



# **DISCOVERY SERIES II**

## **BOSCH M5.2.1**

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## Preface

This document has been issued to support the introduction of a new engine management system. The information contained within this document relates to the features and specification of the engine management system at launch.

Every effort has been taken to ensure the information contained in this document is accurate and correct. However, technical changes may have occurred following the date of publication. This document will not necessarily have been updated as a matter of course. Therefore, details of any subsequent change may not be included in this copy.

The primary function of this document is to support the Technical Academy training programme. It should not be used in place of the workshop manual. All applicable technical specifications, adjustment procedures and repair information can be found in the relevant document published by Rover Group Technical Communication.

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## Petrol engine management

### Bosch M5.2.1

Bosch supplies the engine management system used on petrol derivatives of New Discovery. It is referred to as the Bosch Motronic 5.2.1 system. It is a dedicated variant of the Bosch system used on the BMW 7/8 Series. The system supports sequential fuel injection and wasted spark ignition. The system is designed to optimise 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 optimise 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 (ISC)
- 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 '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 inputs

The Bosch 5.2.1 system optimises 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
- Engine coolant temperature sensor (ECT)
- Knock sensors
- Air mass flow and temperature sensor (MAF)
- Oxygen sensors (O<sub>2</sub>)
- Immobilisation signal
- Fuel level signal
- Vehicle speed sensor
- Rough road detection signal
- Automatic temperature control (ATC) system request
- Automatic gearbox information
- Fuel tank pressure sensor (NAS only)

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

| Position | Colour | Use                                                                              | Number |
|----------|--------|----------------------------------------------------------------------------------|--------|
| 1        | Black  | Main power supply and ground connections                                         | C634   |
| 2        | Black  | Oxygen sensor inputs and Oxygen sensor heaters, fuel pump and main relay control | C635   |
| 3        | Black  | All sensor inputs and outputs                                                    | C636   |
| 4        | Black  | Most related vehicle system communications. CAN bus and K-line                   | C637   |
| 5        | Black  | Ignition coil control                                                            | C638   |

**Pin out details connector C0634**

| Pin No. | Function                 | Signal type          | Reading |
|---------|--------------------------|----------------------|---------|
| 1       | Ignition position II     | Input                | 12 V    |
| 2       | Not used                 | -                    | -       |
| 3       | Not used                 | -                    | -       |
| 4       | Chassis earth            | Earth                | 0V      |
| 5       | Fuel injectors earth     | Earth                | 0V      |
| 6       | Power stage earth        | Earth                | 0V      |
| 7       | Permanent battery supply | Input battery supply | 12V     |
| 8       | Switched relay positive  | Input switched       | 0-12V   |
| 9       | Not used                 | -                    | -       |

Pin out details connector C0635

| Pin No. | Function                         | Signal type   | Reading         |
|---------|----------------------------------|---------------|-----------------|
| 1       | HO2S heater RH bank - downstream | Output        | PWM 12-0V       |
| 2       | Not used                         | -             | -               |
| 3       | Not used                         | -             | -               |
| 4       | Not used                         | -             | -               |
| 5       | Not used                         | -             | -               |
| 6       | Not used                         | -             | -               |
| 7       | HO2S heater LH bank - downstream | Output        | PWM 12-0V       |
| 8       | HO2S sensor RH bank - downstream | Earth/ Signal | 0V              |
| 9       | HO2S sensor LH bank - upstream   | Earth/ Signal | 0V              |
| 10      | HO2S sensor RH bank - upstream   | Earth/ Signal | 0V              |
| 11      | HO2S sensor LH bank - downstream | Earth/ Signal | 0V              |
| 12      | Not used                         | -             | -               |
| 13      | HO2S heater RH bank - upstream   | Output        | PWM 12-0V       |
| 14      | HO2S sensor RH bank - downstream | Input/ Signal | 0-5V            |
| 15      | HO2S sensor LH bank - upstream   | Input/ Signal | 0-5V            |
| 16      | HO2S sensor RH bank - upstream   | Input/ Signal | 0-5V            |
| 17      | HO2S sensor LH bank - downstream | Input/ Signal | 0-5V            |
| 18      | Fuel pump relay                  | Output        | PWM 12-0V       |
| 19      | HO2S heater LH bank - upstream   | Output        | PWM 12-0V       |
| 20      | Not used                         | -             | -               |
| 21      | Not used                         | -             | -               |
| 22      | Not used                         | -             | -               |
| 23      | Main relay                       | Output        | Switch to earth |
| 24      | Not used                         | -             | -               |

Pin out details connector C0636

| Pin No. | Function                   | Signal type       | Reading              |
|---------|----------------------------|-------------------|----------------------|
| 1       | Injector cylinder number 1 | Output            | Switch to earth      |
| 2       | Injector cylinder number 5 | Output            | Switch to earth      |
| 3       | Purge valve                | Output, signal    | PWM 12-0V            |
| 4       | Not used                   | -                 | -                    |
| 5       | Not used                   | -                 | -                    |
| 6       | Fuel tank pressure sensor  | Earth             | 0V                   |
| 7       | MAF sensor 5V supply       | Output, reference | 5V                   |
| 8       | Not used                   | -                 | -                    |
| 9       | MAF sensor earth           | Earth             | 0V                   |
| 10      | TP sensor 5V supply        | Output, reference | 5V                   |
| 11      | Not used                   | -                 | -                    |
| 12      | Not used                   | -                 | -                    |
| 13      | Not used                   | -                 | -                    |
| 14      | Injector cylinder number 7 | Output            | Switch to earth      |
| 15      | Injector cylinder number 6 | Output            | Switch to earth      |
| 16      | Not used                   | -                 | -                    |
| 17      | CMP sensor                 | Earth             | 0V                   |
| 18      | Low range switch (manual)  | Input, signal     | Active low           |
| 19      | Not used                   | -                 | -                    |
| 20      | CMP signal                 | Input, signal     | Digital switch 0-12V |
| 21      | ECT sensor                 | Earth             | 0V                   |
| 22      | Coolant temperature signal | Input, signal     | Analogue 0-5V        |
| 23      | MAF sensor signal          | Input, signal     | Analogue 0-5V        |
| 24      | TP sensor signal           | Input, signal     | Analogue 0-5V        |

| Pin No. | Function                              | Signal type     | Reading               |
|---------|---------------------------------------|-----------------|-----------------------|
| 25      | TP sensor earth                       | Earth           | 0V                    |
| 26      | Not used                              | -               | -                     |
| 27      | Injector cylinder number 3            | Output          | Switch to earth       |
| 28      | Injector cylinder number 8            | Output          | Switch to earth       |
| 29      | Hill decent control output            | Output, signal  | PWM 12-0V             |
| 30      | Charcoal canister vent valve solenoid | Output          | Switch to earth       |
| 31      | Cooling fan                           | Output          | Switch to earth       |
| 32      | CKP sensor signal                     | Input, signal   | Analogue, 0-300V peak |
| 33      | Not used                              | -               | -                     |
| 34      | IAT sensor signal                     | Input, signal   | Analogue 0-5V         |
| 35      | KS bank B earth                       | Earth           | Switch to earth       |
| 36      | KS bank B signal                      | Input, signal   | 0V                    |
| 37      | Not used                              | -               | Analogue              |
| 38      | Not used                              | -               | -                     |
| 39      | Not used                              | -               | -                     |
| 40      | Injector cylinder number 4            | Output          | -                     |
| 41      | Injector cylinder number 1            | Output          | Switch to earth       |
| 42      | Idle air control valve open           | Output, signal  | PWM 12-0V             |
| 43      | Idle air control valve close          | Output, signal  | PWM 12-0V             |
| 44      | ECT sensor signal                     | Output, signal  | PWM 12-0V             |
| 45      | CKP sensor earth screen               | Earth           | 0V                    |
| 46      | CKP sensor signal                     | Earth reference | 0V                    |
| 47      | Not used                              | -               | -                     |
| 48      | KS bank A earth                       | Earth           | 0V                    |
| 49      | KS bank A signal                      | Input, signal   | Analogue              |
| 50      | Not used                              | -               | -                     |
| 51      | Not used                              | -               | -                     |
| 52      | Not used                              | -               | -                     |

## Pin out details connector C0637

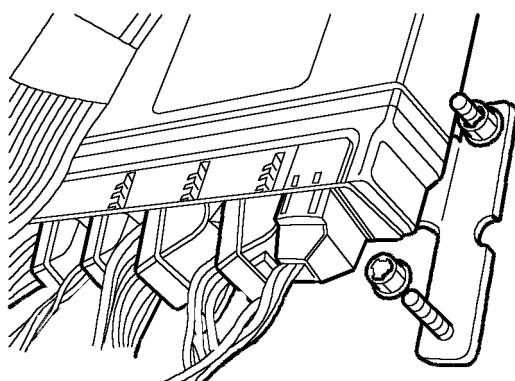
| Pin No. | Function                        | Signal type       | Reading        |
|---------|---------------------------------|-------------------|----------------|
| 1       | Not used                        | -                 | -              |
| 2       | Not used                        | -                 | -              |
| 3       | Not used                        | -                 | -              |
| 4       | Not used                        | -                 | -              |
| 5       | Not used                        | -                 | -              |
| 6       | Not used                        | -                 | -              |
| 7       | Not used                        | -                 | -              |
| 8       | Low fuel level                  | Input, signal     | Active high    |
| 9       | Fuel tank pressure sensor       | Output, reference | 5V             |
| 10      | Not used                        | -                 | -              |
| 11      | Not used                        | -                 | -              |
| 12      | Not used                        | -                 | -              |
| 13      | Not used                        | -                 | -              |
| 14      | Fuel tank pressure sensor       | Input, signal     | Analogue 0-5V  |
| 15      | Not used                        |                   |                |
| 16      | ATC compressor request          | Input, signal     | Active low     |
| 17      | Engine speed output             | Output, signal    | PWM 0-5V       |
| 18      | Not used                        | -                 | -              |
| 19      | Not used                        | -                 | -              |
| 20      | Malfunction indicator lamp 'ON' | Output            | Switched earth |
| 21      | Not used                        | -                 | -              |

| Pin No. | Function                   | Signal type    | Reading        |
|---------|----------------------------|----------------|----------------|
| 22      | Vehicle speed signal (VSS) | Input, signal  | PWM 0-12V      |
| 23      | Not used                   | -              | -              |
| 24      | Not used                   | -              | -              |
| 25      | Not used                   | -              | -              |
| 26      | Not used                   | -              | -              |
| 27      | Not used                   | -              | -              |
| 28      | Not used                   | -              | -              |
| 29      | ATC compressor relay       | Output         | Switched earth |
| 30      | Not used                   | -              | -              |
| 31      | Not used                   | -              | -              |
| 32      | Diagnostic connector       | Bi-directional | Serial 0-12V   |
| 33      | Immobiliser serial W link  | Input, signal  | Serial 0-12V   |
| 34      | Rough road signal          | Input, signal  | PWM 0-12V      |
| 35      | Not used                   | -              | -              |
| 36      | CAN data bus 'high line'   | Bi-directional | 5-2.5V         |
| 37      | CAN data bus 'low line'    | Bi-directional | 0-2.5V         |
| 38      | ATC stand by               | Input, signal  | Active low     |
| 39      | Not used                   | -              | -              |
| 40      | Not used                   | -              | -              |

#### Pin out details connector C0638

| Pin No. | Function                    | Signal type | Reading         |
|---------|-----------------------------|-------------|-----------------|
| 1       | Not used                    | -           | -               |
| 2       | Ignition, Cylinders 2 and 3 | Output      | Switch to earth |
| 3       | Not used                    | -           | -               |
| 4       | Not used                    | -           | -               |
| 5       | Ignition coil earth         | Earth       | 0V              |
| 6       | Ignition, Cylinders 1 and 6 | Output      | Switch to earth |
| 7       | Ignition, Cylinders 4 and 7 | Output      | Switch to earth |
| 8       | Ignition, Cylinders 5 and 8 | Output      | Switch to earth |
| 9       | Not used                    | -           | -               |

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 fitted 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 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 New Discovery, is an improvement over existing systems. When Land Rover first produced vehicles, all petrol engines were fuelled by carburettor. When several countries around the world started to enforce legislation concerning the amount of pollutants a vehicle was legally allowed to exhaust, Land Rover started to use fuel injection as a method of supplying the engine with the optimum amount of fuel for the current operating condition. When further legislation was introduced, it became necessary for Land Rover not only to electronically control the amount of fuel entering the engine but also to electronically control the precise time of injection and ignition. 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 EOBDII legislation. Once recorded, details of a fault will stay in the ECM's memory for 40 'trips'.

| PCM DIAGNOSTIC TROUBLE CODES                                 | DTC   | MIL | Drive cycle |
|--------------------------------------------------------------|-------|-----|-------------|
| Mass or Volume Air Flow Circuit Malfunction                  | P0100 | Y   | A           |
| Mass or Volume Air Flow Circuit Range/Performance Problem    | P0101 | Y   | B           |
| Mass or Volume Air Flow Circuit Low Input                    | P0102 | Y   | A           |
| Mass or Volume Air Flow Circuit High Input                   | P0103 | Y   | A           |
| Intake Air Temperature Circuit Range/Performance Problem     | P0111 | Y   | B           |
| Intake Air Temperature Circuit Low Input                     | P0112 | Y   | B           |
| Intake Air Temperature Circuit High Input                    | P0113 | Y   | B           |
| Engine Coolant Temperature Circuit Malfunction               | P0115 | Y   | D           |
| Engine Coolant Temperature Circuit Range/Performance Problem | P0116 | Y   | D           |

| PCM DIAGNOSTIC TROUBLE CODES                                | DTC   | MIL | Drive cycle |
|-------------------------------------------------------------|-------|-----|-------------|
| Engine Coolant Temperature Circuit Low Input                | P0117 | Y   | D           |
| Engine Coolant Temperature Circuit High Input               | P0118 | Y   | D           |
| Throttle/Pedal Position Sensor/Switch A Circuit Malfunction | P0120 | Y   | B           |
| Throttle/Pedal Position Sensor/Switch A Circuit Low Input   | P0122 | Y   | B           |
| Throttle/Pedal Position Sensor/Switch A Circuit High Input  | P0123 | Y   | B           |
| 02 Sensor Circuit Malfunction (Bank 1 Sensor 1)             | P0130 | Y   | C           |
| 02 Sensor Circuit Low Voltage (Bank 1 Sensor 1)             | P0131 | Y   | C           |
| 02 Sensor Circuit High Voltage (Bank 1 Sensor 1)            | P0132 | Y   | C           |
| 02 Sensor Circuit Slow Response (Bank 1 Sensor 1)           | P0133 | Y   | C           |
| 02 Sensor Circuit No Activity Detected (Bank 1 Sensor 1)    | P0134 | Y   | C           |
| 02 Sensor Heater Circuit Malfunction (Bank 1 Sensor 1)      | P0135 | Y   | C           |
| 02 Sensor Circuit Malfunction (Bank 1 Sensor 2)             | P0136 | Y   | C           |
| 02 Sensor Circuit Low Voltage (Bank 1 Sensor 2)             | P0137 | Y   | C           |
| 02 Sensor Circuit High Voltage (Bank 1 Sensor 2)            | P0138 | Y   | C           |
| 02 Sensor Circuit No Activity Detected (Bank 1 Sensor 2)    | P0140 | Y   | C           |
| 02 Sensor Heater Circuit Malfunction (Bank 1 Sensor 2)      | P0141 | Y   | C           |
| 02 Sensor Circuit Malfunction (Bank 2 Sensor 1)             | P0150 | Y   | C           |
| 02 Sensor Circuit Low Voltage (Bank 2 Sensor 1)             | P0151 | Y   | C           |
| 02 Sensor Circuit High Voltage (Bank 2 Sensor 1)            | P0152 | Y   | C           |
| 02 Sensor Circuit Slow Response (Bank 2 Sensor 1)           | P0153 | Y   | C           |
| 02 Sensor Circuit No Activity Detected (Bank 2 Sensor 1)    | P0154 | Y   | C           |
| 02 Sensor Heater Circuit Malfunction (Bank 2 Sensor 1)      | P0155 | Y   | C           |
| 02 Sensor Circuit Malfunction (Bank 2 Sensor 2)             | P0156 | Y   | C           |
| 02 Sensor Circuit Low Voltage (Bank 2 Sensor 2)             | P0157 | Y   | C           |
| 02 Sensor Circuit High Voltage (Bank 2 Sensor 2)            | P0158 | Y   | C           |
| 02 Sensor Circuit No Activity Detected (Bank 2 Sensor 2)    | P0160 | Y   | C           |
| 02 Sensor Heater Circuit Malfunction (Bank 2 Sensor 2)      | P0161 | Y   | C           |
| Fuel Trim Malfunction (Bank 1)                              | P0170 | Y   | C           |
| System too Lean (Bank 1)                                    | P0171 | Y   | C           |
| System too Rich (Bank 1)                                    | P0172 | Y   | C           |
| Fuel Trim Malfunction (Bank 2)                              | P0173 | Y   | C           |
| System too Lean (Bank 2)                                    | P0174 | Y   | C           |
| System too Rich (Bank 2)                                    | P0175 | Y   | C           |
| Injector Circuit Malfunction - Cylinder 1                   | P0201 | Y   | A           |
| Injector Circuit Malfunction - Cylinder 2                   | P0202 | Y   | A           |
| Injector Circuit Malfunction - Cylinder 3                   | P0203 | Y   | A           |
| Injector Circuit Malfunction - Cylinder 4                   | P0204 | Y   | A           |
| Injector Circuit Malfunction - Cylinder 5                   | P0205 | Y   | A           |
| Injector Circuit Malfunction - Cylinder 6                   | P0206 | Y   | A           |
| Injector Circuit Malfunction - Cylinder 7                   | P0207 | Y   | A           |
| Injector Circuit Malfunction - Cylinder 8                   | P0208 | Y   | A           |
| Cylinder 1 Injector Circuit Low                             | P0261 | Y   | A           |
| Cylinder 1 Injector Circuit High                            | P0262 | Y   | A           |
| Cylinder 2 Injector Circuit Low                             | P0264 | Y   | A           |
| Cylinder 2 Injector Circuit High                            | P0265 | Y   | A           |
| Cylinder 3 Injector Circuit Low                             | P0267 | Y   | A           |
| Cylinder 3 Injector Circuit High                            | P0268 | Y   | A           |
| Cylinder 4 Injector Circuit Low                             | P0270 | Y   | A           |
| Cylinder 4 Injector Circuit High                            | P0271 | Y   | A           |
| Cylinder 5 Injector Circuit Low                             | P0273 | Y   | A           |
| Cylinder 5 Injector Circuit High                            | P0274 | Y   | A           |
| Cylinder 6 Injector Circuit Low                             | P0276 | Y   | A           |

| PCM DIAGNOSTIC TROUBLE CODES                                                | DTC   | MIL | Drive cycle |
|-----------------------------------------------------------------------------|-------|-----|-------------|
| Cylinder 6 Injector Circuit High                                            | P0277 | Y   | A           |
| Cylinder 7 Injector Circuit Low                                             | P0279 | Y   | A           |
| Cylinder 7 Injector Circuit High                                            | P0280 | Y   | A           |
| Cylinder 8 Injector Circuit Low                                             | P0282 | Y   | A           |
| Cylinder 8 Injector Circuit High                                            | P0283 | Y   | A           |
| Random/Multiple Cylinder Misfire Detected                                   | P0300 | Y   | C           |
| Cylinder 1 Misfire Detected                                                 | P0301 | Y   | C           |
| Cylinder 2 Misfire Detected                                                 | P0302 | Y   | C           |
| Cylinder 3 Misfire Detected                                                 | P0303 | Y   | C           |
| Cylinder 4 Misfire Detected                                                 | P0304 | Y   | C           |
| Cylinder 5 Misfire Detected                                                 | P0305 | Y   | C           |
| Cylinder 6 Misfire Detected                                                 | P0306 | Y   | C           |
| Cylinder 7 Misfire Detected                                                 | P0307 | Y   | C           |
| Cylinder 8 Misfire Detected                                                 | P0308 | Y   | C           |
| Knock Sensor 1 Circuit Malfunction (Bank 1 or Single Sensor)                | P0325 | N   | B           |
| Knock Sensor 1 Circuit Low Input (Bank 1 or Single Sensor)                  | P0327 | N   | B           |
| Knock Sensor 1 Circuit High Input (Bank 1 or Single Sensor)                 | P0328 | N   | B           |
| Knock Sensor 2 Circuit Malfunction (Bank 2)                                 | P0330 | N   | B           |
| Knock Sensor 2 Circuit Low Input (Bank 2)                                   | P0332 | N   | B           |
| Knock Sensor 2 Circuit High Input (Bank 2)                                  | P0333 | N   | B           |
| Crankshaft Position Sensor A Circuit Malfunction                            | P0335 | Y   | A           |
| Crankshaft Position Sensor A Circuit Range/Performance                      | P0336 | Y   | A           |
| Camshaft Position Sensor Circuit Malfunction                                | P0340 | Y   | A           |
| Catalyst System Efficiency Below Threshold (Bank 1)                         | P0420 | Y   | C           |
| Catalyst System Efficiency Below Threshold (Bank 2)                         | P0430 | Y   | C           |
| Evaporative Emission Control System Malfunction                             | P0440 | Y   | C           |
| Evaporative Emission Control System Incorrect Purge Flow                    | P0441 | Y   | C           |
| Evaporative Emission Control System Leak Detected (small leak)              | P0442 | Y   | C           |
| Evaporative Emission Control System Purge Control Valve Circuit Malfunction | P0443 | Y   | C           |
| Evaporative Emission Control System Purge Control Valve Circuit Open        | P0444 | Y   | C           |
| Evaporative Emission Control System Purge Control Valve Circuit Shorted     | P0445 | Y   | C           |
| Evaporative Emission Control System Vent Control Circuit Malfunction        | P0446 | Y   | C           |
| Evaporative Emission Control System Vent Control Circuit Open               | P0447 | Y   | C           |
| Evaporative Emission Control System Vent Control Circuit Shorted            | P0448 | Y   | C           |
| Evaporative Emission Control System Vent Valve/Solenoid Circuit Malfunction | P0449 | Y   | C           |
| Evaporative Emission Control System Pressure Sensor Malfunction             | P0450 | Y   | C           |
| Evaporative Emission Control System Pressure Sensor Range/Performance       | P0451 | Y   | C           |
| Evaporative Emission Control System Pressure Sensor Low Input               | P0452 | Y   | C           |
| Evaporative Emission Control System Pressure Sensor High Input              | P0453 | Y   | C           |
| Evaporative Emission Control System Leak Detected (gross leak)              | P0455 | Y   | C           |
| Fuel Level Sensor Circuit Malfunction                                       | P0460 | N   | A           |
| Fuel Level Sensor Circuit Range/Performance                                 | P0461 | N   | A           |
| Fuel Level Sensor Circuit Low Input                                         | P0462 | N   | A           |
| Fuel Level Sensor Circuit High Input                                        | P0463 | N   | A           |
| Vehicle Speed Sensor Malfunction                                            | P0500 | Y   | B           |
| Vehicle Speed Sensor Range/Performance                                      | P0501 | Y   | B           |
| Vehicle Speed Sensor Circuit Low Input                                      | P0502 | Y   | B           |
| Idle Control System Malfunction                                             | P0505 | Y   | A           |
| System Voltage Malfunction                                                  | P0560 | N   | A           |
| System Voltage Unstable                                                     | P0561 | N   | A           |
| System Voltage Low                                                          | P0562 | N   | A           |
| System Voltage High                                                         | P0563 | N   | A           |

| PCM DIAGNOSTIC TROUBLE CODES                                              | DTC   | MIL | Drive cycle |
|---------------------------------------------------------------------------|-------|-----|-------------|
| Serial Communication Link Malfunction                                     | P0600 | Y   | A           |
| Internal Control Module Memory Check Sum Error                            | P0601 | Y   | A           |
| Internal Control Module Keep Alive Memory (RAM) Error                     | P0603 | Y   | A           |
| Internal Control Module Random Access Memory (RAM) Error                  | P0604 | Y   | A           |
| PCM Processor Fault                                                       | P0606 | N   | A           |
| Malfunction Indicator Lamp (MIL) Control Circuit Malfunction              | P0650 | N   | A           |
| Engine RPM Output Circuit Malfunction                                     | P0654 | N   | A           |
| O2 Sensors Swapped Bank to Bank (Sensor 1)                                | P1129 | Y   | C           |
| Downstream Fuel Trim Malfunction (Bank 1)                                 | P1170 | Y   | C           |
| System Too Lean Bank A                                                    | P1171 | Y   | B           |
| System too rich bank A and bank B                                         | P1172 | Y   | B           |
| Downstream Fuel Trim Malfunction (Bank 2)                                 | P1173 | Y   | C           |
| System Too Lean Bank B                                                    | P1174 | Y   | B           |
| System Too Rich Bank B                                                    | P1175 | Y   | B           |
| Fuel Pump Relay Malfunction                                               | P1230 | N   | A           |
| Fuel Pump Relay Circuit Low                                               | P1231 | N   | A           |
| Fuel Pump Relay Circuit High                                              | P1232 | N   | A           |
| Misfire Detected Sufficient to Cause Catalyst Damage                      | P1300 | Y   | C           |
| Misfire Detected at Low Fuel Level                                        | P1319 | N   | C           |
| IACV Opening Coil Malfunction                                             | P1509 | Y   | A           |
| IACV - Opening Coil Circuit Malfunction                                   | P1510 | Y   | A           |
| IACV - Opening Coil Circuit Low                                           | P1513 | Y   | A           |
| IACV Opening Coil Circuit High                                            | P1514 | Y   | A           |
| Air Conditioning Compressor Request Malfunction                           | P1535 | N   | A           |
| Air Conditioning Compressor Request Range / Performance                   | P1536 | N   | A           |
| Air Conditioning Compressor Request Low Input                             | P1537 | N   | A           |
| Air Conditioning Compressor Request High Input                            | P1538 | N   | A           |
| IACV - Closing Coil Malfunction                                           | P1550 | Y   | A           |
| IACV - Closing Coil Circuit Malfunction                                   | P1551 | Y   | A           |
| IACV - Closing Coil Circuit Low                                           | P1552 | Y   | A           |
| IACV - Closing Coil Circuit High                                          | P1553 | Y   | A           |
| ABS Rough Road Signal Circuit Malfunction                                 | P1590 | N   | A           |
| ABS Rough Road Signal Circuit Low                                         | P1591 | N   | A           |
| ABS Rough Road Signal Circuit High                                        | P1592 | N   | A           |
| Throttle Angle / Torque Signal Circuit Malfunction                        | P1663 | N   | A           |
| Throttle Angle / Torque Signal Circuit Low                                | P1664 | N   | A           |
| Throttle Angle / Torque Signal Circuit High                               | P1665 | N   | A           |
| Engine Anti Theft Signal Circuit Malfunction                              | P1666 | N   | A           |
| Engine Anti Theft Signal Circuit Low                                      | P1667 | N   | A           |
| Engine Anti Theft Signal Circuit High                                     | P1668 | N   | A           |
| Engine Control Module Cooling Fan Circuit Malfunction                     | P1669 | Y   | B           |
| Engine Control Module Cooling Fan Circuit Low                             | P1670 | Y   | B           |
| Engine Control Module Cooling Fan Circuit High                            | P1671 | Y   | B           |
| Engine Anti Theft Signal Wrong Code Received                              | P1672 | N   | A           |
| Engine Anti Theft Signal New Engine Control Module Not Configured         | P1673 | N   | A           |
| Engine Anti Theft Signal                                                  | P1674 | N   | A           |
| Transfer Box Indicated Range - Performance                                | P1700 | N   | C           |
| Transfer box has signalled a fault condition to the Engine Control Module | P1701 | Y   | B           |
| Transfer Box - Signal Line Communication Frame Error                      | P1702 | Y   | B           |
| Transfer box link - signal line permanently high                          | P1703 | Y   | B           |
| Transfer box link - signal line permanently at ground                     | P1708 | Y   | B           |
| Transmission Control System Torque Interface Malfunction                  | P1776 | N   | B           |

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 (NAS)
- Purge (all markets) / evaporative loss leak detection diagnostic (NAS)
- Oxygen sensor diagnostics
- O<sup>2</sup> 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.

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 be 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 temperature
- Road speed

On NAS vehicles 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 fault strategy is referred to as 'debouncing' the fault. There is one exception, this being the ECM detecting that a catalyst-damaging misfire is currently occurring. In this case, the ECM will flash the MIL lamp immediately the fault is detected. If the fault rectifies itself, the ECM will stop flashing the MIL lamp, changing it to continuously 'on'.

The MIL lamp is triggered by a MIL event. In non-NAS markets the ECM merely stores a MIL event. This is treated exactly the same by the ECM, with the exception of the MIL lamp remaining extinguished. The MIL lamp is switched on only if the vehicle is of NAS specification, except for a bulb check facility when the ignition is switched to position II, or if the automatic gearbox requests it.

## Ignition switch

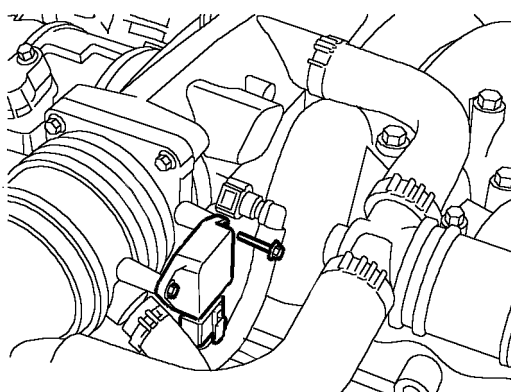
The ignition switch supplies a signal to the ECM whenever it is turned to position II ('ignition on'). Using this signal, the ECM is able to detect when the ignition switch is turned 'on' and when it is turned 'off'. The ECM will initiate its 'power-up' sequence whenever the ignition is turned 'on'. At this time it will energise the main relay (which, amongst other things, supplies the main feed to the ECM), energise 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-energising 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. 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.

### Throttle position 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 tallied.

In this application, the TPS sensor does not rely on any form 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:

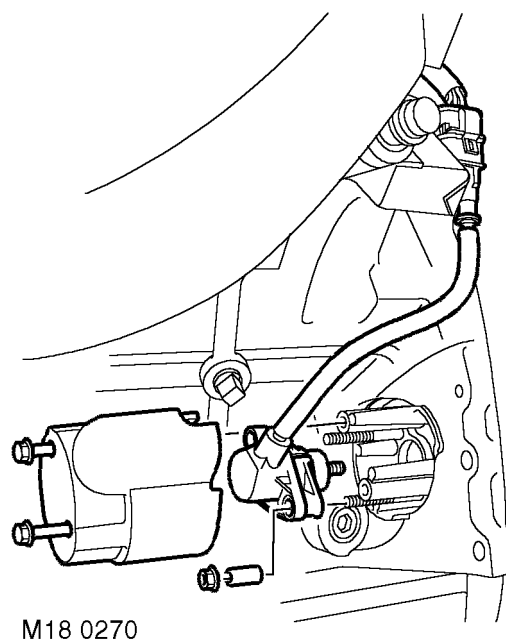
- The engine will idle poorly
- The vehicle will default to 3rd / 4th gear (limp home strategy automatic vehicles only)
- The engine will run poorly and respond poorly to throttle pedal movement
- The gearbox will not kickdown (automatic vehicles only)
- Altitude adaptations will be incorrect (engine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

TestBook will retrieve the fault code (referred to as a 'P' code for OBD II regulations) 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**

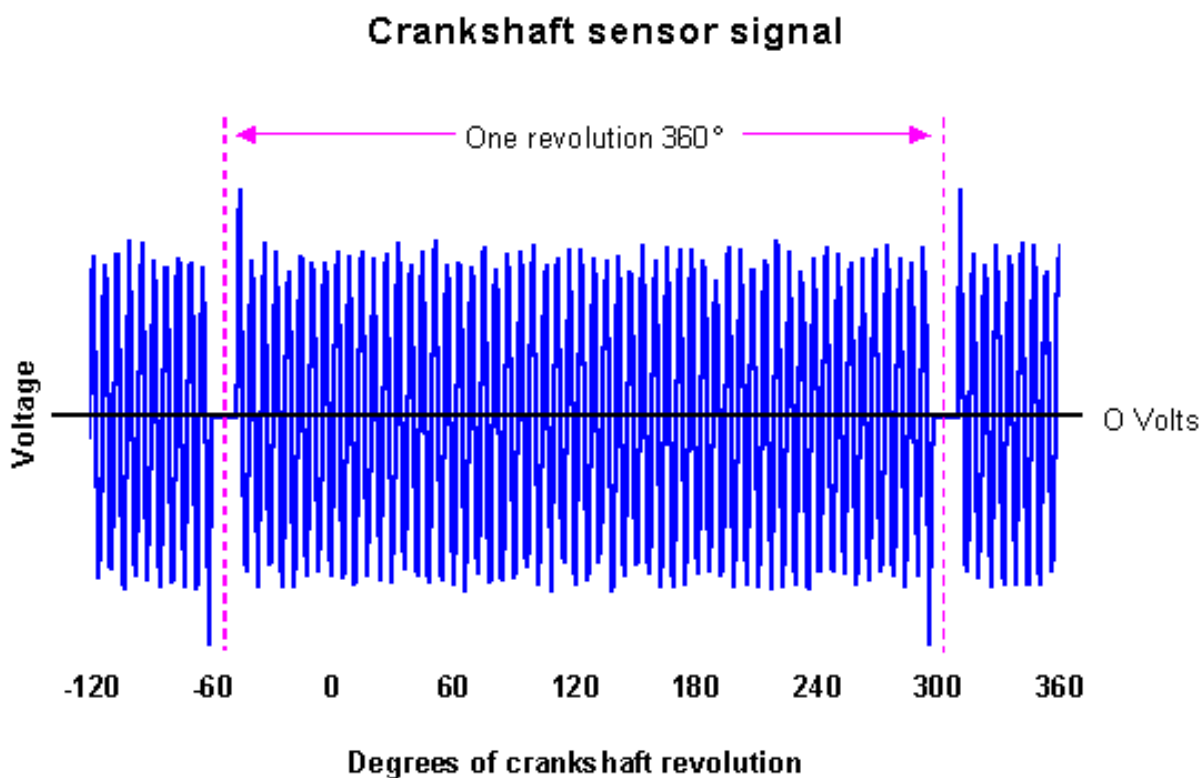
The crankshaft position sensor is located in the engine block, just below number 7 cylinder. It protrudes through the cylinder block and is positioned adjacent to the face of the flywheel or flexplate. The sensor reacts to a 'drilled reluctor' incorporated into either the flywheel or the flexplate to 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 14mm thick on vehicles fitted with manual transmission and 18mm thick on vehicles fitted 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 flexplate. 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.

## Crankshaft sensor location



The crankshaft sensor is an inductive type sensor which produces a sinusoidal output voltage signal. The diagram below illustrates 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 rev/min. 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 in this application 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.

## Crankshaft sensor signal



## Crankshaft reluctor



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 ECU and the SLABS ECU are supplied via the CAN link, whilst the signals to the ACE ECU and the instrument pack are carried via a frequency dependent digital signal.

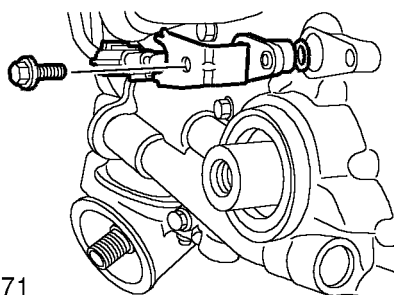
The signal produced by the crankshaft position sensor is critical to engine running. There is no back-up strategy for this sensor and failure of the signal will result in the engine stalling and/or failing to start. If the sensor fails when the engine is running, then the engine will stall, a fault code will be stored and details captured, of the battery voltage, 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 (all market variants).

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 fitted to engines using the GEMS EMS looks similar, but this gear is fitted in place of the correct gear a fault will be stored, as the two gears have a different tooth spacing pattern.

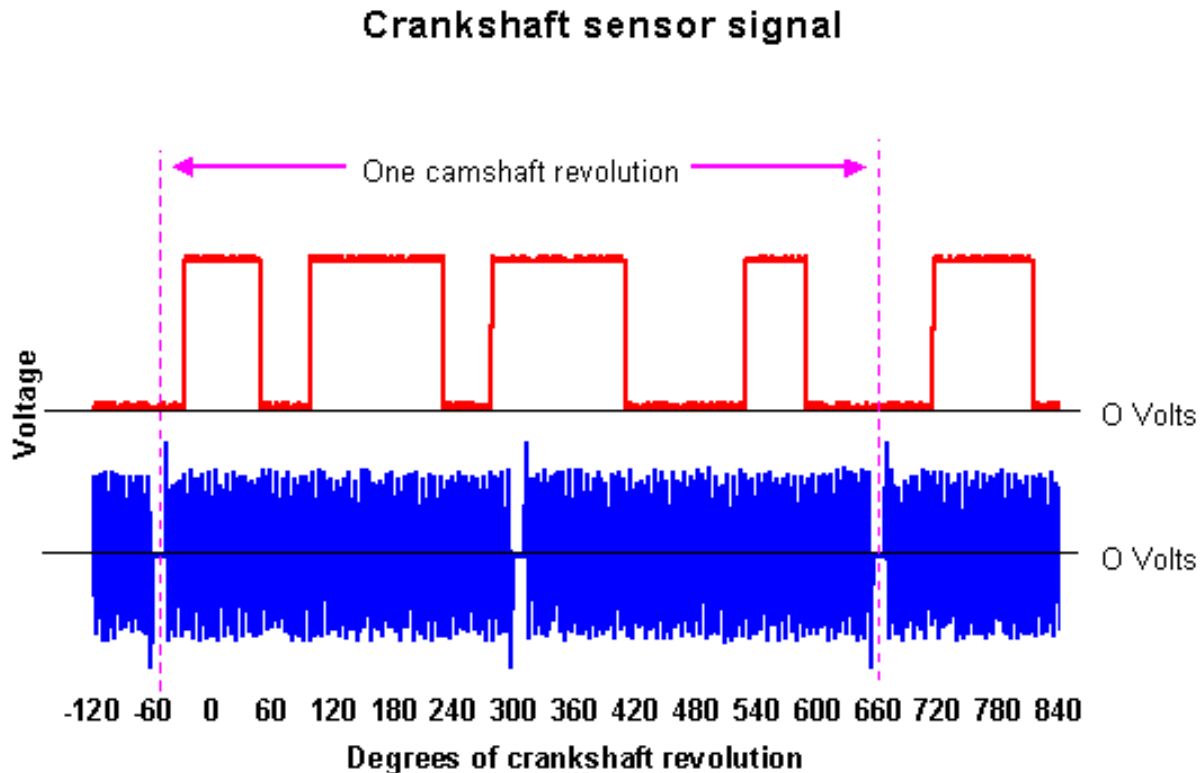
#### Camshaft position sensor



M18 0271

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 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:

Camshaft sensor signal



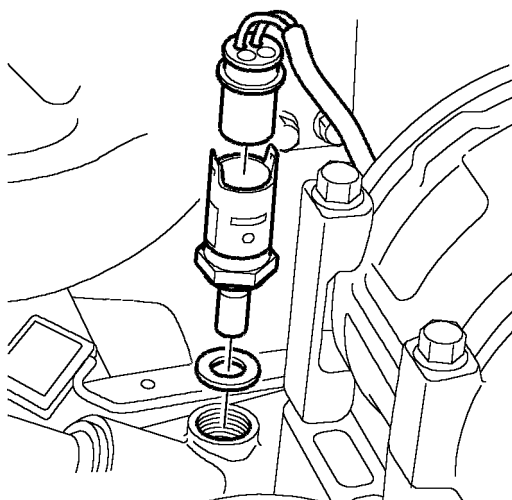
- The MIL lamp illuminated after 'debouncing' the fault (NAS only; MIL event all other markets)
- Loss of performance, due to the corrective ignition strategy being disabled. A default ignition map is used which retards the timing to a safe position
- Injector operation possibly 360° out of phase, i.e. 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, and the engine load calculation and the engine rev/min. 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 New Discovery applications and all four are used in 1999 MY Range Rover applications. The sensor conforms to the conventional negative temperature coefficient (NTC) electrical characteristics.

## Coolant temperature sensor



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 65°C (150°F). 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:

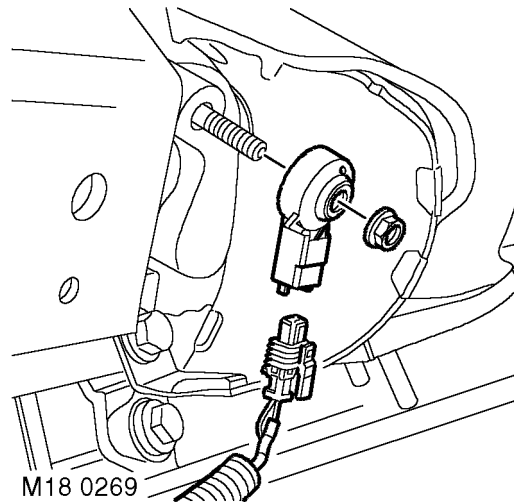
- The MIL lamp illuminated after 'debouncing' the fault (NAS only; MIL event all other markets)
- Poor engine hot and cold start
- Overheat warning lamp (incorporated within the Instrument pack) is illuminated
- Excessively hot or cold needle reading on the temperature gauge

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.

## Knock sensors

There are two knock sensors on the V8 engine, both located directly on the cylinder block, one on each side. The diagram below identifies their position relative to the engine block. 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.

## Knock sensor



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 fitting 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 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. 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 whilst 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.

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 '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.

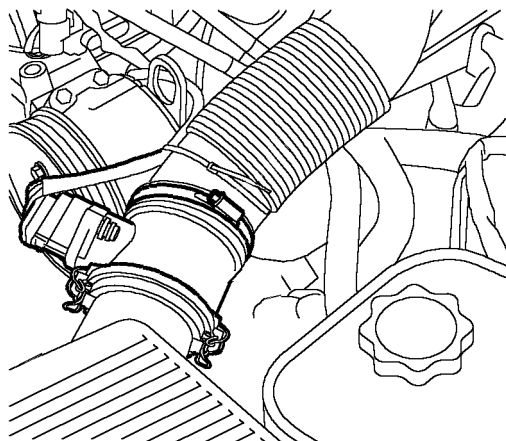
### **Air mass flow and temperature sensor**

The air mass flow (AMFS) meter is located in the air intake ducting, between the air filter housing and the plenum chamber. The AMF meter 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:

1. The sensor incorporates a hot film element. This film is heated by the circuitry in the AMF meter. 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 AMF meter also incorporates an air temperature sensor. This sensor is an NTC 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 AMF meter 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.

### Air flow meter



If the AMF meter 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 'debounced' (NAS only)
- 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 45°C (112°F). 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 fitted to petrol derivatives of New Discovery built to NAS specification. Oxygen sensors are not fitted to ROW specification vehicles and only two Oxygen sensors are fitted to vehicles that fall outside these two categories.

If the vehicle is fitted with four sensors, two of the sensors are located in each downpipe. One sensor is fitted prior to the catalyst, i.e. between the catalyst and the engine, and one is fitted immediately downstream of the catalyst. The two sensors fitted prior to the catalyst are referred to as 'pre-catalyst' sensors, whilst the two sensors fitted after the catalysts are referred to as 'post-catalyst' sensors. It should be noted that the 'pre-catalyst' Oxygen sensors are not interchangeable with the 'post' catalyst Oxygen sensors. Only pre-catalyst sensors are fitted if the vehicle features just two sensors.

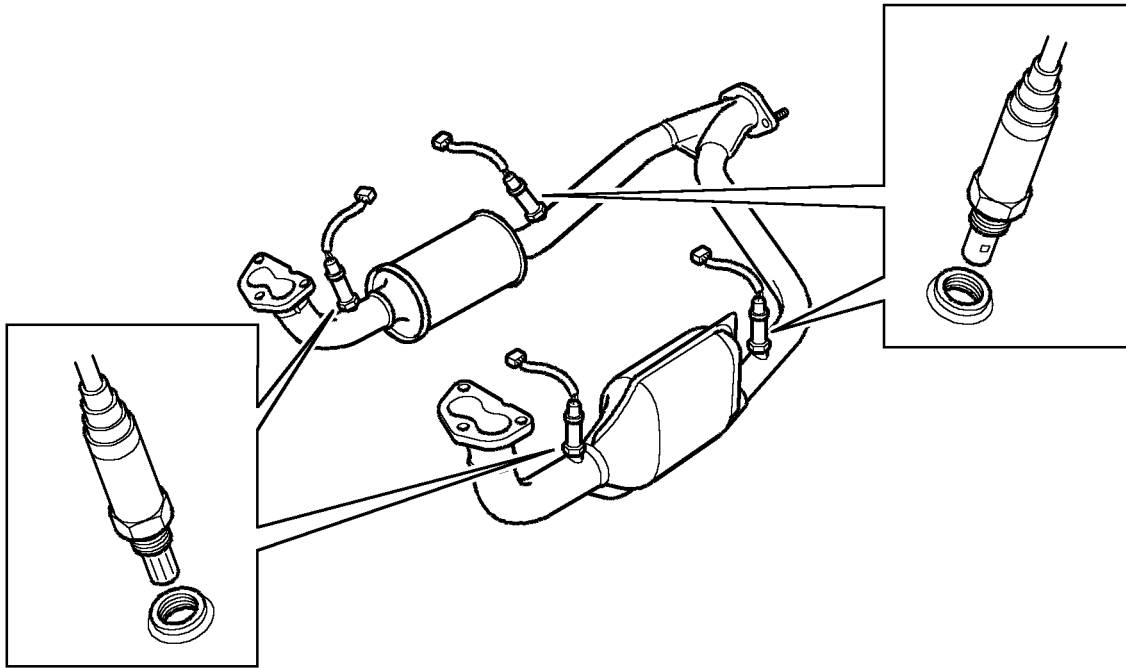
The Oxygen sensors are very sensitive devices. They must be handled carefully at all times. Failure to handle correctly will result in a very short service life, or non-operation.

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 refitted, 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, which is surrounded by a gas permeable ceramic material. 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 – 500mV). The voltage will fall in value to approximately 0.1 volts (900mV), 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. The ECM monitors the effect of altering the injector pulse widths using the information supplied by the Oxygen sensors. Injector pulse width is the length of time the injector is energised, 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.

## Oxygen sensor configuration



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 recognised, the ECM will illuminate the MIL lamp (NAS only) and store details of engine speed, engine load and the Oxygen sensor voltage (all markets other than ROW). 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 kilometres/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 (NAS only) and store a fault code (NAS and non-ROW markets). At the same time, the ECM will capture details of the engine speed, engine load and battery voltage. This feature eliminates the need for a 'service engine' lamp (NAS only). As the sensor response time will deteriorate over its life, the sensor must be replaced every 200,000 km (120,000 miles). Always refer to the maintenance schedules for the exact service replacement periods.

On NAS vehicles 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 lamp (after debouncing 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 350°C (670°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. 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 (NAS only).

### **Immobilisation signal**

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

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

The immobilisation code must also be relearned in cases where an ECM from one vehicle is fitted to another. The only circumstance where this action is not necessary is where an ECM is replaced on a NAS vehicle. To prevent this condition being misused, engineers have ensured that NAS ECM's cannot be fitted to any other market derivative, unless the immobilisation code is reset.

If the ECM detects an incorrect immobilisation 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 ( $\text{Lambda} < 0.8$ ). 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 TCU via the CAN link. The vehicle speed signal is produced by the SLABS ECU. The signal represents the 'average' of the road speed signals received from 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  $124^{\circ}\text{C}$  ( $255^{\circ}\text{F}$ ). The ECM will turn on the condenser fans if the engine coolant temperature exceeds  $100^{\circ}\text{C}$  ( $212^{\circ}\text{F}$ ). 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 TCU 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 TCU is able to request the illumination of the MIL lamp (NAS only; MIL event stored non-NAS markets) if it detects a fault within its systems that might lead to the vehicle emitting excessive levels of pollutants. It is good practise to check both ECM and the automatic gearbox TCU 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 vapour pressure within the fuel tank. It is used as a feedback device within the ECM's evaporative loss control (ELC) 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 ECU's

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

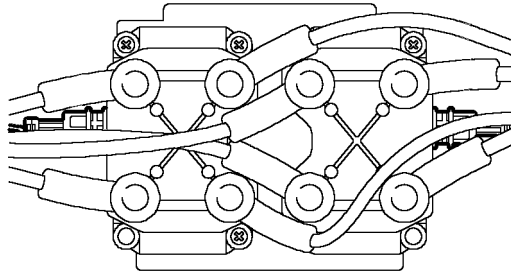
The V8 petrol engine installed in New Discovery is fitted with two twin-ignition coils (total of four coils). The two coils are located behind the plenum chamber at the rear of the engine. Each coil contains two primary windings and two secondary windings. There is a three-pin connector on each coil. 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 wasted spark technology to produce a powerful and precise spark. The cylinders are paired according to the table below.

|           |     |     |     |     |
|-----------|-----|-----|-----|-----|
| 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.

Coil pack



## Fuel injectors

There are eight injectors (one per cylinder) fitted to the V8 petrol 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 3.5 Bar. As indicated, the fuel pressure is fixed and the relief valve provides no compensation for increases or decreases in manifold depression. The ECM alters injector duration to accommodate such changes.

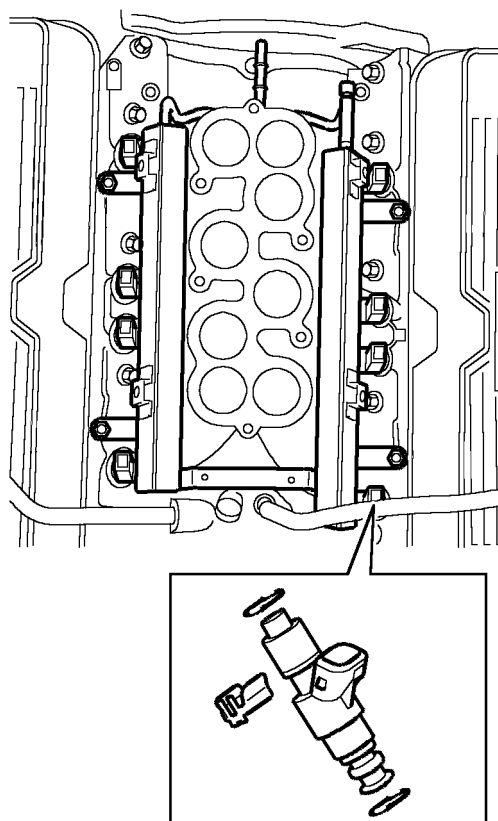
Connecting an appropriate gauge to the Schrader valve on the fuel rail provides a method of checking the fuel pressure. The valve is located to the rear of injector no. 7.

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 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.

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 20°C (68°F) with a tolerance of  $\pm 0.7$  ohms.

## Injector rail



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.

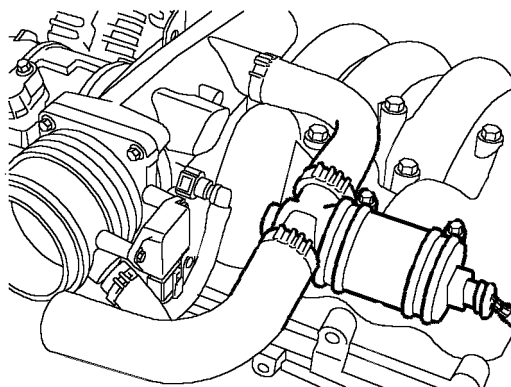
TestBook will also display data regarding injector operation via its live readings. Care must be taken when analysing this data, as the precise timings will vary considerably. Individual timings will be affected by any current engine load.

## 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 effectively 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.

#### Idle speed actuator



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 precise model specification and the operating conditions of the engine. These pre-set speeds are detailed in the table below.

| Vehicle derivative                              | Air conditioning | High range gears | Low range gears |
|-------------------------------------------------|------------------|------------------|-----------------|
| Manual (first 20 seconds after a cold start)    | N/A              | 1200             | 1200            |
| Automatic (first 20 seconds after a cold start) | N/A              | 1200             | 1200            |
| Low battery voltage detected                    | N/A              | 850              | 850             |
| Manual                                          | On               | 740              | 740             |
| Manual                                          | Off              | 660              | 660             |
| Automatic drive selected                        | On               | 740              | 580             |
| Automatic drive selected                        | Off              | 660              | 580             |
| Automatic park/ neutral selected                | On               | 740              | 580             |
| Automatic park/ neutral selected                | Off              | 660              | 580             |

The market specification programmed into the vehicle can have an effect upon the idle speed. In some markets the idle speed is raised slightly to aid engine cooling.

For 20 seconds immediately following cold start, the idle speed will be raised to 1200 rev/min. 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 rev/min. 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.

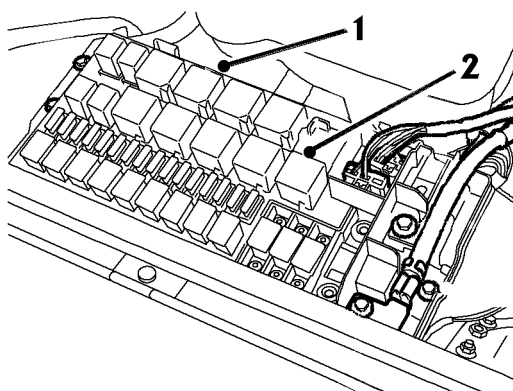
If ECM control of the idle speed actuator is suspended, (i.e. fault stored), then the driver may notice the following symptoms relating to engine performance:

- 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-bonnet fuse box.

Under bonnet fusebox



1.Main relay  
2.Fuel pump relay

The ECM energises 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.

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 (whilst 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 whilst the engine is running.

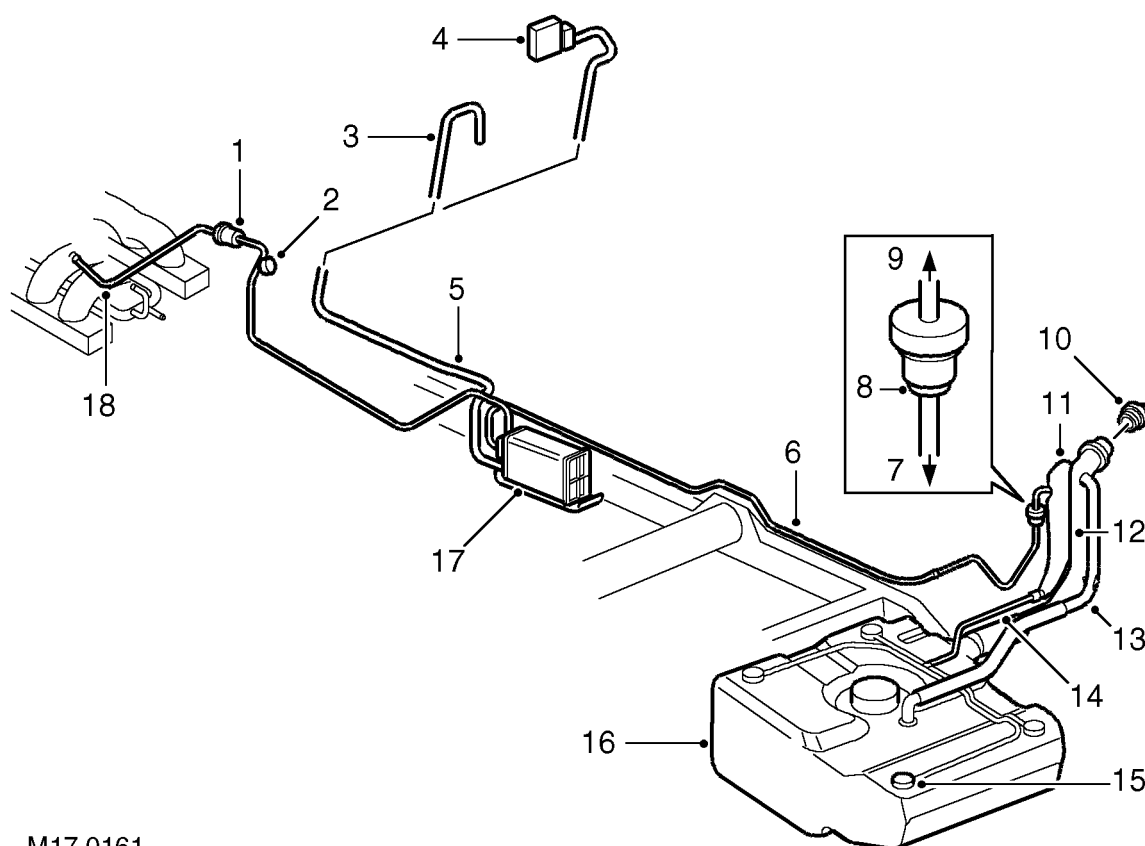
Failure of the fuel pump relay will result in engine non-start. If the fuel pump fails whilst the engine is running, the symptoms will be engine hesitation and engine misfire. These symptoms will worsen progressively until the engine stops. The ECM will store several fault codes under this condition.

### **Purge valve**

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

- The charcoal canister, which is located on the right hand inner chassis rail by the handbrake drum
- The fuel tank pressure sensor (NAS only), located in the fuel sender unit
- The intake manifold

The ECM controls the amount of vapour 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 vapour level of 1% can affect the air/fuel ratio by as much as 20%.



M17 0161

1. Purge valve
2. Service port
3. Snorkel tube (UK / ROW only)
4. CVS unit (NAS only)
5. Charcoal canister breather tube
6. Vent pipe – fuel tank to charcoal canister
7. Relief valve regulated flow
8. Relief valve (UK / ROW only)
9. Relief valve free flow
10. Fuel filler cap
11. Liquid vapour separator (UK / ROW type

- shown)
12. Fuel filler hose (UK / ROW type shown)
13. Tank breather hose (UK / ROW only)
14. Vent hose
15. Roll over valves (ROV's) – (4 off, UK / ROW spec. shown)
16. Fuel tank and breather assembly
17. Charcoal canister
18. Purge line connection to engine manifold

The ECM can diagnose faults with the purge valve and the rest of the ELC 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 ELC system has failed:

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

## Engine speed

The engine speed signal is supplied from the ECM to the automatic gearbox TCU 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 TCU 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 ECU 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 valve
- The throttle position sensor (TPS)
- The Oxygen sensors
- The airflow meter (MAFS)
- 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 fitted, 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 TCU. 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 refitted. 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 | Adaption |
|--------------|----------|
| 1800 - 3000  | 1        |
| 3001 - 3800  | 2        |
| 3801 - 4600  | 3        |
| 4601 - 5400  | 4        |

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 whilst the vehicle is moving at speed.

1. Use TestBook to clear any adaptations 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 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 FTP requirements 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 lamp (NAS only). 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 rev/min., engine load and engine coolant temperature. It will also flash the MIL lamp (NAS only) 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).

### **Evaporative loss control system (NAS derivatives only)**

The evaporative loss control (ELC) system serves to control the amount of hydrocarbon vapour emitted from the vehicle. It does this by controlling the amount of vapour purged from the charcoal canister and by monitoring the state of the fuel tank and fuel system.

It detects any mechanical failure in the sealing of the fuel system. Legislation dictates 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, (figure based upon the amount permitted to escape through a 1mm (0.04") hole). The ECM uses the purge system and the fuel tank pressure gauge to assess the integrity of the fuel system.

The ECM completes this test only if the vehicle is stationary and at idle. The test compensates for the natural evaporation of petrol, 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.

The ECM purges the charcoal canister of vapour and then closes the charcoal canister vent valve. This action produces a depression within the fuel tank. At a predetermined depression, 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 equalise rapidly. 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 ELC 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 recognised. If the ECM detects a fault within the ELC system on two consecutive 'journeys', then it will illuminate the MIL lamp.

### **Setting the CO (ROW derivatives only)**

The Carbon Monoxide (CO) emissions can be set manually on non-catalyst vehicles. On these vehicles, the CO is adjusted by reprogramming the ECM's software using TestBook. TestBook has three specific functions relating to the setting of the CO. These are:

- Read the current CO value
- Adjust the current CO value
- Programme the required CO value into the ECM

The ECM stores the base CO setting as a number in a range between 0 and 255. The nominal setting is 128. TestBook can be used to adjust this value in increments of 1 or 10 units.

It is important that the CO adjustment is made following the procedure detailed below.

#### **Preparation:**

1. Disconnect the electrical connector from the purge valve
2. Warm up the exhaust gas analyser and position it appropriately
3. Connect TestBook to the vehicle (TestBook must be connected to the vehicle via the vehicle battery supply lead)

**Procedure:**

1. Drive the vehicle until the engine coolant temperature stabilises, indicating that the thermostat is open fully. This signal can be monitored via the live reading display on TestBook. The temperature must stay above 86°C (187°F) for the duration of this procedure
2. Drive the vehicle to the exhaust gas analyser, and, without delay, measure the CO. Adjust the setting to obtain the correct CO

**Care Point:**

- a. The exhaust gas reading must be allowed to stabilise between adjustments
  - b. Do not allow the engine to idle for than 30 seconds during the procedure (the engine speed should be raised to 2000 rev/min., with the vehicle in neutral gear if this occurs)
  - c. If the total adjustment process takes longer than 2 minutes, then the vehicle must be driven (as described in Procedure 1) again
3. When the correct CO setting has been achieved, the reading must be programmed into the ECM memory. TestBook must be used to do this. Once completed, the ignition should be switched off for at least 15 seconds
  4. The purge valve must be reconnected and the purge valve fault code cleared from the ECM's memory

**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 rectification.

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.