Section 6C1-1
Engine Management V6 – General Information

ATTENTION

Before performing any service operation or other procedure described in this Section, refer to Section 00 Warnings, Cautions and Notes for correct workshop practices with regard to safety and / or property damage.

1 General Information

WARNING

The V6 engine management system incorporates functions and components that could cause personal injury or vehicle damage. Refer to Section 6C1-2 Engine Management – V6 – Diagnostics, and Section 6C1-3 Engine Management – V6 – Service Operations, before attempting any diagnosis or repairs.

1.1 Introduction

The V6 engine management system is designed to improve engine performance and increase vehicle safety while meeting the stringent Euro 2 vehicle emission standard. This is achieved by the introduction of the following engine management sub-systems and components:

- Throttle actuator control (TAC) System – the TAC system allows the engine control module (ECM) to electronically control the throttle plate opening eliminating the need for the following components:
  - mechanical link between the throttle plate and accelerator pedal,
  - cruise control module, and
  - idle air control motor.

  Refer to 3.5 Throttle Actuator Control System for details of the TAC System operation and to 3.7 Cruise Control System for details of the cruise control operation.

  This feature results in improved driveability, better fuel economy and emission control. In addition, the TAC system allows the ABS-TCS electronic control unit (if fitted) to request engine speed reduction from the ECM to improve the vehicle's braking and traction control performance. Refer to Section 5B ABS / TCS / ESP – General Information.
- Wide band heated oxygen sensor (Alloytec190 only) – provides a more accurate measurement of the oxygen concentration in the exhaust gas. Refer to 4.14 Heated Oxygen Sensors.
- Intake manifold runner control (Alloytec190 only) – enables the ECM to change the intake manifold configuration according to engine demand. The variable intake manifold configuration allows the optimum engine intake air flow during low or high engine speed, which improves engine performance. Refer to 4.17 Intake Manifold Runner Control Valve.
- Pencil Coil – allows the ignition coil to be fitted directly on the spark plug eliminating the need for spark plug wires. Refer to 4.15 Ignition Coil and Spark Plug.
- Camshaft Position Actuators – enables the ECM to adjust the camshaft timing according to the demand placed on the engine. The variable camshaft timing provides better balance between engine power output, fuel economy and emission control. Refer to 3.6 Camshaft Position Actuator Control System.

The engine management system has a self diagnostic capability, as well as connections to enable diagnosis of faults. If the ECM recognises operational problems it can alert the driver via the check powertrain icon in the instrument cluster multi-function display. The ECM also interfaces with other systems in the vehicle as required.

For further information on the air-conditioning system refer to:

- Section 2A HVAC Climate Control (Manual A/C) – Description and Operation or
- Section 2D HVAC Occupant Climate Control (Auto A/C) – Description and Operation.

For the location of fuses, fusible links and relays, refer to Section 12O Fuses, Relays, and Wiring Harnesses.

1.2 Emission Control

Euro 2 Emissions Standards

The vehicle has been configured to comply with Euro 2 vehicle emissions standards. Euro 2 is a European standard which sets vehicle emissions targets to compel vehicle manufacturers to reduce harmful vehicle emissions such as carbon monoxide (CO), hydrocarbons (HC) and the various oxides of nitrogen (NOx).

Australian Design Rule 79/00 implements the 'Euro 2' exhaust and evaporative emissions requirements for light vehicles to reduce air pollution. The following tests are prescribed:

- average tailpipe emissions after a cold start,
- carbon monoxide emission at idling speed,
- emission of crankcase gases,
- evaporative emissions, and
- durability of pollution-control devices.

2 Component Locations

2.1 Cylinder Numbering

Engine cylinder identification follows the international standard OBD II. This standard calls for the engine cylinder bank number one to be identified by the location of cylinder number one. Therefore the numbering for the V6 engine is:

The V6 engine cylinders are numbered as follows:

- 1, 3, 5 – Right-hand side (Bank 1),
- 2, 4, 6 – Left-hand side (Bank 2).

The engine firing order is 1, 2, 3, 4, 5, 6.

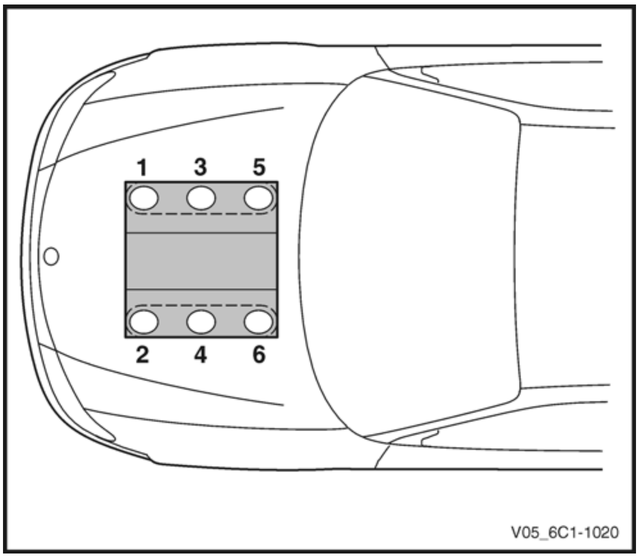

Figure 6C1-1 – 1

2.2 Engine Compartment

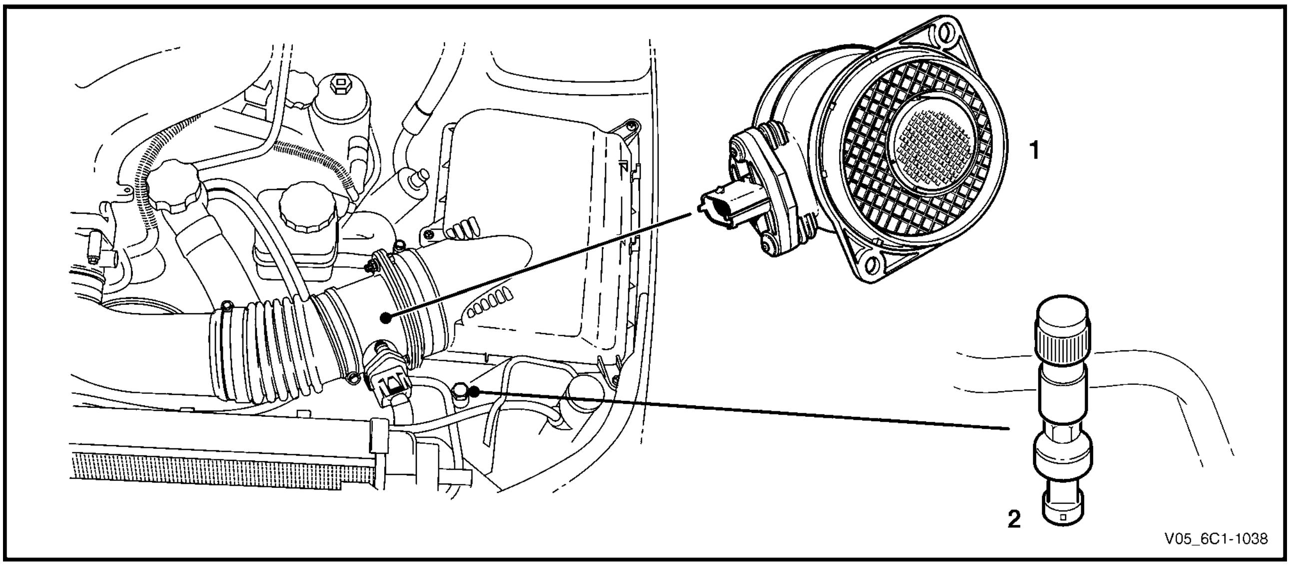

Figure 6C1-1 – 2

Legend

1 Mass Air Flow (MAF) Sensor

2 Air-conditioner Refrigerant Pressure Sensor

2.3 Engine

Alloytech

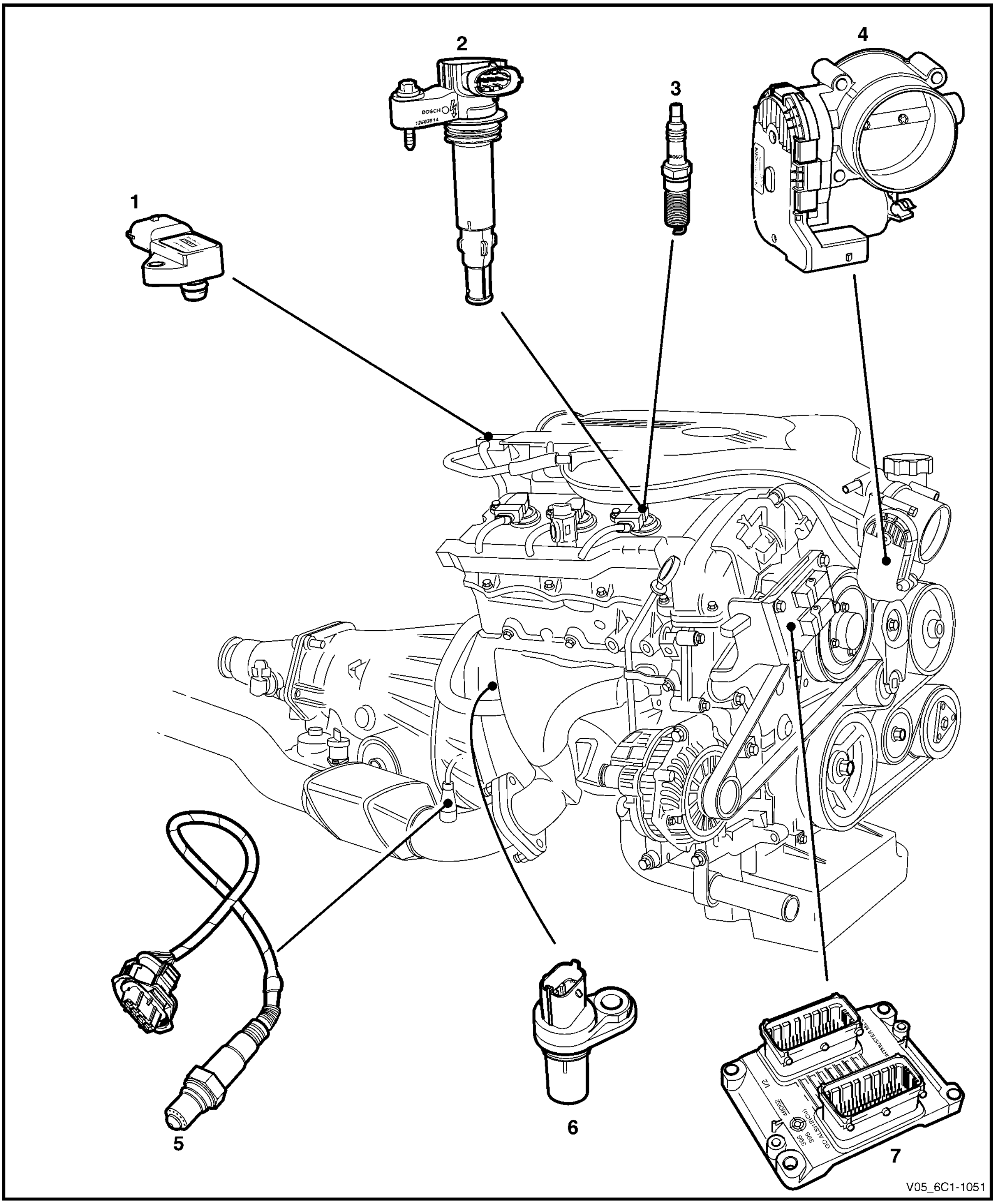

Figure 6C1-1 – 3

1 Barometric Pressure (BARO) Sensor
2 Ignition Coil Assembly (six places)
3 Spark Plug (six places)
4 Throttle Body Assembly
5 Heated Oxygen Sensor (HO2S), Pre-Catalyst (two places)
6 Crankshaft Position (CKP) Sensor
7 Engine Control Module (ECM)

Alloytech 190

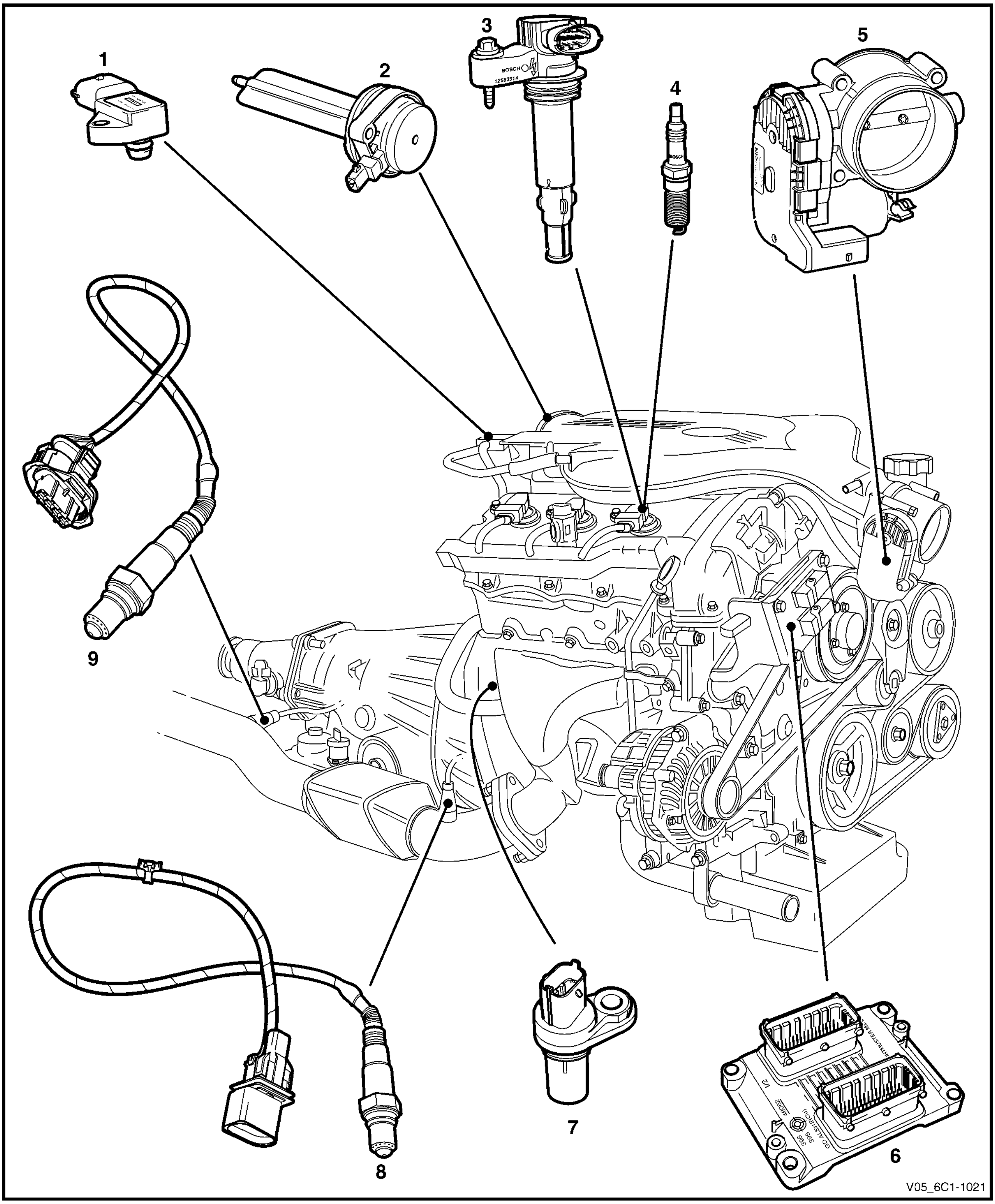

Figure 6C1-1 – 4

Legend

1 Barometric Pressure (BARO) Sensor
2 Intake Manifold Runner Control (IMRC) Valve
3 Ignition Coil Assembly (six places)
4 Spark Plug (six places)
5 Throttle Body Assembly
6 Engine Control Module (ECM)
7 Crankshaft Position (CKP) Sensor
8 Heated Oxygen Sensor (HO2S), Pre-Catalyst (two places)
9 Heated Oxygen Sensor (HO2S), Post-Catalyst (two places)

All Engines

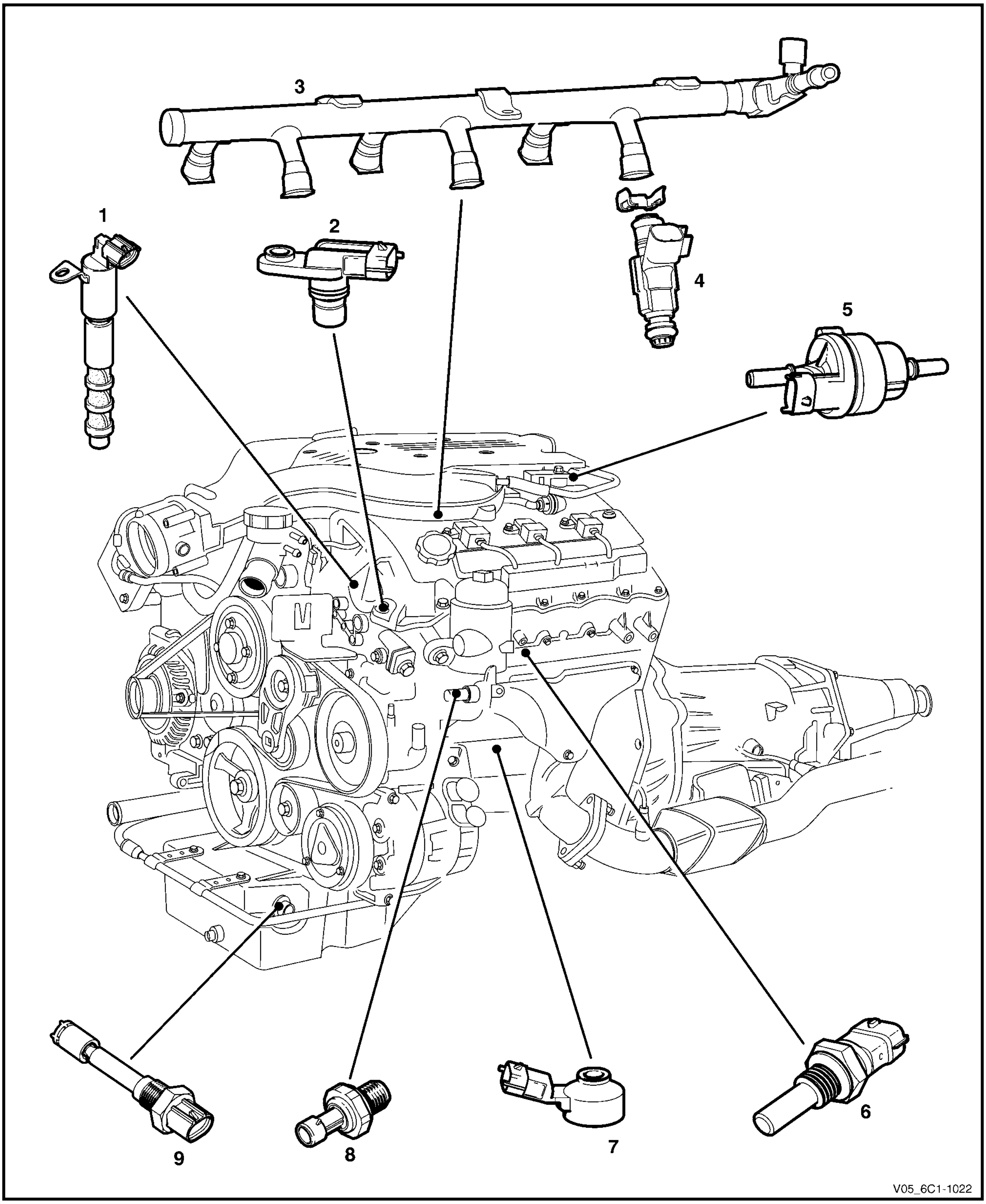

Figure 6C1-1 – 5

Legend

1 Camshaft Position (CMP) Actuator Solenoid, Alloytec (two places), Alloytec190 (four places)

2 Camshaft Position (CMP) Sensor, Alloytec (two places), Alloytec190 (four places)

3 Fuel Rail Assembly

4 Fuel Injector (six places)

5 Evaporative Canister Purge (EVAP) Valve

6 Engine Coolant Temperature (ECT) Sensor

7 Knock (KS) Sensor (two places)

8 Engine Oil Pressure Sensor

9 Engine Oil Level / Temperature Sensor

2.4 Manual Transmission

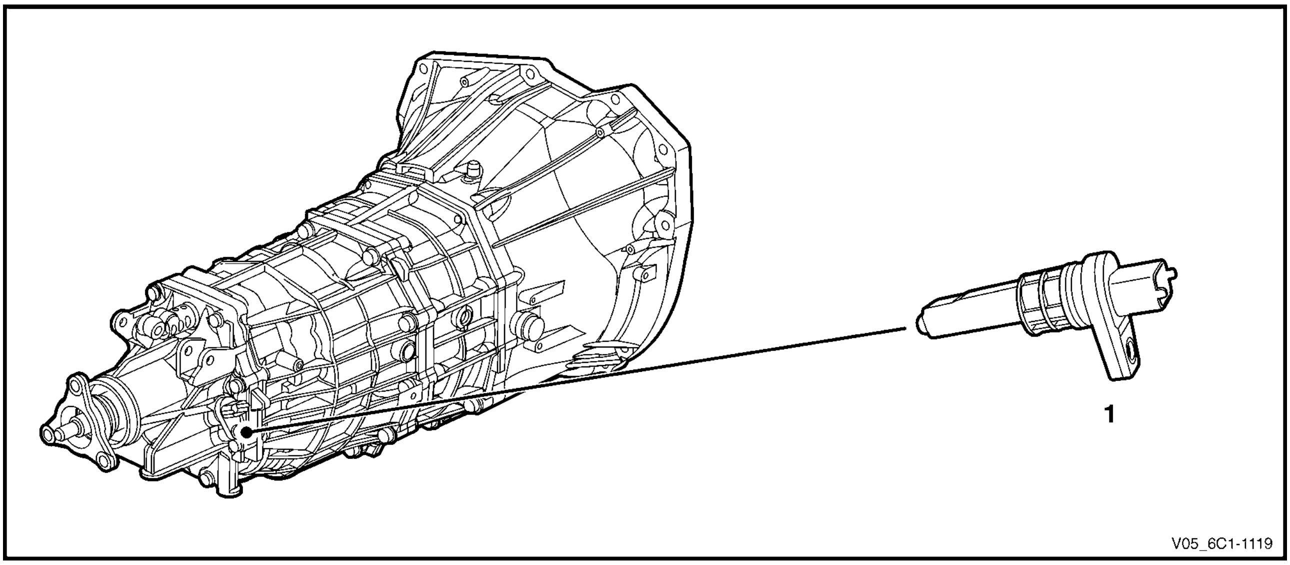

Figure 6C1-1– 6

Legend

1 Vehicle Speed Sensor (VSS)

2.5 Interior

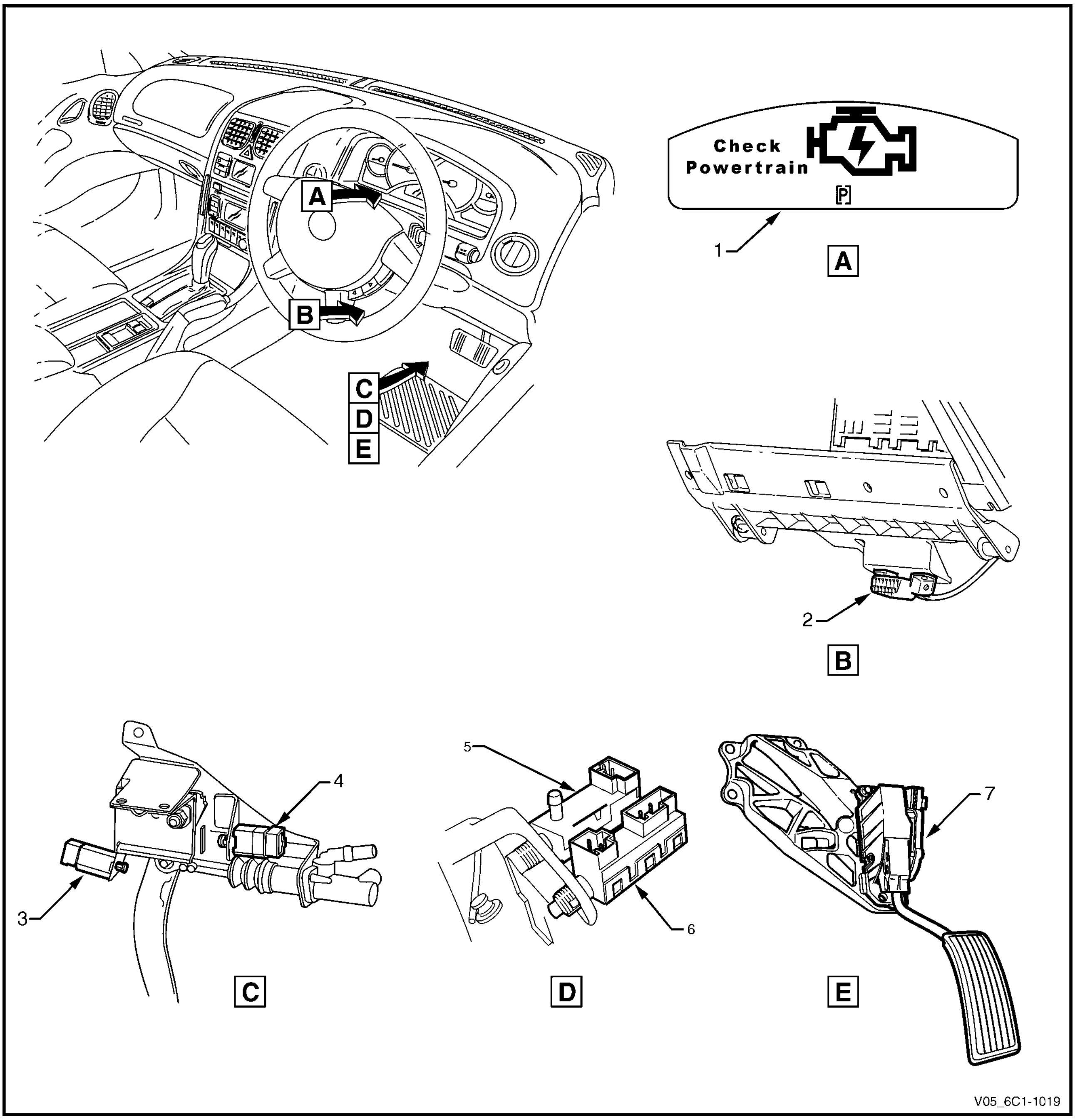

Figure 6C1-1 – 7

Legend

1 Check Powertrain Icon
2 Data Link Connector (DLC)
3 Clutch Pedal Cruise Control Cancel Switch
4 Clutch Pedal Position Switch
5 Extended Brake Pedal Travel and Brake Pedal Cruise Control Cancel Switch
6 Stop Lamp and BTSI Switch Assembly
7 Accelerator Pedal Assembly

3 System Operation

The engine control module (ECM) is the control centre of the V6 engine management system. The ECM constantly monitors and evaluates inputs from various sensors and switches. Based on these inputs, the ECM controls the operation of the engine management system. Refer to Figure 6C1-1 – 8 for the illustration of the inputs and outputs of the ECM.

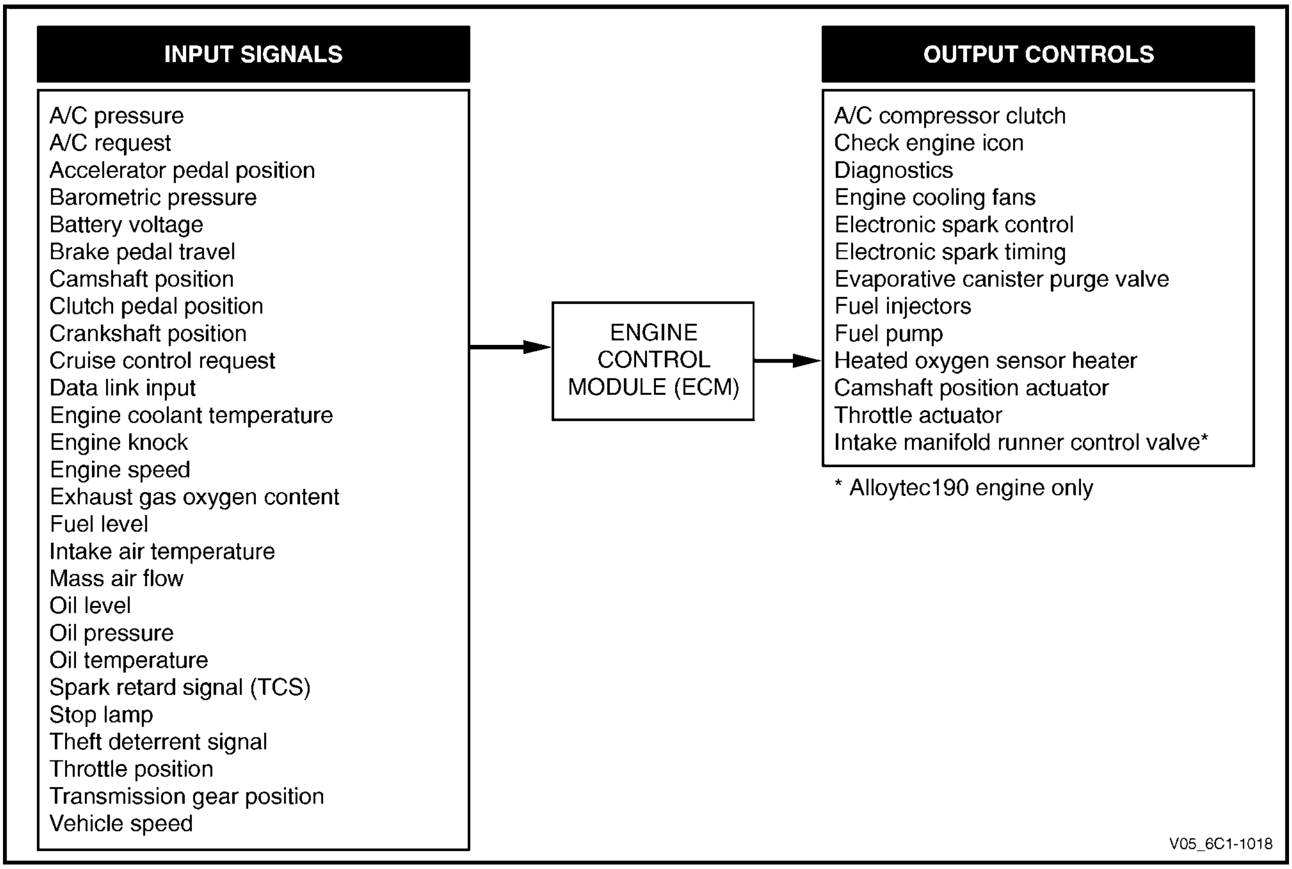

Figure 6C1-1 – 8

3.1 Fuel Delivery System

Fuel System Pressure

When the ignition switch is turned on, the ECM energises the fuel pump circuit and the fuel pump runs and builds up pressure in the fuel system. The fuel pump will continue to operate if the engine is started or as long as the engine is cranking or running and the ECM detects crankshaft position (CKP) sensor signal pulses. If the CKP sensor signal pulses stop, the ECM de-energises the fuel pump circuit within two seconds, which stops the fuel pump operation.

The vehicle is fitted with a modular fuel pump and sender assembly that provides delivery of fuel from the fuel tank and information on the fuel level. The fuel delivery system is a single line, on-demand design. With the fuel pressure regulator incorporated into the modular fuel pump and sender assembly, the need for a return pipe from the engine is eliminated.

The electric fuel pump contained in the modular fuel pump and sender assembly provides fuel at a pressure greater than the regulated pressure which is supplied to the fuel rail. The fuel is then distributed through the fuel rail to six injectors located directly above each cylinder's two intake valves.

Having a single line fuel supply system reduces the internal temperature of the fuel tank by not returning hot fuel from the engine. In reducing the internal temperature of the fuel tank, lower evaporative emissions are achieved.

Unleaded fuel must be used to ensure correct emission parameters and engine operation. Leaded fuel damages the emission control system and use of leaded fuel can result in loss of emission warranty. Using unleaded fuel will also minimise any spark plug fouling and extend engine oil life.

Fuel Injection System

Each cylinder of the V6 engine is fitted with one fuel injector. The engine control relay applies ignition positive voltage to the fuel injector ignition circuit. The ECM controls the operation of the fuel injectors by applying a pulse width modulated (PWM) ground to the fuel injector control circuit to control each fuel injector on-time.

While the engine is running, the ECM constantly monitors the various inputs and recalculates the appropriate on-time for each injector. The calculation is based on the following:

- the injector flow rate,
- mass of fuel passed by the energised injector per unit of time,
- the desired air / fuel ratio, and
- actual air mass in each cylinder.

The ECM calculates the duration of the fuel injector on-time to deliver the correct amount of fuel for optimum drivability and emission control. The period of time the fuel injector is energised is called the injector on-time and is measured in milliseconds (thousandths of a second).

The V6 engine uses the sequential fuel injection system. Each fuel injector is energised individually at the correct moment during its firing stroke as the cylinder's intake valves are closing to provide enough time for the fuel to atomise completely and mix with the intake air.

Short Term Fuel Trim

The short term fuel trim (STFT) represents the duration of the fuel injector on-time as calculated by the ECM while the ECM is in Closed Loop mode. The STFT allows the ECM to calculate the fuel injector on-time based on the heated oxygen sensor (HO2S) signal input to the ECM. Therefore, the STFT is disabled when the ECM is in Open Loop mode.

- If the air / fuel mixture in the exhaust is balanced (lambda = 1) or when the STFT is disabled, the STFT value is 0%.
- When the HO2S sends an input signal to the ECM indicating the air / fuel mixture is rich, the STFT will be less than 0%, which indicates the ECM is decreasing the fuel injector on-time to reduce the amount of fuel in the air / fuel mixture.
- When the HO2S sends an input signal to the ECM indicating the air / fuel mixture is lean, the STFT will be greater than 0%, which indicates the ECM is increasing the fuel injector on-time to increase the amount of fuel in the air / fuel mixture.

The percentage values of the STFT range from -25% – 25% and are directly proportional to the duration of the fuel injector on-time.

Long Term Fuel Trim

The ECM stores the long term fuel trim (LTFT) in its memory to adjust the fuel injector on-time according to the long term changes or deterioration in the engine components. The normal LTFT value is 0%.

The following describes the LTFT operation when the engine air filter is dirty that causes a restricted intake airflow fault condition:

1. The HO2S sends an input signal to the ECM the air / fuel mixture is rich because of the reduced airflow. The STFT may reduce to a value of -10%, which decreases the fuel injector on-time to reduce the amount of fuel in the air / fuel mixture supplied to the engine.

   Without the use of the LTFT, the restricted airflow caused by the dirty air filter may reduce the STFT value to -10% until the air filter is replaced. This will decrease the range of negative adjustment available to the STFT to compensate for other factors.

2. When the ECM detects the STFT has remained at -10% for a specific period, the ECM switches to the LTFT. The LTFT adjusts the duration of the fuel injector on-time until the air / fuel mixture in the exhaust is balanced (lambda = 1) and the STFT value returns to 0%.

3. The ECM stores this Long Term FT value in its memory, which is used to calculate the base fuel injector on-time.

The percentage values of the Long Term FT range from -100% – 100%. If the ECM detects the LTFT values are outside the specified percentage range for a predetermined period, the ECM will set a Diagnostic Trouble Code and switch to Open Loop mode.

3.2 Air / Fuel Control System

The engine control module (ECM) controls the amount of air and fuel delivered into each of the engine cylinders. Based on the various ECM inputs, the ECM switches to the following air / fuel control system mode to provide the optimum air / fuel ratio under all engine operating conditions.

Starting Mode

When the ignition switch is moved to the START position and the engine begins to turn, a prime pulse may be injected to speed starting. As soon as the ECM receives an input signal from the camshaft position (CMP) and crankshaft position (CKP) sensor and determines which cylinder is in the firing stroke, the ECM applies a pulse width modulated (PWM) ground to the injector control circuit. The ECM monitors mass air flow, intake air temperature, engine coolant temperature, and throttle position to determine the required fuel injector on-time required for starting the engine.

Run Mode

The engine switches to run mode when the engine speed reaches 480 r.p.m. after being started. The run mode has two sub-modes called Open Loop and Closed Loop.

Open Loop Mode

The heated oxygen sensor (HO2S) does not produce a usable signal voltage output until it reaches operating temperature. Therefore, while the HO2S is below its operating temperature, the ECM switches to open loop mode.

In open loop, the ECM ignores the signals from the HO2S and calculates the required injector pulse width based primarily on inputs from the mass air flow (MAF), intake air temperature (IAT), and engine coolant temperature sensors. The system will stay in the open loop mode until the HO2S produce a usable output.

Closed Loop Mode

Once the HO2S reaches operating temperature and starts producing its own signal voltage output, the ECM switches to the closed loop mode.

In closed loop mode, the ECM initially calculates injector pulse width based on the same sensors used in open loop, and additionally the ECM uses the oxygen sensor signals to modify and fine tune the fuel pulse width calculations to precisely maintain the ideal 14.7 to 1 air / fuel ratio.

Acceleration Mode

The ECM monitors and calculates input signals from the accelerator pedal position (APP) and MAF sensor signals to determine when the vehicle is being accelerated. If the ECM detects the accelerator pedal is depressed and there is a demand for the vehicle to accelerate, the ECM switches to acceleration mode. In acceleration mode, the ECM increases the fuel injector on-time to provide more fuel accordingly.

Deceleration Mode

The ECM monitors and calculates input signals from the APP and MAF sensor signals to determine when the vehicle is being decelerated. If the ECM detects the vehicle is decelerating, the ECM switches to deceleration mode. In deceleration mode, the ECM decreases the fuel injector on-time, or disables the fuel injectors for short periods, to reduce exhaust emissions and improve fuel economy.

Fuel Shut-off Mode

To protect the engine from damage or to improve the vehicle's driveability, the ECM switches to the fuel shut-off mode. In fuel shut-off mode, the ECM performs the following:

- The ECM disables the six fuel injectors under the following conditions:
  - ignition off – to prevent engine dieseling,
  - ignition on but no ignition reference signal – prevents flooding or backfiring,
  - at high engine speed – greater than the red line (rev limiter),
  - at high vehicle speed – greater than the rated tire speed (vehicle speed limiter), or
  - extended high speed closed throttle coast-down – reduces engine emissions and increases engine braking.
- The ECM selectively disables the appropriate number of fuel injectors under the following conditions:
  - torque management enabled – transmission shifts or abusive maneuvers, or
  - traction control enabled – in conjunction with brake application.

Battery Voltage Correction Mode

The ECM monitors the battery voltage circuit to ensure the voltage available to the engine management system stays within the specified range. A low system voltage changes the voltage across the fuel injectors, which affects the fuel injector flow rate. In addition, a low system voltage fault condition may cause other engine management system components to malfunction.

The ECM switches to battery voltage correction mode when the ECM detects a low battery voltage fault condition. While in battery voltage correction mode, the ECM performs the following functions to compensate for the low system voltage:

- increases the injector on-time to maintain the correct amount of fuel being delivered, and
- increases the idle speed to increase the generator output.

Limp Mode

The programming in the ECM software allows the engine to run in a back-up fuel strategy or limp mode when the ECM fails to receive signal inputs from critical sensors or when a critical engine management fault condition exists.

The ECM switches to limp mode to enable the vehicle to be driven until service operations can be performed.

Engine Protection Mode

Engine protection mode is engaged to protect engine components from friction damage in the event of an engine over-temperature condition being detected by the ECM.

When the ECM is in engine protection mode, fuel injectors are systematically disabled and re-activated. The injectors that have been shut down allow the air being drawn into the engine to assist with engine cooling.

Clear Flood Mode

If the engine is flooded with fuel during starting and will not start, the clear flood mode can be manually selected by depressing the accelerator pedal to wide open throttle (WOT). In this mode, the ECM will completely disable the fuel injectors, and will maintain this state during engine cranking as long as the ECM detects a WOT condition with engine speed less than 1,000 r.p.m.

3.3 Ignition Control System

The electronic ignition system provides a spark to ignite the compressed air / fuel mixture at the correct time. The ECM maintains correct spark timing and dwell for all engine operating conditions. The ECM calculates the optimum spark parameters from information received from the various sensors and triggers the appropriate ignition module / coil to fire the spark plug.

3.4 Starter Motor Operation

The engine control module controls the activation of the start relay in response to inputs from:

- Ignition switch,
- battery,
- theft deterrent engine crank inhibitor (a function of the theft deterrent system), and
- automatic transmission gear selector position / clutch pedal position switch for vehicles with manual transmissions.

Auto Start Feature

Once the ignition switch has been turned to the START position, the starter motor will crank the engine.

If the ignition switch is returned to the ON position before the engine has started, the starter motor will continue to operate until the engine starts. If the engine fails to start, cranking will continue for approximately four seconds from when the ignition switch was returned to the ON position.

Turning the ignition switch to the OFF position will cancel the Auto Start and the starter motor will stop cranking. For further information on the starter motor system, refer to Section 6D1-2 Starting System – V6.

Clutch Pedal Position Switch

The clutch pedal position switch provides an input to the ECM to ensure the clutch pedal is depressed while the vehicle is being started. For further information on the clutch pedal position switch, refer to 4.6 Clutch Pedal Switch Assemblies – Manual Vehicles Only.

3.5 Throttle Actuator Control System

Description

The throttle actuator control (TAC) system is used to improve emissions, fuel economy and driveability. The TAC system eliminates the mechanical link between the accelerator pedal and the throttle plate and eliminates the need for a cruise control module and idle air control motor. The TAC system comprises of:

- The accelerator pedal assembly which includes:
  - the accelerator pedal,
  - the accelerator pedal position (APP) sensor one,
  - the accelerator pedal position (APP) sensor two.

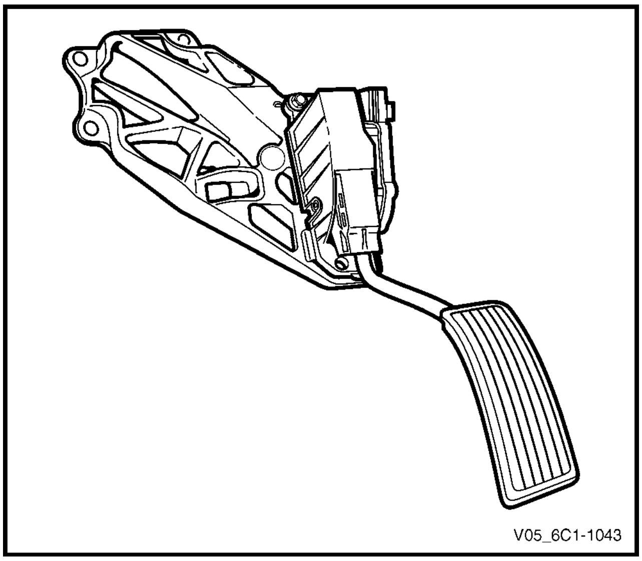

Figure 6C1-1 – 9

WARNING

To avoid serious personal injury, never attempt to rotate the throttle plate manually whilst the throttle body harness connector is connected to the throttle body.

- The throttle body assembly which includes:
  - the throttle position (TP) sensor one,
  - the throttle position (TP) sensor two,
  - the throttle actuator control (TAC) motor, and
  - the throttle plate.
- The engine control module (ECM).

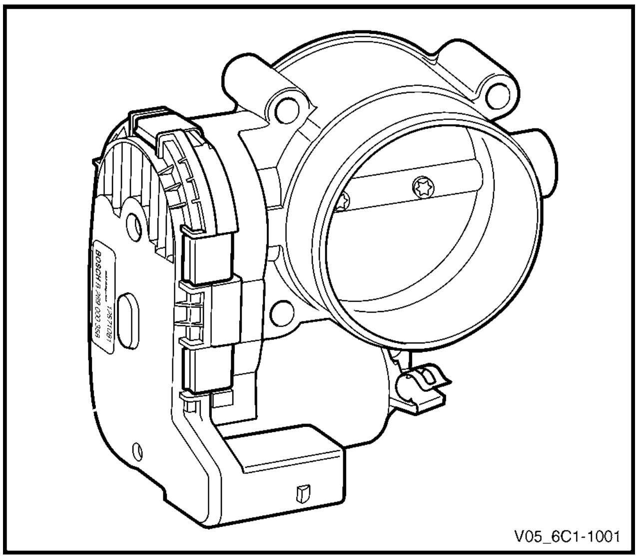

Figure 6C1-1 – 10

The ECM monitors the accelerator pedal position through the two APP sensors and processes this information along with other system sensor inputs to command the throttle plate to a certain position.

The throttle plate is controlled by a direct current motor called the throttle actuator control motor. The ECM operates this motor in the forward or reverse direction by controlling battery voltage and / or ground to two internal drivers. The throttle plate is held at a rest position of seven percent open using a constant force return spring. This spring holds the throttle plate to the rest position when there is no current flowing to the actuator motor.

The ECM monitors the throttle plate angle through two TP sensors. Using this information, the ECM can precisely adjust the throttle plate.

The ECM performs diagnostics that monitor the voltage levels of both APP sensors, both TP sensors and the throttle actuator control motor circuit. It also monitors the spring return rate. These diagnostics are performed at different times based on whether the engine is running, not running, or whether the ECM is currently in a throttle body relearn procedure.

Two sensors within the accelerator pedal assembly and throttle body assembly are used to provide redundancy. If a malfunction is detected, the throttle plate is moved to a pre-determined position.

Every ignition cycle, the ECM performs a quick throttle return spring test to ensure the throttle plate can return to the seven percent rest position from the zero percent position. This is to ensure the throttle plate can be brought to the rest position in case of an actuator motor circuit failure.

Throttle Body Relearn Procedure

The ECM stores values that include the lowest possible TP sensor positions (zero percent), the rest positions (seven percent), and the spring return rate. These values will only be erased or overwritten if the ECM is reprogrammed or if a throttle body relearn procedure is performed.

NOTE

If the battery has been disconnected, the ECM performs a throttle body relearn procedure once the battery has been reconnected and the ignition turned on.

The ECM performs a throttle body relearn procedure anytime the ignition is turned on and the following conditions have been met:

- the engine has been off for greater than 29 seconds,
- the engine speed is less than 40 r.p.m.,
- the vehicle speed is 0 km/h,
- the engine coolant temperature (ECT) is 5 – 60°C; if Tech 2 is used to perform the relearn procedure, the ECT is 5 – 100°C,
- the intake air temperature (IAT) is greater than 5 – 60°C; if Tech 2 is used to perform the relearn procedure, the IAT is 5 – 100°C,
- the APP sensor angle is less than 15 percent, and
- ignition voltage is greater than 10 V.

The throttle body relearn procedure is performed 29 seconds after the ignition is turned on. The ECM commands the throttle plate from the rest position (even percent open) to full closed (zero percent), then to around 10 percent open. This procedure takes about six – eigth seconds. If any faults occur in the TAC system, a DTC sets. At the start of this procedure, the Tech 2 TAC Learn Counter parameter should display 0, then count up to 11 after the procedure is completed. If the counter did not start at 0, or if the counter did not end at 11, a fault has occurred and a DTC should set.

TAC System Default Actions / Reduce Power Modes

The ECM switches to the following reduce power modes if the ECM detects a fault condition in the TAC system:

- If an APP sensor circuit fault or TP sensor circuit fault is detected, the ECM limits engine torque so the vehicle cannot reach speeds of greater than 100 km/h. The ECM remains in this reduce power mode during the entire ignition cycle, even if the fault is corrected.
- If there is a fault condition with the throttle actuator control circuits, a throttle actuator command vs. actual position fault, a return spring check fault, or a TP sensor one circuit fault, the ECM limits engine speed to 2500 r.p.m. and three – six fuel injectors are randomly disabled. At this time the reduce power indicator is commanded on. The ECM remains in the reduce power mode during the entire ignition cycle even if the fault is corrected.

NOTE

If a TP sensor one or throttle actuator control circuit fault is present at the time the vehicle is at idle, with no accelerator pedal angle, the engine may stall.

Forced Engine Shutdown

A further safety feature which is built into the TAC system is the ECM will initiate an engine shut down if, the ECM's internal monitoring functions detects a serious internal fault, the fuel injectors will be turned off.

3.6 Camshaft Position Actuator Control System

The Alloytec engine has variable timing on the intake camshafts only, while the Alloytec190 engine has variable timing on both intake and exhaust camshafts.

NOTE

The parameters under which variable valve timing will occur is very complex. The conditions outlined below is a brief summary of the conditions the ECM uses to determine the point at which variable valve timing will commence:

The ECM will only initiate variable timing if all of the following conditions exist:

- Engine coolant temperature is greater than -12°C and less than 130°C,
- air intake temperature is greater than -48°C,
- engine oil temperature is greater than -10°C and less than 155°C, and
- engine speed is greater than 1000 r.p.m. for longer than two seconds, and less than 7320 r.p.m.

The ECM adjusts the timing of each camshaft by applying a pulse width modulated (PWM) control signal to the camshaft position (CMP) actuator solenoid valve (1), which in turn controls the oil pressure / flow to the CMP actuator (2). Refer to Figure 6C1-1 – 11.

The engine control module (ECM) advances or retards the camshaft timing, based on various system inputs, to provide optimum valve overlap over the entire operating range of the engine.

The intake camshafts can be advanced up to 25 camshaft degrees, and the exhaust camshafts can be retarded up to 25 camshaft degrees.

The crankshaft position (CKP) sensor and the camshaft position (CMP) sensors are used to monitor changes in the camshaft positions.

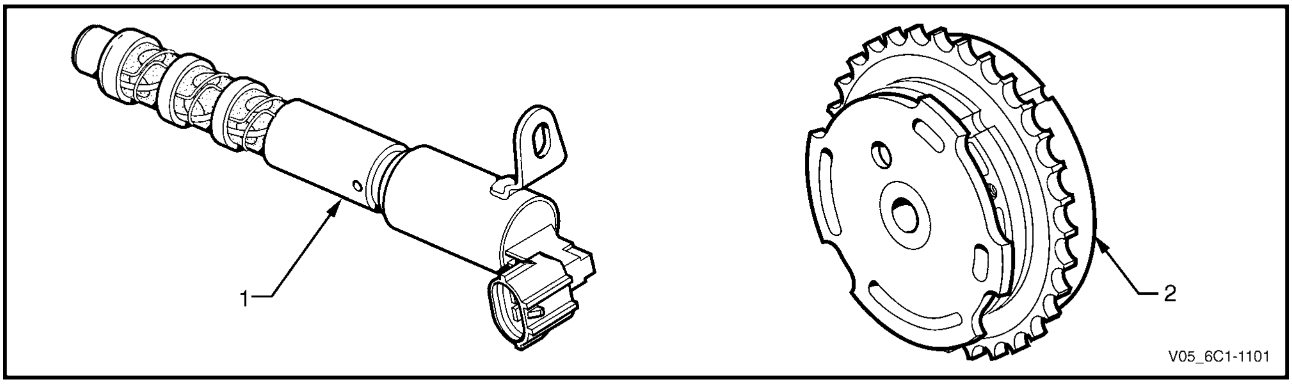

Figure 6C1-1 – 11

Operation

A CMP actuator assembly is fitted to each variable camshaft (1). The actuator has an outer housing (2) that is driven by the engine timing chain, and an inner housing (3), refer to Figure 6C1-1 – 12.

When the engine is not running or at idle, a lock pin (4) contained in each actuator locks the camshaft to the outer housing, to prevent camshaft timing adjustment.

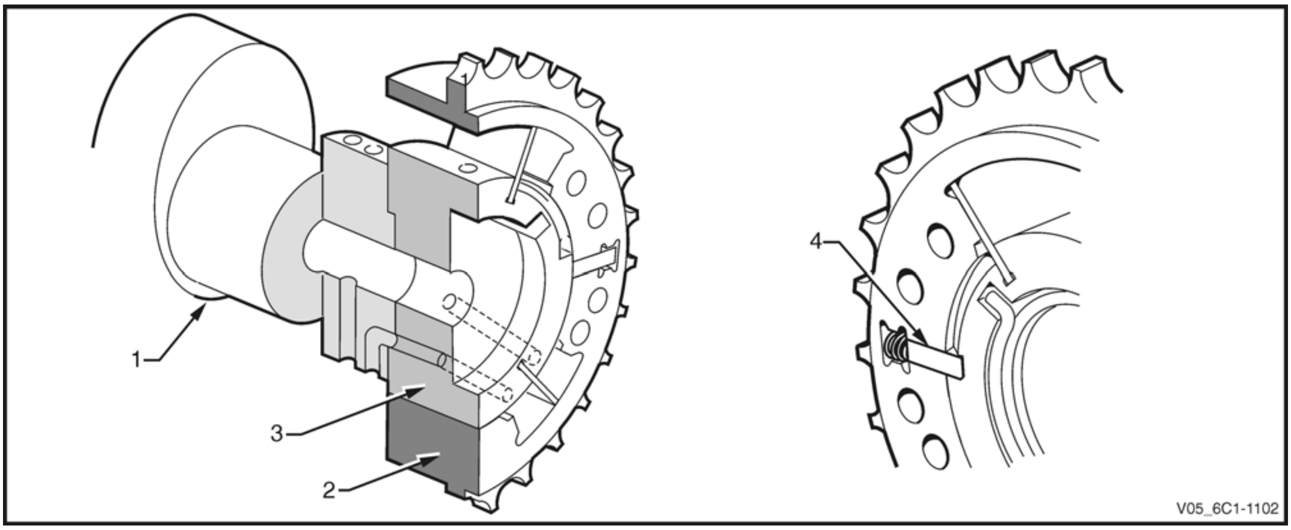

Figure 6C1-1 – 12

Variable Valve Timing Phases

Variable Valve Timing – Increase

When the ECM commands the actuator solenoid valve (1) to redirect the oil pressure supply to the CMP actuator (2), the oil pressure supply (A) moves the lock pin (3) in the direction of the arrow (B) to unlock the actuator, refer to Figure 6C1-1 – 13.

At the same time, oil pressure (A) is applied to the one side of each of the four fixed vanes (4). The oil pressure builds up, until it overcomes the CMP actuator return spring (not shown) and starts to advance the camshaft (intake) or retard the camshaft (exhaust). As the camshaft starts to move, the oil (C) on the opposite side of the vane where the oil pressure is currently being applied, drains back through the CMP actuator oil galleries and out through the actuator solenoid valve (D).

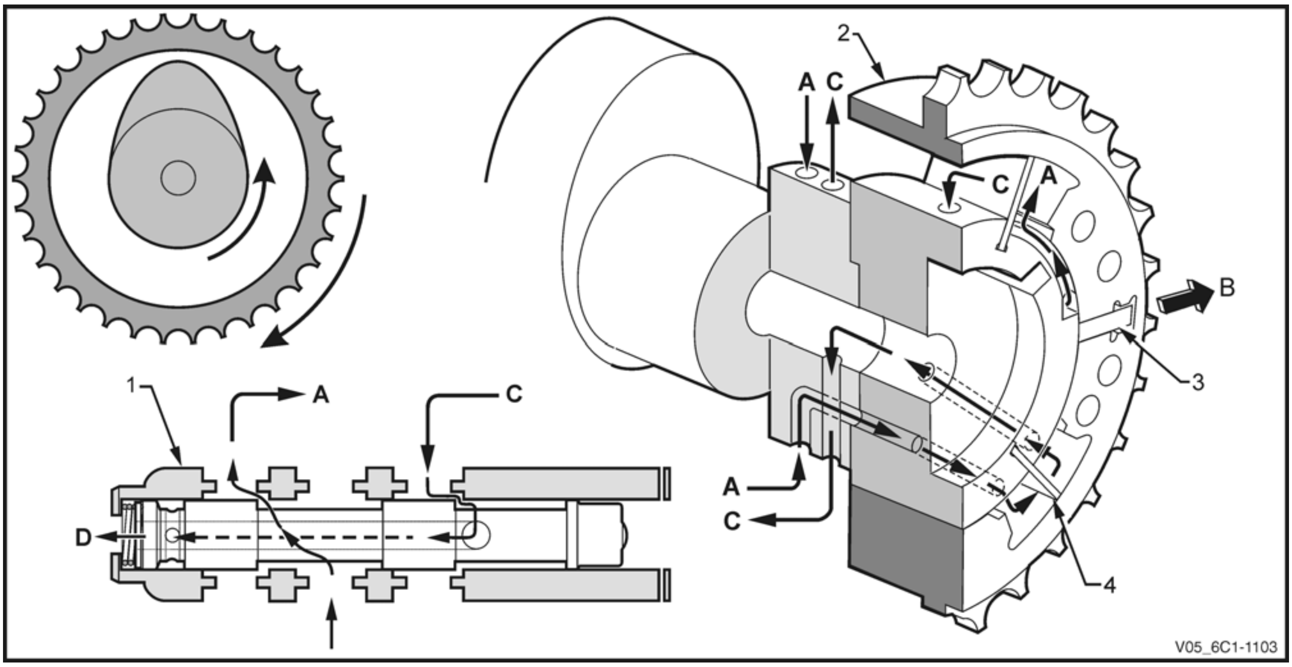

Figure 6C1-1 – 13

Variable Valve Timing – Maintained

When the valve timing has been advanced or retarded, and the timing is to be maintained, the actuator solenoid valve (1) applies oil pressure (A) and (C) to both sides of the fixed vane.

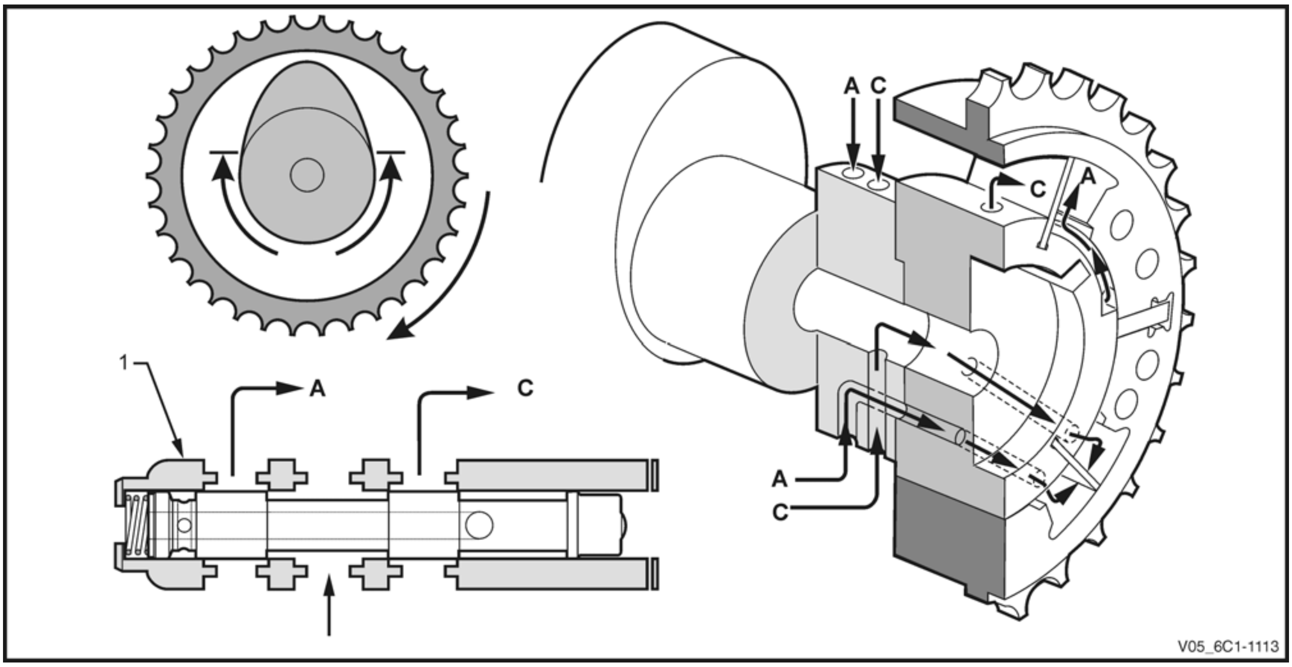

Figure 6C1-1 – 14

Variable Valve Timing – Reduced

When the amount of variable valve timing is reduced, the actuator solenoid valve (1) applies oil pressure (C), to one side of the vane (2) (this is to the opposite side of the vane used to increase the valve timing).

As the camshaft begins to move, the oil (A) on the opposite side of the vane where the oil pressure is currently being applied, drains back through the CMP actuator oil galleries and out through the actuator solenoid valve (D).

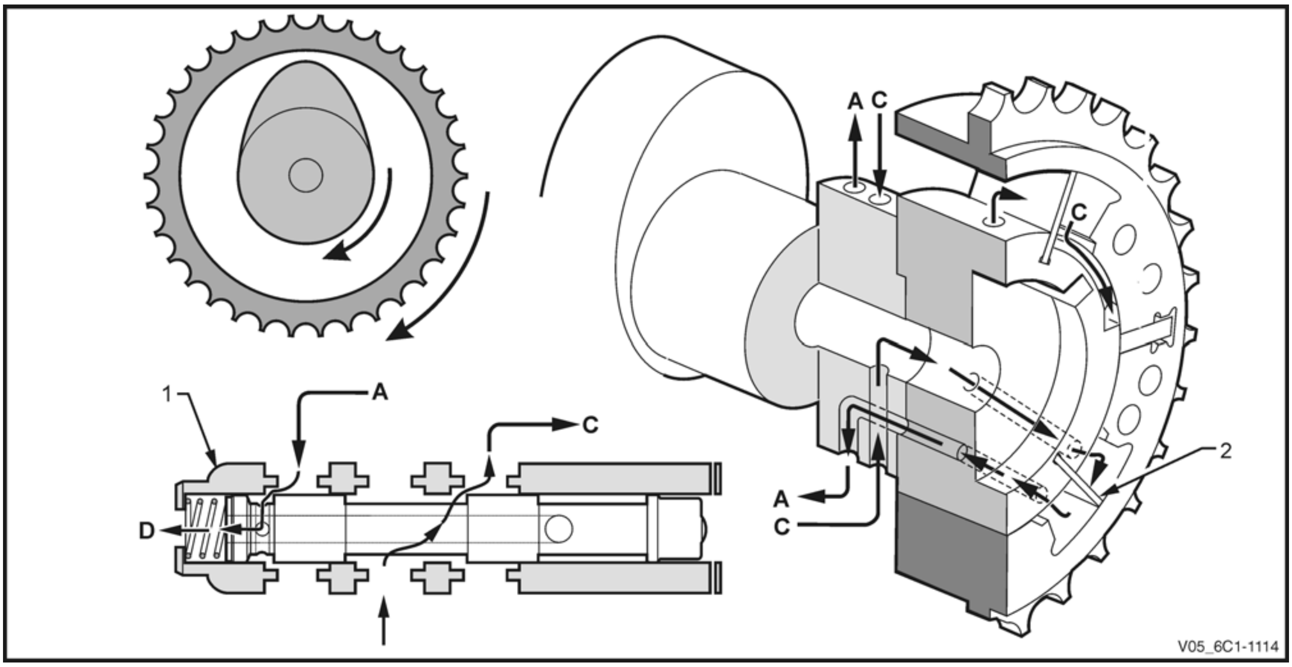

Figure 6C1-1 – 15

3.7 Cruise Control System

The cruise control system integrates with the engine control module (ECM) through the powertrain interface module (PIM), to control the electronic throttle actuator and maintain the vehicle at the speed set by the driver.

When the cruise ON-OFF button is pressed, the PIM, on receiving the input from the cruise control switch, outputs a signal via the serial data bus to the ECM. The ECM recognises the command from the PIM to engage the cruise control. The ECM then provides a signal for the instrument cluster, via the PIM, to inform the user that cruise control is Engaged.

The user activates the cruise control at a desired speed greater than 40 km/h by rotating the cruise control switch assembly to SET–DECEL. The PIM, on receiving the input from the cruise control switch, outputs a signal via the serial data bus to the ECM. The ECM then activates the cruise control and sets the speed. The ECM receives all the various inputs required to maintain the correct speed and then controls the throttle plate depending on the load on the engine (ascending or descending hills, etc).

The cruise control is deactivated by either pressing the brake pedal, clutch pedal or by the cruise control ON-OFF button. In each of these instances, the ECM receives an input when any of these switches are activated. For further information on the cruise control system, refer to Section 12E Cruise Control.

3.8 Brake Torque Management

Brake torque management places limits on engine torque when the brakes are applied, regardless of the accelerator pedal position (APP). The conditions under which brake torque management occur are as follows:

- The accelerator has been depressed before the brakes are applied,
- the brakes are applied and the ECM receives an input from the stop lamp switch,
- vehicle speed is greater than 5 km/h,
- engine speed is greater than 1200 r.p.m. and
- conditions exist for greater than 2.5 seconds.

When brake torque management has been implemented, the torque is reduced by altering the throttle plate opening by 25%. The ECM will monitor the rate at which the vehicle is slowing and adjust the throttle plate opening accordingly.

3.9 Emission Control Systems

Evaporative Emission Control System

The evaporative emission control system used is the activated carbon (charcoal) canister storage method. Fuel vapour is drawn from the fuel tank into the canister where it is held by the activated carbon until the ECM commands the evaporative emission (EVAP) purge solenoid valve to open.

The ECM energises the EVAP purge solenoid valve by applying a pulse width modulated (PWM) ground to the EVAP purge solenoid valve control circuit.

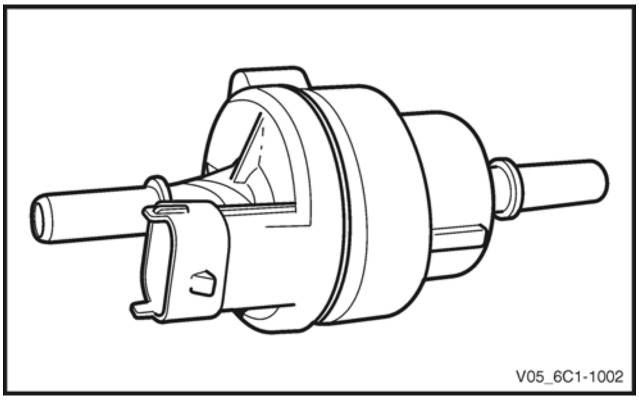

Figure 6C1-1 – 16

When ECM commands the EVAP valve (1) to open, the fuel vapours are drawn from the canister line (2) into the intake manifold where it is consumed in the normal combustion process.

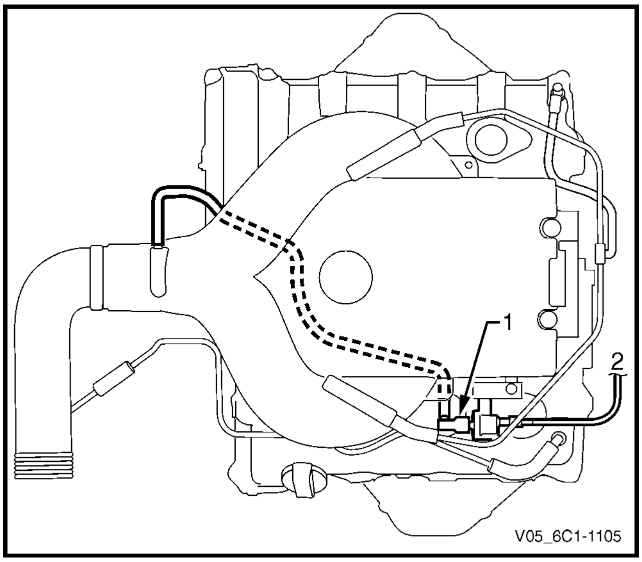

Figure 6C1-1 – 17

The ECM energises the EVAP valve when the appropriate conditions have been met, such as:

- engine coolant temperature is less than 20°C at cold start up and the engine has been running longer than three minutes and 10 seconds, or
- engine coolant temperature is greater than 80°C and the engine has been running longer than five seconds, or
- engine is not in decel fuel cut-off mode and the throttle opening is less than 96%, or
- the engine is in closed loop fuel mode.

A higher purge rate is used under conditions that are likely to produce large amounts of vapour, when the following conditions have been met:

- intake air temperature is greater than 50°C, or
- engine coolant temperature is greater than 100°C, or
- the engine has been running for greater than 15 minutes.

The EVAP purge PWM duty cycle varies according to operating conditions determined by mass air flow, fuel trim and intake air temperature. The EVAP canister purge valve is re-enabled when throttle position angle decreases below 96%. For further information on the evaporative emission control system, refer to Section 8A1 Fuel System.

Engine Ventilation System

The engine ventilation system contains a Positive crankcase ventilation (PCV) valve (1) located in the right-hand camshaft cover. A hose is routed from the PCV valve to each side of the intake manifold which provides an even distribution of crankcase fumes, thereby improving spark plug reliability and a reduction in emissions.

A breather pipe is routed from the intake manifold to the left-hand camshaft cover and provides fresh filtered air from the intake duct to the engine.

For further information of the engine ventilation system, refer to Section 6A1 Engine Mechanical – V6.

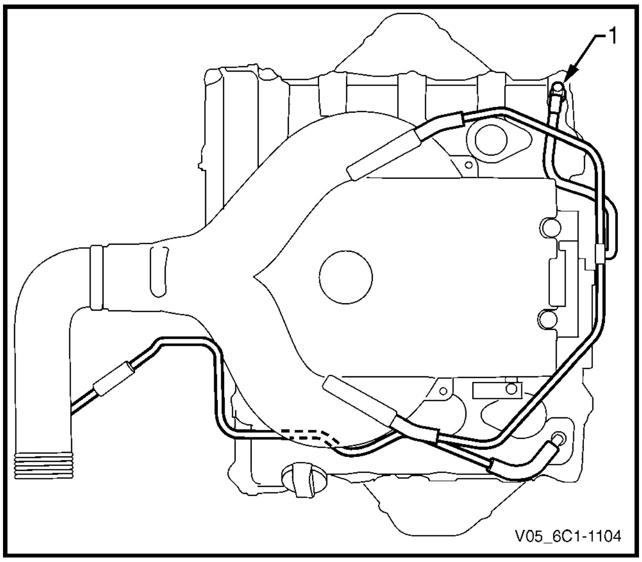

Figure 6C1-1 – 18

3.10 Serial Data Communication System

The engine control module (ECM) communicates directly with the following control units using the General Motors local area network (GM LAN) serial data communication protocol:

- Transmission control module (TCM)
- ABS-TCS electronic control unit (ECU) (If fitted)
- Powertrain interface module (PIM)

The body control module (BCM) and other vehicle control modules communicate with each other through the universal asynchronous receive and transmit (UART) serial data protocol where the BCM is the Bus Master. Refer to Section 12J Body Control Module for further information.

As the GM LAN serial data communication protocol is not compatible with the UART serial data communication protocol, a powertrain interface module (PIM) is integrated to the serial data communication system to perform the following tasks (Refer to Section 6E1 Powertrain Interface Module – V6):

- Translate the GM LAN serial data transmitted by the ECM, TCM and ABS-TCS ECU into a UART serial data that can be received and recognised by the BCM, Instrument Cluster Assembly and other vehicle control modules.
- Translate the UART serial data transmitted by the BCM and other vehicle control modules into GM LAN serial data that can be received and recognised by the ECM, TCM and ABS-TCS ECU.
- Translate the cruise control switch signal into a GM LAN serial data that can be received and recognised by the ECM.

3.11 Self Diagnostics System

The ECM constantly performs self-diagnostic tests on the engine management system. When the ECM detects a malfunction, it also stores a diagnostic trouble code (DTC). A stored DTC will identify the problem area(s) and is designed to assist the technician in rectifying the fault. In addition, DTCs are classified as either Current or History DTC.

Depending on the type of DTC set, the ECM may command the multifunction display (MFD) Check Powertrain icon (1) to illuminate and warn the driver there is a fault in the Engine Management System. Refer to Section 12C Instrumentation for further information on the Check Powertrain Icon.

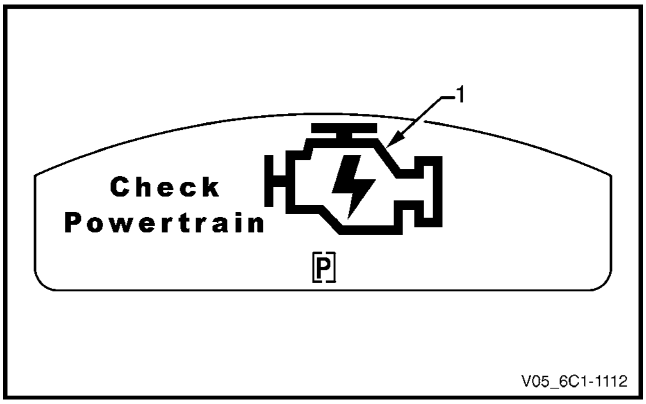

Figure 6C1-1 – 19

3.12 Service Programming System

The ECM has an Electronically erasable programmable read only memory (EEPROM) where the software and calibration information required to operate the engine management system are stored.

The ECM features a service programming system (SPS) to flash program the EEPROM in the ECM with the latest ECM software to provide optimum performance, driveability and emissions control or to program a new ECM.

Flash programming refers to the SPS used to transfer (or download) ECM data from a computer terminal to the vehicle's ECM. The system is designed so the vehicle verification procedures are required to eliminate EEPROM tampering that could increase engine emission levels.

There are three main flash programming techniques:

1 Direct programming (pass through). This is where the vehicle's data link connector (DLC) is connected directly to a computer terminal. On screen directions are then followed for downloading.

2 Remote Programming. Reprogramming information is downloaded from a computer terminal to Tech 2. Tech 2 is then connected to the vehicle's DLC. On screen directions are then followed for downloading.

3 Off-board Programming. The off-board programming method is used when a re-programmable ECM must be programmed while it is removed from the vehicle. For example, an independent repair facility may find it necessary to replace a faulty ECM. On flash programming equipped vehicles, the replacement ECM must be programmed with data for the specific vehicle identification number (VIN) or the vehicle may not operate properly.

3.13 Theft Deterrent System

The vehicle incorporates a theft deterrent system. After the ignition switch is turned to the ON position, and the powertrain interface module (PIM) has authenticated the body control module (BCM), the PIM sends an encrypted security code to the engine control module (ECM). The ECM compares the received security code with its own security code, and if it is valid, the ECM enables the vehicle to be started. For further information and diagnosis of the theft deterrent system, refer to Section 12J Body Control Module.

For further information on the PIM, refer to Section 6E1 Powertrain Interface Module – V6.

4 Component Description and Operation

4.1 A/C Refrigerant Pressure Sensor

The engine control module (ECM) applies a positive 5 V reference voltage and ground to the air-conditioner (A/C) refrigerant pressure sensor (1). The A/C refrigerant pressure sensor provides signal voltage to the ECM that is proportional to the A/C refrigerant pressure. The ECM monitors the A/C refrigerant pressure sensor signal voltage to determine the refrigerant pressure.

- The A/C refrigerant pressure sensor voltage increases as the refrigerant pressure increases.
- When the ECM detects the refrigerant pressure exceeds a predetermined value, the ECM activates the cooling fans to reduce the refrigerant pressure.
- When the ECM detects the refrigerant pressure is too high or too low, the ECM disables the A/C clutch to protect the A/C compressor from damage.

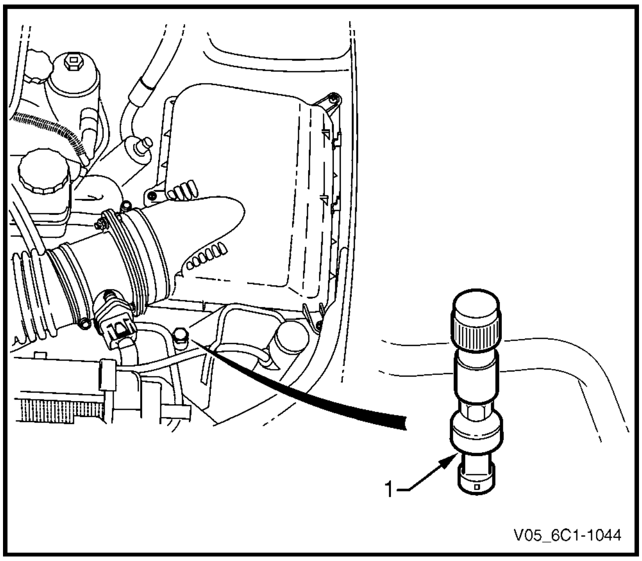

Figure 6C1-1 – 20

4.2 Brake Pedal Switches

Stop Lamp and BTSI Switch Assembly

The stop lamp and BTSI switch assembly (1) is located on the brake pedal support.

The engine control module (ECM) uses the stop lamp switch signal voltage to determine when the brake pedal is depressed.

The ECM uses this input for brake torque management, for cross referencing the stop lamp switch against the cruise control cancel switch for correct operation etc. For further information on brake torque management, refer to 3.8 Brake Torque Management.

The stop lamp switch is a normally open switch with the brake pedal at rest.

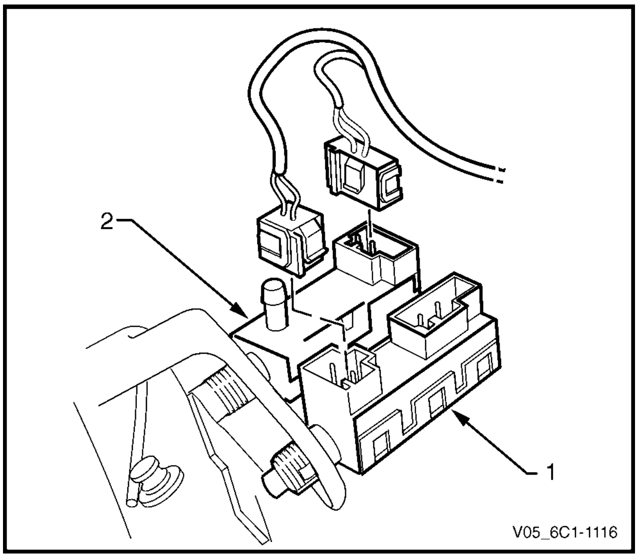

Figure 6C1-1 – 21

Cruise Control Release and Extended Brake Travel Switch Assembly

The cruise control release and extended brake travel switch assembly (2) is located on the brake pedal support. Refer to Figure 6C1-1 – 21.

The engine control module (ECM) uses the cruise control release switch signal voltage to determine when the brake pedal is depressed. The ECM uses this input to cancel cruise control operation, for cross referencing the cruise control release switch against the stop lamp switch for correct operation etc.

The engine control module (ECM) uses the extended brake travel switch signal voltage to determine when full brake pedal travel has been achieved. The ECM uses this input to compensate for the air being used by the brake booster.

Both of these switches are normally closed when the brake pedal is in the rest position, opening when the pedal is pressed. Activation of this switch removes the signal to the ECM.

For further information on the cruise control system, refer to 3.7 Cruise Control System, refer to 3.8 Brake Torque Management.

4.3 Barometric Pressure Sensor

The barometric pressure (BARO) sensor measures barometric (atmospheric) pressure. The ECM uses this signal to make corrections to the operating parameters of the system based on changes in air density, since the oxygen content of atmospheric air varies proportionally to air density (barometric / atmospheric pressure). Barometric pressure is affected mainly by altitude and climate.

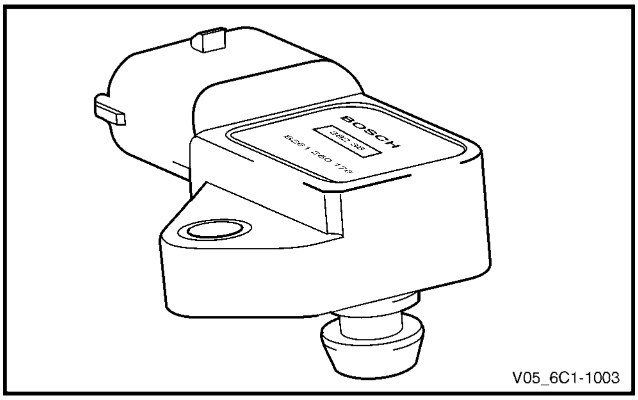

Figure 6C1-1 – 22

The BARO sensor provides a voltage signal to the ECM that is a function of barometric pressure. It does this through a series of deformation resistors, which change resistance when a mechanical force is applied. This force is applied to the resistors by a diaphragm on which the atmospheric pressure acts.

The ECM supplies the BARO sensor with a 5 V reference and a ground circuit.

4.4 Camshaft Position Sensor

Alloytec engines are fitted with two camshaft position (CMP) sensors, one for each intake camshaft. Alloytec190 engines have four, one for every camshaft.

The CMP sensors are used by the ECM to determine the position of the camshafts. In conjunction with the crankshaft position sensor, the CMP enables the ECM to determine engine rotational position.

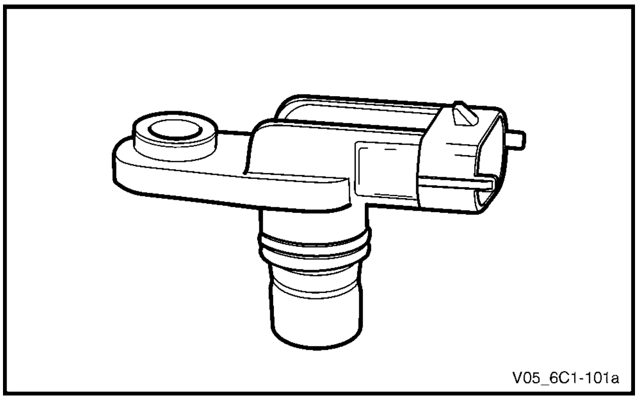

Figure 6C1-1 – 23

The CMP sensor operates on the dual-Hall sensing principle. The sensor contains two hall elements (1) which operate in conjunction with a two-track trigger wheel (2) mounted on the camshaft.

As the tracks (3) on the trigger wheel pass the elements, magnetic flux affects a voltage in the Hall elements. The integrated circuit inside the sensor conditions the signal generated by the Hall elements to provide a rectangular wave on / off signal to the ECM.

The ECM supplies the CMP sensors with a 5 V reference and ground circuit.

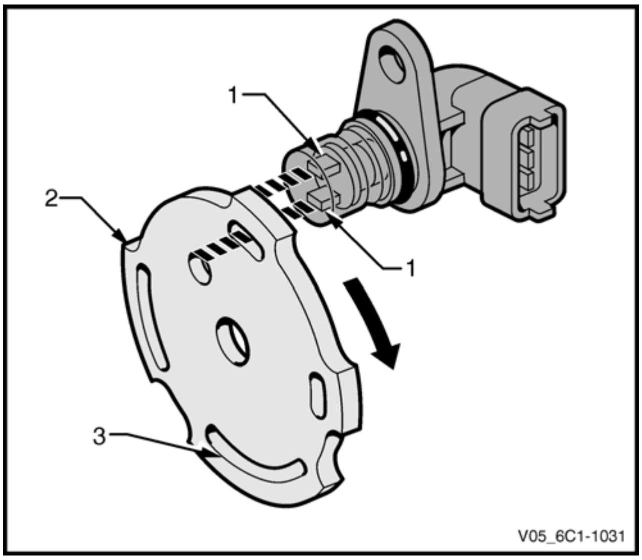

Figure 6C1-1 – 24

4.5 Crankshaft Position Sensor

In conjunction with the camshaft position sensor, the crankshaft position (CKP) sensor enables the ECM to determine engine rotational position. The CKP is also used to determine engine speed (r.p.m.).

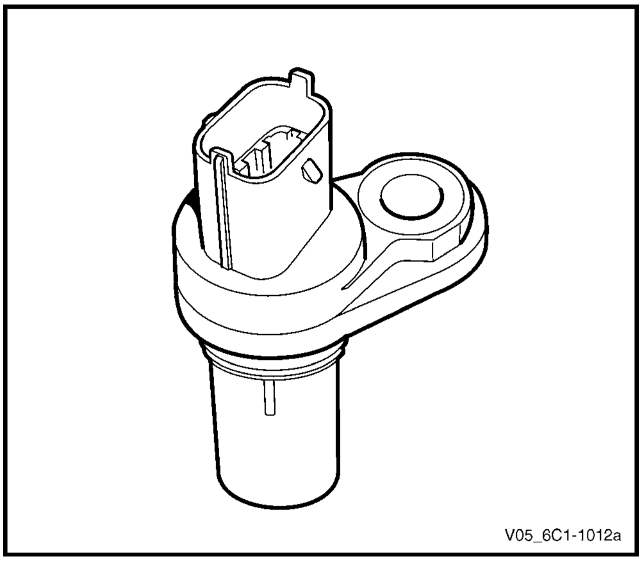

Figure 6C1-1 – 25

The CKP sensor (1) operates on the variable reluctance (pulse generator) sensing principle. It contains a magnet and pickup coil and is used in conjunction with a 58 tooth ferromagnetic reluctor wheel (2) attached to the crankshaft (3).

As the crankshaft rotates, the reluctor wheel revolves past the CKP, causing fluctuations in the magnetic field inside the sensor. This action creates an AC voltage across the pickup coil which is processed by the ECM. An increase in engine speed will increase the output voltage and frequency.

The reluctor wheel teeth are placed six degrees apart. Having only 58 teeth leaves a 12 degree open span, which creates a signature pattern that enables the ECM to determine the crankshaft position. The ECM determines which two cylinders are approaching the top dead centre based on the crankshaft position sensor signal. The CMP sensor signals are used by the ECM to determine which cylinder is on the firing stroke.

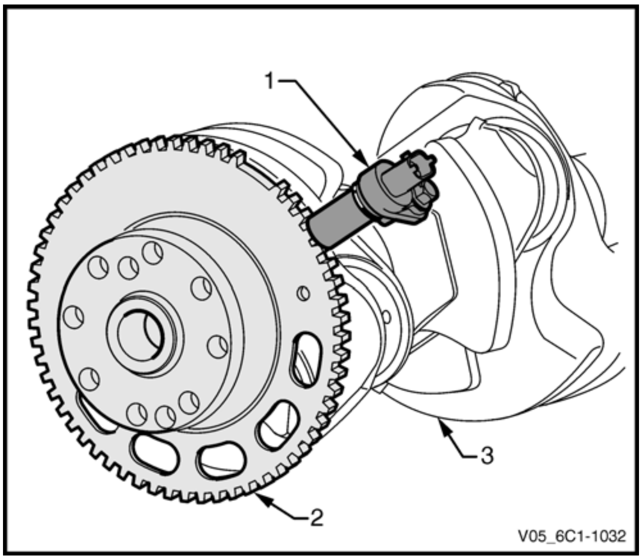

Figure 6C1-1 – 26

4.6 Clutch Pedal Switch Assemblies – Manual Vehicles Only

There are two clutch pedal switch assemblies, the cruise control cancel switch (1) and the clutch pedal position switch (2).

The cruise control cancel switch is normally closed when the clutch pedal is at rest, opening when the pedal is pressed. Activation of this switch removes the signal to the ECM which will then deactivate the cruise control. For further information on the cruise control system, refer to Section 7A1 Clutch – V6.

The clutch pedal position switch is normally open when the clutch pedal is at rest, closing when the pedal is fully pressed. Activation of this switch sends a signal to the ECM which will then allow operation of the starter motor. For further information on the starting system, refer to Section 6D1-2 Starting System – V6.

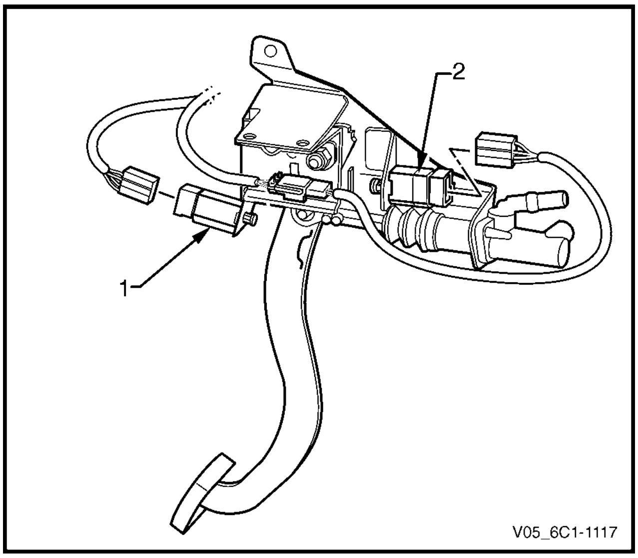

Figure 6C1-1 – 27

4.7 Engine Control Module

Located at the right front of the engine assembly, the engine control module (ECM) monitors input signals from the various sensors and switches connected to the engine management system. The ECM processes this information, to control the following:

- fuel delivery and injection system,
- throttle actuation system,
- inlet manifold runner control valve (Alloytec190 engine only),
- camshaft position actuators,
- ignition system,
- on-board diagnostics,
- the engine cooling fans, and
- the air-conditioner compressor clutch (where fitted).

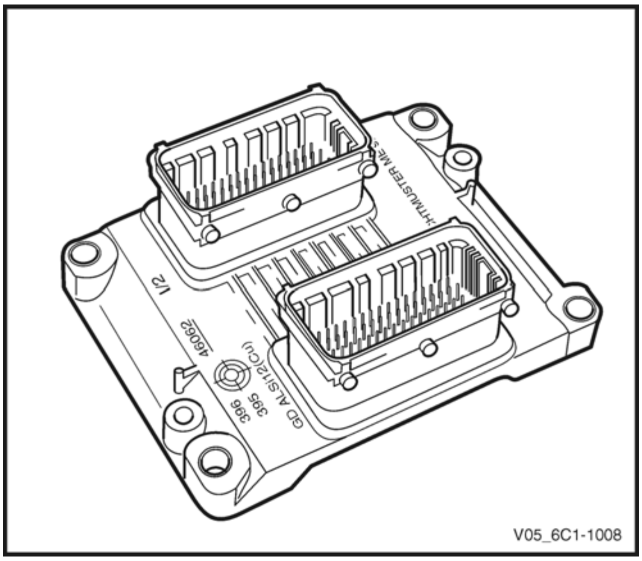

Figure 6C1-1 – 28

The ECM supplies 5 V to the various sensors through pull-up resistors to the internal regulated power supplies.

The ECM controls output circuits such as the injectors, cooling fan relays, etc. by applying control signal to the ground circuits of the components through transistors or a device inside the ECM called a driver. The exception to this is the fuel pump relay control circuit. The fuel pump relay is the only ECM controlled circuit where the ECM controls the 12 V sent to the coil of the relay. The ground side of the fuel pump relay coil is connected to engine ground.

The ECM communicates directly with the various control units within the vehicle using the General Motors local area network (GM LAN) serial data communication protocol. Refer to 3.10 Serial Data Communication System.

4.8 Engine Coolant Temperature Sensor

The engine coolant temperature (ECT) sensor is a thermistor, which is a resistor that changes it's resistance value based on temperature.

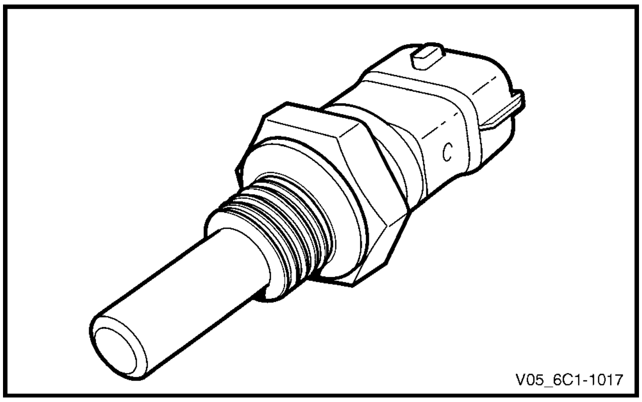

Figure 6C1-1 – 29

The ECT is mounted in the engine coolant stream and as it is a negative temperature coefficient (NTC) type, low engine coolant temperature produces a high sensor resistance while high engine coolant temperature causes low sensor resistance.

Legend

A Temperature

B Resistance

The ECM provides a 5 V reference signal to the ECT and monitors the return signal which enables it to calculate the engine temperature.

The ECM uses this signal to make corrections to the operating parameters of the system based on changes in engine coolant temperature.

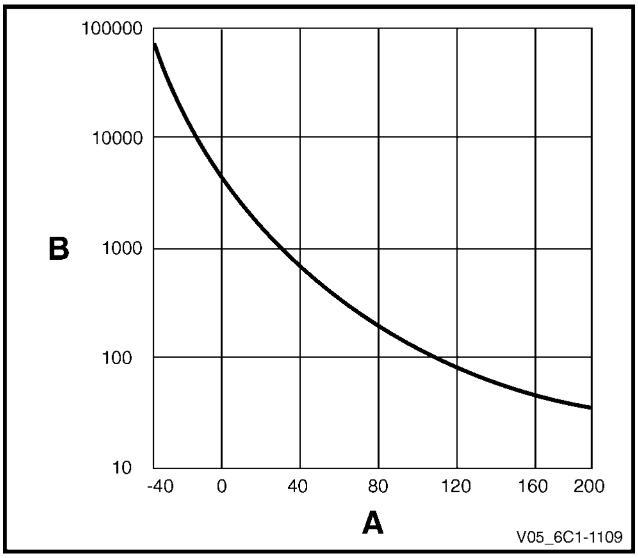

Figure 6C1-1 – 30

4.9 Electric Cooling Fans

The ECM controls the operation of two dual speed electric engine cooling fans. The ECM operates the fans at either low or high speed based on inputs from engine coolant temperature, vehicle speed and air-conditioner request. For further information on cooling fan operation refer to Section 6B1 Engine Cooling – V6.

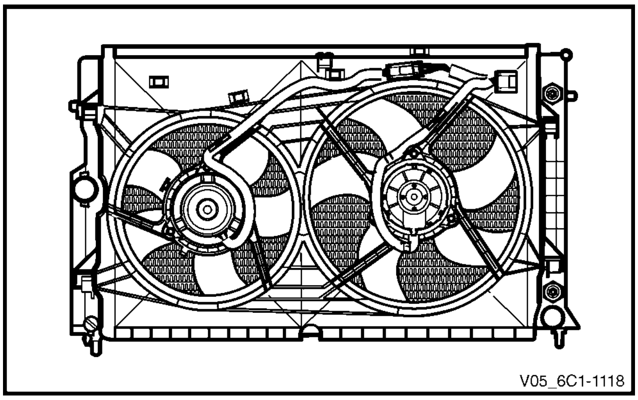

Figure 6C1-1 – 31

4.10 Engine Oil Level and Temperature Sensor

The engine oil level (EOL) and temperature sensor is a dual purpose sensor and is fitted in the engine sump. It combines a switch to signal oil level and a thermistor type temperature sensor to provide oil temperature signal to the ECM.

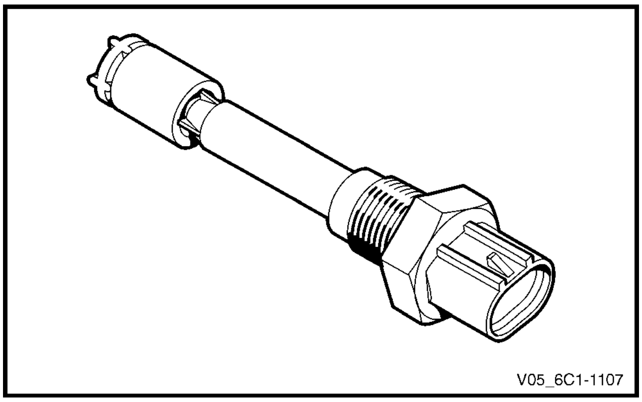

Figure 6C1-1 – 32

Engine Oil Temperature Sensor

The engine oil temperature sensor is a negative temperature coefficient (NTC) type. At low engine oil temperature, the sensor produces a high resistance, whilst at high temperature the sensor produces a low resistance.

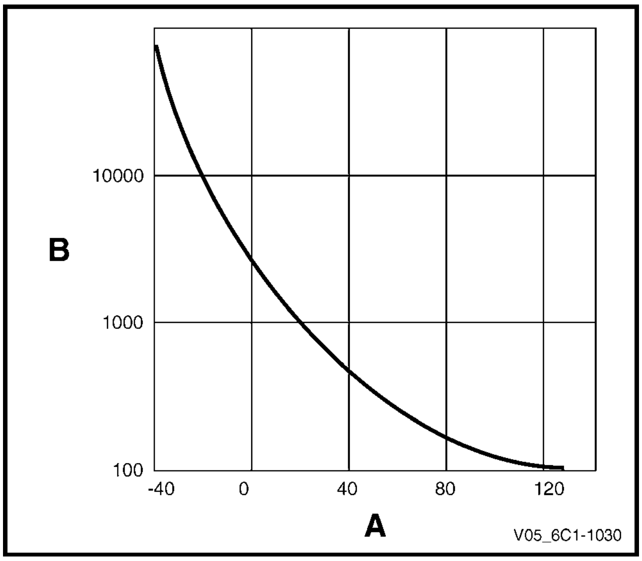

Figure 6C1-1 – 33

Legend

A Temperature

B Resistance

The ECM provides a 5 V reference signal to the engine oil temperature sensor and monitors the return signal which enables it to calculate the engine oil temperature.

The ECM uses oil temperature as one of the inputs in determining the point at which camshaft phasing will commence. For further information on camshaft phasing, refer to 3.6 Camshaft Position Actuator Control System.

Engine Oil Level Sensor

The engine oil level sensor is comprised of a magnetic reed switch (1) contained within the sensor, a float (2) and a magnetic pin (3). The magnetic reed switch is a normally open switch, which closes when a magnet field is present.

When the engine oil level is within specifications, the pin on the inside of the float is pushed up against the reed switch (view A). When the oil level drops and the magnetic pin moves away from the reed switch (view B), the switch contacts opens.

The ECM provides a 5 V reference signal to the engine oil temperature sensor and monitors the return signal. The ECM only monitors the oil level signal prior to engine start-up, and once the engine is cranking, the ECM disregards the oil level sensor signal.

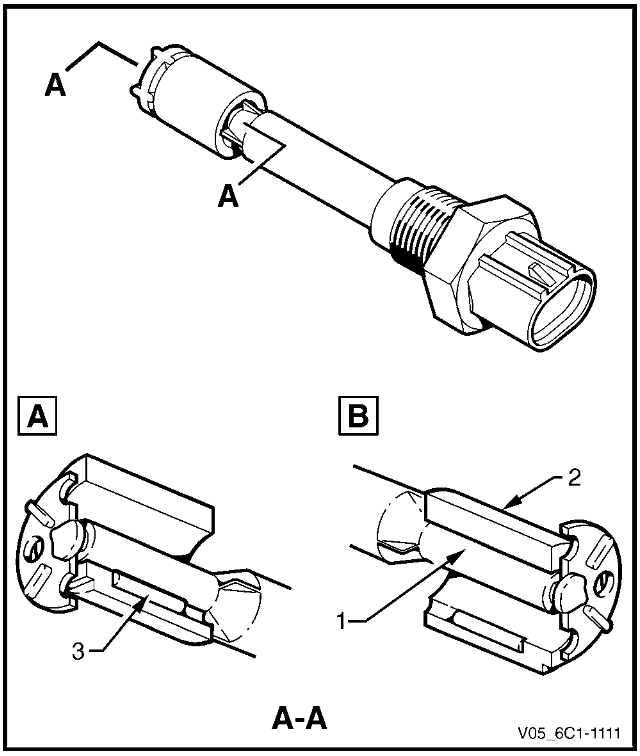

Figure 6C1-1 – 34

4.11 Engine Oil Pressure Sensor

The engine oil pressure (EOP) sensor measures engine oil pressure. When the EOP sensor signal is below a certain value, the ECM activates the Check Oil warning message in the instrument cluster multi-function display (MFD).

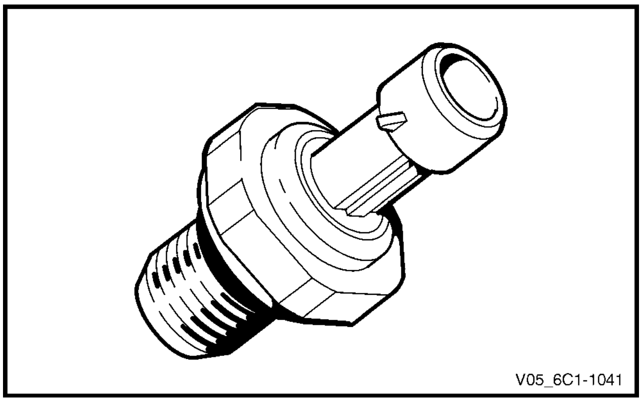

Figure 6C1-1 – 35

The EOP sensor provides a voltage signal to the ECM that is a function of engine oil pressure. It does this through a series of deformation resistors (1), which change resistance when a mechanical force is applied. This force is applied to the resistors by a diaphragm on which the engine oil pressure acts (2).

The sensor has an internal evaluation circuit (3) and is provided with a 5 V reference voltage, a ground and a signal circuit.

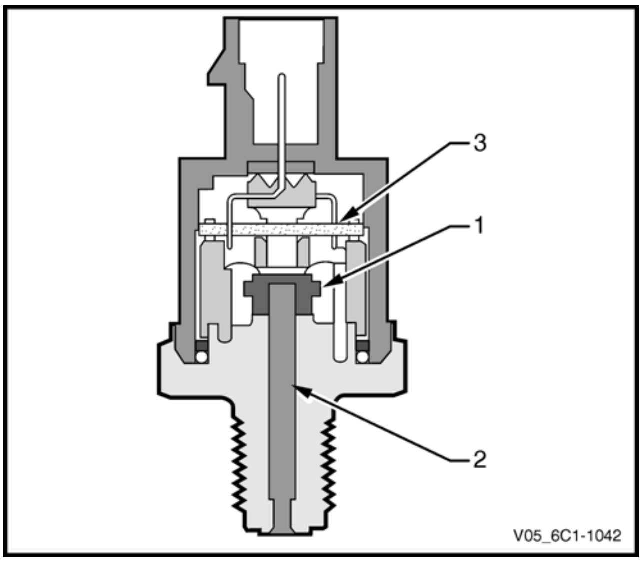

Figure 6C1-1 – 36

4.12 Fuel Injectors

A fuel injector is a solenoid device that is controlled by the ECM. The six injectors deliver a precise amount of fuel into the intake ports as required by the engine.

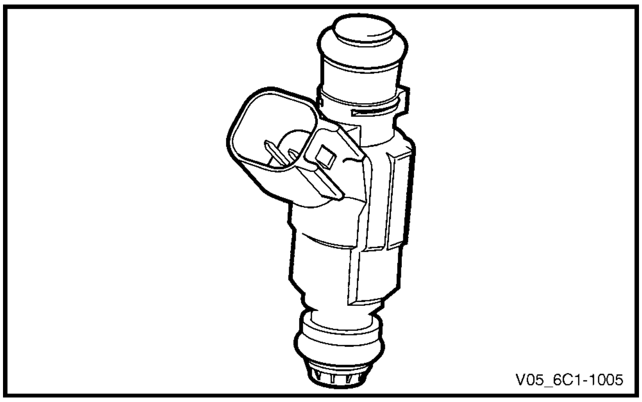

Figure 6C1-1 – 37

The fuel port (1) connects to the fuel rail. A strainer (2) is provided in the port to protect the injector from fuel contamination.

In the de-energised state (no voltage), the valve needle and sealing ball assembly (3) are held against a cone-shaped valve seat (4) by spring force (5) and fuel pressure.

When the injector is energised by the ECM, the valve needle, which has an integral armature, is moved upward by the injector solenoids magnetic field, un-seating the ball.

An orifice plate (6), located at the base of the injector has four small holes which provide very fine atomisation of the fuel. The plate is insensitive to fuel deposits ensuring reliable fuel delivery.

The fuel is directed at each of the intake valves, causing the fuel to become further vaporised before entering the combustion chamber.

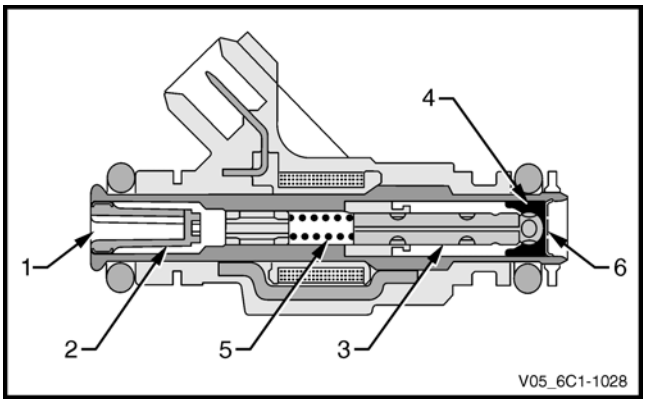

Figure 6C1-1 – 38

4.13 Fuel Rail Assembly

The fuel rail assembly is mounted on the lower intake manifold and distributes the fuel to each cylinder through individual fuel injectors. The fuel rail assembly consists of:

- the pipe that carries fuel to each injector,
- a fuel pressure test port,
- six individual fuel injectors,
- wiring harness, and
- wiring harness tray.

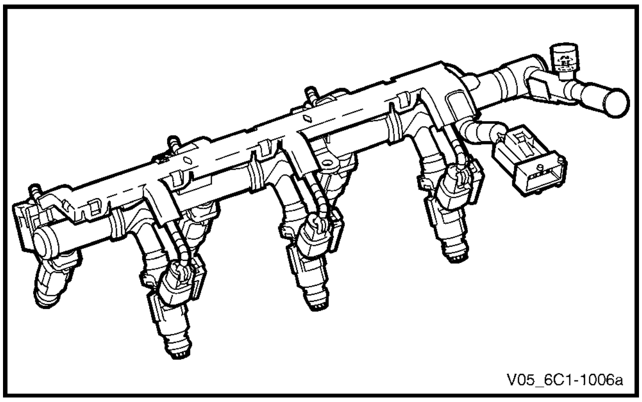

Figure 6C1-1 – 39

4.14 Heated Oxygen Sensors

The heated oxygen sensors (HO2S) are mounted in the exhaust system and enable the ECM to measure oxygen content in the exhaust stream. The ECM uses this information to accurately control the air / fuel ratio, because the oxygen content in the exhaust gas is indicative of the air / fuel ratio of engine combustion.

When the sensor is cold, it produces little or no signal voltage, therefore the ECM only reads the HO2S signal when the HO2S sensor is warm. As soon as the HO2S are warm and outputting a usable signal, the ECM begins making fuel mixture adjustments based on the HO2S signals. This is known as closed loop mode.

Alloytec engines are fitted with two LSF 4.2 two-step planar type HO2S, one in each exhaust pipe upstream of the catalytic converter. Alloytec190 engines have four HO2S, one LSU 4.2 wide-band planar type HO2S upstream of the catalytic converter in each exhaust pipe, and one LSF 4.2 two-step planar type HO2S in each exhaust pipe downstream of the catalytic converter.

LSF 4.2 Two-step Planar Heated Oxygen Sensors

The LSF 4.2 two-step planar heated oxygen sensors have four wires:

- The internal heater element supply, which has 12 V continually applied whenever the ignition is on.
- Heater element ground – The ECM applies pulse width modulated (PWM) ground to the HO2S heater control circuit to control the rate at which the sensor heats up. This reduces the risk of the sensor being damaged from heating up too quickly under certain conditions such as extreme cold temperatures. Once the sensor has reached the desired operating temperature, the ECM will monitor and continue to maintain the sensor temperature.
- Sensor signal to the ECM.
- Sensor ground.

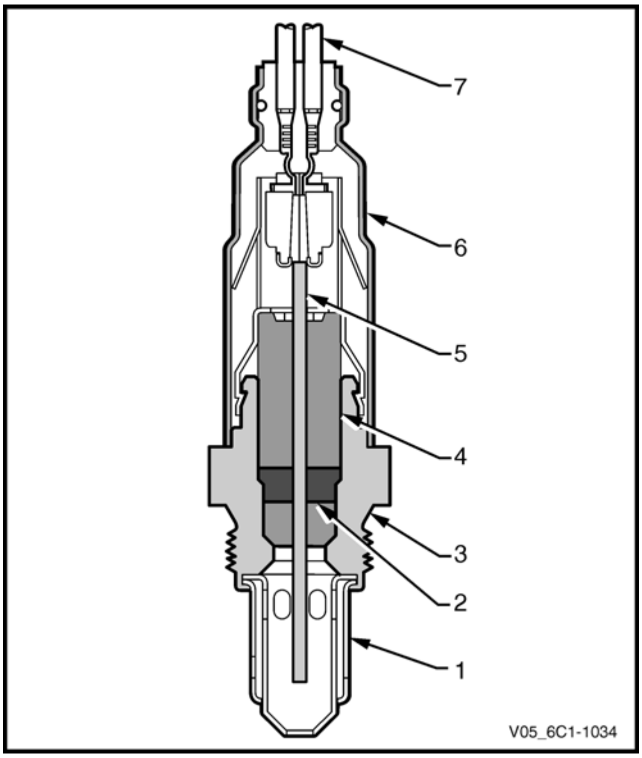

Figure 6C1-1 – 40

Legend

1 Protective Tube
2 Ceramic Seal Packing
3 Sensor Housing
4 Ceramic Support Tube
5 Planar Measuring Element
6 Protective Sleeve
7 Connection Cable

Measurement is achieved by comparing the oxygen content of the exhaust gas to the oxygen content of a reference gas (outside air) using the Nernst principle. Oxygen molecules from the exhaust gas will accumulate on the outer electrode, while oxygen molecules from the reference gas will accumulate on the inner electrode. This creates a voltage difference across the Nernst cell, between the two electrodes, which is the signal voltage to the ECM.

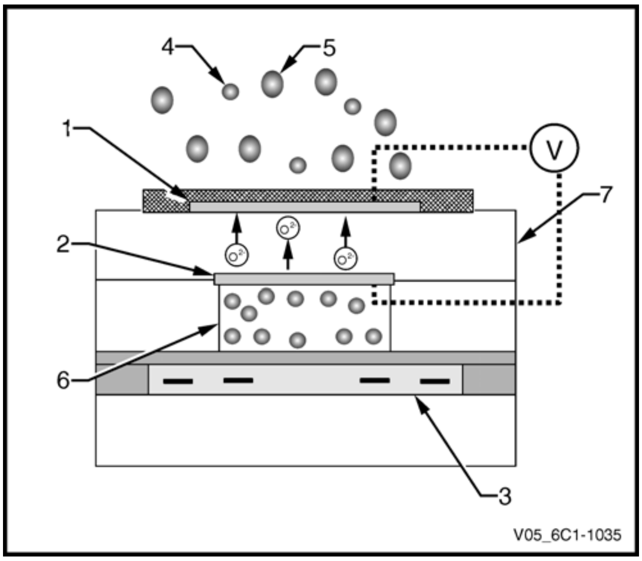

Figure 6C1-1 – 41

Legend

1 Outer Electrode
2 Inner Electrode
3 Heater Element
4 Oxygen Molecule (in exhaust stream)
5 Other Molecules (in exhaust stream)
6 Reference Gas (outside air)
7 Nernst Cell
V Signal Voltage

When the fuel system is correctly operating in the closed-loop mode, the oxygen sensor voltage output is rapidly changing several times per second, fluctuating from approximately 100mV (high oxygen content – lean mixture) to 900mV (low oxygen content – rich mixture). The transition from rich to lean occurs quickly at about 450-500 mV (air flow (A/F) ratio 14.7:1, or lambda = 1). Due to this, two-step HO2S sensors are also known as switching type HO2S sensors.

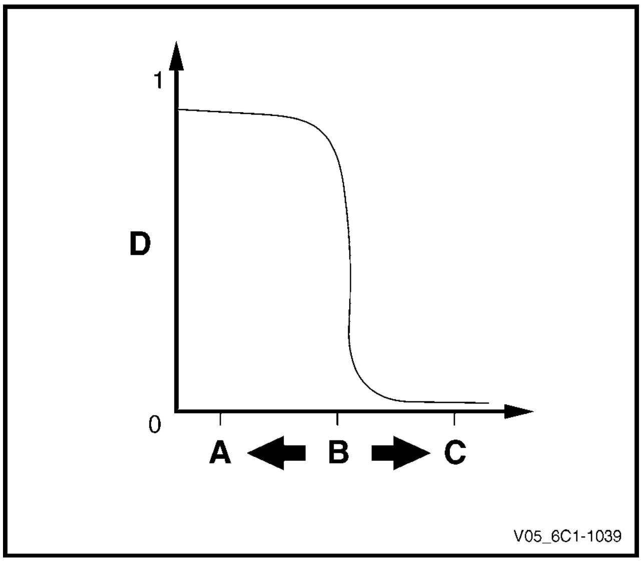

Figure 6C1-1 – 42

Legend

A	Rich Mixture
B	A/F Ratio 14.7:1 (Lambda = 1)
C	Lean Mixture
D	Sensor Voltage

LSU 4.2 Wide-band Planar Heated Oxygen Sensors

The LSU 4.2 wide-band planar heated oxygen sensors have six wires:

- The internal heater element supply, which has 12 V continually applied whenever the ignition is on.
- Heater element ground – The ECM applies pulse width modulated (PWM) ground to the HO2S heater control circuit to control the rate at which the sensor heats up. This reduces the risk of the sensor being damaged from heating up too quickly under certain conditions such as extreme cold temperatures. Once the sensor has reached the desired operating temperature, the ECM will monitor and continue to maintain the sensor temperature.
- Output voltage.
- Sensor ground.
- Trim current.
- Pumping current.

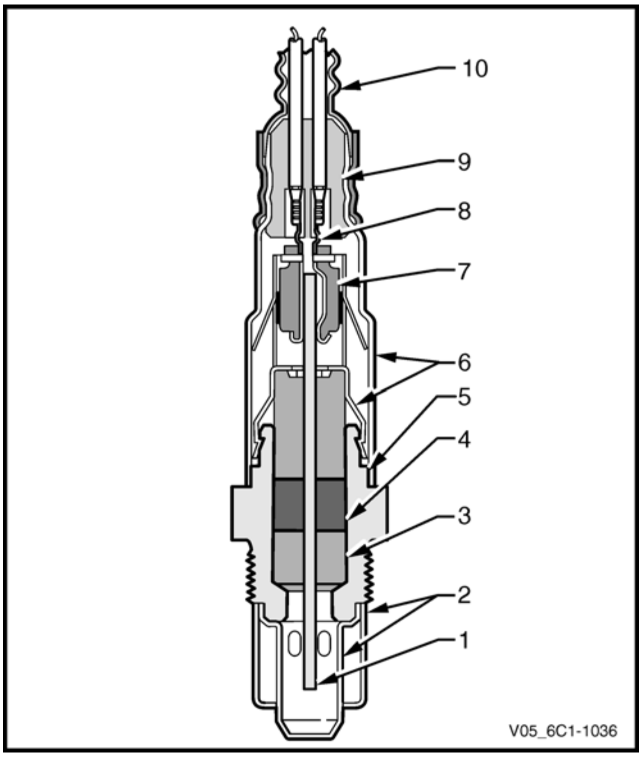

Figure 6C1-1 – 43

Legend

1	Measuring Cell (nernst cell and pump cell)
2	Double Protective Tube
3	Seal Ring
4	Seal Packing
5	Sensor Housing
6	Protective Sleeve
7	Contact Holder
8	Contact Clip
9	PTFE Sleeve (teflon)
10	PTFE Shaped Sleeve

Similar to the two-step HO2S, measurement is achieved by comparing the oxygen content of the exhaust gas to the oxygen content of a reference gas. However, the way in which the ECM calculates the exhaust oxygen content is different, and results in a continual signal. This allows the ECM to monitor not only whether the fuel mixture is rich or lean, but exactly how rich or how lean. The wide-band HO2S is basically a two-step HO2S with the addition of a pump cell.

The ECM applies a pump voltage across the pump cell, which causes oxygen to be pumped from the exhaust gas into or out of the diffusion gap through the diffusion barrier. While monitoring the Nernst cell, the ECM varies the pump current so the gas in the diffusion gap remains constant at an A/F ratio of 14.7:1 (nernst cell output of 450 mV).

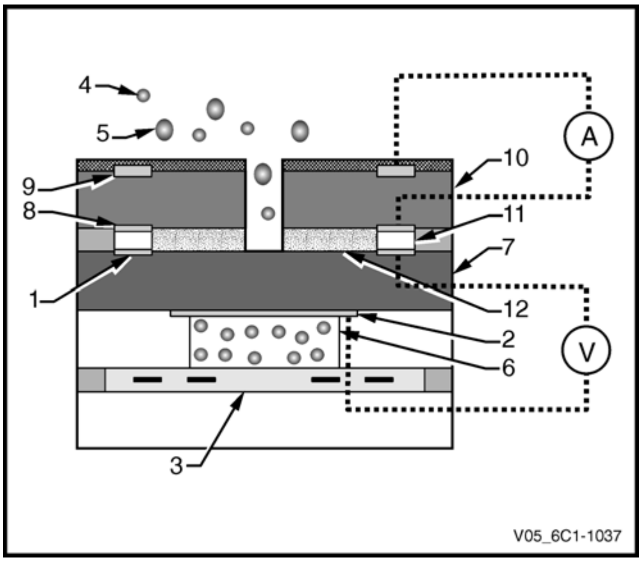

Figure 6C1-1 – 44

Legend

1 Outer Electrode
2 Inner Electrode
3 Heater Element
4 Oxygen Molecule (in exhaust stream)
5 Other Molecules (in exhaust stream)
6 Reference Gas (outside air)
7 Nernst Cell
8 Pump Cell Electrode
9 Pump Cell Electrode
10 Pump Cell
11 Diffusion Gap
12 Porous Diffusion Barrier
A Pump Current
V Nernst Cell Voltage

If the exhaust gas is lean, the pump cell pumps oxygen to the outside (positive pump current). If the exhaust gas is rich, oxygen is pumped from the exhaust gas into the diffusion gap (negative pump current). By monitoring how much it has to vary the pumping current, the ECM determines the exact A/F ratio.

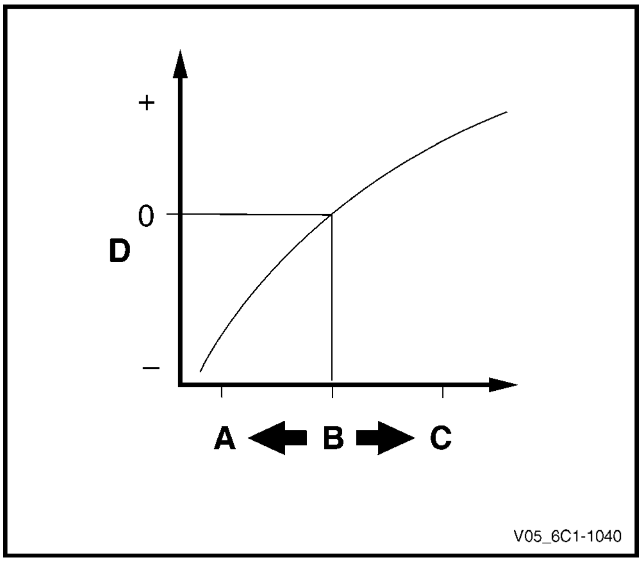

Figure 6C1-1 – 45

Legend

A Rich Mixture
B A/F Ratio 14.7:1 (Lambda = 1)
C Lean Mixture
D Sensor Current

4.15 Ignition Coil and Spark Plug

Long-life platinum tip spark plugs are used which, along with the ignition coil spark plug boot and spring, require replacement at 100,000 kilometre service intervals. The spark plugs, featuring a J-gap and a conical seat, do not require inspection between services, and must not be re-gapped.

Individual pencil-type ignition coils, one for each cylinder, are mounted in the centre of the camshaft covers, and have short boots connecting the coils directly to the spark plugs.

The pencil coil makes use of the space available in the spark plug cavity in the cylinder head and camshaft cover. As a pencil coil is always mounted directly on to the spark plug, no high-tension ignition leads are required, further enhancing reliability.

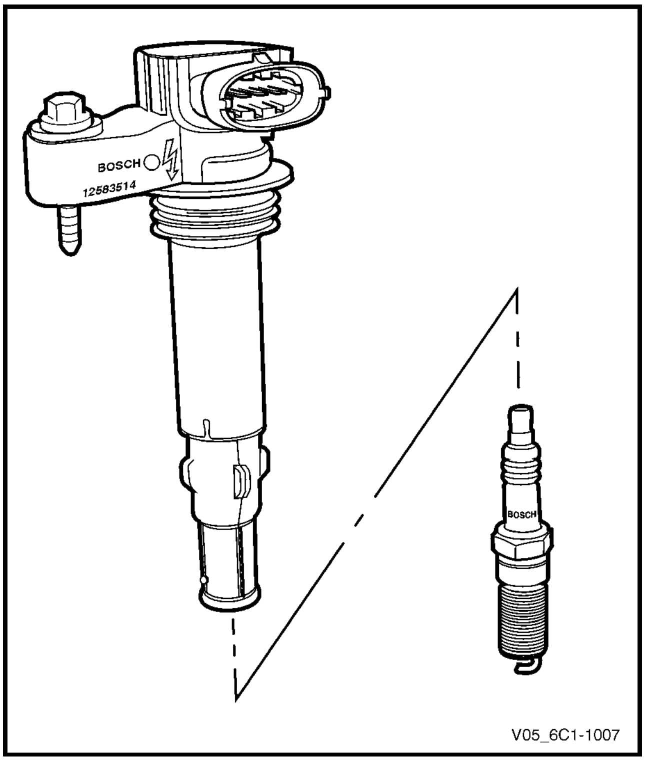

Figure 6C1-1 – 46

Pencil coils operate similarly to other compact coils, however due to their shape, the structure differs considerably.

The central rod core (1) consists of laminations of varying widths, stacked in packs that are nearly spherical. A yoke plate (2), made from layered electrical sheet steel, provides the magnetic circuit. The primary winding (3) is located around the secondary winding (4), which supports the core.

A printed circuit board, or driver module, (5) is located at the top of the coil and controls the firing of the coil based on input from the ECM.

The ECM is responsible for maintaining correct spark timing and dwell for all driving conditions. The ECM calculates the optimum spark parameters from information received from the various sensors, and triggers the appropriate ignition module which then operates the coil.

The ignition coil / modules are supplied with the following circuits:

- Ignition feed circuit.
- Ground circuit.
- Ignition control circuit.
- Reference low circuit.

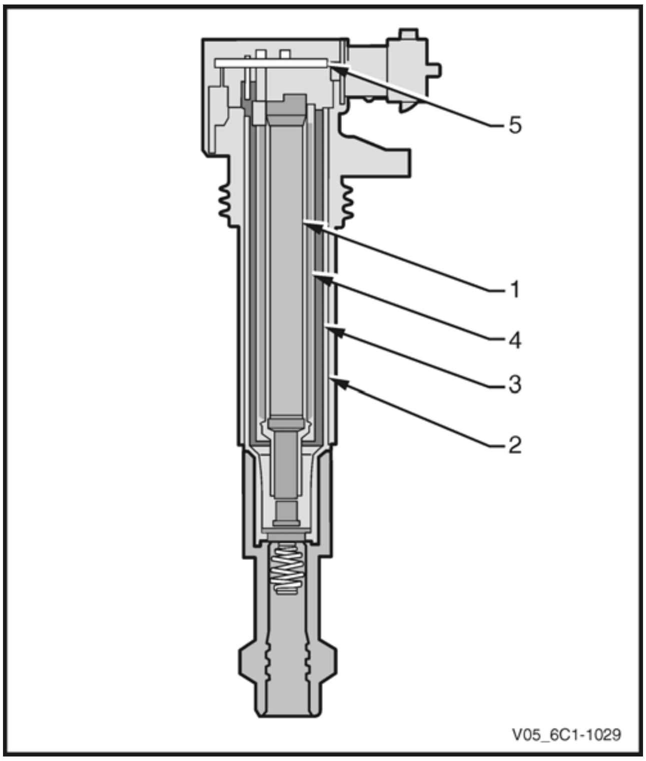

Figure 6C1-1 – 47

4.16 Intake Air Temperature Sensor

The air intake temperature (AIT) sensor is a thermistor, which is a resistor that changes it's resistance value based on temperature.

The IAT sensor is part of the air mass sensor and is not a serviceable item. The sensor is a negative temperature coefficient (NTC) type, intake air temperature produces a high sensor resistance while high engine coolant temperature causes low sensor resistance.

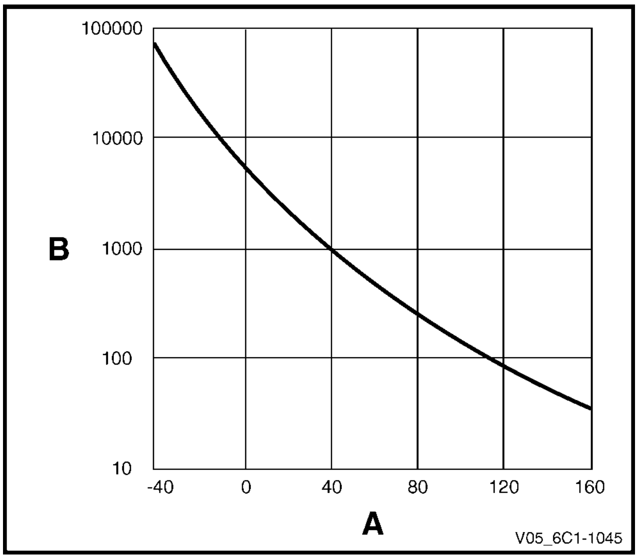

Figure 6C1-1 – 48

Legend

A Temperature

B Resistance

The ECM provides a 5 V reference signal to the IAT and monitors the return signal which enables it to calculate the intake air temperature.

The ECM uses this signal to make corrections to the operating parameters of the system based on changes in air intake temperature.

4.17 Intake Manifold Runner Control Valve

The intake manifold runner control (IMRC) valve is fitted into the intake manifold of Alloytec190 engines only.

The purpose of the IMRC is to alter the length and volume of the intake manifold runners. Varying the intake manifold takes advantage of the natural pulse / pressure waves occurring in the manifold that are created by the process of air induction into the cylinders.

During induction with an open intake valve, a return pressure wave is generated in the intake manifold. At the open (throttle) end of the intake manifold, the pressure wave encounters ambient, inactive air and is reflected back again, returning in the direction of the intake valve.

The waves vary in length and speed, and are proportional to engine speed, and the length and volume of the intake manifold runners. Therefore, at a given engine speed, the manifold can be tuned to increase the air charge into the cylinders via the returning pulse waves to achieve higher engine torque. By using varying geometry intake manifold tubing, there is a wider speed range in which the tuning can be effected.

The IMRC valve is supplied with ignition voltage via the main relay and its operation is controlled by the ECM by switching the ground circuit.

At lower engine speeds the valve flap is open (A), while at higher engine speeds, the ECM commands the valve to close (B) by switching the circuit to ground, refer to Figure 6C1-1 – 50.

The characteristic flow in the manifold is altered by the IMRC valve position.

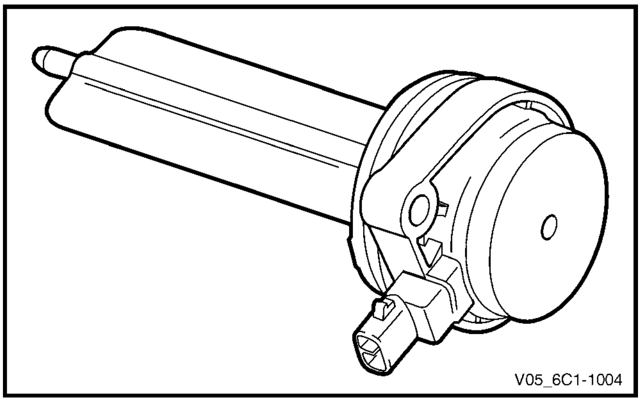

Figure 6C1-1 – 49

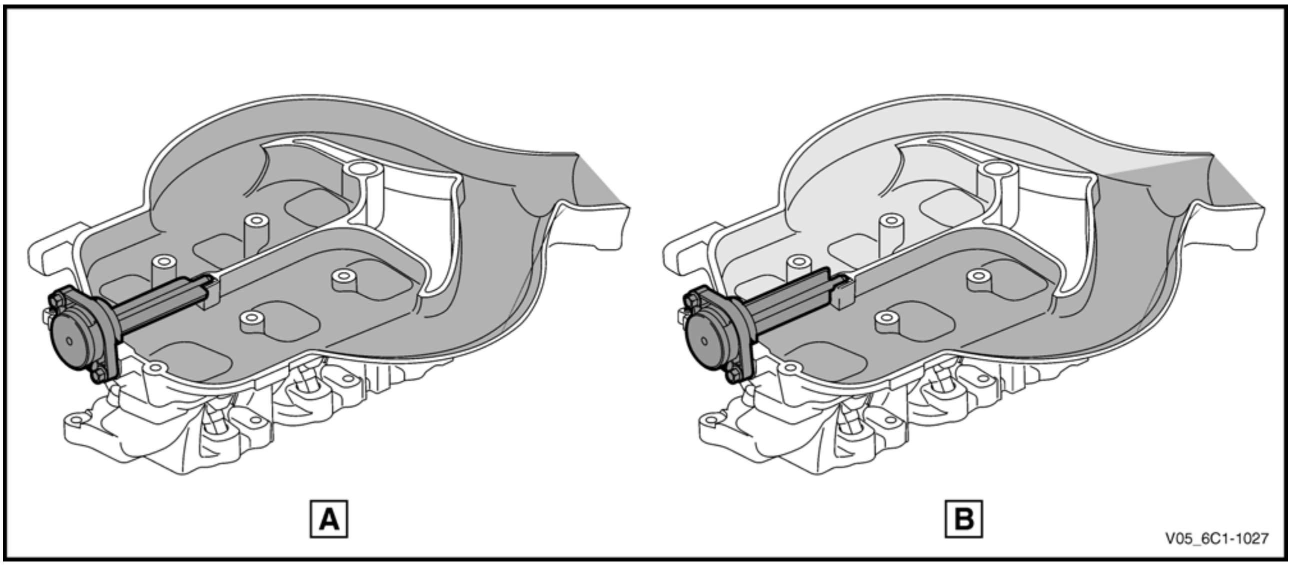

Figure 6C1-1 – 50

4.18 Knock Sensor

The knock sensor (KS) signal is used by the ECM to provide optimum ignition timing while minimising engine knock or detonation.

The ECM monitors the voltage of the left-hand (Bank 2) sensor during the 45 degrees after cylinder 2, 4, or 6 has fired and the voltage of the right-hand (Bank 1) sensor during the 45 degrees after cylinder 1, 3, or 5 has fired.

If knock occurs in any of the cylinders, the ignition will be retarded by three degrees for that particular cylinder. If the knocking then stops, the ignition will be restored to what it was before in steps of 0.75 degrees.

Should knocking continue in the same cylinder despite of the ignition being retarded, the ECM will retard the ignition an additional step of three degrees, and so on, up to a maximum of 12.75 degrees. The ignition will also be retarded at high ambient temperatures to counteract knocking tendencies provoked by high intake air temperatures.

Should either Bank 1 or Bank 2 sensor fail to work, or should an open circuit occur, the ignition timing will then be set at a default strategy that will retard the ignition much more than normal.

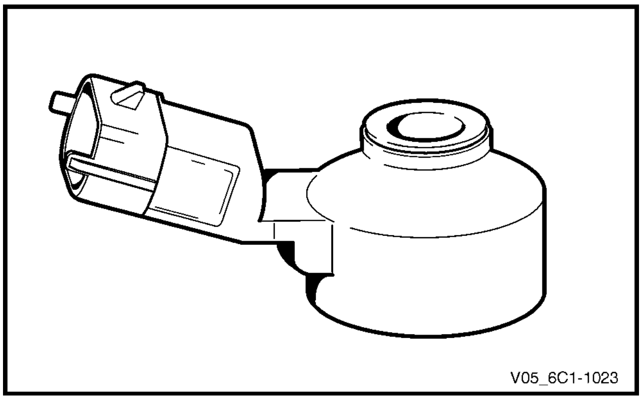

Figure 6C1-1 – 51

The knock sensor is tuned to detect the frequency of the vibration created by combustion knock. The vibration is transferred to the knock sensor through the cylinder block (1).

Inside the sensor is a mass (2) that is excited by this vibration, and the mass exerts a compressive force onto a piezo-ceramic element (3). The compressive force causes a charge transfer inside the element, so that an AC voltage appears across the two outer faces (4) of the element. The amount of the AC voltage produced is proportional to the amount of knock.

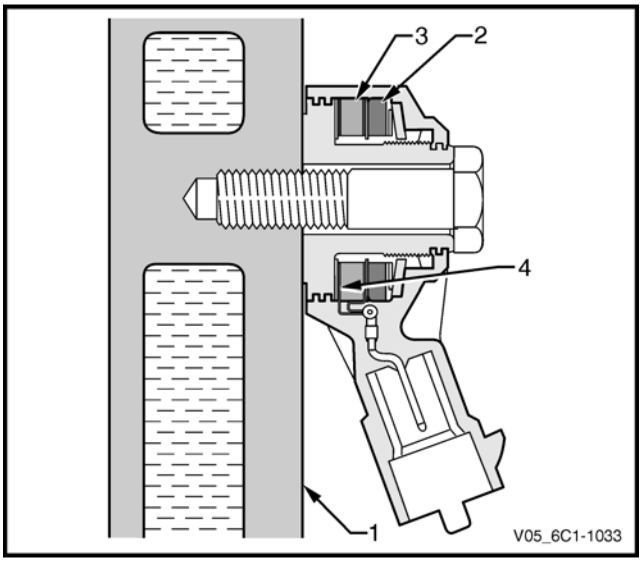

Figure 6C1-1 – 52

4.19 Mass Air Flow Sensor

Air Intake System

The air intake system draws outside air through an air cleaner assembly (1). The air is then routed through a mass air flow (MAF) sensor (2) and into the throttle body and intake manifold. The air is then directed into the intake manifold runners, through the cylinder heads and into the cylinders.

An arrow marked on the body of the MAF sensor indicates correct air flow direction. The arrow must point toward the engine.

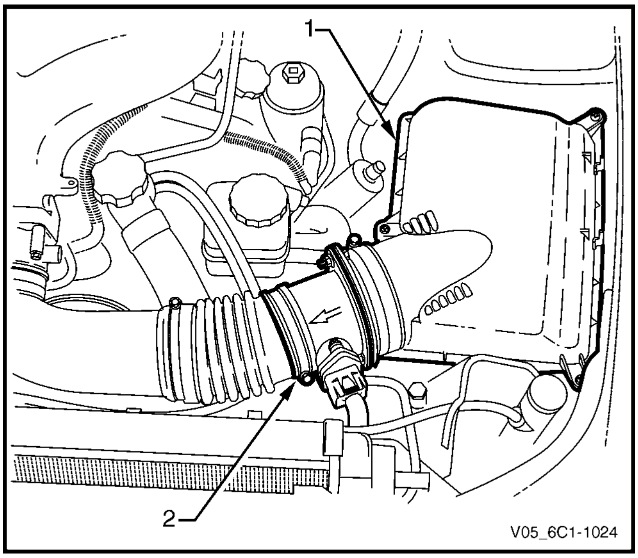

Figure 6C1-1 – 53

Mass Air Flow Sensor

A hot film type mass air flow (MAF) sensor is used which measures the air mass inducted into the engine, regardless of the engine's operating state. The MAF precisely measures a portion of the total airflow and takes into account the pulsation and reverse flows generated by the engine's inlet and exhaust valves.

Changes in intake air temperature have no effect on measuring accuracy.

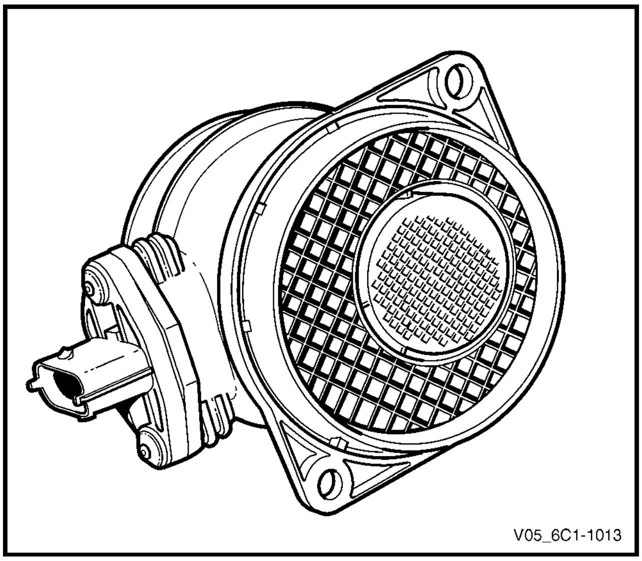

Figure 6C1-1 – 54

Construction

Projecting into the MAF sensor body is the compact design sensor assembly (1), which consists of:

- the sensor element (2),
- partial airflow measuring tube (3), and
- integrated evaluation electronics (4).

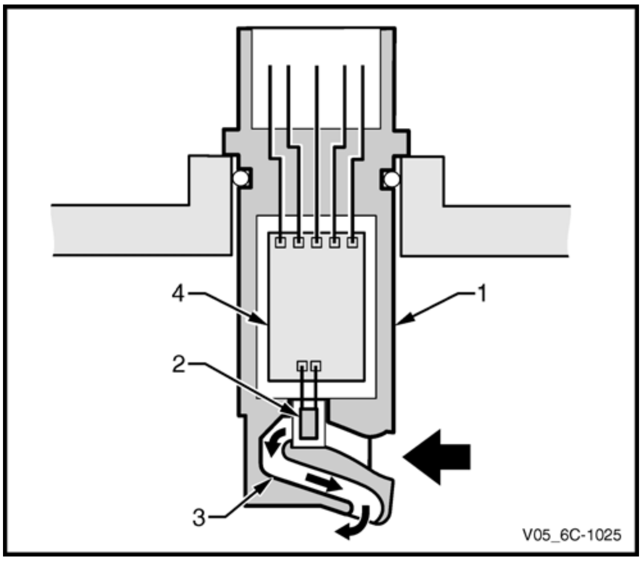

Figure 6C1-1 – 55

Operation

A diaphragm (1) on the sensor element (2) is heated by a centrally mounted heater resistor (3), which is held at a constant temperature. The temperature drops sharply each side of the heating zone.

Temperature of the diaphragm is registered to the evaluation electronics by two temperature-dependent resistors located on the upstream (4) and downstream (5) side of the resistor.

With no air flow through the air flow measuring tube and over the sensor element, the temperature characteristic is the same each side of the heating zone and the resistance values are identical.

As air flows over the sensor element, the upstream resistor value alters due to the cooling effect of the air flow. As the air flows over the heating zone the air temperature is increased.

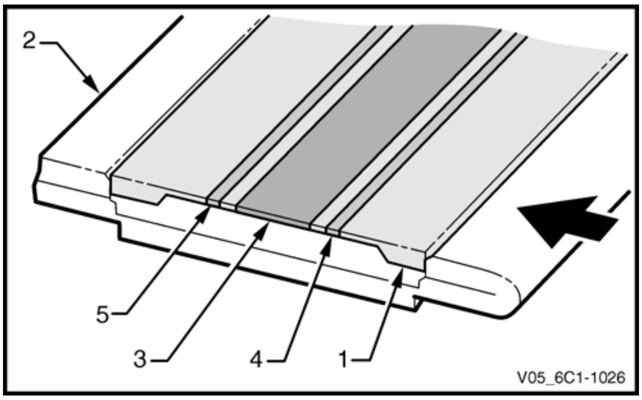

Figure 6C1-1 – 56

The air then passes over the downstream resistor and alters the resistance value, but as the air temperature is higher, the value is different to the upstream resistor. This change in temperature creates a temperature differential between the two resistors.

It is this differential that is used to calculate the air mass flow, which is independent of absolute temperature. The differential is also directional, which means the MAF not only measures the mass of the incoming air, but also its direction.

As the evaluation electronics are measuring the resistance differential between the resistors, the air mass flow for the entire amount of air passing through the MAF is calculated and sent to the ECM as an analog signal of 0 – 5 V.

The ECM can also detect air flow that is inappropriate for a given operating condition based on the signal voltage, or a signal that appears to be fixed based on the lack of normal signal fluctuations expected during engine operation.

Tech 2 can display the MAF value in grams per second (g/s). Values should change rather quickly on acceleration, but should remain fairly stable at any given engine speed.

4.20 Vehicle Speed Sensor – Manual Transmission Only

The vehicle speed sensor (VSS) (1) operates on the Hall sensing principle. The sensor contains a hall element which operates in conjunction with a toothed trigger wheel (2) mounted on the transmission output shaft.

As the teeth on the gear trigger wheel passes the element, magnetic flux affects a voltage in the Hall element. The integrated circuit inside the sensor conditions the signal generated by the Hall element to provide a rectangular wave on / off signal to the ECM.

The ignition control relay applies battery voltage to the VSS, and the ground circuit of the sensor is directly connected to ground.

The engine control module (ECM) converts and outputs the VSS signal to the instrument cluster assembly via a dedicated circuit.

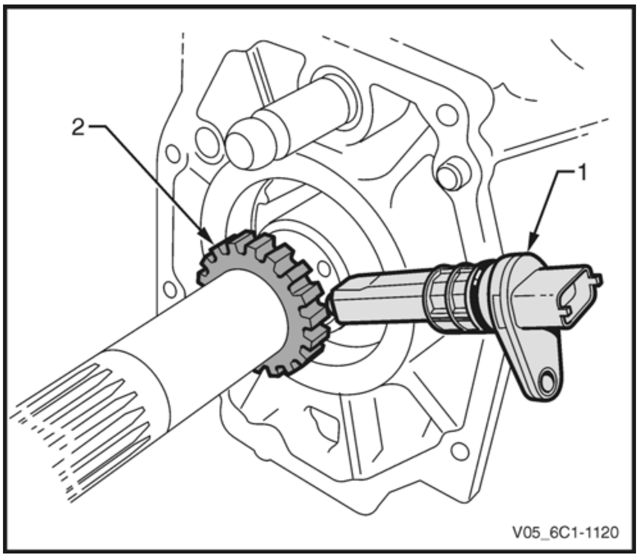

Figure 6C1-1 – 57

5 Abbreviations and Glossary of Terms

Abbreviations and terms used in this Section are listed below in alphabetical order with an explanation of the abbreviation or term.

Abbreviation	Description
A/C	Air-conditioning
AC	Alternating Current – An electrical current where the polarity is constantly changing between positive and negative
A/F	Air / Fuel (A/F Ratio)
Analogue Signal	An electrical signal that constantly varies in voltage within a given parameter
Barometric Pressure	Barometric absolute pressure (atmospheric pressure)
CAN	Controller Area Network – A type of serial data for communication between electronic devices.
Catalytic Converter	A muffler-shaped device fitted in the exhaust system, usually close to the engine. Through chemical reaction, a catalytic converter converts harmful gases produced by the combustion process such as HC, CO, and Nox, into environmentally safe water vapour, carbon dioxide, and nitrogen.
CKT	Circuit
Closed Loop	A fuel control mode of operation that uses the signal from the exhaust oxygen sensor(s), to control the air / fuel ratio precisely at a 14.7 to 1 ratio. This allows maximum efficiency of the catalytic converter.
CO	Carbon Monoxide. One of the gases produced by the engine combustion process.
DC	Direct Current
Digital Signal	An electrical signal that is either on or off.
DLC	Data Link Connector. Used at the assembly plant to evaluate the engine management system. For service, it allows the use of Tech 2 in performing system checks.
DLC Data Stream	An output from the ECM initiated by Tech 2 and transmitted via the Data Link Connector(DLC).
DMM (10 MΩ)	Digital Multimeter. A multipurpose meter that has capability of measuring voltage, current flow and resistance. A digital multimeter has an input impedance of 10 MΩ (megohms), which means they draw very little power from the device under test, they are very accurate and will not damage delicate electronic components
Driver	An electronic device, usually a power transistor, that operates as an electrical switch.
DTC	Diagnostic Trouble Code. If a fault occurs in the engine management system, the ECM may set a four digit diagnostic trouble code (DTC) which represents the fault condition. Tech 2 is used to interface with the ECM and access the DTC(s). The ECM may also operate the check powertrain icon in the instrument cluster multi function display.
Duty Cycle	The time, in percentage, that a circuit is on versus off.
ECT Sensor	Engine Coolant Temperature sensor. A device that provides a variable voltage to the ECM based on the temperature of the engine coolant.
EEPROM	Electrically Erasable Programmable Read Only Memory. A type of read only memory (ROM) that can be electrically programmed, erased and reprogrammed using Tech 2. Also referred to as Flash Memory
EMI or Electrical Noise	An unwanted signal interfering with a required signal. A common example is the effect of high voltage power lines on an AM radio.
Engine Braking	A condition where the engine is used to slow the vehicle on closed throttle or low gear.
EPROM	Erasable Programmable Read Only Memory. A type of Read Only Memory (ROM) that can be erased with ultraviolet light and then reprogrammed.
ESD	Electrostatic Discharge. The discharge of static electricity which has built up on an insulated material
EVAP	Evaporative emission control system. Used to prevent fuel vapours from the fuel tank from entering into the atmosphere. The vapours are stored in a canister that contains an activated charcoal element. The fuel vapours are purged from the canister into the manifold to be burned in the engine.
GM LAN	General Motors Local Area Network - A type of serial data for communication between electronic devices.
Fuse	A thin metal strip which melts when excessive current flows through it, creating an open circuit and protecting a circuit from damage.
HC	Hydrocarbon. Result of unburned fuel produced by incomplete combustion.
Heavy Throttle	Approximately 3/4 of accelerator pedal travel (75% throttle position)
IAT Sensor	Intake Air Temperature sensor. A device that provides a variable voltage to the ECM based on the temperature of air entering the intake system.
Ideal Mixture	The air / fuel ratio which provides the best performance, while maintaining maximum conversion of exhaust emissions, typically 14.7 to 1 on spark ignition engines
IGN	Ignition
Inputs	Information from sensors (MAF, TP, etc.) and switches (A/C request, etc.) used by the ECM to determine how to control its outputs.

Abbreviation	Description
Intermittent	An electrical signal that occurs now and then; not continuously. In electrical circuits, refers to occasional open, short, or ground in a circuit
Light Throttle	Approximately 1/4 of accelerator pedal travel (25% throttle position)
Low	A voltage less than a specific threshold. Operates the same as a ground and may, or may not, be connected to chassis ground.
MAF Sensor	Mass Air Flow Sensor. A device that provides a variable voltage to the ECM based on the amount of air flow entering in the intake system.
Medium Throttle	Approximately 1/2 of accelerator pedal travel (50% throttle position)
N.C	Normally Closed. Switch contacts that are closed when they are in the normal operating position
N.O	Normally Open. Switch contacts that are normally open when in the normal operating position
NOx	Nitrogen Oxide. One of the pollutants found in spark ignition engine exhaust that is formed from normal combustion and increases in severity with combustion temperature.
O2 Sensor	Oxygen Sensor. A device located in the exhaust system that provides a variable voltage to the ECM based on the oxygen content of exhaust gas. May also include a heating circuit to provide faster initial warm-up (HO2 sensor).
OBD	On Board Diagnostic
Open Loop	ECM control of the fuel control system without the use of the oxygen sensor signal.
Output	Functions that are controlled by the ECM, typically these can include solenoids and relays, etc.
ECM	Engine Control Module. An electronic device which controls the engine management system.
ECU	Electronic Control Unit. An electronic device which controls specific system functions
PCV	Positive Crankcase Ventilation. Method of reburning crankcase fumes rather than passing them directly into the atmosphere
PIM	Powertrain Interface Module – The PIM acts as a communication translator between the ECM and other on-board controllers that use a different serial data protocol.
PM	Permanent Magnet
PWM	Pulse Width Modulated. A digital signal turned on and off for a percentage of available cycle time. A signal that is 30% on and 70% of would be termed a 30% on PWM signal.
Quad Driver	A transistor in the ECM capable of operating four separate outputs. Outputs can be either on-off or pulse width modulated.
RAM	Random Access Memory. A microprocessor can write into or read from this memory as needed. This memory is volatile and needs a constant power supply to be retained. If the power is lost or removed, RAM data is lost.
r.p.m.	Revolutions Per Minute
Serial Data	Serial data is a series of rapidly changing voltage signals pulsed from high to low. These signals are typically 5 V (UART), 7 V (Class II), and 12 or 0 V (high or low) and are transmitted through a wire often referred to as the Serial Data Circuit.
SFI	Sequential Fuel Injection. Method of injecting fuel into the engine one cylinder at a time in relation to the engines firing order.
Solenoid	An electromagnetic coil which creates a magnetic field when current is applied, causing a plunger or ball to move.
Switch	Device to opens and close a circuit, thereby controlling current flow.
Tech 2	Tech 2 is a peripheral device that aids in the diagnosis and repair of electronic systems such as engine management, transmission control, ABS, etc. Tech 2 connects to the vehicle’s Data Link Connector (DLC).
TP Sensor	Throttle Position sensor. A device that provides a variable voltage to the ECM based on the position of the throttle plate.
Vacuum – manifold	Vacuum sourced downstream of the throttle plate.
Vacuum – ported	Vacuum sourced upstream of the throttle plate.
VSS	Vehicle Speed Sensor. A permanent magnet type device that provides a digital voltage to the ECM.
UART	Universal Asynchronous Receive and Transmit. A type of serial data for communication between electronic devices.
WOT	Wide Open Throttle – Full travel of the accelerator pedal (100% throttle position).