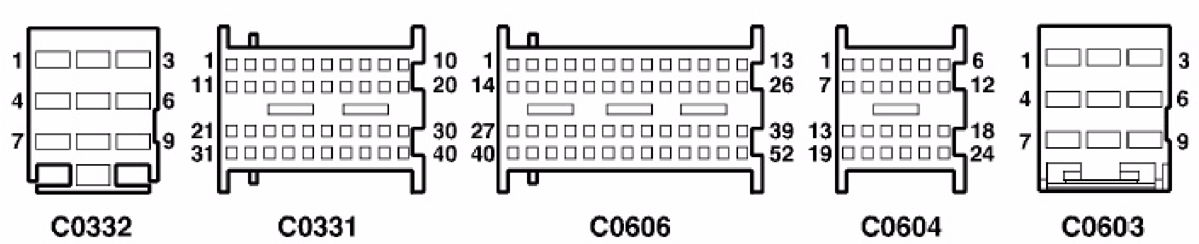
When the purge valve is open fuel vapour is drawn from the EVAP canister into the Intake manifold. The ECM detects the resultant enrichment of the AFR, from the inputs of the front HO2S, and compensates by reducing the duty cycle of the fuel injectors.

Variable Intake System (VIS) Valves
The ECM operates the two VIS valve motors to open and close the VIS valves in a predetermined sequence based on engine speed and throttle opening. Each VIS valve motor has a permanent power feed from the main relay, feedback and signal connections with the ECM, and a permanent earth connection. When the engine starts, the VIS valve motors are both in the valve open position. To close the VIS valves, the ECM applies a power feed to the signal line of the applicable VIS valve motor. To open the VIS valves, the ECM disconnects the power feed from the signal line and the VIS valve motor is closed by the power feed from the main relay.

Warning Lamps
Two warning lamps in the instrument are used to indicate faults with the engine management system. The engine malfunction lamp consists of an amber SERVICE ENGINE legend and is illuminated to indicate the detection of a non emissions related fault. The Malfunction Indicator Lamp (MIL) consists of an amber SERVICE ENGINE SOON legend and is illuminated to indicate the detection of an emissions related fault. The ECM operates the warning lamps, by communicating with the instrument pack on the CAN bus. If a fault that can cause catalytic converter damage is detected, the warning lamps flash. For other faults the warning lamps are continuously illuminated.

Diagnostics
The ECM incorporates On Board Diagnostics (OBD) software that complies with market legislation current at the time of manufacture. During engine operation the ECM performs self test and diagnostic routines to monitor the performance of the engine and the EMS. If a fault is detected the ECM stores a related diagnostic trouble code (also known as a 'P' code) in a non volatile memory and, for most faults, illuminates the engine SERVICE ENGINE and/or the SERVICE ENGINE SOON warning lamps. Codes are retrieved using TestBook/T4, which communicates with the ECM via an ISO 9141 K line connection from the diagnostic socket.

Siemens MS43 ECU Pin Out Tables



Connector C0603

Pin Number	Wire Color	Circuit Description	Circuit Status
1-01	W	Ignition sense	
1-02			
1-03			
1-04	B	Electronic earth	
1-05	B	Injector earth	
1-06	B	Power stage earth	
1-07	NG	Permanent battery supply	
1-08	NK	Main relay power	
1-09	NK	Main relay power	

Connector C0604

Pin Number	Wire Color	Circuit Description	Circuit Status
2-01	UY	LH bank front HO2S heater drive	12 – 0V Switching
2-02			
2-03			
2-04			
2-05			
2-06			
2-07	GY	LH bank rear HO2S heater drive	12 – 0V Switching
2-08			
2-09			
2-10			
2-11			

Pin Number	Wire Color	Circuit Description	Circuit Status
2-12			
2-13	GY	RH bank front HO2S heater drive	12 – 0V Switching
2-14	UN	LH bank front HO2S signal	.2 - .8V Switching *
2-15	GN	RH bank front HO2S signal	.2 - .8V Switching *
2-16	UN	LH bank rear HO2S signal	.2 - .8V Switching *
2-17			
2-18	GN	RH bank rear HO2S signal	.2 - .8V Switching*
2-19	UY	RH bank rear HO2S heater drive	12 – 0V Switching
2-20	BG	LH bank front HO2S earth	
2-21	BG	RH bank front HO2S earth	
2-22	BG	LH bank rear HO2S earth	
2-23	NG	Main relay drive	Active low
2-24	BG	RH bank rear HO2S earth	

* Note: The signal circuits are held at .5V by ECM when the HO2S's are not switching.

Connector C0606

Pin Number	Wire Color	Circuit Description	Circuit Status
3-01	GW	MAF sensor signal	0 – 5V
3-02			
3-03	BS	Brake vacuum enhancer solenoid valve	Batt + in Gear
3-04			
3-05	UG	CMP sensor signal	0 – 5V Square wave
3-06			
3-07	NW	Throttle feedback potentiometer supply	5V
3-08	WU	CKP sensor signal	0 – 5V Square wave
3-09			
3-10	NU	Throttle feedback potentiometer 2 signal	5V @ Closed Throttle
3-11	SB	VIS balance motor drive	Active low

Pin Number	Wire Color	Circuit Description	Circuit Status
3-12			
3-13			
3-14			
3-15			
3-16			
3-17	YW	MAF sensor earth	
3-18	BS	CMP sensor earth	
3-19	NP	Throttle feedback potentiometer 1 signal	0V 2 Closed Throttle
3-20	NG	Throttle feedback potentiometer earth	
3-21	BS	CKP sensor earth	
3-22	OG	IAT sensor signal	
3-23	OS	IAT sensor earth	
3-24	KB	ECT sensor signal	
3-25	KG	ECT sensor earth	
3-26			
3-27			
3-28			
3-29	BO	LH bank knock sensor	
3-30	BK	LH bank knock sensor	
3-31	LGS	RH bank knock sensor	
3-32	BK	RH bank knock sensor	
3-33	Y	Fuel injector 1	
3-34	YU	Fuel injector 3	
3-35	YP	Fuel injector 5	
3-36	YN	Fuel injector 2	
3-37	YG	Fuel injector 6	
3-38	YR	Fuel injector 4	
3-39			
3-40			

Pin Number	Wire Color	Circuit Description	Circuit Status
3-41			
3-42	BO	EVAP purge valve drive	0 –12V PWM
3-43	NB	Throttle motor open drive	0 – 12V PWM
3-44	GW	Throttle motor closed drive	0 – 12V PWM
3-45			
3-46			
3-47			
3-48	B	Knock sensors screen	
3-49	BG	VIS power valves motor drive	Active low
3-50			
3-51	BG	DMTL heater drive	
3-52			

Connector C0331

Pin Number	Wire Color	Circuit Description	Circuit Status
4-01			
4-02			
4-03			
4-04	UW	Engine cooling fan control	0 – 12V PWM
4-05			
4-06			
4-07	RU	APP sensor earth 2	
4-08	YR	APP sensor signal 2	.7 – 3.7V Closed – Open throttle
4-09	RN	APP sensor supply 2	
4-10	BP	Fuel pump relay control	
4-11			
4-12	UR	APP sensor earth 1	
4-13	RY	APP sensor signal 1	.35 – 1.85V Closed – Open throttle
4-14	NR	APP sensor supply 1	

Pin Number	Wire Color	Circuit Description	Circuit Status
4-15			
4-16			
4-17			
4-18			
4-19			
4-20	GR	DMTL pump motor	
4-21	GK	Alternator load sensing	0 – 12V PWM
4-22	WO	Vehicle speed	
4-23	OB	VIS balance valve position feedback	Active high
4-24	PG	Brake pedal sensor input	12V with pedal pressed
4-25			
4-26			
4-27	RG	Cruise control interface MFL signal	
4-28	GR	Brake pedal sensor input	12V with pedal pressed
4-29	UB	Air con compressor clutch relay	
4-30	U	DMTL solenoid valve drive	
4-31			
4-32	K	Diagnostic ISO 9141 K Line	
4-33	YR	Immobilisation signal	0 – 12V Data
4-34	UK	VIS power valves position feedback	Active high
4-35			
4-36	YB	CAN bus ‘high’ signal	
4-37	YN	CAN bus ‘low’ signal	
4-38	GU	Thermostat monitoring sensor earth	
4-39	UG	Thermostat monitoring sensor signal	
4-40			

Connector C0332

Pin Number	Wire Color	Circuit Description	Circuit Status
5-01	BP	Ignition coil 5	
5-02	BW	Ignition coil 3	
5-03	BR	Ignition coil 1	
5-04			
5-05	B	Ignition earth	
5-06	B	Ignition coil earth	
5-07	BY	Ignition coil 4	
5-08	BU	Ignition coil 6	
5-09	BG	Ignition coil 2	

DENSO ENGINE MANAGEMENT

General

The V8 4.2 Liter supercharged engine is controlled by an ECM manufactured by DENSO. The Engine Management System (EMS) controls the following:

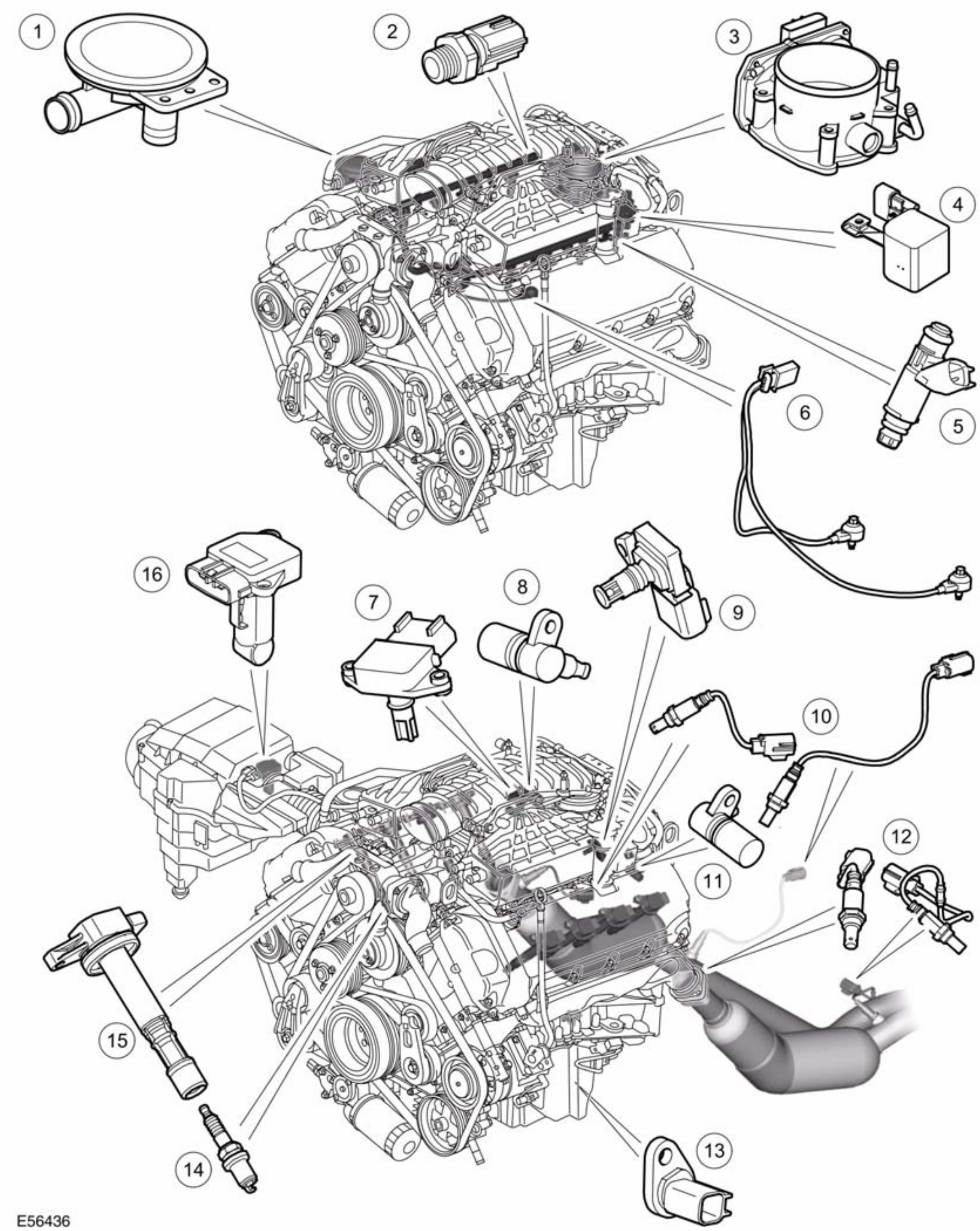
- Engine fueling
- Ignition timing
- Closed loop fueling
- Knock control
- Idle speed control
- Emission control
- OBD
- Interface with the immobilization system
- Speed control

The ECM controls the engine fueling by providing sequential fuel injection to all cylinders. Ignition is controlled by a direct ignition system, provided by eight plug top coils. The ECM is able to detect and correct for ignition knock on each cylinder and adjust the ignition timing for each cylinder to achieve optimum performance.

The ECM uses a torque-based strategy to generate the torque required by the driver and other vehicle control modules. The EMS uses various sensors to determine the torque required from the engine. The EMS also interfaces with other vehicle electronic control modules's, via the CAN bus, to obtain additional information (e.g. road speed from the ABS control module). The EMS processes these signals and decides how much torque to generate. Torque is then generated by using various actuators to supply air, fuel and spark to the engine (electronic throttle, injectors, coils, etc.).

4.2 Liter Electronic Engine Controls

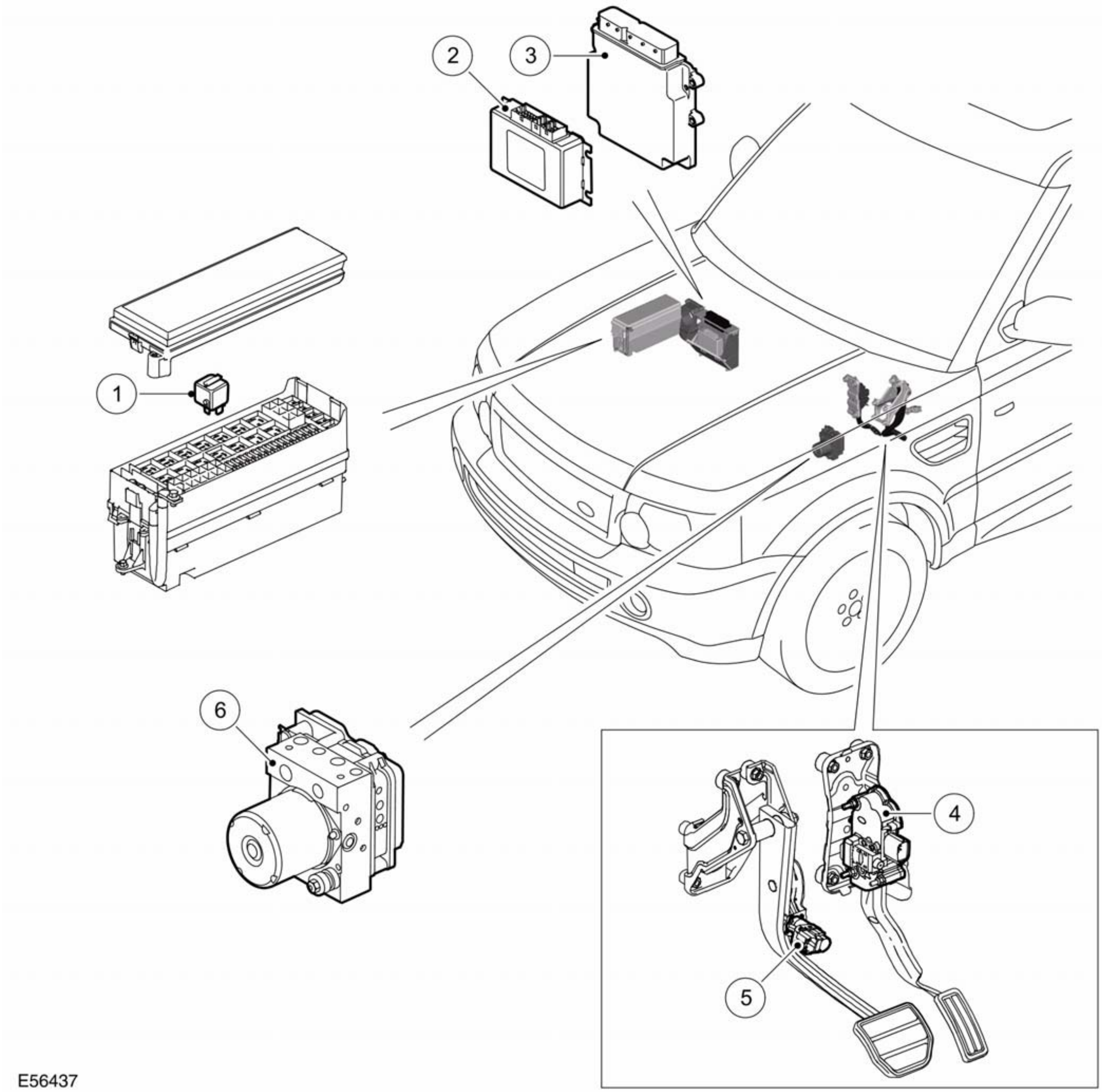
NOTE: Component Location (Sheet 1of 2)



1	PCV valve	7	MAPT sensor	13	CKP sensor
2	Fuel rail temperature sensor	8	CMP sensor	14	Spark plugs
3	Electric throttle	9	MAP sensor	15	Ignition coils
4	RFI capacitor	10	Universal Heated Exhaust Gas Oxygen (UHEGO) sensors	16	MAF/IAT
5	Injectors	11	CMP sensor		
6	Knock sensor	12	Heated Exhaust Gas Oxygen (HEGO) sensors		

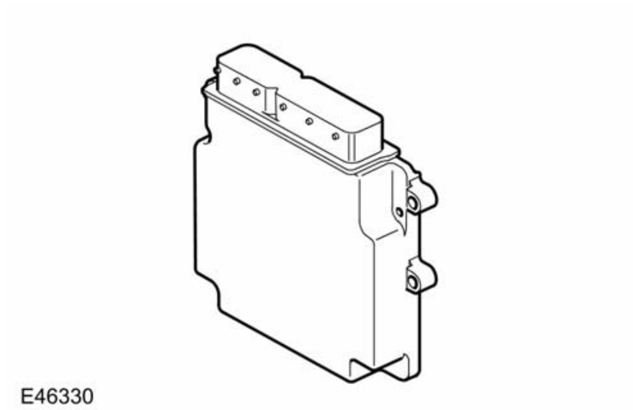
4.2 Liter Electronic Engine Controls

NOTE: Component Location (Sheet 2 of 2)



1	Main relay	3	ECM	5	Brake light switch
2	Transfer box control module	4	APP	6	ABS control module

Engine Control Module (ECM)



The ECMis located in the E-Box in the plenum area on the passenger side of the engine compartment attached to the bulkhead.

System ECM has the following inputs:

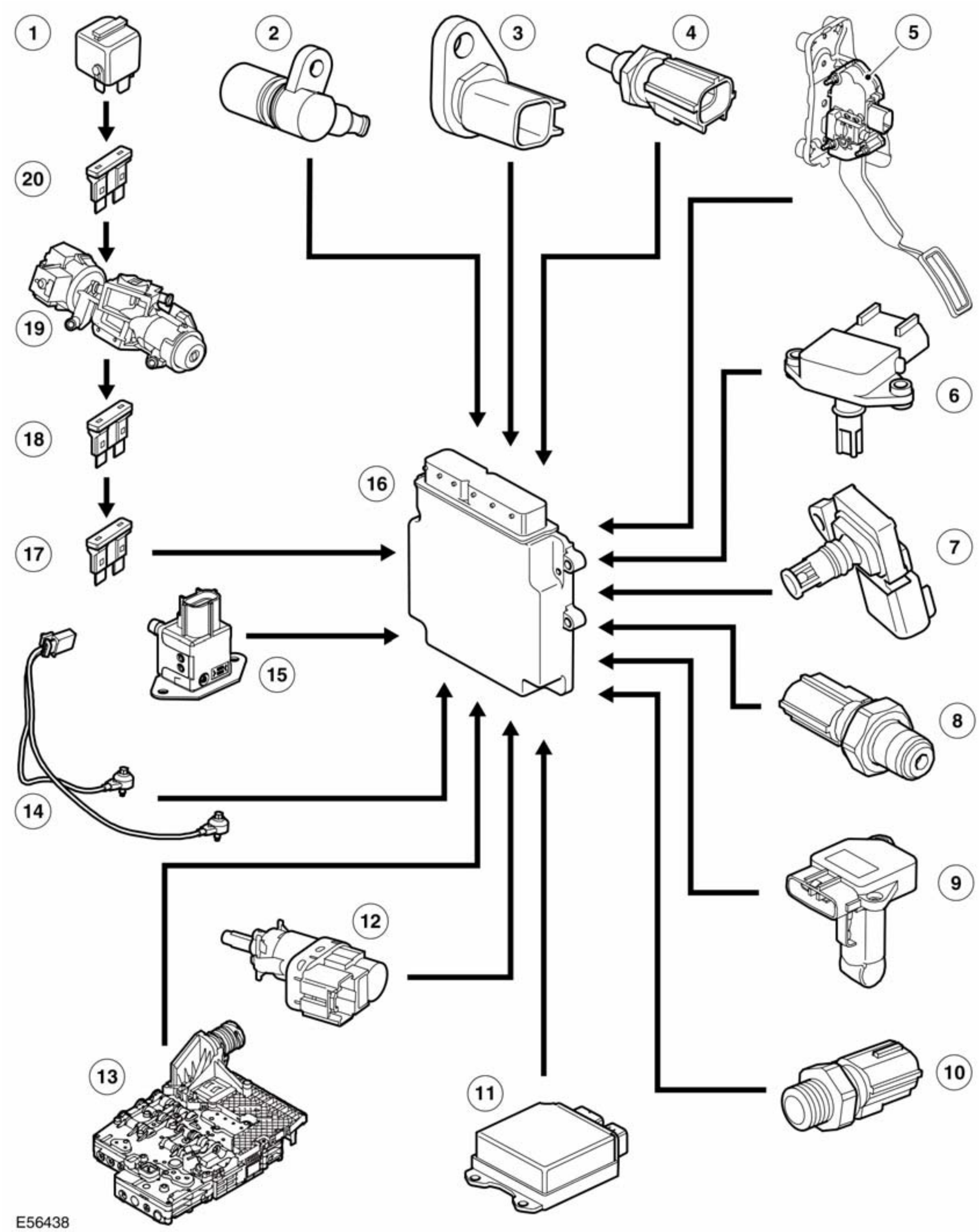
- RCM
- Park/neutral switch
- Ignition coil feedback x2
- Fuel rail temperature
- Fuel rail pressure
- Supercharger inlet pressure
- Mass air flow
- Engine speed
- Camshaft position x2
- Driver demand
- Brake pedal position switch
- Speed control switches
- Generator load
- Oxygen sensors pre catalyst x2
- Oxygen sensors post catalyst x2
- Throttle position
- Cooling fan speed
- Ignition switch position
- Knock sensors x2
- MAP
- Intercooler temperature
- Coolant temperature
- Engine oil temperature

The ECM outputs to the following:

- Throttle Actuator
- Brake vacuum pump relay
- Ignition coils (x8)
- Oxygen sensor heaters (4)
- Fuel injectors (8)
- Purge Valve
- Engine Cooling Fan
- Fuel pump relay
- Starter Relay
- EMS Main Relay
- Viscous Fan Control
- Generator Control
- Diagnostic Module Tank Leakage (DMTL) (NAS Only)
- E box fan
- FPDM

4.2 Liter Electronic Engine Controls-Input Control Diagram (Sheet 1 of 2)

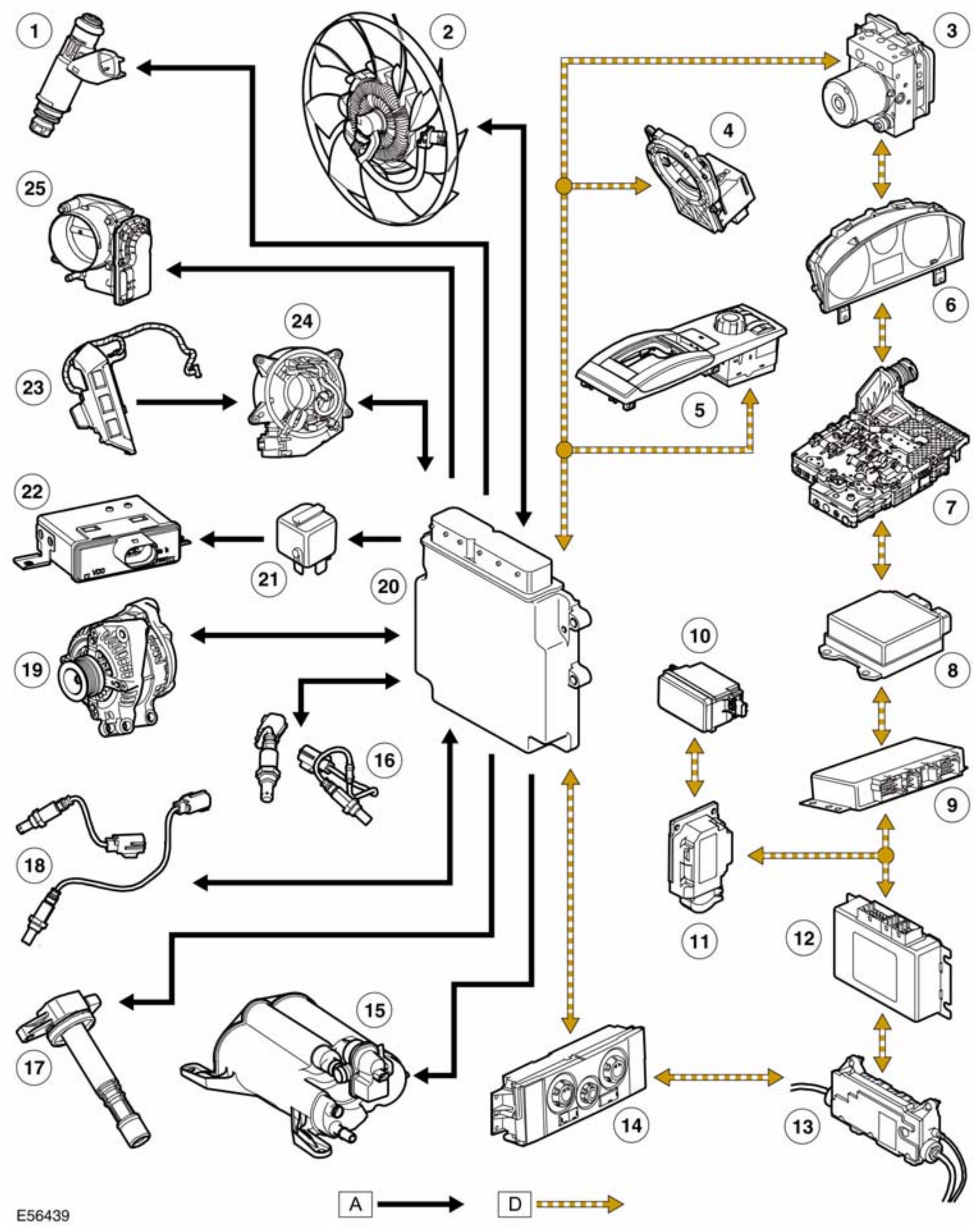
NOTE: Voltage sensor inputs



1	Main relay	8	Engine oil temperature sensor	15	Fuel rail pressure sensor
2	CMP sensor x2	9	MAF/IAT sensor	16	ECM
3	CKP sensor	10	Fuel rail temperature sensor	17	Fuse 27E
4	ECT sensor	11	RCM	18	Fuse 13E
5	APP sensor	12	Brake light switch	19	Ignition switch
6	MAPT sensor	13	Park/ neutral signal from TCM	20	Fuse 10E
7	MAP sensor	14	Knock sensors		

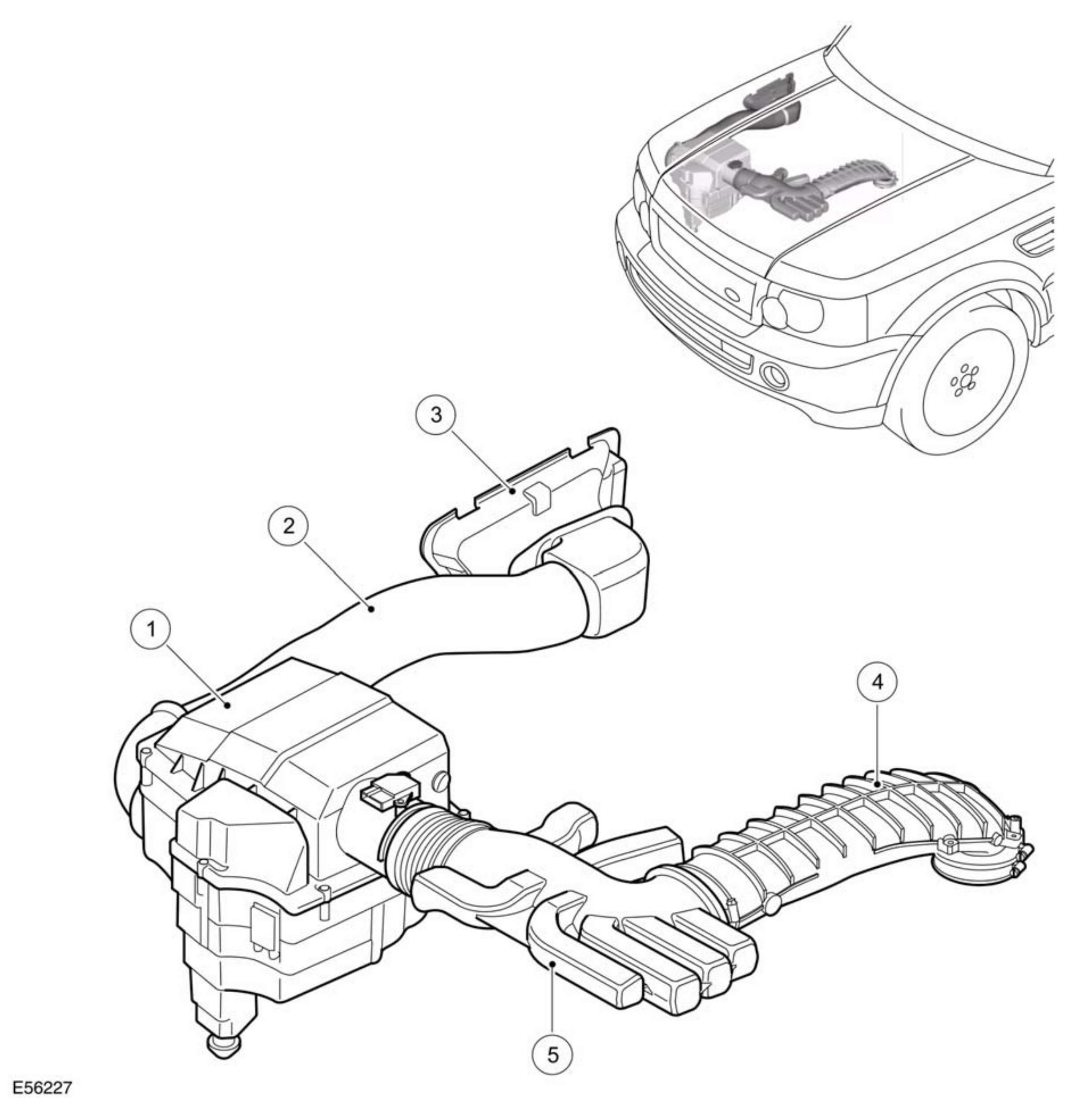
4.2 Liter Electronic Engine Controls-Control Diagram (Sheet 2 of 2)

NOTE: A= Hardwired D= CAN



1	Injectors	10	Adaptive speed control sensor	19	Generator
2	Engine cooling fan control/monitor	11	Adaptive speed control module	20	ECM
3	ABS control module	12	Transfer box control module	21	Fuel pump relay
4	Steering angle sensor	13	Electric park brake control module	22	FPDM
5	Terrain response control module	14	ATC control module	23	Speed control switches
6	Instrument cluster	15	DMTL pump	24	Clock spring
7	TCM	16	UHEGOs	25	Electric throttle
8	RCM	17	Ignition coils		
9	Differential control module	18	HEGOs		

Air Intake System



1	Air filter box	3	Air intake	5	Induction resonator chambers
2	Porous duct	4	Throttle body intake		

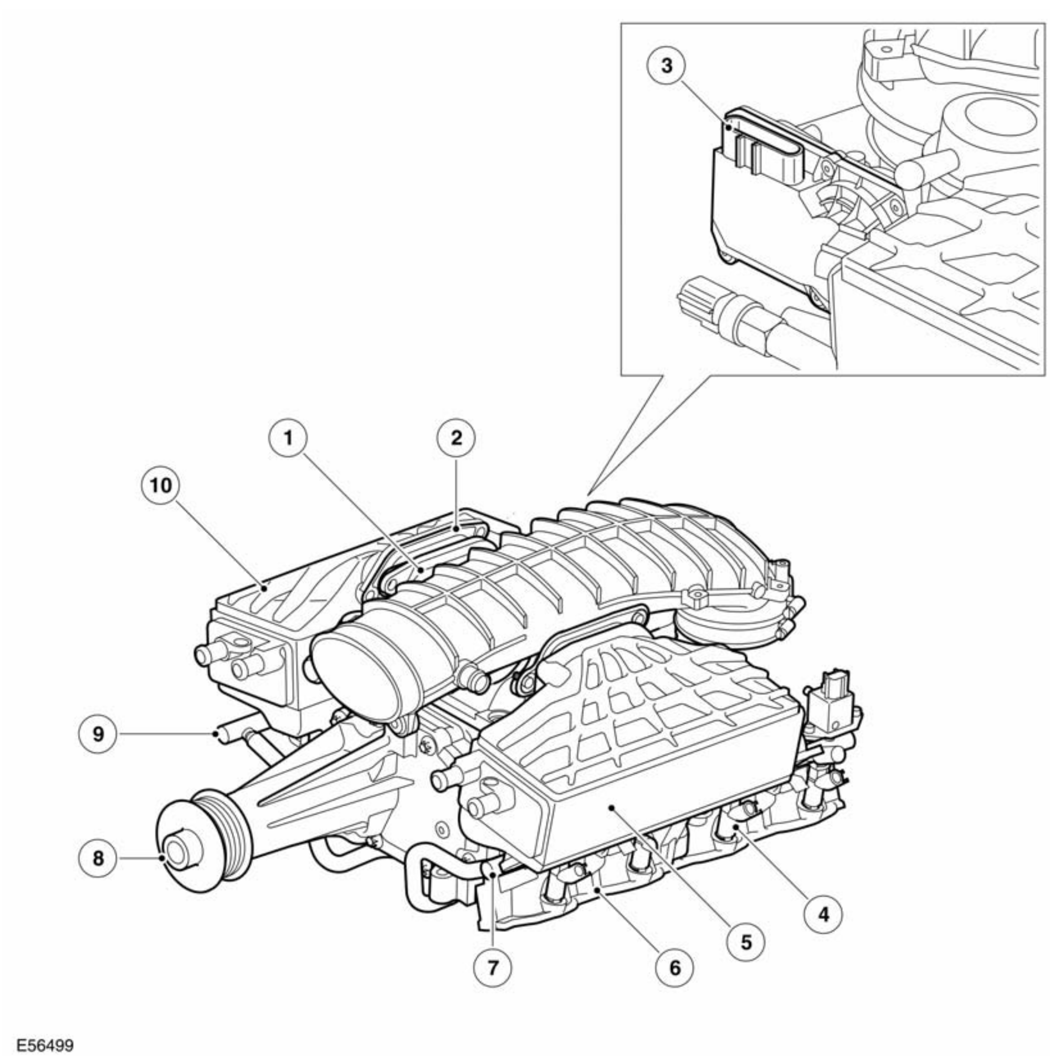
The 4.2 Liter V8 SC engine air intake and distribution system comprises:

- Air filter box
- Air intake
- Porus duct
- Air filter and filter box
- Intake duct
- Electronic throttle.

Air Filter Box
The air filter box is located in the front of the engine bay on the inside of the RH front wing. Air is drawn from the air intake in the wing through a porous duct and into the air filter box. The filter box contains a paper air filter element.

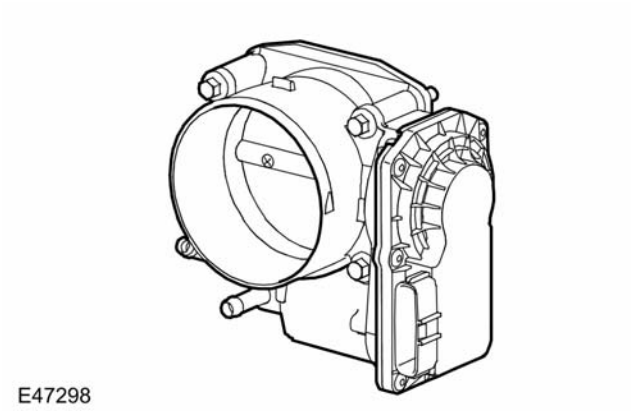
Air Intake Duct
The air intake duct runs from the throttle body to the air filter box. The duct comprises two separate pieces. One piece runs from the air filter box to the front of the engine and the other from the front of the engine to the rear of the engine locating on the throttle body. The front half is manufactured from plastic and incorporates a number of resonator chambers. The rear part of the duct is manufactured from cast aluminum.

Component Locations



1	Induction elbow	5	LH intercooler	9	RH fuel rail
2	Charge air ducts	6	Fuel rail adapter	10	RH intercooler
3	Electronic throttle body	7	LH fuel rail		
4	Injectors (8 of)	8	Supercharger		

Electronic Throttle



The V8 EMS incorporates an electric throttle control system. The electronic throttle body is located on the air intake manifold in the engine compartment. The system comprises three main components:

- Electronic throttle control valve
- APP
- ECM

When the accelerator pedal is depressed the APP sensor provides a change in the monitored signals. The ECM compares this against an electronic “map” and moves the electronic throttle valve via a PWM control signal which is in proportion to the APP angle signal. The system is required to:

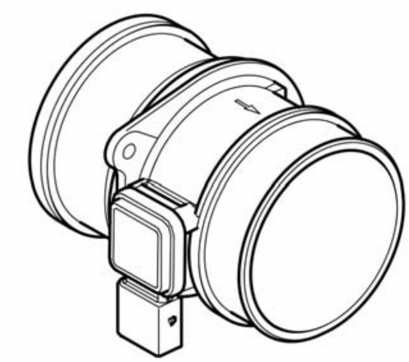
- Regulate the calculated intake air load based on the accelerator pedal sensor input signals and programmed mapping.
- Monitor the drivers input request for cruise control operation.
- Automatically position the electronic throttle for accurate cruise control.
- Perform all dynamic stability control throttle control interventions.
- Monitor and carry out maximum engine and road speed cut out.
- Provide differing responses for differing Terrain response modes.

A software strategy within the ECM enables the throttle position to be calibrated each ignition cycle. When the ignition is turned ON, the ECM performs a self test and calibration routine on the electronic throttle by closing the throttle full, then opening again. This tests the default position springs.

Electronic Throttle Pin Out Table

Pin No	Description	Pin No	Description
1	Motor +	4	Sensor 2 signal
2	Motor -	5	5 volt supply
3	Sensor ground	6	Sensor 1 signal

Mass Air Flow/Inlet Air Temperature SENSOR (MAF/AT)



E47308

The MAF/IATis located in the clean air duct immediately after the air filter box.

The air mass flow is determined by the cooling effect of inlet air passing over a “hot film” element contained within the device. The higher the air flow the greater the cooling effect and the lower the electrical resistance of the “hot film” element. The ECM then uses this signal from the MAF to calculate the air mass flowing into the engine.

The measured air mass flow is used in determining the fuel quantity to be injected in order to maintain the stichometric air/fuel mixture required for correct operation of the engine and exhaust catalysts. Should the device fail there is a software backup strategy that will be evoked once a fault has been diagnosed.

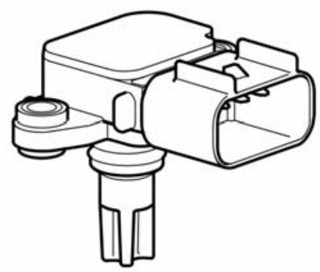
The following symptoms may be observed if the sensor fails:

- During driving the engine RPM might dip, before recovering.
- Difficulty in starting or start - stall.
- Poor throttle response / engine performance.
- Lambda control and idle speed control halted.
- Emissions incorrect.
- AFM signal offset

The IAT sensor is integrated into the MAF meter. It is a temperature dependent resistor (thermistor), i.e. the resistance of the sensor varies with temperature. This thermistor is a NTC type element meaning that the sensor resistance decreases as the sensor temperature increases. The sensor forms part of a voltage divider chain with an additional resistor in the ECM. The voltage from this sensor changes as the sensor resistance changes, thus relating the air temperature to the voltage measured by the ECM.

The ECM stores a 25 Degrees Celsius (77° F) default value for air temperature in the event of a sensor failure.

Manifold Absolute Pressure Sensor (MAP)- Supercharger Inlet Pressure



E47588

The MAP sensor provides a voltage proportional to the absolute pressure in the supercharger intake. This signal allows the load on the engine to be calculated and used within the internal calculations of the ECM. The sensor is located below the electric throttle on the induction elbow.

MAP Pin Out Table

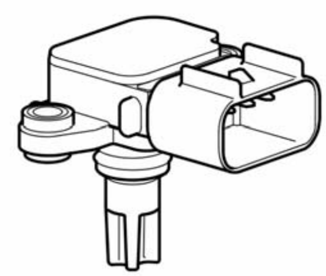
Pin No	Description
1	MAPsignal
2	Sensor supply
3	Not used
4	Sensor ground

The output signal from the MAP sensor, together with the CKP and IAT sensors, is used by the ECM to calculate the amount of air induced into the cylinders. This enables the ECM to determine ignition timing and fuel injection duration values.

The MAP sensor receives a 5V supply voltage from pin 48 of ECM connector C0634 and provides an analogue signal to pin 38 of ECM connector C0634, which relates to the absolute manifold pressure and allows the ECM to calculate engine load. The ECM provides a ground for the sensor via pin 11 of ECM connector C0634.

If the MAP signal is missing, the ECM will substitute a default manifold pressure reading based on crankshaft speed and throttle angle. The engine will continue to run with reduced drivability and increased emissions, although this may not be immediately apparent to the driver. The ECM will store fault codes which can be retrieved using T4.

Manifold Absolute Pressure And Temperature Sensor (TMAP)



E47588

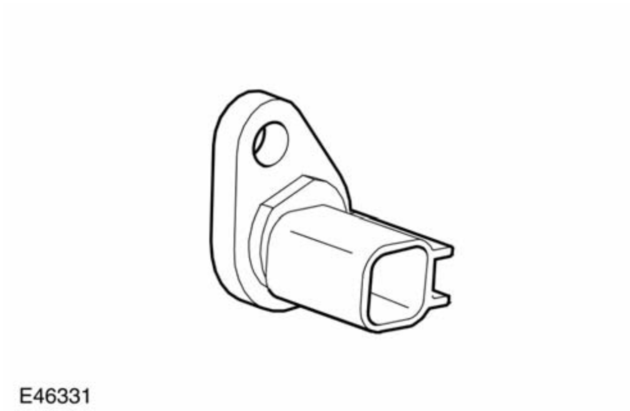
The MAPT is located to the rear of the RH engine bank intercooler outlet. The sensor measures the pressure and temperature of the inducted air prior to it entering the cylinders.

The sensor fits and seals using a radial ‘O’ ring seal directly to the inlet manifold.

The MAPT signal is used to retard the ignition timing relative to boost pressure. The intercooler temperature is used for air charge density calculations and for intercooler diagnostic purposes.

Pin No	Description	Input/Output
1	Boost pressure	Output
2	Sensor supply	Input
3	Intercooler outlet temperature	Output
4	Sensor ground	-

Crankshaft Position Sensor (CKP)

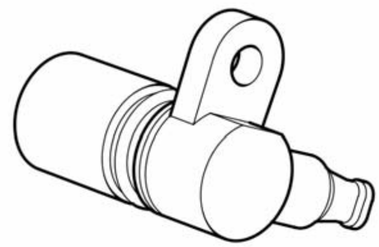


The crankshaft position sensor is mounted at the rear underside of the engine near the transmission bell housing. Connection between the sensor and the harness is via a link harness and a two-way connector. Both wires go directly to the ECM. The sensor produces the signal which enables the ECM to determine the angle of the crankshaft, and the engine rpm. From this, the point of ignition, fuel injection, etc. is calculated. If the signal wires are reversed a 3 degrees advance in timing will occur, as the electronics within the ECM uses the falling edge of the signal waveform as its reference / timing point for each tooth.

The reluctor is pressed into the flywheel and has a "tooth" pattern based on 36 teeth at 10° intervals and approximately 5° wide: one of the teeth is removed to provide a hardware reference mark which is 30 degrees BTDC No.1 cylinder. Because of the crankshaft sensor's orientation, the target wheel uses windows stamped into the face, rather than actual teeth.

The sensor operates by generating an output voltage caused by the change in magnetic field that occurs as the windows pass in front of the sensor. The output voltage varies with the speed of the windows passing the sensor, the higher the engine speed, the higher the output voltage. Note that the output is also dependent on the air gap between the sensor and the teeth (the larger the gap, the weaker the signal, the lower the output voltage). The ECM transmits the engine speed to other vehicle control modules on CAN.

Camshaft Position Sensor (CMP)


E46332

Two sensors are located at the rear of the engine, in the cylinder head (one per bank), above the rear cylinders. The sensors are Variable Reluctor Sensor (VRS) type, producing four pulses for every two engine crankshaft revolutions. The sensing element is positioned between 0 and 2mm from the side of the cam gear wheel.

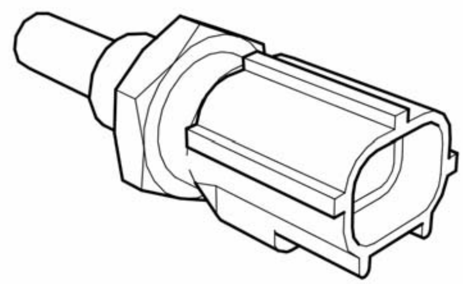
The camshaft timing wheel is a sintered component which has four teeth on it to enable the EMS to detect cylinder identification. The signal is used for:

- Cylinder recognition
- Enabling sequential fuel injection
- Knock control
- Cylinder identification for diagnostic purposes.

Failure symptoms include:

- Ignition timing reverting to the base mapping, with no cylinder correction.
- Active knock control is disabled, along with its diagnostic (Safe ignition map - loss of performance).
- Quick cam/crank synchronisation on start disabled.

Engine Coolant Temperature Sensor (ECT)

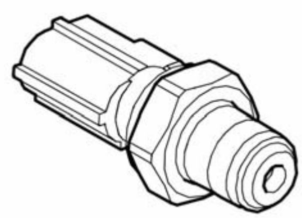


E47309

The ECT sensor is located at the front of the engine at the rear of the thermostat housing. The ECT sensor is a thermistor used to monitor the engine coolant temperature. The engine coolant temperature sensor is vital to the correct running of the engine as a richer mixture is required at lower block temperatures for good quality starts and smooth running, leaning off as the temperature rises to maintain emissions and performance.

The sensor has an operating temperature range of -30 Degrees Celsius to 125 Degrees Celsius (-22° F to 257° F). The maximum engine coolant temperature the ECM outputs on the CAN is the 119 Degrees Celsius (246° F). When a defective coolant sensor is detected, the ECM uses the oil temperature sensor value.

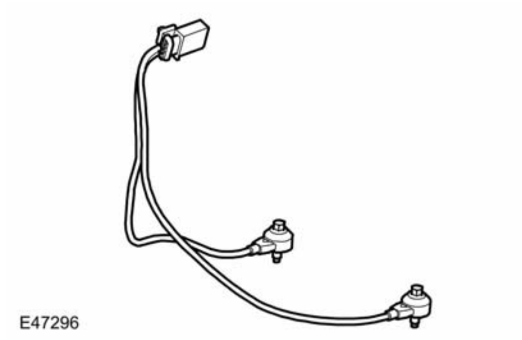
Engine Oil Temperature Sensor



E46333

Oil temperature is monitored through a temperature sensor mounted in the oil system. This component is a NTC. The sensor is mounted next to the oil pressure sensor at the front of the engine and locates into the oil filter bracket.

Knock Sensors



The V8 EMS has two knock sensors located in the V of the engine, one per cylinder bank. The sensors are connected to the ECM via a twisted pair.

The knock sensors produce a voltage signal in proportion to the amount of mechanical vibration generated at each ignition point. Each sensor monitors the related cylinder bank.

The knock sensors incorporate a piezo-ceramic crystal. This crystal produces a voltage whenever an outside force tries to deflect it, (i.e. exerts a mechanical load on it). When the engine is running, the compression waves in the material of the cylinder block, caused by the combustion of the fuel/air mixture within the cylinders, deflect the crystal and produce an output voltage signal. The signals are supplied to the ECM, which compares them with `mapped' signals stored in memory. From this, the ECM can determine when detonation occurs on individual cylinders. When detonation is detected, the ECM retards the ignition timing on that cylinder for a number of engine cycles, then gradually returns it to the original setting.

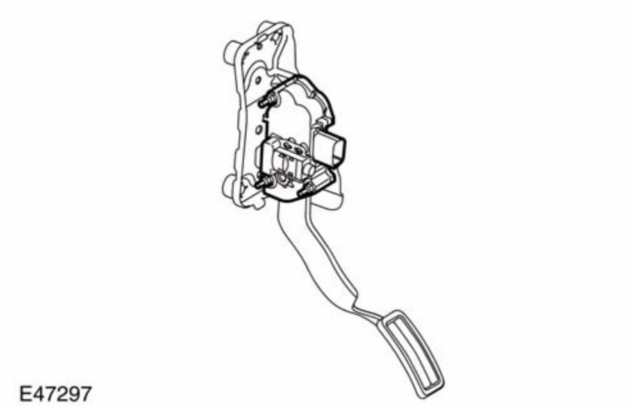
Care must be taken at all times to avoid damaging the knock sensors, but particularly during removal and fitting procedures. The recommendations regarding torque and surface preparation must be adhered to. The torque applied to the sensor and the quality of the surface preparation both have an influence over the transfer of mechanical noise from the cylinder block to the crystal.

The ECM uses the signals supplied by the knock sensors, in conjunction with the signal it receives from the camshaft sensor, to determine the optimum ignition point for each cylinder. The ignition point is set according to preprogrammed ignition maps stored within the ECM. The ECM is programmed to use ignition maps for 98 RON premium specification fuel. It will also function on 91 RON regular specification fuel and learn new adaptions. If the only fuel available is of poor quality, or the customer switches to a lower grade of fuel after using a high grade for a period of time, the engine may suffer slight pre-ignition for a short period. This amount of pre-ignition will not damage the engine. This situation will be evident while the ECM learns and then modifies its internal mapping to compensate for the variation in fuel quality. This feature is called adaption. The ECM has the capability of adapting its fuel and ignition control outputs in response to several sensor inputs.

The ECM will cancel closed loop control of the ignition system if the signal received from either knock sensor becomes implausible. In these circumstances the ECM will default to a safe ignition map. This measure ensures the engine will not become damaged if low quality fuel is used. The MIL will not illuminate, although the driver may notice that the engine 'pinks' in some driving conditions and displays a drop in performance and smoothness.

When a knock sensor fault is stored, the ECM will also store details of the engine speed, engine load and the coolant temperature.

Accelerator Pedal Position Sensor (APP)



The APP sensors are located on the accelerator pedal assembly.

The APP sensors are used to determine the driver's request for vehicle speed, acceleration and deceleration. This value is used by the ECM and the throttle is opened to the correct angle by an electric motor integrated into the throttle body.

The APP Sensor signals are checked for range and plausibility. Two separate reference voltages are supplied to the pedal. Should one sensor fail, the other is used as a 'limp – home' input. In limp home mode due to an APP signal failure the ECM will limit the maximum engine speed to 2000 rpm.

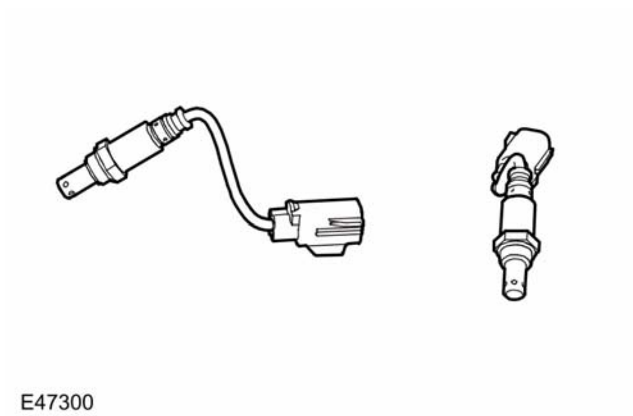
APP Pin Out Table

Pin No	Description
1	APP 1 ground
2	APP 1 demand
3	APP2 ground
4	Not used
5	APP 2 demand
6	Supply 2, 5 volt
7	Supply 1, 5 volt
8	Not used

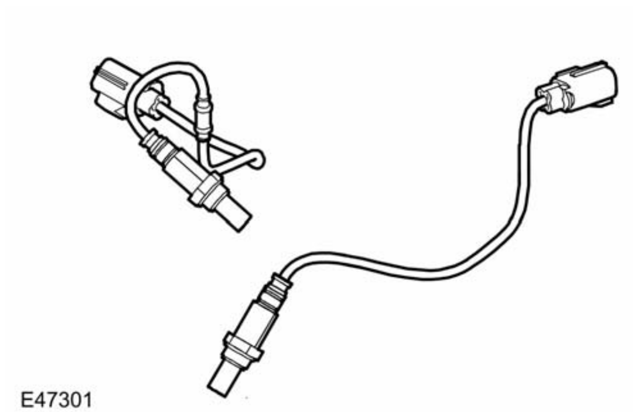
Oxygen Sensors

There are four oxygen sensors located in the exhaust system. Two upstream before the catalytic converter and two down stream after the catalytic converter. The sensor monitors the level of oxygen in the exhaust gases and is used to control the fuel/air mixture. Positioning a sensor in the stream of exhaust gasses from each bank enables the ECM to control the fueling on each bank independently of the other, allowing much closer control of the air / fuel ratio and catalyst conversion efficiency.

Upstream Oxygen Sensors



Downstream Oxygen Sensors



The oxygen sensors need to operate at high temperatures in order to function correctly. To achieve the high temperatures required, the sensors are fitted with heater elements that are controlled by a PWM signal from the ECM. The heater elements are operated immediately following engine start and also during low load conditions when the temperature of the exhaust gases is insufficient to maintain the required sensor temperatures. A non-functioning heater delays the sensor’s readiness for closed loop control and influences emissions. The PWM duty cycle is carefully controlled to prevent thermal shock to cold sensors.

UHEGO (Universal Heated Exhaust Gas Oxygen) sensors also known as Linear or "Wide Band" sensors produces a constant voltage, with a variable current that is proportional to the oxygen content. This allows closed loop fueling control to a target lambda, i.e. during engine warm up (after the sensor has reached operating temperature and is ready for operation). This improves emission control.

The HEGO sensor uses Zirconium technology that produces an output voltage dependant upon the ratio of exhaust gas oxygen to the ambient oxygen. The device contains a Galvanic cell surrounded by a gas permeable ceramic, the voltage of which depends upon the level of O2 defusing through. Nominal output voltage of the device for l =1 is 300 to 500m volts. As the fuel mixture becomes richer (l<1) the voltage tends towards 900m volts and as it becomes leaner (l>1) the voltage tends towards 0 volts. Maximum tip temperature is 1,000 Degrees Celsius (1832° F) for a maximum of 100 hours.

Sensors age with mileage, increasing their response time to switch from rich to lean and lean to rich. This increase in response time influences the ECM closed loop control and leads to progressively increased emissions. Measuring the period of rich to lean and lean to rich switching monitors the response rate of the upstream sensors.

Diagnosis of electrical faults is continually monitored in both the upstream and downstream sensors. This is achieved by checking the signal against maximum and minimum threshold, for open and short circuit conditions.

Oxygen sensors must be treated with the utmost care before and during the fitting process. The sensors have ceramic material within them that can easily crack if dropped / banged or over-torqued. The sensors must be torqued to the required figure, (40-50Nm), with a calibrated torque wrench. Care should be taken not to contaminate the sensor tip when anti-seize compound is used on the thread. Heated sensor signal pins are tinned and universal are gold plated. Mixing up sensors could contaminate the connectors and affect system performance.

Failure Modes

- Mechanical fitting & integrity of the sensor.
- Sensor open circuit / disconnected.
- Short circuit to vehicle supply or ground.
- Lambda ratio outside operating band.
- Crossed sensors bank A & B.
- Contamination from leaded fuel or other sources.
- Change in sensor characteristic.
- Harness damage.
- Air leak into exhaust system.

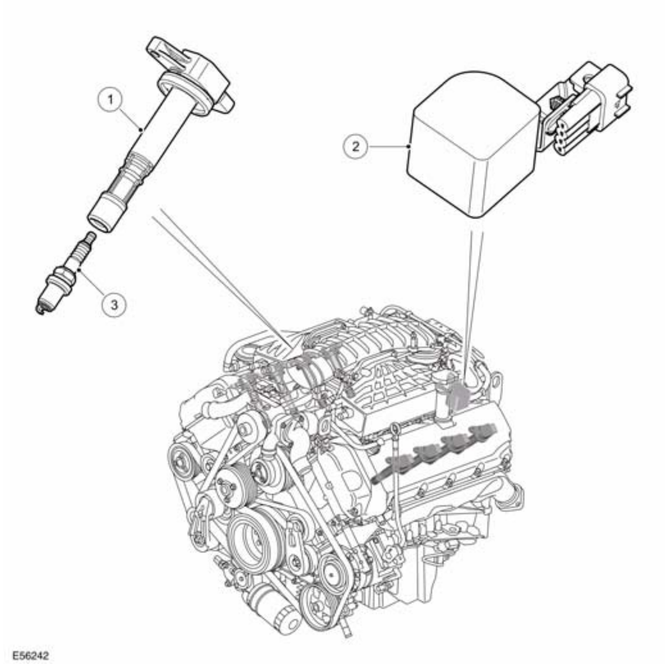
Failure Symptoms

- Default to Open Loop fueling for the particular cylinder bank
- High CO reading.
- Strong smell of H02S (rotten eggs) till default condition.
- Excess Emissions.

It is possible to fit front and rear sensors in their opposite location. However the harness connections are of different gender and color to ensure that the sensors cannot be incorrectly connected. In addition to this the upstream sensors have two holes in the shroud, whereas the down stream sensors have four holes in the shroud for the gas to pass through.

Ignition Coils

Component Location



1	Ignition coil wth combined amplifier	2	Capacitor	3	Spark plug

The V8 engine is fitted with eight plug-top coils that are driven directly by the ECM. This means that the ECM, at the point where sufficient charge has built up, switches the primary circuit of each coil and a spark is produced in the spark plug. The positive supply to the coil is fed from a common fuse. Each coil contains a power stage to trigger the primary current. The ECM sends a signal to each of the coils power stage to trigger the power stage switching. Each bank has a feedback signal that is connected to each power stage. If the coil power stage has a failure the feedback signal is not sent, causing the ECM to store a fault code appropriate to the failure.

The ECM calculates the dwell time depending on battery voltage and engine speed to ensure constant secondary energy. This ensures sufficient secondary (spark) energy is always available, without excessive primary current flow thus avoiding overheating or damage to the coils.

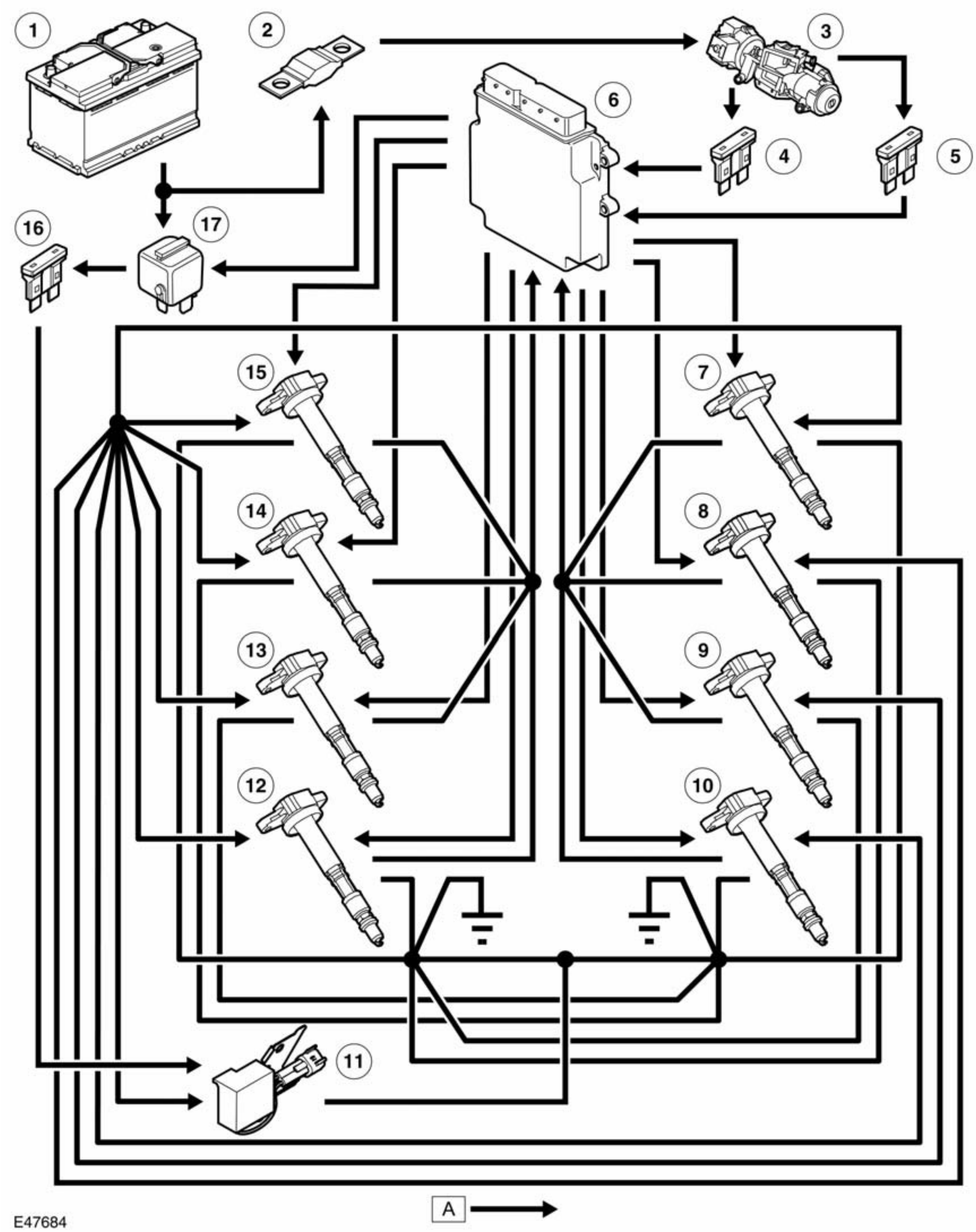
Power for the ignition coils is supplied from the main relay and a fuse in the BJB. A capacitor is connected in parallel with the power supplies to the ignition coils to suppress RFI (radio frequency interference).

The individual cylinder spark timing is calculated from a variety of inputs:

- Engine speed and load.
- Engine temperature.
- Knock control.
- Auto gearbox shift control.
- Idle speed control.

Ignition System Overview

NOTE: A = Hardwired connections



1	Battery	7	Ignition coil and spark plug 5	13	Ignition coil and spark plug 7
2	Fusible link 11E, BJB	8	Ignition coil and spark plug 2	14	Ignition coil and spark plug 6
3	Ignition switch	9	Ignition coil and spark plug 3	15	Ignition coil and spark plug 1
4	Fuse 25P, ignition feed, CJB	10	Ignition coil and spark plug 8	16	Fuse 6E, BJB
5	Fuse 60P, crank feed, CJB	11	Capacitor	17	Main relay
6	ECM	12	Ignition coil and spark plug 4		

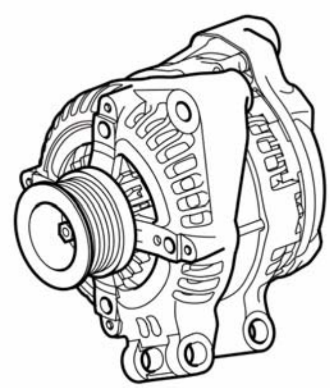
Viscous Fan Control
The ECM controls a viscous coupled fan to provide engine cooling. The ECM supplies the fan with a PWM signal that controls the amount of slippage of the fan, thus providing the correct amount of cooling fan speed and airflow. The EMS uses a Hall effect sensor to determine the fan speed.

Terrain Response™
Terrain Response ™ system allows the driver to select a program which will provide the optimum settings for traction and performance for prevailing terrain conditions.

As part of Terrain Response ™ there will be different throttle pedal progression maps associated with different Terrain Response ™ modes. The two extremes are likely to be a sand map (quick build up of torque with pedal travel) and grass/gravel/snow (very cautious build up of torque).

The V8 Super Charged implementation of throttle progression is based on a fixed blend time. The torque will blend from that on one map to that on the new map (for the same pedal position) over a fixed time. This means blending will always take the same amount of time but when the torque change is small the torque increase over time will be small, whilst if the torque change is greater then the torque increase over time will be steeper. The resulting acceleration of the vehicle will depend on the torque difference between the two maps as well as on the gear and range selected.

Generator



E47591

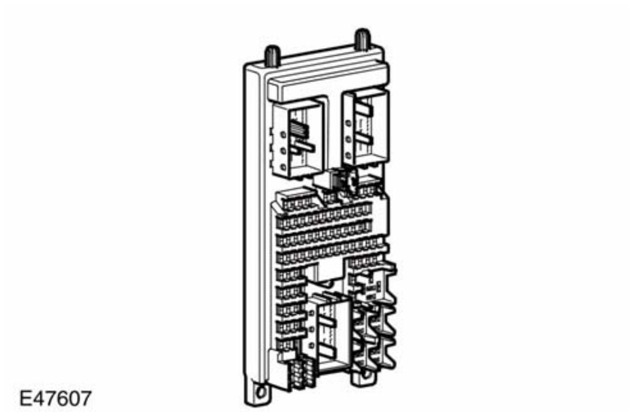
The Generator has a multifunction voltage regulator for use in a 14V charging system with 6÷12 zener diode bridge rectifiers.

The ECM monitors the load on the electrical system via PWM signal and adjusts the generator output to match the required load. The ECM also monitors the battery temperature to determine the generator regulator set point. This characteristic is necessary to protect the battery; at low temperatures battery charge acceptance is very poor so the voltage needs to be high to maximize any rechargeability, but at high temperatures the charge voltage must be restricted to prevent excessive gassing of the battery with consequent water loss.

The Generator has a smart charge capability that will reduce the electrical load on the Generator reducing torque requirements, this is implemented to utilize the engine torque for other purposes. This is achieved by monitoring three signals to the ECM:

- Generator sense (A sense), measures the battery voltage at the CJB.
- Generator communication (Alt Com) communicates desired Generator voltage set point from ECM to Generator.
- Generator monitor (Alt Mon) communicates the extent of Generator current draw to ECM. This signal also transmits faults to the ECM which will then sends a message to the instrument cluster on the CAN bus to illuminate the charge warning lamp.

Central Junction Box



The ECM is connected to ignition switch I and II. When the ignition is turned ON, 12V is applied to the ignition sense input. The ECM then starts its power up routines and turns ON the ECM main relay, the main power to the ECM and it's associated system components. When the ignition is turned OFF the ECM will maintain its powered up state for up to 20 minutes while it initiates its power down routine and on completion will turn OFF the ECM main relay. The ECM will normally power down in approximately 60 seconds, do not disconcert the battery until the ECM is completely powered down.

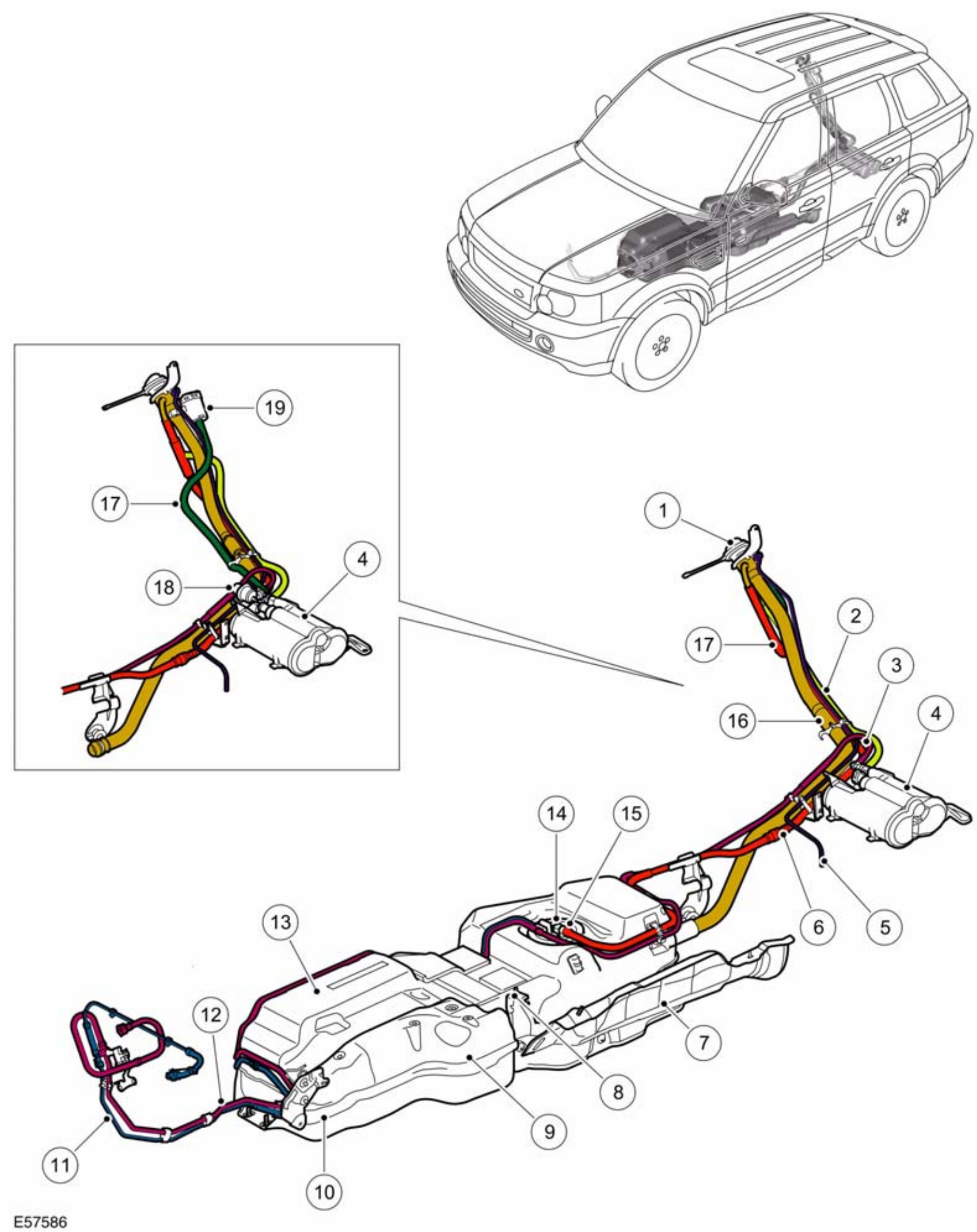
Fuel Tank and Lines

The major components of the 4.2L V8 supercharged fuel system comprise a fuel tank, a fuel pump, a fuel filler assembly and two fuel level sensors.

The 4.2L V8 supercharged fuel system uses an electronic returnless fuel system which comprises a pump module mounted in the fuel tank to deliver fuel at variable flow and pressure to the fuel rails which supply fuel to all fuel injectors. The fuel pump operation is regulated by a fuel pump driver module which is controlled by the engine management system. The control module regulates the flow and pressure supplied by controlling the operation of the fuel pump using a Pulse Width Modulation (PWM) output.

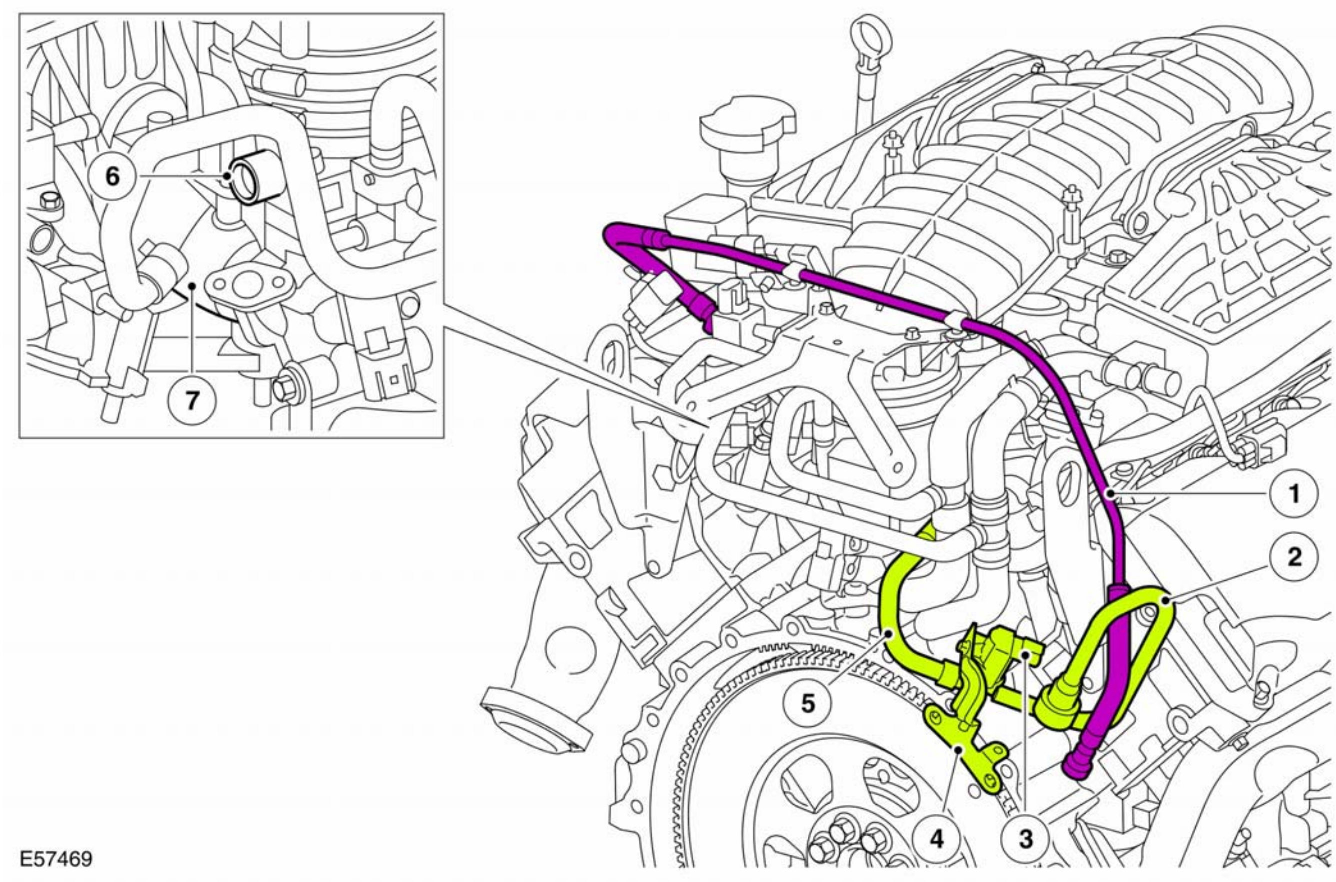
Fuel Delivery System Component Location

NOTE: 4.2L V8 Supercharged



1	Filler cap and lanyard	8	Mounting screw (6 off)	15	Tank breather pipe
2	Breather line 'Y' piece to charcoal canister	9	Cover	16	Fuel filler pipe
3	Charcoal canister purge line	10	Cradle	17	Charcoal canister vent pipe
4	Charcoal canister	11	Pipe - Fuel pump to engine (feed)	18	DMTL pump (NAS only)
5	Rear differential breather pipe	12	Pipe - EVAP purge valve to charcoal canister	19	DMTL filter (NAS only)
6	Tank breather pipe	13	Fuel tank		
7	Heat shield	14	Fuel pump module assembly		

Purge Valve



1	Fuel feed jump hose (Ref. only)	4	Bracket	7	Induction elbow
2	Purge hose connector	5	Purge hose		
3	Purge valve	6	Electronic throttle		

The purge valve is located at the rear of the engine, on a bracket which is attached to the transmission bell housing. The purge hose is routed from the purge valve, along the left hand side of the air intake manifold, to the induction elbow assembly which locates the electronic throttle.

The purge hose is connected, at the right hand rear of the engine, with a quick release coupling to the purge line which runs parallel with the fuel feed line along the top of the fuel tank to the charcoal canister.

The purge hose continues from the purge valve and is routed to a connection on the air intake elbow assembly. The hose is connected to the elbow with a quick release connector.

The purge valve is located on a bracket on the bell housing and is secured with a single bolt. The purge valve is a solenoid operated valve which is closed when de-energised. The valve is controlled by the Engine Control Module (ECM) and is operated when engine operating conditions are correct to allow purging of the charcoal canister.

The ECM keeps the purge valve closed (de-energised) below a predetermined engine coolant temperature and engine speed to protect the engine tune and catalytic converter performance. If the purge valve is opened during cold running conditions or at engine idle speed, the additional fuel vapor can cause the engine to have erratic idle speed or even stall. When engine operating conditions are correct, the ECM opens the purge valve (energised) and the depression at the inlet manifold draws a fuel vapor and fresh air mix from the charcoal canister. When the purging process is active, fresh air is drawn into the charcoal canister via the DMTL pump atmospheric vent connection and its filter on NAS vehicles and via the atmospheric vent hose connection and the spider trap on non NAS vehicles.

On NAS vehicles the system does not include a pressure test point. Pressure testing of the purge valve hose is achieved by disconnecting the purge valve joint on the underside of the vehicle, forward of the fuel tank and connecting a special tool to allow the system to be pressure tested. The test performs a pressure test on the purge hose connection forward of the fuel tank back to the charcoal canister. The special tool is then connected to the purge hose connection forward of the fuel tank to perform a pressure test on the purge hose to the purge valve.

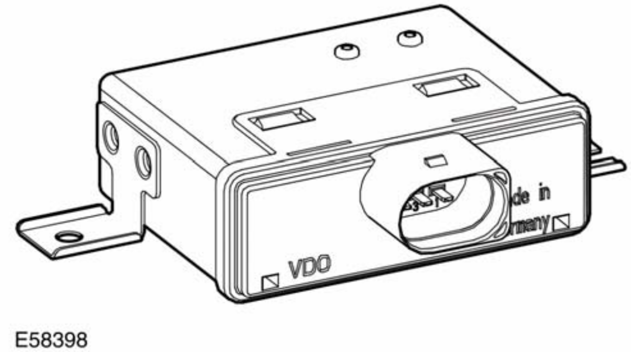
Fuel Pump

The submersible electric fuel pump is attached to a carrier and is located at the bottom of the swirl pot inside the fuel tank. The fuel pressure regulator, which controls the fuel pressure in the feed pipe to fuel rail, is located in the fuel manifold in the fuel tank.

Fuel Pump Relay

The ECM controls the fuel pump relay which in turn controls the power supply to the fuel pump driver module. The ECM energizes the relay ON with ignition ON, via pin A95 of the ECM.

Fuel Pump Driver Module



The fuel pump driver module is located in the rear LH quarter adjacent to the parking aid control module.

The fuel pump is control by the ECM. The ECM sends a PWM signal to the fuel pump driver module from pin B20 of the ECM, the frequency of the signal determines the duty cycle of the pump. the PWM signal to the pump represents half the ON time of the pump. If the ECM transmits a 50% on time the fuel pump driver module drives the pump at 100%. If the ECM transmits a 5% ON time the fuel pump driver module drives the pump at 10%. The fuel pump driver module will only turn the fuel pump ON if it receive a valid signal between 4% and 50%. When The ECM requires the fuel pump to be turned OFF the ECM transmits a duty cycle signal of 75%.

The status of the fuel pump driver module is monitored by the ECM on pin B21. Any errors can be retrieved from The ECM. The fuel pump driver module cannot be interrogated for diagnostic purposes.

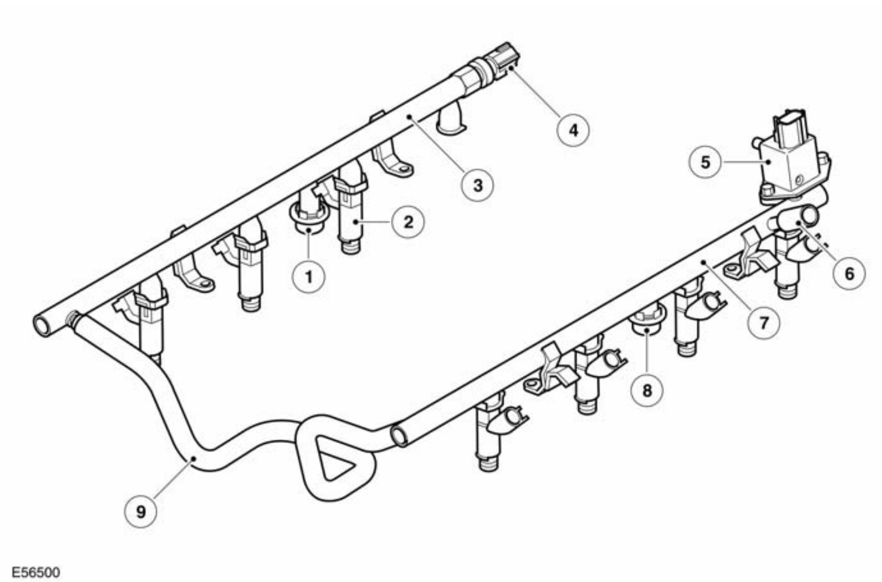
The MAP controls The fuel pump driver module in response to inputs from the fuel rail pressure sensor, MAP and the MAF/IAT sensor.

The fuel pressure range is 0.9 - 5.4 bar (13 - 78 psi).

Harness Connector C2369 pin out details

Pin No	Description	Input/Output
1	Pump +	Output
2	Pump -	-
3	ECMPWM signal	Input
4	Diagnostic signal	Output
5	Battery voltage	Input
6	GND	-

Fuel Rails



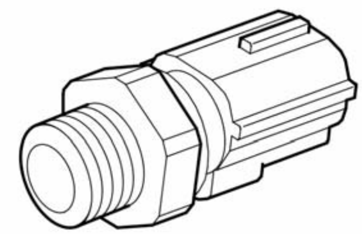
1	RH fuel pressure accumulator	4	Fuel temperature sensor	7	LH fuel rail
2	Injectors (8 of)	5	Fuel pressure sensor	8	LH fuel pressure accumulator
3	RH fuel rail	6	Fuel supply	9	Fuel supply cross over pipe

Four fuel injectors are installed in each intercooler adapter and are connected to the fuel rail. 'O' ring seals are used to seal the injectors in the fuel rails and the intercooler adapters.

A fuel pressure accumulator is attached to each of the fuel rails.

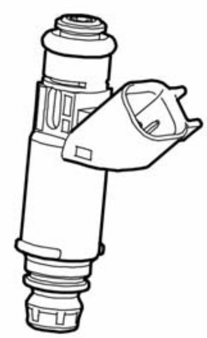
Fuel Rail Pressure Sensor
The fuel rail pressure sensor is located on top of the fuel rail adjacent to the fuel inlet. The fuel rail pressure sensor measures the pressure of the fuel in the fuel rail. This input is then used by the ECM which commands the FPDM to control the amount of fuel delivered to the fuel rail.

Fuel Rail Temperature Sensor


E47606

The fuel rail temperature sensor measures the temperature of the fuel in the fuel rail. This input is then used to deliver the correct quantity of fuel to the engine. The sensors operating range is -40 Degrees Celsius to 150 Degrees Celsius (-40° F to 302° F). The fuel rail temperature sensor is fitted on the rear of the right hand bank (bank A) fuel rail.

Fuel Injectors

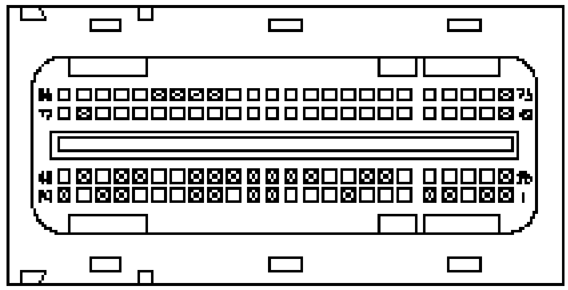

E47305

The engine has 8 fuel injectors (one per cylinder), each injector is directly driven by the ECM. The injectors are fed by a common fuel rail as part of a ‘return less’ fuel system. The fuel rail pressure is regulated to 4.5 bar by a fuel pressure regulator which is integral to the fuel pump module, within the fuel tank. The injectors can be checked by resistance checks. The ECM monitors the output power stages of the injector drivers for electrical faults.

The injectors have a resistance of 13.8 Ohms ± 0.7 Ohms @ 20 Degrees Celsius (68° F)

Denso ECM Pinouts

Connector C0634



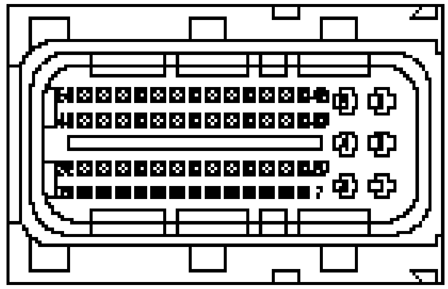
Pin No	Wire Color	Description	Input/ Output
1	Y	Not used	-
2	GB	Not used	-
3	WG	Generator monitor	Input
4		Not used	-
5		Not used	-
6	B	CKP sensor -	Input
7	R	CMP sensor 1GND	-
8	N	CMP sensor 2GND	-
9		Not used	-
10	BG	TP sensor GND	-
11	BG	MAP sensor ground	-
12	GB	FRP sensor ground	-
13		Not used	-
14		Not used	Input
15	BG	ECT ground	-
16		Not used MAF ground	-
17		Not used	-
18	BP	MAF sensor ground	-
19	B	Knock sensor 1A ground	-
20	S	Knock sensor 1B ground	-
21		Not used	-
22		Not used	-

Pin No	Wire Color	Description	Input/ Output
23	Y	Oil temperature sensor	Input
24		MAPT sensor 5v ref	Output
25		Not used	-
26	N	UHEGO sensor bank B signal	Input
27	G	UHEGO sensor bank B GND	-
28	R	UHEGO sensor bank A signal	Input
29	Y	UHEGO sensor bank A GND	-
30	O	CKP sensor +	Input
31		Not used	-
32		Not used	-
33	G	CMP signal bank B	Input
34	Y	CMP signal bank A	Input
35		Not used	-
36		Not used	-
37		Not used	-
38		MAPsignal	Input
39		IAT	Input
40		Not used	Input
41		Not used	Input
42	N	Knock sensor 1 A +	Input
43	G	Knock sensor 1 B +	Input

Pin No	Wire Color	Description	Input/ Output
44		Not used	-
45		Not used	-
46	YR	Fuel rail temperature sensor	Input
47		Fuel rail pressure sensor 5 V ref voltage	Output
48	OY	MAP sensor 5 V ref voltage	Output
49		Not used	-
50	YU	Not used	-
51	YR	Not used	-
52	YG	Not used	-
53	YU	Not used	-
54	YR	Ignition coil cylinder 4B	Output
55	GR	Ignition coil cylinder 4A	Output
56	GR	Ignition coil cylinder 3B	Output
57	YR	Ignition coil cylinder 3A	Output
58	GW	Ignition coil cylinder 2B	Output
59	Y	Ignition coil cylinder 2A	Output
60	GW	Ignition coil cylinder 1B	Output
61	GU	Ignition coil cylinder 1A	Output
62	GB	Ignition failure signal bank A	Input
63	Y	Viscous fan speed monitor	Input
64	YB	Ignition failure signal bank B	Input
65	R	TP sensor 1	Input
66	U	MAF	Input
67	Y	TP sensor 2	Input
68	UY	ECT	Input
69	BP	Inlet manifold boost pressure	Input
70	GW	MAF	Input
71		Fuel rail pressure sensor signal	Input

Pin No	Wire Color	Description	Input/ Output
72	OY	Electric throttle 5V reference	Output
73		Not used	-
74	RW	Throttle valve open direction -	Output
75	GW	Throttle valve open direction +	Output
76	RU	UHEGO Heater bank A	Output
77	RW	UHEGO Heater bank B	Output
78	BG	Injector cylinder 1A	Output
79	BR	Injector cylinder 1B	Output
80	BP	Injector cylinder 2A	Output
81	BO	Injector cylinder 2B	Output
82	BG	Injector cylinder 3A	Output
83	U	Injector cylinder 3B	Output
84	BW	Injector cylinder 4A	Output
85	UY	Injector cylinder 4B	Output
86	Y	Not used	-
87	YU	Not used	-
88		Not used	-
89		Not used	-
90		Not used	-
91		Not used	-
92	UY	Purge valve	Output
93	B	Viscous fan request	Output
94	UB	E box fan	Output
95	YN	FPDM power	Output
96	WR	Generator control	Output

Connector C0635



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Pin No	Wire Color	Description	Input/ Output
1	B	Signal ground 1	-
2	B	Power ground 1	-
3	B	Power ground 3	-
4	NO	Power ground 2	-
5	B	ECM power	Output
6	RG	Electric throttle power	Input
7	YLG	APP sensor ground 1	-
8	BG	APP sensor ground 2	-
9		Not used	-
10		Not used	-
11		Not used	-
12		Not used	-
13		Not used	-
14		Not used	-
15	GO	Park/ Neutral signal	Input
16	NU	EMS relay	Output
17	WR	Crank request	Input
18		Not used	-
19	OY	APP sensor 2 5V ref	Output
20		FPDM control	Output
21		FPDM monitor	Input
22	RB	HEGO sensor A GND	-
23	G	DMTL heater	Output
24	RB	APP sensor 1 signal	Output
25	U	HEGO sensor A	Input
26	WU	HEGO sensor B	Input
27		Not used	-
28	YG	RCM	Input
29		Not used	-
30	BO	Ignition switch	Input
31		Not used	-
32	R	APP sensor 1 5V reference	Output
33	Y	DMTL pump	Output
34	RB	HEGO sensor B GND	-
35	R	Speed control switch -	Output
36	PU	Speed control switch +	Input
37		Not used	-
38	U	APP sensor 2 demand	Input
39		Not used	-
40		Not used	-
41	GP	Brake pedal switch	Input
42		Not used	-
43		Not used	-
44	YB	CAN out -	Input/output
45	YB	CAN in -	Input/output

Pin No	Wire Color	Description	Input/ Output
46	WO	HEGO heater A	Output
47	G	HEGO heater B	Output
48	R	DMTL valve	Output
49		Not used	-
50	G	Vacuum pump relay	Output
51	UR	Starter relay	Output
52		Not used	-
53		Not used	-
54	NO	Battery voltage	Input
55		Not used	-
56		Not used	-
57	YN	CAN out +	Input/out-put
58	YN	CAN in +	Input/out-put

GLOSSARY

Air Cleaner (ACL): Air Cleaner

Air Cleaner Filter (ACL Filter): Air Cleaner Filter Element

Air Conditioning Clutch (ACC): Air Conditioning Clutch signal commands status of the A/C clutch

Accelerator Pedal (AP): Accelerator Pedal

Battery Positive Voltage (B+): The positive voltage from the battery or any circuit connected directly to the battery

Brake On/Off (BOO): Brake On/Off signal; indicates the position of the brake pedal

Bypass Air (BPA): Bypass Air is the mechanical control of throttle bypass air

Camshaft Position Sensor (CMP Sensor): Camshaft Position Sensor indicates camshaft position

Canister Purge (CANP): Canister Purge solenoid controls purging of the EVAP canister

Closed Loop (CL): Closed Loop controls the engine operation when the engine operates in closed loop fuel control (most normal driving)

Crankshaft Position Sensor (CKP Sensor): Crankshaft Position sensor indicates crankshaft position

Data Link Connector (DLC): Data Link Connector provides access and/or control of the vehicle information, operating conditions and diagnostic information

Diagnostic System Manager (DSM): Software that manages the operation of OBD II monitors.

Diagnostic Trouble Code (DTC): Diagnostic Trouble Code is an alpha/numeric identifier for afault condition identified by the On-Board Diagnostic System

Direct Ignition System (DIS System): Direct Ignition is a system in which the ignition coil secondary circuit is dedicated to specific spark plugs without the use of a distributor.

Engine Control Module (ECM): Engine ECU: Electronic Control Unit

Engine Coolant Temperature (ECT): Engine Coolant Temperature signal and sensor indicates the temperature of the engine coolant

Engine Coolant Temperature Sensor (ECT Sensor): CTS: Coolant Temperature Sensor

Engine Speed (RPM): Rotational speed of the engine crankshaft

Evaporative Emission System (EVAP System): Evaporative Emission is a system to prevent vapor from escaping into the atmosphere. The Land Rover system includes a charcoal canister to store fuel vapors

Fan Control (FC): Fan Control is for controlling the engine cooling fan

Freeze Frame: OBD II diagnostic screen where that indicates the exact operating conditions when the MIL was illuminated.

Fuel Pump (FP): Fuel Pump is a pump used to deliver fuel to the engine

Generator (GEN): Generator (formerly alternator) is a rotating machine designed to convert mechanical energy to electric energy

GEMS: Generic Engine Management System

Ground (GND): Ground is an electrical conductor used as a common return for an electrical circuit(s) and with a zero relative potential

Heated Oxygen Sensor (H02S): Heated Oxygen sensor (formerly HEGO) is an Oxygen Sensor (02S) that is electrically heated

Idle Air Control (IAC): Idle Air Control indicates electrical control of throttle bypass air

Ignition Control Module (IC Module): Ignition Control Module is the logic module that controls the ignition system

Inertia Fuel Shutoff (IFS): Inertia Fuel Shutoff is a switch that shuts off the fuel delivery system when activated by predetermined acceleration force

Intake Air Temperature Sensor (IAT Sensor): Also called Air Charge Temperature sensor

Knock Sensor (KS): Detects spark knock within a certain frequency and intensity range, and produces an electrical signal to the PCM

Lambda Sensor: Oxygen sensor

Long Term Fuel Trim (LT Fuel Trim): Long Term Fuel Trim

Malfunction Indicator Lamp (MIL): Malfunction Indicator Lamp illuminates on the instrument panel when an emission related component or monitor fails

Manifold Absolute Pressure (MAP): Manifold Absolute Pressure is the absolute pressure of the intake manifold air

Manual Lever Position (MLP): Manual Lever Position sensor signal now called Transmission Range (TR)

Mass Air Flow (MAF): Mass Air Flow is a sensor which provides information on the mass flow rate of the intake air to the engine

Multiport Fuel Injection (MFI): Multiport Fuel Injector is a fuel-delivery system in which each cylinder is individually fueled

On-Board Diagnostic System (OBD): System that provides self-diagnostics of engine management system components.

Open Loop (OL): Open Loop

P1000 Code: Appears when the vehicle has not completed all OBD II monitors since the GEMS memory was last cleared.

Park/Neutral Position Switch (PNP Switch): Park/Neutral Position sensor indicates the selected non-drive modes of the transmission

Power Steering Pressure (PSP): Power Steering Pressure switch indicates a pressure limit in the power steering system

Sequential Multiport Fuel Injection (SFI): Sequential Multiport Fuel Injector is a multiport fuel delivery system in which each injector is individually energized and timed

Short Term Fuel Trim (SFT): Short term fuel trim, injector control strategy

Stoichiometric Ratio: Fuel mixture at which the ratio of air and fuel (14.7 to 1) permits complete burning.

Tachometer (TACH): Tachometer is a circuit that provides input for an electronic tachometer display

Three Way Catalyst Converter (TWC): Catalytic Converter

Throttle Position Output (TPOUT): Signal provided by the TP sensor

Throttle Position Sensor (TP Sensor): TPS: Throttle Body Sensor

Transmission Control Module (TCM): Electronic Control Module responsible for transmission operation

Vehicle Speed Sensor (VSS): Vehicle Speed Sensor is a sensor which provides vehicle speed information

Warm-up Cycle: Engine operation after an engine OFF period, where coolant temperature rises to at least 40° F and reaches at least 160° F.

Wide Open Throttle (WOT): A condition of maximum air flow through the throttle valve