



FREELANDER 2001 MY

Workbook

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Preface

This document has been issued to support the Freelander model range 01MY. The information contained within this document relates to the features and specification of this model.

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 Service 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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Freelander 2001 MY

Introduction

In 1997 to much acclaim Land Rover launched Freelander. This new model range saw a significant departure from the traditional Land Rover engineering format and carried the Land Rover brand into the medium and small segments of the four wheel drive leisure market. Again, Land Rover has captured the leading position within the market segment and continues to develop its position.

Freelander was something new from Land Rover. Designed to be adaptable and accessible, broadening the appeal of the Land Rover Brand. It featured many innovative solutions designed to create car-like ride and handling for enjoyable and adventurous driving, both on the road and off it. Freelander is modern and contemporary, without denying its Land Rover heritage. A range of body styles are available: the three door comes in either Softback or Hardback versions and there is also a five door Station Wagon.

The key features of the vehicle which are carried over to Freelander 2001 model year are as follows:

- All round independent suspension
- Power assisted rack and pinion steering
- Permanent four wheel drive
- Four channel ABS
- Electronic Traction Control.
- Hill Descent Control
- Integrated Body/Chassis design
- Use of engineering polymers and other advanced materials
- Driver and passenger airbags
- Pyrotechnic front seat belt pretensioners
- Three-point centre rear seat belt (where three rear seat belts fitted)
- Sophisticated integrated vehicle security system
- 1.8 litre K Series petrol engine
- Intermediate reduction drive
- Wide range of accessories

Major changes

The major change to Freelander 2001 model year is the introduction of new powertrain derivatives. The familiar K1.8/PG1 has been modified to meet ECD 3 legislation and will be supported by the new 2.5 litre KV6 engine with Jatco automatic steptronic transmission. The L series 2.0 litre diesel engine is replaced by the BMW common rail M47R engine. The M47R is available with both the Jatco automatic transmission and a new manual transmission the Getrag 283.

Other feature changes include:

- Revised anti-lock braking system (ABS) fitted as standard with hill descent control (HDC), electronic traction control (ETC) and electronic brakeforce distribution (EBD)
- Full controller area network (CAN) bus system
- Cruise control (both petrol and diesel automatic derivatives)
- New instrument pack
- New immobilisation system - (EWS-3D)
- HEVAC upgrades including variable displacement compressor, pulse width modulated (PWM) cooling fans and air conditioning pollen filter
- Heated seats with lumbar adjust available on driver's seat
- Electric rear windows
- One shot down on driver's window
- Revised and improved audio system including steering wheel switches

Window lift system

New features of the window lift system include rear electric windows; a one-shot down function on the driver's window and a timer delay function allowing the electric windows to be operated for a predetermined amount of time after the ignition has been switched 'off'. Five door derivatives have an isolator switch located in the centre console for the rear side door windows.

The driver's window one shot facility is controlled by a window lift ECU which is located on the driver's side 'A' post, level with the lower edge of the fascia. If driver's door window switch is pressed for 0.2 seconds or less the window will be driven down to the full extent of its travel.

The window lift switches are located in a new position on the centre console providing easier access and operation.

The central control unit controls the power feed to the window lift relay, located inside the passenger compartment fusebox. The window lift relay supplies power to the driver's window lift ECU and to the other electric window circuits directly. The output is enabled by the CCU with the ignition 'on' (position II). When the ignition is turned 'off' a timer function of the CCU enables the front and rear electric windows to be operated for forty seconds after ignition 'off'.

Environmental Box

The environmental 'E' box is designed to keep the temperature of the components contained within it at the same temperature as the cabin temperature. Air is circulated from the cabin through the 'E' box and back into the cabin.

The 'E' box is fitted to Freelander KV6 and M47R derivatives and enables their use in +50°C markets.

The following components are contained within the box:

- Engine control module
- Automatic transmission control unit (if fitted)
- Glow plug relay (diesel only)
- Temperature sensor

The E-box is a container that provides a protected environment for the ECM, the glow plug relay and the EAT ECU. An open hub, centrifugal fan powered by an electric motor ventilates the E-box with air from the passenger compartment. Air from the E-box is directed back into the passenger compartment. The ventilating and exhaust air is routed between the passenger compartment and the E-box through plastic ducting and corrugated rubber hoses. Operation of the cooling fan is controlled by a thermostatic switch in the E-box. The thermostatic switch receives a power feed while the ignition switch is in position II. If the temperature in the E-box reaches 35°C (95°F) the thermostatic switch closes and connects the power feed to the fan, which runs to cool the E-box with air from the passenger compartment. When the temperature in the E-box decreases to 27°C (80°F), the thermostatic switch opens and stops the fan. To prevent the fan seizing up in cold climates, where it may not operate for long periods of time, the fan also receives a power feed from the starter circuit so that it runs each time while the engine is cranked.

E-Box location



Figure 1

1. E-Box
2. Engine compartment fusebox

Body modifications

The following list identifies new features that are available with Freelander 2001 MY. Availability will be market dependent for a number of the features:

New features

- KV6 front end extended with unique bumper covers
- Shift interlock (JATCO)
- Rear seat belt automatic locking retractors
- Front seatbelt load limiters
- Front seat belt buckle warning
- Dark tinted privacy glass
- Powerfold door mirrors
- Illuminated sunvisor
- V6 badge
- New range of alloy wheels

Power distribution and bus systems

Power distribution

Power distribution within the vehicle and the safe delivery of that power is carried out by the battery, the alternator, the harness and the fuseboxes. The fuseboxes protect and isolate all systems but there is also additional protection for many individual systems contained within individual circuits and ECU's.

Battery and alternator specification

Component	KV6	M47	K 1.8
Battery	Delphi H6 75 Ah	Delphi H7 80 Ah	Delphi H5 55 Ah
Alternator	Denso 120 A	Valeo 115 A	A/C Denso 105 A Non A/C Denso 90A

Battery

All Freelander 2001 MY batteries are sealed for life and maintenance free. Located on top of the battery is a condition indicator which can indicate three battery states:

1. Green - battery is in good state of charge
2. Dark (turning to black) - battery requires charging
3. Clear (or light yellow) - battery must be replaced

Fuseboxes

There are two fuseboxes fitted to Freelander 2001 MY. One is located in the engine compartment near to the 'E' box and the other is located behind the fascia beneath the steering column. The engine compartment fusebox contains three types of fuse:

1. Blade type fuse: Conventional pull out male type fuse used to protect circuits between 5 amps and 30 amps
2. J-case fuse: A square shaped pull out female fuse used to protect circuits from 30 amps to 60 amps
3. Bolt down fuse: Sometimes called a fusible link they are used to protect circuits 40 amps to 250 amps

The passenger compartment fusebox contains only the conventional blade type fuses and several relays.

Passenger compartment fusebox

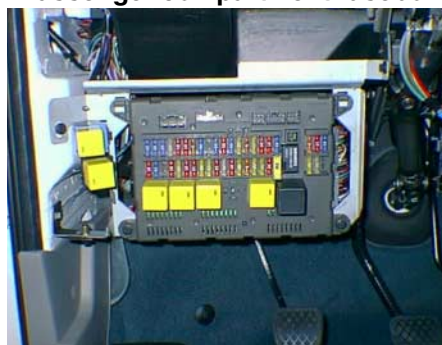


Figure 2

Introduction to Bus technology

Technological advancement in vehicle electronics has led to many changes and improvements in vehicle electrical systems. Vehicles are now fitted with systems which, although complex in functionality, are user friendly and very reliable. Electronic control units are used to control and monitor the operation of the systems they are fitted to and are increasingly being used to transfer information to other system ECU's via bus technology.

An ECU is populated with solid state components, the capacity of which is matched to the complexity of the system it has to control. ECU's receive input signals corresponding to the current state of the system under its control. The signals to the ECU come from various sensors and switches and these inputs dictate the outputs the ECU's send to the actuators of the system.

The powertrain electrical architecture of Freelander 2001 has been designed to exploit the potential of its technological advances. Rather than having an ECU dedicated to its system and unaware of the operation of other systems, the powertrain systems around Freelander 2001 are linked together. The ECU's are linked to each other via the CAN-Bus-system, allowing communication and exchange of information.

Control unit locations

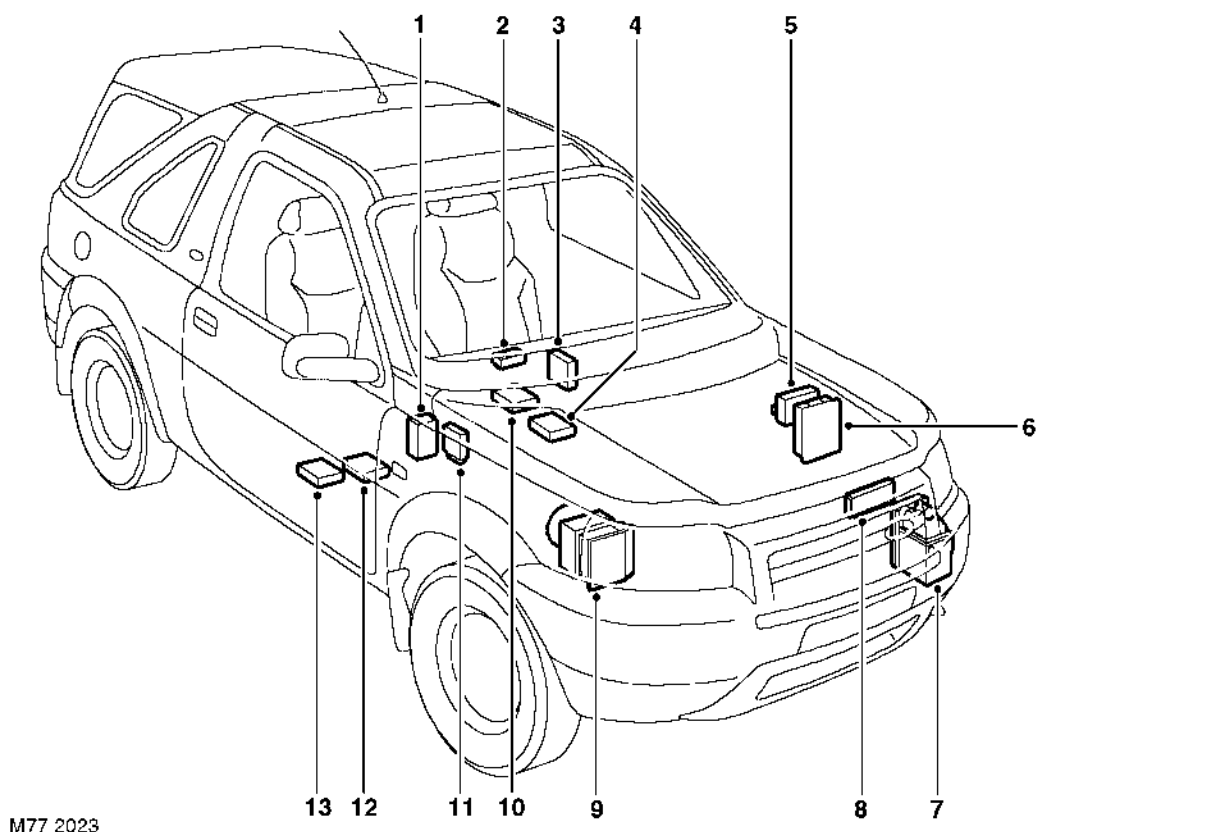


Figure 3

- | | |
|---------------------------------------|---|
| 1.CCU | 8.Cooling fan ECU |
| 2.RF receiver | 9.ABS modulator |
| 3.Immobilisation ECU | 10.Folding door mirror ECU (where fitted) |
| 4.SRS DCU | 11.Window lift ECU |
| 5.EAT ECU (automatic gearbox models) | 12.Cruise control interface ECU |
| 6.ECM | 13.Cruise control ECU (where fitted) |
| 7.Fuel burning heater ECU (M47R only) | |

The diagnostic information from each of the vehicle ECU's is accessed using TestBook via the relevant bus system.

CAN-Bus (controller area network)

The CAN-Bus system has been developed by Bosch and is becoming the industry standard for Europe. The CAN system is a high speed serial data bus system linked by an unscreened twisted pair of wires: yellow/black and yellow/brown. The wires are twisted to minimise electromagnetic interference from the signal passing down the lines to other systems in the vehicle, such as the radio system. Both wires carry information and for CAN to operate, both signals must be present. The CAN system is the fastest of the Bus-systems, capable of carrying 500,000 bits of information every second. This speed is recognised as the fastest practical operating speed without a requirement for screened cable. It is used for systems where the speed of exchange of information is vital for their performance; engine management systems, automatic transmission and traction control.

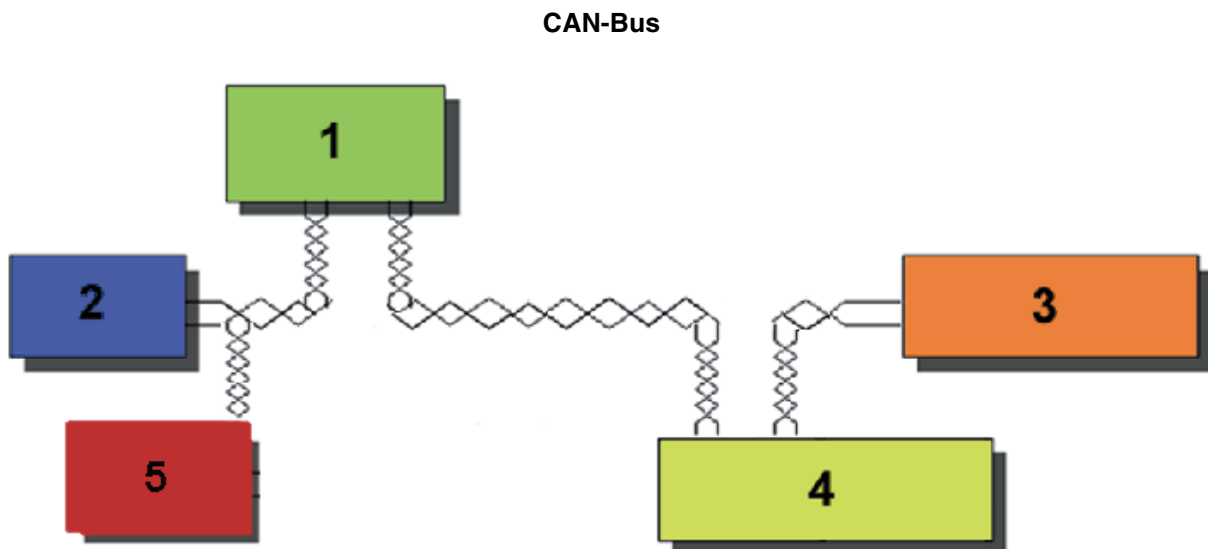


Figure 4

- 1.ABS ECU
- 2.Instrument pack
- 3.Engine management system
- 4Automatic transmission control unit
- 5.Diesel cruise control interface unit

The CAN system consists of the main bus length and shorter stubs. The main bus length terminates at the ECM and the IPK and must not be longer than 40 metres. Any untwisted portion of the bus should not be longer than four centimetres. Freelander 01 MY uses a 'daisy chain' set up with the M47R cruise interface unit tapping off the system to enable its CAN functionality. The interface unit is a CAN based ECU which listens on the CAN system and communicates with the diesel engine management system using multi function logic.

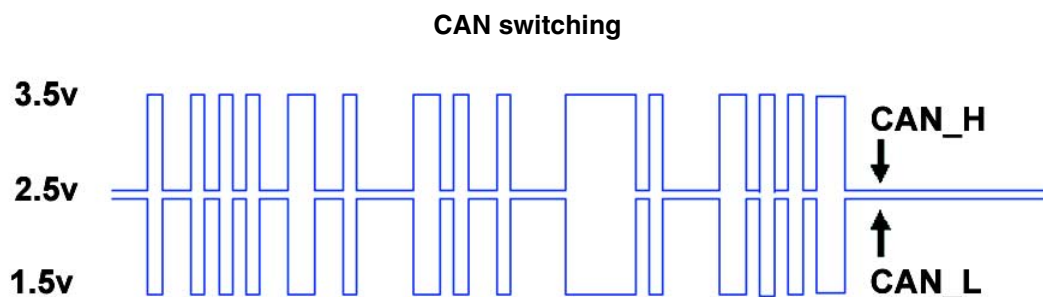


Figure 5

As stated, CAN consists of a twisted pair of wires. One line is called CAN high (CAN_H) and is yellow and black. The other line is called CAN low (CAN_L) and is yellow and brown. CAN_L switches between 2.5 and 1.5 volts. CAN_H switches between 2.5 and 3.5 volts.

With both CAN_H and CAN_L both at 2.5 volts there is no potential difference (voltage) between them and this is known as the recessive state and is equivalent to logic 1.

With CAN_H switched to 3.5 volts and CAN_L switched to 1.5 volts there is a potential difference of 2 volts between them and this is known as the dominant state and is equivalent to logic 0.

CAN_H and CAN_L always switch together and these two states are the only two possible. When an ECU transmits a signal, it is made up of a series of dominant and recessive states generated by the simultaneous switching of the CAN wires. The signal is a combination of the two possible states, in effect 0 and 1, hence a digital signal.

The structure of a CAN-Bus signal is made up of several parts as shown below:

CAN message structure

Start	Identifier / Name	Control Field	Data 0-64 Bits	CRC Test	Confirm	End of Frame
-------	-------------------	---------------	----------------	----------	---------	--------------

The whole message structure can vary from a minimum of 44 bits in length to a maximum of 108 bits.

The message will begin with data to signify the 'start' of the message and will also contain data to signal the message end, 'end of frame'. The 'identifier' part of the signal will determine the content of the signal and the priority of the signal. Arbitration is necessary when a message is transmitted at the same time as another message.

The 'control field' carries information as to the number of bytes to follow and the data field is the actual value of the signal being transmitted.

As an ECU transmits a signal onto CAN it also reads back the identifier on CAN. If it does not recognise the identifier as its own this means it has lost arbitration to another signal transmission and it stops the transmission of its own message. The ECU will wait until the Bus is quiet before transmitting its message again.

Error checking of the signal is performed by the cyclic redundancy check (CRC). All the bits that make up the signal are assembled into an algorithm and this is sent as the CRC part of the signal. The receiver ECU will assemble the signal into the same algorithm and the result should match the CRC part of the signal. If they do not match, an error is recognised and the message is ignored. No acknowledgement (confirm) is given to the erroneous message. Because the ECU which transmits the message is also waiting to receive an acknowledgement, it recognises that the message is faulty and re-transmits the message. Calculations for the amount of error messages which escape these checks have shown an average of 1 error per 10,000,000,000,000 messages manages to get through.

For correct operation of the bus, the bus line must be terminated at both ends (ECM and IPK) with a resistor of nominal value 120 ohms, connected between CAN_H and CAN_L. These terminations ensure that bit errors due to signal reflections are avoided.

Fault finding

In trying to diagnose and locate a fault on the CAN-Bus or any of its associated components a logical approach should be used. Examples:

- Are the tachometer and coolant gauges working? If either is working, this indicates the CAN link from the ECM to the IPK is operating.
- Does the 'park, reverse, neutral, drive and low (PRNDL) display show the current gear on the IPK? If it does, this indicates that the CAN link from the automatic transmission control unit to the IPK is operating.
- During the start up bulb check, the HDC warning lamps in the IPK illuminates for approximately two seconds and then extinguish. If this occurs it is an indication that the CAN link from the ABS ECU to the IPK is operating.

Note: *TestBook must be used to diagnose the CAN system.* It is a complex interconnected system and TestBook will assist the operator through the diagnostic route.

ECU's are very reliable and ECU failures rare. Wiring faults and poor connections are more common and the symptoms of the fault will vary with the location and severity of the fault. Faults on the system can be diagnosed logically by observing the symptoms and using a process of elimination. TestBook will guide the operator through the process.

If either CAN_H or CAN_L short to ground or short against each other, the CAN-Bus will not function and, therefore, communication will not take place. If a break appears in one of the lines, diagnostic equipment may be used to interrogate each ECU and find out what it is receiving and what it is not. When the CAN system is inoperative, each system ECU will operate independently-some in a default 'limp home' mode.

When repairing a section of harness care must be taken with the CAN twisted pair of wires. It is important that the twisted pair should not be unwound more than 3 - 4 cm.

Diagnostic bus

The diagnostic buses connect the diagnostic socket to the ECU's on the CAN bus and to individual system ECU's. The diagnostic buses enable fault diagnosis, system testing and vehicle configuration. The diagnostic socket is located above the transmission tunnel. On RHD vehicles the connector is situated to the left of the centre console, and on LHD vehicles to the right of the centre console.

ISO 9141 K line

The ISO 9141 K line connects the diagnostic socket to the majority of the ECU's fitted to the vehicle. The protocol used means that non TestBook diagnostic equipment, such as scan tools, can be used to access SRS and emission related faults stored in the ECU memories.

DS2 Bus

The DS2 bus connects the diagnostic socket to the EWS-3D ECU. The protocol used means that only TestBook can communicate with the immobilisation system.

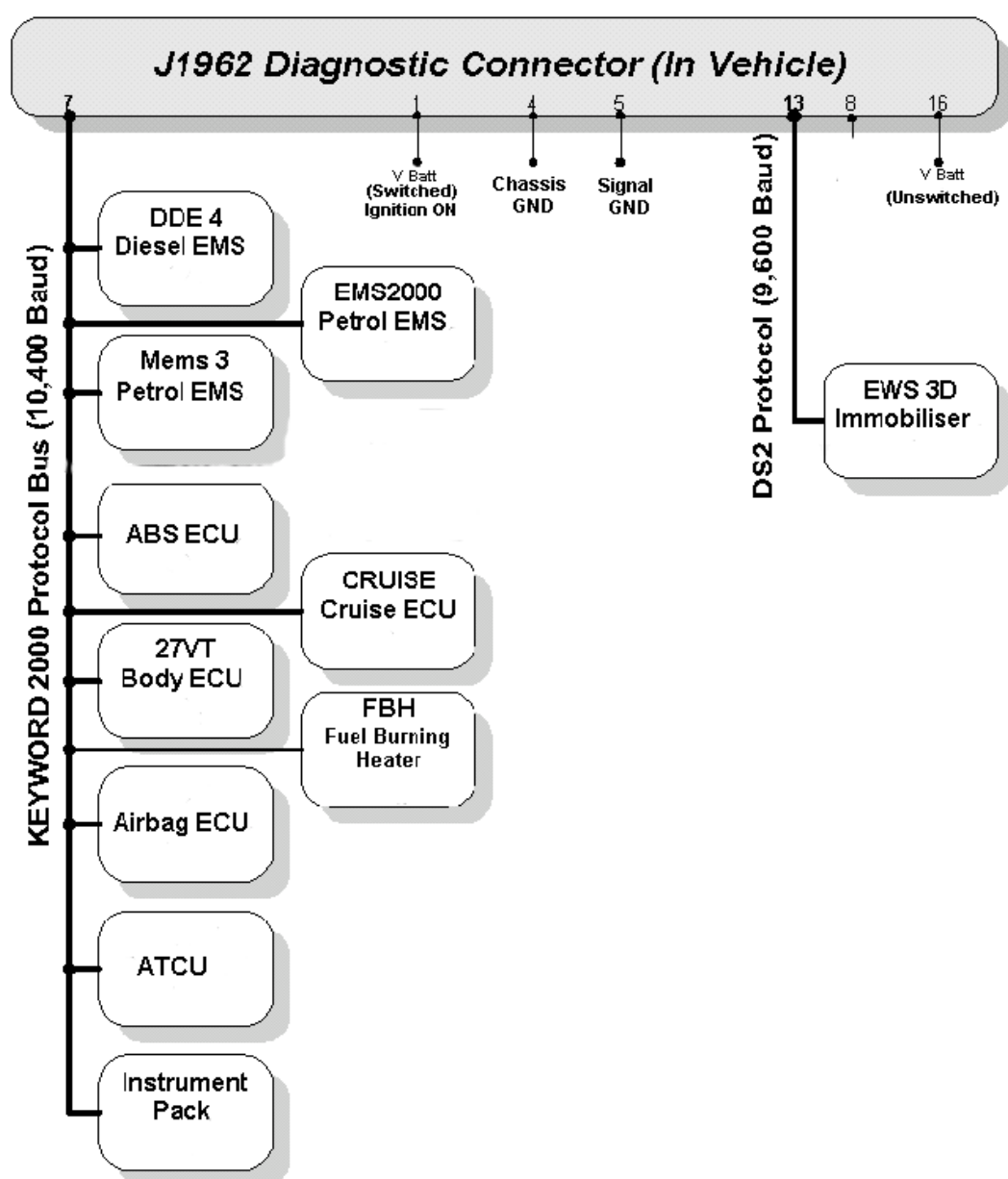
Diagnostic set up

Figure 6

Central control unit

Introduction

The central control unit (CCU) is used to control several systems fitted to Freelander is attached to the passenger compartment fusebox which is beneath the steering column. It is a similar unit fitted to existing Freelander models but with some functional differences.

This CCU controls the following vehicle systems:

- Vehicle locking and alarm system
- Interior lamps
- Rear fog lamps
- Tail door window operation
- Audible and visual warnings
- Front and rear wipers
- Heated rear window

In addition, the CCU also incorporates the following features:

- Timer Control
- Programmable Features
- Window lift enable
- Transit mode

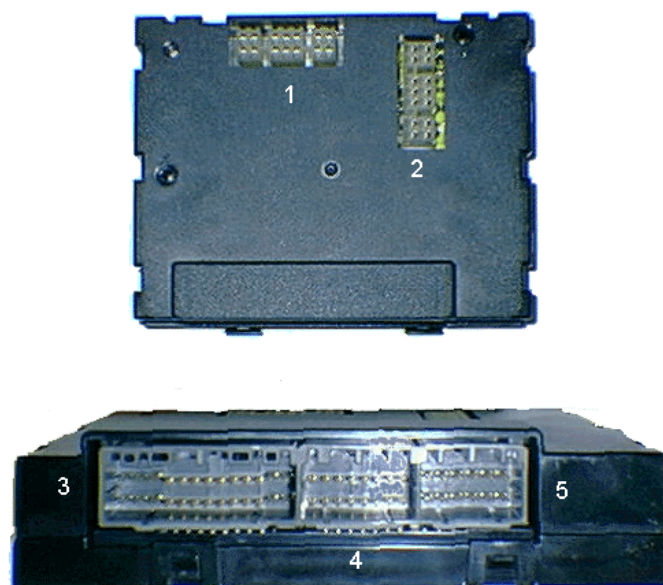


Figure 7

1.Passenger fusebox connector
2.Passenger fusebox connector
3.Connector C0428

4.Connector C0429
5.Connector C0430

Transit mode

To help prevent battery discharge in transit the CCU can be programmed, using TestBook, into 'transit mode'. In transit mode many vehicles systems and system features are disabled. The minimum number of features are enabled allowing the vehicle to function safely. A specific warning sound is emitted by the CCU when the vehicle is in transit mode with the ignition 'on' and the engine not running.

The following functions are disabled in transit mode:

- RF receiver power
- Central door locking
- Interior lamps
- Tail window
- Tail door actuator

Self test mode

The CCU can be put into self test mode to enable the inputs and outputs from the CCU to be tested for correct functionality without the need for TestBook. To put the CCU into self test mode the ignition should be off with the vehicle unlocked and unarmed and the following sequence must be followed:

1. Turn the ignition 'on'
2. Press and hold the rear fog switch 'on'
3. Turn the ignition 'off'
4. Turn the ignition 'on'
5. Release rear fog switch within four seconds of ignition 'on'

On successful entry to the self test mode the sounder will sound for 0.8 seconds and the courtesy lamps will illuminate for 0.8 seconds.

When testing an input, for example a door open switch, on successful receipt of the input the CCU will sound the sounder for 0.8 seconds and illuminate the courtesy lamps for 0.8 seconds.

Outputs are tested in sequence using the CDL lock switch to progress through the outputs. A CDL unlock requests repeats the last test. Outputs are either operated continuously until the CDL lock switch is released, or operated in a pulsed fashion until the next operation of the CDL lock switch. Output formats are described in the table 'Self test outputs'.

Self test outputs

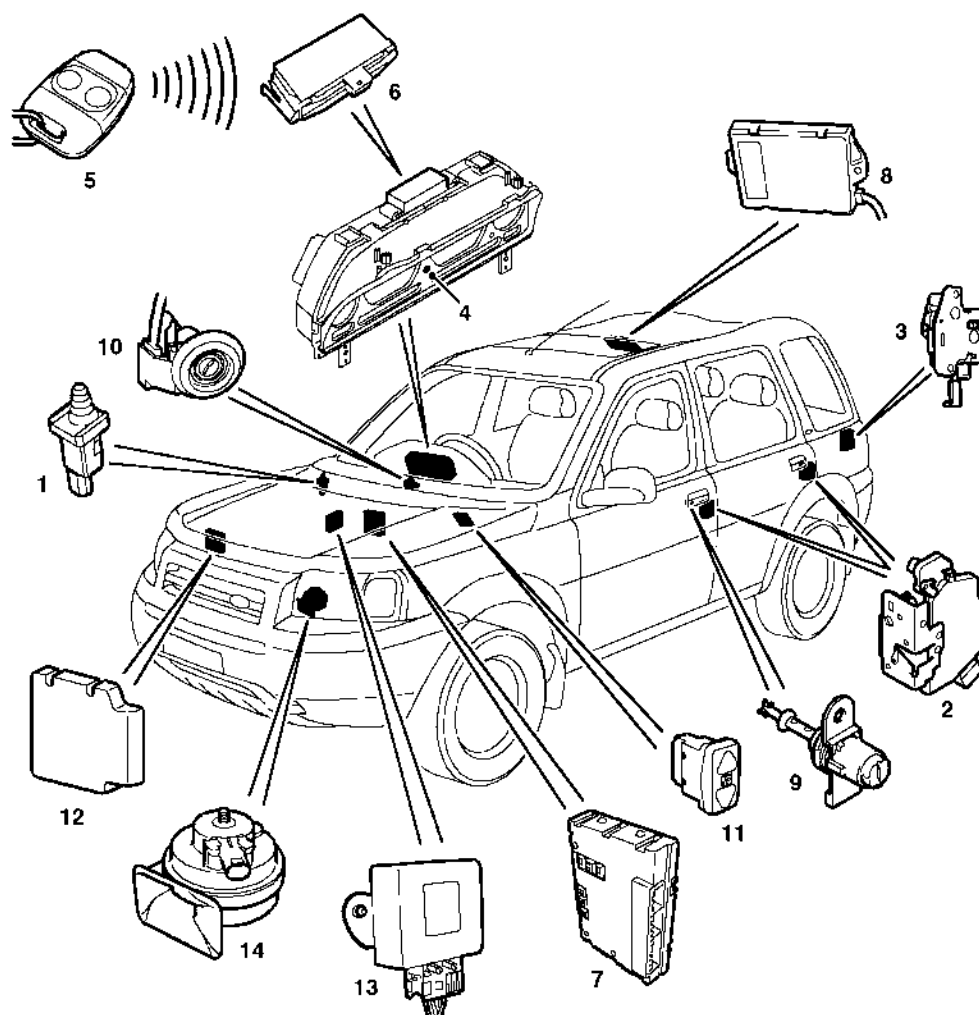
Output	Test type
Rear fog lamps	Continuous
Lock	Pulsed
Superlock	Pulsed
Unlock	Pulsed
Front wiper	Continuous
Alarm LED	Continuous
Volumetrics	Continuous
Horn	Pulsed
BBUS	Pulsed
Heated rear window	Pulsed
Tail window down	Pulsed
Tail door actuator	Pulsed
Tail window up	Pulsed
Rear wiper	Continuous
Hazard lights	Continuous
Door open warning lamp	Continuous
Seatbelt warning lamp	Continuous
Handbrake warning lamp	Continuous

Self test mode is exited upon ignition 'off', if oil pressure is sensed (engine running) or if the vehicle speed exceeds 1kph.

Locking and alarm systems

Introduction

In this document reference is made to various vehicle locked states. For clarity the following terms will be used: CDL locked, locked and superlocked. The term "CDL locked" will be used to refer to the condition attained following operation of the CDL switch. The term "locked" will be used to refer to the state attained following a successful key lock operation. The term "superlocked" will be used to refer to the state attained following a successful key superlock operation, or a remote lock operation.



M86 5313

Figure 8

- | | |
|------------------------------------|------------------------|
| 1. Bonnet switch | 10. Ignition switch |
| 2. Door latches | 11. CDL switch |
| 3. Tail door latch | 12. ABS ECU |
| 4. Alarm LED | 13. Immobilisation ECU |
| 5. Remote handset | 14. Horn |
| 6. RF receiver | |
| 7. Body control unit | |
| 8. Volumetric sensor | |
| 9. Driver's door key barrel switch | |

Locking

On all models a CDL switch is mounted in the centre console. This switch allows the occupants to centrally lock the vehicle without arming the alarm, (similar to conventional sill lock). The vehicle can also be centrally unlocked from the switch, providing the alarm is disarmed. The vehicle will not centrally lock from the CDL switch if the inertia switch is in the tripped state. In addition, the CCU will automatically unlock all doors from the CDL locked state, in cases where it detects the inertia switch moving to the tripped state whilst the alarm is disarmed.

Key & Remote Handset Locking

In addition to the CDL switch, the vehicle can be locked and unlocked using the door key or the remote handset. The precise way in which a vehicle responds to a key or remote handset input, with regard to vehicle locking/unlocking and alarm arming/disarming, will depend upon the programmed state of the CCU.

The programmed state of the CCU will be configured automatically when the vehicle's Market Option is set. The Market Option selected is determined by territory. New vehicles are programmed during the manufacturing process. In service TestBook must be used to set the Market Option. Once the Market Option has been set the CCU will function according to a predetermined strategy. Some features within these strategies will be fixed, whilst a number will remain selectable, e.g. the precise locking and unlocking functionality.

In summary, vehicles can be:

- CDL Locked = vehicle locked via CDL switch
- Key Locked = turn the top of the key towards the rear of the vehicle once
- Key Super Locked = turn the top of the key towards the rear of the vehicle twice (note: the second turn must be made within 1 second of the first)
- Remote Locked (provides super lock) = single press of the lock button on the remote handset.

Additional Locking Information

It should be noted that any CDL or arm request made using the key or the remote handset will be ignored while the ignition is 'on' (although the driver's door will mechanically lock in response to a key lock attempt). In addition, if any of the passenger compartment doors are open when a superlock request is received, then the system will only attempt to lock.

In line with the functionality of other Land Rover products, whenever the inertia switch is tripped, while the ignition is 'on' and the alarm is disarmed, all the doors will be unlocked (irrespective of their current locked state). Subsequent attempts to lock the doors will then be inhibited until the ignition is switched 'off' and the driver's door is opened and closed and the inertia switch is reset.

Tail door release, carried out by way of the exterior door handle, can be achieved while the vehicle is in the unlocked and disarmed state. The CCU will inhibit operation of the tail door release mechanism if the vehicle is travelling at a speed greater than approximately 5 km/h. The CCU receives a vehicle speed input signal from the ABS ECU.

The driver's door latch is designed to mechanically inhibit slam locking. If it is necessary to externally lock a vehicle without arming the alarm, then the driver's door must be sill locked and then the vehicle must be slam locked using a passenger door.

In order for the system to respond to a remote handset lock or unlock request, the handset must be synchronised with the CCU. It will become unsynchronised with the CCU in circumstances where the power supply to either the remote handset or to the vehicle is lost.

To re-synchronise a remote handset with the CCU, press the lock or unlock button five times, or any combination of both buttons five times, in succession with the ignition 'off'.

Single point entry

An additional feature, referred to as Single Point Entry (SPE), is selectable on all models. This feature is designed to enhance the security of the vehicle and its user. SPE will operate when unlocking the vehicle from the superlocked state using the remote handset. The remote handsets transmit a coded frequency signal. This signal is received by a unit located on top of the instrument pack. This unit transmits the lock/unlock information directly to the ECU, which will respond accordingly.

Receiver location



Figure 9

1.RF Receiver

In such circumstances, a single press of the unlock button will cause the driver's door to fully unlock and the passenger's doors to change from the superlocked state to the locked state. Access to the vehicle's interior will be permitted through the unlocked driver's door, but not through any of the passenger's doors.

Latch motor protection

The side door latches used on Freelander models are innovative units which have been jointly developed by Land Rover and BMW. The units are unique in their design and are shielded for protection. To further enhance vehicle security and reduce complexity all switches, actuators and electrical systems are integrated into the latch assembly.

To prevent damage occurring to the door latch motors through continual operation, the system incorporates a Latch Motor Protection feature. This means the CCU will only allow a maximum of eight changes of state, i.e. a change from locked to unlocked, or from super locked to locked, to occur within 16 seconds.

The CCU will suspend operation of the latch motors if more than eight changes of state are requested within this period. The latch motor operation will always be suspended in the unlocked state and therefore in some circumstances, nine changes of state will be permitted. Once suspended, the latch motor operation will be suspended for a total of 16 seconds.

Alarm arming and disarming

It should be noted that although the vehicle can be locked and unlocked from the CDL switch in the centre console, the alarm cannot be armed or disarmed from this switch. The precise response to an arming action will vary according to the selected Market Option and the programmed state of the CCU.

Perimetric protection

Perimetric protection refers to the protection offered against an illegal intrusion through any of the vehicle's hinged panels and by removal of roof. The term perimetric is derived from the word perimeter, meaning an object's boundary. Perimetric protection is achieved by monitoring the state of the hinged panels and the roof, once the alarm has been armed. The panel open switches on the driver's door, passenger doors, tail door, bonnet and roof are all monitored by the CCU. If a panel opens once the alarm has been armed, then the alarm is triggered. The door switches are incorporated into the door latch assemblies.

Perimetric protection is activated once a valid arm request is received. If any panel is "open" when perimetric protection is activated, other than the roof, then the system will be armed in the partially armed state (see Partial Arming).

Volumetric protection

Volumetric protection refers to the protection provided to the vehicle's interior. The volumetric sensor monitors this area and will trigger the alarm if it detects any unauthorised movement, whilst the alarm is armed appropriately.

In certain circumstances, e.g. when the vehicle is parked with a window open, the vehicle may need to be secured without the volumetric protection armed. This requirement can be catered for by using the appropriate locking procedure, as previously described.

Volumetric protection is a desirable feature of any vehicle security system and provides a high level of protection against theft. However, it can be the cause of considerable customer annoyance, and has generated a reputation for causing false alarm triggers. In recognition of this, a number of precautions have been taken on Freelander derivatives to prevent accidental or nuisance triggering occurring. These precautions include a settling period following system arming, a minimum trigger signal duration and a volumetric "gain" setting, specifically suited to the vehicle body style. The following describes the triggering conditions in more detail:

- Following a suitable arm request, the CCU will refuse to act upon any movement detect signal supplied by the volumetric sensor, until a period of 15 seconds has elapsed. This gives sufficient time following door closure etc.
- Once armed the CCU will only trigger the alarm if a valid movement detect signal, i.e. a signal of at least 50 milliseconds duration, is received from the volumetric sensor. This ensures that spurious one-off movements are suitably ignored.
- If the alarm has been triggered (by any means), the CCU is programmed to ignore any movement detect signal supplied by the volumetric sensor for the duration of the alarm sounding period, i.e. 30 seconds. At the end of this period, the CCU will initiate another 15 second settling period, unless the maximum number of 10 alarm triggers has been reached since the last alarm arming, before it resets volumetric protection.
- A volumetric gain setting, suited to the body style of the vehicle will be issued by the CCU to

the volumetric sensor. This setting is designed to avoid under/over sensitivity. The vehicle body style is automatically deduced by the CCU from the VIN stored in its memory. If required the setting can be tuned using TestBook.

Partial arming

In circumstances where an attempt is made to arm the alarm when the vehicle is not fully secure, i.e. one or more of the hinged panels is open at the time when the CCU receives the arm request, the alarm will enter the partially armed state.

The partial arming feature is designed to maximise the level of protection provided to the vehicle in such circumstances. The system achieves this by evaluating which panel (or panels), is open at the time when the alarm is armed, and subsequently activating as much of the alarm as is possible. In addition to the circumstances described above, the partial arming feature also enables the system to maximise the level of protection it provides in the event of a failure of one (or more) of the panel open switches or their respective wiring.

Freelander derivatives are able to enter four slightly different partially armed states. The precise partially armed state entered is determined by which panel is open. The four different states are defined as follows:

1. **Alarm armed with the driver's door open:** If the vehicle enters the partially armed state due to an open driver's door, then the CCU will suspend activation of super locking and volumetric protection and will continue to monitor the panel left open. All other functions of the alarm system will be fully armed.
2. **Alarm armed with the passenger door or doors open:** If the vehicle enters the partially armed state due to an open passenger door, then the CCU will suspend activation of super locking and volumetric protection and will continue to monitor the panel left open. All other functions of the alarm will be fully armed.
3. **Alarm armed with the tail door open:** If the vehicle enters the partially armed state due to an open tail door, then the CCU will allow activation of super locking, will suspend activation of volumetric protection and will continue to monitor the panel left open. All other alarm functions will be fully armed.
4. **Alarm armed with the bonnet open:** If the vehicle enters the partially armed state due to an open bonnet, then the CCU will allow activation of super locking and volumetric protection, and will continue to monitor the panel left open. All other alarm functions will be fully armed.

When an attempt is made to arm the alarm with one or more panels open, i.e. when the vehicle enters the partially armed state, a number of visual and audible warnings are provided to inform the vehicle user of the armed state. The precise warnings provided will be dependent upon the Market Option selected and the programmed state of the CCU.

An audible mislock warning sound may be given on some vehicles. This warning will be generated either by the vehicle's horn, or by the BBUS (Battery Backed Up Sounder). If the warning is generated by the horn then it will be a single sound of approximately 20 milliseconds duration. In cases where the BBUS generates the warning then it will be a single sound of approximately 100 milliseconds.

Two forms of visual indication may be provided when the vehicle enters the partially armed state. Firstly, there will be no fast flash from the alarm LED, immediately following entry of the armed state. Secondly, there will be no flash at all from the hazard warning lights, immediately following entry of the armed state.

To further enhance vehicle security, the CCU is programmed in such a way, that it allows a vehicle which has been armed in the partially armed state, to automatically “upgrade” to the fully armed condition. The CCU will initiate this change of state if it senses that the panel, that originally caused the mislock, has been securely closed. With the exception to partial armed states caused by an open driver's door, the CCU does not require a further arm request to upgrade to the fully armed state.

In circumstances where the partial armed state was caused by an open driver's door the CCU will require a further arm request. If a driver's door is subsequently closed after causing a mislock, then perimeter protection will be automatically extended to the driver's door. However, because the locked state of the door is not automatically upgraded, i.e. it remains in the CDL state, then volumetric protection will not be armed, even if it was originally requested.

Alarm triggers

When the alarm is set in the fully armed state it will be triggered by the CCU if it receives any of the following input signals:

- Bonnet opening.
- Tail door opening.
- Any side door opening
- Ignition switched on.
- A valid movement detect signal from the volumetric sensor (when volumetric protection armed)
- Removal of the roof (if it was in place when the alarm was armed)

In response to a valid alarm trigger input, the CCU will activate audible and visual warnings for a maximum duration of approximately 30 seconds. The precise type of warning generated will vary according to the Market Option selected and the CCU's programmed state.

When set, the audible warning will be provided by the vehicle's horn, by the alarm BBUS, or by both. The warning will either be continuous, or will be pulsed at 0.5 second intervals, i.e. 0.5 seconds on, off for 0.5 seconds, on for 0.5 seconds repeated. The visual warning will be provided by the hazard lights and will be pulsed at the same frequency, if set.

The CCU will trigger the alarm up to 10 times in any armed period. It will not trigger the alarm more than 10 times during this period, even if it receives further valid alarm trigger input signals.

The CCU incorporates a memory buffer. This enables the CCU to record the cause of the four most recent alarm triggers. Using this feature, the CCU can be interrogated via TestBook to establish precisely which input, or inputs, caused the CCU to trigger the alarm on the last four occasions.

Immobilisation

Engine immobilisation EWS-3D

The immobilisation system used on Freelander 2001 MY is referred to as EWS-3D (Elektronische Wegfahrsperre). The main function of the system is to prevent unauthorised starting of the vehicle by creating a secure interface which cannot be copied or bypassed in any way. It also checks systems to ensure that the vehicle is in a safe condition for starting. Immobilisation is carried out by disabling the starter motor and by preventing engine fuelling via the ECM. Although the EWS-3D system uses components in common with the locking and alarm system it is a stand alone system.

EWS-3D component layout

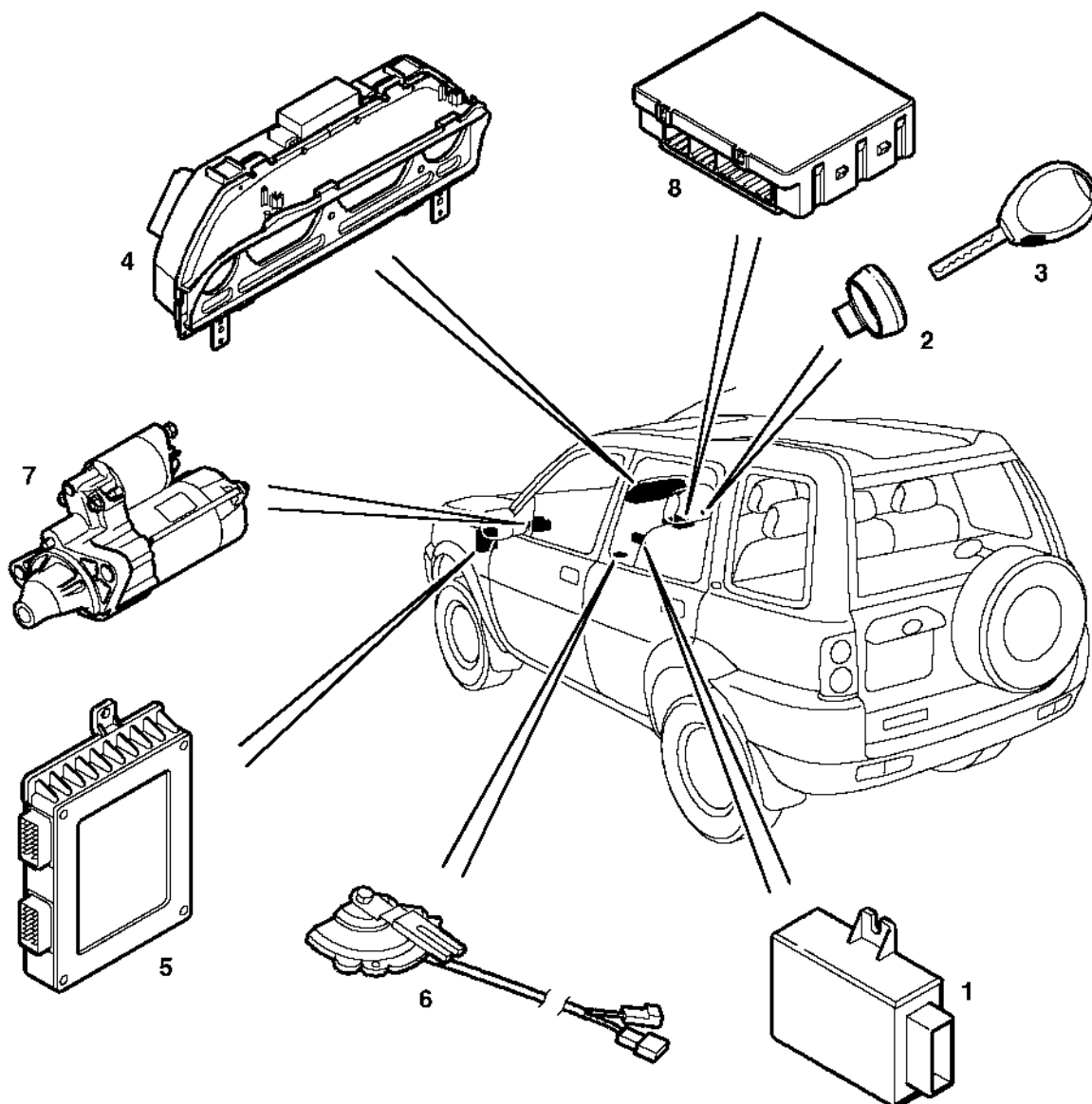


Figure 10

- 1.EWS-3D ECU
- 2.Ring antenna
- 3.Key
- 4.IPK

- 5.ECM
- 6.Automatic transmission position switch
- 7.Starter motor
- 8.CCU

When a key is inserted in the ignition, a three stage check is carried out. Each key has a unique identification number and this is sent by the key transponder to the EWS-3D ECU. A password unique to the key is used by the EWS-3D ECU to communicate with the transponder. The final stage of the key identification is the confirmation that the rolling code from the transponder matches with the EWS-3D ECU rolling code. Once the EWS-3D has confirmed that a valid key is requesting the starting of the vehicle, it will energise the starter motor relay and inform the ECM that starting has clearance by sending the correct code to the ECM.

The EWS-3D ECU controls the starting of the vehicle by communicating with the ECM via a unidirectional data line. The EWS-3D also controls the operation of the starter motor via control of a starter motor relay. This relay is internal to the EWS-3D ECU.

Control block diagram

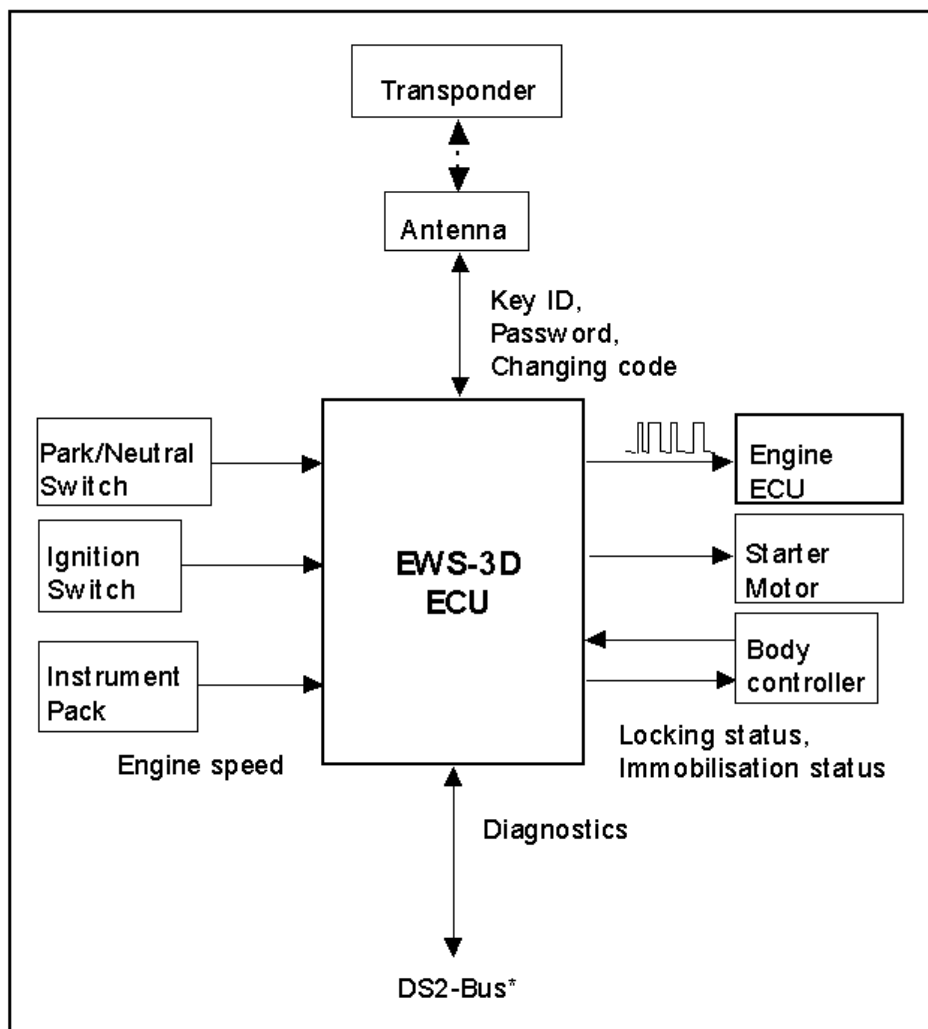


Figure 11

EWS-3D electronic control unit

The EWS-3D ECU is located behind the centre of the fascia and is secured by two fixings. The ECU arrives from the supplier as a blank unit and is programmed with a starting code during vehicle manufacture. This code has to be learnt by the ECM and this programming is also carried out during the manufacture of the vehicle. This starting code is then used as a base point for the rolling code by both the EWS-3D and the ECM.

The EWS-3D electronic control unit governs the overall immobilisation and re-mobilisation of the vehicle. Without it receiving a valid signal from a key transponder it will inhibit starting of the vehicle. The starter motor will be disabled and the ECM will not initiate fuelling of the vehicle. Each key has its own identity and the EWS-3D is capable of supporting up to ten keys.

When all the key slots have been used and more keys are required, the EWS-3D must be removed and a new EWS-3D fitted. Therefore, a maximum of 10 keys per vehicle are available at any given time. When new keys are supplied, they arrive ready for use with the vehicle, having been pre-programmed with the relevant coding. This coding relates to a new slot in the EWS-3D ECU. The ECU is capable of recognizing the first use of the new key and initiates the rolling code transfer from then on.

The EWS-3D can communicate with the different types of engine management systems used by Freelander 2001 MY using the same protocol. The EWS-3D ECU also uses information from other vehicle systems which can affect system functionality: It uses a 12 volt signal from the central control unit to ascertain the locking status of the vehicle and it derives the engine speed from the instrument pack. On vehicles fitted with automatic transmission, there is an input from the Park/Neutral switch which must be present before the EWS-3D allows re-mobilisation of the vehicle.

If a fault occurs with the EWS-3D ECU a replacement is available only through a recognized dealership, which will follow a strict process for the replacement of immobilisation components. Here, the relevant information for every EWS-3D ECU is stored against the vehicle identification number in a database. This information cannot be read directly from the EWS-3D ECU using TestBook or any other diagnostic tool. At the appropriate centre this information is accessed and is programmed into the replacement EWS-3D ECU. It will arrive at the dealership ready for fitment to the vehicle. Once the replacement part has been fitted to the vehicle, TestBook will be required to re-synchronise the EWS-3D ECU with the engine control module.

EWS-3D also incorporates a starter motor protection function. When the engine speed exceeds a predetermined value, a starter relay inside the EWS-3D ECU is disabled. This relay is in series with the main starter motor solenoid and therefore when disabled cuts off the power supply to the starter motor. This prevents destruction of the starter motor in the event of a sticking ignition switch.

Engine control module (ECM)

The EWS-3D ECU is capable of working with the three different engine control modules fitted to Freelander 2001 derivatives. The KV6 2.5 litre engine use a Siemens 2000 engine management system. The K1.8 uses Rover modular engine management system (MEMS 3). The diesel M47 uses the digital diesel electronic (DDE 4.0) engine management system.

Siemens 2000 engine control module*Figure 12*

Each ECM arrives from the supplier in a blank condition. (i.e. without a starting code base point). During the manufacture of the vehicle, there is a process carried out whereby the ECM learns the starting code from the EWS-3D ECU. This process means that the swapping of the ECM or the EWS-3D ECU from one vehicle to another is not possible because the correct code will not be present in both ECU's. The ECM will allow starting of the vehicle only on reception of a valid code from the EWS-3D.

Each ECM can learn only one starting code. For it to learn another it must first be blanked by the supplier. A new ECM will be required in most circumstances and TestBook will be needed to transfer the codes from the EWS-3D ECU to the blank ECM.

Central control unit

The main function of the CCU in the immobilisation of the vehicle is to provide the EWS-3D with the locking status of the vehicle. When the vehicle is in a superlocked, or alarm armed state the CCU sends a 12 volt input to the EWS-3D ECU. The vehicle will not start in a superlocked state or if the alarm is armed.

If, upon receiving a valid key signal, the EWS-3D ECU receives a signal from the CCU that the vehicle is superlocked or armed state, the starting process will be suspended momentarily. The EWS-3D will then send a 12 volt output pulse informing the CCU of the mobilised status of the vehicle. The CCU will then change the vehicle from the superlocked state (and/or disarm the alarm) to an unlocked state. The 12 volt input to the EWS-3D ECU from the CCU is then removed and starting of the vehicle can then take place.

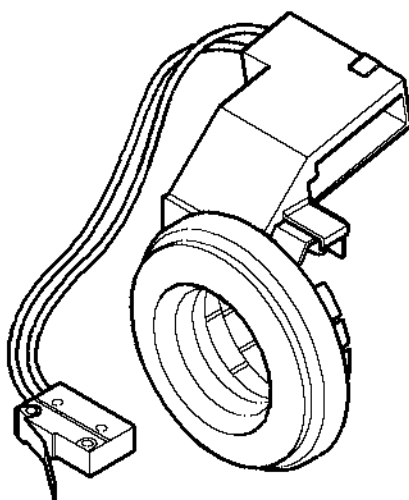
Superlocking of the vehicle is carried out by pressing the remote lock button located on the keyhead. It is possible to inadvertently press this button prior to inserting the key in the ignition. The car would then be in the superlocked state and intervention is necessary to prevent starting and driving of the vehicle in this state.

Ring antenna and keys

The ring antenna is clipped onto the ignition key barrel. When the key is placed in the ignition and switched to auxiliary position, the ring antenna energises the transponder in the key. This is achieved by induction using a 125 KHz frequency power supply from the EWS-3D ECU. This enables transfer of data to take place to and from the transponder in the key.

The transponder has to impart its unique identification number and a valid rolling code. When a valid key signal is read, the vehicle can be started and a new rolling code is written to the transponder for the next operation by the EWS-3D ECU.

Ring antenna



M86 5306

Figure 13

The key is made up of a mechanical blade and a transponder. The key blade has an external mechanical waveform. The data for the transponder and waveform is stored on a database in Germany. The transponder chip consists, primarily of a wireless electrical erasable programmable read only memory (EEPROM). This can be written to and read from by the EWS-3D ECU. The range for communication between the ring antenna and the transponder is 2 centimetres. Identification data is programmed into the blank transponder during vehicle manufacture. Each transponder is matched with one of the 10 key slots contained in the EWS-3D ECU. Once it is programmed it cannot be overwritten.

Codes for all 10 slots are programmed randomly into the EWS-3D ECU during manufacture of the vehicle. Two of these slots are taken up immediately by the two keys which are coded during vehicle manufacture for the vehicle's initial owner. The data and codes for each of the 10 slots are stored in a database at Dingolfing in Germany. When a new key or lock set is required it must be processed through a recognised dealership, which will order the new component. The relevant data will need to be accessed from Dingolfing, Germany.

If a key is lost, the slot it is addressed to should be disabled to prevent unauthorised starting of the vehicle. This is carried out using TestBook and requires all available valid keys to complete the process. This way, TestBook can read the identity of all the keys still available and can disarm the slot of the missing key. If the key is subsequently found, the process can be reversed and the slot made valid again.

A valid key is required to be in the ignition to disable/re-enable a key slot and it is not possible to disable the key slot of the key in the ignition. This makes it impossible to accidentally disable all key slots using TestBook, which would immobilise the vehicle.

Note: *The EWS-3D drive for the ring antenna is not capable of carrying battery voltage and care must be taken when fault finding and probing the system otherwise permanent damage to the ECU may result.*

Instrument pack

The instrument pack supplies the EWS-3D with the vehicle engine speed, converted from a CAN signal into a pulse train compatible with the EWS-3D ECU. This is used by the EWS-3D starter motor protection feature which isolates the starter motor when the engine speed reaches a predetermined threshold.

Emergency access

There is no emergency key access (EKA) facility with Freelander 2001 model year. Any key will facilitate entry into the vehicle, even if the CDL system is non functional. Re-mobilisation of the vehicle will only be possible with a valid key in the ignition, with a working transponder and with the valid codes.

Immobilisation ECU and/or key ordering procedure

The immobilisation system is a highly secure system and to maintain security, the supply of spare/replacement keys and immobilisation ECU's is restricted to franchised dealers only. The EWS-3D ECU is non serviceable and failure of any of its internal parts means a replacement EWS-3D ECU has to be ordered. Unlike keys, an ECU identical to the original can be ordered making it possible to use the existing keys, reducing further cost.

Key and ECU ordering procedure – All markets (except Japan)

Each dealer must adhere to the following procedure when ordering keys and/or immobilisation ECU's.

1. The dealer receives a request from the customer for a spare/replacement key or a replacement immobilisation ECU and key set.
2. The dealer must request from the customer proof of ownership and Vehicle Identification Number (VIN). This may be in the form of a registration document for example. If proof of ownership cannot be supplied, the dealer must not proceed with ordering keys.
3. The dealer must raise a Vehicle Off Road (VOR) order quoting the VIN and the part number of the part(s) required.
4. The dealer must pass the VOR order to the corporate wholesaler, European distribution centre or importer on the Unipart parts ordering system before 12:45 pm for next day delivery.
5. Unipart will validate the VIN and, if correct, will send an order to BMW GB on the Direct Factory Supplier (DFS) system before 1:00 pm for the same day delivery to Unipart. If Unipart find the VIN to be incorrect, they will contact the dealer to revalidate the VIN.
6. BMW GB record the order and pass it to BMW AG in Dingolfing, Germany who interrogate their database to establish that the VIN is valid. From the database, BMW AG confirm that immobilisation codes remain available.
7. If no codes are available, the order is returned to BMW GB who inform Unipart that all available codes have been used and that a new immobilisation ECU and key set is required. Unipart inform the corporate wholesaler, European distribution centre or importer on a parts information sheet that order has been rejected and reason for rejection. The corporate wholesaler, European distribution centre or importer inform the dealer who will advise the customer that a new immobilisation ECU and key set is required. If customer agrees, then the ordering procedure is repeated from step 3.
8. BMW AG will establish mechanical and electrical key configuration, update the database and create a bar code order form from which the spare/replacement key or immobilisation ECU and key set is made.
9. BMW AG will pass the completed order form to the BMW GB key cutting centre who use the bar code to produce the new keys or new immobilisation ECU and key sets.
10. BMW GB will despatch the part(s) to Unipart at circa 3:30 pm on the same day in order to get the parts on the Unipart overnight VOR delivery.
11. In the UK market, Unipart will despatch the part(s) to the corporate wholesaler overnight to arrive circa 8:30 am next day. The corporate wholesaler will deliver the part(s) to the dealer at circa 12:00 pm on the same day.
12. In ROW markets, Unipart will despatch the part(s) to the European distribution centre or importer next day to arrive by 12:00 pm the following day. The European distribution centre will deliver the part(s) overnight to arrive at the dealer at circa 8:30 am the following day. In importer markets, courier delivery times to the dealer can be typically 5/6 days for South America/Asia and 8/12 days for Australia.

Instrument pack

Introduction

The primary function of an instrument pack (IPK) is to provide the driver with continuously updated information about the vehicle and to indicate faults as they occur, usually by illuminating a warning lamp. The IPK fitted to the Freelander 2001 is an intelligent unit controlled by a microprocessor and acts as the gateway for the CAN-Bus-system.

The IPK is designed to display information quickly and unambiguously. For this reason, the IPK has a central and prominent position within the driver's field of vision, requiring only the slightest eye adjustment to access the data displayed. The IPK uses a combination of analogue and digital displays combining new technology with proven effective display gauges.

General

The instrument packs fitted to all Freelander models are similar, with the only differences being the mph or km/h speedometer, odometer readings, tachometer maximum rev/min band and certain warning lamps.

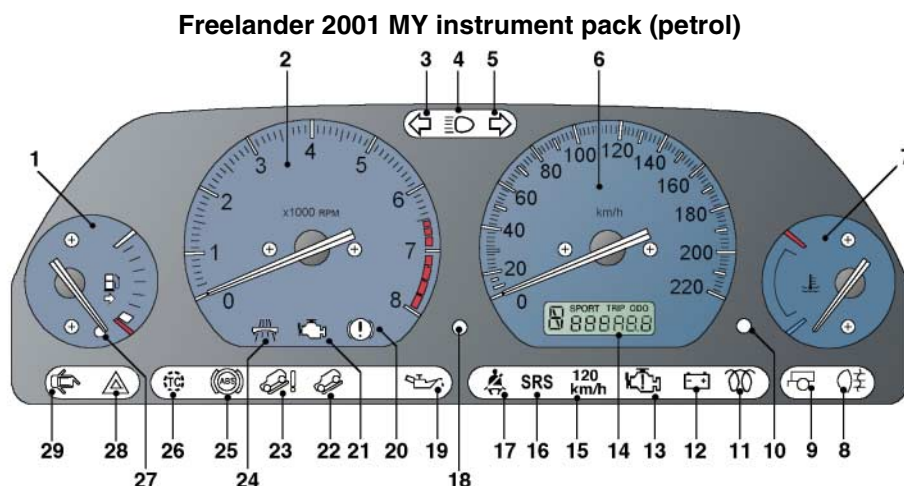


Figure 14

- | | |
|--|--|
| 1. Fuel level gauge | 16. SRS warning lamp |
| 2. Tachometer | 17. Seat belt warning lamp |
| 3. LH direction indicator warning lamp | 18. Alarm LED |
| 4. Headlamp main beam warning lamp | 19. Low oil pressure warning lamp |
| 5. RH direction indicator warning lamp | 20. Handbrake and brake system warning lamp |
| 6. Speedometer | 21. Malfunction Indicator Lamp (MIL) |
| 7. Engine coolant temperature gauge | 22. Hill descent Control (HDC) active warning lamp |
| 8. Rear fog lamp warning lamp | 23. HDC failure warning lamp |
| 9. Trailer direction indicator/hazard failure warning lamp | 24. Cruise control active warning lamp |
| 10. Trip counter reset button | 25. Anti-lock Braking System (ABS) warning lamp |
| 11. Glow plug warning lamp | 26. Traction control active warning lamp |
| 12. Ignition/No charge warning lamp | 27. Low fuel level warning lamp |
| 13. Engine malfunction warning lamp | 28. Hazard flasher warning lamp |
| 14. Liquid Crystal display (LCD) | 29. Door open warning lamp |
| 15. Overspeed warning lamp | |

The instrument pack is a totally electronic device receiving electrical signals from sender units and CAN messages from the Engine Control Module (ECM), ABS modulator ECU and the Electronic Automatic Transmission (EAT) ECU and transposing them into analogue gauge readouts and warning lamp illumination.

The instrument pack is connected to the fascia harness by connectors C0230 and C0233 which provide all input and output connections for instrument pack operation.

Freelander 2001 MY instrument pack (petrol) rear

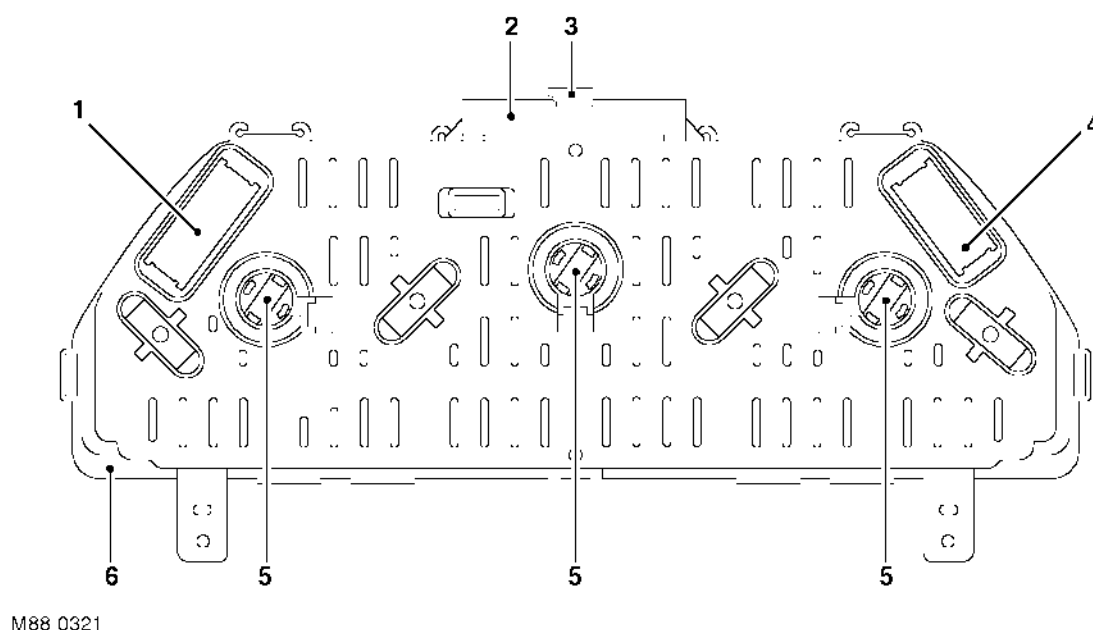


Figure 15

- 1.Connector C0230
- 2.RF receiver
- 3.RF Receiver connector
- 4.Connector C0233
- 5.Panel illumination bulb (3 off)
- 6.Instrument pack rear housing

A Printed Circuit Board (PCB) is located on the rear of the pack. The analogue displays, warning lamps and the LCD are integral with the PCB. No internal components are serviceable.

The instrument pack features the following displays:

- Tachometer - large analogue display
- Speedometer - large analogue display
- Fuel gauge - small analogue display
- Engine coolant temperature gauge - small analogue display
- Odometer, trip meter - Liquid Crystal Display (LCD)
- Gearbox status (JATCO derivatives only) - LCD

The instrument pack also features a number of warning lamps. The warning lamps illuminate in one of four colours which indicate the level of importance of the warning as follows:

- Red = Warning
- Yellow = Caution
- Green = System operative
- Blue = Headlamp main beam operative

The warning lamps are located in various positions around the periphery of the analogue gauges in the instrument pack display and in the lower half of the tachometer. The direction indicators and main beam warning lamps are located at the top of the display.

The following warning lamps are available:

- Left and right hand indicators (Green)
- Headlamp main beam (Blue)
- Glow plug (Yellow) - Diesel models only
- Seat belt (Red) - Selective markets only
- SRS (Red)
- Engine Malfunction Indicator Lamp (MIL) (Yellow) - All markets except NAS
- Service Engine Soon (MIL) (Yellow) – NAS only
- Anti-lock Braking system (ABS) (Yellow)
- Door open (Red)
- Hazard warning (Red)
- Hill descent control information (Green)
- Hill descent control fault (Yellow)
- Handbrake and brake system (Red)
- Low oil pressure (Red)
- Ignition/No charge (Red)
- Engine malfunction (Yellow) - Diesel models only - All markets except NAS
- Service Engine (Engine malfunction) (Yellow) - NAS only
- Overspeed (Red) - Selective markets only
- Cruise control (Yellow) - JATCO models only
- Low fuel level (Yellow)
- Trailer lamp failure warning lamp

Operating Modes

The instrument pack will function in seven modes:

- Shut down
- Normal
- Standby normal
- Powered/Unpowered
- Diagnostic
- Crank
- Low battery voltage

Shut down mode

The instrument pack enters shut down mode when the ignition is moved from position II to the off position (0). Ignition voltage is removed and only the permanent battery feed is available. All CAN gateway, diagnostic, instrument pack and warning lamp functions are suspended. Some conventionally wired warning lamps can still function in shut down mode, i.e.; hazard warning lamp.

When the instrument pack senses that the ignition supply has been removed, it can remain in normal mode for up to fifteen seconds to allow the microprocessor to power down. In shut down mode the total current draw for the instrument pack does not exceed 1mA.

Normal mode

The instrument pack enters normal mode when battery voltage from ignition switch position II is received. The ECM transmits a message for the CAN standard. If this message is correct or not received, the instrument pack remains in normal mode. If an incorrect CAN standard message is received, the instrument pack will enter standby normal mode.

Standby normal mode

Standby normal mode is used if an incorrect CAN standard message is received and also allows access to diagnostics. In this mode all CAN transmissions are terminated and the pack will not respond to any CAN messages received. All conventionally wired warning lamps will function normally and the pack can enter diagnostic mode if required. A fault flag is recorded in the EEPROM for the CAN standard message fault.

Powered/unpowered modes

Powered mode is the standard operational condition for the instrument pack. In this condition the pack receives a permanent 12V battery supply, no ignition supply or CAN messages. The microprocessor is also 'off' but the real time clock will remain powered.

Unpowered mode is entered when the vehicle battery is disconnected. When the power supply is restored, the pack will resume powered mode.

Diagnostic mode

To enter diagnostic mode, the instrument pack must first be in normal or standby normal mode and TestBook or another diagnostic tool must be connected to the diagnostic socket. The instrument pack will enter diagnostic mode when it receives a valid message on the ISO9141 K Line. Confirmation of access to this mode is given by a 'dIAG' message in the LCD.

Diagnostic mode is exited by receipt of a message from the diagnostic tool to terminate diagnostics. Removal of the ignition switch position II battery supply or disconnection of the diagnostic communication to the socket will also terminate the diagnostic mode.

Crank mode

When the starter motor is cranking the engine, the current drain may cause the values of inputs and CAN messages to become corrupted or invalid. The instrument pack senses that cranking is operative when ignition switch positions II and III are active and the ignition feed from switch position II falls to approximately 3V.

During cranking, all inputs to gauges are suspended and the gauges will remain in their pre-crank state. The odometer display is not affected.

Low battery operation

If the permanent battery supply voltage falls to below 8V, CAN message transmissions will be suspended and received CAN messages will be ignored, analogue gauges will read zero and warning lamp operation is suspended. When the voltage rises above 8V, normal instrument pack operation is resumed.

Speedometer

The speedometer is electronically operated and contains an LCD. Each model has a maximum scale indication of 136 mph (220 km/h).

The speedometer is driven by CAN messages from the ABS ECU. The messages are generated by an ABS wheel speed sensor which produces pulses as the reluctor rotates. The instrument pack microprocessor processes the incoming CAN message from the ABS ECU and converts it into electrical signals for speedometer operation. The message received from the ABS ECU is an average of all four working wheel speed sensors.

If the CAN message fails for more than 64ms the microprocessor will terminate speedometer operation and record a fault flag. The recorded fault can be accessed using TestBook.

Liquid crystal display (LCD)

The LCD shows odometer readings up to 99999.9 miles or kilometres and trip computer readings up to 999.9 miles or kilometres. A trip counter reset button is located at the bottom of the speedometer and resets the counter to zero when pressed for more than two seconds. A short press will change the LCD display from odometer to trip.

On KV6 vehicles with JATCO automatic gearbox, the LCD also displays current gear selected. If a fault occurs with the gearbox which causes the transmission into 4th gear default mode, the display will alternatively flash 'F' and '4'.

Tachometer

The tachometer is electronically operated and is driven by CAN messages from the ECM. The ECM output is derived from the crankshaft position (CKP) sensor. Loss of the CAN message will cause the tachometer to read zero until the engine speed message is restored.

Petrol models have a maximum tachometer scale reading of 8000 rev/min and Diesel models have a maximum scale reading of 6000 rev/min.

The tachometer scale has a red segment which denotes the maximum engine speed for the model. The engine must not be operated beyond the start of the red segment. The maximum engine speed for the models is as follows:

- Petrol models - 6500 rev/min
- Diesel models - 4500 rev/min

Three warning lamps are located in the lower part of the tachometer face; Cruise control, Malfunction Indicator Lamp (MIL) and handbrake and brake warning lamp.

Fuel Level Gauge

The fuel level gauge pointer indicates the current fuel level in the fuel tank. The fuel level gauge pointer returns to the empty position when the ignition is switched 'off'.

The gauge is operated by an output from the fuel gauge to the fuel tank sender which is integral with the fuel pump. The sender is a float operated rotary potentiometer which provides a variable resistance to earth for the output from the gauge. Movement of the sender unit float arm varies the electrical resistance across the sender unit, so the voltage of the control signal and the resultant deflection of the gauge pointer are directly related to the level of fuel in the tank. When the sender float is at its lowest point, indicating an empty fuel tank, the resistance to earth is at its greatest.

The measured resistance is processed by the instrument pack to implement an anti-slosh function. This monitors the signal and updates the fuel gauge pointer position at regular intervals. This prevents constant needle movement caused by fuel movement in the tank due to cornering or braking.

A warning lamp is located in the face of the fuel gauge and illuminates when the fuel level is at or below 2.2 gallons (10 litres).

The fuel level sender signal is converted into a CAN message by the instrument pack as a direct interpretation of the fuel tank contents in litres. The ECM uses the CAN message to suspend OBD misfire detection when the fuel level is below 15% capacity.

Sender Unit Resistance, Ω (Ohms)	Nominal Gauge Reading
503	Empty
413	Low fuel level illumination
302	Half full
135	Full

Engine coolant temperature gauge

The coolant temperature gauge indicates the temperature of the engine coolant. When the engine reaches normal operating temperature, the gauge rests at the mid-point of the temperature scale.

If the engine coolant temperature becomes too high, the pointer will rise to the red segment of the scale to warn of an engine cooling fault. At this position the engine coolant temperature is too high and continued operation could result in engine damage; the vehicle should be stopped as soon as possible.

The engine coolant temperature gauge is driven by a CAN message from the ECM. The ECM derives the engine coolant temperature from an engine coolant temperature (ECT) sensor.

The temperature gauge is fitted with a return magnet causing the gauge to return to zero when the ignition is switched 'off'. The coolant temperature gauge is only operative when the ignition switch is in position II or when diagnostics are selected.

When the engine is hot, the gauge will display normal temperature until the engine has been running for more than 15 seconds. This prevents the gauge moving to the red sector of the gauge if the ignition is turned 'off' and then 'on' after a journey. If the engine is not started, the coolant pump will not circulate coolant and local hot spots occur in the engine and give an incorrect temperature reading. The 15 second delay allows for the engine to be started and coolant circulated, allowing the gauge to display the true average temperature.

Coolant temperature gauge needle position	Engine coolant temperature °C (°F)
Cold	40 (104)
Normal	75 - 115(167 - 239)
Hot (Red zone)	120 (248)

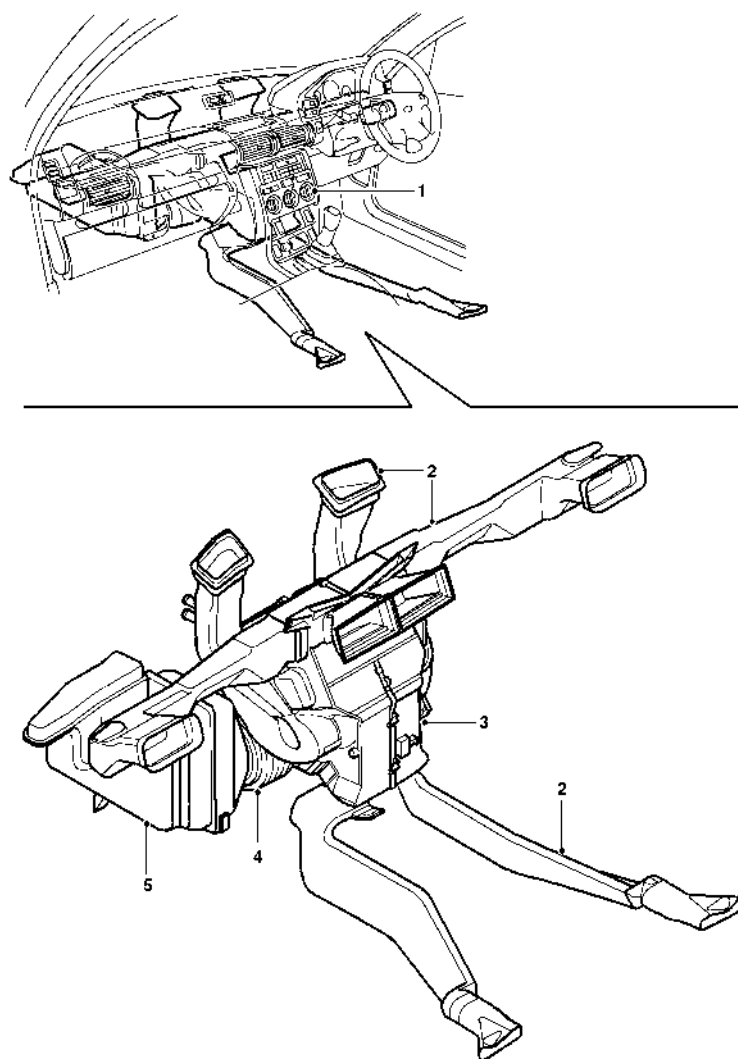
Instrument illumination

The instrument pack back lighting illumination is provided by three, T10 single filament 3.4W 14V bulbs. The bulbs are rated at 14V to improve their resistance to failure and are fitted with a coloured shroud to give the required back light illumination colour.

The lamps illuminate when the side lamps or headlamps are switched 'on' and are also controlled by the instrument illumination dimmer control.

Heating, ventilation and air conditioning

Heating and ventilation



M80 0456

Figure 16

- 1. Control panel
- 2. Distribution ducts
- 3. Heater assembly
- 4. Connector hose
- 5. Air inlet duct

The heating and ventilation system controls the temperature and distribution of air supplied to the vehicle interior. Air is drawn into a heater assembly through a connector hose and an air inlet duct, or through the cooling unit on vehicles with air conditioning.

In the heater assembly, the air can be heated and supplied as required to fascia and floor level outlets. An electrical variable speed blower, and/or ram effect when the vehicle is in forward motion, forces the air through the system. Temperature, distribution and blower controls are installed on a panel on the centre console.

The air inlet duct connects the passenger's side of the plenum to the heater assembly, to provide the fresh air inlet. The upper end of the duct locates in a slot in the body and the lower end of the duct is connected to the heater assembly via a corrugated connector hose. A pollen filter is installed in the air inlet duct and retained by four scrivenets.

The heater assembly heats and distributes air as directed by selections made on the control panel. The assembly is installed on the vehicle centre-line, between the fascia and the engine bulkhead.

The heater assembly consists of a two-piece plastic casing containing a blower, resistor pack, heater matrix and control flaps. Integral passages guide the air through the casing from the inlet to the distribution outlets. A wiring harness connects the blower and resistor pack to the blower switch on the control panel.

Four control flaps are installed in the heater assembly to control the temperature and distribution of air. A blend flap controls the temperature by directing air inlet flow through or away from the heater matrix. Two distribution flaps control the air flow distribution to the selected vents. The fourth flap closes the air path from the off side of the heater matrix to the blend chamber. This helps to reduce heat pick-up causing a rise in temperature at the foot and defrost outlets in comparison to the temperature at the face vent outlets.

The blower switch and the resistor pack control the operation of the blower, which can be selected to run at one of four speeds. The resistor pack supplies reduced voltages to the blower motor for blower speeds 1, 2 and 3. For blower speed 4, the resistor pack is bypassed and battery voltage drives the motor at full speed. The pack is installed in the RH side of the casing, in the air outlet from the blower fan, so that any heat generated is dissipated by the air flow.

The heater matrix provides the heat source to warm the air being supplied to the distribution outlets. It is installed in the LH side of the casing behind a protective cover. The matrix is a copper and brass, two pass, fin and tube heat exchanger. Engine coolant is supplied to the matrix through two brass tubes that extend through the bulkhead into the engine compartment. When the engine is running, coolant is constantly circulated through the heater matrix by the engine coolant pump. On diesel models, the coolant flow is assisted by an electric pump when the fuel burning heater system is operating.

Heating and ventilation operation

Air flow through the heater assembly is directed to the outlets selected by the distribution control knob. The temperature of the air from all except the face level vents depends on the setting of the temperature control knob. Hot air is available from the face level vents only when the temperature control knob is at the maximum heat setting. As the temperature control knob is turned towards cold, the temperature of the air from the face level vents rapidly decreases to ambient (non A/C vehicles) or evaporator outlet temperature (A/C vehicles). The forward speed of the vehicle and the setting of the blower control knob determines the volume of air flowing through the system.

Air distribution

Turning the distribution knob on the control panel turns the control flaps in the heater assembly to direct air to the corresponding fascia and footwell outlets.

Air temperature

Turning the temperature knob on the control panel turns the related blend flaps in the heater assembly. The blend flaps vary the proportion of air going through the cold air bypass and the heater matrix. The proportion varies, between full bypass/no heat and no bypass/full heat, to correspond with the position of the temperature knob.

Blower speed

The blower can be selected 'off', or to run at one of four speeds. While the ignition is on and the blower switch is set to positions 1, 2, 3 or 4, ignition power energises the blower relay, which supplies battery power to the blower. At switch positions 1, 2 and 3, the blower switch also connects the blower to different earth paths through the resistor pack, to produce corresponding differences of blower operating voltage and speed. At position 4, the blower switch connects an earth direct to the blower, bypassing the resistor pack, and full battery voltage drives the blower at maximum speed.

Fresh/Recirculated inlet air

When the recirculated air switch is latched in, the indicator LED in the switch illuminates and an earth is connected to the recirculated air side of the fresh/recirculated air servo motor. The fresh/recirculated air servo motor then turns the control flaps in the air inlet duct to close the fresh air inlet and open the recirculated air inlets.

When the latch of the recirculated air switch is released, the indicator LED in the switch extinguishes and the earth is switched from the recirculated air side to the fresh air side of the fresh/recirculated air servo motor. The fresh/recirculated air servo motor then turns the control flaps in the air inlet duct to open the fresh air inlet and close the recirculated air inlet.

Air conditioning

Where fitted, the air conditioning system supplies cooled and dehumidified, fresh or recirculated air to the interior of the vehicle. Air is cooled by drawing it through the matrix of an evaporator. The air is then ducted into the heater assembly, from where it is distributed to the vehicle interior through the heating and ventilation system air ducts.

In the heater assembly, the temperature of the air distributed to the vehicle interior can be adjusted by passing a proportion, or all, of the cooled air through the heater matrix. The volume of air being distributed is controlled by the variable speed blower in the heater assembly. For details of temperature control and distribution.

The air conditioning system uses a pressure sensor and evaporator temperature sensor to provide operating condition feedback to the engine management system to enable the ECM to predict engine load and run the cooling fans in response to changing atmospheric conditions and driver demand.

Refrigerant system

The refrigerant system is a sealed closed loop system which is charged with Refrigerant R134a as the heat transfer medium. It works in combination with a blower unit, blend unit and control system to achieve the desired air temperature. ND-8 oil is added to the refrigerant to lubricate the internal components of the compressor. The refrigerant system comprises of the following main components connected together by refrigerant lines:

- Compressor (variable load)
- Condenser (with modulator)
- Thermostatic expansion valve
- Evaporator

To accomplish the transfer of heat, the refrigerant is circulated around the system, where it passes through two pressure/temperature regimes. In each of the pressure/temperature regimes, the refrigerant changes state, during which process maximum heat absorption or release occurs. The low pressure/temperature regime is from the thermostatic expansion valve, through the evaporator to the compressor; the refrigerant decreases in pressure and temperature at the thermostatic expansion valve, then changes state from liquid to vapour in the evaporator, to absorb the heat. The high pressure/temperature regime is from the compressor, through the condenser and modulator (receiver/drier), back into the condenser where it is supercooled and then to the thermostatic expansion valve. The refrigerant increases in pressure and temperature as it passes through the compressor, then releases heat and changes state from vapour to liquid in the condenser.

Fan blown air is passed through the evaporator where it is cooled by absorption due to the low temperature refrigerant in the evaporator. Most of the moisture held in the air is condensed into water by the evaporator and drains away beneath the vehicle via a drain tube.

The compressor receives the returned low pressure, warm, vaporised refrigerant from the evaporator to complete the refrigeration cycle.

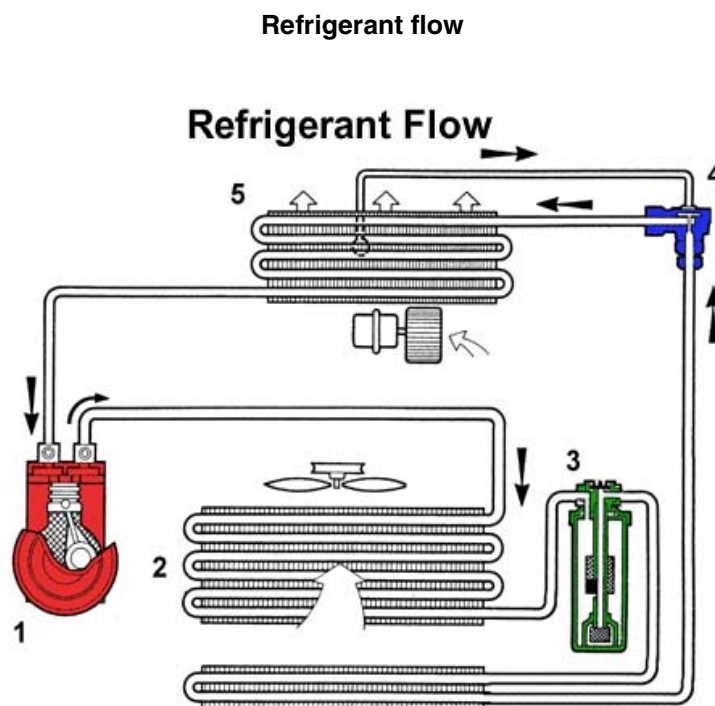


Figure 17

1. Compressor
2. Condenser
3. Receiver drier (integral to the condenser)
4. Thermostatic expansion valve
5. Evaporiser

The compressor (1) compresses the refrigerant, which is in gas/vapour form at this stage and, in doing so, increases the refrigerant temperature and pressure. The refrigerant flows into the condenser (2) located at the front of the vehicle, in front of the coolant radiator. The cooling effect of the air flow condenses the refrigerant into a liquid form which then flows to the receiver/drier (3), still at high pressure. The receiver/drier acts as a refrigerant storage tank, absorbs moisture/water and filters out any particles in the refrigerant. From here, the liquid refrigerant flows back through the lower portion of the condenser to further cool the liquid refrigerant (sub-cooling). The refrigerant then flows into the thermostatic expansion valve (4) which controls the amount of refrigerant entering the evaporator (5) and lowers its pressure allowing it to expand. The pressure drop rapidly reduces the temperature of the refrigerant. The heat from the air flowing into the vehicle interior is much warmer and heat transfers from the air to the refrigerant cooling the air and warming the refrigerant. The refrigerant changes back into gas/vapour and is sucked back into the compressor for the cycle to begin again.

Only gas must be drawn into the compressor or it can cause hydrostatic lock and stall.

When operating, the top of the condenser will normally be full of warm/hot gas and the bottom full of warm liquid refrigerant.

The refrigerant boiling point is very low (approx–30°C at atmospheric pressure) but can be compressed back to liquid form by increasing the pressure at which it is contained. Compression of the refrigerant produces heat, and this heat is removed by the condenser located at the front of the vehicle.

Compressor

A variable displacement compressor is driven from the crankshaft via the ancillary drive belt. An electro-mechanical clutch is used to engage and disengage the drive between the drive belt pulley and the compressor. Operation of the compressor clutch is controlled by the Engine Control Module (ECM).

Power to the A/C compressor clutch is via the normally open contacts of an associated A/C compressor clutch relay which is located in the engine compartment fusebox. When the coil of the relay is grounded by the ECM, the relay contacts close and the clutch is powered to engage the compressor to the drive belt pulley.

When the compressor is operational, pressurised refrigerant is circulated through the system. The compressor pressurises low pressure, warm, vaporised refrigerant which it receives from the evaporator, causing the refrigerant vapour to become very hot. The high pressure vaporised refrigerant is passed from the compressor to the condenser mounted in front of the radiator. The refrigerant increases in pressure and temperature as it passes through the compressor, then releases heat and changes state from vapour to liquid in the condenser.

The compressor is attached to a mounting bracket on the engine, and is a seven cylinder wobble plate unit with variable displacement. Operation of an electrically actuated clutch is controlled by the Engine Control Module (ECM).

The compressor consists of a housing which contains a shaft mounted in radial and thrust bearings. A lug plate is pressed onto the shaft and the clutch and pulley assembly is splined to the end of the shaft at the front of the housing. A wobble plate is installed on the shaft and connected to the lug plate by two guide pins. The wobble plate is a sliding fit on the shaft and biased away from the lug plate by a spring. The outer circumference of the wobble plate is engaged in the ends of seven pistons, which are located in cylinders equally spaced around the housing interior. Two pressure chambers in the rear of the housing are connected to inlet and outlet ports in the housing wall. Suction and discharge valves, between each cylinder and the chambers, control the flow of vapour into and out of the cylinders. A control valve assembly regulates a servo (control) pressure supplied through drillings in the housing of the chamber containing the wobble plate.

The control valve assembly consists of a ball valve operated by a push rod connected to a diaphragm. Spring and atmospheric pressure on one side of the diaphragm are opposed by inlet pressure on the opposite side of the diaphragm, and also by outlet pressure and a spring acting on the ball valve. The ball valve controls a flow of vapour from the outlet pressure chamber to produce the servo pressure in the wobble plate chamber.

When the engine is running and A/C is off, the clutch is de-energised and the compressor pulley freewheels under the influence of the drive belt. Vapour pressures are equalised throughout the compressor. The spring between the lug plate and the wobble plate holds the wobble plate at the minimum tilt angle (to minimise load during system start-up).

When A/C is requested, the electro-magnetic clutch is engaged and the pulley turns the central shaft of the compressor. The lug plate and the wobble plate turn with the shaft, and the movement of the angled wobble plate produces reciprocating movement of the pistons. Vapour from the inlet pressure chamber is drawn into the cylinders, compressed, and discharged into the outlet pressure chamber, producing a flow around the refrigerant circuit.

The flow rate through the compressor is determined by the length of the piston stroke, which is controlled by the tilt angle of the wobble plate. The tilt angle of the wobble plate is set by the servo pressure and compressor inlet pressure acting on the pistons during their induction stroke. A relative increase of inlet pressure over servo pressure moves the pistons along their cylinders to increase the wobble plate tilt angle, the piston stroke and the refrigerant flow rate.

The control valve regulates the servo pressure in the wobble plate chamber as a function of inlet pressure, so that the flow rate of the compressor matches the thermal load at the evaporator, i.e. the more cooling effort that is required in the cabin of the vehicle, corresponds to a higher thermal load and flow rate. Servo pressure varies between inlet pressure and inlet pressure + 1 bar (14.5 lbf.in²).

On start-up, the compressor inlet pressure is relatively low. In the control valve, the diaphragm and push rod hold the ball valve open. This allows a restricted flow of outlet pressure through the ball valve into the wobble plate chamber, which maintains the wobble plate at a low tilt angle. As the refrigerant flows through the evaporator and absorbs heat (i.e. as the thermal load increases) the pressure of the vapour entering the compressor increases. In the control valve, the increased inlet pressure causes the diaphragm and push rod to move to close the ball valve. The resultant reduction in wobble plate chamber pressure, together with the increase in inlet pressure, causes pistons on their induction stroke to move the wobble plate to a higher tilt angle and increase the piston stroke and the refrigerant flow through the compressor. When the thermal load of the evaporator decreases, the subsequent decrease in pressure of vapour entering the compressor causes the control valve to open. This increases the wobble plate chamber pressure, which in turn reduces the tilt angle of the wobble plate and the refrigerant flow through the compressor.

By matching the refrigerant flow to the thermal load of the evaporator, the variable compressor maintains a relatively constant evaporator temperature of approximately 3 to 4 °C (37 to 39°F).

Air Conditioning Control System

In conjunction with the Engine Control Module (ECM), the air conditioning control system operates the cooling/condenser fans and the compressor clutch to control the flow of refrigerant through the system.

The air conditioning control system comprises of a compressor clutch relay, an evaporator temperature sensor, a refrigerant pressure sensor, a cooling fan control module and control switches. These controls, in conjunction with the cooling fans, compressor clutch, blower and heater distribution and blend unit, maintain the required environment inside the vehicle with minimal input from the driver.

When air conditioning is not selected, air is supplied by ram effect or blower operation to the areas selected by the air distribution control. The air mix flap on the heater assembly blend unit controls the temperature of the air being delivered. No cooled air is available.

Selecting air conditioning provides the added facility of cooled air available to be mixed with heated air in the blend unit. When required, a fully cold condition can be selected by turning the temperature control selector to the cold position, this automatically closes the path of inlet air through the heater matrix.

Mixtures of cooled, fresh, and hot air can be selected to give the required interior environmental conditions by selection at the control panel.

Compressor clutch relay

The compressor clutch relay switches power to the compressor clutch under the control of the ECM. The relay is located in the engine compartment fusebox. The compressor clutch is energized to engage and de-energized to disengage.

Compressor

Operation of the clutch is controlled by the engine control module (ECM). To protect the refrigerant system from unacceptably high pressure, a pressure relief valve is installed in the outlet side of the compressor. The pressure relief valve is set to operate at 3430 kPa (497.5 lbf/in²) and vents excess pressure into the engine compartment.

The ECM controls the operation of the compressor via the compressor clutch relay in the engine compartment fuse box. When the A/C switch is used to request air conditioning, the ECM energises the compressor clutch relay to supply a power feed to the compressor clutch. Engagement of the compressor clutch is withheld, or discontinued, if refrigerant pressure exceeds upper or lower pressure limits:

- The upper pressure limit is 29 bar (421 lbf/in²), e.g. due to a blockage. Compressor engagement is re-enabled when the pressure decreases to 23 bar (334 lbf/in²).
- The lower pressure limit is 1.6 bar (23.2 lbf/in²), e.g. due to a leak. Compressor engagement is re-enabled when the pressure increases to 2.0 bar (29.0 lbf/in²).

Refrigerant pressure sensor

The refrigerant pressure sensor is located in the refrigerant lines. On LHD vehicles with KV6 engines it is located at the RH side of the engine compartment close to the outlet from the condenser in the refrigerant line leading to the thermostatic expansion valve. On all other engine/vehicle derivatives the sensor is located in the same refrigerant line at the LH side of the engine compartment. The refrigerant pressure sensor provides the ECM with a pressure input from the high pressure side of the refrigerant system.

The ECM uses the signal from the refrigerant pressure sensor to protect the system from extremes of pressure, by disengaging the compressor clutch. The signal is also used for cooling fan control. The temperature sensor used has a low pressure range of 0 – 600 psi and provides the following functions:

- Provide a safety cut-out function if the refrigerant pressure goes either too high or too low
- Indicate when the refrigerant pressure reaches such a point that additional cooling is required – if the pressure reaches the medium point, the cooling fans will be switched to high speed
- The pressure sensor is used in conjunction with the evaporator temperature sensor to predict compressor load for load management at idle/part throttle

On petrol engine vehicles, the pressure sensor signal is fed directly to the ECM. On diesel model vehicles, the pressure sensor is connected to the Instrument Pack, and the signal is relayed to the ECM from the Instrument Pack via the CAN Bus.

Because the compressor is lubricated by oil suspended in the refrigerant, a low pressure signal from the sensor is used by the ECM to prevent operation of the compressor unless there is a minimum refrigerant pressure, and thus refrigerant and oil in the system.

Evaporator temperature sensor

The evaporator temperature sensor is an encapsulated thermistor with a negative temperature coefficient (NTC) that provides the ECM with an input of the evaporator air outlet temperature. The sensor is connected to the ECM to provide it with a temperature signal, so that it can prevent the air conditioning system from operating when the evaporator is frozen. Frosting of the evaporator cooling fins will cause a reduction in the effectiveness of the cooling system.

If the temperature at the evaporator falls low enough for ice to form on the fins, the ECM withholds or discontinues engagement of the compressor clutch. When the temperature at the evaporator rises sufficiently, the ECM engages the compressor clutch.

The evaporator temperature sensor is also used in conjunction with the refrigerant pressure sensor to facilitate compressor load prediction for optimum idle speed control and load management. The A/C system places an extra load on the engine when the compressor is operating, so the ECM automatically adjusts the idle speed to compensate for the additional load.

Air conditioning operation

Air conditioning operates only while the engine is running and the blower in the heater assembly is on (any speed). Fresh or recirculated air can be selected with or without the air conditioning being on, provided the ignition is 'ON'.

When the air conditioning switch is selected 'ON', the indicator lamp in the switch illuminates and an air conditioning request signal is input to the ECM via the Instrument pack and CAN Bus. The air conditioning request signal consists of a positive voltage supply via the blower switch and A/C switch, hard wired to the instrument pack. The instrument pack interprets the A/C request signal and informs the ECM of the condition using a message on the CAN Bus. The ECM is also in receipt of signals from the refrigerant pressure sensor and the evaporator temperature sensor, which it uses to determine the necessary cooling fan speed and compressor clutch control.

On receipt of the air conditioning request signal, the ECM switches air conditioning on by signalling the compressor clutch relay module to engage the compressor clutch and the cooling fan controller to run the cooling fans at the appropriate speed using a PWM signal. The engine drives the compressor to circulate the refrigerant. The blower draws fresh or recirculated air through the evaporator. As the air flows through the evaporator, moisture condenses out from the relatively warm air onto the cold evaporator. The dehumidified air is then fed into the heater assembly, from where it is distributed to the vehicle interior.

When the air conditioning switch is selected 'OFF', or if the blower is selected 'OFF' the indicator lamp in the air conditioning switch extinguishes and the air conditioning request signal is removed from the ECM. The ECM then switches air conditioning off by signalling the relay module to disengage the compressor clutch and cooling fan controller to terminate the operation of the cooling fans.

Fuel burning heater

Fuel burning heater fuel pump

The fuel burning heater (FBH) regulates the fuel supply to the FBH unit. The FBH fuel pump is installed in a rubber mounting attached to the underside of the chassis near the rear RH wheelarch. The pump is a self priming, solenoid operated plunger pump, with a fixed displacement of 0.063 cm³ / Hz (0.002 US fl.oz / Hz). The ECU in the FBH unit outputs a pulse width modulated signal to control the operation of the pump. When the pump is de-energised, it provides a positive shut-off of the fuel supply to the FBH unit.

FBH fuel pump nominal operating speeds/outputs

Operating phase	Speed, Hz	Output, l/h (US galls/h)
Start sequence	0.70	0.159 (0.042)
Part load	1.35	0.306 (0.081)
Full load	2.70	0.612 (0.163)

The solenoid coil of the FBH fuel pump is installed around a housing which contains a plunger and piston. The piston locates in a bush, and a spring is installed on the piston between the bush and the plunger. A filter insert and a fuel line connector are installed in the inlet end of the housing. A non-return valve and a fuel line connector are installed in the fuel outlet end of the housing.

While the solenoid coil is de-energised, the spring holds the piston and plunger in the 'closed' position at the inlet end of the housing. An 'O' ring seal on the plunger provides a fuel tight seal between the plunger and the filter insert, preventing any flow through the pump. When the solenoid coil is energised, the piston and plunger move towards the outlet end of the housing, until the plunger contacts the bush. In this condition, fuel is drawn through the inlet connection and filter. The initial movement of the piston also closes transverse drillings in the bush and isolates the pumping chamber at the outlet end of the housing. Subsequent movement of the piston then forces fuel from the pumping chamber through the non-return valve and into the line to the FBH unit. When the solenoid coil de-energises, the spring moves the piston and plunger back towards the closed position. As the piston and plunger move towards the closed position, fuel flows past the plunger and through the annular gaps and transverse holes in the bush to replenish the pumping chamber.

Fuel Burning Heater (FBH) Unit

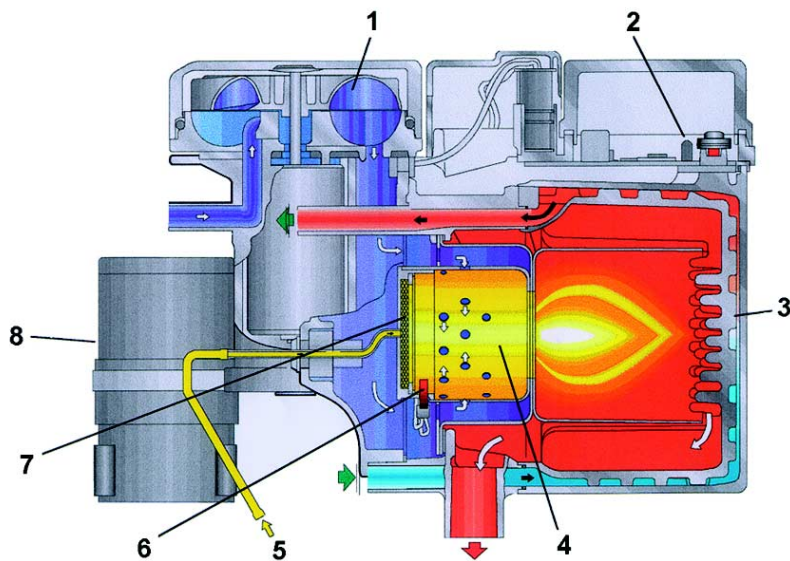


Figure 18

1. Combustion air fan
2. Electronic board
3. Heat exchanger
4. Stainless steel burner
5. Fuel supply
6. Glowpin/Flame detector
7. Evaporiser
8. Water pump

The FBH unit is located at the LH side of the engine compartment, behind the front of the LH wheelarch. The unit is connected in series with the coolant supply to the heater assembly. Two electrical connectors on the top of the FBH unit connect to the vehicle wiring.

The fuel burning heater unit consists of:

- A circulation pump
- A combustion air fan
- A burner housing
- An ECU/heat exchanger
- An air inlet hose
- An exhaust pipe

Circulation pump

The pump runs continuously while the FBH unit is in standby or active operating modes. While the FBH unit is inactive, coolant flow is reliant on the engine coolant pump.

Combustion air fan

The combustion air fan regulates the flow of air into the unit to support combustion of the fuel supplied by the FBH pump. It also supplies the air required to purge and cool the FBH unit. Ambient air is supplied to the combustion air fan through an air inlet hose containing a sound deadening foam ring.

Burner housing

The burner housing contains the burner insert and also incorporates connections for the exhaust pipe, the coolant inlet from the circulation pump and the coolant outlet to the heater assembly. The exhaust pipe directs exhaust combustion gases to atmosphere at the bottom of the engine compartment.

The burner insert incorporates the fuel combustion chamber, an evaporator and a glow plug/flame sensor. Fuel from the FBH fuel pump is supplied to the evaporator, where it evaporates and enters the combustion chamber to mix with air from the combustion air fan. The glow plug/flame sensor provides the ignition source of the fuel/air mixture and, once combustion is established, monitors the flame.

ECU/Heat exchanger

The ECU controls and monitors operation of the FBH system. Ventilation of the ECU is provided by an internal flow of air from the combustion air fan. The heat exchanger transfers heat generated by combustion to the coolant. A sensor in the heat exchanger provides the ECU with an input of heat exchanger casing temperature, which the ECU relates to coolant temperature and uses to control system operation. The temperature settings in the ECU are calibrated to compensate for the difference between coolant temperature and the heat exchanger casing temperature detected by the sensor. Typically: as the coolant temperature increases, the coolant will be approximately 7 °C (12.6 ° F) hotter than the temperature detected by the sensor.

K series 1.8 petrol engine

Introduction

The well proven K series 16 valve 1.8 litre engine has undergone changes to meet new quality and legislative standards. Specific enhancement include:

- EU3 emissions compliance
- New generation engine management system (MEMS 3) including full on-board diagnostics of emission control equipment
- New camshaft drive belt auto-tensioners to reduce noise and increase service life from 60,000 to 90,000 miles
- New camshaft sensor - required by MEMS 3 for sequential fuelling
- New camshaft and timing belt covers with higher content of recyclable material and the camshaft cover now facilitates the camshaft sensor
- New ignition system including plug top coils and coil covers
- New single supplier (Bosch) of electrical ancillaries
- Pre-catalytic converter fitted to the exhaust manifold down pipe
- Modified cylinder head assembly to allow for the camshaft sensor
- The alternator heat shield now covers the exhaust manifold
- The alternator/air conditioning belt now has an automatic tensioner
- Recyclable material for the camshaft timing and auxiliary belts
- The flow rate of the injectors have changed to meet emission targets

General

The K Series engine is built up from aluminium castings bolted together. These consist of three major castings; the cylinder head, cylinder block and a bearing ladder, which is line bored to provide the main bearing bores. Attached to these are three minor castings; above the cylinder head, the camshaft carrier and the camshaft cover. Below the bearing ladder is an oil rail.

Each of the ten cylinder head bolts passes through the cylinder head, cylinder block and bearing ladder to screw into the oil rail. This puts the cylinder head, cylinder block and bearing ladder into compression with all the tensile loads being carried by the cylinder head bolts.

When the cylinder head bolts are removed; additional fixings are used to retain the bearing ladder to the cylinder block and the oil rail to the bearing ladder.

The cross flow cylinder head is based on a four valve, central spark plug, combustion chamber with the inlet ports designed to induce swirl and control the speed of the induction charge. This serves to improve combustion and hence fuel economy, performance and exhaust emissions. The twin overhead camshafts operate the valves via hydraulic tappets, one camshaft operates the exhaust valves while the other operates the inlet valves. The camshafts are driven from the crankshaft by a timing belt, belt tension being maintained by an automatic tensioner. The camshafts are retained by the camshaft carrier, which is line bored with the cylinder head.

Timing belt components

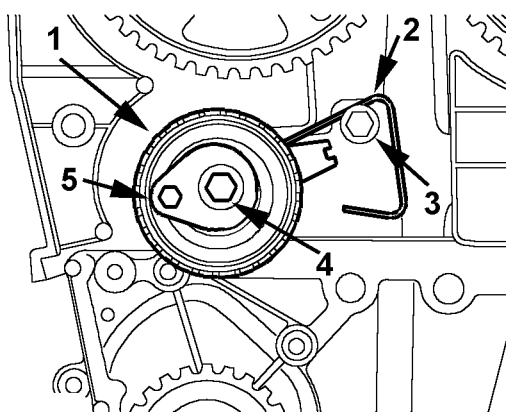


Figure 19

- 1.Upper front cover - timing belt
- 2.Seal - upper cover
- 3.Lower cover - timing belt
- 4.Seal - lower cover
- 5.Crankshaft pulley
- 6.Special washer - pulley bolt
- 7.Crankshaft pulley bolt
- 8.Camshaft timing belt
- 9.Camshaft timing gears
- 10.Tensioner
- 11.Index wire
- 12.Pointer
- 13.Crankshaft timing gear
- 14.Rear cover

When installing the new type belt tensioner, ensure that the index wire is positioned over the pillar bolt and that the tensioner lever is at the 9 o'clock position.

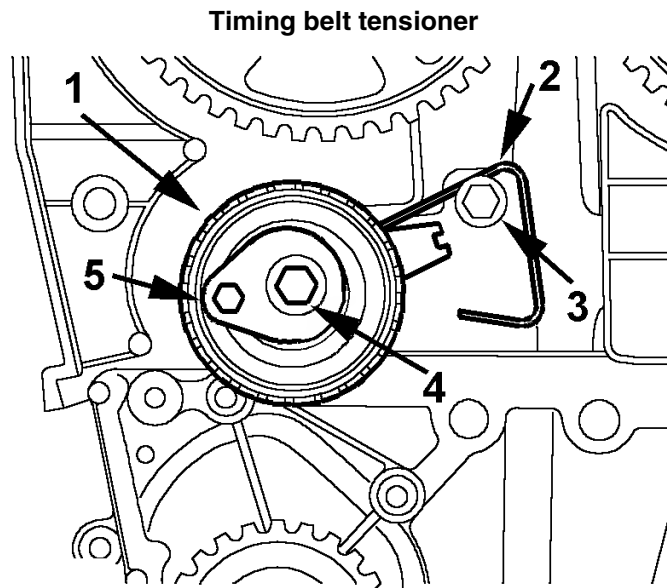


Figure 20

- 1. Automatic tensioner
- 2. Index wire
- 3. Pillar bolt
- 4. Securing bolt
- 5. Tensioner lever

Fit a new tensioner securing bolt and tighten until it is just possible to move the tensioner lever then install the timing belt.

Using a 6 mm Allen key, rotate the tensioner anti-clockwise and align the centre of the indent on the tensioner pointer to the index wire. Ensure that the pointer approaches the index wire from above.

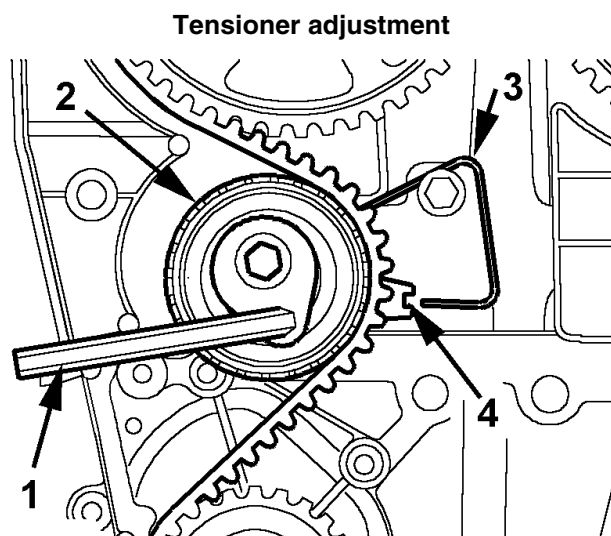


Figure 21

- 1. 6 mm Allen key
- 2. Tensioner
- 3. Index wire
- 4. Pointer indent

NOTE: For the full procedure of this process refer to the workshop manual.

The plug-top coil ignition system utilises a camshaft sensor located in the camshaft carrier, adjacent to the exhaust camshaft. The camshafts have an integral reluctor ring, which provides an input to the camshaft sensor. Twin coils are fitted on top of the camshaft cover, each coil supplying HT voltage to one pair of spark plugs.

Plug-top coil

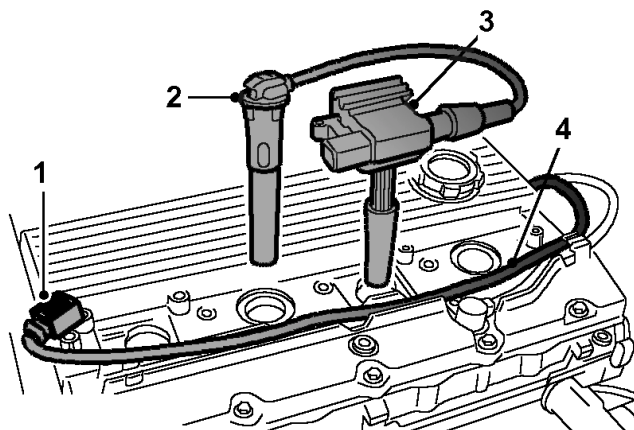


Figure 22

- 1. Multiplug
- 2. HT lead
- 3. Coil
- 4. harness

Self-adjusting hydraulic tappets are fitted on top of each valve and are operated directly by the camshafts. The valve stem oil seals are moulded onto a metal base which also act as the valve spring seat on the cylinder head.

Exhaust valves are of the carbon break-type. A machined profile on the valve stem removes any build up of carbon in the combustion chamber end of the valve guide thereby preventing valves from sticking.

The stainless steel cylinder head gasket has moulded seals around all coolant, breather and oil apertures and has steel cylinder bore eyelets. Limiters at each end of the gasket control compression of the gasket.

The cylinder block is fitted with 'damp' cylinder liners, the bottom, stepped half of the damp liner, being a sliding fit into the lower part of the cylinder block. The liners are sealed in the block with a bead of Hylomar. The bead is applied around the stepped portion of the liner. The cylinder head gasket effects the seal at the cylinder head with the liner top acting as a break between the combustion chamber and gasket.

The aluminium alloy, thermal expansion pistons have a semi- floating gudgeon pin, which is offset towards the thrust side and has interference fit in the small end of the connecting rod. Pistons and cylinder liners are supplied in two grades. Big-end bearing diametric clearance is controlled by three grades of selective shell bearing.

The five bearing, eight balance weight crankshaft has its end-float controlled by thrust washer halves at the top of the central main bearing. Bearing diametric clearance is controlled by three grades of selective shell bearing. Oil grooves are provided in the upper halves of main bearings No. 2, 3 and 4 to supply oil, via drillings in the crankshaft, to the connecting rod big-end bearings.

Manifolds and exhaust system

The following section covers the inlet manifold, exhaust manifold and exhaust system.

Inlet Manifold

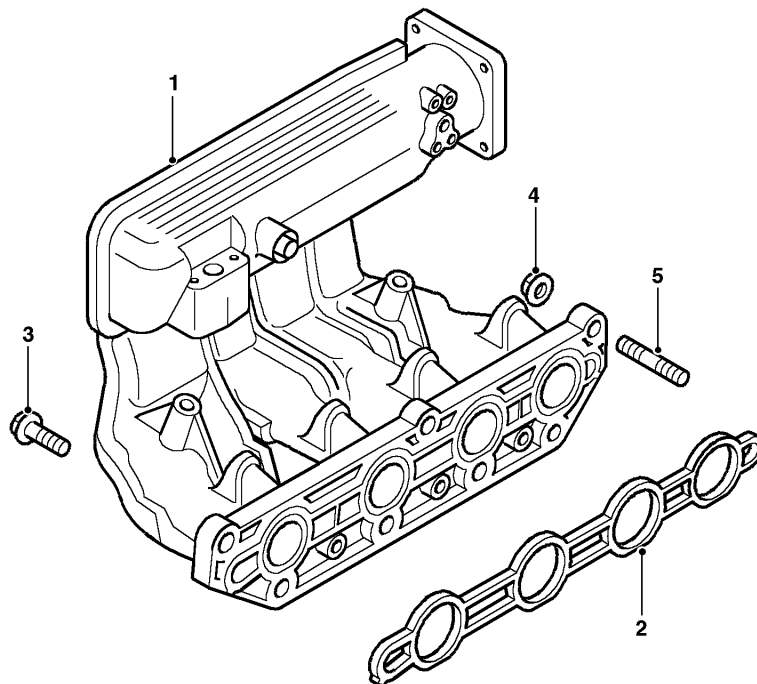


Figure 23

- 1. Inlet manifold
- 2. Gasket
- 3. Screw
- 4. Nut (6 off)
- 5. Stud (6 off)

The inlet manifold is a one piece plastic moulding which is attached to the cylinder head on six locating studs and nuts and further retained by one bolt. A rubber moulded gasket, which is located in a corresponding recess in the inlet manifold mounting face, seals the manifold to the cylinder head.

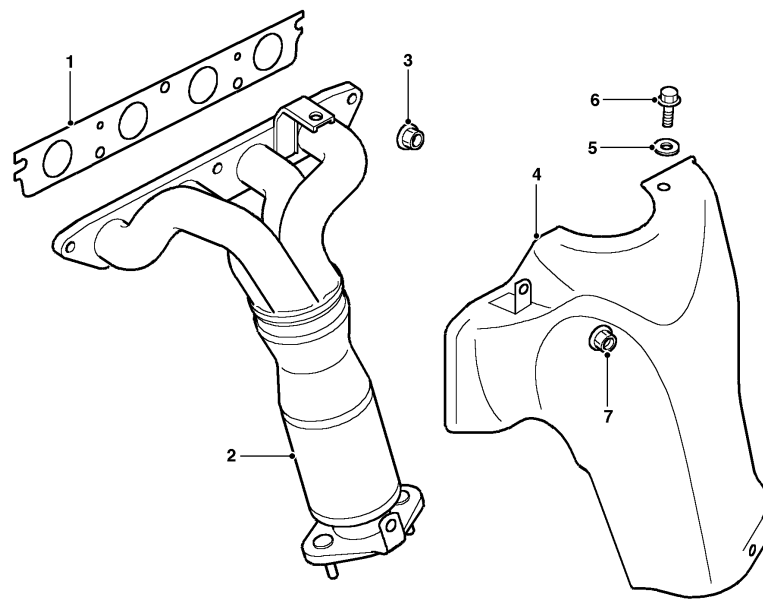
The inlet manifold has vacuum take-off points for the fuel pressure accumulator, the brake servo and the purge valve. A further take-off point vents the camshaft cover into the inlet manifold.

Two threaded lugs on the inlet manifold provide for the attachment of the fuel rail. Four ports at the base of each inlet tract house the injectors which are sealed to the manifold with O-ring seals and retained in position by the fuel rail.

The Idle Air Control (IAC) valve is attached to the inlet manifold, adjacent to the throttle housing and is secured with four Torx bolts and sealed to the manifold with an O-ring seal.

The throttle housing is attached to the left hand end of the inlet manifold and is secured with four bolts and sealed with an O-ring seal. The Intake Air Temperature (IAT) sensor is mounted in No. 4 inlet tract.

Exhaust Manifold



M30 1022

Figure 24

- 1. Gasket
- 2. Exhaust manifold
- 3. Nut (5 off)
- 4. Heat shield
- 5. Spacer
- 6. Screw (2 off)
- 7. Nut

The exhaust manifold is a fabricated and welded steel construction. The four branch manifold is located on five studs in the cylinder head and secured with five nuts. A metal corrugated gasket seals the exhaust manifold to the cylinder head. The four separate branches of the manifold merge into one at a starter catalytic converter. The starter catalytic converter is fitted with a flange which mates with the exhaust system front pipe and is sealed with a metal gasket. Two captive studs in the manifold pass through the mating flange of the front pipe and are secured with nuts.

A threaded boss above the starter catalytic converter allows for the fitment of a pre-catalyst Heated Oxygen Sensor (HO2S). The HO2S measures the oxygen content of the exhaust gases before they enter the starter catalyst.

Exhaust System

The exhaust system comprises of a front pipe assembly incorporating a catalytic converter, intermediate pipe assembly and a tailpipe assembly.

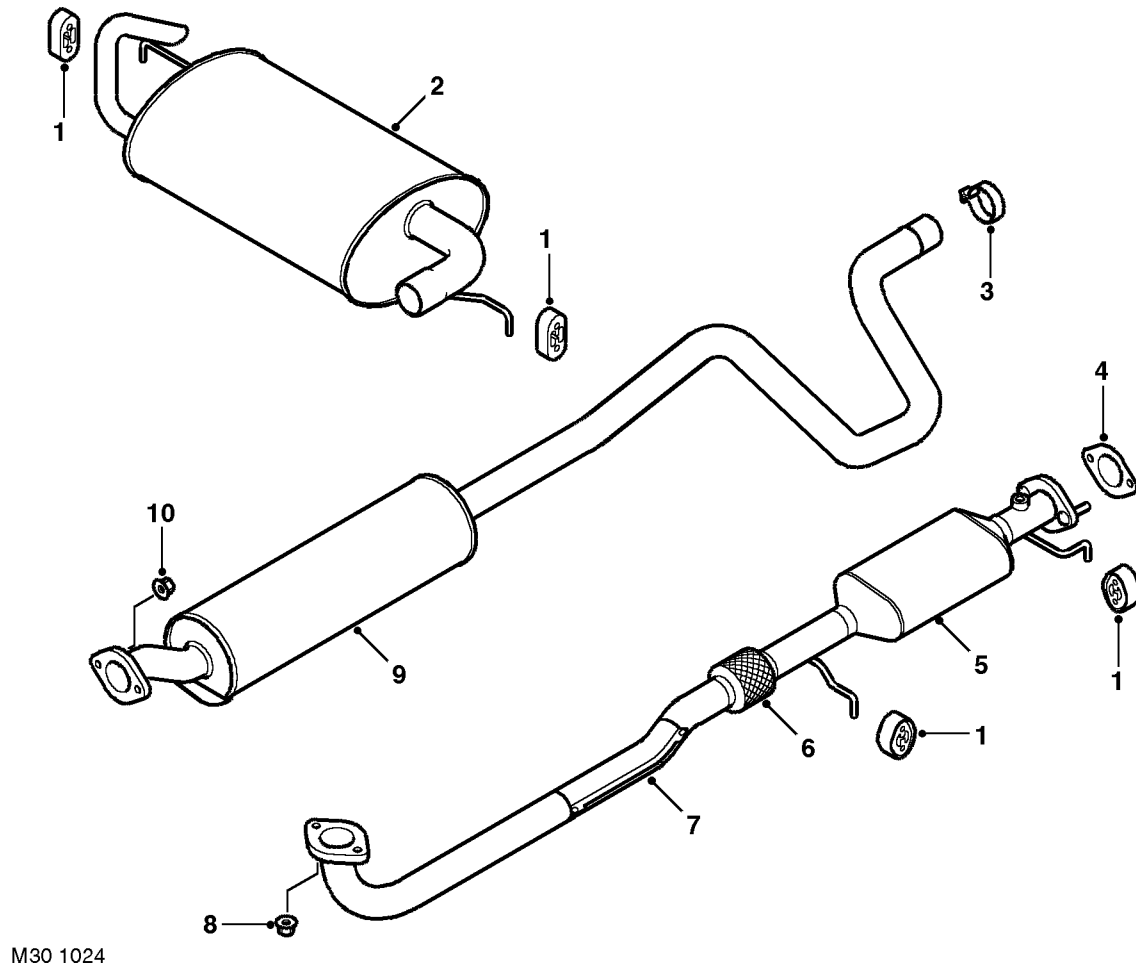


Figure 25

1. Mounting rubber (3 off)
2. Tail pipe assembly
3. Clamp
4. Gasket
5. Catalytic converter
6. Front pipe assembly
7. Heat shield
8. Nut (2 off)
9. Intermediate pipe assembly
10. Nut (2 off)

Technical data

The table titled 'Technical data' displays technical information regarding the K series 1.8 16 valve petrol engine.

Technical data

Description	Data
Type	16 valve DOHC
Capacity	1796 cm ³
Compression ratio	10.5:1
Firing order	1 - 3 - 4 - 2
Valve operation	Self-adjusting hydraulic tappets
Ignition system	MEMS 3
Emission standard	ECD3 (EU3)
Power	118 PS @ 5550 rpm
Torque	165 Nm @ 2750 rpm
Lubrication system	Cast aluminum wet sump; crankshaft driven eccentric rotor oil pump
Fuel system	Returnless multipoint fuel injection, electronically controlled with electro-mechanical fuel injectors.
Cooling system	By-pass type also cooling the intermediate reduction drive
Clutch	Maintenance free hydraulic system

Modular engine management system version 3

General

The Modular Engine Management System Version 3 (MEMS 3) is a sequential, multiport fuel injection system controlled by the Engine Control Module (ECM).

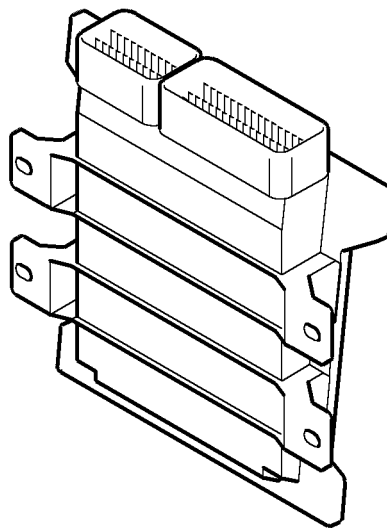
The ECM controls the operation of the fuel system, ignition system, evaporative emission control, cooling system and air conditioning operation.

The ECM uses the speed/density method of air flow measurement to calculate fuel delivery. This method calculates the density of the intake air by measuring its pressure and temperature.

The density signal, combined with the engine speed signal, allows the ECM to make a calculation of the air volume being inducted and determine the quantity of fuel to be injected to give the correct air/fuel ratio.

MEMS 3 is designed to meet new exhaust emission standard; ECD 3 (European Commission Directive Stage 3), also known as OBD (On-Board Diagnostics).

Engine control module



M18 0603

Figure 26

The ECM is located in the environmental box (E-box) on the left hand side of the engine compartment. The ECM is accessible by loosening five cap screws to release the lid on the box.

The ECM electronic components are housed in an aluminium case for heat dissipation and protection from electro-magnetic interference.

With the ignition off, the ECM is supplied with permanent battery voltage to power the memory. The voltage is supplied from the battery positive terminal via the engine compartment fusebox fusible link 1 and fuse 5 to the ECM.

When the ignition switch is in position II (ignition 'ON'), the ECM receives battery voltage, via the engine compartment fusebox fusible link 3 and the passenger compartment fusebox fuse 6, to the ECM. The ECM energises the main relay by completing the earth path for the relay coil, which is connected to the ECM. The main relay provides battery voltage to various peripheral components and also to the ECM.

When the ignition switch is turned to position II, the ECM primes the fuel system by running the fuel pump for approximately two seconds. This is achieved by completing the earth path for the fuel pump relay coil. The fuel pump relay coil is connected to battery voltage from the main relay, the earth being supplied by the ECM. The ECM references the sensors and the IAC valve stepper motor prior to start-up.

Security code information is exchanged between the ECM and the immobilisation ECU.

When the ignition switch is turned to position III (crank), the ECM communicates with the immobilisation ECU. If it receives authority to start, the ECM begins ignition and fuelling when CKP and CMP sensor signals are detected. The ECM will run the fuel pump continuously when CKP sensor signals are received (crank turning).

When the ignition switch is turned to position 0 ('OFF'), the ECM switches 'OFF' ignition and fuelling to stop the engine. The ECM continues to hold the main relay in the on position until it has completed the power down functions. Power down functions include engine cooling and referencing the IAC valve stepper motor and includes memorising data required for the next start up. When the power down process is completed, the ECM switches off the main relay and enters a low power mode. During low power mode the ECM will consume less than 1mA.

If the ECM suffers an internal failure, such as a break down of the processor or driver circuits, there are no back up systems or limp home capability. If a sensor circuit fails to supply an input, this will result in a substitute or default value being adopted where possible. This enables the vehicle to function, but with reduced performance.

Heated oxygen sensor

Heated Oxygen sensor

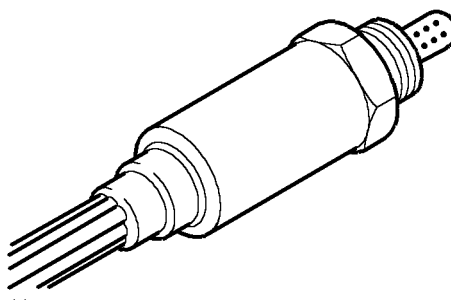


Figure 27

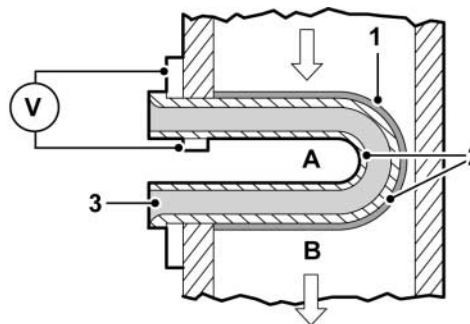
Two HO₂S are used on the MEMS 3 system to comply with the requirements of ECD 3. A pre-catalyst HO₂S is located in the exhaust manifold, upstream of the starter catalyst and a post catalyst HO₂S is located in the exhaust system, downstream of the main catalyst. The sensors provide feedback signals to the ECM which enable it to control the Air/Fuel Ratio (AFR). The principal purpose of the sensors is to enable tight control of AFR around the 14.7:1 AFR (by weight) which produces the best composition of exhaust gas for peak catalyst conversion efficiency.

The upstream (pre-catalyst) sensor is the main sensor used for closed loop fuelling. The downstream (post-catalyst) sensor is used to monitor the performance of the main catalyst and to trim the fuelling provided by the pre-catalyst sensor.

If an HO₂S fails, the ECM adopts an open loop fuelling strategy to minimise emissions, stores fault codes which can be retrieved using TestBook and, on vehicles manufactured after the EDC3 compliance date, illuminates the Malfunction Indicator Lamp (MIL) in the instrument pack.

The HO₂S consists of a sensing element, the outer surface of which is exposed to exhaust gases, while the inner surface is exposed to ambient air. The sensor has a ceramic coating to protect the sensing element from contamination and heat damage.

Heated Oxygen sensor structure



V18 0605

Figure 28

- a. Ambient air
- b. Exhaust gases
 - 1. Protective ceramic coating
 - 2. Electrodes
 - 3. Zirconium Oxide

The amount of oxygen in ambient air is constant at approximately 20%. The oxygen content of the exhaust gases varies with the AFR with a typical value for exhaust gas of around 2%.

The difference in oxygen content of the two gases produces an electrical potential difference across the sensing element. Rich mixtures, which burn almost all of the available oxygen, produce high sensor voltages. During lean running, there is an excess of oxygen in the mixture and some of this oxygen leaves the combustion chamber unburnt.

In these conditions, there is less difference between the oxygen content of the exhaust gas and the ambient air, and a low potential difference (voltage) is output by the HO₂S. The ECM uses the voltage produced in the HO₂S sensing element to calculate the AFR and thereby control fuelling to a high degree of accuracy.

The material used in the sensing element only becomes active at a temperature of 300°C (572°F), therefore it is necessary to provide additional heating via an electrical resistive element. The element uses a 12V supply from the main relay when the ECM energises the relay coil and allows a short warm up time and minimises emissions from start-up. The resistance of the heating element can be measured using a multimeter and should be 6Ω at 20°C (68°F).

Heating element resistance

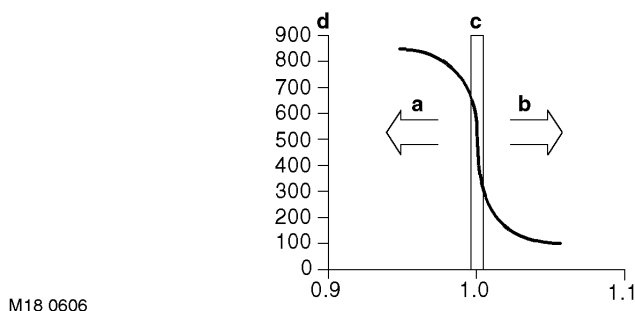
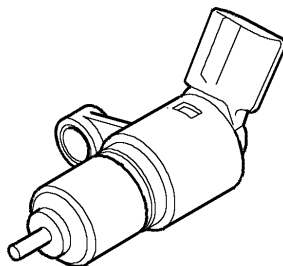


Figure 29

- a. Rich AFR
- b. Lean AFR
- c. Lambda window
- d. HO2S Output in mV.

Crankshaft position sensor



M18 0676

Figure 30

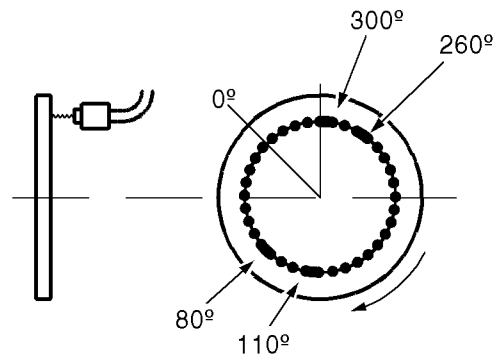
The variable reluctance crankshaft position (CKP) sensor is mounted at the rear of the engine with the sensor tip facing the engine face of the flywheel and is secured in the casting with a single screw. The sensor tip of the CKP sensor is adjacent to a profiled target ring formed on the inner face of the flywheel.

The signal produced by the CKP sensor allows the ECM to calculate the rotational speed and angular position of the crankshaft. This information is required by the ECM to calculate ignition timing, fuel injection timing and fuel quantity during all conditions when the engine is cranking or running. If the CKP sensor signal is missing, the vehicle will not run as there is no substitute signal or default.

The CKP sensor is a variable reluctance sensor and provides an analogue voltage output, relative to the speed and position of the target on the flywheel. A permanent magnet inside the sensor applies a magnetic flux to a sensing coil winding. This creates an output voltage which is read by the ECM.

As the gaps between the poles of the target pass the sensor tip, the magnetic flux is interrupted and this causes a change to the output voltage.

Sensor targets

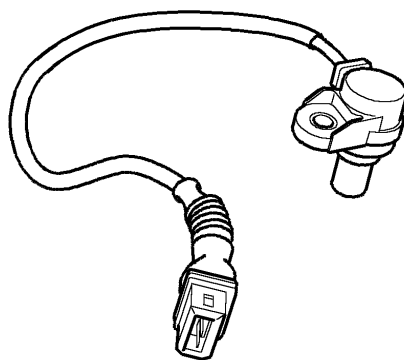


M18 0607

Figure 31

It is important to note that the ECM is unable to determine the exact position of the engine with its four stroke cycle from the CKP sensor alone: the CMP sensor must also be referenced to provide sufficient data for ignition control and sequential injection.

Camshaft sensor



M18 0608

Figure 32

The camshaft (CMP) sensor provides a signal which enables the ECM to determine the position of the camshaft relative to the crankshaft. This allows the ECM to synchronise fuel injection for start and run conditions. The CMP sensor provides an output to the ECM. The ECM provides an earth for the sensor.

The CMP sensor is located on the camshaft cover (under the plastic cover) at the opposite end to the camshaft drive and reads off a reluctor on the exhaust camshaft.

The sensor is a hall effect sensor which detects the reluctor mounted on the exhaust camshaft. The sensor receives a battery supply from the main relay. The sensor operates on the principle of a voltage generated when the sensor is exposed to a magnetic flux. This causes a potential difference in voltage as the reluctor passes the sensor which is detected as a digital signal by the ECM.

The reluctor consists of a single 'tooth' design which extends over 180° of the camshaft's rotation, for this reason it is known as a half moon cam wheel.

Camshaft reluctor

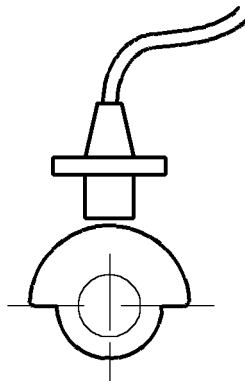


Figure 33

The half moon cam wheel reluctor enables the ECM to provide sequential fuel injection at start up, but it cannot provide a back-up signal in cases of CKP sensor failure.

If the CMP sensor signal is missing, the engine will still start and run, but the fuel injection may be out of phase. This will be noticeable by a reduction in performance and drivability, together with an increase in fuel consumption and emissions.

As the camshaft rotates the signal will switch between the high and low voltages. The position of the half moon cam wheel relative to the camshaft is not adjustable. The air gap between the CMP sensor tip and the half moon cam wheel is not adjustable.

Manifold absolute pressure sensor

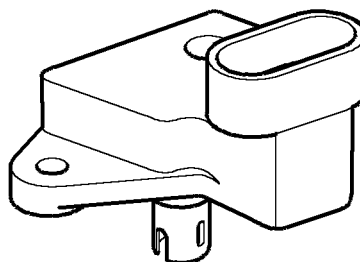


Figure 34

The manifold absolute pressure (MAP) sensor is located on the forward face of the inlet manifold and is secured with two Torx screws.

The output signal from the MAP sensor, together with the CKP and intake air temperature (IAT) sensors, is used by the ECM to calculate the amount of air induced into the cylinders. This enables the ECM to determine ignition timing and fuel injection duration values.

The MAP sensor receives a $5V \pm 4\%$ supply voltage from the ECM and provides an analogue signal to the ECM, which relates to the absolute manifold pressure and allows the ECM to calculate engine load. The ECM provides an earth for the sensor.

If the MAP signal is missing, the ECM will substitute a default manifold pressure reading based on crankshaft speed and throttle angle. The engine will continue to run with reduced drivability and increased emissions, although this may not be immediately apparent to the driver. The ECM will store fault codes which can be retrieved using TestBook.

Engine coolant temperature sensor

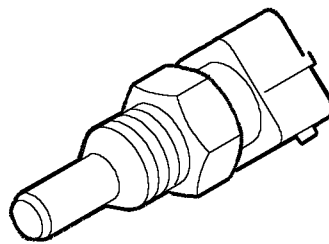


Figure 35

The engine coolant temperature sensor (ECT) sensor is located in the cooling system outlet elbow from the cylinder head and provides a signal which allows the engine temperature to be determined. The ECM provides an earth for the sensor.

On vehicles with air conditioning, the A/C clutch will be disengaged if the engine temperature reaches a predetermined level, and will not re-engage until it falls to a predetermined level.

The ECT sensor consists of an encapsulated Negative Temperature Coefficient (NTC) thermistor which is in contact with the engine coolant. The ECM uses engine temperature to calculate fuelling and ignition timing parameters during start up. It is also used to provide a temperature correction for fuelling and ignition timing when the engine is warming up, running normally or overheating. The ECT signal is used by the ECM to control the engine cooling fans.

If the ECT sensor fails or becomes disconnected, the ECM will use a default value which is based on values from the engine oil temperature sensor. The driver may not notice that a fault is present although a fault code will be stored in the ECM which can be retrieved using TestBook. The default value will also include operation of the cooling fans in fast mode when the engine is running.

Intake air temperature sensor

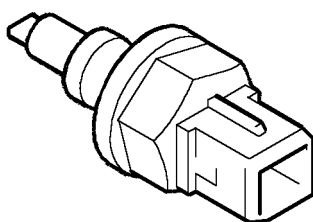


Figure 36

The intake air temperature (IAT) sensor is located in the intake manifold near cylinder number four fuel injector. The sensor consists of an NTC thermistor mounted in an open housing to allow air flow over the sensing element.

The IAT sensor provides a signal, which enables the ECM to adjust ignition timing and fuelling quantity according to the intake air temperature, thus ensuring optimum performance, drivability and low emissions. The ECM provides an earth for the sensor.

The IAT sensor is part of a voltage divider circuit which consists of a regulated 5 volt supply, and a fixed resistor (both are inside the ECM) and a temperature dependent variable resistor (the IAT sensor).

If the IAT sensor fails, or is disconnected, the vehicle will continue to run. The ECM will substitute a default value using the information from the speed/load map to run the engine, but adaptive fuelling will be disabled.

This condition would not be immediately apparent to the driver, but the ECM will store fault codes which can be retrieved using TestBook.

Engine oil temperature sensor

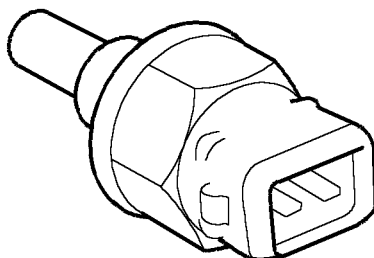


Figure 37

The engine oil temperature sensor is located in the oil filter housing. The oil temperature measured by the ECM is used to adjust fuelling values according to engine oil temperature.

The use of an engine oil temperature sensor allows the ECM to provide optimum engine performance and minimum emissions during the engine warm up phase. The ECM provides an earth for the sensor.

The sensor consists of an encapsulated Negative Temperature Coefficient (NTC) thermistor which is in contact with the engine oil.

If the sensor fails, the ECM will substitute a default value which is ramped up 90°C (194°F). This condition will not be apparent to the driver.

The vehicle will run but may suffer from reduced engine performance and increased emissions as adaptive fuelling is disabled. The ECM will store fault codes which can be retrieved using TestBook.

Throttle position sensor

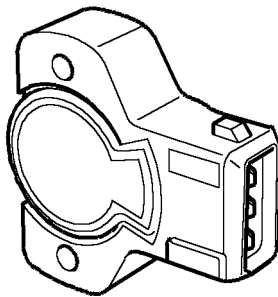


Figure 38

The throttle position sensor (TP) sensor is mounted on the throttle body and is driven from the end of the throttle spindle. The TP sensor consists of a potentiometer which provides an analogue voltage that the ECM converts to throttle position information.

The TP sensor signal is required for the following vehicle functions:

- Idle speed control
- Throttle damping
- Deceleration fuel cut off
- Engine load calculations
- Acceleration enrichment
- Full load enrichment
- Automatic gearbox shift points

The TP sensor is a potentiometer which acts as a voltage divider in an external ECM circuit. The potentiometer consists of a $4\text{k}\Omega \pm 20\%$ resistive track and a wiper arm, driven by the throttle spindle, which sweeps over the track.

The track receives a regulated $5\text{ V} \pm 4\%$ supply from the ECM, together with an earth. As the wiper arm moves over the track it will connect to areas of different voltage ranging from 0 to 5 volts. The 'output' from the wiper arm is connected to the ECM, to provide an analogue voltage signal.

The TP sensor requires no adjustment as the ECM will learn the lower voltage limit which corresponds to closed throttle.

If the TP sensor signal is missing the vehicle will continue to run but may suffer from poor idle control and throttle response. The ECM will store fault codes which can be retrieved using TestBook.

Idle air control valve (Bi-polar stepper motor)

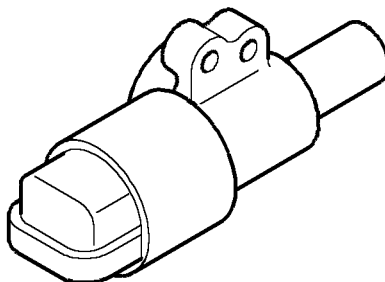


Figure 39

The idle air control valve (IAC) valve is located on the inlet manifold. It allows the ECM to control the engine idling speed by regulating the amount of air which by-passes the throttle valve. It also allows the ECM to provide a damping function when the throttle is closed under deceleration which reduces hydrocarbon (HC) emissions.

The IAC valve is controlled by the ECM using a stepper motor. This consists of a core which is rotated by magnetic fields produced by two electro-magnet bobbins set at 90° to each other.

The stepper motor controls the volume of air passing through a duct which leads from the inlet manifold to a pipe connected to the throttle body. The bobbins are connected to the ECM driver circuits.

Each of the four connections can be connected to 12 volts or earth, enabling four 'phases' to be obtained. The ECM drives the four phases, known as 'A', 'B', 'C' and 'D', to obtain the desired idle speed.

When the ignition is switched 'OFF' the ECM enters a power down routine which includes 'referencing' the stepper motor. This means that the ECM will rotate the motor so that it can memorise the position when it next needs to start the engine.

The stepper motor referencing procedure can take from three to five seconds. If the ECM cannot reference the stepper motor during power down, it will do so at ignition on. If the stepper motor fails, there are no back up idle control systems. The idle speed may be too high or too low and if a load is placed on the engine it may stall. The ECM will store fault codes which can be retrieved by TestBook.

Ignition coils

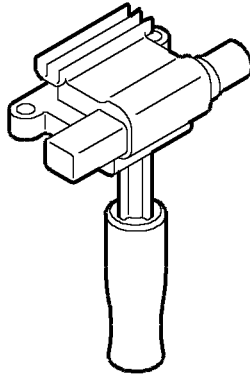


Figure 40

Two ignition coils are mounted on the camshaft cover above the spark plugs for cylinders 1 and 3 and secured with screws.

Each coil operates a pair of spark plugs using the wasted spark principle. The coil has a plug connection on its lower face and an HT lead which connects to the second plug.

Coil No. 1 and No. 2 are connected to earth via the ECM. Each coil receives a battery supply from the main relay, via fuse 2 in the engine compartment fusebox.

Coil No. 1 is fitted above cylinder 1 and is attached to the spark plug for cylinder 1 and the HT lead connects to the spark plug for cylinder 4.

Coil No. 2 is fitted above cylinder 3 and is attached to the spark plug for cylinder 3 and the HT lead connects to the spark plug for cylinder 2.

Each ignition coil consists of a pair of windings wrapped around a laminated iron core. The primary winding has a resistance of 0.7Ω and the secondary winding has a resistance of $10\text{ k}\Omega$.

Fuel injectors

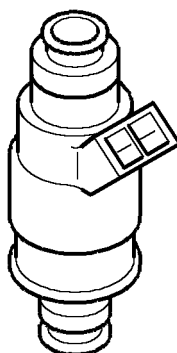


Figure 41

The fuel injectors are located directly under the fuel rail and connect to the intake manifold runners. Each injector delivers fuel to the engine in a targeted, atomised spray (onto the intake valve heads) which takes place once per cycle. Each injector opens during the intake stroke of the cylinder it supplies.

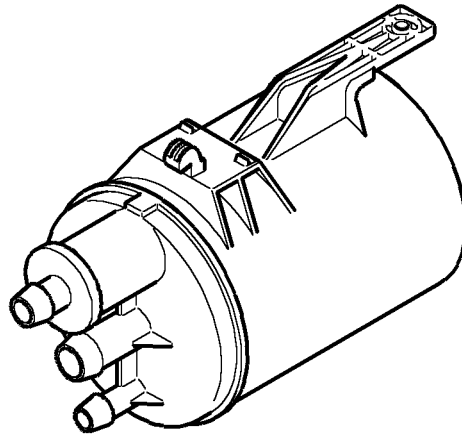
An injector consists of a pintle type needle and seat, and a solenoid winding which lifts the needle against a return spring. The injector nozzle delivers the fuel spray to precise areas of the intake ports to maximise the benefits of the swirl and turbulence in the manifold and head ports.

The solenoid winding has a resistance of 13 - 16 Ω at 20°C (68°F). The fuel injectors operate at a regulated pressure of 3.5 bar (50 lbf/in²). The regulator is located on the end of the fuel rail.

The injectors receive fuel under pressure from the fuel rail and a 12 volts supply from the main relay. To deliver fuel to the engine, the ECM has to lift the needle off the injector seat by energising the solenoid.

If an injector fails, the engine may lose power and drivability. The ECM will store fault codes which can be retrieved using TestBook.

Evaporative emissions purge valve



M18 0618

Figure 42

The evaporative emissions (EVAP) purge valve is located in the engine compartment, on the LH inner wing, below the E-box. The purge valve is connected via a flexible pipe to the inlet manifold. The EVAP canister is located in the RH rear wheel arch, behind the liner.

The purge valve consists of a solenoid operated valve which is controlled by the ECM which provides a PWM earth signal. The purge valve receives a battery feed from the main relay via fuse 1 in the engine compartment fusebox.

The EVAP purge valve controls the flow of fuel vapors from the EVAP canister to the intake manifold of the engine. When the vehicle is being driven the ECM will purge the EVAP canister by opening the canister purge valve, this allows the vacuum present in the intake manifold to draw fuel vapour from the canister into the cylinders for combustion.

When fuel vapour is being removed from the canister, fresh air is allowed to enter via an automatic one-way valve, this makes the canister ready for the next 'absorption' phase. The amount of fuel vapour which enters the cylinders can affect the overall AFR, therefore the ECM must only open the canister purge valve when it is able to compensate by reducing fuel injector duration.

The purge valve will only operate under the following conditions:

- Engine at normal operating temperature
- Adaptive fuelling enabled
- Closed loop fuelling enabled.

Alternator

The alternator is located on a bracket which is attached to the cylinder block on the front RH side of the engine. The alternator is driven by a Polyvee belt from the crankshaft pulley. The alternator converts mechanical energy into electrical energy to power the electrical systems and maintain the battery charge.

The alternator outputs a signal, which represents the electrical load on the vehicle systems and the mechanical load exerted on the engine by the alternator. The signal output from the alternator is a variable PWM signal which is proportional to the load applied to the engine.

The ECM uses the load signal to provide idle speed compensation and to reduce engine speed fluctuations. If the load signal fails, the ECM uses a default value and stores a fault code which can be retrieved using TestBook.

Ignition switch signal

A hardwired digital input provides an ignition on signal. When the ECM has been idle for a period of time, it goes into 'sleep' (power saving) mode.

When the ECM receives an ignition 'ON' signal from the ignition switch, the ECM 'wakes up' and energises the main relay.

Main relay

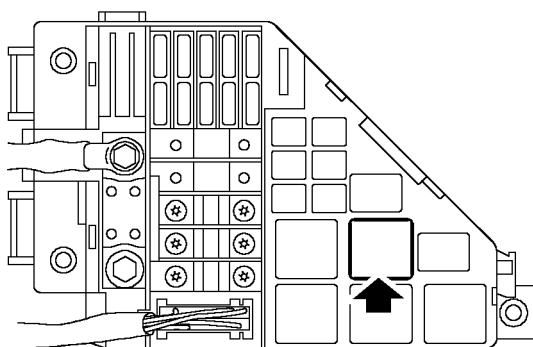


Figure 43

The main relay is located in the engine compartment fusebox which is located on the LH side of the engine compartment.

The main relay is normally open when the ignition is 'OFF'. When the ignition is switched 'ON' to position II, the ECM provides an earth path for the relay coil which energises, closing the contacts.

A permanent battery supply is provided direct to the relay contacts. The main relay supplies battery voltage to the following components:

- ECM
- Pre and post HO2S
- CMP sensor
- Purge valve
- Fuel injectors
- Ignition coils
- A/C relay coil
- Fuel pump relay coil

If the main relay fails, power will not be supplied to the above components and the engine will not start. The ECM will store fault codes which can be retrieved using TestBook.

Fuel pump relay

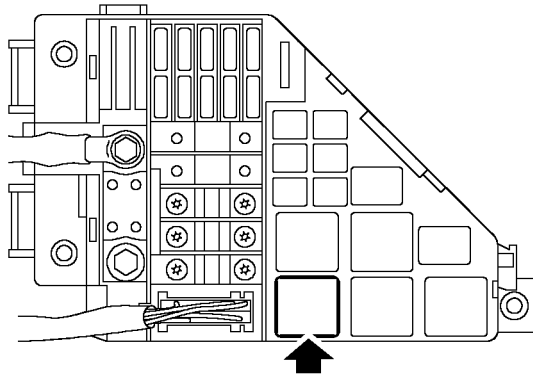


Figure 44

The fuel pump relay is located in the engine compartment fusebox which is positioned on the LH side of the engine compartment. The relay is normally open when the ignition is 'OFF'.

When the ignition is switched 'ON' to position II, the ECM provides an earth path for the relay coil. With the ignition 'ON', the relay receives a feed from the main relay which energises the relay coil, closing the contacts.

A permanent battery supply is provided to the relay contacts from fuse 10 in the engine compartment fusebox, via the fuel shut-off switch. The feed passes through the relay contacts and operates the fuel pump to pressurise the fuel system. The relay will be energised for a short time only to pressurise the fuel system.

When the ignition switch is moved to the crank position III, the ECM will energise the relay when the engine starts cranking and will remain energised until the engine stops.

If the engine stalls and the ECM stops receiving a signal from the CKP sensor, the ECM will remove the earth path for the relay, stopping the fuel pump.

The fuel shut-off switch, when tripped, cuts off the power supply to the relay contacts, disabling the fuel pump in the event of a sudden deceleration. If the fuel pump fails to operate, check that the fuel shut-off switch is not tripped. The switch is reset by depressing the rubber cap on the top of the switch.

If the fuel pump relay fails, power will not be supplied to the fuel pump and the engine will not start or will stop if already running due to fuel starvation. The ECM will store fault codes which can be retrieved using TestBook.

Engine cooling fans

On vehicles without air conditioning (A/C) a single speed cooling fan is located behind the radiator. The fan is controlled by the ECM via a relay located in the E-box.

On vehicles with A/C, a cooling fan is located behind the radiator, adjacent to a second similar cooling fan used by the air conditioning system for condensor cooling. For engine cooling and air conditioning both fans operate in parallel controlled by the ECM via a fan controller.

Cooling fan - without A/C

The ECM will energise the cooling fan relay in the E-box at a coolant temperature of 102°C (215°F) and will go off when the coolant temperature decreases to less than 96°C (204°F).

When the engine is switched off, the ECM maintains the cooling fan in an active condition for up to eight minutes. If the temperature does not reach a predetermined value within four minutes, the ECM will terminate the active period. If the fan is active and the temperature falls below a predetermined value, the ECM will terminate further fan operation.

Cooling Fan - with air conditioning

The engine cooling fan and the condensor fan are operated in parallel by the ECM via a fan controller. The fan controller, which is located behind the radiator below the bonnet closing panel, receives a Pulse Width Modulated (PWM) signal from the ECM. The frequency of the PWM signal, which is varied by the ECM, is used by the fan controller to determine the output voltage supplied to the fan motors.

The fan operation is also dependent on vehicle road speed. The ECM will calculate the required fan speed in relation to the road speed using CAN signals received from the ABS ECU.

The ECM varies the duty cycle of the PWM signal between 10% and 90%. At duty cycles of between 10% and 49% the fan controller will not supply any power to the fan motors. At a duty cycle of 50%, the fan controller supplies 6 volts to the fan motors to operate them at minimum speed. As the duty cycle increases above 50%, the fan controller increases the voltage, non-linearly, to the fan motors up to 90%. At this point the fan motors are supplied with 12 volts and operate at maximum speed of approximately 3000 rev/min.

When the main relay is energised, the fan controller requires a PWM signal from the ECM of between 10% and 90% duty cycle. If this condition is not detected, the ECU will assume a fault condition (open or short circuit) exists and operate the fans continuously at full speed when the main relay is energised to ensure that the engine and A/C system do not overheat.

The ECM will operate the fans in response to inputs from the ECT sensor and the A/C switch and A/C pressure sensor. Refer to A/C system for details.

When the engine is switched off, the ECM maintains the cooling fans in an active condition for up to 8 minutes. If the temperature does not reach a predetermined value within 4 minutes, the ECM will terminate the active period. If the fans are active and the temperature falls below a predetermined value, the ECM will terminate further fan operation.

Fuel tank level sensor

The ECM receives a fuel tank level signal on the CAN from the fuel tank level sensor via the instrument pack and the ABS ECU. This signal is stored in a misfire freeze frame by the ECM for OBD misfire detection when the fuel tank level falls to below 15% of maximum capacity.

Malfunction indicator lamp

The malfunction indicator lamp (MIL) is located in the instrument pack to inform the driver that there is fault with an emission critical part of the engine management system. When the ignition is switched to position II, the MIL is illuminated until the engine starts to check bulb function.

If a fault occurs on an emission related component, the ECM provides a CAN message to the instrument pack, via the ABS ECU, to operate the MIL LED.

Tachometer drive

The tachometer drive is a CAN message output from the ECM to the instrument pack, via the ABS modulator.

Vehicle immobilisation

The vehicle immobilisation system operates by the EWS3D immobilisation ECU transmitting a unique code to the ECM when the ignition is switched on. If the code is recognised by the ECM it will energise the injectors and allow the engine to start.

If no code is received or the code is incorrect, the ECM will disable the vehicle by not energising the fuel injectors.

The immobilisation ECU also controls the starter relay and will passively disarm the starter relay when the key is removed from the ignition switch. Rearming is performed by the turning the ignition 'ON' which activates a coil around the ignition key barrel.

The coil transmits a waveform signal which excites the remote handset to transmit a re-mobilisation signal. When the signal is received by the anti-theft alarm ECU, the starter relay will be enabled.

Replacement ECM's are supplied blank and must learn the immobilisation ECU security code for the vehicle to which it is fitted. When the ECM is connected to the vehicle, TestBook is required to enable the ECM to learn the immobilisation ECU code. If a new immobilisation ECU is fitted, the ECM will need to learn the new security code using TestBook. A procedure must be followed when replacing the ECM or immobilisation ECU. This procedure is detailed in the Security Description and Operation section.

Rough road detection

MEMS 3 has a misfire detection facility which is part of the On-Board Diagnostics (OBD) system. Misfire detection is disabled when the ECM senses that the vehicle is on a 'rough road'. The system software receives rough road signal outputs from the ABS ECU and can disable misfire detection to prevent incorrect faults being logged by the ECM.

The 'rough road' signal is passed from the ABS ECU on the CAN to the ECM. The CAN message is a measure of the maximum wheel acceleration from any one of the four wheel sensors, which is updated by the ABS ECU every 20 ms and passed to the ECM on the CAN.

Fuel shut-off switch (Inertia switch)

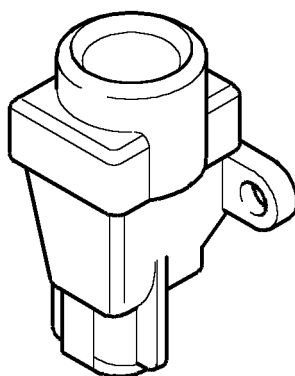


Figure 45

The fuel shut-off switch is located in the engine compartment on the bulkhead. In the event of a sudden deceleration the switch removes the power supply to the fuel pump relay, stopping the fuel pump.

The fuel shut-off switch, when tripped can be reset by depressing the rubber top of the switch. The switch receives a power supply from fuse 10 in the engine compartment fusebox. The supply is passed through the switch to the contacts of the fuel pump relay in the engine compartment fusebox. The supply from the switch is also passed to the Central Control Unit (CCU) to unlock the doors in the event of a collision causing the fuel shut-off switch to be tripped.

Throttle pedal switch (Throttle position sensor)

The throttle pedal switch is located at the top of the pedal box and secured in a cut-out hole in the fabrication. The switch is a proximity type Hall effect switch which senses a target located on the throttle pedal. The switch is connected on a single wire to the ECM.

The switch is normally open when the throttle pedal is at rest. When the throttle pedal is depressed, the target on the pedal moves away from the switch causing the switch to close and complete an earth path from the ECM. This is sensed by the ECM which uses the signal as a throttle status to detect for stuck throttle when using Hill Descent Control (HDC). The pedal status is compared with the inputs from the TP sensor to confirm that the throttle is being depressed.

Diagnostics

A diagnostic socket allows the exchange of information between the ECM and TestBook or a diagnostic tool using Keyword 2000 protocol.

The diagnostic socket is located in the driver's footwell behind the centre console.

A dedicated diagnostic (ISO 9141 K Line) bus is connected between the ECM and the diagnostic socket and allows the retrieval of diagnostic information and the programming of certain functions using TestBook.

The ECM uses a 'P' code diagnostic strategy and can record faults relating to the engine management system. P codes are accessed via the ECM when TestBook is connected.

On-Board diagnostics

The MEMS 3 ECM software is programmed to meet current emission standard ECD 3. This regulation is being introduced throughout Europe from the year 2000 and is similar to the OBD (phase II) regulations in place in North America.

On-Board diagnostics (OBD) is concerned with the monitoring of certain functions, the failure of which would result in an increase of exhaust emissions above legislated thresholds. The OBD is concentrated on the engine management system.

If a fault occurs the ECM will store an applicable 'P' code in its memory and the MIL will be illuminated. The failure codes can be accessed with TestBook. The faults stored by the ECM are normally qualified by one of the following failure types:

- Min - the minimum expected value has been exceeded
- Max - the maximum expected value has been exceeded
- Signal - the signal is not present
- Plaus - an implausible condition has been detected

The OBD operates in the background, monitoring the operations controlled by the ECM. The systems are monitored as the driver operates the vehicle, although the driver will be unaware that any monitoring is being performed. Individual system tests take place as the applicable circumstances occur.

KV6

General

KV6 Engine



M12 6812

Figure 46

The KV6 is of all aluminium construction, with a 90° V configuration. The KV6 uses long cylinder head bolts engaging in threads 70 mm below the mating face of the cylinder block to attach the cylinder head to the cylinder block. This ensures sufficient structural stiffness to take advantage of the compressive strength of aluminium alloy and minimise tensile loadings. There are 8 cylinder head bolts for each cylinder head, located below the camshafts.

The engine features 24 valves, sequential fuel injection, liquid cooling and is transverse mounted. It is controlled by a Siemens 2000 engine management system utilising a range of sensors to constantly monitor and optimise engine performance.

Cylinder block structure

Cylinder block components

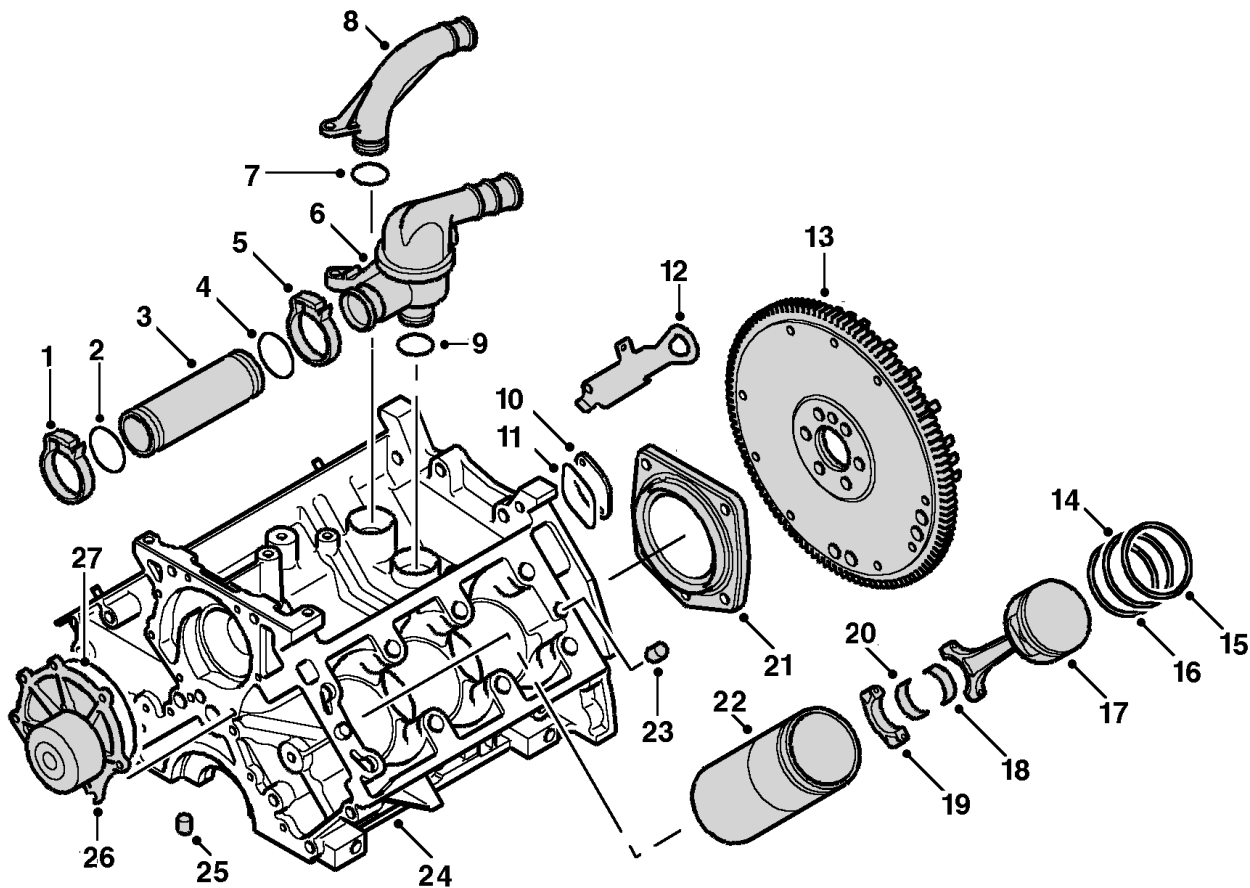


Figure 47

1. Clip (plastic) – coolant pump to thermostat pipe
2. 'O' ring – coolant pump to thermostat pipe
3. Pipe – coolant pump to thermostat
4. 'O' ring – coolant pump to thermostat pipe
5. Clip (plastic) – coolant pump to thermostat pipe
6. Thermostat housing
7. 'O' ring – coolant outlet elbow to cylinder block
8. Coolant outlet elbow
9. 'O' ring – thermostat housing to cylinder block
10. Blanking plate – coolant outlet
11. Seal – blanking plate
12. Engine lifting bracket – rear
13. Flywheel

14. 2nd compression ring
15. Top compression ring
16. Oil control ring
17. Piston
18. Big-end upper bearing shell
19. Big-end bearing cap
20. Big-end lower bearing shell
21. Crankshaft rear oil seal
22. Cylinder liners
23. Dowels – cylinder block to cylinder head
24. Cylinder block
25. Dowels – cylinder block to lower crankcase
26. Engine coolant pump
27. Seal – coolant pump to cylinder block

The cylinder block components are described below:

Cylinder block and main bearing ladder

The cylinder block is constructed of an aluminium alloy and is cast in three sections:

- Cylinder block
- Main bearing ladder
- Lower crankcase extension

For strength and rigidity, the bearing ladder is manufactured from special alloy A357TF as used in manufacturing components in the aero industry. The main bearing ladder is secured to the cylinder block with 16 bolts, thus creating a very rigid crankcase 'box'. A separate outer crankcase extension adds further strength to the lower end of the cylinder block. The lower crankcase extension is sealed to the underside of the cylinder block using Hylogrip 3000 sealant and bolted to the underside of the cylinder block with 10 bolts. Fitted to the lower crankcase is an aluminium alloy sump.

Pistons and cylinder liners

The aluminium alloy, thermal expansion, lightweight pistons, with semi-floating gudgeon pins, which are offset to the thrust side, are carried on forged steel connecting rods. Pistons and cylinder liners are supplied in two grades, 'A' and 'B' and are also colour coded to assist identification. The pistons are marked to ensure they are correctly oriented in the cylinder liner, the 'FRONT' mark should be toward the front of the engine.

The cylinder block is fitted with 'damp' cylinder liners, the bottom stepped half of the cylinder liner being a sliding fit into the lower part of the cylinder block. The liners are sealed in the block with a bead of sealant applied around the stepped portion of the cylinder liner. The top of the cylinder liner is sealed by a multi-layer steel cylinder head gasket when the cylinder head is fitted.

The cylinder liner diameters are smaller than the big-end forging of the connecting rods and need to be removed complete with pistons and connecting rods from the cylinder block.

Connecting rods

The KV6 engine utilises forged steel H-sectioned connecting rods, with the gudgeon pin being an interference fit in the small end of the connecting rod. The big-ends are horizontally split.

Big-end bearing diametric clearance is controlled by selective bearing shells with three grades of thickness. The big-end upper and lower bearing shells are plain with locating tags.

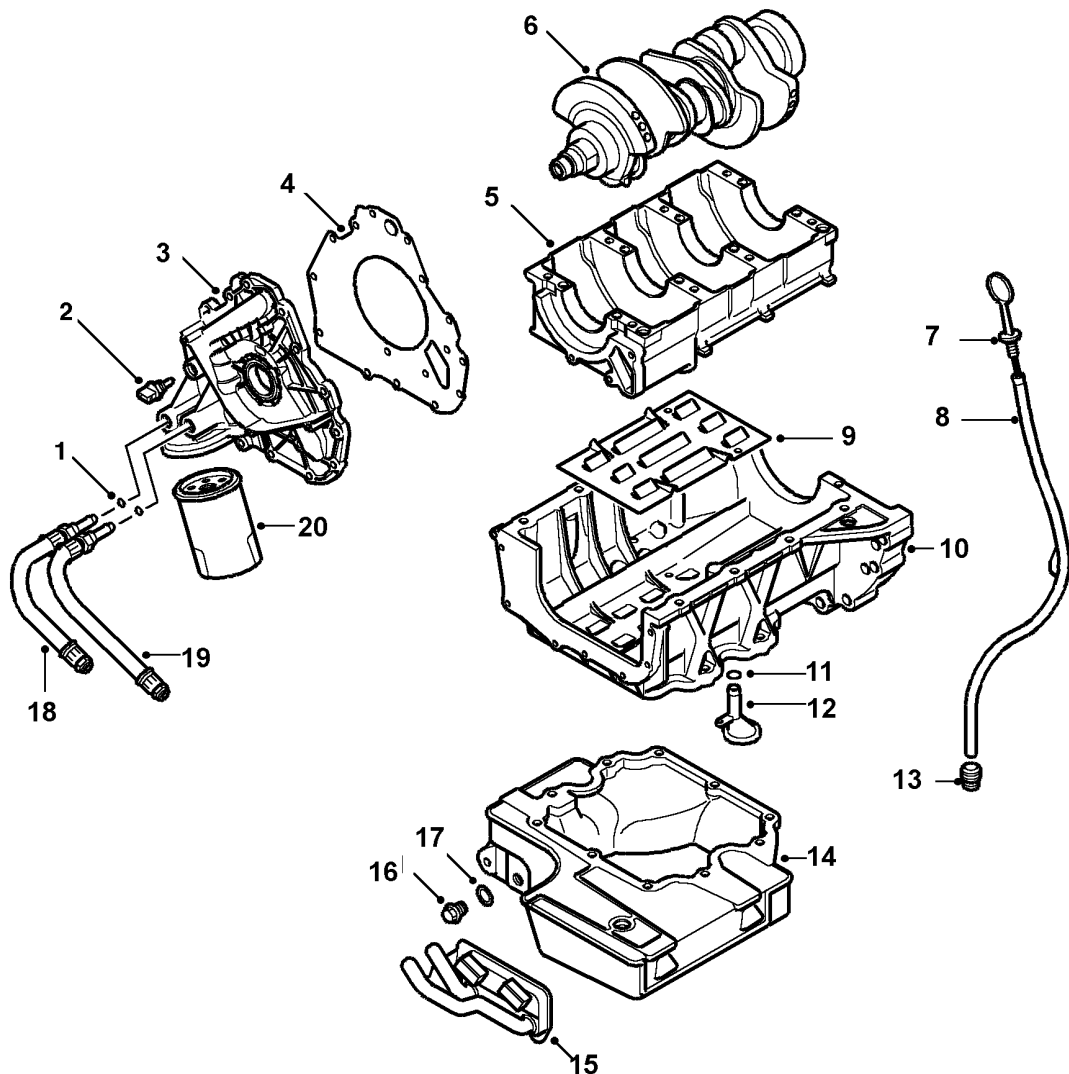
Piston rings

Each piston is fitted with two compression rings and an oil control ring.

The top compression rings are chrome-plated steel. The 2nd compression rings are chrome-plated cast iron. The oil control rings have stainless steel top and bottom rails and integral expander rings.

Crankshaft, sump and oil pump components

Crankshaft components



M12 6645

Figure 48

- 1.'O' rings – oil filter housing to oil cooler pipes
- 2.Oil pressure switch
- 3.Oil pump and oil filter housing assembly
- 4.Gasket – oil pump housing
- 5.Bearing ladder
- 6.Crankshaft
- 7.Dipstick
- 8.Dipstick tube
- 9.Baffle plate – lower crankcase extension
- 10.Lower crankcase extension
- 11.'O' ring – oil pick-up pipe
- 12.Oil pick-up pipe with integral strainer
- 13.Connector (quick fit) – dipstick tube to

- sump
- 14.Oil cooler
- 15.Sump
- 16.Seal – oil drain plug
- 17.Oil drain plug
- 18.Pipe – oil filter housing to oil cooler
- 19.Pipe – oil cooler to oil filter housing
- 20.Oil filter cartridge

The crankshaft and sump components are described below:

Crankshaft

The short, stiff crankshaft is supported on four main bearings, with each pair of crankpins mutually offset by 30° to give equal firing intervals. Cast in spheroidal graphite iron (SG), the crankshaft has cold rolled fillets on all journals, except the outer mains, for toughness and failure resistance. End-float is controlled by thrust washer halves at the top and bottom of the rear main bearing.

Main bearings

Oil grooves are provided in the upper halves of all the main bearing shells to supply oil, via drillings in the crankshaft, to the connecting rod big-end bearings. The lower halves of the bearing shells in the bearing ladder are plain.

Sump

The cast aluminium sump is a wet-type, sealed to the lower crankcase extension using sealant applied to the sump flange. The sump is fixed to the lower crankcase extension using 10 bolts.

Cast aluminium sump

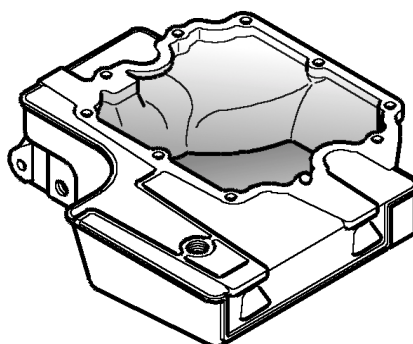


Figure 49

A baffle plate is fitted in the lower crankcase extension to minimise the effects of oil slosh.

Baffle plate

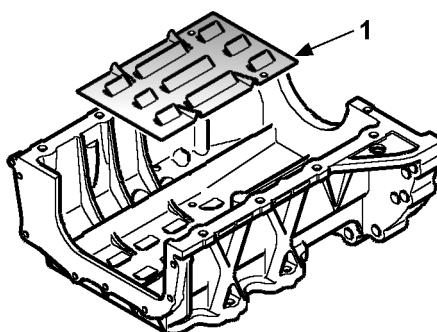


Figure 50

1. Baffle plate

An oil pick-up with integral strainer is located in the centre of the sump oil well, as a source for the supply of engine lubrication oil to the oil pump. Oil is sucked up through the end of the pick-up and strained to prevent solid matter from entering the oil pump.

Oil pump

The oil pump is directly driven from the crankshaft. The oil pump housing includes the oil pressure relief valve, oil filter, oil pressure switch and return/supply outlets for the engine oil cooler.

Oil filter

A full-flow, disposable canister-type oil filter is attached to a housing which is integral with the oil pump assembly at the front of the engine.

Oil cooler

A liquid cooled oil cooler keeps the engine lubrication oil cool, under heavy loads and high ambient temperatures.

The oil cooler is cooled by the engine cooling system and attached to a bracket secured to the front of the sump by three bolts. Oil is delivered to and from the oil cooler through hoses connected to the oil filter adaptor. Hoses from the engine cooling system are connected to two pipes on the oil cooler for the supply and return of coolant.

Liquid cooled oil cooler

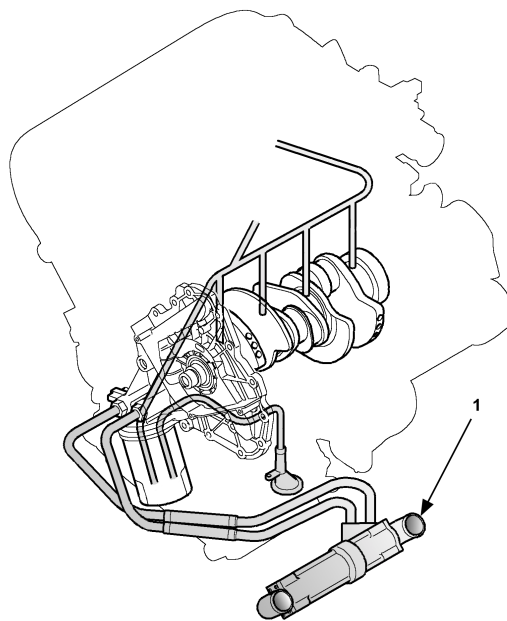


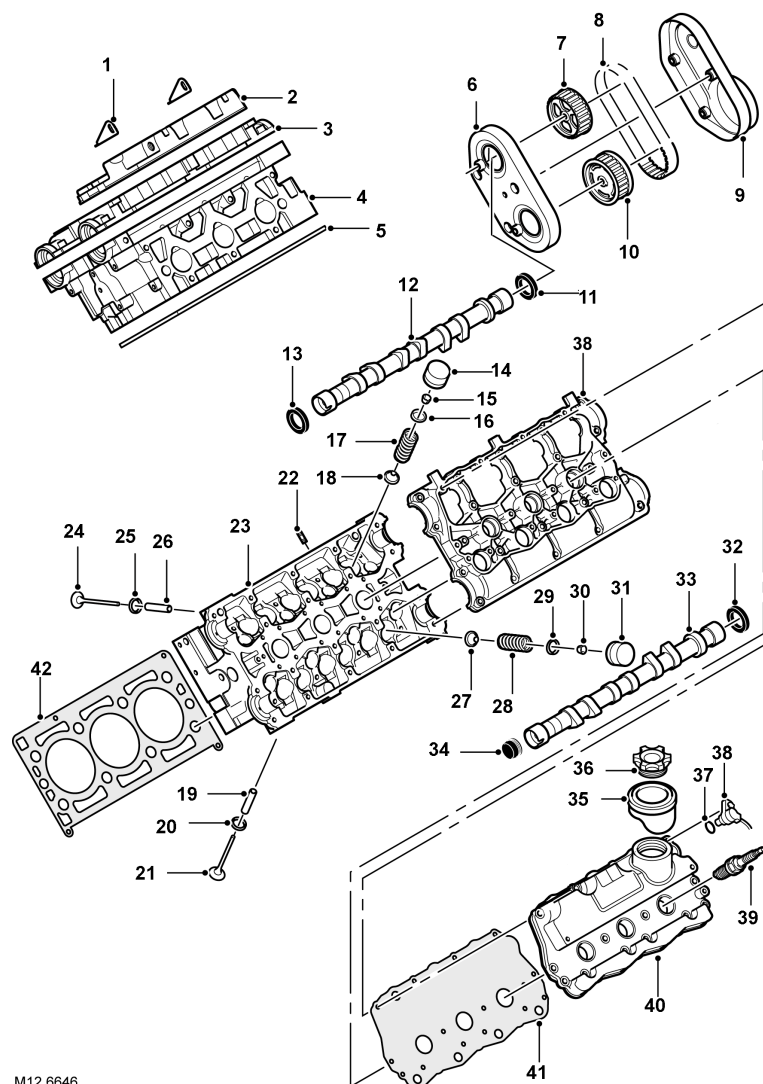
Figure 51

1.Oil cooler

Oil pressure switch

The oil pressure switch is located in a port at the outlet side of the oil filter. It detects when a safe operating pressure has been reached during engine starting and initiates the illumination of a warning light in the instrument pack if the oil pressure drops below a given value.

Cylinder head components



M12 6646

Figure 52

- | | |
|--|---|
| 1.Bracket – camshaft cover | 22.Studs – cylinder head to inlet manifold |
| 2.Camshaft cover (LH similar) | 23.Cylinder head |
| 3.Camshaft carrier | 24.Exhaust valve |
| 4.Cylinder head – RH | 25.Valve seat insert – exhaust |
| 5.Gasket – cylinder head to cylinder block | 26.Valve guide – exhaust |
| 6.Rear drive belt inner cover | 27.Valve stem oil seal – exhaust |
| 7.Camshaft gear | 28.Valve spring – exhaust |
| 8.Drive belt – rear camshaft | 29.Valve spring cap – exhaust |
| 9.Rear drive belt outer cover | 30.Collets – exhaust valves |
| 10.Camshaft gear | 31.Tappets – exhaust valve |
| 11.Seal – inlet camshaft, rear oil | 32.Seal – exhaust camshaft, rear oil |
| 12.Inlet camshaft | 33.Exhaust camshaft |
| 13.Seal – inlet camshaft, front | 34.Seal – exhaust camshaft, front |
| 14.Tappets – inlet valve | 35.Seal – filler cap |
| 15.Collets – inlet valves | 36.Filler cap |
| 16.Valve spring cap – inlet | 37.'O'ring – camshaft position sensor |
| 17.Valve spring – inlet | 38.Camshaft position sensor |
| 18.Valve stem oil seal – inlet | 39.Spark plug |
| 19.Valve guide – inlet | 40.Camshaft cover |
| 20.Valve seat insert – inlet | 41.Gasket – camshaft cover |
| 21.Inlet valve | 42.Gasket – cylinder head to cylinder block |

The cylinder head components are described below:

Cylinder head

The cross-flow cylinder heads are based on a four valve, central spark plug combustion chamber, with the inlet ports designed to induce swirl and control the speed of the induction charge. This serves to improve combustion and hence fuel economy, performance and exhaust emissions.

LH and RH cylinder heads are identical castings.

Camshafts

Twin camshafts on each cylinder bank are retained by a camshaft carrier, line bored with the cylinder head. The camshafts are located by a flange which also controls end-float. A crossover drive for the exhaust camshaft, from the rear of the inlet camshaft is by a short toothed belt, which allows for a much shorter and simpler run for the main camshaft drive belt at the front of the engine.

The exhaust camshaft drive gears have dampers integral with the gear to minimise torsional vibration. The inlet camshaft for the LH cylinder head incorporates a reluctor which is used in conjunction with the camshaft position sensor to measure engine position and cycle. The camshaft position sensor is bolted to the LH camshaft cover.

Cylinder head gasket

The KV6 utilises a multi-layer stainless steel cylinder head gasket. The gasket comprises four stainless steel functional layers, and a stainless steel distance layer to maintain fitted thickness. A full embossment profile is employed to seal the combustion gases and half embossments are used to provide a durable fluid seal. Sealing characteristics are further enhanced by the application of a fluoro-elastomer surface coating to all layers of the gasket.

Hydraulic tappets

Self-adjusting, lightweight, hydraulic tappets are fitted on top of each valve and are operated directly by the camshaft. The valve stem oil seals are moulded onto a metal base which also acts as the valve spring seat on the cylinder head.

Valves

The exhaust valves are of the carbon break type. A machined profile on the valve stem removes any build up of carbon in the combustion chamber end of the valve guide. All valve seats are machined in three planes, improving valve to seat sealing.

Exhaust valve

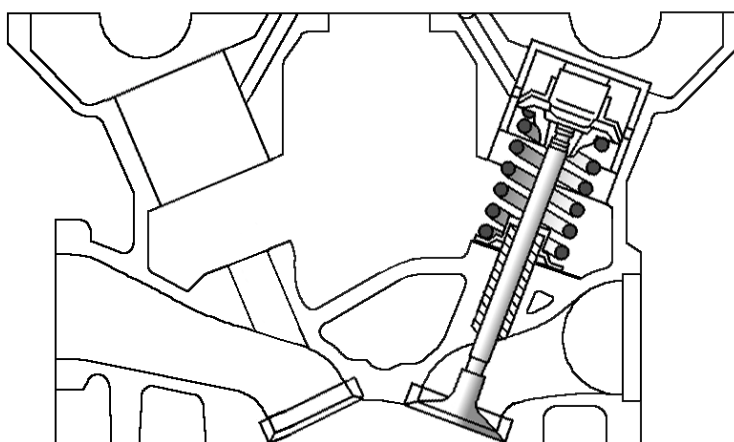
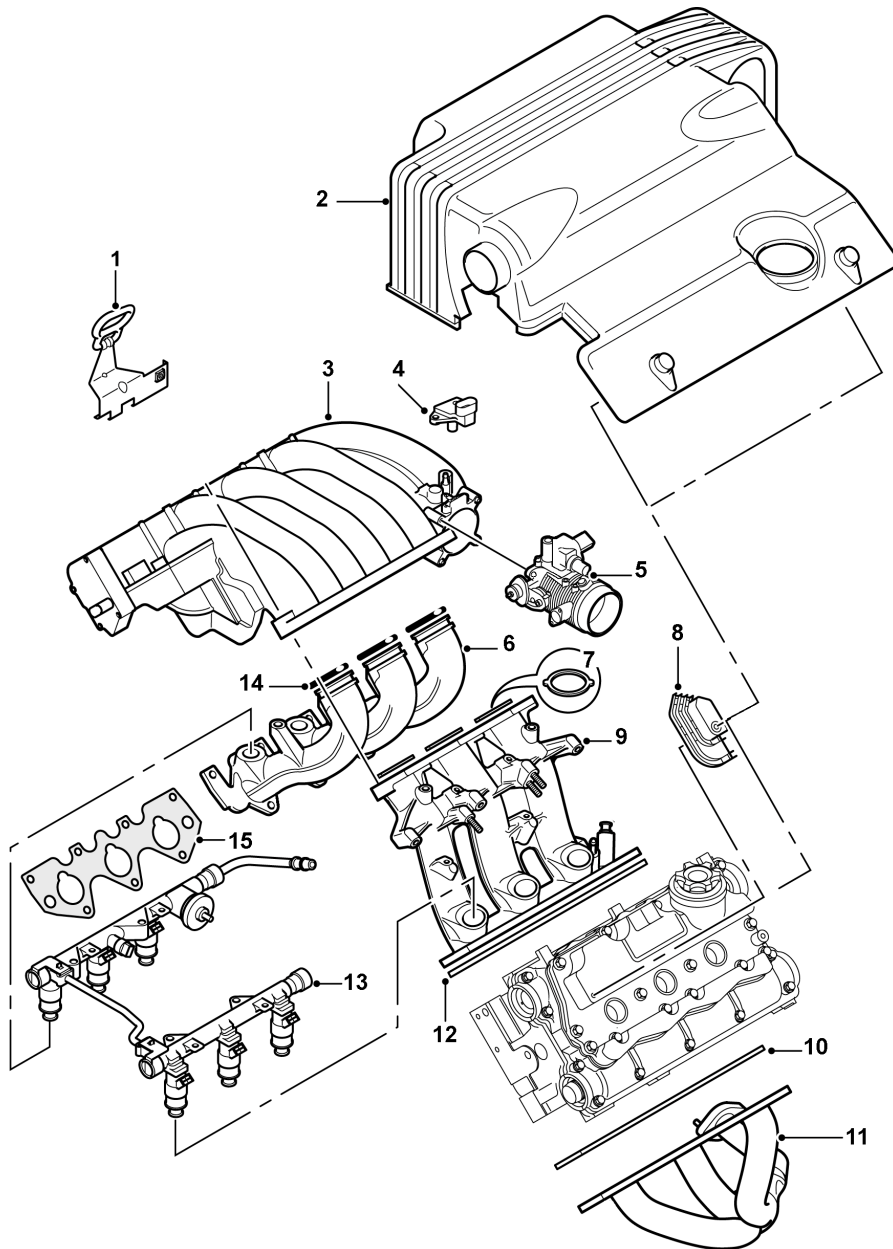


Figure 53

Camshaft cover and engine cover components

Camshaft cover components



M12 6647

Figure 54

1. Bracket
2. Engine acoustic cover
3. Manifold chamber
4. Temperature and manifold absolute pressure (TMAP) sensor
5. Throttle body assembly
6. Inlet manifold, RH
7. Seals - manifold chamber to LH inlet manifold
8. HT lead clamps
9. Inlet manifold, LH

10. Gasket - exhaust manifold to cylinder head (LH)
11. Exhaust manifold (LH)
12. Gasket - inlet manifold to cylinder head (LH)
13. Fuel rail
14. 'O' rings - inlet manifold (RH) to top cover
15. Gasket - inlet manifold to cylinder head, RH

The camshaft cover and engine cover components are described below:

Acoustic cover

A moulded plastic acoustic cover is fitted over the engine to absorb engine generated noise. Foam is bonded on the inside surface of the acoustic cover and a rubber seal is fitted around the oil filler cap.

Throttle body assembly

The throttle body comes in one of two variants, with and without cruise control. The correct one must be selected if the throttle body assembly is to be replaced in service.

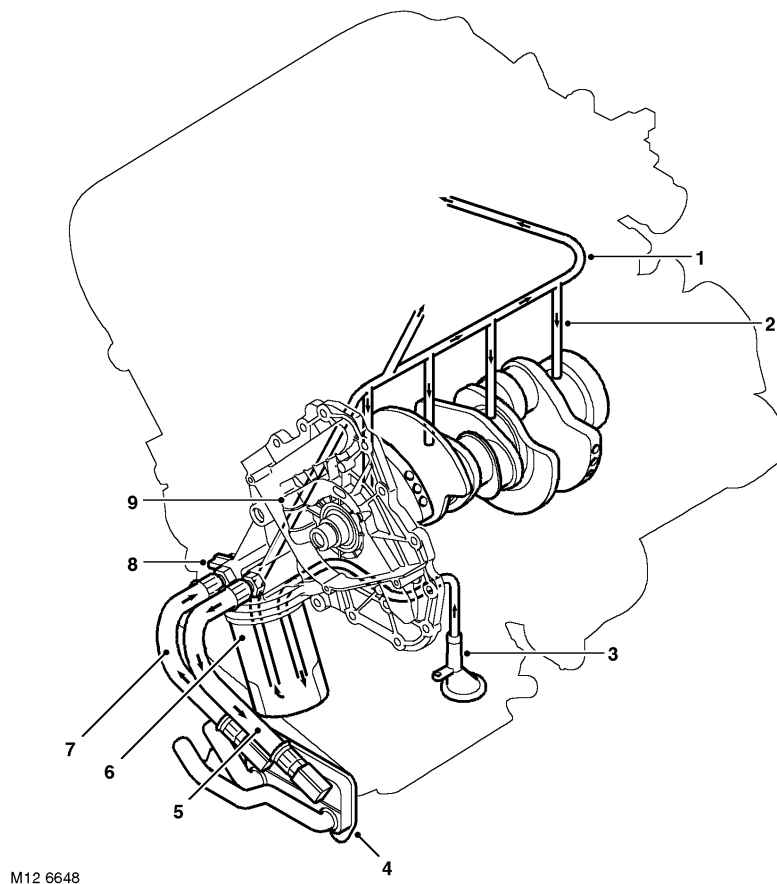
Inlet manifold chamber

The inlet manifold chamber is a sealed plastic assembly. The inlet manifold chamber combines plenum resonance for good low speed torque, with variable length primary tracts for optimum mid and high speed torque.

The throttle body assembly feeds into a 'Y' piece which separates into two secondary inlet pipes. The secondary pipes feed into two main plenums, one for each bank of three cylinders. At the closed end of the plenums is a balance valve, which is actuated by an electronic actuator that connects the two plenums together.

The variable intake system uses valves and actuators to vary the overall tract length of the inlet manifold chamber. The aluminium alloy inlet manifolds are sealed to each cylinder head with gaskets and to the inlet manifold chamber with 'O' rings and seals.

Lubrication circuit



M12 6648

Figure 55

- | | |
|--|---|
| 1. Cylinder block main oil gallery | 6. Oil filter cartridge |
| 2. Cross drillings to crankshaft main bearings | 7. Oil cooler return pipe |
| 3. Oil pick-up pipe with integral strainer | 8. Oil pressure switch |
| 4. Oil cooler | 9. Oil pump with integral oil pressure relief valve |
| 5. Oil cooler supply pipe | |

The lubrication system is of the full-flow filtration, force fed type.

Oil is drawn, via a strainer and pick-up pipe in the sump, through the bearing ladder and into a crankshaft driven oil pump which has an integral pressure relief valve. The strainer in the pick-up pipe prevents any ingress of foreign particles from passing through to the inlet side of the oil pump and damaging the oil pump and restricting oil drillings. The oil pressure relief valve in the oil pump opens if the oil pressure becomes excessive and diverts oil back around the pump.

Pressurised oil is pumped through a full-flow cartridge type oil filter, mounted on the oil pump housing. The lubrication system is designed so that a higher proportion of oil flow is directed to the cylinder block main oil gallery while a lower proportion of oil flow, (controlled by a restrictor in the oil filter housing), is directed to the engine oil cooler. The remainder of the oil flow from the outlet side of the oil filter is combined with the return flow from the oil cooler before being passed into the cylinder block main oil gallery.

The main oil gallery has drillings that direct the oil to the main bearings. Cross drillings in the crankshaft main bearings carry the oil to the connecting rod big-end bearings.

The oil pressure switch is located at the outlet side of the oil filter housing to sense the oil pressure level before the oil flow enters the main gallery in the engine block. A warning lamp in the instrument pack is illuminated if low oil pressure is detected.

Cylinder head component oil supply

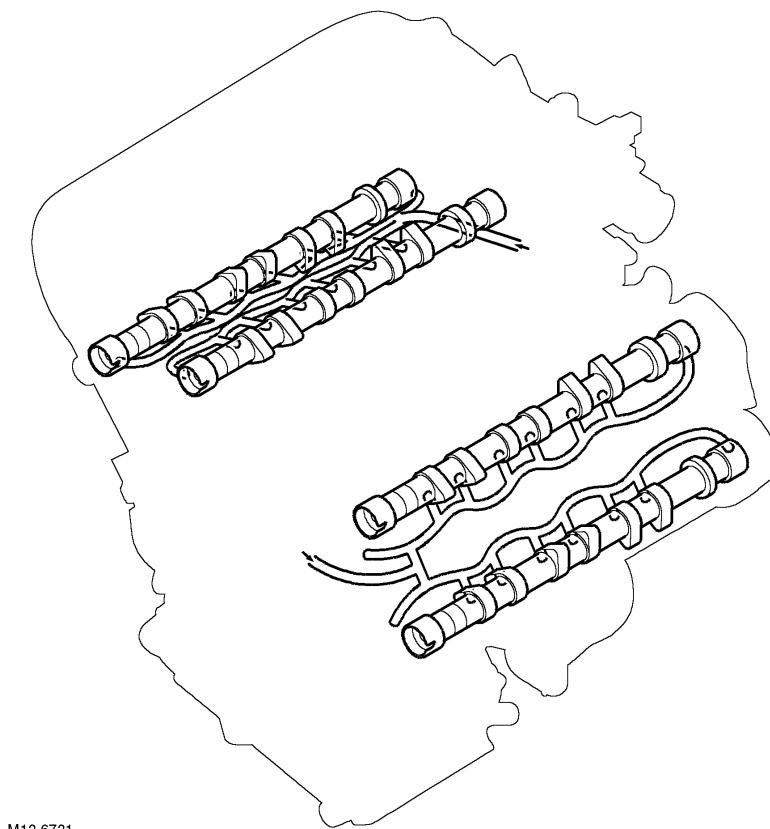


Figure 56

Oil at reduced pressure is directed to each cylinder bank via two restrictors in the cylinder block/cylinder head locating dowels, one at the front on the LH bank and the other at the rear on the RH bank. Oil then passes through a drilling in the cylinder head to the camshaft carrier, where it is then directed via separate galleries to the camshaft bearings and hydraulic tappet housings. Exhausted oil from the cylinder head returns to the sump via the cylinder head bolt passages.

Crankcase ventilation

A positive crankcase ventilation system is used to vent blow-by gas from the crankcase to the air intake system. The blow-by gas passes through a gauze oil separator in the camshaft cover, and then through hoses into the throttle housing and inlet manifold.

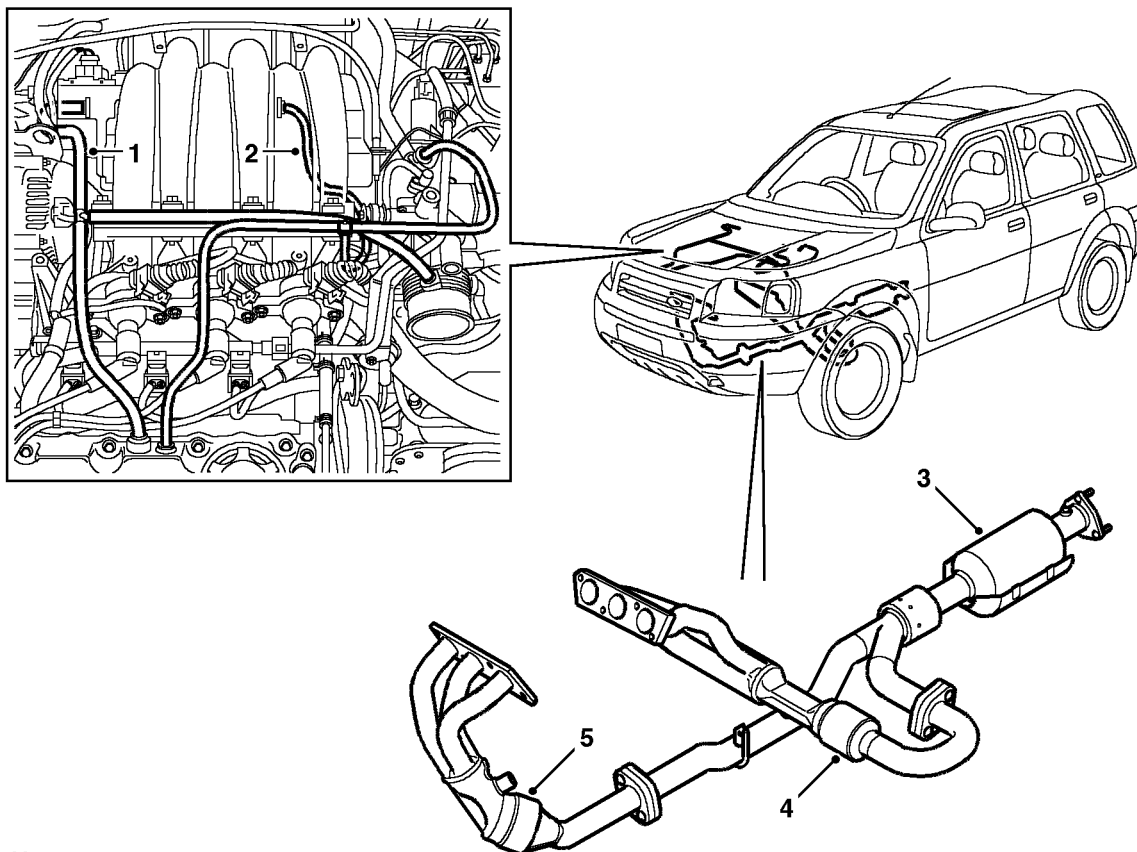
Emission control

The vehicle is fitted with the following control systems to reduce emissions released into the atmosphere:

- Crankcase emission control
- Evaporative emissions (EVAP) control
- Exhaust emission control

The emission control systems fitted to the vehicle are designed to keep the emissions within the legal limits, at the time of manufacture, provided that the engine is correctly maintained and is in good mechanical condition.

Crankcase emission control system



M17 0271

Figure 57

1.Crankcase breather hose to throttle body
2.Crankcase breather hose to inlet manifold

3.Main (downstream) catalytic converter
4.Starter (upstream) catalytic converter
5.Starter (upstream) catalytic converter

The crankcase is vented via the oil drain passages in the cylinder blocks and cylinder heads and two ports in each camshaft cover. The larger ports in the camshaft covers are connected to the throttle body, on the upstream side of the throttle disc, by plastic pipes. The smaller ports in the camshaft covers are connected to the air intake duct downstream of the throttle body, also by plastic pipes. Each of the smaller ports incorporate a restrictor and a gauze oil separator to prevent oil being drawn out of the camshaft covers with the blow-by gases. Quick release locking collars and 'O' rings are used for all of the pipe connections with the camshaft covers, throttle body and air intake duct.

When the engine is running with the throttle disc closed, the depression downstream of the throttle disc draws crankcase gases into the inlet manifold through the smaller ports in the camshaft covers. Clean air, from the upstream side of the throttle disc, is drawn into the crankcase through the larger ports in the camshaft covers to limit the depression produced in the crankcase.

When the engine is running with the throttle disc wide open, the upstream and downstream sides of the throttle disc, and thus the two ports in each camshaft cover, are subjected to similar, relatively weak, depression levels. Crankcase gases are then drawn out of both ports in each camshaft cover, with the majority being drawn out of the unrestricted larger ports and into the throttle body.

At interim throttle disc positions the flow of the crankcase gases varies, between those produced at the closed and wide open throttle disc positions, depending on the depression levels produced upstream and downstream of the throttle disc.

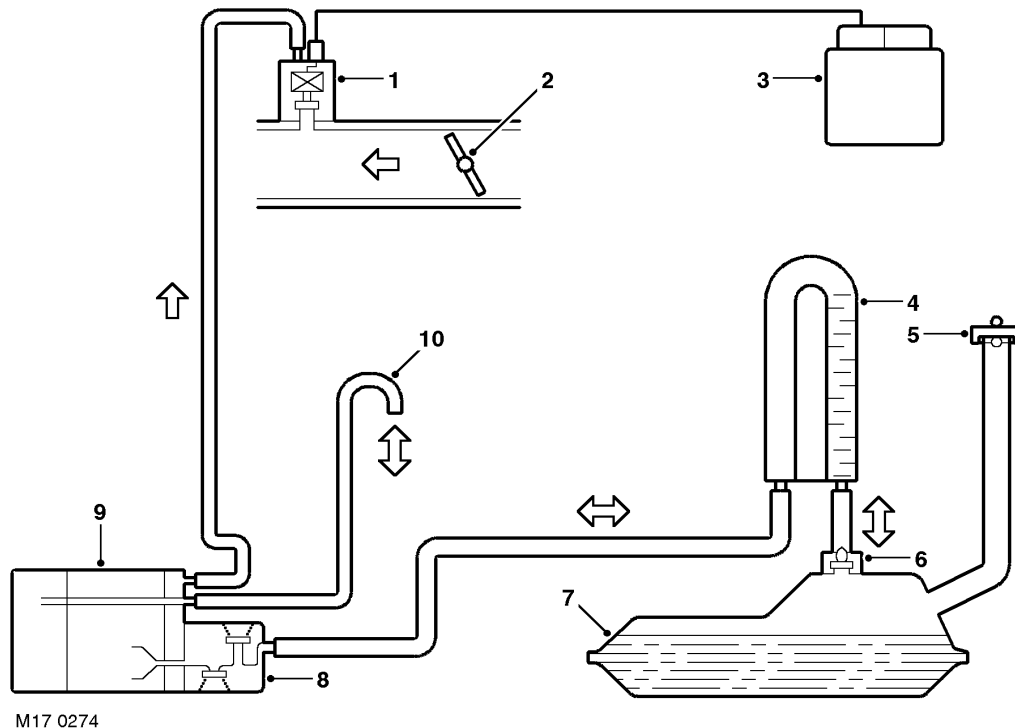
Evaporative emissions control

Figure 58

1. Purge valve
2. Throttle disc
3. ECM
4. Vapour separator
5. Fuel cap filler
6. Fuel cut-off valve
7. Fuel tank
8. Two-way valve
9. Evaporative emission canister
10. Vent line to atmosphere

The EVAP control system reduces the level of hydrocarbons released into the atmosphere by fuel vapour venting from the fuel tank. The system comprises a two way valve, vent lines, an EVAP canister and a purge valve.

Fuel vapour, generated in the tank as the fuel heats up, is stored in the tank until the pressure is sufficient to open the outward venting side of the two-way valve. When the two-way valve opens, excess vapour is released through a fuel cut-off valve and a vapour separator and into the vent line to the EVAP canister. The vapour separator prevents condensing fuel from entering the vent line. In the EVAP canister, charcoal absorbs and stores fuel from the vapour and relatively fuel free air is vented to atmosphere. When the fuel tank cools and vapour pressure in the tank decreases sufficient to open the inward venting side of the two-way valve, outside air is drawn through the EVAP canister and vent line into the tank.

The charcoal in the EVAP canister has a finite capacity and is therefore purged of fuel when the engine is running. Opening the purge valve draws fuel stored in the EVAP canister into the inlet manifold, where it is burned during the combustion process. The purge valve is installed on the inlet manifold chamber, next to the throttle body, and connected to the EVAP canister by a vent line.

Operation of the purge valve is controlled by the ECM. When the engine is above preset temperature and speed values, the ECM opens the purge valve and outside air is drawn through the charcoal in the EVAP canister and into the inlet manifold, purging the charcoal of fuel.

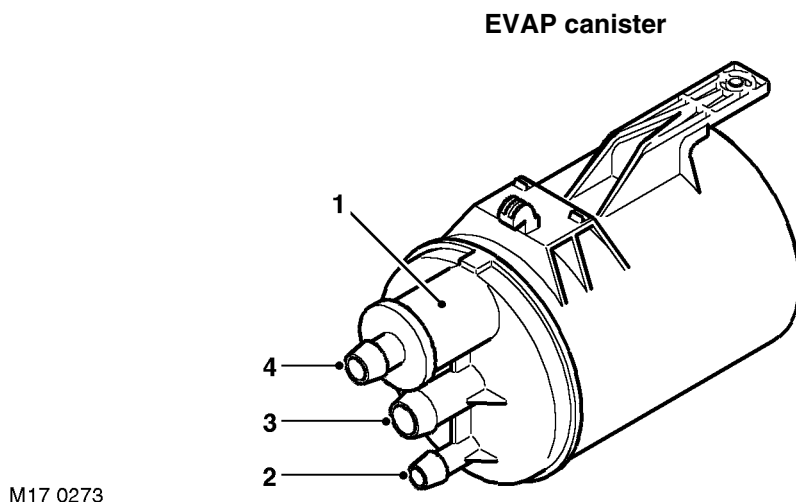


Figure 59

- 1. Two way valve
- 2. Outlet connection to purge valve
- 3. Atmospheric vent connection
- 4. Inlet connection from vapour separator

The EVAP canister contains charcoal which absorbs and stores fuel from the vapour vented from the fuel tank while the engine is not running. When the EVAP canister is not being purged, the fuel remains in the charcoal and clean air exits the canister via the atmospheric vent.

When the engine is running, when conditions are correct for fuel to be purged from the EVAP canister the ECM opens the purge valve. This opens a manifold vacuum line to the EVAP canister. Outside air from the atmospheric vent is then drawn through the charcoal, where it absorbs fuel, and the resultant vapour is burned in the engine.

Purge valve

The operation of the purge valve is controlled by the ECM. The purge valve is installed on the inlet manifold chamber, next to the throttle body, and connected to the EVAP canister by a vent line. The purge valve remains closed below preset coolant and engine speed values to protect engine tune and catalytic converter performance. If the EVAP canister is purged during cold running or at idle, the additional enrichment of the fuel mixture delays the catalytic converter light off time and causes erratic idle speed. When the purge valve is opened, fuel vapour from the charcoal canister is drawn into the throttle housing for combustion.

Two-way valve

The two-way valve in the vent line allows tank pressure to build to 0.018 to 0.050 bar (0.26 to 0.73 lbf/in²). Above this pressure, vapour is allowed to pass along the vent line to the EVAP canister. Vapour is allowed to flow back into the fuel tank, as the pressure in the tank decreases, through a non return valve within the body of the two-way valve.

Exhaust emission control

The engine management systems provide accurately metered quantities of fuel to the combustion chambers to ensure the most efficient use of fuel and to minimise the exhaust emissions. To reduce the carbon monoxide, Oxides of Nitrogen (NOx) and hydrocarbons content of the exhaust gases, catalytic converters are installed in the exhaust systems.

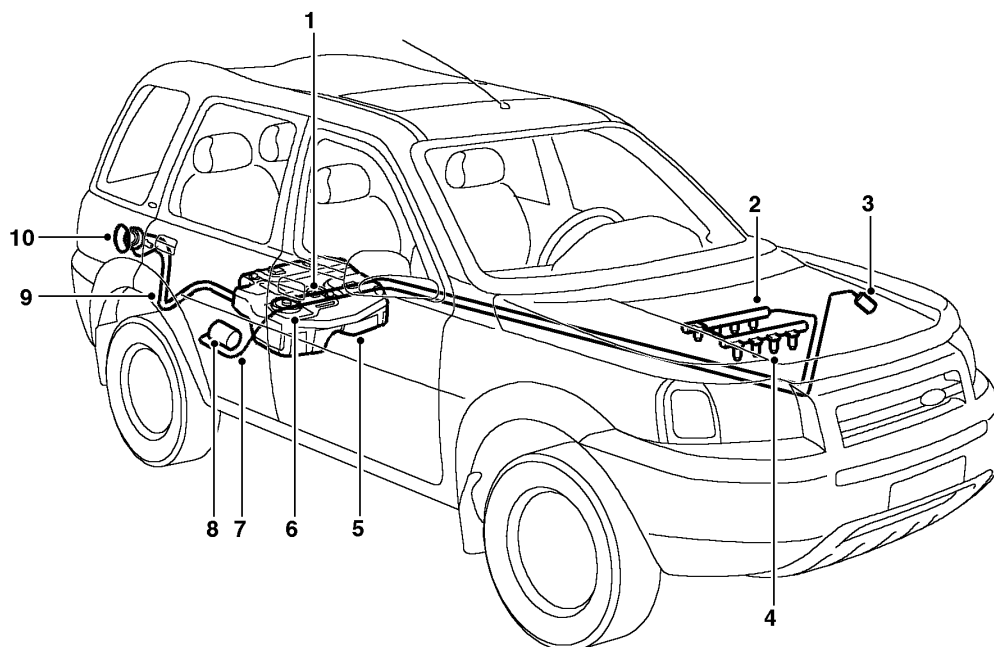
In the catalytic converter the exhaust gases are passed through honeycombed ceramic elements coated with a special surface treatment called 'washcoat'. The washcoat increases the surface area of the ceramic elements by a factor of approximately 7000. On top of the washcoat is a coating containing the elements which are the active constituents for converting harmful emissions into inert by-products. Depending on the installation, the active constituents consist of palladium, rhodium and/or platinum. Platinum and palladium add oxygen to the carbon monoxide and the hydrocarbons in the exhaust gases, to convert them into carbon dioxide and water respectively. The rhodium removes oxygen from the NOx to convert them into nitrogen.

The active constituents of the catalytic converters are platinum, rhodium and palladium. The correct operation of the catalytic converters is dependent upon close control of the oxygen content of the exhaust gas. The quantity of oxygen in the exhaust gas is monitored by the Engine Control Module (ECM) using an input from the Heated Oxygen Sensor (HO2S) upstream of the catalytic converters. The ECM also monitors the condition of the catalytic converters using an input from the HO2S downstream of the catalytic converters.

Fuel delivery system

The fuel delivery system consists of a fuel tank containing an electric fuel pump to supply fuel at a constant pressure to the engine fuel rail. A pipe, routed along the underside of the vehicle, connects the fuel pump to the fuel rail.

Fuel delivery system component layout



M19 3256

Figure 60

- 1. Fuel pipe
- 2. Fuel rail
- 3. Fuel pump relay
- 4. Injector
- 5. Fuel tank
- 6. Fuel pump
- 7. Vent line
- 8. Evaporative emissions canister
- 9. Filler tube
- 10. Filler cap

Fuel tank

The fuel tank is located on the underside of the vehicle, forward of the rear suspension subframe. The tank is constructed from moulded plastic and is retained by a tubular cradle which is secured to the vehicle floorpan with four bolts. A heat shield is installed on the left-hand side of the support cradle to protect the tank from heat radiated by the exhaust system. A fire shield is installed on the right-hand side of the support cradle.

The fuel tank has a capacity of 60 litres (15.85 US gallons). An aperture in the top surface of the tank allows for the fitment of the fuel pump.

The fuel tank filler is located on the right hand rear wing panel and is closed by a lockable filler cap. The plastic filler tube is connected to the tank by clamps and a rubber hose. A breather pipe is connected to the neck of the filler tube to allow air to escape from the tank during filling. The location of the breather tube connection on the fuel tank ensures an air space remains in the tank after filling, to allow for heat expansion of the fuel. A vent pipe, connected to three cut-off valves in the tank, ventilates the tank to atmosphere via the Evaporative emissions (EVAP) canister.

The cut-off valves are float valves that prevent fuel from entering the vent pipe due to fuel slosh or if the vehicle overturns.

Fuel tank and fuel pump

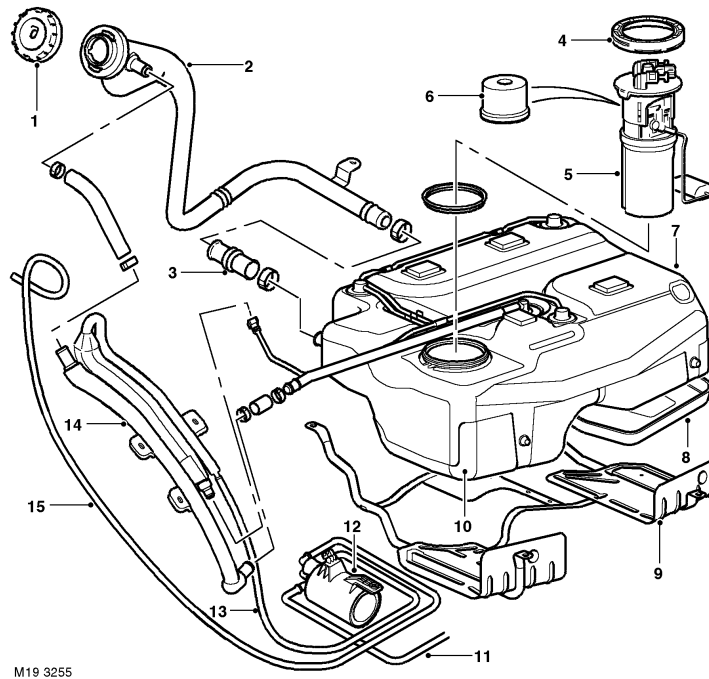


Figure 61

1. Filler cap
2. Filler tube
3. Flexible tube
4. Locking ring
5. Fuel pump and fuel gauge potentiometer
6. Fuel filter
7. Fuel tank
8. Fire shield
9. Cradle
10. Heat shield
11. Vent to EVAP purge valve
12. EVAP Canister
13. Tank vent pipe to EVAP canister
14. Vent pipe
15. EVAP canister atmospheric vent

Fuel pump

The fuel pump is electrically operated and is located in the top face of the fuel tank. A notched locking ring retains the fuel pump in the tank and requires a special tool for removal and installation. An access panel below the rear passenger seats provides access to the fuel pump for maintenance. The top face of the fuel pump has an electrical connector with power and ground connections to the pump and the fuel gauge rotary potentiometer. A quick fit coupling provides attachment for the fuel feed pipe. A non return valve in the pump outlet prevents fuel draining from the feed pipe back into the tank when the pump is stopped.

The fuel pump is housed in a plastic body which incorporates a coarse mesh filter and a serviceable fine mesh filter. The bottom part of the body forms a swirl pot which maintains a constant fuel level at the pump pick-up. A pressure regulator in the pump body ensures that the fuel rail and the injectors are supplied with fuel at a constant pressure of 3.5 bar (51 lbf.in²). The regulator relieves excess fuel from the pump outlet back to the swirl pot.

The fuel pump is controlled by the Engine Control Module (ECM), which switches the fuel pump relay in the engine compartment fuse box to control the power feed to the pump. The fuel pump outputs more fuel than the maximum load requirement of the engine, in order to maintain a constant pressure in the fuel rail under all running conditions.

The electrical circuit for the fuel pump incorporates an inertia switch attached to the LH front suspension turret. In a collision above a preset deceleration speed, the inertia switch breaks the circuit to the fuel pump to stop the delivery of fuel to the engine. The switch is reset by pressing the rubber top.

Fuel rail

Three fuel injectors are installed in each inlet manifold and connected to the fuel rail. The injectors are sealed in the fuel rail and the inlet manifolds by 'O' ring seals. A quick release coupling connects the feed pipe from the fuel tank to the end of the fuel rail on the LH inlet manifold.

An accumulator is attached to the fuel rail, on the RH inlet manifold, to damp out pressure pulses from the pump and ensure that the pressure in the fuel rail is constant (the same component functions as the pressure regulator on vehicles with a return fuel delivery system). The accumulator is connected by a pipe to the inlet manifold from which it receives a vacuum to aid the damping process. A schraeder valve is installed in the 'fuel return' pipe of the accumulator to allow pressure to be released from the fuel rail and fuel feed pipe prior to maintenance.

Cooling system

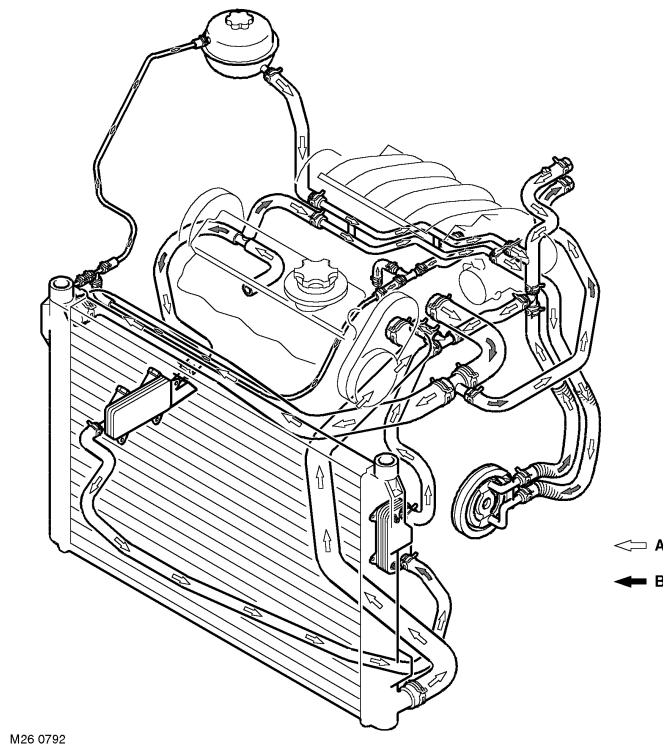


Figure 62

- a. Cold
- b. Hot

The engine cooling system maintains the engine within the optimum operating temperature range under varying ambient temperature and engine load conditions. In addition, the system cools the engine oil, the Intermediate Reduction Drive (IRD) and the transmission fluid, and provides the heat source for passenger compartment heating. The system consists of:

- A coolant pump
- A radiator
- A thermostat
- An expansion tank
- Interconnecting hoses and coolant rail
- Two cooling fans

Engine oil and transmission fluid are cooled by plate type heat exchangers. The engine oil cooler is attached to the sump at the front of the engine. The transmission oil cooler is attached to the front of the gearbox. The IRD is cooled by an internal plate type heat exchanger incorporated into the IRD lubrication circuit.

Coolant pump

The rotor type coolant pump is integrated into the front of the engine, between the cylinder blocks. The pump is driven by the camshaft timing belt via a plain pulley installed on the pump rotor shaft. The pulley also acts as an idler pulley for the camshaft timing belt.

Expansion tank

The expansion tank is installed in the rear RH corner of the engine compartment. The expansion tank provides a reservoir of coolant and accommodates the increase in coolant volume produced by heat expansion. A cap on the expansion tank provides a system filling point and incorporates a pressure relief valve that releases pressure from the system if it exceeds 1 bar (14.5 lbf/in²). Expansion pipes connect the expansion tank to the radiator and the inlet manifolds. A hose connects an outlet on the expansion tank to the coolant rail.

Hoses and coolant rail

The coolers and the heater matrix are connected together, by hoses and the coolant rail, in a circuit from outlets at the right front corner of the cylinder block and the top hose, to the return hose connection on the thermostat housing. A bleed screw in the heater outlet hose enables air to be bled from the system during filling.

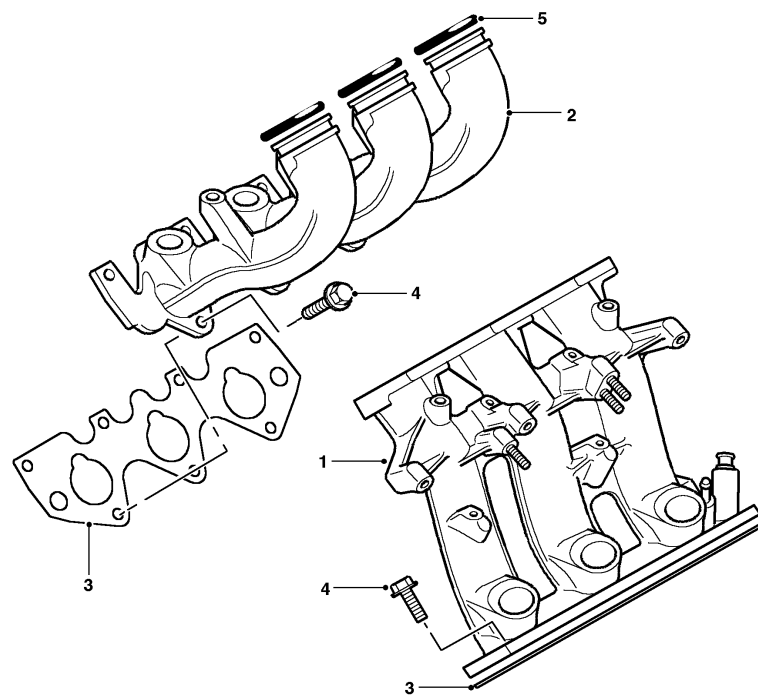
Cooling fans

The cooling fans are variable speed electric fans installed in a housing attached to the rear of the radiator. The motor of each cooling fan is connected to a cooling fan ECU installed behind a cover in the top left corner of the cooling fan housing. An air scoop on the cooling fan housing directs cooling air over the ECU.

Manifolds and exhaust systems

The following section is divided into four groups:

1. Inlet manifolds
2. Inlet manifold chamber
3. Exhaust manifolds
4. Exhaust system

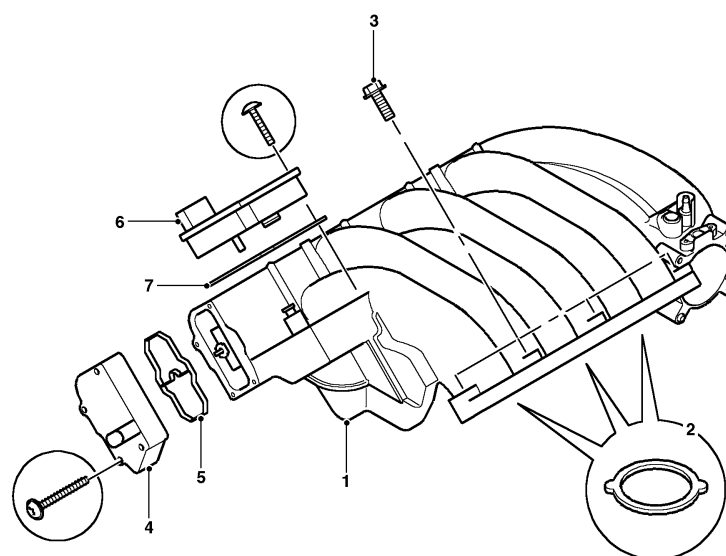
Inlet manifolds*Figure 63*

- 1. Inlet manifold LH
- 2. Inlet manifold RH
- 3. Gaskets
- 4. Flanged bolt (14 off)
- 5. 'O' ring (3 off)

The inlet manifold on the KV6 engine is located on the top of the engine, between the cylinder banks. The manifolds direct intake air into the cylinders where it is mixed with fuel delivered by the injectors prior to ignition in the cylinders. The inlet manifold comprises left and right hand cast aluminium inlet manifolds and a plastic moulded inlet manifold chamber.

Two handed aluminium inlet manifolds are secured to the cylinder heads using fourteen bolts and sealed with one piece composite gaskets. Three injectors, which are sealed with 'O' rings, are located in each manifold and are retained in position by the fuel rail. The fuel rails are secured to each manifold using two bolts. A coolant outlet is located in the left hand end of each manifold and a vacuum take-off point is located on the left hand manifold. Three 'O' rings and three moulded seals provide the seal between the inlet manifolds and the inlet manifold chamber.

Inlet Manifold Chamber



M30 1017

Figure 64

- | | |
|--|------------------------------|
| 1. Inlet Manifold Chamber | System (VIS) |
| 2. Seal (3 off) | 5. Seal |
| 3. Flanged bolt (4 off) | 6. Power valve motor – (VIS) |
| 4. Balance valve motor – Variable Intake | 7. Seal |

The inlet manifold chamber is a one piece plastic moulding which is fitted on the inlet manifolds and secured with four bolts. Three 'O' rings and three moulded seals locate in recesses and seal between the inlet manifold chamber and the inlet manifolds.

The inlet manifold chamber features a single throttle body which feeds into a 'Y' piece, which separates into two secondary pipes. The secondary pipes connect to two main plenums, one for each bank of cylinders. At the closed end of the plenums is a balance valve which is operated by an electric motor. This valve enables the two plenums to be connected together.

From the two plenums, the primary tract length to the cylinder head face is approximately 500 mm. Each of these tracts has a side junction with a power valve leading to a short inlet tract plenum, approximately 350 mm from the cylinder head. Each power valve is connected to a link rod which is operated by a single electric motor.

Variable intake system

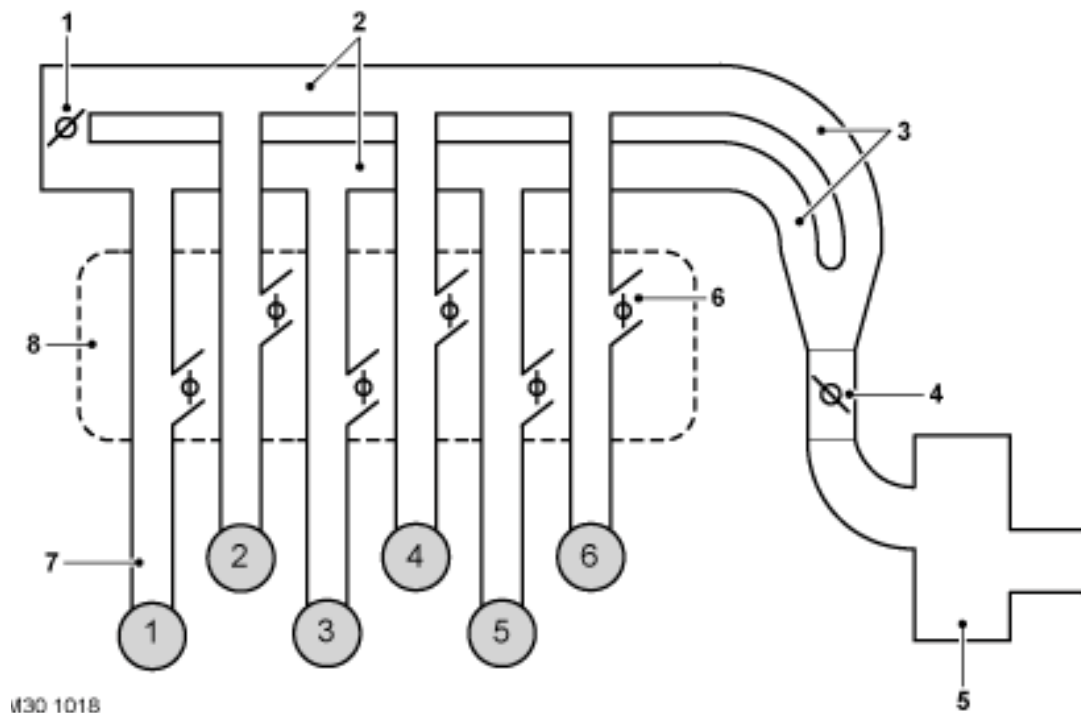


Figure 65

1. Balance valve
2. Main plenums
3. Secondary tracts
4. Throttle housing
5. Air cleaner
6. Power valves (6 off)
7. Primary tracts
8. Short tract plenum

The VIS operates in three conditions:

- Low speed
- Mid-range
- High speed

Low speed

At low speed the balance valve and power valves are closed. This effectively allows the engine to breathe as two, three cylinder engines, each having a separate plenum and long primary tracts. The primary and secondary tracts and the plenum volume are tuned to resonate at 2700 rev/min, giving peak torque at this speed.

Mid-range

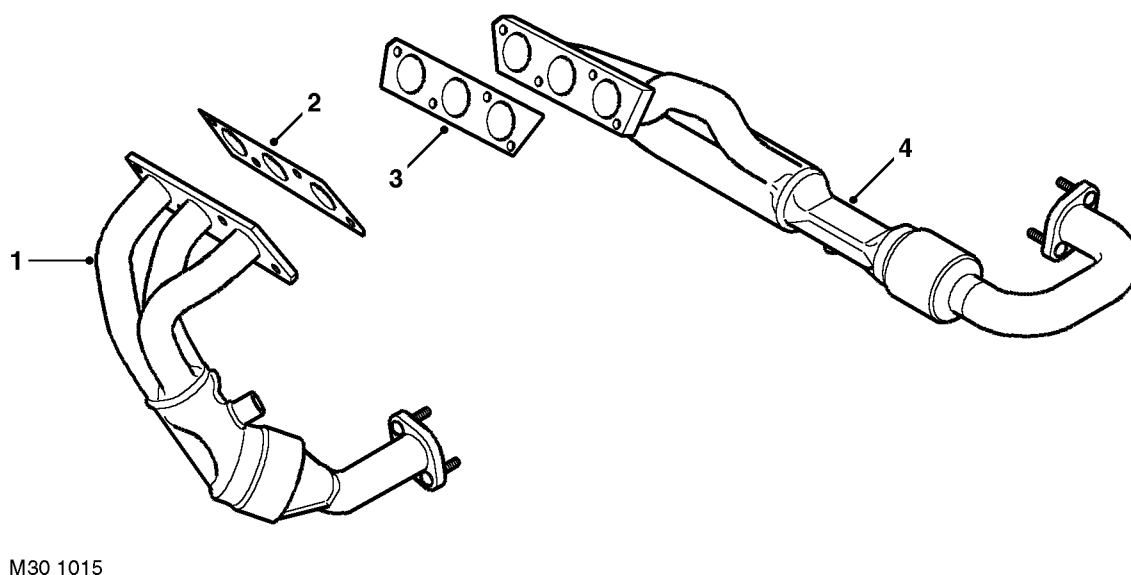
For increased mid-range torque performance, the plenums are connected using the balance valve. The power valves remain closed. This allows the engine to use the long primary tract length, which is tuned with the balance valve to produce maximum torque at 3750 rev/min.

High speed

At high engine speeds the balance valve remains open and the six power valves are opened. This allows the engine to breathe from the short tract plenum via the short primary tract lengths. These lengths and diameters are tuned to produce a spread of torque from 4000 rev/min upwards, with maximum power produced at 6250 rev/min.

The manifold also gives an improvement in part load fuel consumption. At part load, throughout the emissions cycle the manifold operates as at high speed. The pressure dynamics significantly reduce the pump losses below 4000 rev/min resulting in improved fuel consumption.

Exhaust manifolds



M30 1015

Figure 66

- 1.Exhaust manifold LH
- 2.Gasket LH
- 3.Gasket RH
- 4.Exhaust manifold RH

Two handed, steel fabricated exhaust manifolds are fitted. Each manifold has three branches which merge into one flanged outlet. Each manifold is sealed to the cylinder head with a composite gasket. Four studs in each cylinder head locate each manifold which is secured with nuts.

A starter catalyst is fitted to each manifold at the point where the three branches merge. Each manifold also has a HO₂S located upstream of the pre-catalyst.

Exhaust system

The exhaust system comprises three major parts; a front pipe assembly incorporating a catalytic converter, an intermediate pipe assembly and a tail silencer.

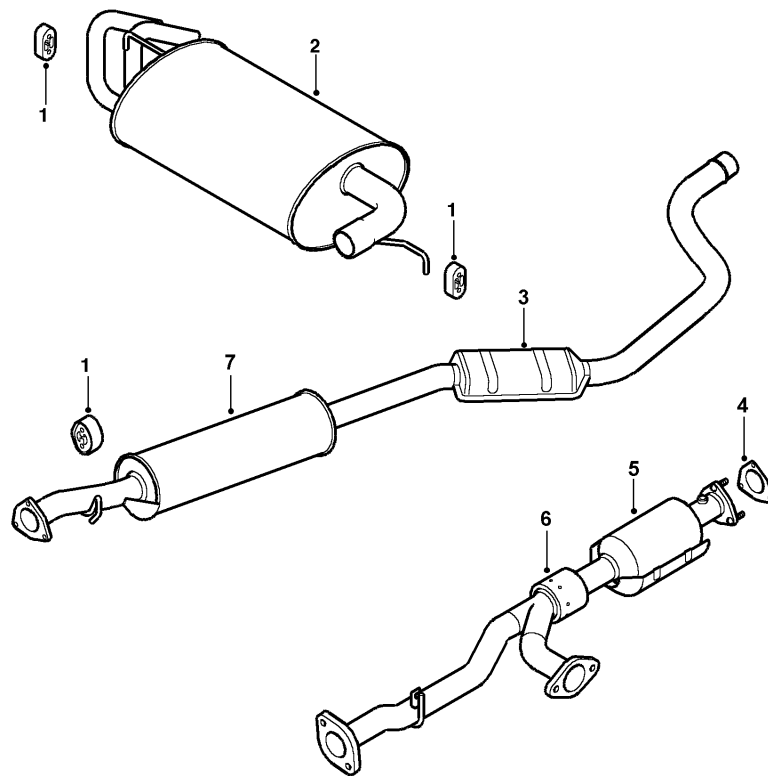


Figure 67

- 1. Mounting rubbers
- 2. Silencer
- 3. Intermediate silencer
- 4. Gasket
- 5. Catalytic converter
- 6. Joint
- 7. Front silencer

Front pipe assembly

The front pipe is connected to the flanged connections of the left and right hand exhaust manifolds. The front pipe locates on two studs on each manifold and is secured with nuts. A bracket near the front flange is secured to a gearbox attachment bolt. The two manifold pipes merge into an integral flexible pipe which in turn connects with the catalytic converter. The flexible pipe is formed into a concertina shape which is protected by a metal shroud. The flexible pipe allows for ease of exhaust system alignment and also absorbs engine vibrations.

A further pipe section from the catalytic converter is terminated by a flanged connection with captive studs. This pipe section also has a threaded port which provides for the location of the post catalyst HO₂S. Refer to the Emissions section for details of catalyst and HO₂S operation.

Intermediate pipe assembly

The intermediate pipe has a flange at its forward end which locates on the three studs on the front pipe and is secured with nuts. The joint between the two flanges is sealed with a metal gasket.

A circular silencer is located midway along the system and is braced to the pipe at each end to resist bending. A short section of pipe from the silencer connects to another smaller rectangular section silencer. A further pipe section from this silencer has a series of bends to allow clearance for the suspension and terminates in an open end which mates with the tail pipe assembly. The intermediate pipe is supported between the flange and the silencer by a welded support bracket and mounting rubber.

Tailpipe assembly

The tail pipe assembly is of fabricated and welded construction and comprises a large capacity silencer, a connecting pipe and two tail pipes. The curved connecting pipe is welded to the left hand end of the silencer and mates with the intermediate pipe. The connecting pipe is a sliding fit on the intermediate pipe and is secured with a clamp.

Two tail pipes are welded to the right hand end of the silencer and direct exhaust emissions downwards from the right hand end of the bumper.

Technical data

The table titled 'Technical data' displays technical information regarding the KV6 2.5 24 valve petrol engine.

Technical data

Description	Data
Type	2.5 litre V6 direct injection petrol, 24 valve, air assisted fuel injection, water cooled, transverse mounted
Cylinder arrangement	90° V6, numbered from the front of the engine: • Left bank cylinders 1, 3 and 5 • Right bank cylinders 2, 4 and 6
Bore	80 mm (3.15 in)
Stroke	82.8 mm (3.26 in)
Firing order	1-6-5-4-3-2
Compression ratio	10.5 :1 ± 0.5 : 1
Maximum power	130 kW (177 bhp) @ 6500 rev/min
Maximum torque	240 Nm (177 lbf.ft) @ 4000 rev/min
Valve operation	Self-adjusting lightweight hydraulic tappets operated directly by the camshafts
Fuel injection system: • Make • Type	Siemens engine management system. Multi-point, air assisted fuel injection controlled by ECM and electro-mechanical injectors with twin sprays targeted at back of inlet valves
Emissions standard	ECD3

Siemens 2000 Engine management system

General

The KV6 engine is fitted with a Siemens Engine Management System (EMS). The Siemens EMS is an adaptive system that maintains engine performance at the optimum level throughout the life of the engine.

The EMS consists of an Engine Control Module (ECM) that uses inputs from engine sensors and from other vehicle systems to continuously monitor driver demand and the current status of the engine. From the inputs the ECM calculates the Air Fuel Ratio (AFR) and ignition timing required to match engine operation with driver demand, then outputs the necessary control signals to the fuel injectors and ignition coils. The ECM also outputs control signals to operate the:

- Idle Air Control (IAC) valve
- Air Conditioning (A/C) compressor
- Cooling fans
- Evaporative emissions (EVAP) canister purge valve
- Fuel pump
- Variable Intake System (VIS)

The EMS interfaces with the:

- Immobilisation ECU, for re-mobilisation of the engine fuel supply
- Cruise control interface ECU, to enable the system
- Electronic Automatic Transmission (EAT) ECU, to assist with control of the gearbox

Sensor inputs and engine performance are monitored by the ECM, which illuminates a Malfunction Indicator Lamp (MIL) if a fault is detected.

As part of the security system's immobilisation function, a vehicle specific security code is programmed into the ECM and immobilisation ECU during production. The ECM cannot function unless it is connected to an immobilisation ECU with the same code. In service, replacement ECM are supplied uncoded and must be programmed using TestBook to learn the vehicle security code from the immobilisation ECU.

A 'flash' Electronic Erasable Programmable Read Only Memory (EEPROM) allows the ECM to be externally configured, using TestBook, with market specific or new information.

The ECM memorises the position of the crankshaft and the camshaft when the engine stops, which allows immediate sequential fuel injection and ignition timing during cranking on the subsequent start. The position data is lost if the battery is disconnected or the battery voltage is too low (e.g. flat battery). After battery recharging or reconnection, during the subsequent start sequence fuelling and ignition is delayed slightly until the ECM has determined the position of the crankshaft and the camshaft from the CKP and CMP sensor inputs.

To achieve optimum performance the ECM is able to 'learn' the individual characteristics of an engine and adjust the fuelling calculations to suit. This capability is known as adaptive fuelling. Adaptive fuelling also allows the ECM to compensate for wear in engine components and to compensate for the tolerance variations of the engine sensors.

If the ECM suffers an internal failure, such as a breakdown of the processor or driver circuits, there is no back up system or limp home capability. If a sensor circuit fails to supply an input, where possible the ECM adopts a substitute or default value, which enables the engine to function, but with reduced performance.

Engine starting

When the ignition switch is in position II a power feed is connected from the ignition switch to the ECM. The ECM then initiates 'wake up' routines and energises the main and fuel pump relays. If the ignition switch remains in position II without the engine running, the ECM de-energises the fuel pump relay after approximately 2 seconds. When the ignition switch is in position II with the engine running, or position III, the fuel pump relay is permanently energised.

When the engine cranks, the ECM initiates fuelling and ignition to start the engine. Provided a valid mobilisation signal is received from the immobilisation ECU, the ECM maintains fuelling and ignition control of the engine as necessary to meet driver demand. If no mobilisation code is received from the immobilisation ECU, or the code is invalid, the ECM stops the engine after 2 seconds.

The electrical circuit from the fuel pump relay to the fuel pump is routed through the fuel cut-off inertia switch, located below the E-box in the engine compartment. In the event of a collision the switch breaks the circuit to prevent further fuel being delivered to the engine. The switch is reset by pressing down the centre of the rubber cover on the top of the switch.

During the start sequence, the ECM also illuminates the MIL, as a bulb check, for 4 seconds after the ignition switch turns to position II or until the ignition switch turns to position III.

Engine stopping

When the ignition switch is turned to position I, the ECM switches off the ignition coils, injectors and fuel pump to stop the engine. The ECM continues to energise the main relay until the power down functions are completed. Power down functions include engine cooling, referencing the IAC valve stepper motor and memorising data for the next start up. When the power down process is completed, the ECM de-energises the main relay and enters a low power mode. In the low power mode, maximum quiescent drain is 0.5 mA.

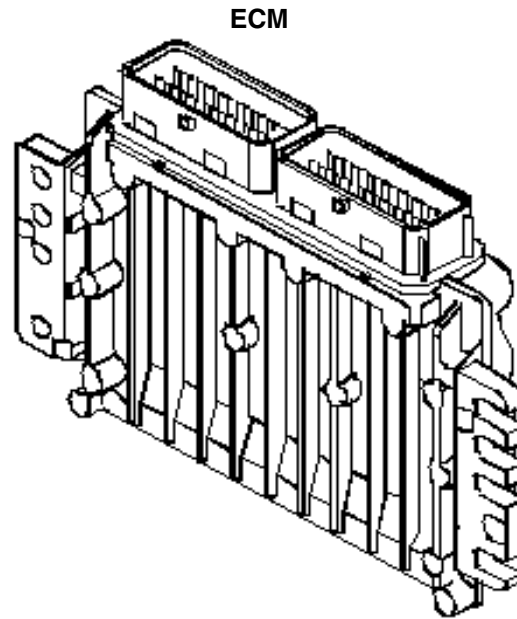


Figure 68

The ECM is located in the engine compartment, in the Environmental (E) box behind the battery carrier. A dual connector provides the interface between the ECM and the vehicle wiring.

Controller Area Network (CAN) bus

The ECM is connected to the Anti-lock Braking System (ABS) modulator, EAT ECU and the instrument pack by the CAN bus. The CAN bus is a serial communications data bus, consisting of a pair of wires twisted together, that allows the high speed exchange of digital messages between control units.

Engine sensors

The EMS incorporates the following engine sensors

- A Camshaft Position (CMP) sensor
- A Crankshaft Position (CKP) sensor
- An Engine Coolant Temperature (ECT) sensor
- Three Heated Oxygen Sensors (HO2S)
- An Intake Air Temperature/ Manifold Absolute Pressure (IAT/MAP) sensor
- Two knock sensors
- A Throttle Position (TP) sensor
- An accelerator pedal position sensor

Crankshaft Position (CKP) sensor

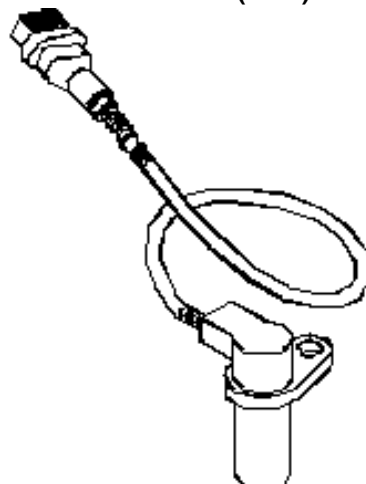


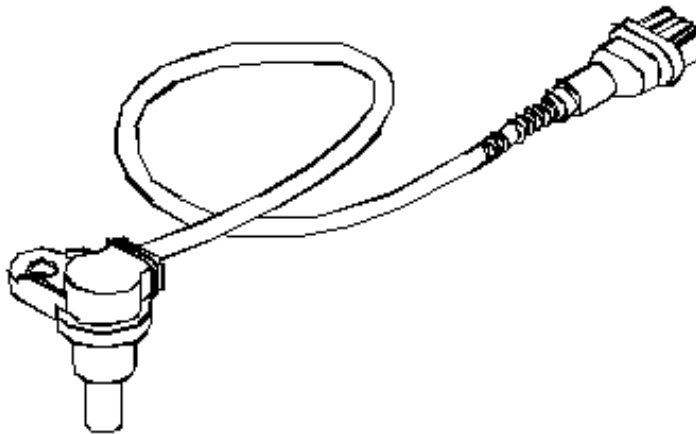
Figure 69

The CKP sensor provides the ECM with a digital signal of the rotational speed and angular position of the crankshaft, for use in ignition timing, fuel injection timing and fuel quantity calculations. To determine the exact position of the crankshaft in the engine cycle, the ECM must also use the input from the CMP sensor.

The CKP sensor is mounted on the front of the gearbox housing, in line with the outer circumference of the torque converter. The sensing tip of the CKP sensor is adjacent to a reluctor ring formed in the periphery of the torque converter. The reluctor ring has 58 teeth spaced at 6° intervals. A gap equivalent to two missing teeth, 36° After Top Dead Centre (ATDC) of No. 1 cylinder, provides the ECM with a reference point.

The CKP sensor operates using the Hall effect principle. A permanent magnet inside the sensor applies a magnetic flux to a semiconductor, which receives a power supply from the main relay. The output voltage from the semiconductor is fed to the ECM. As the gaps between the poles of the reluctor ring pass the sensor tip the magnetic flux is interrupted, causing a fluctuation of the output voltage and producing a digital signal.

If the CKP sensor fails the ECM immediately stops the engine.

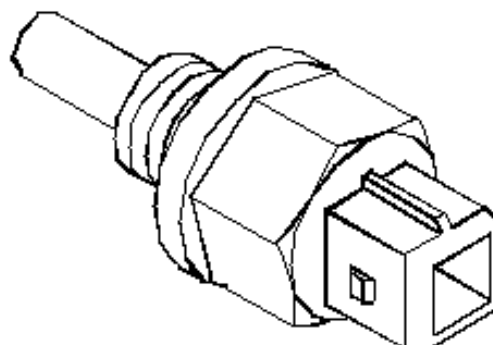
Camshaft Position (CMP) sensor*Figure 70*

The CMP sensor provides a signal which enables the ECM to determine the position of the camshaft relative to the crankshaft. This allows the ECM to synchronise fuel injection for start and run conditions.

The CMP sensor is located on the camshaft cover of the LH cylinder bank, at the opposite end to the camshaft drive, in line with a 'half moon' reluctor on the exhaust camshaft. The reluctor comprises a single tooth which extends around 180° of the camshaft circumference.

The CMP sensor operates using the Hall effect principle. A permanent magnet inside the sensor applies a magnetic flux to a semiconductor, which receives a power supply from the main relay. The output voltage from the semiconductor is fed to the ECM. As the gap in the reluctor passes the sensor tip, the magnetic flux is interrupted, causing a fluctuation of the output voltage and producing a digital signal.

If the CMP sensor fails during engine running, the engine will run normally until turned 'OFF', but will not restart until the CMP sensor input is restored.

Engine Coolant Temperature (ECT) sensor*Figure 71*

The ECT sensor provides the ECM with a signal voltage that varies with coolant temperature. The ECT sensor is located between the cylinder banks, between cylinders 3 and 6.

The ECT sensor consists of an encapsulated Negative Temperature Coefficient (NTC) thermistor which is in contact with the engine coolant. As the coolant temperature increases the resistance across the sensor decreases and as the coolant temperature decreases the sensor resistance increases. To determine the coolant temperature, the ECM supplies the sensor with a regulated 5 volts power supply and monitors the return signal voltage.

If the ECT signal is missing, or outside the acceptable range, the ECM assumes a default temperature reflecting a part warm engine condition. This enables the engine to function, but with reduced driveability when cold and increased emissions, resulting from an over rich mixture, when the engine reaches normal operating temperature. The ECM will also switch on the cooling fans to prevent the engine and gearbox from overheating.

Intake Air Temperature/ Manifold Absolute Pressure (IAT/MAP) sensor

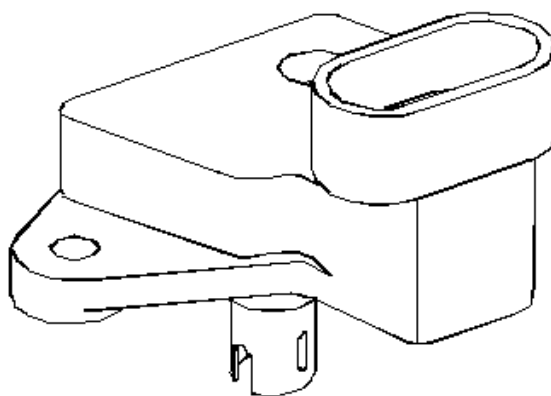
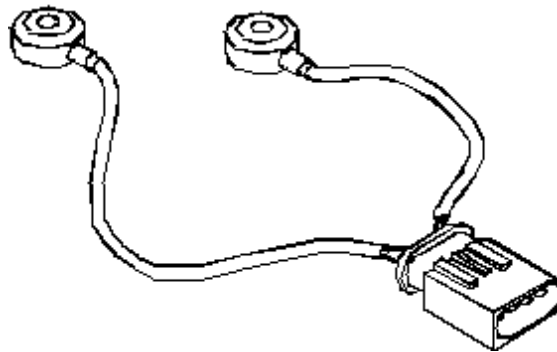


Figure 72

The dual IAT/MAP sensor provides the ECM with temperature and pressure signals for use in mass air flow calculations. The IAT/MAP sensor is located on the throttle body, downstream of the throttle plate.

IAT sensor: The IAT sensor is a NTC thermistor which is exposed to the intake air. As the intake air temperature increases the resistance across the sensor decreases and as the intake air temperature decreases the sensor resistance increases. To determine the intake air temperature, the ECM supplies the sensor with a regulated 5 volts power supply and monitors the output signal voltage. If the IAT sensor fails the ECM adopts a default temperature value of 45 °C (113 °F) and disables adaptive fuelling. The fault may not be apparent to the driver.

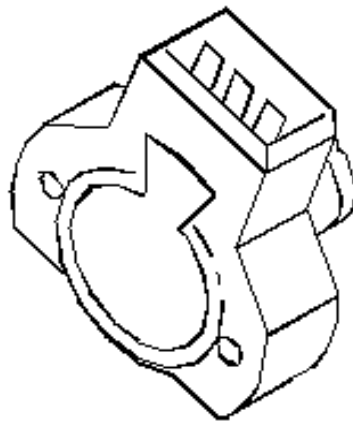
MAP sensor: The MAP sensor is a piezo resistive sensor. The resistance of the sensor varies in proportion to the pressure of the intake air. The ECM supplies the sensor with a regulated 5 volts power supply and, from the sensor output voltage, calculates the pressure of the intake air. If the MAP sensor signal is missing the ECM will adopt a default value based on crankshaft speed and throttle angle. The engine will continue to run with reduced driveability and increased emissions, although this may not be apparent to the driver.

Knock sensors*Figure 73*

The knock sensors enable the ECM to operate the engine at the limits of ignition advance, for optimum efficiency, without combustion knock damaging the engine. The ECM uses two knock sensors, one for each cylinder bank, located between the cylinder banks on cylinders 3 and 4.

The knock sensors consist of piezo ceramic crystals that oscillate to create a voltage signal. During combustion knock, the frequency of crystal oscillation increases, which alters the signal output to the ECM. The ECM compares the signal to known signal profiles in its memory. If the onset of combustion knock is detected the ECM retards the ignition timing for a number of cycles. When the combustion knock stops, the ignition timing is gradually advanced to the original setting.

The knock sensor leads are of different lengths to prevent incorrect installation.

Throttle Position (TP) sensor*Figure 74*

The TP sensor provides the ECM with a throttle plate position signal. The TP sensor is located on the throttle body.

The TP sensor is a variable potentiometer that consists of a resistive track and a sliding contact. The sliding contact is connected to the spindle of the throttle plate. The sensor receives a regulated 5 volts supply from the ECM. As the throttle is opened and closed, the sliding contact moves along the resistive track to change the output voltage of the sensor. The ECM determines throttle plate position and angular change rate by processing the output voltage, which ranges from approximately 0.14V at closed throttle to 4.36V at wide open throttle.

The TP sensor requires no adjustment in service, since the ECM adapts to any minor changes of the upper and lower voltage limits which occur due to normal wear. However, when a new TP sensor or ECM is fitted, a TestBook initialisation procedure must be carried out to enable the ECM to 'fast learn' the TP sensor positions and, in the case of a new TP sensor, overwrite old data. Without the initialisation procedure, poor throttle response and idle control may be experienced until the ECM adapts to the voltage limits of the sensor.

If the TP signal is missing the ECM will substitute a value based on information from the IAT/MAP sensor and CKP sensor. The engine will continue to run but may suffer from poor idle control and throttle response.

Heated Oxygen Sensors (HO2S)

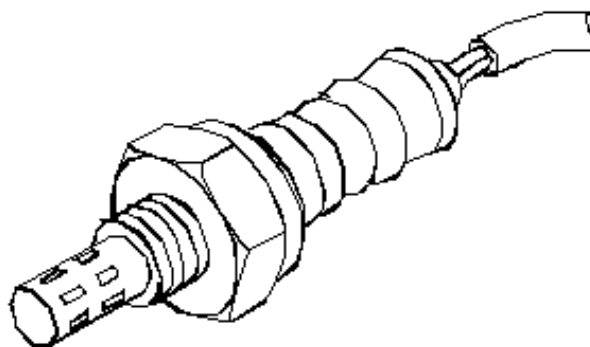


Figure 75

The EMS has three HO2S:

- One in each exhaust manifold, upstream of the starter catalytic converter, identified as LH and RH front HO2S
- One in the exhaust front pipe immediately downstream of the main catalytic converter, identified as the rear HO2S

The LH and RH front HO2S enable the ECM to determine the AFR of the mixture being burned in each cylinder bank of the engine. The rear HO2S enables the ECM to monitor the performance of the catalytic converters.

Each HO2S consists of a sensing element with a protective ceramic coating on the outer surface. The outer surface of the sensing element is exposed to the exhaust gas, and the inner surface is exposed to ambient air. The difference in the oxygen content of the two gases produces an electrical potential difference across the sensing element. With a rich mixture, the low oxygen content in the exhaust gas results in a higher sensor voltage. With a lean mixture, the high oxygen content in the exhaust gas results in a lower sensor voltage.

During closed loop control the voltage of the two front HO2S switches from less than 0.3 volt to more than 0.5 volt. The voltage switches between limits every two to three seconds. This switching action indicates that the ECM is varying the AFR within the Lambda window tolerance, to maximise the efficiency of the catalytic converters.

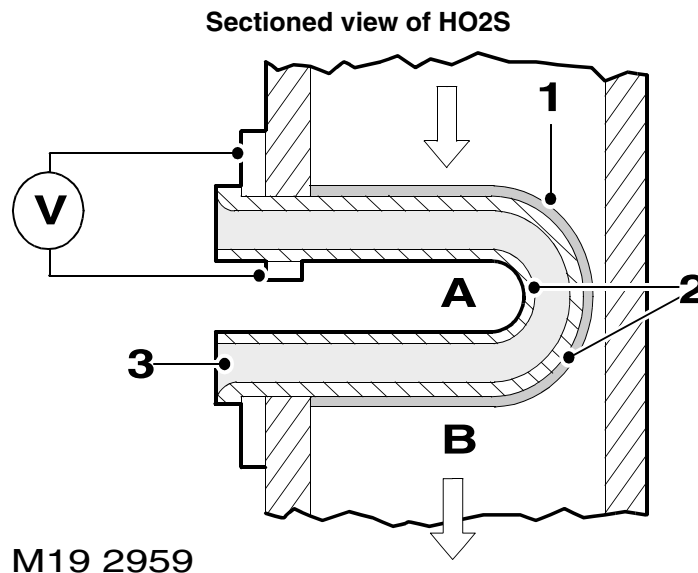


Figure 76

A = Ambient air; B = Exhaust gases

- 1. Protective ceramic coating
- 2. Electrodes
- 3. Zirconium oxide

The material of the sensing element only becomes active at a temperature of approximately 300 °C (570 °F). To shorten the warm up time and minimise the emissions from a cold start, each HO2S contains a heating element powered by a supply from the main relay. The earth paths for the heating elements are controlled by the ECM. On start up, the current supplied to the heating elements is increased gradually to prevent sudden heating from damaging the ceramic coating. After the initial warm up period the ECM modulates the earth of the heating elements, from a map of engine speed against mass air flow, to maintain the HO2S at the optimum operating temperature.

The nominal resistance of the heating elements is 6 Ω at 20 °C (68 °F).

If a front HO2S fails the ECM adopts open loop fuelling and catalytic converter monitoring is disabled. If the rear HO2S fails only catalytic converter monitoring is affected.

Accelerator pedal position sensor

The accelerator pedal position sensor enables the ECM to detect when the accelerator pedal is pressed by the driver. The ECM uses the accelerator pedal position sensor input to detect a sticking throttle, by ensuring there is genuine driver demand from the accelerator pedal when the TP sensor input indicates that the throttle is above idle.

The accelerator pedal position sensor is a Hall effect sensor installed in the pedal box. The sensor consists of an inner sensor in an outer mounting sleeve. To ensure correct orientation, the sensor is keyed to the mounting sleeve and the mounting sleeve is keyed to the pedal box. Mating serrations hold the sensor in position in the mounting sleeve. While the accelerator pedal is at idle, a tang on the upper end of the pedal rests against the end of the sensor. When the accelerator pedal is pressed, the tang moves away from the sensor and induces a change of sensor output voltage.

If the accelerator pedal position sensor input is missing, or the TP sensor input is implausible, the ECM inhibits the throttle angle message on the CAN bus which disables the Hill Descent Control (HDC) function of the ABS modulator and reduces the performance of the automatic gearbox (harsh gear changes and loss of kickdown).

Ignition coils

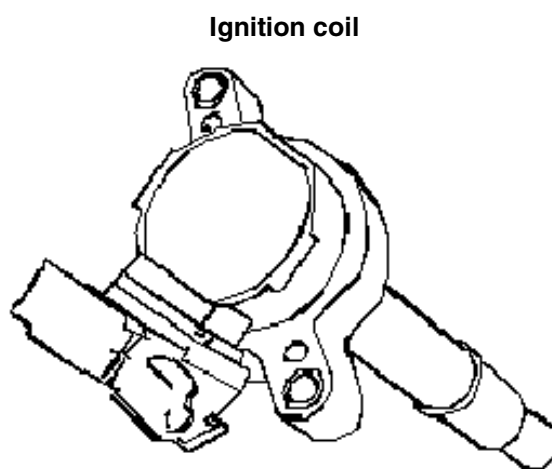


Figure 77

The ECM uses a separate ignition coil for each spark plug. The ignition coils for the LH bank spark plugs are positioned on the forward tracts of the inlet manifold and connected to the spark plugs with High Tension (HT) leads. The ignition coils for the RH bank spark plugs are of the plug top design, secured to the camshaft cover with 2 screws.

Each ignition coil has 3 connections in addition to the spark plug connection; an ignition feed from the main relay, an earth wire for the secondary winding and a primary winding negative (switch) terminal. The switch terminal of each ignition coil is connected to a separate pin on the ECM to allow independent switching. The ignition coils are charged whenever the ECM supplies an earth path to the primary winding negative terminal. The duration of the charge time is held relatively constant by the ECM for all engine speeds. Consequently, the dwell period increases with engine speed. This type of system, referred to as Constant Energy, allows the use of low impedance coils with faster charge times and higher outputs.

The ECM calculates dwell angle using inputs from the following

- Battery voltage (main relay)
- CKP sensor
- Ignition coil primary current (internal ECM connection)

The spark is produced when the ECM breaks the primary winding circuit. This causes the magnetic flux around the primary winding to collapse, inducing HT energy in the secondary coil, which can only pass to earth by bridging the air gap of the spark plug.

Ignition related faults are monitored indirectly by the misfire detection function.

Ignition timing

The ECM calculates ignition timing using inputs from the following sensors:

- CKP sensor
- Knock sensors
- IAT/MAP sensor
- TP sensor (idle only)
- ECT sensor

At start up and idle the ECM sets ignition timing by referencing the ECT and CKP sensors. Once above idle the ignition timing is controlled according to maps stored in the ECM memory and modified according to additional sensor inputs and any adaptive value stored in memory. The maps keep the ignition timing within a narrow band that gives an acceptable compromise between power output and emission control. The ignition timing advance and retard is controlled by the ECM in order to avoid combustion knock.

Knock control

The ECM uses active knock control to prevent combustion knock damaging the engine. If the knock sensor inputs indicate the onset of combustion knock, the ECM retards the ignition timing for that particular cylinder by 3°. If the combustion knock indication continues, the ECM further retards the ignition timing, in decrements of 3°, for a maximum of 15° from where the onset of combustion knock was first sensed. When the combustion knock indication stops, the ECM restores the original ignition timing in increments of 0.75°.

To reduce the risk of combustion knock at high intake air temperatures, the ECM retards the ignition timing if the intake air temperature exceeds 55 °C (169 °F). The amount of ignition retard increases with increasing air intake temperature.

Idle speed control

The ECM controls the engine idle speed using a combination of ignition timing and the IAC valve.

When the engine idle speed fluctuates the ECM initially varies the ignition timing, which produces rapid changes of engine speed. If this fails to correct the idle speed, the ECM also operates the IAC valve stepper motor to vary the amount of air allowed to bypass the throttle plate. To increase the idle speed the ECM signals the stepper motor to allow more air to bypass the throttle plate. To decrease the idle speed the ECM signals the stepper motor to allow less air to bypass the throttle plate. The IAC valve is also opened during deceleration to decrease the manifold vacuum and reduce emissions.

Misfire detection

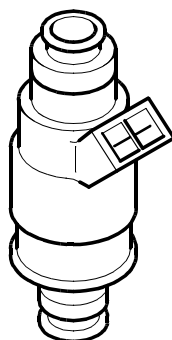
The ECM uses the CKP sensor input to monitor the engine for misfires. As the combustion charge in each cylinder is ignited the crankshaft accelerates, then subsequently decelerates. By monitoring the acceleration/ deceleration pulses of the crankshaft the ECM can detect misfires.

Low fuel level: When the fuel tank is almost empty there is a risk that air may be drawn into the fuel system, due to fuel 'slosh', causing fuel starvation and misfires. If a misfire occurs when the fuel tank content is less than 15% (8.85 litres; 2.34 US galls), the ECM stores an additional fault code to indicate the possible cause of the misfire.

Rough road disable: When the vehicle is travelling over a rough road surface the engine crankshaft is subjected to torsional vibrations caused by mechanical feedback from the road surface through the transmission. To prevent misinterpretation of these torsional vibrations as a misfire, the misfire monitor is disabled when a road surface exceeds a roughness limit programmed into the ECM. The roughness of the road is calculated by the ABS modulator, from the four ABS sensor inputs, and transmitted to the ECM on the CAN bus.

Fuel injectors

Fuel injector



M19 2845A

Figure 78

A split stream, air assisted fuel injector is installed for each cylinder. The injectors are located in the inlet manifolds and connected to a common fuel rail assembly.

Each injector contains a pintle type needle valve and a solenoid winding. The needle valve is held closed by a return spring. An integral nozzle shroud contains a ported disc, adjacent to the nozzles. 'O' rings seal the injector in the fuel rail and the inlet manifold.

The solenoid winding of each injector receives a 12 volt supply from the main relay. To inject fuel, the ECM supplies an earth path to the solenoid winding, which energises and opens the needle valve. When the needle valve opens, the two nozzles direct a spray of atomised fuel onto the back of each inlet valve. Air drawn through the shroud and ported disc improves atomisation and directional control of the fuel. The air is supplied from a dedicated port in the IAC valve via a plastic tube and tracts formed in the gasket face of the intake manifolds.

Each injector delivers fuel once per engine cycle, during the inlet stroke. The ECM calculates the open time (duty cycle) of the injectors from:

- Engine speed
- Mass air flow
- Engine temperature
- Throttle position

The fuel in the fuel rail is maintained at a pressure of 3.5 bar (51 lbf/in²) by a pressure regulator incorporated into the pump unit in the fuel tank. An accumulator is attached to the fuel rail on the RH inlet manifold to damp out pressure pulses from the pump and ensure that the pressure in the fuel rail is constant (the same component functions as the pressure regulator on vehicles with a return fuel delivery system). The accumulator is connected by a pipe to the inlet manifold from which it receives a vacuum to aid the damping process. A schraeder valve is installed in the 'fuel return' pipe of the accumulator to allow pressure to be released from the fuel rail and fuel feed pipe prior to maintenance.

The nominal resistance of the injector solenoid winding is 13 - 16 Ω at 20 °C (68 °F).

Idle air control (IAC) valve

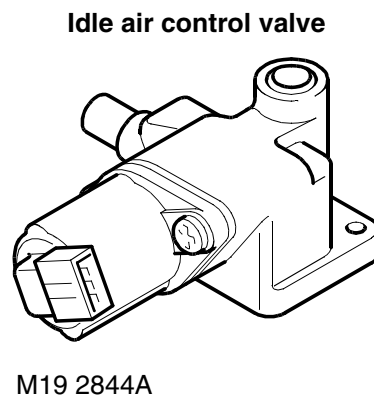


Figure 79

The IAC valve regulates the flow of throttle bypass air and the flow of air to the fuel injectors. The throttle bypass air enables the ECM to:

- Control engine idle speed
- Provide a damping function when the throttle plate closes during deceleration, to reduce Hydrocarbon (HC) emissions

The IAC valve is located on a port in the throttle body downstream of the throttle plate. A hose, from the duct between the air cleaner and the throttle body, is connected to an inlet port on the valve housing to provide a source of air from upstream of the throttle plate. A tube supplies air from an outlet port on the valve housing to the intake manifolds, for the air assisted fuel injectors. A stepper motor on the valve housing operates a pintle valve to control the flow of air through the valve housing.

The stepper motor core is rotated by the magnetic fields of two electro-magnetic bobbins set at 90° to each other. The bobbins are connected to driver circuits in the ECM. Each of the four connections can be connected to 12 volts or earth, enabling four phases to be produced. The ECM modulates the four phases as necessary to move the motor core and pintle valve, and so adjust the flow of air from the inlet port to the throttle bypass and fuel injector outlet ports.

When the ignition is switched off the ECM enters a power down routine which includes referencing the stepper motor. During referencing the ECM rotates the stepper motor fully closed to provide a position datum for when it next needs to start the engine. The referencing procedure takes from three to five seconds. If the ECM cannot reference the stepper motor during power down, e.g. due to a power failure, referencing is performed the next time the ignition is switched 'ON'.

There are no back up idle control systems. If the stepper motor fails the idle speed may be too high or too low, the engine may stall and/or the engine may be difficult to start.

Evaporative emissions (EVAP) canister purge valve

The ECM provides a PWM earth path to control the operation of the purge valve. When the ECM is in the open loop fuelling mode the purge valve is kept closed. When the vehicle is moving and in the closed loop fuelling mode the ECM opens the purge valve.

When the purge valve is open fuel vapour is drawn from the EVAP canister into the inlet manifold. The ECM detects the resultant enrichment of the AFR, from the inputs of the front HO2S, and compensates by reducing the duty cycle of the fuel injectors.

Variable intake system (VIS) valves

The ECM operates the two VIS valve motors to open and close the VIS valves in a predetermined sequence based on engine speed and throttle opening. Each VIS valve motor has a permanent power feed from the main relay, feedback and signal connections with the ECM, and a permanent earth connection. When the engine starts, the VIS valve motors are both in the valve open position. To close the VIS valves, the ECM applies a power feed to the signal line of the applicable VIS valve motor. To open the VIS valves, the ECM disconnects the power feed from the signal line and the VIS valve motor is closed by the power feed from the main relay.

Malfunction Indicator Lamp (MIL)

The MIL is located in the instrument pack and consists of an engine graphic on a yellow background (all except NAS) or a yellow SERVICE ENGINE SOON legend (NAS). The ECM operates the MIL by communicating with the instrument pack on the CAN bus.

Diagnostics

The ECM incorporates On Board Diagnostics (OBD) software that complies with market legislation current at the time of manufacture. During engine operation the ECM performs self test and diagnostic routines to monitor the performance of the engine and the EMS. If a fault is detected the ECM stores a related diagnostic trouble code (also known as a 'P' code) in a non volatile memory and, for most faults, illuminates the MIL. Codes are retrieved using TestBook, which communicates with the ECM via an ISO 9141 K line connection from the diagnostic socket.

M47R Diesel engine

Introduction

The diesel engine fitted to Freelander is known as the M47R. This engine is a new member of the latest generation of diesel engines and is made in Steyr, Austria.

Equipped with a chain-driven overhead camshaft and four valves per cylinder, Freelander also becomes Land Rover's first 'multivalve' diesel.

Common rail technology appeared for the first time at the end of 1997 when Alfa Romeo launched the 2.4-litre 156. Mercedes then launched a 2.2-litre common rail engine in the C-class, and the technology has also appeared in Isuzu vehicles.

Development objectives

The development objectives for the M47R diesel engine were:

- to develop a new four cylinder diesel engine featuring four valve technology and direct fuel injection
- to reduce fuel consumption
- to maintain operating refinements and interior acoustics comparable to those on indirect injection diesel engines
- to comply with the European commission directive stage 3 (ECD-3) exhaust emission limits from model launch and to create the conceptional prerequisites for achieving the stringent requirements of European on-board diagnostics (E-OBD)
- class competitive service times

Technical features

The technical features of the M47R diesel engine are:

- In-line four cylinder engine with cast iron cylinder block and light alloy cylinder head
- Four valve technology with centrally arranged injectors
- Exhaust turbocharger with intercooler
- Direct fuel injection with common rail technology and electronic diesel engine management
- Electronically controlled exhaust gas re-circulation (EGR) with hot-film mass air-flow meter
- Exhaust re-treatment by means of a diesel-specific oxidation catalytic converter
- Inspection intervals of 15,000 miles
- Swirl and tangential intake ports
- Chain driven camshafts
- Hydraulic valve adjustment

General

The M47R diesel engine is a 2.0 litre, 4 cylinder, in-line direct injection unit having four valves per cylinder operated by twin overhead camshafts. The engine emissions comply with ECD-3 (European Commission Directive) legislative requirements and employs an Oxidising catalytic converter, positive crankcase ventilation and exhaust gas recirculation to limit the emission of pollutants. The unit is water cooled and turbo-charged and is controlled by an electronic engine management system. Fuel injection features common rail technology.

The engine is controlled by a Bosch DDE 4.0 engine management system.

The cylinder block is of cast iron construction with a cast aluminium stiffening plate bolted to the bottom to improve lower structure rigidity. The cylinder head is cast aluminium with a moulded plastic camshaft cover. The engine sump is a two-piece cast aluminium assembly. A moulded plastic acoustic cover is fitted over the upper engine to reduce engine generated noise.

Cylinder block components

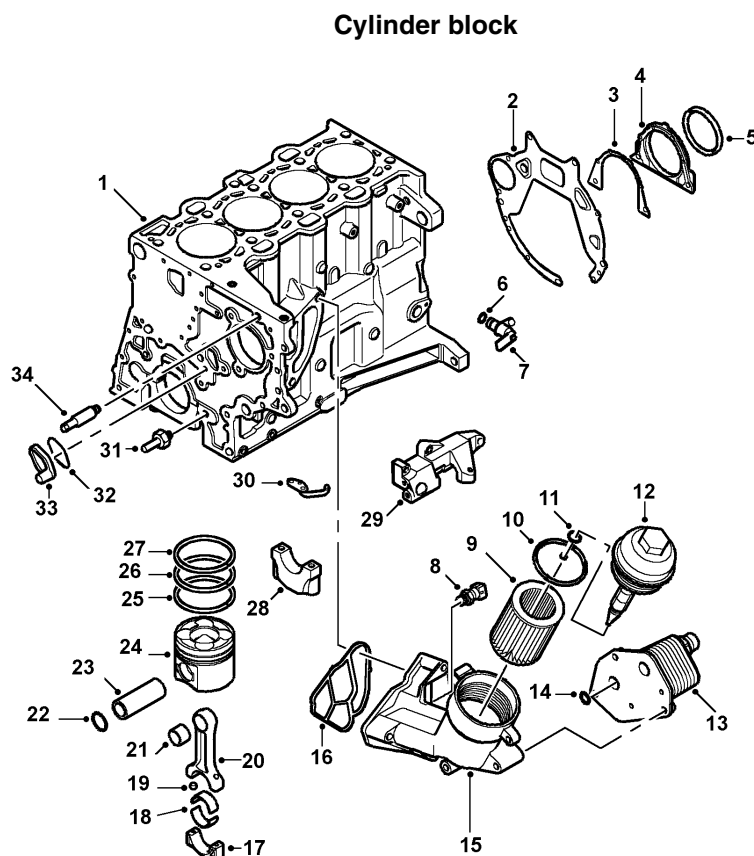


Figure 80

- | | |
|---|---|
| 1. Cylinder block | 19. Dowels – big end bearing cap to connecting rod |
| 2. Gearbox closure assembly plate | 20. Connecting rod |
| 3. Gasket – crankshaft rear seal housing to engine block | 21. Small-end bush |
| 4. Crankshaft rear seal housing | 22. Circlip |
| 5. Crankshaft rear seal | 23. Gudgeon pin |
| 6. 'O' ring – crankshaft position sensor | 24. Piston |
| 7. Crankshaft position sensor | 25. Oil control ring |
| 8. Oil pressure switch | 26. 2nd compression ring |
| 9. Oil filter element | 27. Top compression ring |
| 10. Sealing ring – oil filter | 28. Main bearing cap |
| 11. Sealing washers – oil filter head | 29. Alternator to engine block mounting bracket |
| 12. Oil filter housing head assembly | 30. Piston cooling jet |
| 13. Oil cooler assembly | 31. Pins – ancillary chain guide to cylinder block |
| 14. 'O' rings – oil cooler assembly to oil filter housing | 32. 'O' ring – cylinder block blanking plate |
| 15. Oil filter housing | 33. Cylinder block (front) blanking plate |
| 16. Gasket – oil filter housing to cylinder block | 34. Pin – cylinder block, front (drive chain guide) |
| 17. Big-end bearing cap | |
| 18. Big-end bearing shells | |

The cylinder block components are described below:

Cylinder block

The cylinders and crankcase are contained in a single grey cast iron construction with hollow beam structure. The cylinders are direct bored. Lubrication oil is supplied via lubrication jets for piston and gudgeon pin lubrication and cooling.

Lubrication oil is distributed throughout the block via the main oil gallery to critical moving parts through channels bored in the block which divert oil to the main bearings, and to the big-end bearings via holes machined into the crankshaft.

An oil cooler is fitted to the side of the oil filter assembly with ports in the oil cooler mating with ports in the oil filter assembly, to facilitate coolant and oil flow from the cylinder block. An oil pressure switch is included in a tapping in the oil filter assembly which is used to determine whether sufficient oil pressure is available to provide engine lubrication and cooling.

A tapping at the front right hand side of the cylinder block connects a pipe to the turbocharger by means of a banjo connection. Oil under pressure from the oil pump provides lubrication for the turbocharger bearings.

Cylinder cooling is achieved by coolant circulating through chambers in the engine block casting. Note that the water jacket does not have core plugs.

Two hollow metal dowels are used to locate the cylinder block to the cylinder head, one on each side at the front of the unit. Two additional hollow metal dowels are used to locate the timing cover to the cylinder block.

Engine identification number

The engine number is stamped on the right hand side of the cylinder block.

Engine identification number location

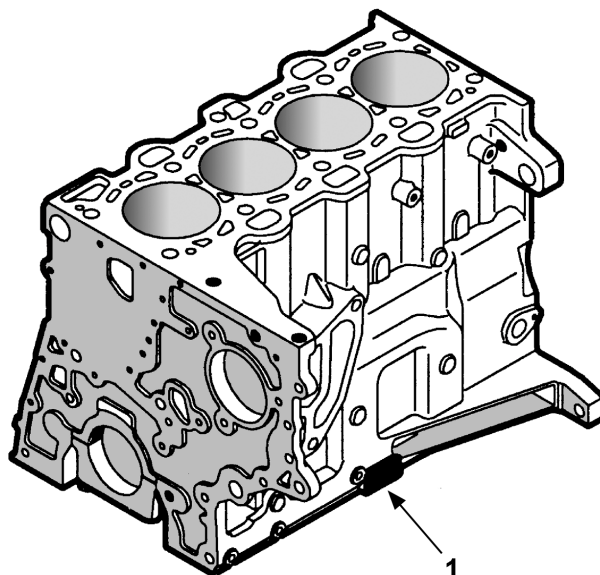


Figure 81

1.Engine identification number

Connecting rods

The connecting rods are machined 'H'-sectioned steel forgings. The big-end bearing shells are plain split halves. The upper half bearing shell fitted to the connecting rod is treated using the sputtering process (cathodic surface coating process) to improve its resistance to wear.

Big-end bearing shell

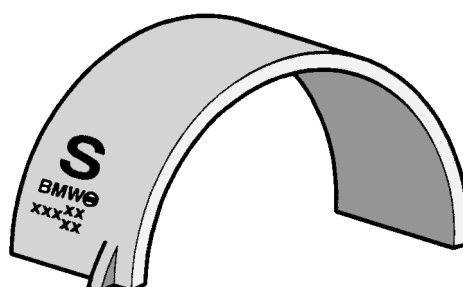


Figure 82

The small-end of the connecting rod has a bushed solid eye which is free to move on the gudgeon pin. The small-end bushing is a hand-push transition fit.

Pistons

The four pistons have graphite-compound coated aluminium alloy skirts, which are gravity die cast and machined.

Each of the pistons has a swirl chamber machined in the head which partly contains the inlet air during the combustion process and helps provide turbulence for efficient air/fuel mixture to promote complete combustion. The recesses in the piston's crown also provide clearance for the valve heads.

Indirect and direct injection piston comparison

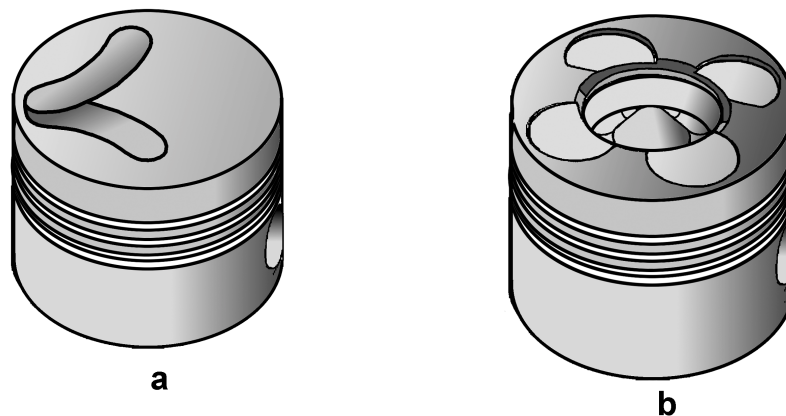


Figure 83

- a. Indirect
- b. Direct

The pistons are attached to the small-end of the connecting rods by fully floating gudgeon pins which are retained in the piston by circlips.

The pistons incorporate an oil cooling channel for piston and gudgeon pin cooling, oil being supplied under pressure from the piston lubrication jets.

Piston rings

Each piston is fitted with two compression rings and an oil control ring.

The top ring is barrel-edged and chrome plated, the 2nd compression ring is taper-faced and the oil control ring is chrome plated and features a bevelled ring with spring.

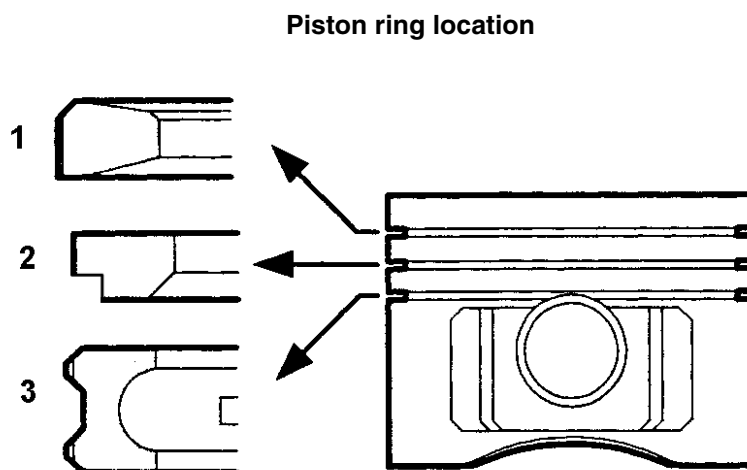


Figure 84

- 1. 1st compression ring
- 2. 2nd compression ring
- 3. Oil ring

Piston lubrication jets

The four lubrication jets (one for each cylinder) have a long hook-type nozzle and are fitted at the bottom right hand side of each cylinder by two socket screws.

The jets provide lubrication to the cylinder walls, and to the piston underskirt for cooling the pistons and lubricating the gudgeon pins and small-end bearings. The input port to each lubrication jet mates with a port provided in each mounting position, tapped at the underside of the cylinder block from a main gallery on the right hand side of the block.

Oil cooler and oil filter housing

The engine oil cooler assembly is located on the oil filter housing and is connected to the vehicle cooling system. Oil from the cylinder block passes through the oil filter housing and partial flow is directed through the oil cooler before it is returned to the cylinder block. The oil filter housing has an integral thermostatic valve which controls the amount of oil flowing through the oil cooler, dependent on the oil temperature.

Oil pressure switch

The oil pressure switch is located in a port in the oil filter housing. It detects when a low oil pressure condition occurs and initiates the illumination of a warning light in the instrument pack if the pressure drops below a given value.

High pressure fuel pump

The high pressure fuel pump supplying the common fuel rail is fixed to a flange on the front left hand side of the cylinder block. The pump is a 3 radial piston type controlled by the Bosch DDE 4.0 engine management system and chain driven from the crankshaft at 0.75 x engine speed.

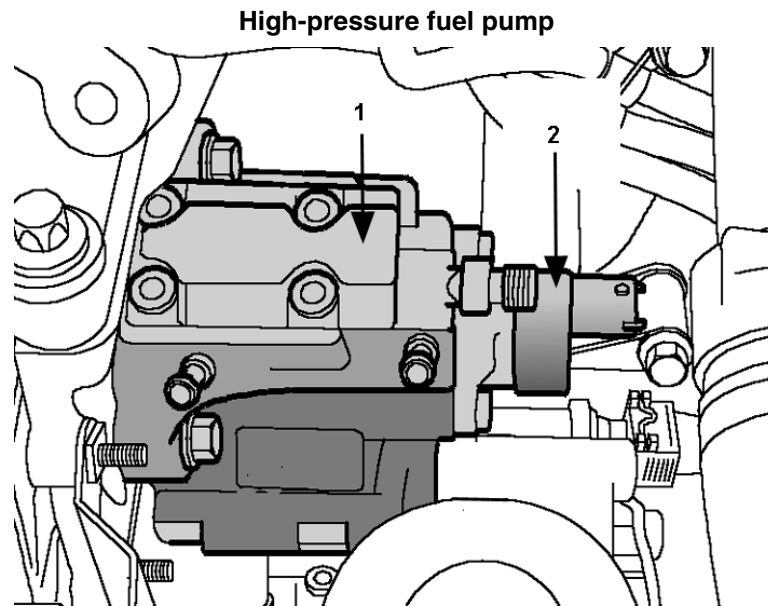


Figure 85

- 1.High-pressure fuel pump
- 2.Pressure control valve

Crankshaft position sensor

The crankshaft position sensor is mounted on the rear left hand side of the cylinder block and works on the variable reluctance principle. This uses the disturbance of the magnetic field which is set around the sensor, caused by the rotation of a reluctor 'target' attached to the crankshaft. The reluctor is a steel ring with 58 teeth and a space where two teeth are missing, this is the 'target'.

Sump, crankshaft and oil pump components

Sump, crankshaft and oil pump components

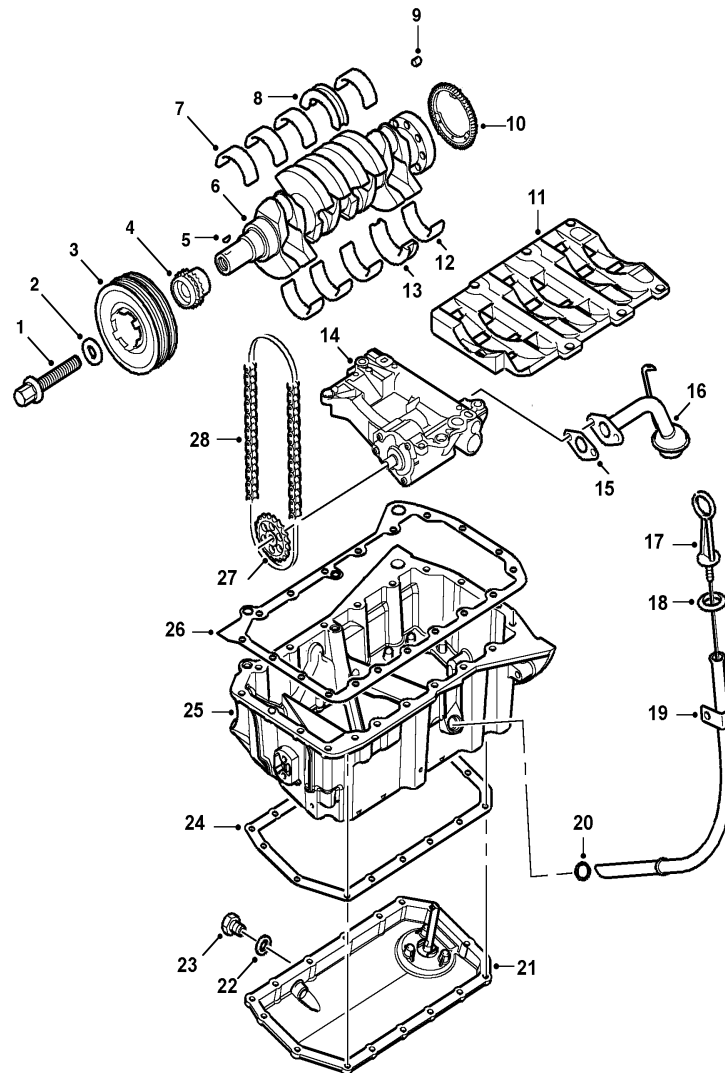


Figure 86

- | | |
|---|--|
| 1. Bolt – TV damper/crankshaft pulley | 14. Oil pump assembly |
| 2. Washer – crankshaft pulley bolt | 15. Gasket – oil pick-up pipe to oil pump assembly |
| 3. TV damper and crankshaft pulley | 16. Oil pick-up pipe and strainer |
| 4. Crankshaft sprocket | 17. Dipstick |
| 5. Woodruff key | 18. 'O' ring – dipstick to dipstick tube |
| 6. Crankshaft | 19. Dipstick tube |
| 7. Main bearing shells (grooved) – upper halves | 20. 'O' ring – dipstick tube to sump |
| 8. No. 4 main bearing with integral thrust washers (grooved) – upper half | 21. Sump bottom plate |
| 9. Dowel – flywheel to crankshaft | 22. Washer – oil drain plug sealing |
| 10. Crankshaft timing impulse wheel | 23. Plug – sump oil drain |
| 11. Bolts – impulse wheel to crankshaft | 24. Gasket – sump bottom plate to sump |
| 12. Main bearing shells (plain) – lower | 25. Sump |
| 13. No. 4 main bearing shell (plain with integral thrust washers) – lower | 26. Gasket – sump to cylinder block |
| | 27. Oil pump sprocket |
| | 28. Oil pump drive chain |

The sump, crankshaft and oil pump components are described below:

Sump

The sump is a two piece aluminium die-cast construction. The sump assembly is sealed to the bottom of the engine block by means of a rubber and metal gasket and 19 fixing bolts. The four bolts at the gearbox end of the engine block are longer than the remaining 15 bolts. Liquid sealing compound is used to seal the sump to the engine block at defined points.

The oil drain plug with sealing washer is fitted to the right hand side of the bottom plate. The bottom plate is attached to the upper portion of the sump by means of 16 bolts, and a rubber-metal gasket seals the interface between the two components.

A port for the dipstick tube is included in the casting on the left hand side of the sump.

An oil pick-up pipe with integral strainer locates in the centre of the sump oil pan to provide oil to the crankshaft driven oil pump.

Stiffener plate

The stiffener plate increases the rigidity of the lower engine block and is secured to the bottom of the cylinder block by 6 bolts.

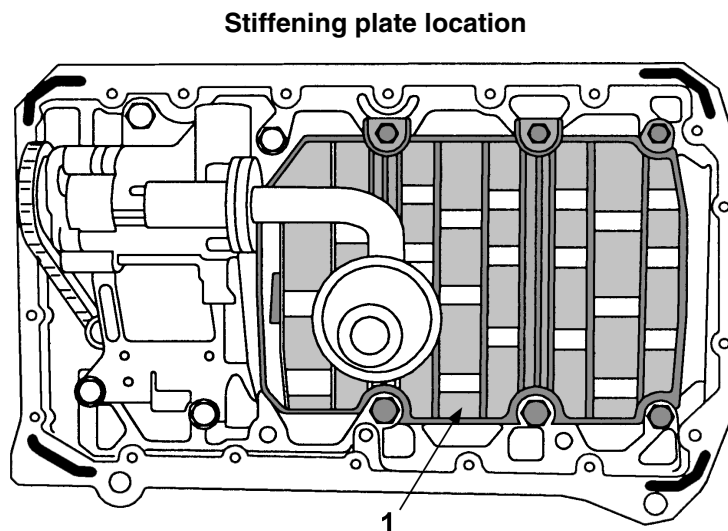


Figure 87

1. Stiffening plate

Oil pump

The oil pump assembly is bolted to the bottom of the cylinder block and is located in front of the engine block stiffener plate. The pump is an internal rotor type with sintered rotors and is driven through a chain and sprocket system from the crankshaft.

A pressure relief valve is included at the outlet side of the oil pump to restrict oil pressure at high engine speeds by recirculating oil through the relief valve back around the pump to the inlet. The relief valve and spring is a plunger type; when oil pressure is great enough to lift the plunger, oil is allowed to escape past the plunger to relieve pressure and prevent further rise.

Oil is delivered to the pump from the pick-up pipe, and the outlet side of the oil pump delivers pressurised oil flow to the engine block main oil delivery gallery.

Oil pump and pick-up

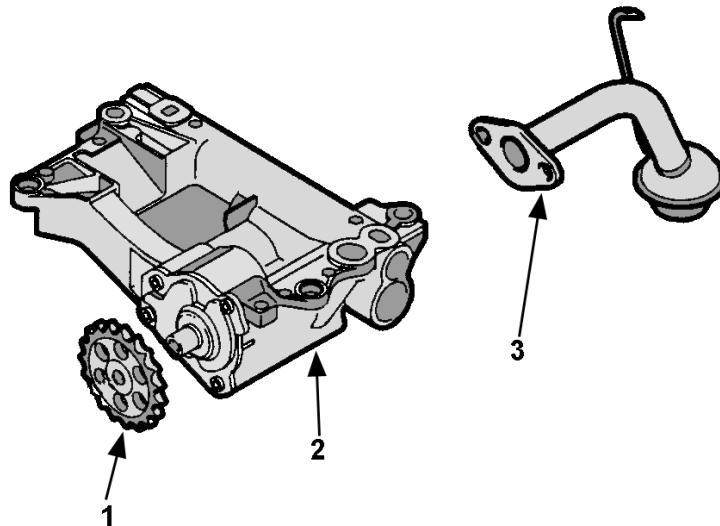


Figure 88

- 1.Pump sprocket
- 2.Pump body
- 3.Pick-up pipe

Crankshaft and main bearings

The crankshaft is carried in 5 main bearings, number 4 main bearing having integral thrust washers for controlling end-float.

Cross-drillings in the crankshaft between adjoining main and big-end bearings are used to divert oil from the main bearings to lubricate the big-end bearings.

The crankshaft seals are made from PTFE. The front end of the crankshaft has a torsional vibration damper with integrated pulley attached for driving the ancillary components.

Each of the bearing caps are of cast iron construction and are attached to the cylinder block by two bolts. The bearing shells are of the split cylindrical type. The upper half shells are grooved to facilitate the supply of lubrication oil to the bearings and fit into a recess in the underside of the cylinder block. The lower half bearing shells are plain and fit into the bearing caps.

Cylinder head components

Cylinder head components

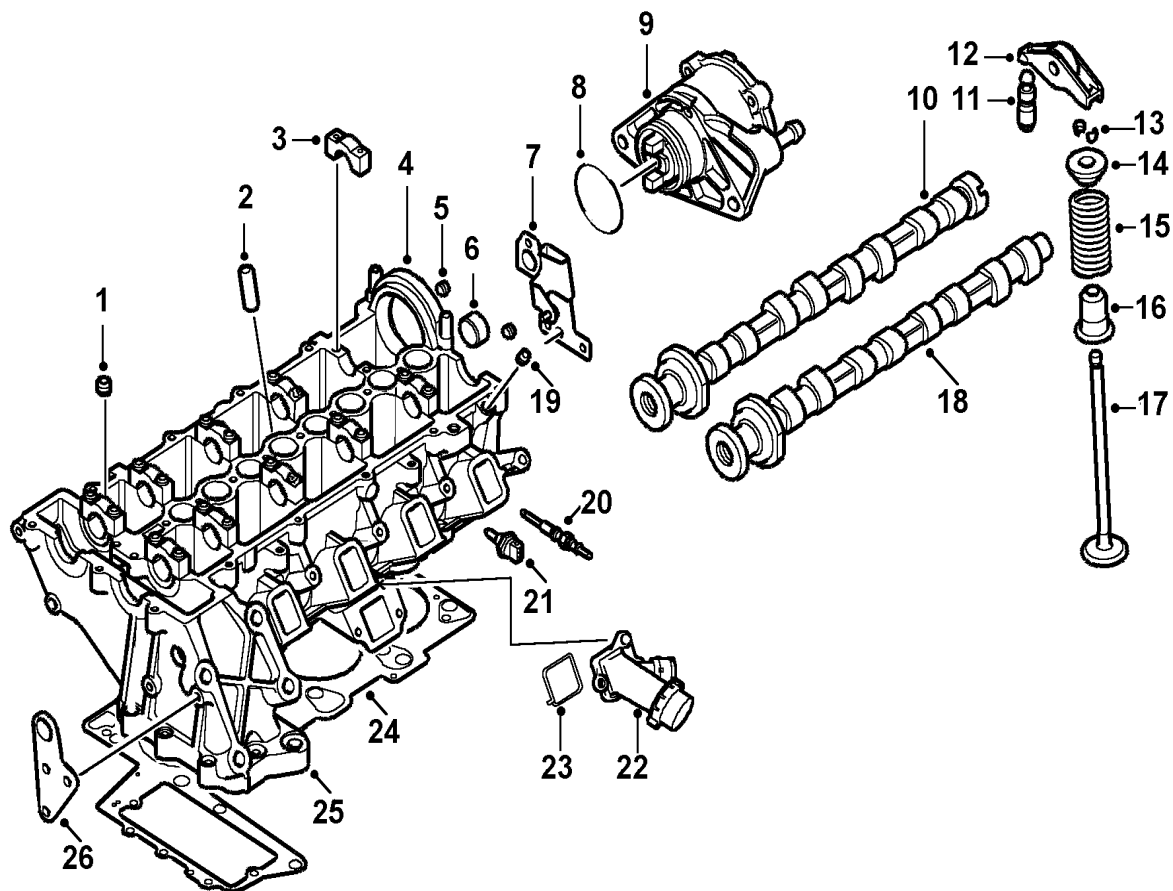


Figure 89

- | | |
|--|--|
| 1.Plug – cylinder head oil channel | 15.Valve spring |
| 2.Valve guide | 16.Valve stem seal |
| 3.Camshaft bearing cap | 17.Valve |
| 4.Vacuum pump bracket | 18.Intake camshaft |
| 5.Plugs – cylinder head (rear) oil gallery | 19.Screw – oil gallery blanking |
| 6.Plug – cylinder head (rear) blanking | 20.Glow plug |
| 7.Engine lifting bracket (rear) | 21.Coolant temperature sensor |
| 8.'O' ring – vacuum pump to cylinder head | 22.Engine coolant hose |
| 9.Vacuum pump | 23.Gasket – coolant outlet elbow to cylinder block |
| 10.Exhaust camshaft | 24.Cylinder head gasket |
| 11.Hydraulic tappet | 25.Cylinder head |
| 12.Rocker | 26.Engine lifting bracket (front) |
| 13.Valve spring collets | |
| 14.Valve spring retainer | |

The cylinder head is of aluminium gravity die casting construction. The cylinder head is bolted to the cylinder block by means of M12 cylinder head bolts arranged beneath each camshaft.

The cylinder head gasket is a multi-layer steel type and is available in three thicknesses. The choice of gasket thickness is dependent on the maximum piston protrusion.

Cylinder head gasket identification

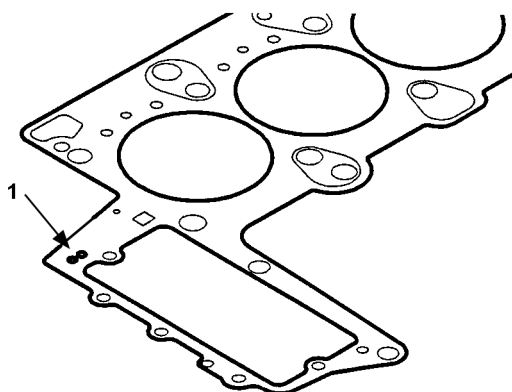


Figure 90

1. Identification holes

The cylinder head has four ports machined at each cylinder location, two exhaust ports and two inlet ports. One of the inlet ports is helical and functions as a swirl port, the other is arranged laterally as a tangential port and functions as a charge port.

The cylinder head cooling system features combined longitudinal/transverse coolant flow. Coolant outlet is through a moulded plastic outlet elbow fixed to the cylinder head by three screws at the centre left hand side of the cylinder head. The coolant thermostat is contained in a cast assembly at the inlet side and is bolted to the water pump which is driven from the ancillary drive belt. The coolant temperature sensor is screwed into an aperture at the rear left hand side of the cylinder head.

The four fuel injection nozzles are centrally mounted above each cylinder and each is fixed to the cylinder head by means of two stud bolts. The central position of the injectors provides a symmetrical spray pattern to the central combustion bowl of the piston.

Glow plugs are arranged centrally on the inlet side of the cylinder head, between the tangential port and the swirl port of each cylinder.

Glow plug location

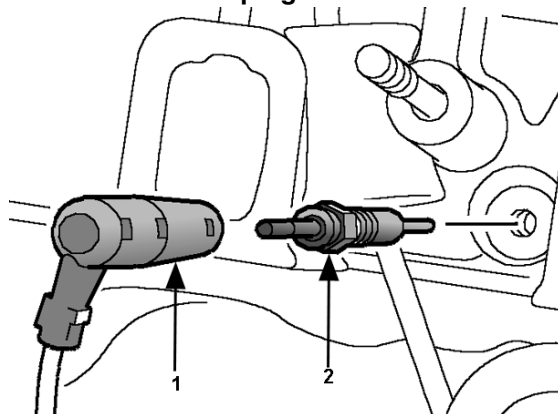


Figure 91

1. Electrical connection
2. Glow plug

A support bracket for the camshaft driven vacuum pump is located at the rear right hand side of the cylinder head.

Vacuum pump

The vacuum pump is located on a support bracket at the rear right hand side of the cylinder head and is driven from the exhaust camshaft.

Camshafts

There is one exhaust camshaft and one intake camshaft. Each of the camshafts are located in five bearings and maintained in position by five bearing caps. Each of the bearing caps are fixed to the cylinder head by two bolts. The camshafts are made using the clear chill casting process and are hollow cast. The cam lobes have a negative cam radius. The camshafts are driven from the crankshaft using a simplex chain and sprocket arrangement.

Each camshaft has eight machined lobes for operating the inlet and exhaust valves through lash adjusters and roller-type finger levers. The exhaust camshaft is machined at the rear end to provide a drive connection for the vacuum pump.

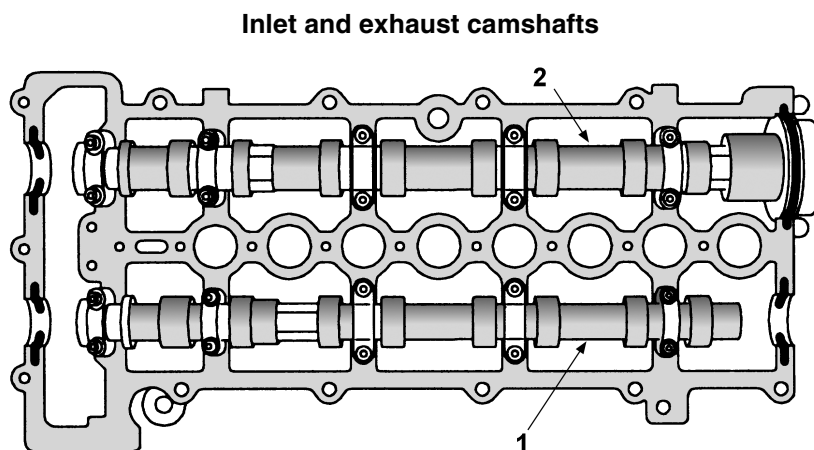


Figure 92

- 1. Inlet camshaft
- 2. Exhaust camshaft

Inlet and exhaust valves

The inlet and exhaust valves are identical and have ground, solid one-piece head and stems made from Nimonic alloy material.

The valve springs are made from spring steel and are of the parallel single-coil type. The bottom end of each spring rests on the flange of a spring retainer which has an integral valve stem seal. The top end of the spring is held in place by a spring retainer which is held in position at the top end of the valve stem by split taper collets. The taper collets have grooves on the internal bore that locate to grooves ground into the upper stems of the valves.

Valve seats and valve guides are an interference fit in the cylinder head.

Hydraulic tappets and roller finger rockers

The valves are operated through roller-type finger rockers and hydraulic tappets, actuated by the camshaft lobes. When the camshaft lobe presses down on the top of a finger rocker, roller mechanism, the respective valve is forced down, opening the effected inlet or exhaust port. The use of this type of actuation method helps reduce friction in the valve timing mechanism.

Roller-type finger rocker location

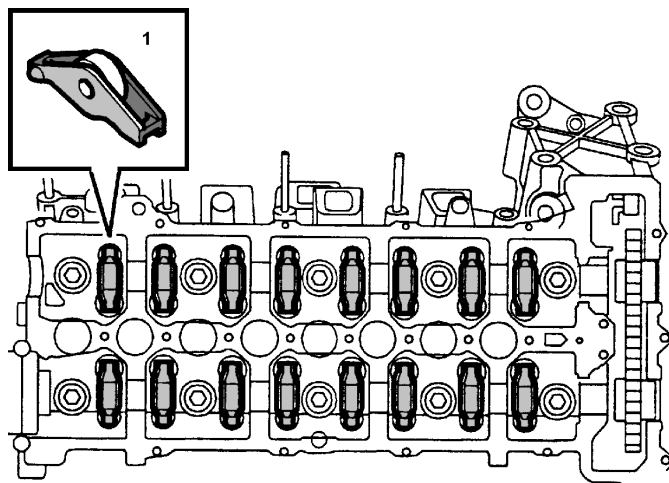


Figure 93

1. Roller-type finger rocker

The body of the hydraulic tappets contains a plunger and two chambers for oil feed and pressurised oil. The pressurised oil is supplied to the tappets via the main oil galleries in the cylinder head and through a hole in the side of the tappet body. The oil passes into a feed chamber in the tappet and then through to a separate pressure chamber via a one way ball valve.

Hydraulic tappet location

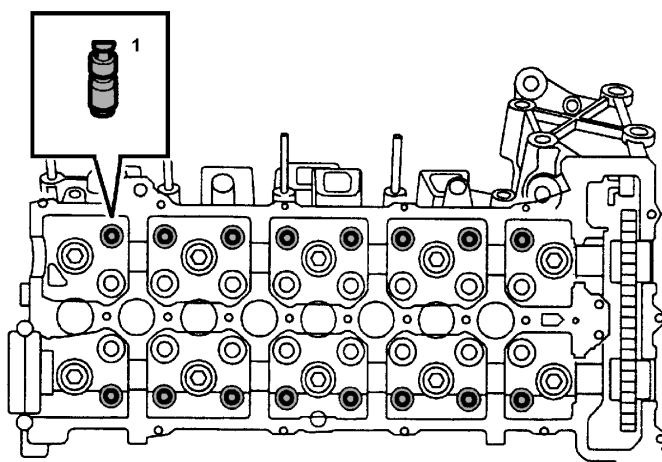
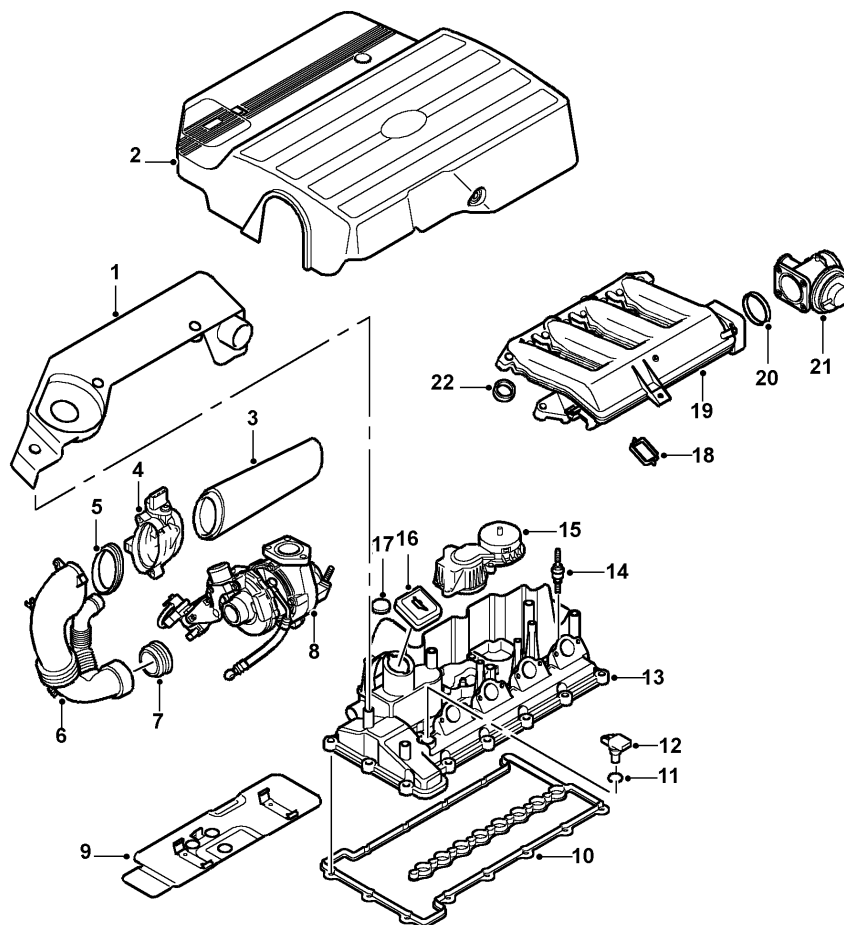


Figure 94

1. Hydraulic tappet

Oil flow from the pressure chamber is determined by the amount of clearance between the tappet outer body and the centre plunger. Oil escapes up the side of the plunger every time the tappet is operated, the downward pressure on the plunger forcing a corresponding amount of oil in the tappet body to be displaced. When the downward pressure from the camshaft and finger rocker is removed (i.e. after the trailing flank of the camshaft lobe has passed), oil pressure forces the tappet's plunger up again. This pressure is not sufficient to effect the valve operation, but eliminates the clearance between the finger rocker and top of the valve stem.

Camshaft cover components



M12 6910

Figure 95

- | | |
|--|--|
| 1. Air cleaner cover | 13. Camshaft cover |
| 2. Acoustic cover | 14. Pillar bolts – camshaft cover to cylinder head |
| 3. Air filter | 15. Oil depression limiter (filter housing) |
| 4. Mass air flow (MAF) sensor assembly | 16. Oil filler cap |
| 5. Grommet – air cleaner upper | 17. Plugs – camshaft cover |
| 6. Duct – Air cleaner assembly to turbocharger | 18. Gasket (tangential ports) – inlet manifold |
| 7. Grommet – air cleaner lower | 19. Inlet manifold assembly |
| 8. Turbocharger | 20. Sealing ring – EGR valve to inlet manifold |
| 9. Camshaft cover blanking plate | 21. EGR valve |
| 10. Gasket – camshaft cover to cylinder head | 22. Gasket (swirl ports) – inlet manifold |
| 11. 'O' ring – camshaft sensor | |
| 12. Camshaft sensor | |

The camshaft cover and engine cover components are described below:

The cover is of moulded plastic construction and is used to seal off the oil chamber in the cylinder head. It shields the oil spray from the camshaft and the chain drive gear and provides the valve gear housing.

An oil separator for the crankcase ventilation system is mounted at the centre top of the cover, which provides preliminary oil separation by cyclone, and fine separation using an internal yarn wrap filter. The separator unit also contains a pressure control valve.

The camshaft cover includes an integrated air filter housing which is de-coupled from the cylinder head to absorb and minimise the transmission of engine noise. The air cleaner is designed in the form of an oval cartridge. The camshaft cover also provides a mounting for the mass air-flow (MAF) sensor.

Camshaft timing train components

Timing train components

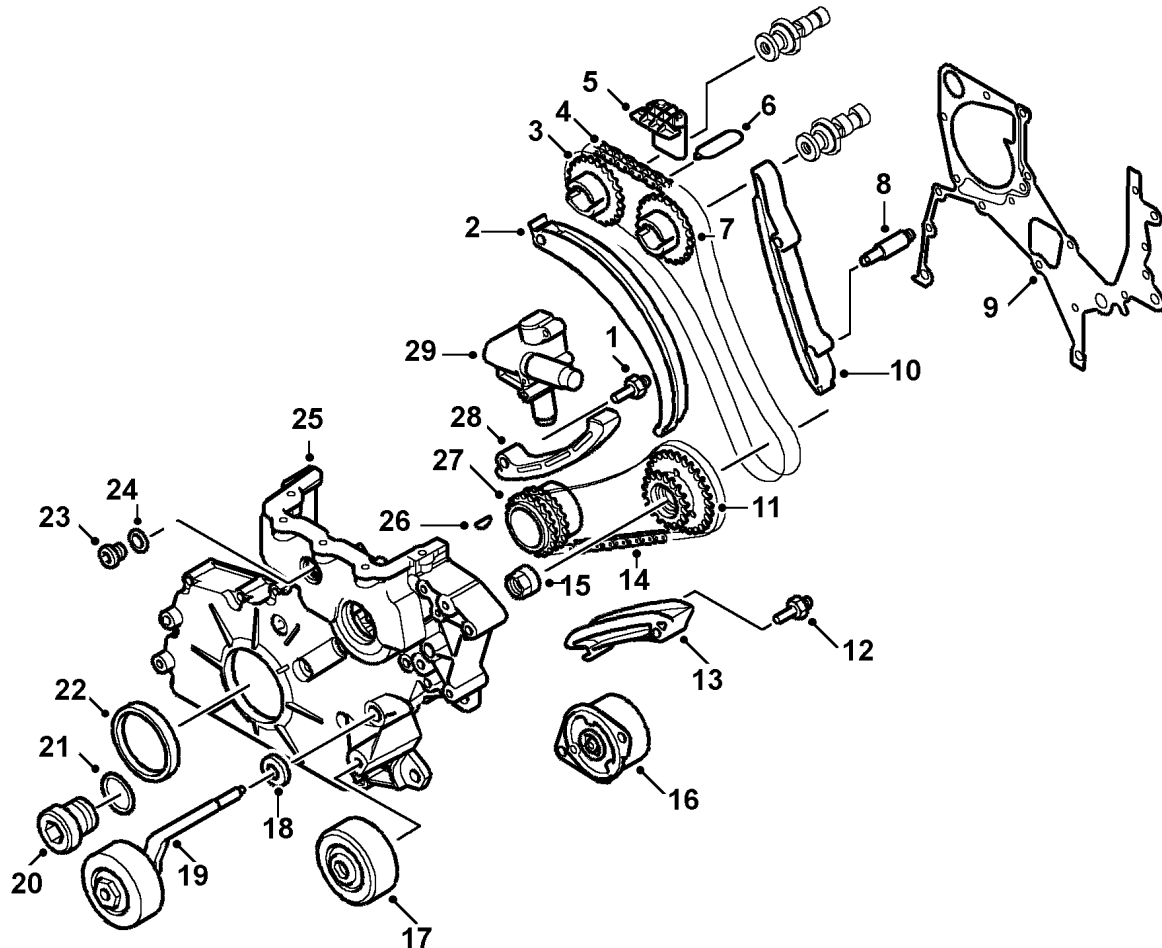


Figure 96

- | | |
|---|---|
| 1.Pin – ancillary drive chain guide (upper) | 16.Ancillary drive belt automatic tensioner |
| 2.Timing chain guide (lower) | 17.Ancillary drive belt deflection pulley |
| 3.Exhaust camshaft sprocket | 18.Sealing washer |
| 4.Timing chain | 19.Ancillary drive belt automatic tensioner pulley |
| 5.Timing chain guide (top) | 20.Blanking plug – timing chain lower cover |
| 6.'O' ring | 21.'O' ring |
| 7.Intake camshaft sprocket | 22.Crankshaft front oil seal |
| 8.Pin – timing chain guide (upper) | 23.Blanking plug – timing chain lower cover |
| 9.Gasket – timing chain lower cover to cylinder block | 24.Washer |
| 10.Timing chain guide (upper) | 25.Timing chain lower cover |
| 11.Fuel injection pump sprocket | 26.Crankshaft Woodruff key |
| 12.Pin – ancillary chain guide (lower) | 27.Crankshaft sprocket |
| 13.Ancillary chain guide (lower) | 28.Ancillary drive chain guide (upper) |
| 14.Ancillary drive chain | 29.Timing chain and ancillary drive chain automatic tensioner |
| 15.Nut – fuel injection pump sprocket to fuel injection pump driveshaft | |

The timing chain cover and timing chain components are described below:

Timing chain cover

The timing chain cover is cast and machined aluminium alloy and is attached to the cylinder block by 14 bolts. Five bolts are used to fix the upper flange of the timing cover to the cylinder head casting, and a further four bolts secure the front of the sump to the timing cover. The bottom of the timing cover is located to the front face of the cylinder block by two metal dowels.

The front of the crankshaft passes through a hole in the timing cover, and an oil seal is used to seal the interface between the front of the crankshaft and the timing cover.

Timing chains

Two chain drives are utilised. The timing chain between the crankshaft sprocket and the fuel injection pump sprocket is a simplex type. The timing chain is contained between one fixed and one hydraulically adjustable tensioning rail.

The chain drive from the fuel injection pump sprocket to the two camshaft sprockets is also a simplex type. The chain between the camshaft and injection pump runs between one fixed guide rail and a hydraulically adjustable tensioning rail to minimise chain flutter. An additional plastic chain guide is located above the two camshaft sprockets.

The adjustable tensioning rails are of aluminium die casting construction with clip-fastened plastic slide linings. The fixed guide rails are moulded plastic. The tensioner rails are attached to the front of the cylinder blocks using pivot bolts which allow the tensioner rail to pivot about its axis.

The hydraulic tensioner for both chains is provided from a single unit which contains two hydraulically operated plungers that operate on the tensioning rails at the slack side of each of the timing chains. Pressurised oil for the adjuster is supplied through the back of the unit from an oil supply port in the front of the cylinder block. The lateral movement in the tensioner arm causes the timing chain to tension and consequently, compensation for chain flutter and timing chain wear is automatically controlled.

The timing chains are oil splash lubricated via the oil pump and chain tensioner. Oil spray is directed to the chain from several oil supply ports in the front of the cylinder block and cylinder head.

An additional chain from the crankshaft sprocket connects to the oil pump sprocket for oil pump operation.

Drive chain structure

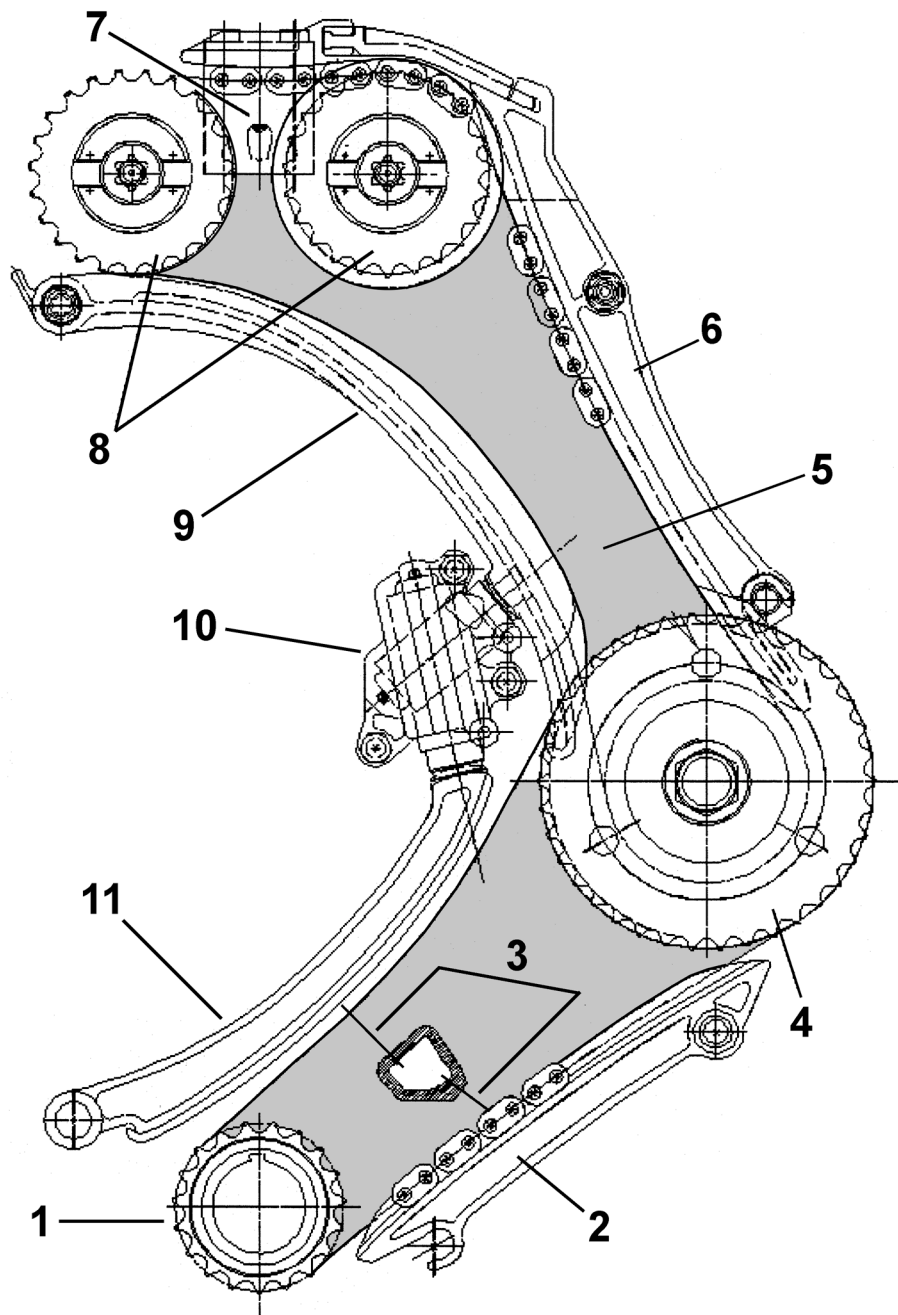


Figure 97

- 1.Crankshaft sprocket
- 2.Guide rail
- 3.Oil spray nozzles
- 4.High pressure pump sprocket
- 5.Oil spray nozzle
- 6.Guide rail
- 7.Oil spray nozzle
- 8.Camshaft sprockets
- 9.Tensioning rail
- 10.Chain tensioner
- 11.Tensioning rail

Lubrication circuit

Oil from the sump is drawn up through a fabricated metal pick-up pipe which contains a mesh to filter out any relatively large pieces of material which could cause damage to the oil pump. The head of the pick-up is centrally immersed in the sump oil and oil is delivered to the inlet side of the eccentric rotary pump.

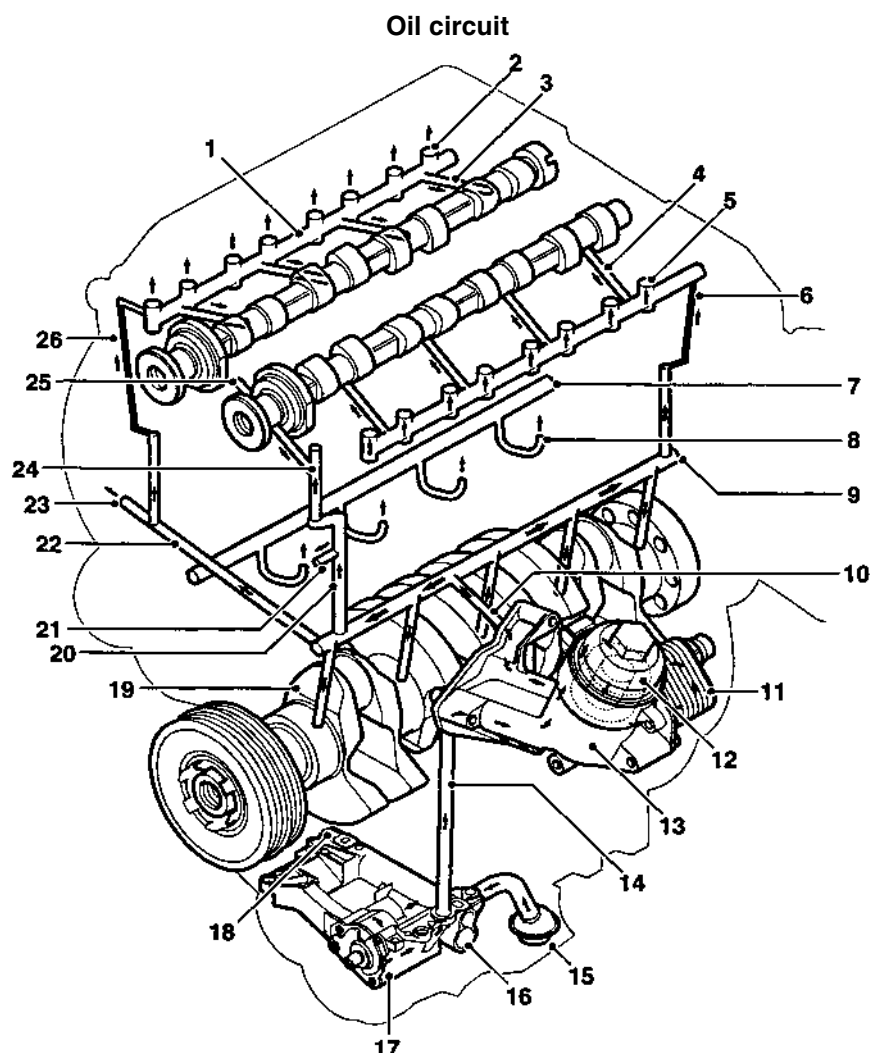


Figure 98

- | | |
|---|--|
| 1. Hydraulic tappet gallery | 14. Oil pump to oil filter housing channel |
| 2. Hydraulic tappet, exhaust side | 15. Oil pick-up pipe |
| 3. Channels to camshaft bearings, exhaust side | 16. Pressure relief valve |
| 4. Channels to camshaft bearings, inlet side | 17. Oil pump assembly |
| 5. Hydraulic tappet, inlet side | 18. Port to cylinder block main gallery, right hand side |
| 6. Riser channel to tappet gallery, intake side | 19. Oil feed channels to crankshaft main bearings |
| 7. Cylinder block main gallery feed to lubrication jets | 20. Riser channel for chain lubrication jets |
| 8. Piston lubrication jets | 21. Pressure supply to chain tensioner |
| 9. Cylinder block main oil gallery feed for crankshaft bearings | 22. Pressure supply channel for turbocharger bearing lubrication |
| 10. Oil filter housing to cylinder block | 23. Out put port for turbocharger oil feed |
| 11. Oil cooler | 24. Riser channel for upper chain lubrication |
| 12. Oil filter element | 25. Pressure supply for upper chain lubrication |
| 13. Oil filter housing | 26. Riser channel for tappet gallery |

The oil pump is driven from the crankshaft by a chain and sprocket system. Pressurised oil from the pump is passed through a port in the bottom of the cylinder block and is directed up to the oil inlet port of the oil filter housing via a port in the right hand side of the cylinder block. The oil pump contains an oil pressure relief valve which opens to allow oil to be recirculated back around the pump if the oil pressure increases to a high enough level.

The inlet port of the oil filter housing has an integral non-return valve which allows flow into the filter, but prevents unfiltered oil draining back out of the filter housing when oil pressure is reduced.

The oil passes through the oil filter element and out to the oil cooler. The percentage of oil flow passed through to the oil cooler is dependent on a thermostatic by-pass valve which is integrated into the oil filter housing. An increase in oil temperature causes the by-pass valve to open and allow a greater percentage of oil flow to be directed through the oil cooler. The remainder of the oil flow from the outlet side of the filter element is directed to the outlet port of the oil filter housing where it combines with the oil flow being returned from the oil cooler before being passed back into the cylinder block.

An oil pressure switch is included in the outlet port of the oil filter housing to sense the oil pressure level before the oil flow enters the main oil gallery in the engine block. A warning lamp in the instrument pack is switched 'on' if the oil pressure is detected to be too low.

Oil pressure switch location

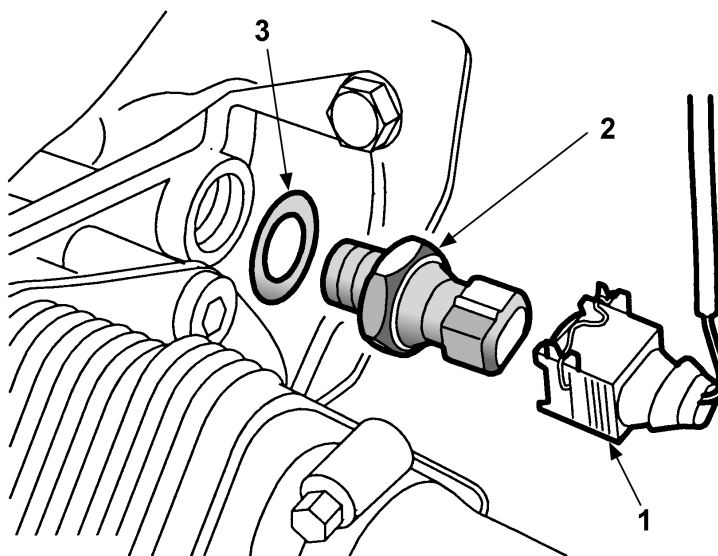


Figure 99

- 1. Electrical connection
- 2. Oil pressure switch
- 3. Sealing washer

The oil entering the cylinder block main gallery passes through drillings to the crankshaft main bearings and cross drillings in the crankshaft direct oil to the big-end bearings. An additional four drillings in the cylinder block supply oil at reduced pressure to the lubrication jets for piston and cylinder cooling and gudgeon pin lubrication.

A cross channel from the left hand main oil gallery crosses to the right hand side of the cylinder block where there is an outlet port which provides a pressurised oil supply to the turbocharger bearings via a banjo connection and external piping.

Riser channels at the front right hand side and rear left hand side of the cylinder block are used to channel oil to mating ports in the cylinder head and provide a source for cylinder head lubrication and operating pressure for the hydraulic tappets.

Oil is fed through oil galleries at the left hand and right hand sides of the engine and four cross channels from each gallery directs oil to the camshaft bearings. Lubrication oil fed to the tappets passes up through the tappet body to the finger rockers for lubrication of the surfaces between the finger rockers and the camshaft lobes.

Tapered plugs seal the cylinder head main oil galleries at the rear of the cylinder head, and an additional tapered plug is included inside the cylinder head at the front of the right hand gallery.

An additional riser channel from the cylinder block left hand main oil gallery is used to supply lubrication to the timing chain system through several outlet ports at the front of the cylinder block and cylinder head.

Emission control

The vehicle is fitted with the following control systems to reduce emissions released into the atmosphere:

Emission control components

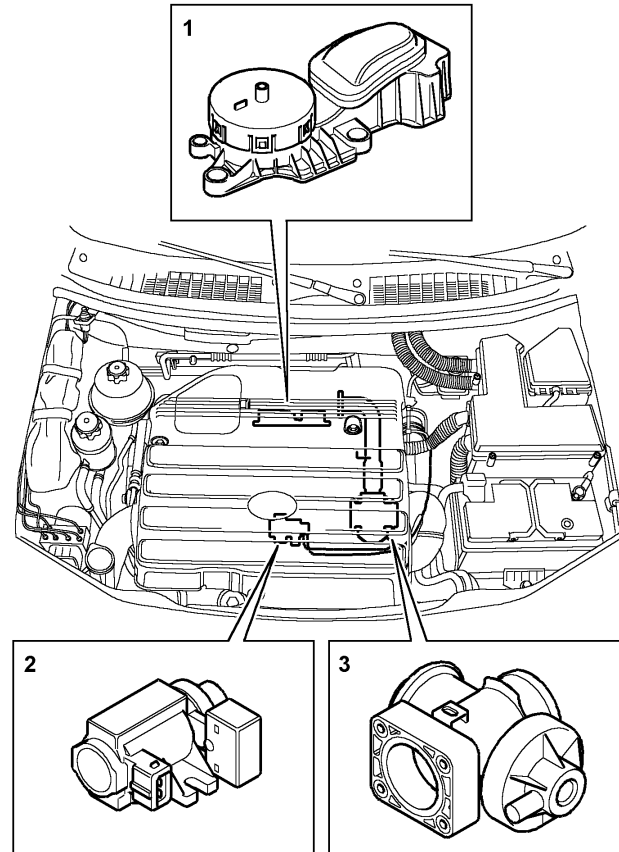


Figure 100

- 1.Crankcase emission control
- 2.Exhaust emission control
- 3.Exhaust gas recirculation

The emission control systems fitted to the vehicle are designed to keep the emissions within the legal limits, at the time of manufacture, provided that the engine is correctly maintained and is in good mechanical condition.

Crankcase emission control

Crankcase emissions are vented into the turbocharger inlet duct via a depression limiter valve installed on the camshaft cover. A dedicated bore in the cylinder block and cylinder head connect the crankcase to the inlet of the depression limiter valve. The outlet of the depression limiter valve is connected to the turbocharger inlet duct by a passageway integrated into the camshaft cover and a tube between the camshaft cover and the inlet duct.

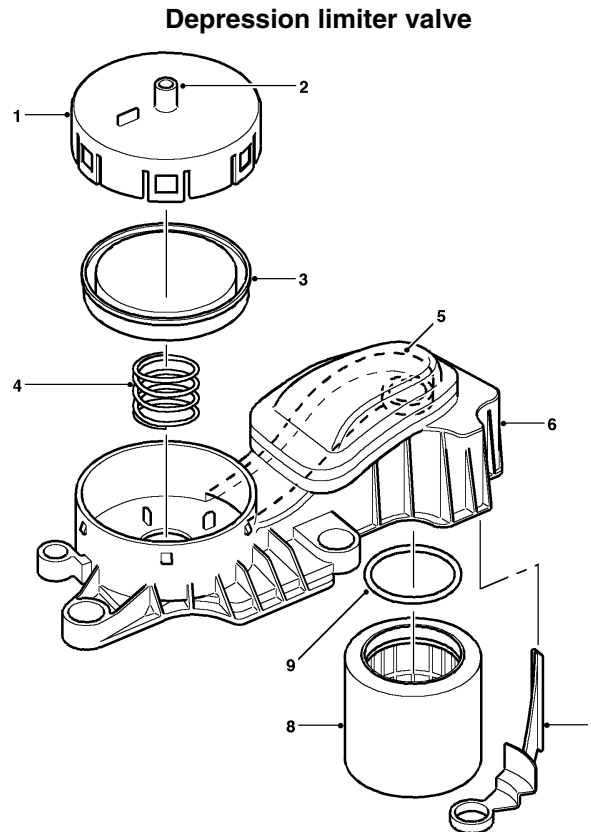


Figure 101

- 1.Cap
- 2.Atmospheric vent
- 3.Diaphragm valve
- 4.Spring
- 5.Integral passageway
- 6.Housing
- 7.Locating arm
- 8.Oil separator
- 9.'O' ring

The housing of the depression limiter valve contains two chambers interconnected by an integral passageway.

One chamber contains an oil separator consisting of yarn wound onto a cylindrical cage and covered with a fibre gauze sleeve. The cage is closed at one end and open at the other. The open end of the cage locates over one end of the integral passageway in the housing. An 'O' ring seals the joint between the cage and the housing.

The second chamber contains a diaphragm valve and a spring. The diaphragm valve is installed in the cap of the chamber and located, by the spring, over an outlet port into the passageway in the camshaft cover. When the cap is installed the diaphragm valve forms a seal between the upper and lower parts of the chamber. An atmospheric vent in the cap exposes the top of the diaphragm to ambient pressure.

Crankcase emissions schematic

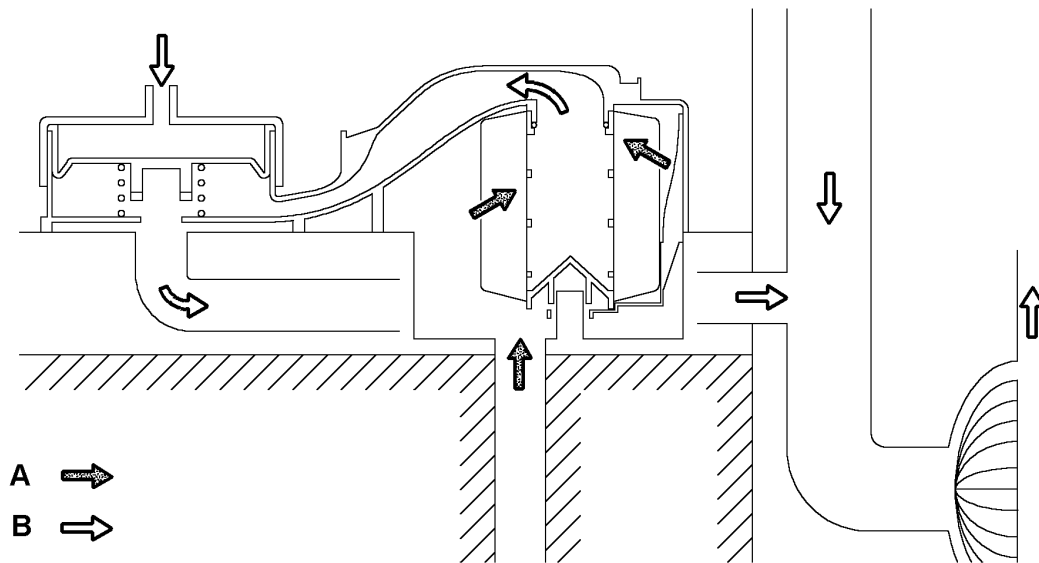


Figure 102

- a. Crankcase emissions
- b. Clean air

The diaphragm valve is normally held open by the spring. With the engine running, blow-by gases are drawn from the crankcase, through the depression limiting valve, by the depression in the turbocharger inlet duct. Any oil in the blow-by gases is removed by the oil separator and drains back to the sump through the bore in the cylinder block and cylinder head. The depression in the turbocharger inlet duct varies with engine speed and load. To limit the depression in the crankcase, the diaphragm valve controls the flow of blow-by gases through the depression limiting valve. Crankcase pressure is sensed on the underside of the diaphragm valve and, when crankcase pressure reduces to the preset limit, ambient pressure acting on the top of the diaphragm valve overcomes the spring and moves the diaphragm valve to close the outlet port. As the diaphragm valve closes, so blow-by gases begin to increase the pressure in the crankcase again until the diaphragm valve moves to open the outlet port.

Exhaust Gas Recirculation (EGR)

During certain running conditions the EGR system directs exhaust gases into the inlet manifold to be used in the combustion process. The principal effect of this is to reduce combustion temperatures, which in turn reduces NO_x emissions.

A vacuum operated EGR valve on the inlet manifold controls the flow of recirculated exhaust gases. The exhaust gases are supplied to the valve through a pipe connected to the left hand end of the exhaust manifold. From the EGR valve, the gases flow into the inlet manifold and the turbocharger inlet.

The EGR valve is controlled by an EGR solenoid valve, on the front of the cylinder block, which modulates a vacuum supply from the brake servo vacuum pump. The EGR solenoid valve is controlled by the ECM. The ECM uses the input from the air flow meter to monitor EGR operation, using the principle that an increase in EGR decreases the intake air flow.

Exhaust gas re-circulation cooling

Land Rover is employing an exhaust gas re-circulation cooling system on diesel vehicles fitted with automatic transmission. Due to the fuelling strategy used to compensate for any power loss through the automatic transmission, there tends to be a slight increase in NOx emissions.

EGR cooling can reduce NOx emissions by up to 15% and particle emissions by up to 8%.

The EGR cooler is fitted in the EGR line between the exhaust manifold and the EGR valve. The exhaust gas flows through a series of pipes surrounded by coolant.

Exhaust emission control

The engine management system provides accurately metered quantities of fuel to the combustion chambers to ensure the most efficient use of fuel and to minimise the exhaust emissions. In European Union markets, to further reduce the carbon monoxide and hydrocarbons content of the exhaust gases, a catalytic converter is integrated into the intermediate pipe of the exhaust system.

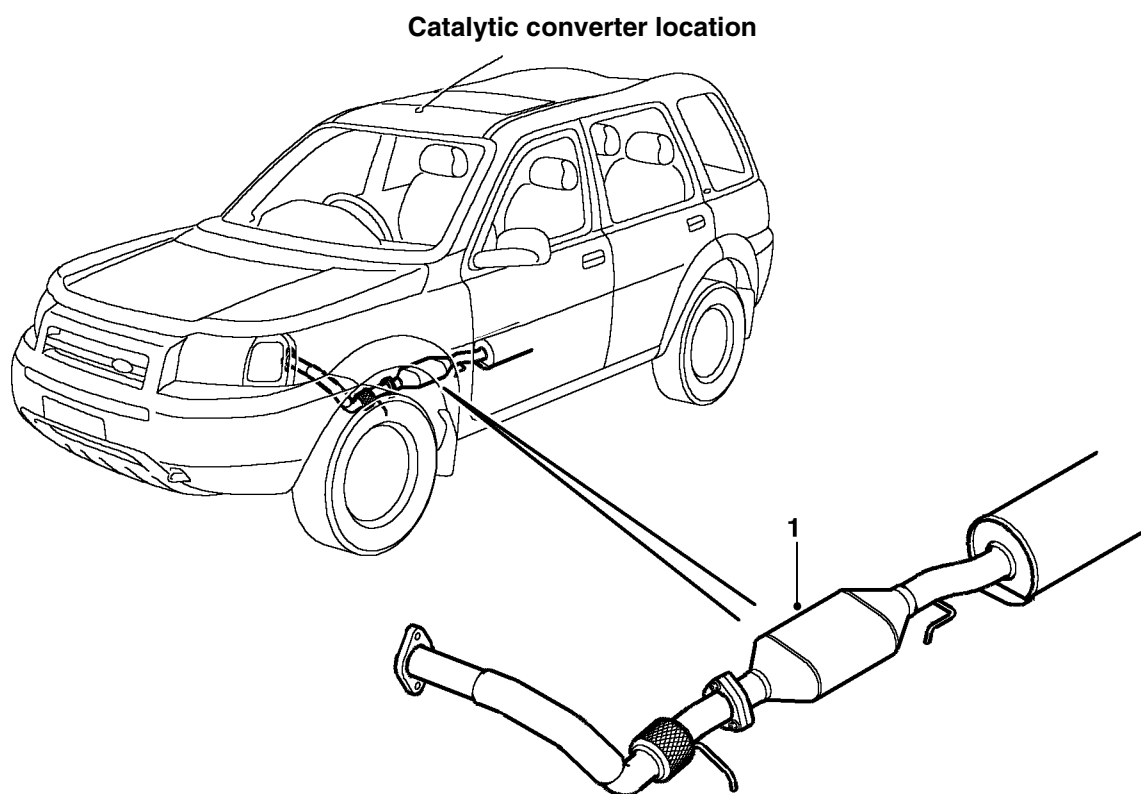


Figure 102

1.Oxidising catalytic converter

In the catalytic converter the exhaust gases are passed through honeycombed ceramic elements coated with a special surface treatment called 'washcoat'. The washcoat increases the surface area of the ceramic elements by a factor of approximately 7000%. On top of the washcoat is a coating containing platinum, which is the active constituent for converting harmful emissions into inert by-products. The platinum adds oxygen to the carbon monoxide and the hydrocarbons in the exhaust gases, to convert them into carbon dioxide and water respectively.

Introduction to the common rail fuel delivery system

A research company by the name of Elasis in Naples, developed common rail technology. In 1993 an Italian company produced a prototype of their new fuel injection system. Problems with the tolerances of the injectors stopped the planned volume production and prompted the search for a partner at the turn of the year 1993/94. Bosch bought the patents and took over Elasis.

Bosch presented the new system to the market one year earlier than any other manufacturer.

Requirements

Increasingly stringent regulations governing exhaust and noise emissions and the demand for lower fuel consumption mean that the injection system of a diesel engine must consistently fulfil new requirements.

- Highest possible metering accuracy over the entire service life
- Pre-injection and main injection
- It is possible to independently determine the injection pressure and injection volume for every operating point of the engine which gives additional degree of freedom for ideal mixture preparation
- The injection volume and pressure should be as low as possible at the start of injection to prevent ignition delay between the start of injection and the start of combustion to obtain smoother engine operation (pre-injection)

Functional principle

The Freelander is the first Land Rover diesel engine to be equipped with a high-pressure accumulator fuel injection system (common rail). With this new fuel injection process, a high-pressure pump delivers a uniform level of pressure to the shared fuel line (the common rail) which serves all the fuel injectors. Pressure develops to an optimum level for smooth operation. This means that each injector nozzle is capable of delivering fuel at pressures of up to 1300 bar.

The common rail system disconnects fuel injection and pressure generation functions. Fuel injection pressure is generated independently of the engine speed and fuel injection volume and is made available in the rail (high pressure fuel accumulator) for injection to the cylinders.

The fuel injection timing and fuel volume are calculated individually in the EDC control unit and delivered to each engine cylinder by the injectors, each of which is actuated by energising the appropriate solenoid valve.

Advantages:

1. Fuel injection at exactly the right moment
2. Precisely metered fuel quantity
3. Constant high pressure
4. Fuel consumption optimised
5. Emission reduction
6. Very smooth engine operation
7. Pre-injection:
 - The ignition delay at the point of main injection is shortened
 - Combustion pressure peaks are reduced (Smoother combustion)
 - Emissions are reduced
8. Main injection:
 - Variable operating pressure according to engine demands
 - The injection pressure remains constant over the entire injection period thus enabling more accurate volume metering
 - The main injection is responsible for torque generation

System structure

The fuel system is divided into 2 sub-systems:

- Low-pressure system
- High-pressure system

The low-pressure system features the following components:

- Fuel tank
- Advance fuel pump (in tank)
- Outlet protection valves
- In-line electric fuel pump
- Fuel filter with outlet pressure sensor
- Pressure relief valve (low pressure system)

and in the fuel return line:

- Fuel cooling control (bimetal valve)
- Fuel cooler

The high-pressure system features the following components:

- High-pressure fuel pump
- Fuel high-pressure accumulator (rail)
- Pressure control valve
- Rail pressure sensor
- Injectors

Common rail fuel system

The diesel fuel system consists of an extra, under-bonnet, fuel pump and fuel return lines. Also, a diesel cooler is fitted to the fuel tank return line. Unlike the in-tank filter fitted to petrol derivatives, the diesel filter is fitted externally to the tank in an under-bonnet location.

The extra pump is fitted before the fuel filter and increases the pressure to assist the fuel through any potential blockage of the filter during cold starts. The extra pump helps to ensure all engine-fuelling requirements are satisfied in all conditions.

A pressure regulator is located after the filter and relieves fuel into the secondary pump feed.

Fuel leaves the tank and is transferred to a secondary low-pressure fuel pump. The ECM via a single relay controls both the primary and secondary low-pressure fuel pumps. The spill return from the high-pressure pump and injectors is returned to the tank via a connection to the right hand section of the fuel tank.

The ECM detects pressure in the low-pressure side of the system via a pressure sensor installed in the fuel filter head. The sensor output is required by the ECM to determine if the high-pressure fuel pump is receiving sufficient pressure. If the ECM detects insufficient inlet pressure to the high-pressure fuel pump, it will reduce engine speed and fuel rail pressure accordingly to prevent damage to the high-pressure fuel pump.

Conventional injection characteristics

In conventional injection systems, such as the use of distributor and in-line injection pumps, only a single injection takes place. Pressure generation is coupled to injection volume preparation.

This has the following consequences for the injection characteristics:

- The injection pressure rises as the engine speed and injection quantities increase
- The injection pressure decreases during injection

As a result:

- At low pressures small quantities are injected
- The peak pressure is more than twice the average fuel injection pressure

Peak pressure determines the load, which can be applied to the components of an injector pump and its drive unit.

The average injection pressure is, however, important for the quality of the fuel/air mixture in the combustion chamber.

Common rail injection characteristics

Common rail fulfils the following demands:

- It is possible to independently determine the injection pressure and injection volume for every operating point of the engine which gives an additional degree of freedom for the ideal mixture preparation
- After the start of combustion, it should be possible to select the injection pressure throughout the entire period of injection

These requirements have been fulfilled in the common rail, accumulator injection system with preliminary and main injection.

Noise and vibration characteristics are affected to a large extent by the degree of combustion. Therefore, a carefully planned adaption of fuel injection has taken on an important role. The influencing of the engine combustion takes place by means of a preliminary injection in the common rail system. This makes disturbance-free combustion at lowest noise levels possible.

Because of its modular design the system can be easily matched to various engines; the conventional injection nozzle holder, can be substituted by the common rail injectors and the high-pressure pump can be mounted on the engine. The transition from conventional system to a common rail system can thus be made quite easily. A comparison between the conventional and common rail component structure can be seen in table 'Component comparison'.

Component comparison

Description	Common rail system	Conventional system
High pressure generation	High pressure pump	Distributor-type injection pump
Pressure distribution	Thick high-pressure lines	High-pressure lines
Supply reservoir	Rail	N/A
Injection	Injector - electronic	Injection nozzle - mechanical

Fuel delivery system structure

The structure of the fuel delivery system and its individual components are described below:

Fuel system schematic

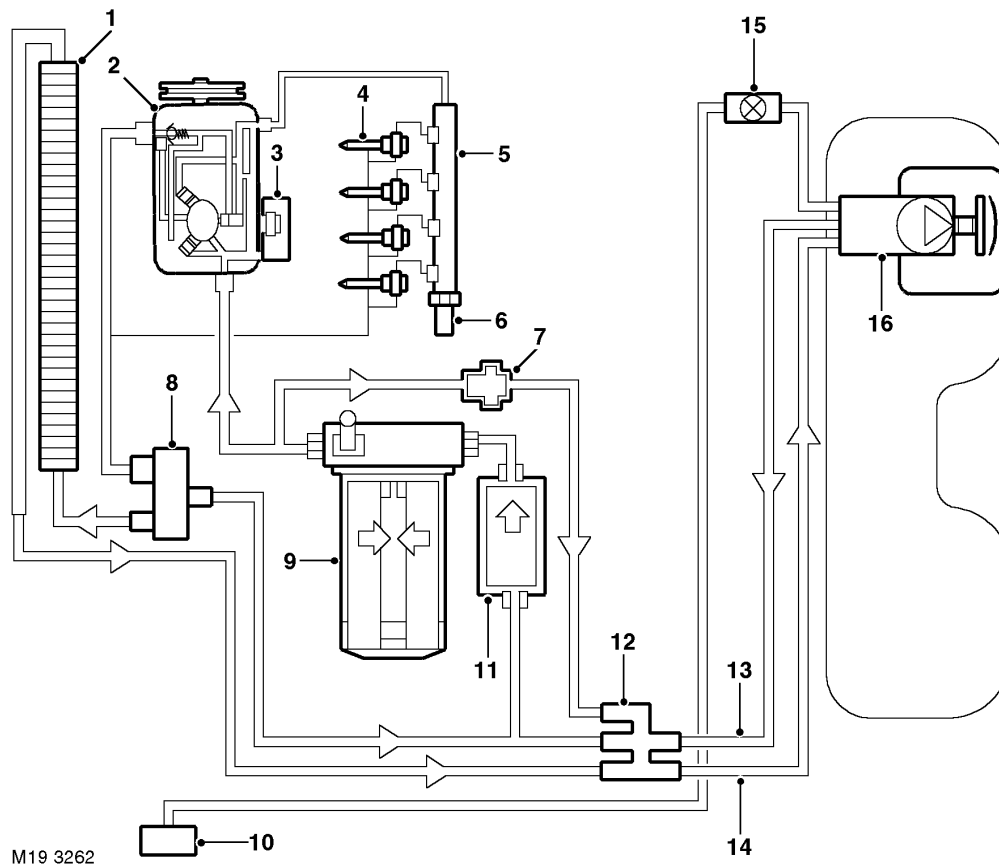


Figure 103

- | | |
|--|--|
| 1. Fuel cooler | 11. Secondary Low-pressure fuel pump |
| 2. High-pressure fuel pump | 12. Restrictor |
| 3. Fuel pressure control valve | 13. Supply from primary Low-pressure fuel pump |
| 4. Electronically controlled injectors (x 4) | 14. Spill return to fuel tank |
| 5. Fuel rail | 15. One way valve |
| 6. Rail pressure sensor | 16. Primary Low-pressure fuel pump |
| 7. Differential pressure valve | |
| 8. Bimetallic valve | |
| 9. Filter | |
| 10. Vent to atmosphere | |

Fuel tank

The fuel tank is located on the underside of the vehicle, forward of the rear suspension subframe. The tank is constructed from moulded plastic and is retained by a tubular cradle which is bolted to the vehicle floorpan with four bolts. A reflective metallic covering shields the tank from heat generated by the exhaust system.

The fuel tank has a capacity of 60 litres (13.2 gallons).

An aperture in the top surface of the tank allows for the fitment of the primary low-pressure fuel pump.

The fuel tank filler is located on the right-hand rear wing panel and is protected by a lockable cap. The plastic tube from the filler is connected to the tank by a flexible rubber tube and secured with clamps. A small vent pipe allows air and vapour displaced by the fuel to escape to atmosphere during filling of the tank.

The fuel tank incorporates a 'Roll Over Valve' (ROV) to allow the vapour in the tank to escape to atmosphere. The tank must not be over-filled to maintain a vapour space above the fuel level and allow the tank to 'breathe'. The ROV is welded onto the top surface of the tank and is vented to atmosphere near to the filler cap via a pipe. During normal operation the ROV is open allowing vapour to pass to atmosphere. In the event of the vehicle being overturned the ROV shuts-off, sealing the tank and preventing fuel flowing down the vent pipe.

Primary low-pressure fuel pump

The primary low-pressure pump is located in an aperture in the top face of the fuel tank. The pump is sealed in the tank with a rubber seal and secured with a locking ring, which requires a special tool for installation and removal. Access to the pump is via an access panel located below the right-hand rear seat.

An electrical connector on top of the pump supplies power and ground connections for the pump and the fuel gauge potentiometer. The pump receives a power supply from the fuel pump relay.

The pump is submerged in the fuel tank and draws fuel from an integral swirl pot which maintains a constant fuel level around the pick-up. The swirl pot also mixes warm fuel returning to the tank with cool fuel in the tank.

A float operated potentiometer is also located on the pump and provides a variable resistance to earth for an output from the fuel gauge to the instrument pack. The potentiometer float moves with the fuel level in the tank and the resultant resistance is interpreted by the gauge for the level of the remaining fuel.

The pump has a connection for a fuel supply to the burning heater pump, located in the right-hand wheel arch, on vehicles fitted with this option.

Secondary low-pressure fuel pump

The secondary low-pressure fuel pump is located in a plastic housing, adjacent to the fuel filter, in the engine compartment on the left-hand inner wing.

The pump is a secondary in-line pump designed to aid fuel flow through the filter in cold condition. The pump has a fuel input pipe connection at the bottom and a fuel output pipe connection to the filter at the top. An electrical connector on the top of the pump supplies power and ground connections for the pump motor. The pump receives a power supply from the fuel pump relay, simultaneously with the primary pump. Both pumps are operated together under all conditions.

Fuel filter

The fuel filter is located in a plastic housing, adjacent to the secondary low-pressure fuel pump in the engine compartment on the left-hand inner wing.

The fuel filter cleans fuel from the fuel tank and helps prevent premature wear to delicate components. Insufficient filtration can cause damage to pump components, pressure valves and fuel injection nozzles.

To prevent clogging up the filter at low temperatures, there is a bimetal valve in the return line. This valve prevents heated fuel residue from mixing with cool fuel from the tank.

Fuel pump relay

The fuel pump relay is located on a bracket on the 'A' post, adjacent to the passenger compartment fusebox. When energised, the relay supplies power to the primary and secondary low-pressure fuel pumps.

In the event of a fuel pump relay failure any of the following symptoms may be observed:

- Engine stalls or will not start
- No fuel pressure at the fuel rail

Low Pressure fuel sensor

The low-pressure fuel sensor is located in the fuel filter housing, adjacent to the battery box in the engine compartment.

Low-pressure fuel sensor location

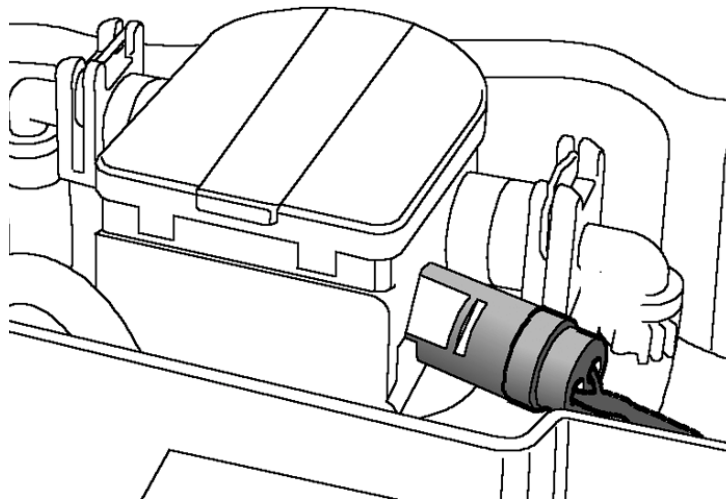


Figure 104

It supplies a signal to the ECM, which corresponds with fuel pressure in the fuel filter.

Output from the low-pressure fuel sensor is a variable voltage signal dependent upon fuel pressure.

In the event of a low-pressure fuel sensor failure the 'check engine' light will be illuminated.

High-pressure side

The high-pressure fuel pump supplies fuel to the fuel rail.

High-pressure fuel rail

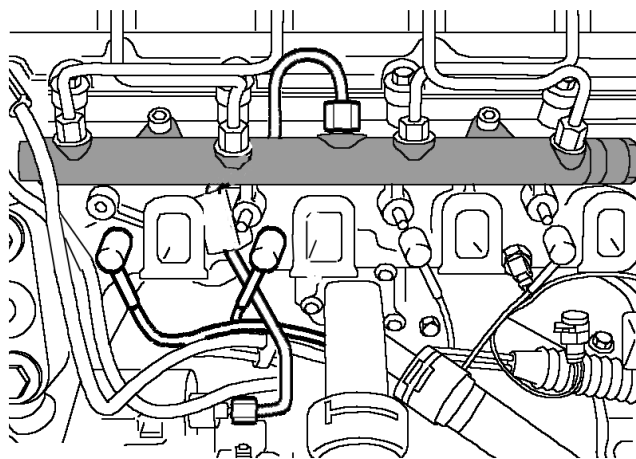


Figure 105

The pump is directly driven by the engine and is located at the front of the engine block. Fuel rail pressure is variable to allow for fuelling strategies such as noise limitation and surge control. The maximum fuel pressure is 1300 bar.

Fuel pressure is controlled by the ECM via the fuel pressure regulator valve located at the rear of the high-pressure fuel pump. The ECM uses the output signal from the fuel rail pressure sensor, mounted on the end of the fuel rail, to maintain the optimum fuel pressure for the current conditions. The fuel pressure regulator reduces pressure by diverting fuel from the high-pressure output back to the fuel tank.

The minimum operating pressures are, 200 bar during cranking, and 300 bar during idle, failure to reach these pressures will result in a non-start situation, stalling or erratic idle.

Fuel return system

The diverted fuel from the pressure regulator is hot, due to the pumping process within the high-pressure fuel pump, and must be passed through a fuel cooler before it returns to the fuel tank. If the fuel is not over a predetermined temperature, a bimetallic bypass valve directs the fuel to the fuel tank.

If the fuel temperature is above the predetermined temperature, fuel is directed back to the fuel tank via the fuel cooler.

Fuel cooler

The fuel cooler is located below the bonnet locking platform. Diesel fuel becomes heated during pressurisation in the high-pressure pump.

Ambient heat in the engine bay also contributes to the heating of the fuel returning to the fuel tank. To avoid problems associated with the lower viscosity of high temperature fuel, the returning diesel fuel is diverted into the cooler, if it is over 73 °C (163 °F), via a bimetallic valve.

Bimetallic valve

The bimetallic valve controls the fuel flow into the fuel cooler. It is located on the inlet pipe connection to the fuel cooler. The valve contains a bimetallic strip, which moves according to the temperature of the fuel flowing over it. If the temperature of the returning fuel is less than 73 °C (163 °F), fuel is diverted into the inlet supply of the secondary low pressure pump, with any remaining fuel being returned to the swirl pot in the tank. If the temperature of the returning fuel is more than 73 °C (163 °F), the bimetallic valve diverts the fuel through the fuel cooler before it returns to the swirl pot in the tank.

Pressure relief valve

The five-port pressure relief valve is located at the bottom of the left-hand inner wing, near the bulk head. The valve is manufactured from moulded plastic and is secured to the inner wing with a plastic clip.

The valve intersects the fuel return line from the fuel cooler. The valve also intersects the pressure supply to the secondary low-pressure pump. A connection to this line joins the fuel return line from the bimetallic valve to the fuel cooler return line to allow returning fuel to recirculate through the secondary pump.

Fuel pressure control valve

The pressure control valve is mounted on the high-pressure pump and controls the fuel pressure within the fuel rail.

Pressure control valve location

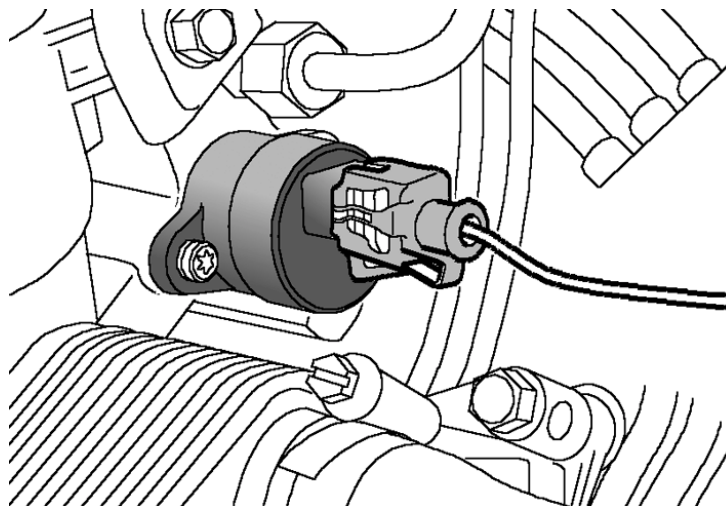


Figure 106

It is an electrically operated solenoid valve controlled by the ECM with only two states, open and closed. When de-energised, the valve is held closed by a spring, diverting fuel to the return line. This decreases the fuel pressure in the fuel rail. In this state fuel rail pressure is approximately 100 bar. When energised, the valve is closed, allowing maximum fuel pressure in the fuel rail. This pressure can reach approximately 1300 bar. The ECM controls the fuel rail pressure by operating the pressure control valve with a pulse width modulated signal. The longer the opening time (duty cycle) of the valve, the lower the pressure in the fuel rail. The shorter the opening time (duty cycle) of the valve, the higher the pressure in the fuel rail.

The pressure control valve receives a PWM signal of 0-12 volts from the ECM. ECM actuation of the pressure regulator is determined by the following:

- Fuel rail pressure
- Engine load
- Accelerator pedal position
- Engine temperature
- Engine speed

In the event of a pressure regulator failure, any of the following symptoms may be observed:

- Engine will not start
- Severe loss of power
- Engine stalls

Electronic fuel injector

There are four electronic fuel injectors (one for each cylinder), each located in the centre of a cylinder's four valves.

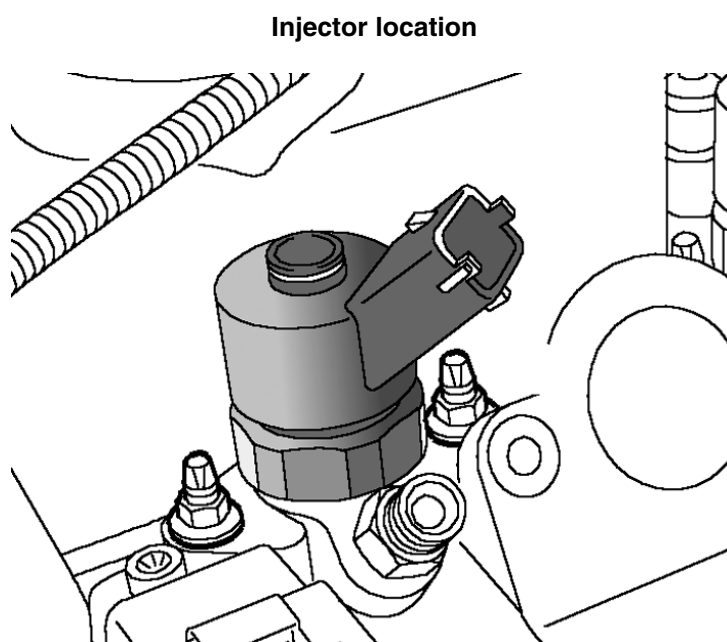


Figure 107

The electronic fuel injectors are supplied with fuel from the fuel rail and deliver finely atomised fuel directly into the combustion chambers. Each injector is controlled individually by the ECM according to the firing order. The injectors are provided with a 80-volt power supply from the capacitor in the ECM. The ECM provides the earth path for the electronic fuel injectors. By using an injection/timing map within its memory, the ECM is able to determine precise pilot and main injection timing for each cylinder.

If battery voltage falls to between 6 and 9 volts, the electronic fuel injector operation is restricted, affecting the engine maximum speed range and idle speed.

Input to the electronic fuel injectors takes the form of electrical pulses (80V) from the capacitor in the ECM. The length of each pulse determines the amount of fuel injected.

In the event of a fuel injector failure, any of the following symptoms may be observed:

- Engine misfire
- Idle faults
- Reduced engine performance
- Reduced fuel economy
- Difficult cold-start
- Difficult hot-start
- Increased smoke emissions

Fuel rail pressure sensor

The fuel rail pressure sensor is located on the end of the fuel rail.

Fuel rail pressure sensor location

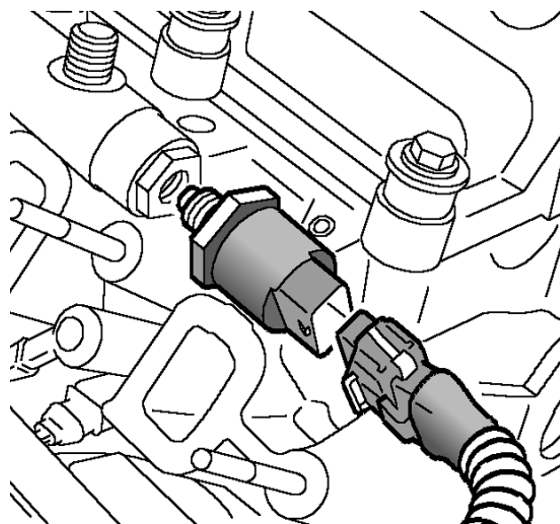


Figure 108

A diaphragm located within the sensor is in contact with the pressurised fuel. An electronic resistive element, attached to the diaphragm, distorts as the diaphragm changes in shape due to the pressure exerted by the fuel. The resistance values are converted into an analogue voltage within the pressure sensor and the ECM then processes this signal. The ECM compares the signal to stored values to calculate current fuel pressure.

The fuel rail pressure sensor consists of the following components:

- Sensor housing with electrical connection
- Printed circuit board with electrical evaluation switch
- Diaphragm with integrated sensor element

The electrical input, to the fuel rail pressure sensor, is a 5 volts supply from the ECM. Output is an analogue voltage between 0.5 - 4.5 volts.

In the event of a fuel rail pressure sensor failure, any of the following symptoms may be observed:

- Engine will not start
- Severe loss of power
- Engine stalls

Cooling system

The cooling system employed is the by-pass type, allowing coolant to circulate around the engine and the heater circuit while the thermostat is closed. The cooling systems primary function is to maintain the engine within an optimum temperature range under changing ambient and engine operating conditions. A secondary function of the cooling system is to provide additional cooling for the intermediate reduction drive (IRD) and to provide heating for the passenger meeting

The cooling system comprises:

- A radiator
- An IRD cooler
- A coolant pump
- A thermostat
- An expansion tank
- Two cooling fans
- Connecting hoses and pipes
- A fuel burning heater (selected markets only)

The coolant is circulated by a centrifugal type pump mounted on the front of the engine and driven by the ancillary drive 'polyvee' belt. The coolant pump circulates coolant around the cylinder block and cylinder head, to the radiator, engine oil cooler, transmission oil cooler (automatic, selected markets only) and heater matrix via the coolant hoses.

The thermostat is located in a housing attached to the coolant pump on the inlet side of the cooling circuit. This provides a more stable control of the coolant temperature in the engine.

When the engine is cold, the thermostat is closed and the coolant is prevented from circulating through the radiator. Coolant is able to circulate through the by-pass and heater circuits.

As temperature increases, the thermostat gradually opens, bleeding cool fluid from the radiator bottom hose through the pump and into the cylinder block. This allows hot coolant to flow from the cylinder block to the radiator through the top hose, balancing the flow of hot and cold fluid to maintain the optimum operating temperature. When the thermostat opens fully, the full flow of coolant passes through the radiator.

The radiator is a cross flow type with an aluminium matrix and moulded plastic end tanks. The radiator end tanks have brackets which allow for the attachment of the fan assembly, intercooler and, if fitted, air conditioning system condenser. The bottom of the radiator is located in rubber bushes supported by plastic brackets which are clipped into the body longitudinals. The top of the radiator is located in rubber bushes secured by brackets fitted to the bonnet locking platform.

The radiator top hose is connected to a coolant outlet elbow which is bolted to the cylinder head. The elbow also has a connection for the feed to the fuel burning heater (if fitted) or the heater matrix. The radiator bottom hose is connected to a pipe which is routed around the front of the engine and is connected to the coolant pump housing.

For additional air-flow through the radiator matrix, particularly when the vehicle is stationary, two electric cooling fans are fitted to the rear of the radiator.

The temperature of the cooling system is monitored by the engine control module (ECM) via signals from the engine coolant temperature sensor (ECT) sensor, which is mounted in the cylinder head.

The cooling system is also used to cool the IRD. The IRD oil is cooled with fluid from the cylinder block. The fluid passes through a plate type heat exchanger located in the IRD. The plate contains waterways which cool the IRD oil and recirculates the coolant via the heater circuit.

A bleed screw is installed in the return pipe from the heater matrix. This screw is used to bleed air from the cooling system during filling.

Inlet and exhaust manifolds

The inlet manifold directs cooled compressed air from the turbocharger and intercooler into the cylinders, where it is mixed with fuel from the injectors. Exhaust gases from the exhaust manifold can also be directed into the inlet manifold via a pipe from the exhaust manifold and an Exhaust Gas Recirculation (EGR) valve on the inlet manifold. The exhaust manifold allows combustion gases from the cylinders to leave the engine where they are directed into the turbocharger and exhaust system.

The exhaust system is attached to the turbocharger and is directed along the underside of the vehicle to emit exhaust gases from a tailpipe at the rear of the vehicle. An oxidation catalytic converter is installed midway along the system and a tail silencer is located at the rear of the vehicle.

Exhaust manifold

The cast iron exhaust manifold is secured to the cylinder head using eight studs with nuts. Two metal gaskets seal the manifold to the cylinder head with a turbocharger.

A flanged connection on the underside of the manifold provides for the attachment of the turbocharger. The turbocharger is attached to the flange with three bolts and sealed with a metal gasket.

A second flange, located on the left hand end of the manifold provides the connection point for the EGR pipe. The pipe flange is secured to the manifold with two bolts. There is no gasket used between the EGR pipe and the exhaust manifold.

Turbocharger

For the first time, Land Rover are using a variable nozzle turbine (VNT) with boost pressure of up to 2.1 bar (new turbocharging range).

The VNT makes it possible to vary the exhaust gas flow of the turbine, dependent on engine operation. Closing the guide vanes results in a reduction of the exhaust gas flow and an increase in the flow rate of exhaust gas to the turbine wheel. This improves the power transfer to the turbine wheel and compressor, particularly at low engine speeds, thus increasing the boost pressure. The guide vanes are opened progressively as the engine speed increases so that the power transfer always remains in balance with the required charger speed and the required boost pressure level. Variable turbine geometry facilitates better use of the exhaust gas energy so as to further improve the efficiency of the turbocharger and thus of the engine, compared to the more conventional 'wastegate control'.

Variable nozzle turbine

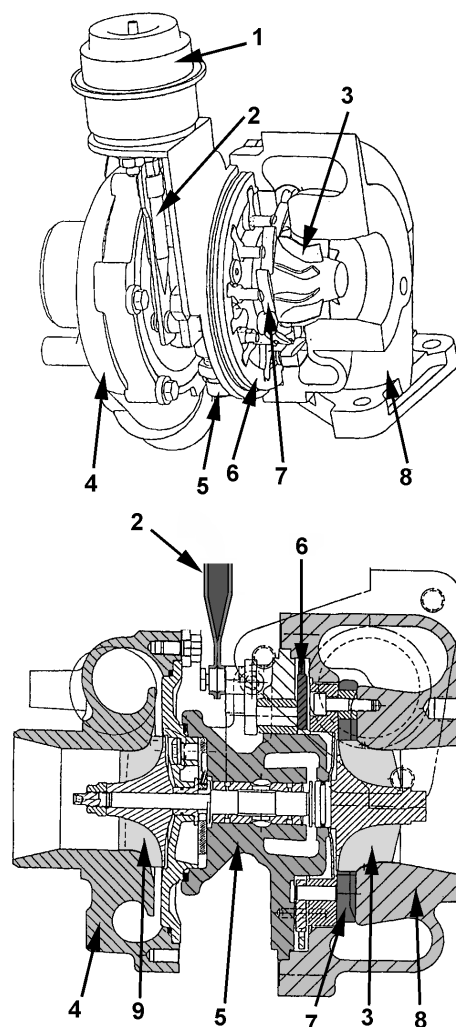


Figure 109

- 1. Control cell
- 2. Control rod
- 3. Turbine wheel
- 4. Compressor housing
- 5. Bearing housing

- 6. Adjustment ring
- 7. Guide vanes
- 8. Turbine housing
- 9. Compressor wheel

Advantages:

- High torque at both high and low engine speeds
- Continuous and optimum adjustment for all engine speeds
- No wastegate valve required, exhaust energy is better utilised, less back-pressure in conjunction with same compressor work
- Low thermal and mechanical load improves engine power output
- Low emissions
- Optimised fuel consumption over the entire engine speed range

When the control cell has no vacuum, the guide vanes contact angle, of the VNT vane mechanism, is larger; for example, the flow rate to the turbine wheel is reduced. The boost pressure decreases.

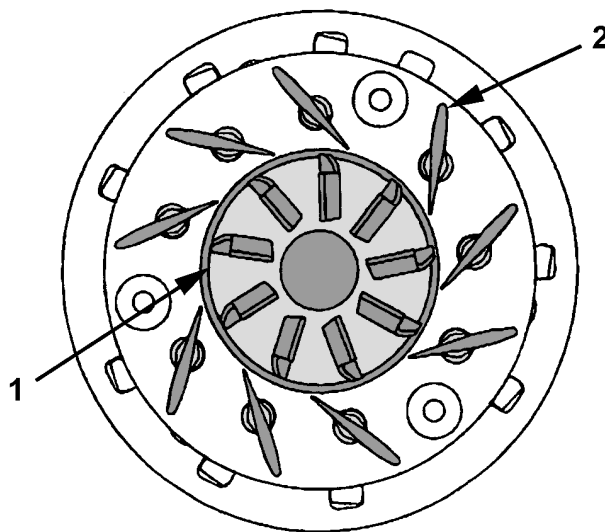
Variable nozzle turbine vane mechanism in the open position (no vacuum)

Figure 110

- 1.Exhaust turbine
- 2.Guide vanes

When vacuum is applied to the control cell, the contact angle of the guide vanes is small; for example, the flow rate to the turbine is increased. The boost pressure increases.

Variable nozzle turbine vane mechanism in the closed position (full vacuum)

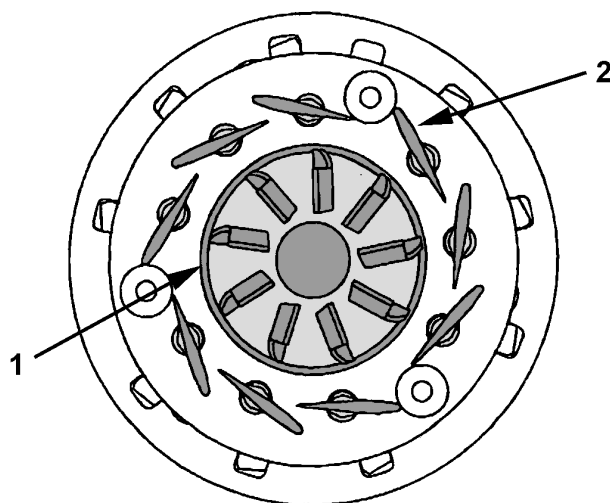


Figure 111

- 1.Exhaust turbine
- 2.Guide vanes

The turbochargers characteristic map is controlled by the engine control module (ECM) via a vacuum modulator. This allows the vacuum to be controlled between 0 mBar and, approximately, 640 mBar depression (vanes fully closed).

Vane guide spacing

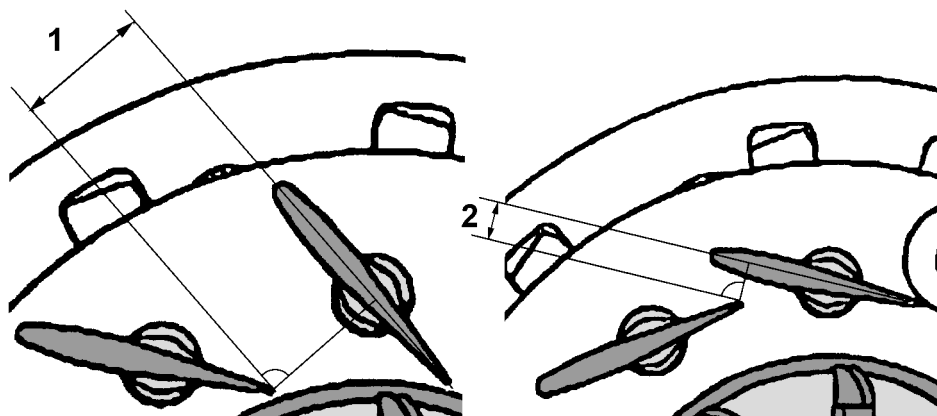


Figure 112

- 1.Open
- 2.Closed

The exhaust turbocharger features an emergency mode function if the vacuum system should fail. If no vacuum is applied, the vanes are set in the open position. This means the engine develops less torque in the lower speed range.

Inlet manifold

The inlet manifold is a one piece plastic moulding with inlet tracts feeding intake air into the cylinder head ports directly in the cylinder head and via the camshaft cover. The manifold is secured to the cylinder head using four studs with nuts and one bolt, all incorporating sealing washers and compression limiters.

The manifold is secured to the camshaft cover with eight bolts incorporating compression limiters. Sealing between the manifold, cylinder head and camshaft cover is achieved using moulded rubber seals located in recesses in the manifold.

A boost pressure sensor is located in the right hand end of the inlet manifold. The sensor is secured to the manifold with a bolt and sealed with an 'O' ring. On the left hand end of the manifold, four threaded holes provide for the attachment of the EGR valve. The valve is sealed to the manifold with an 'O' ring.

Inlet manifold components

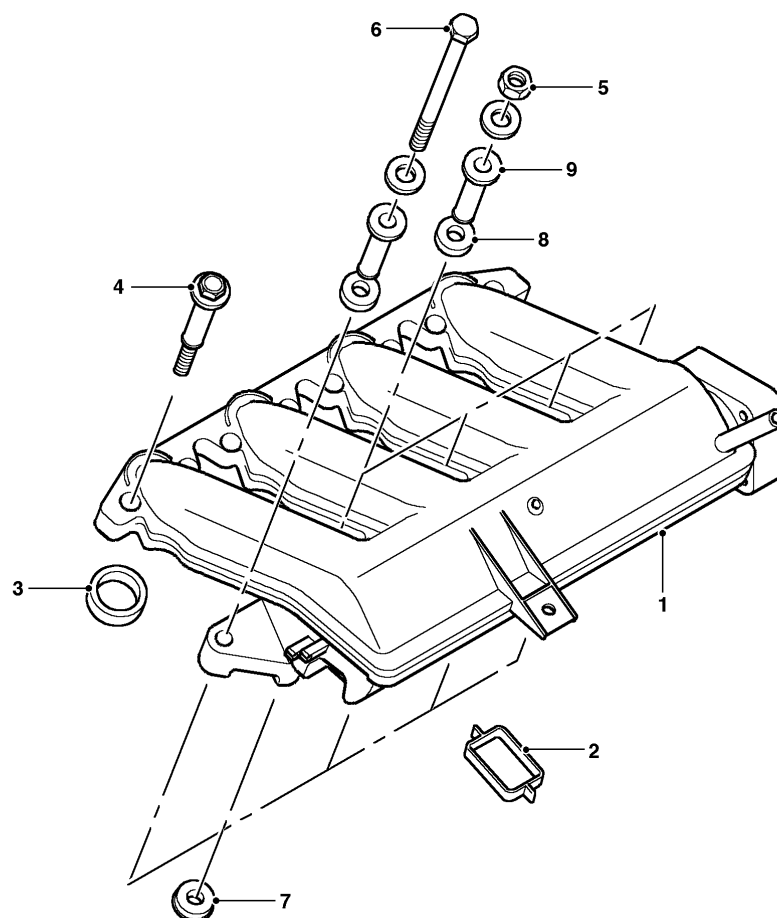


Figure 113

- 1. Inlet manifold
- 2. Seal (4 off)
- 3. Seal (4 off)
- 4. Bolt and compression limiter (8 off)
- 5. Nut (4 off)
- 6. Bolt
- 7. Seal (5 off)
- 8. Seal (5 off)
- 9. Compression limiter (5 off)

Technical data

The following tables are divided into two groups, 'General technical data' and 'Fuel system technical data'.

General technical data

Description	Data
Engine designation	M47R
Model type	2.0 litre, direct injection, 16 valve, DOHC, turbo charged and intercooled
Cylinder arrangement	4 in-line, transverse, No.1 cylinder at front of engine
Firing order	1-3-4-2
Compression ratio	18.1 ± 0.5:1
Capacity	1950 cm ³
Bore	84.00 mm (3.307 in.)
Stroke	88.00 mm (3.465 in.)
Maximum power	85 kW (116 bhp) @ 4000 rev/min.
Maximum torque	260 Nm (192 lbf.ft) @ 1750 rev/min
Injection system	Common rail direct injection (1350 bar typical) controlled by a Bosch DDE 4.0 engine management system
Emission standard	ECD3
Head gasket	Multi layer steel, 3 sizes
Valve train	Chain driven camshafts, roller finger levers and hydraulic valve adjustment
Intake ports	One high swirl helical port and one tangential port
Turbocharger	Garrett GT1749 VNT

Fuel system technical data

Description	Data
System	Common rail, direct injection
Fuel specification	EN590 Diesel
Pressure control valve setting	350 kPa (3.5 bar)
Fuel tank pump	Electric, in fuel tank
Fuel pump output	250 kPa (2.5 bar)
Fuel injection pump	Bosch CP1 mechanical high-pressure pump
Fuel pump drive	Crankshaft driven chain at 0.75 engine speed
Pressure control valve limit	22 bar
Injector make	Bosch
Nozzle type	DSLA 145P 868
Position	Central
Injector operating pressure	250 - 1340 bar
Pre - injection	60° BTDC
Main injection	20° BTDC

Electronic diesel control

General

The M47R engine has an Electronic Diesel Control (EDC) engine management system. The system is controlled by an Engine Control Module (ECM) and is able to monitor, adapt and precisely control the fuel injection. The ECM uses multiple sensor inputs and precision control of actuators to achieve optimum performance during all driving conditions.

The advantages of the system are:

- Greater fuel economy.
- Reduced exhaust emissions.
- Reduced engine noise.
- More effective cold starting.
- Smoother engine operation.

The ECM controls fuel delivery to all four cylinders via a Common Rail (CR) injection system. The CR system uses a fuel rail to accumulate highly pressurised fuel and feed four electronically controlled fuel injectors. The fuel rail is located in close proximity to the four fuel injectors, which maintains full system pressure at each injector at all times.

The ECM utilises the drive by wire principle for acceleration control. There are no control cables or physical connections between the accelerator pedal and the engine. Accelerator pedal demand is communicated to the ECM by the Accelerator Pedal Position (APP) sensor, which is installed on the pedal box. A variable reading from the throttle potentiometer enables the ECM to determine the position, and the rate and direction of movement of the accelerator pedal. The ECM uses this information to facilitate the correct engine response.

The ECM controls the Exhaust Gas Recirculation (EGR) system which is fitted to reduce the formation of oxides of nitrogen (NO_x). This group of gases is formed in the combustion chamber under conditions of high temperature and pressure. It is not desirable to reduce the compression ratio, so the ECM reduces the combustion temperature by introducing a controlled volume of inert gas into the cylinders on the induction stroke.

The inert gas used is exhaust gas, which is freely available. It is directed from the exhaust manifold, via a control valve, into the intake manifold. The flow of gas is monitored by the ECM using the MAF sensor. The EGR system is not required until the engine is hot, and is turned off during engine idling and wide open 'throttle' to preserve smooth operation and driveability.

The ECM processes information from the following input sources:

- Brake switch.
- Clutch switch (manual gearbox models).
- Crankshaft Position (CKP) sensor.
- Camshaft Position (CMP) sensor.
- Anti-lock Brake System (ABS) ECU.
- Engine Coolant Temperature (ECT) sensor.
- Boost Pressure (BP) sensor.
- Low side fuel pressure sensor.
- throttle potentiometer.
- Mass Air Flow/ Intake Air Temperature (MAF/ IAT) sensor.
- Fuel rail pressure sensor.
- Controller Area Network (CAN).

The input from the sensors constantly updates the ECM with the current operating condition of the engine. Once the ECM has compared current information with map information within its memory, the ECM can make any required adjustment to the operation of the engine via the following actuators:

- EGR modulator.
- Glow-plug relay.
- Fuel pressure regulator valve.
- Electronic fuel injectors.
- Cooling fan relay.
- A/C compressor clutch relay.

The ECM also communicates with other systems on the vehicle, both receiving information used to influence fuelling and transmitting information of importance to the other systems.

The systems are as follows:

- ABS ECU.
- Electronic Automatic Transmission (EAT) ECU.
- Glow-plug relay.
- Instrument pack.
- Immobilisation ECU.
- Cruise control interface ECU.

Engine Control Module (ECM)

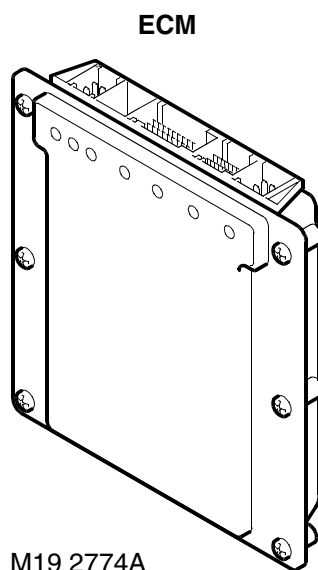


Figure 114

The ECM has a steel casing to provide protection from electromagnetic radiation and is located in the E box in the engine compartment.

The ECM contains data processors and memory microchips. The output signals to actuators are in the form of earth paths provided by driver circuits contained within the casing. The ECM driver circuits produce heat during normal operation and dissipate this heat via the casing. The airflow around the ECM should not be obstructed. There are regulated voltage outputs to some sensors which use less than 12 volts to avoid voltage drop during engine cranking.

The ECM cannot be tested directly, diagnosis must be performed by ensuring that inputs and outputs conform to specifications. TestBook is available for this purpose. If the ECM is to be replaced, the new ECM will be supplied 'blank' and must be configured to the vehicle using TestBook. When the ECM is fitted to the vehicle it must also be synchronised to the immobilisation ECU using TestBook. Engine control modules must not be swapped between vehicles.

Inputs and outputs

The ECM is connected to sensors fitted to the engine which allow it to monitor engine operating conditions. The ECM processes these signals and decides the actions necessary to maintain optimum engine performance in terms of driveability, fuel efficiency and exhaust emissions. The memory of the ECM is programmed with instructions for how to control the engine, this is known as the strategy. The memory also contains data in the form of maps which the ECM uses as a basis for fuelling and emission control. By comparing the information from the sensors to the data in the maps, the ECM is able to calculate the various output requirements. The ECM contains an adaptive strategy which updates the system when components vary due to production tolerances or ageing.

The ECM has an interface of 134 pins via five connectors providing both input information and output control. Not all 134 pins are used.

Vehicle speed signal

Vehicle speed is an important input to the ECM strategies and comes from the ABS ECU. The ABS ECU derives the speed signal for the ECM from the front LH ABS sensor. The frequency of this signal changes in accordance with road speed. The ABS ECU transmits the road speed on a hardwired connection to the ECM as a Pulse Width Modulated (PWM) signal. The ECM requires this signal to determine the following:

- How much to reduce engine torque during gear changes (automatic gearbox models).
- When to allow cruise control.
- Cruise control operation.
- For implementation of idle strategy when vehicle is stationary.

Communication

The use of digital communication provides advantages in performance and reliability over conventional analogue systems. Digital systems transmit information as a series of pulses along a single wire, or twisted pair of wires. The wires may be connected to various components in a system, this common information circuit is known as a databus.

There are two databus circuits which connect directly to the ECM:

- CAN bus: used for high speed applications such as ECM, EAT ECU and traction control functions.
- ISO 9141-2 K line bus: used for communication with TestBook and other diagnostic tools using Keyword 2000 protocol.

Throttle potentiometer

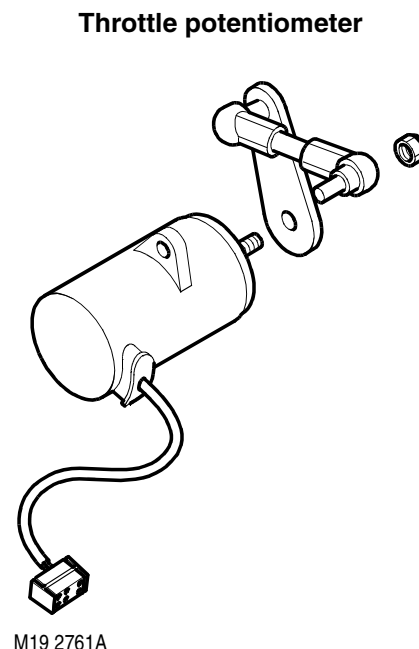


Figure 115

The throttle potentiometer sensor is located on the pedal box in the driver's footwell. The throttle potentiometer consists of two resistance tracks and two sliding contacts, effectively a pair of potentiometers, connected to the accelerator pedal assembly. The use of a pair of identical sensing elements ensures a position signal is still provided even if one of the sensing elements develops a fault; this is required because there is no mechanical linkage between the accelerator pedal and the ECM. As the accelerator pedal is depressed, the sliding contacts move along the resistance tracks to change the output voltage of the sensor.

By monitoring the voltage outputs from the APP, the ECM is able to determine the position, rate of change and direction of movement of the accelerator pedal. It will also store the voltages which correspond with closed 'throttle' and wide open 'throttle' and will adapt to new ones in the event of component wear or replacement.

The ECM uses the APP voltage to determine closed 'throttle' position to instigate idle speed control, and to enable the overrun fuel reduction strategy.

The throttle potentiometer signal is also broadcast on the CAN bus, where it is used by the EAT ECU to determine the correct point for gearshifts and kickdown.

The connector and sensor terminals are gold plated for corrosion resistance and temperature stability, care must be exercised when probing the connector and sensor terminals

The ECM supplies the throttle potentiometer with a regulated 5 volts supply and an earth path for the resistive tracks. The output signals vary according to the position of the accelerator pedal. The throttle potentiometer earth also acts as a screen to protect the integrity of the signal.

If the throttle potentiometer signal fails, the ECM increases the idle speed to 1,250 rev/min, and the engine speed will not increase when the accelerator is depressed.

In the event of an throttle potentiometer signal failure, the following symptoms may be observed:

- No accelerator response.
- Failure of emission control.
- Automatic gearbox kickdown inoperative.

Crankshaft Position (CKP) sensor

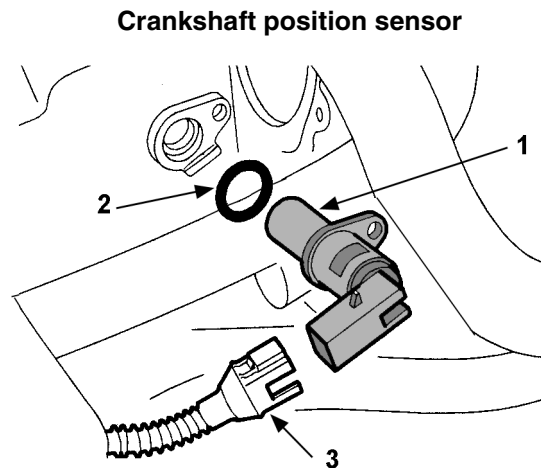


Figure 116

- 1.Crankshaft sensor
- 2.Seal
- 3.Electrical connection

The CKP sensor is located in the engine block, beneath the starter motor, with its tip adjacent to the outer circumference of the crankshaft reluctor ring.

The CKP sensor works on the variable reluctance principle. This uses the disturbance of the magnetic field which is set up around the CKP sensor, caused by the rotation of a reluctor 'target' attached to the crankshaft. The reluctor is a steel ring with 58 'teeth' and a space where two teeth are 'missing'. The teeth, and spaces between, each represent 3° of crankshaft rotation. The two missing teeth provide a reference for angular position. As the reluctor rotates adjacent to the sensor tip, a sinusoidal voltage waveform is produced which can be interpreted by the ECM into crankshaft angular position and velocity.

The signal from the CKP sensor is required by the ECM for the following functions:

- To determine fuel injection timing.
- To enable the fuel pump relay circuit (after the priming period).
- To produce an engine speed message for broadcast on the CAN bus for use by other systems.

The two pins on the sensor are both outputs. To protect the integrity of the CKP signal the cable incorporates a screen. The cable screen earth path is via the ECM. Correct CKP sensor outputs are dependent upon the air gap between the tip of the CKP sensor and the passing teeth of the reluctor ring. The CKP air gap is not adjustable in this application.

In the event of a CKP sensor signal failure any of the following symptoms may be observed:

- Engine cranks but fails to start.
- Engine misfires.
- Engine runs roughly or stalls.

Camshaft Position (CMP) sensor

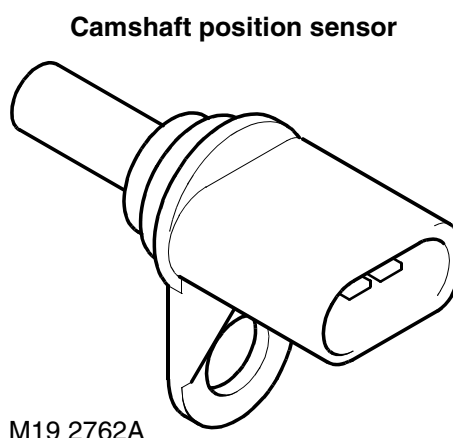


Figure 117

The CMP sensor is located on top of the engine on the camshaft cover. This sensor is a Hall effect sensor producing one pulse for every camshaft revolution. The CMP sensor is only used on start up to synchronise the ECM programme with the CKP signal. This is to identify number one cylinder for correct injection timing. Once this has been achieved the input from the CMP sensor is no longer used in any of the ECM strategies.

Electrical input to the CMP sensor is supplied via the main relay located in engine compartment fuse box. One output is sensor earth, the other is the signal output to the ECM.

In the event of a CMP sensor signal failure the engine will crank but will not start.

Mass Air Flow/ Inlet Air Temperature (MAF/ IAT) sensor

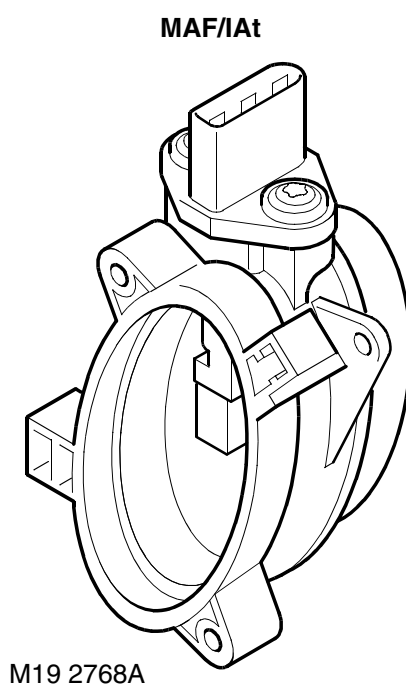


Figure 118

The MAF/ IAT sensor is located on the engine intake air manifold, it combines the two functions into one unit.

The MAF sensor works on the hot film principle. The MAF sensor has two sensing elements contained within a film. One element is at ambient temperature e.g. 25 °C (77 °F) while the other is heated to 200 °C (392 °F) above this temperature e.g. 225 °C (437 °F). As air passes through the MAF sensor it has a cooling effect on the film. The current required to maintain the 200 °C (392 °F) differential provides a precise, although non-linear, signal of the air drawn into the engine. The MAF sensor output is an analogue voltage proportional to the mass of the incoming air. The ECM utilises this data, together with information from the other sensors and the fuelling maps, to determine the correct fuel quantity to be injected into the cylinders. It is also used as a feedback signal for the EGR system.

The IAT sensor incorporates a Negative Temperature Coefficient (NTC) thermistor in a voltage divider circuit. As the temperature of the intake air increases, the resistance in the thermistor decreases. As the thermistor allows more current to pass to earth, the voltage sensed at the ECM decreases. The change in voltage is proportional to the temperature change of the intake air. From the voltage output of the sensor, the ECM can correct the fuelling map for intake air temperature. This correction is an important requirement because hot air contains less oxygen than cold air for any given volume.

Inputs to the MAF sensor are a 12 volt supply from the engine compartment fuse box and an earth path connection. There are two outputs from the MAF sensor, these are in the form of a signal and signal return connection to the ECM. The IAT sensor utilises a 5 volt reference input from the ECM and shares the earth path of the MAF. The output from the IAT is calculated within the ECM by monitoring the changes in the reference voltage which supplies the IAT voltage divider circuit. The MAF/ IAT sensor connector has gold plated terminals.

If the MAF sensor fails the ECM implements a back up strategy, which is based on engine speed. In the event of a MAF sensor signal failure any of the following symptoms may be observed:

- Difficult starting.
- Engine stalls after starting.
- Delayed engine response.
- Emissions control inoperative.
- Idle speed control inoperative.
- Reduced engine performance.

Should the IAT sensor fail the ECM defaults to an assumed air temperature of -5 °C (23 °F).

In the event of an IAT sensor signal failure any of the following symptoms may be observed:

- Over fuelling resulting in black smoke.
- Idle speed control inoperative.

Boost Pressure (BP) sensor

The BP sensor is located on the front side of the intake manifold and has a three pin connector. It provides a voltage signal relative to intake manifold pressure to the ECM. The BP sensor works on the piezo ceramic crystal principal. Piezo ceramic crystals are pressure sensitive and, in the BP sensor, oscillate at a rate dependent on air pressure. The BP sensor produces a voltage between 0 and 5 volts proportional to the pressure level of the air in the intake manifold. A reading of 0 volts indicates low pressure and a reading of 5 volts indicates high pressure. The ECM uses the signal from the BP sensor for the following functions:

- To maintain manifold boost pressure.
- To reduce exhaust smoke emissions while driving at high altitude.
- Control of the EGR system.

ECM supplies the BP sensor with a 5 volt power supply. The output from the BP sensor is measured at the ECM. The earth path is supplied via the ECM.

In the event of a BP sensor signal failure any of the following symptoms may be observed:

- Altitude compensation inoperative (engine will produce black smoke).
- Active boost control inoperative.
- The ECM assumes a default pressure of 0.9 bar (13 lbf/in²).

Vacuum control module

The Vacuum control module is used by the ECM to control the variable nozzle turbine (VNT) within the turbocharger unit.

The variable nozzle turbine improves turbine boost pressure by opening and closing internal vanes. The system uses signals from the boost pressure sensor, road speed signal and engine load to calculate a 'setpoint' boost pressure from an internal software 'map'. This in turn provides an angle for the vanes to be set to (between open and closed) to vary the boost pressure.

Variable nozzle turbine

The variable nozzle turbine makes it possible to vary the exhaust gas flow of the turbine by varying the angle that the guide vanes are set at. With the guide vanes in a closed position the exhaust gas flow is reduced and the gas flow to the turbine wheel is increased. This results in an increase in boost pressure.

The boost pressure sensor provides a feed back a signal relative to inlet manifold pressure to the ECM. The ECM also calculates engine load and uses this along with the boost pressure sensor input to send a signal (PWM) to the vacuum control modlue to determine the amount of vacuum supplied to the vacuum control cell. The amount of vacuum operates between 0 mBar to 640 mBar depression (640 mBar with the vanes fully closed-maximum boost).

Engine Coolant Temperature (ECT) sensor

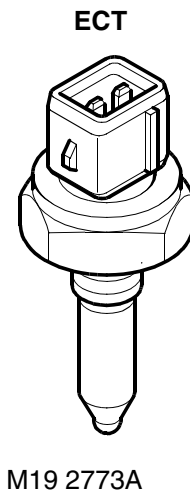


Figure 119

The ECT sensor is located in the cylinder head at the front of the engine. It provides the ECM with engine coolant temperature information. The ECM uses this ECT information for the following functions:

- Fuelling calculations.
- Temperature gauge.
- To limit engine operation if coolant temperature is too high.
- Cooling fan operation.
- Glow plug operating time.

The ECM ECT sensor circuit consists of an internal voltage divider circuit incorporating an external negative temperature coefficient thermistor. As temperature rises, the resistance in the thermistor decreases, as temperature decreases, the resistance in the sensor increases. The output of the sensor is the change in voltage as the thermistor allows more current to pass to earth according to the temperature of the coolant. The ECM compares the signal voltage to stored values and compensates fuel delivery to ensure optimum driveability at all times. The engine will require more fuel when it is cold to overcome fuel condensing onto the cold metal surfaces inside the combustion chamber. To achieve a richer air/fuel ratio the ECM extends the injector opening time. As the engine warms up the air/fuel ratio is leaned off.

The inputs and outputs for the ECT are a reference voltage and an earth return circuit, both provided by the ECM. The ECT signal is measured at the ECM.

In the event of an ECT sensor signal failure any of the following symptoms may be observed:

- Difficult cold start.
- Difficult hot start.
- Driveability concerns.
- Instrument pack temperature warning illuminated.
- Temperature gauge reading does not accurately represent the coolant temperature.

In the event of ECT signal failure the ECM applies a default value of 80 °C (176 °F) coolant temperature for fuelling purposes. The ECM will also run the cooling fan when the ignition is switched on to protect the engine from overheating.

Exhaust Gas Recirculation (EGR) modulator

EGR

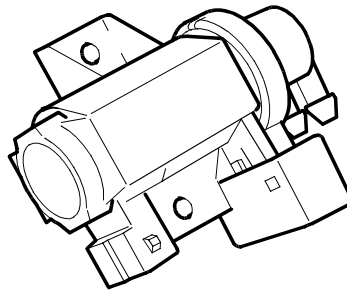


Figure 120

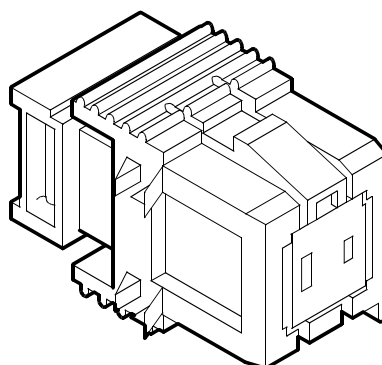
The EGR modulator is located on the front of the engine at the side of the starter motor. The EGR modulator is a solenoid operated valve which regulates the vacuum source to the EGR valve, causing it to open or close. The ECM utilises the EGR modulator to control the amount of exhaust gas being recirculated in order to reduce exhaust emissions and combustion noise. EGR is enabled when the engine is at normal operating temperature and under cruising conditions.

The EGR modulator receives battery voltage from the main relay in the engine compartment fusebox. The ECM completes the earth path to the solenoid winding. The ECM controls the EGR valve operation using a PWM signal. The duty cycle of the solenoid determines the amount of vacuum supplied to the EGR valve and, therefore, the volume of exhaust gas allowed to enter the cylinders.

In the event of an EGR modulator failure the EGR system will become inoperative.

Brake switch

Brake switch



M19 2826A

Figure 121

The brake switch is located on the pedal box assembly, it is a Hall effect switch which detects the position of the brake pedal, and therefore when the driver has applied the brakes. The ECM uses the signal from the brake switch for the following:

- To limit fuelling during braking.
- To inhibit/ cancel cruise control if the brakes are applied.

The brake switch includes two separate circuits, one normally open and one normally closed, connecting to earth. The two circuits are referred to as main brake and brake test.

Brake switch outputs

Switch condition	Brake test circuit	Main brake circuit
Brake not pressed	Open circuit	Earth
Brake pressed	Battery positive	6 – 8V

In the event of a brake switch failure any of the following symptoms may be observed:

- Cruise control will be inactive.
- Increased fuel consumption.

Clutch switch

Clutch switch

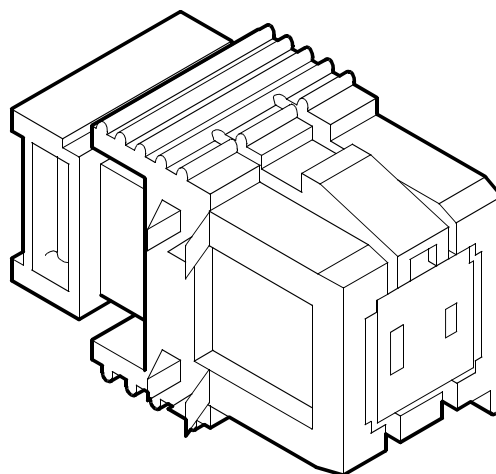


Figure 122

The clutch switch is a Hall effect device and is located on the pedal box assembly. The clutch switch is activated when the clutch pedal is operated. The ECM uses the signal from the clutch switch for the following functions:

- To provide surge damping during gear changes.
- To inhibit / cancel cruise control if the clutch pedal is pressed.

Surge damping stops engine speed rising dramatically during gear changes. Surge damping assists driveability in the following ways:

- Smoother gear changes.
- Greater exhaust gas emission control.
- Improved fuel consumption.

The clutch switch receives a 12 volts reference voltage from the ECM. With the clutch pedal in the rest position the switch is connected to earth. When the clutch pedal is pressed the ECM receives a 12 volt signal.

In the event of a clutch pedal switch failure any of the following symptoms may be observed:

- Surge damping will be inactive
- Cruise control will be inactive

Main relay

The main relay is located in the engine compartment fusebox. The relay controls the voltage supplies to the main peripheral components of the system under the control of the ECM. The ECM has a feed which allows it to become active when it receives an input from the ignition switch position II (ignition on). The ECM will then energise the main relay.

The main relay is a standard normally open 4 pin relay.

The main relay contact supplies battery voltage to the following components:

- ECM
- MAF/ IAT sensor
- CMP sensor
- Fuel pressure regulator
- EGR modulator
- Glow plug relay

Voltage input to the relay winding and the contacts comes from the vehicle battery. When the main relay is energised, the switching contact closes and power is supplied to various components on the vehicle.

The earth path for the main relay winding is supplied by the ECM. When the earth path is completed, the main relay energises.

In the event of a main relay failure any of the following symptoms may be observed:

- Engine will crank but not start
- The engine will stop if the relay fails

Glow plug relay and glow plugs

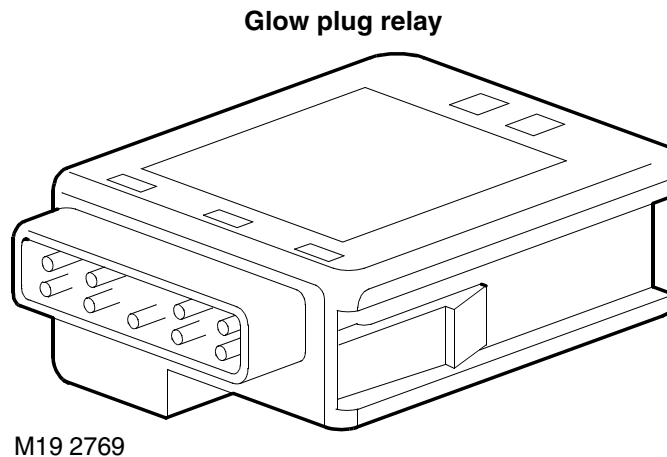


Figure 123

The glow plug relay is located next to the ECM in the 'E' box. The ECM controls all glow plug operations via the glow plug relay. The glow plug warning lamp is controlled by the ECM from information received from the glow plug relay.

The 4 glow plugs are located in the cylinder head on the inlet side. The glow plugs form a vital part of the engine starting strategy. The glow plugs heat the air inside the cylinder during cold starts to assist combustion. The use of glow plugs helps to reduce the amount of extra fuel required on start up, the main cause of black smoke. It also requires less injection advance, which reduces engine noise, particularly when idling with a cold engine.

The main part of the glow plug is a tubular heating element that protrudes into the combustion chamber of the engine. The heating element contains a spiral filament encased in magnesium oxide powder. At the tip of the tubular heating element is the heater coil. Behind the heater coil, and connected in series, is a control coil. The control coil regulates the heater coil to ensure that it does not overheat.

Pre-heat is the length of time the glow plugs operate prior to engine cranking. The ECM controls the pre-heat time of the glow plugs based on battery voltage and coolant temperature information.

Post-heat is the length of time the glow plugs operate after the engine starts. The ECM controls the post-heat time based on ECT information. If the ECT fails, the ECM will operate pre-heat and post-heat time strategies with default values from its memory. The engine will be difficult to start.

The glow plug relay is supplied with power directly from the vehicle battery, an earth connection directly to the vehicle body from the glow plug relay is used. The glow plug relay also receives a voltage signal from the main relay to indicate ignition switch operation. Input information relating to engine temperature and time base calculations comes from the ECM. The glow plug relay is able to process this information and then supply output control to the glow plugs in the engine.

In the event of a glow plug failure any of the following symptoms may be observed:

- Difficult starting.
- Excessive smoke emissions after engine start.

The glow plug relay is not able to generate fault codes.

Common Rail (CR) fuel injection

The CR system is modular in design and is made up of the following components:

- ECM.
- Primary LP fuel pump.
- Secondary LP fuel pump.
- Fuel filter.
- LP fuel sensor.
- HP fuel pump.
- Fuel rail.
- Fuel rail pressure sensor.
- Four electronic injectors.
- Fuel pressure regulator valve.

The fuel rail is fed with pressurised fuel from the HP fuel pump and acts as an accumulator. The fuel is delivered from this intermediate accumulator to the injectors via short, HP fuel pipes. The volume of the fuel rail damps fluctuations in pressure caused by the HP fuel pump delivery and injector operation. The fuel pressure sensor is screwed into the end of the fuel rail and sends a voltage signal corresponding to rail pressure to the ECM.

The advantages of a CR system are as follows:

- Fuel pressure can be maintained regardless of injection duration and engine speed.
- Reduced smoke emission through more efficient atomisation due to higher injector pressures.
- Fuel pressure can be optimised to produce better idle characteristics, and reduced operating noise.
- Greater control of the starting and finishing point of injection, thereby reducing fuel consumption and smoke emissions.

With the CR injection system it is possible to determine injection pressure and injection volume for a wide variety of operating conditions. With this flexibility the CR system can be utilised by the ECM to provide the following benefits:

- Pilot fuel injection.
- Smoke limitation.
- Active surge damping.

Fuel delivery – High Pressure (HP) side

The HP fuel pump supplies fuel to the fuel rail. The pump is directly driven by the engine and is located at the front of the engine block. Fuel rail pressure is variable to allow for fuelling strategies such as noise limitation and surge control. The maximum fuel pressure is 1300 bar (18850 lbf/in²).

Fuel pressure is controlled by the ECM via the fuel pressure regulator valve located at the rear of the HP fuel pump. The ECM uses the output signal from the fuel rail pressure sensor, mounted on the end of the fuel rail, to maintain the optimum fuel pressure for the current conditions. The fuel pressure regulator reduces pressure by diverting fuel from the HP output back to the fuel tank.

The minimum operating pressures are 200 bar (2900 lbf/in²) during cranking and 300 bar (4350 lbf/in²) during idle, failure to reach these pressures will result in a non start situation, stalling or erratic idle.

Fuel pressure regulator valve

The pressure regulator valve is mounted on the high-pressure pump and controls the fuel pressure within the fuel rail. It is an electrically operated solenoid valve controlled by the ECM with only two states, open and closed. When de-energised, the valve is opened by a spring, diverting fuel to the return line. This decreases the fuel pressure in the fuel rail. In this state fuel rail pressure is approximately 100 bar (1450 lbf/in²). When energised, the valve is closed, allowing maximum fuel pressure in the fuel rail. This pressure can reach approximately 1300 bar (18,854 lbf/in²). The ECM controls the fuel rail pressure by operating the pressure regulator valve with a pulse width modulated signal. The longer the opening time (duty cycle) of the valve, the lower the pressure in the fuel rail. The shorter the opening time (duty cycle) of the valve, the higher the pressure in the fuel rail.

The pressure regulator receives a PWM signal of 0-12 volts from the ECM. ECM actuation of the pressure regulator is determined by the following:

- Fuel rail pressure.
- Engine load.
- Accelerator pedal position.
- Engine temperature.
- Engine speed.

In the event of a pressure regulator failure, any of the following symptoms may be observed:

- Engine will not start.
- Severe loss of power.
- Engine stalls.

Electronic fuel injector

There are four electronic fuel injectors (one for each cylinder), each located in the centre of a cylinder's four valves. The electronic fuel injectors are supplied with fuel from the fuel rail and deliver finely atomised fuel directly into the combustion chambers. Each injector is controlled individually by the ECM according to the firing order. The injectors are provided with an 80volt power supply from the capacitor within the ECM. The ECM provides the earth path for the electronic fuel injectors. By using an injection/ timing map within its memory, the ECM is able to determine precise pilot and main injection timing for each cylinder.

If battery voltage falls to between 6 and 9 volts, the electronic fuel injector operation is restricted, affecting the engine maximum speed range and idle speed.

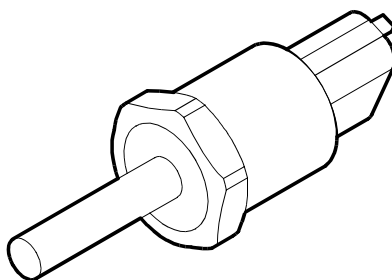
Input to the electronic fuel injectors takes the form of electrical pulses (0 - 12V) from the ECM. The length of each pulse determines the amount of fuel injected.

In the event of a fuel injector failure, any of the following symptoms may be observed:

- Engine misfire.
- Idle faults.
- Reduced engine performance.
- Reduced fuel economy.
- Difficult cold start.
- Difficult hot start.
- Increased smoke emissions.

Fuel rail pressure sensor

Pressure sensor



M19 2763

Figure 124

The fuel rail pressure sensor is located on the end of the fuel rail. A diaphragm located within the sensor is in contact with the pressurised fuel. An electronic resistive element, attached to the diaphragm, distorts as the diaphragm changes in shape due to the pressure exerted by the fuel. The resistance values are converted into an analogue voltage within the pressure sensor and this signal is processed by the ECM. The ECM compares the signal to stored values to calculate current fuel pressure.

The fuel rail pressure sensor consists of the following components:

- Sensor housing with electrical connection
- Printed circuit board with electrical evaluation switch
- Diaphragm with integrated sensor element

Electrical input to the fuel rail pressure sensor is a 5 volts supply from the ECM. Output is an analogue voltage between 0.5 - 4.5 volts.

In the event of a fuel rail pressure sensor failure any of the following symptoms may be observed:

- Engine will not start
- Severe loss of power
- Engine stalls

Cruise control

Introduction

Cruise control is a system which attempts to maintain the speed of a vehicle at a defined setting by automatically controlling the throttle angle. It was designed to make driving long distances on motorways less stressful by taking over throttle control from the driver. Cruise control is available as an option on KV6/JATCO and M47R/JATCO derivatives of Freelander 2001.

An ECU is at the centre of the KV6 cruise control system, monitoring various inputs and changing various outputs to maintain the set speed. Cruise control is a good example of a closed loop control system, with a number of safety inputs which disengage the system for practical reasons. For example, when braking it would be hazardous to continue to allow the cruise control system to attempt to maintain the speed of the vehicle.

Differences exist between the components that make up the cruise control petrol system and the diesel system, but the driver interface and system operation are basically the same.

KV6 cruise control

The KV6 cruise control system is a Hella electro-pneumatic system which, through the controlling ECU, adjusts the throttle angle to suit the set speed. The system uses a vacuum pump to control a pneumatic actuator, which adjusts the throttle angle via a connecting rod. The vacuum pump unit also contains the pressure control valve (regulation valve) and the pressure release valve (dump valve).

Cruise control block diagram

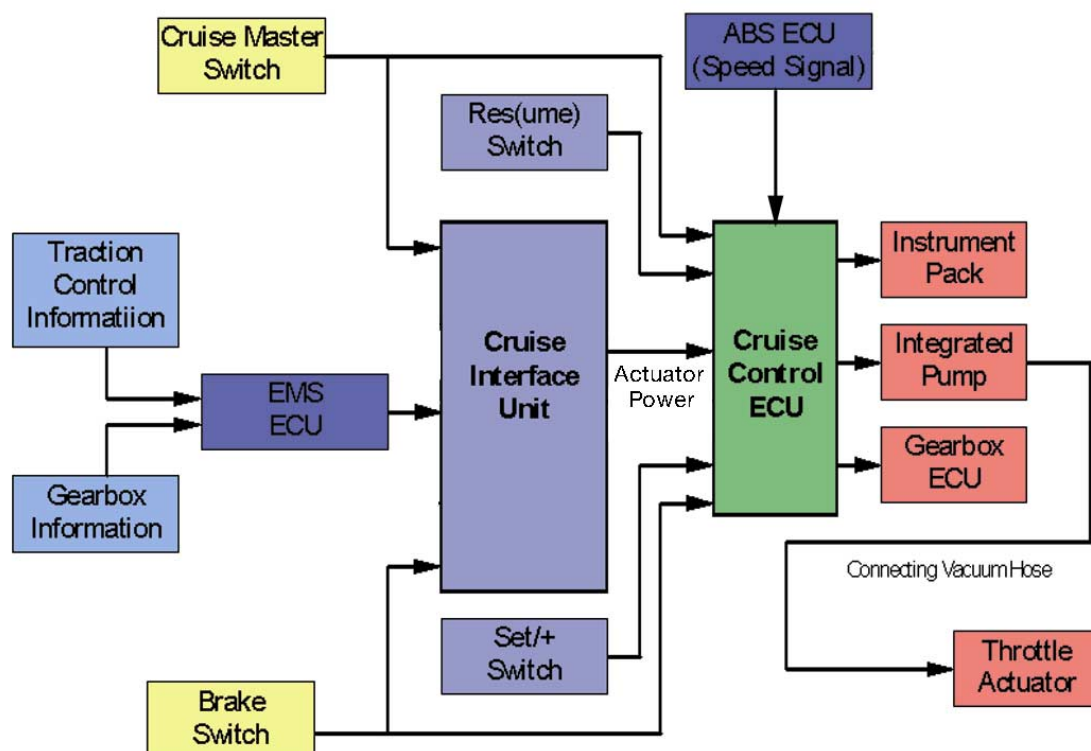


Figure 125

When the vehicle is in cruise control mode and is travelling at the set speed, the cruise ECU is in control of the speed of the vehicle. The cruise control warning lamp located in the instrument pack will be illuminated to inform the driver that cruise control is active. The ECU will have energised the vacuum pump, which, in turn, will have moved the throttle actuator diaphragm to a position which corresponds to the set speed required. The ECU monitors the affect on the speed of the vehicle via the wheel speed signal from the ABS ECU. To maintain the speed, the ECU will continually monitor the wheel speed signal. Varying driving conditions such as gradients and wind resistance can alter the speed of the vehicle. The ECU will control the actuation of the vacuum pump and of the regulator solenoid valve, to increase and decrease the throttle angle, as required.

Cruise control operation

To enter cruise control, the driver needs first to press the cruise master switch located on the dashboard. The cruise system is operative only within the range 28 - 125 mph (40 - 200 km/h) and the driver must be aware of this. When the required cruising speed is reached, using the accelerator pedal, the Set + button on the steering wheel should be pressed. The vehicle will attempt to maintain the current speed as long as the ECU receives no inputs signalling application of the brakes, clutch or throttle.

If the brake pedal or the Res(ume) switch are activated, cruise control will be suspended. On cruise suspension, the set cruise speed will be stored in the cruise ECU. The driver will have complete control of the vehicle and will have to apply throttle to prevent the vehicle from coasting to a stop. Cruise control is restored by pressing the Res switch again and the system will return the vehicle to the speed stored in the cruise control ECU. If the cruise ECU recognises a fault with the system or any of its associated components it will suspend the operation of cruise control indefinitely i.e. Until the fault is rectified.

Accelerating

There are three ways to accelerate the vehicle when cruise control is active:

Cancelling cruise control

Cruise control can be cancelled by pressing the cruise master switch on the dashboard or by turning off the ignition. In both of these cases the cruise speed stored in the cruise control ECU memory will be lost. On reactivation of the cruise control system a new cruise speed will have to be set by pressing the Set+ speed at the appropriate speed.

Components and their functions

The following list outlines the location and functionality of cruise control components:

Master control switch

Located on the dashboard, this mechanically latching switch is placed in series between the ignition feed and the cruise control ECU. It also provides a feed which electrically enables the cruise control interface unit. This switch controls the electrical supply to the system and acts as an isolator or 'On'/'Off' switch. When switched on, the switch is illuminated, indicating that cruise control is available.

Cruise control ECU

Located on a bracket under the right hand front seat the cruise ECU unit controls the system, based on a number of inputs from around the vehicle.

Cruise control electronic control unit



Figure 126

Cruise control interface unit

Located on a bracket under the right hand front seat, and attached to the same bracket as the cruise ECU. This unit controls the enabling of the actuator power feed to the cruise ECU based on inputs from the ECM and the brake switch.

Wheel speed sensor

Wheel speed is supplied to the cruise control system via the ABS ECU from the wheel speed sensors. The ABS wheel speed sensors are passive type sensors operating on inductive principles. The ABS ECU outputs a 0-12 volt square wave to the cruise control ECU which is proportional to the road speed and provides 8,000 pulses per mile.

If the wheel speed signal is not present then the supply to the vacuum pump will not be activated and cruise will not engage. The road speed signal is an average of all working wheel speed sensors. If one to three of the wheel speed sensors fail the cruise system can still function within its range, operating from the remaining sensor signal. However in this situation the speed accuracy of the system may be impaired.

If all four sensors fail, and the speed input to the cruise ECU is not present, cruise will not be operational.

'Set +' switch

Located on the steering wheel, this non latching push switch is used to set the cruise control speed by pressing once and to increase the set cruising speed by pressing and holding until the desired speed is reached. 1mph increments are achieved by pressing for less than 0.5 seconds.

'Res -' switch

Located on the steering wheel below the Set + switch, this non latching switch is used to return to the stored cruise speed after cruise has been suspended. It is also used to suspend cruise control by pressing it once when cruise control is active.

Brake pedal position sensor

Outputs from the brake pedal position sensor are supplied to the interface ECU and the cruise control ECU to enable the system to detect when the brakes are applied. The brake pedal position sensor is a Hall effect sensor that produces two outputs. One output is supplied to both the interface ECU and the cruise control ECU; the second output is only supplied to the interface ECU. Both outputs should be 0 to 2 volts while the brake pedal is released, then increase to between 8 and battery volts when the brake pedal is pressed.

The brake light input from the hall switch is a normally low voltage into pin 5 of the cruise ECU, but when the brake pedal is pressed, this input is pulled HIGH. On receipt of a HIGH brake light signal, the ECU cancels cruise and removes the supply to the pump. The ECU also de-activates a solenoid on the vacuum pump which dumps all the air currently stored within the actuator.

Circuit diagram

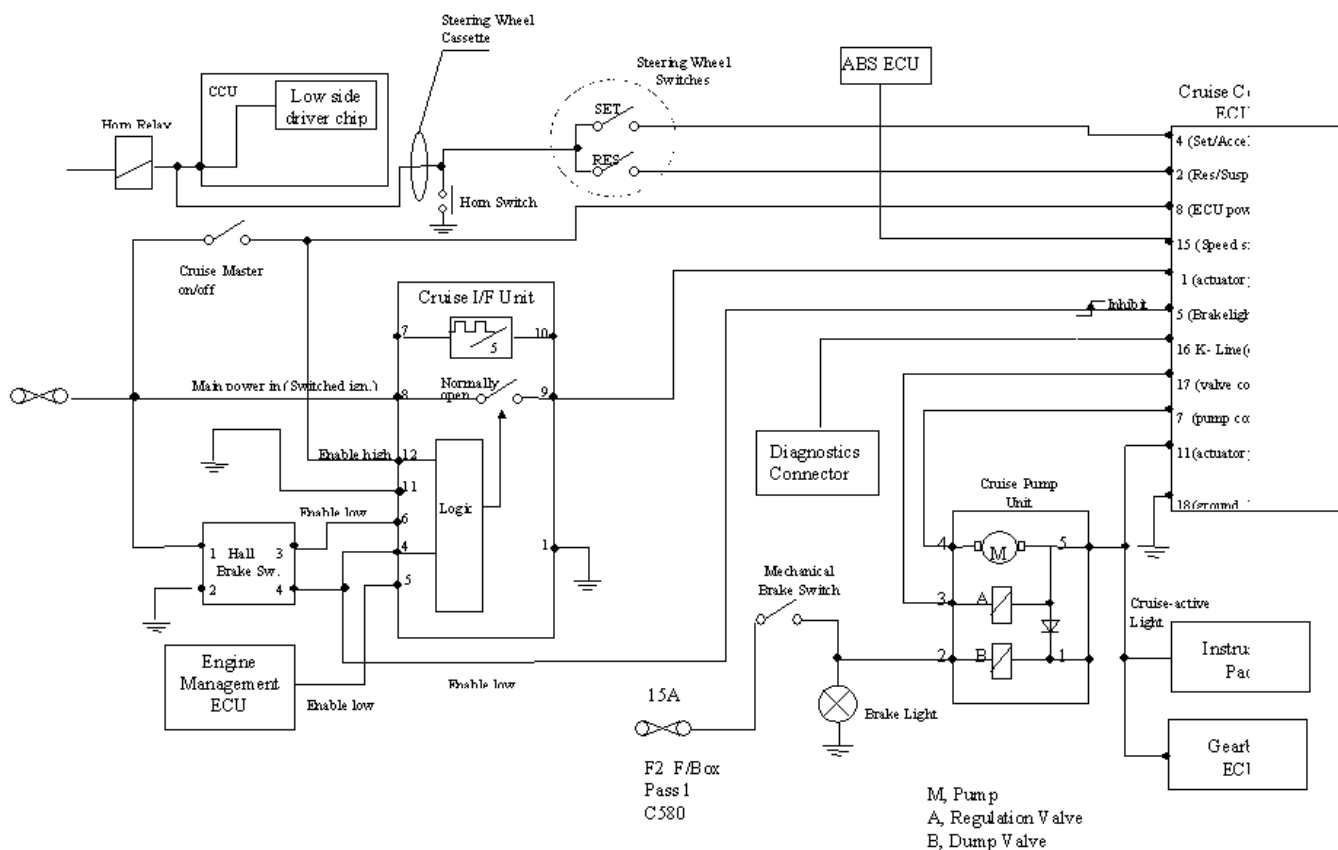


Figure 127

Mechanical brake switch

An output from the brake pedal switch is supplied to the vacuum pump assembly to ensure cruise control disengages when the brakes are applied, even if the vacuum pump assembly remains active. The dump valve in the vacuum pump assembly is earthed via the brake lamps and energised closed while cruise control is active. The brake pedal switch is open while the brake pedal is released. When the brakes are applied, the brake pedal switch closes and connects a power feed to the brake lamps circuit, and thus to the earth side of the dump valve. This ensures the dump valve is de-energised, which allows it to open and release the vacuum from the vacuum actuator.

Integrated vacuum pump

The vacuum pump is located in the LH front corner of the engine compartment, on mounting rubbers attached to the front of the battery box. Integrated with the pump unit are the regulator solenoid valve and the release/dump solenoid valve. Connecting hoses link the outlets of the control valve and the dump valve to the inlet side of the vacuum pump, at a vacuum actuator connection. A further connecting hose links the inlet side of the control valve to the outlet side of the vacuum pump at a common vent. A second vent is provided for the inlet to the dump valve. A non return valve between the vacuum pump and the vacuum actuator connection prevents the reverse flow of air through the vacuum pump. An electrical connector on the underside of the valve housing connects the vacuum pump assembly to the cruise control ECU and the brake pedal switch via the vehicle wiring.

The cruise ECU controls the electrical inputs to the vacuum pump and motor, and to the solenoid valves. Switching 'on' and 'off' of the vacuum pump and the control of the vacuum release dump solenoid valve are governed by the cruise ECU. The cruise ECU controls the throttle actuator and maintains the throttle in the correct position to match the cruise speed selected. It does this by continuously switching the vacuum motor 'on' and 'off', and opening and closing the release/dump solenoid valve. The vacuum release/dump control solenoid is opened fully when cruise is suspended and the power to the vacuum pump and motor is switched off. Therefore, the vacuum acting on the throttle actuator is released. The instrument pack taps off the supply from the cruise ECU to the pump and uses it to illuminate the cruise active indicators. This line is also fed to the automatic transmission control unit (ATCU) and enables selection of the cruise control shift map.

Vacuum pump



Figure 128

Pneumatic actuator

The vacuum actuator translates pneumatic pressure changes into axial movement to operate the throttle. The actuator is installed in a mounting bracket attached to the throttle body.

A diaphragm installed in a chamber is connected to the vacuum pump assembly on one side and vented to atmosphere on the other. An actuating rod connects the diaphragm to the throttle linkage on the throttle body. When cruise control is engaged, the vacuum pump assembly reduces the pressure on one side of the diaphragm and the diaphragm moves the actuating rod to operate the throttle. The operating range of the vacuum actuator is from 0 to 88 ± 4 % of throttle opening. This ensures there is sufficient range to induce normal down gear changes, but prevents kickdown.

The throttle linkage allows the vacuum actuator to operate the throttle without moving the accelerator pedal, and also allows the accelerator pedal to override the vacuum actuator, to increase throttle opening, when the driver wants to accelerate the vehicle above the set speed.

Throttle actuator

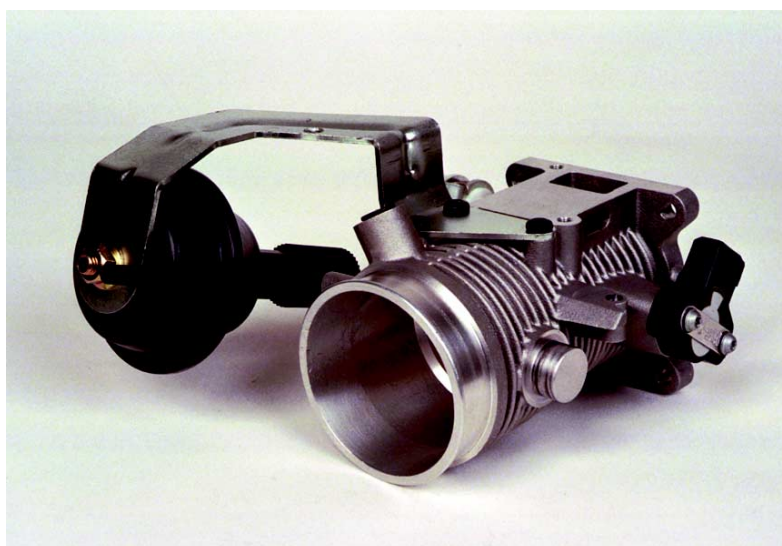


Figure 129

Automatic transmission

When the gear selector lever is in park, neutral or reverse, cruise is inoperative. The ATCU transmits the selected gear onto the CAN bus system. The engine management system receives the CAN signal and only enables cruise, via the cruise interface unit, if the appropriate gear has been selected.

There is also a link to the automatic transmission control unit which informs the ATCU that cruise has been activated and the correct gear shift map can be selected.

Cruise control instrument lamp

When cruise is active, the yellow warning lamp is illuminated on the instrument panel to inform the driver that cruise control is active.

Suspension of petrol cruise control

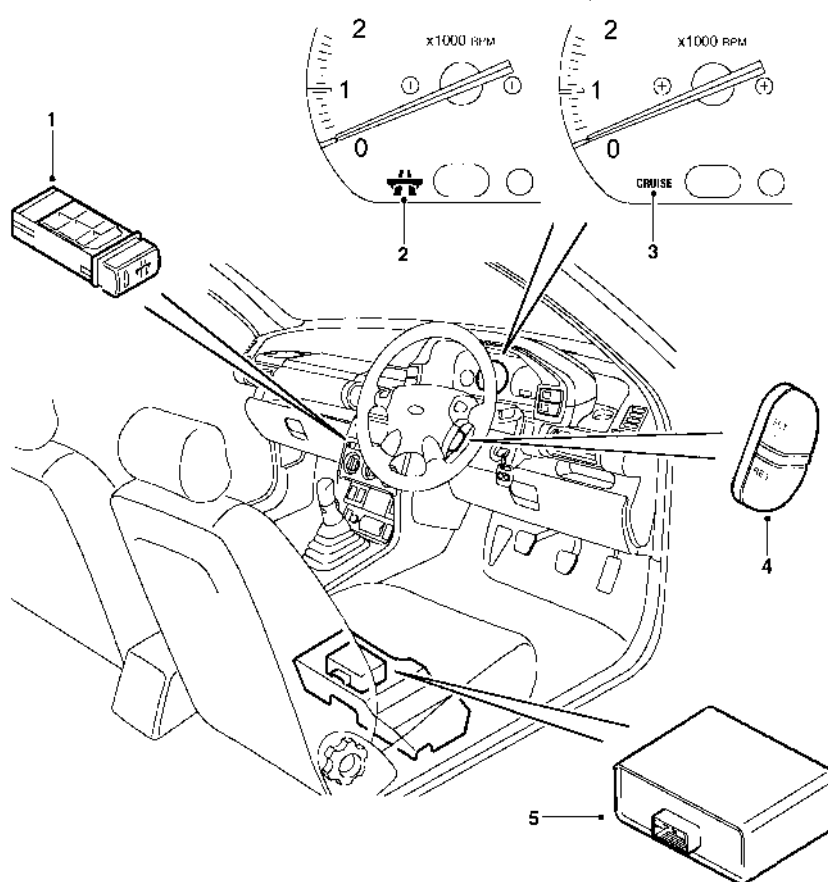
The following are actions and conditions which will cancel the operation of petrol cruise control but retain the set speed in the cruise ECU memory:

- Operation of the RES/SUS switch when cruise is active
- Brake switch operation
- Appropriate forward gear not selected
- Engine speed out of range (0–6550 rpm)
- Road speed out of range 28-125mph
- Acceleration limit exceeded (approx 5m/s²)
- Traction control active
- Vehicle speed drops below 75% of set speed

M47R diesel cruise control

The cruise control system on KV6 is a stand alone system with its own ECU and interface unit and it controls the throttle angle directly. On the M47R engine the cruise control system is integrated into the Bosch engine management system and fuel delivery is controlled via the drive by wire system. There is no vacuum pump or throttle actuator.

Component location



M18 0649

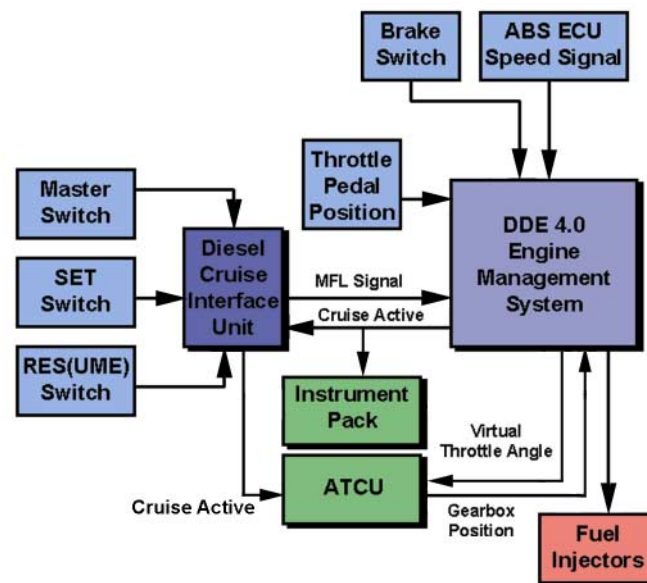
Figure 130

1. Master switch
2. Warning lamp (all except NAS)
3. Warning lamp (NAS only)
4. Steering wheel switches
5. Interface ECU

Software within the engine management system, working in conjunction with associated components around the vehicle, directly controls the fuel injector pulse width. This control ensures the right amount of fuel is delivered to maintain the vehicle at the set speed programmed by the driver.

Other components of the M47RR cruise control system are the cruise interface unit, and inputs from around the vehicle i.e. brake switch, steering wheel switches, the master switch, road speed signal and a signal from the automatic gearbox.

From a customer/driver perspective the activation and adjustment of the diesel cruise control system is the same as that of the KV6 control system.

M47R control diagram*Figure 131***M47R cruise interface unit**

This is an ECU which listens on the CAN-Bus system and converts driver inputs from the master switch and the steering wheel switches into the digital format that is compatible with the ECM. This serial message is termed multi-function logic (MFL) and is transmitted via a discrete link between the interface unit and the ECM. The interface unit also provides a 12 volt hard wired signal to the instrument pack and the ATCU when cruise is active.

A series of pulses between 0 and 12 volts is transmitted from the interface unit to the ECM. The ECM can convert these pulses into a message which determines the status of the cruise switches. This signal is sent continually to the ECM and if it is not present cruise will be suspended by the ECM. The ECM will store an MFL fault in this type of failure.

M47R cruise interface unit



Figure 132

Engine control module

The signal from the interface unit to the ECM will contain information supplied by the steering switches. The ECM monitors various other inputs from around the vehicle and can calculate a fuelling strategy based on the inputs to maintain the required speed. The ECM also delivers a signal to the ATCU, via the CAN system, which is equivalent to the throttle angle (virtual throttle angle). This signal is used by the automatic transmission control unit to control gear shifting to suit requirements.

The brake switch output and the wheel speed signal are fed into the ECM. When circumstances arise requiring suspension of cruise, the ECM sends a signal to the interface unit, via CAN, that it is suspending cruise and the interface unit stops the cruise active signal to the ATCU and the instrument pack.

The road speed signal is sent by the ABS ECU to the engine management system via a CAN link. The signal is an average of all working wheel speed sensors.

This system suspends and cancels cruise in the same circumstances as the KV6 system. The M47R diesel cruise control system will also cancel cruise if the vehicle speed overshoots the stored speed by over 16 km/h for more than 30 seconds. This can be as a result of the vehicle going down hill for long periods or by the driver overriding cruise using the accelerator pedal.

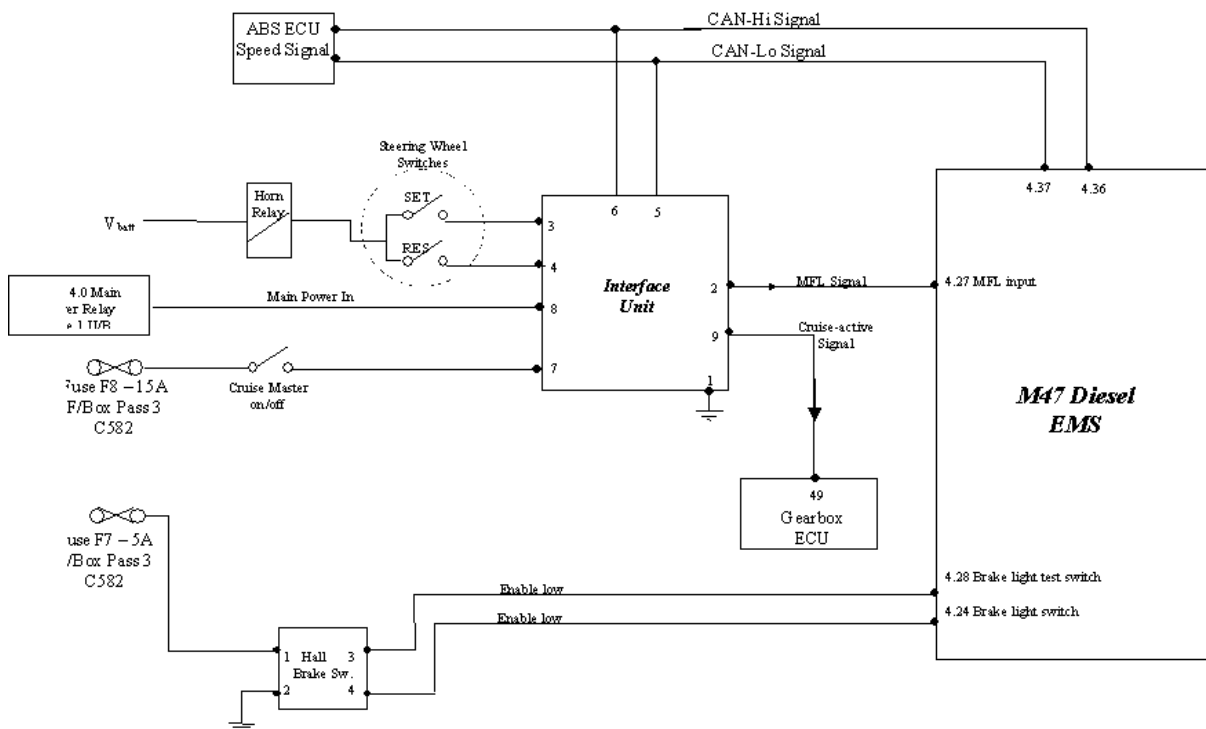


Figure 133

CAN functions

The CAN bus is a serial communications data bus, consisting of two wires twisted together, that allows the high speed exchange of digital messages between control units. The following CAN messages are used for control of the cruise control system:

- Cruise control status, from the ECM. To advise the interface ECU if the ECM cruise control mode is active or inactive. Also used by the instrument pack to operate the cruise control warning lamp.
- Road speed, produced by the ABS modulator from ABS sensor inputs. Used by the ECM for monitoring vehicle speed.
- 'Virtual' accelerator pedal position, calculated by the ECM from the amount of fuel used to maintain the set speed. Used by the EAT ECU for gear change control, in place of the input from the accelerator pedal position sensor.
- Gear position, from the EAT ECU. Used by the ECM to ensure the vehicle is in drive for cruise control operation.

Suspension of diesel cruise control

The following are actions and conditions which will cancel the operation of diesel cruise control but retain the set speed in the EMS memory:

- Operation of the RES/SUS switch when cruise is active
- Brake switch operation
- Appropriate forward gear not selected
- Road speed out of range 28-125mph
- Deceleration limit exceeded
- Traction control active
- Vehicle speed overshoots set speed by 16 k/ph for more than 30 seconds

Diagnostics and fault finding

Diagnostic is carried out using TestBook which interrogates the engine control module for faults stored on the cruise control system. Although the interface unit is an ECU, it cannot communicate with TestBook via the diagnostic line.

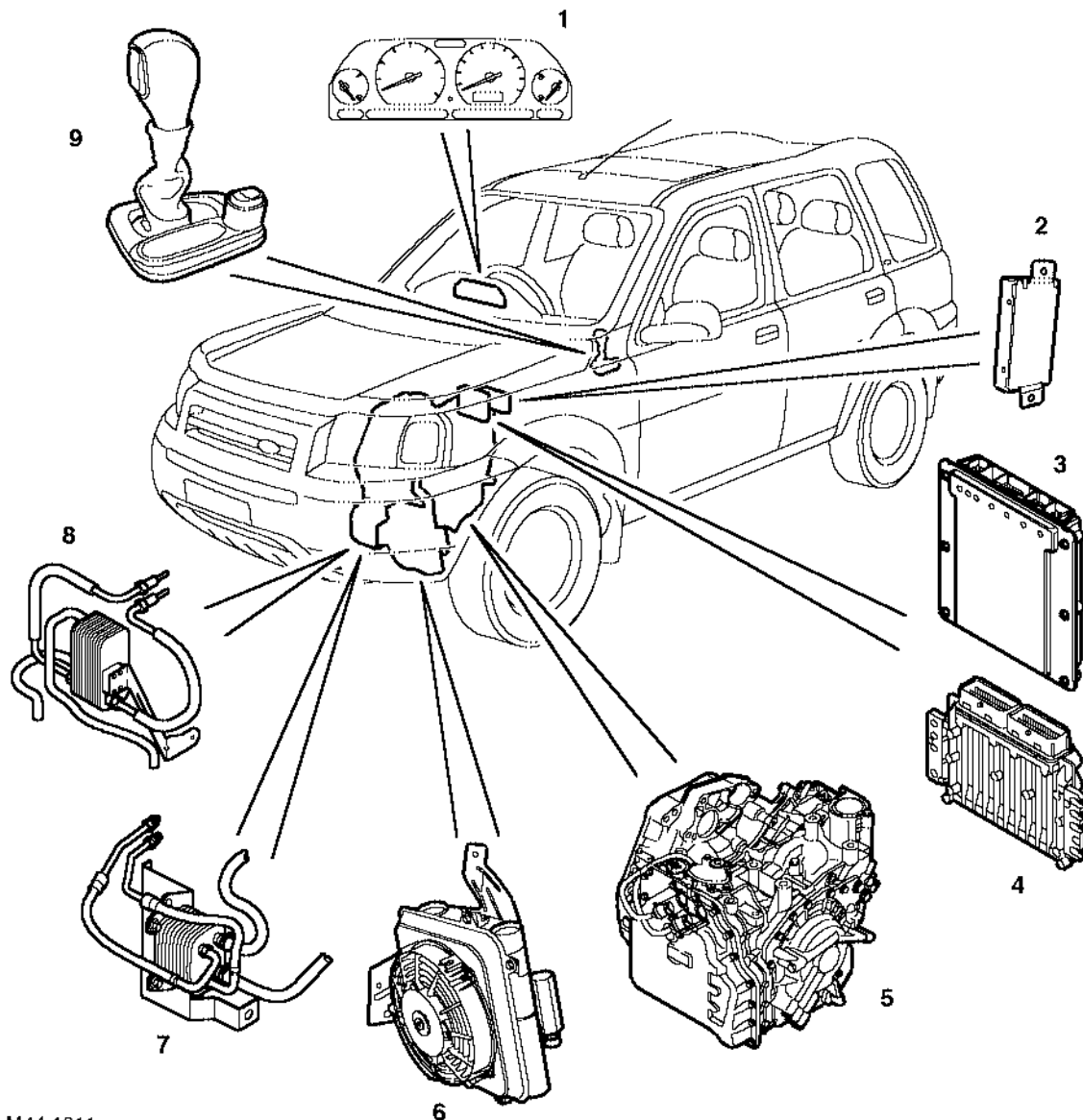
A fault with the interface unit can be detected by measuring the multi-function logic output to the engine management system using a voltmeter. When functioning correctly, the reading will fluctuate midway between 0 and 12 volts e.g. 6 - 8 volts. If the reading is either a constant 0 volts or a constant 12 volts this indicates a failure inside the interface unit. An MFL fault will be stored by the ECM. A faulty CAN harness link from the interface unit to the ECM could trigger the ECM to store an MFL fault because the MFL signal would not be present. If the MFL signal is present at the output from the interface unit but an MFL fault is stored by the ECM, it is logical to assume a fault with the CAN link.

JATCO

General

The JATCO JF506E automatic gearbox is an electronically controlled, five speed gearbox which incorporates software to enable the gearbox to operate as a semi-automatic 'Steptronic' gearbox.

Transmission component location



M44 1611

Figure 134

- 1. Instrument pack
- 2. Electronic Automatic Transmission (EAT) ECU
- 3. Engine Control Module (ECM) - M47R

- 4. Engine Control Module (ECM) - KV6
- 5. JATCO Steptronic gearbox
- 6. Fluid cooler
- 7. Selector lever assembly

The gearbox can be operated as a conventional automatic gearbox by selecting P, R, N, D, 4, 2 or 1 on the selector lever. Moving the selector mechanism across the gate to the 'S/M' position, sends a signal to the Electronic Automatic Transmission (EAT) ECU, also known as the Automatic Transmission Control Unit (ATCU) and puts the gearbox into sport/manual mode.

In sport mode, the gearbox still operates as a conventional automatic transmission, but the unit becomes more responsive to driver demands. Lower gears will be held longer and the transmission will downshift more readily. This gives increased acceleration and improves vehicle response.

When in sport mode, if the selector lever is moved to the + or - positions, the system will automatically change to operate in manual mode. Manual gear changes can be performed sequentially using the selector lever. Movement of the selector lever in the forward (+) direction changes the gearbox up the ratios and movement in a rearward (-) direction changes the gearbox down the ratios.

Gearbox operation is controlled by the EAT ECU and the Engine Control Module (ECM) which communicate via a Controller Area Network (CAN) Bus. The EAT ECU receives information from the ECM and gearbox sensors to calculate the appropriate gear ratio for the conditions and controls solenoid valves to operate the gearbox as required.

The advantages gained with the electronically controlled gearbox are smoother gear changes, quicker and more accurate gear change scheduling and reduced fuel consumption through improved engine/gearbox speed matching.

Steptronic JATCO automatic gearbox

The JATCO five speed automatic gearbox is similar to conventional electronically controlled transmissions but provides the driver with an additional manual mode feature. Manual mode allows the driver to electronically select the five forward gear ratios and operate the gearbox as a semi-automatic manual gearbox.

The individual gear ratios are achieved through three planetary gear sets. The components of the planetary gear sets are driven or locked by means of four multi-plate clutches, two multi-plate brakes, one brake band and two one-way clutch assemblies. The torque is transmitted from the gearbox to the final drive through a reduction gear.

Gearbox casing

The gearbox casing contains the input shaft transmitting the power into the drive train. The drive train is made up of the planetary gear sets and clutches.

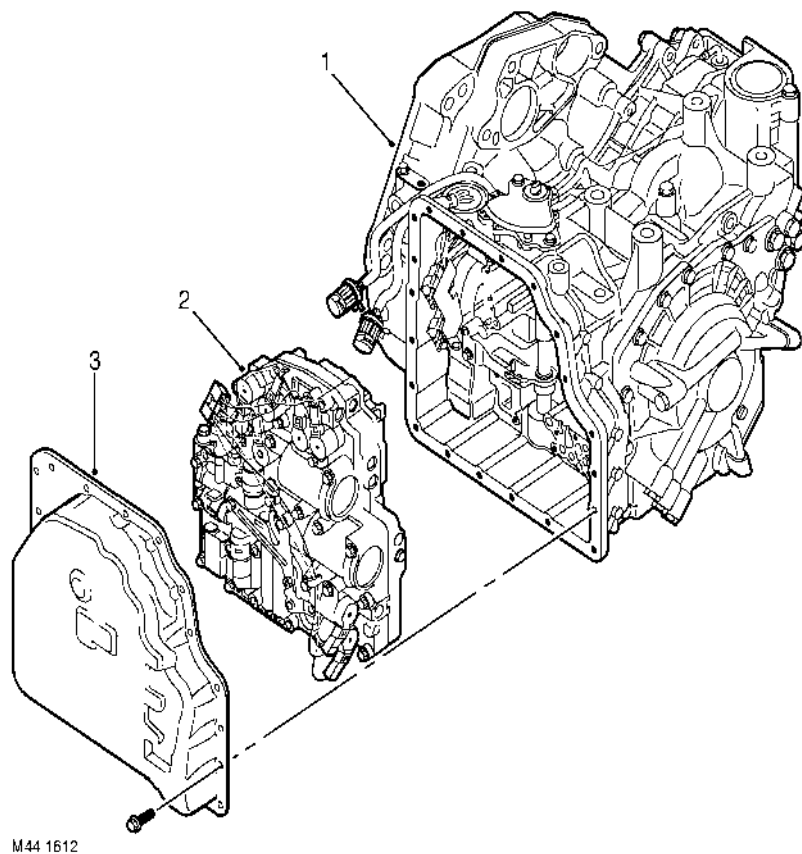


Figure 135

- 1. Gearbox
- 2. Solenoid valves and valve block
- 3. Fluid pan

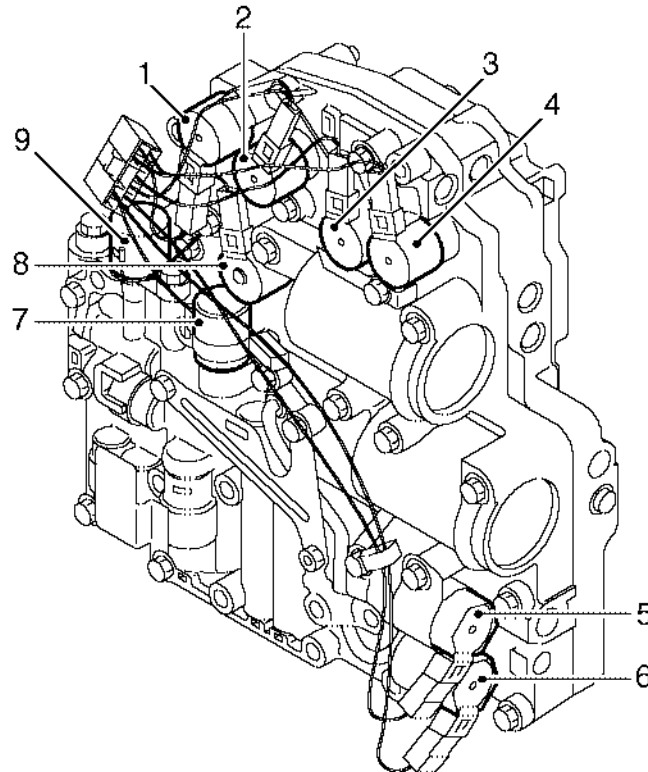
The clutches and brake bands control which elements of the planetary gear sets are engaged and their direction of rotation, to produce the P and N selections, five forward ratios and one reverse gear ratio. Power output is from the drivetrain through a reduction gear into a differential.

Gear Ratios

Gear		Ratio	
KV6		M47R	
1st	3.474		3.801
2nd	1.948		2.131
3rd	1.247		1.364
4th	0.854		0.935
5th	0.685		0.685
Reverse	2.714		2.970
Final Drive Ratio	3.66		2.91

Valve block and solenoid valves

The gearbox uses nine solenoid valves located on the valve block. The solenoid valves are energised/de-energised by the EAT ECU to control the gearbox fluid flow around the gearbox to supply clutches, brakes and brake band (gear change scheduling), fluid to the torque converter, lubrication and cooling.



M441614

Figure 136

- 1.Shift solenoid valve A
- 2.Reduction timing solenoid valve
- 3.Shift solenoid valve B
- 4.Shift solenoid valve C
- 5.2-4 brake duty solenoid valve
- 6.2-4 brake timing solenoid valve
- 7.Low clutch timing solenoid valve
- 8.Lock-up solenoid valve
- 9.Line pressure duty solenoid valve

Each solenoid valve is controlled separately by the EAT ECU. All nine solenoid valves can be classified into two types by their operating type. Three of them are duty solenoid valves and the remaining six are on-off solenoid valves.

Each solenoid valve consists of an internal coil and needle valve. A voltage is passed through the coil of the solenoid to actuate the needle valve. The needle valve opens and closes the fluid pressure circuits. On-off solenoid valves close the fluid pressure circuits in response to current flow.

Duty solenoid valves repeatedly turn on and off in 50 Hz cycles. This opens and closes the fluid circuits allowing a higher level of control on the circuits. For example, smooth operation of the lock-up clutch in the torque converter to eliminate harsh engagement/ disengagement.

All of the solenoid valves are supplied with battery voltage and an earth path by the EAT ECU.

On/Off solenoid valves

The on/off solenoid valves are:

- Shift solenoid valve A
- Shift solenoid valve B
- Shift solenoid valve C
- Low clutch timing solenoid valve
- Reduction timing solenoid valve
- 2-4 brake timing solenoid valve.

The EAT ECU switches the on/off solenoid valves to open and close in response to vehicle speed and throttle opening.

Shift solenoid valves A, B and C are used to engage the different gear ratios within the gearbox. The position of these solenoid valves at any one time determines the gear selected.

Shift solenoid Valve Activation

Shift Solenoid Valve	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear
A	X	O	X	X	O
B	O	O	O	X	X
C	O	X	X	O	O
X = Solenoid Valve Off O = Solenoid Valve On					

The reduction timing solenoid valve, low clutch timing solenoid valve and 2-4 timing solenoid valve are used by the EAT ECU to control the timing of the gear shift changes.

These solenoid valves carry out three main functions:

- **Shift timing control:** For some shifts these three solenoid valves are used to assist line pressure control or 2-4 brake pressure control.
- **Line pressure cut back:** When the gearbox takes up the drive there should be a high line pressure present. The EAT ECU controls the low clutch timing solenoid valve which is related to the vehicle speed in order to switch the fluid circuit of the line pressure to on or off therefore controlling cut back.
- **Reverse inhibition:** If the vehicle exceeds 6 mph (10 km/h) and Reverse (R) is selected, the EAT ECU switches the low clutch timing solenoid valve on. This drains the gearbox fluid from the reverse clutch, therefore the clutch will be unable to engage.

Duty solenoid valves

The duty solenoid valves are:

- Lock-up duty solenoid valve
- Line pressure duty solenoid valve
- 2-4 duty brake solenoid valve.

The lock-up duty solenoid valve is used by the EAT ECU to control the lock-up of the torque converter depending upon the vehicle speed and throttle position.

The EAT ECU will actuate the lock-up solenoid valve, which operates the lock-up control valve to direct fluid to either lock or unlock the torque converter.

The line pressure duty solenoid valve and 2-4 duty brake solenoid valve are used by the EAT ECU to control fluid line pressure in the gearbox.

The EAT ECU calculates the line pressure by using the engine speed, vehicle speed and throttle angle. The EAT ECU then actuates the solenoid valves accordingly to achieve the required line pressure.

The solenoid valves can fail in the following ways:

- Open circuit
- Short circuit to 12 or 5 volts
- Short circuit to earth.

In the event of a solenoid valve failure any of the following symptoms may be observed:

- Gearbox selects fourth gear only (shift solenoid valve failure)
- Gearbox will not upshift to fourth gear (timing solenoid valve failure)
- Increased fuel consumption and emissions (lock-up solenoid valve failure)
- Gear shifts will have no torque reduction therefore gear changes will be very harsh (line pressure duty solenoid valve failure)
- No pressure control will occur therefore gear changes from fifth gear will be very harsh (2-4 brake duty solenoid valve failure).

Torque converter

The torque converter is located inside the torque converter housing which is on the engine side of the gearbox casing.

The torque converter acts as the coupling element between the engine and gearbox. The driven power from the engine is transmitted hydraulically and mechanically in certain gears and operating conditions, through the torque converter lock-up clutch to the gearbox. The torque converter is connected to the engine by a drive plate.

The torque converter consists of an impeller, stator and turbine. The engine drives the impeller, while the turbine drives the gearbox.

The stator is situated between the impeller and turbine on a one-way clutch. The impeller picks up fluid and throws it out into the turbine, thereby causing it also to rotate and transmit power.

The stator redirects the fluid thrown back by the turbine so that it re-enters the impeller in the same direction of rotation as the impeller, and at the best possible angle for efficient power gearbox.

The one-way clutch prevents the stator from moving backwards, so that this accurate redirection of fluid can be achieved. When the engine is idling the impeller throws out very little fluid. The turbine is not forced to turn, and the power is not transmitted to the gearbox.

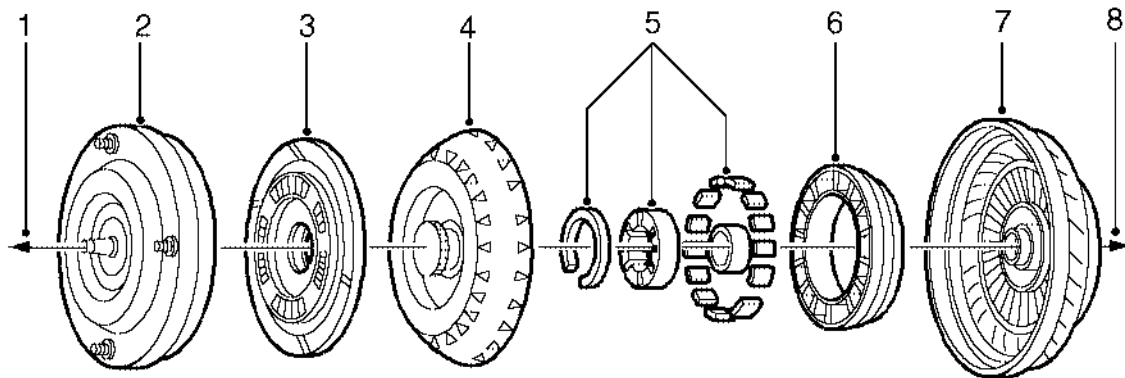
As engine speed increases the impeller throws out more fluid. The turbine begins to turn and picks up speed as the engine speed rises. As the speed of the turbine increases the fluid is thrown against the back of the stator, causing it to turn in the same direction.

When turbine speed approaches impeller speed, centrifugal force in both units is almost equal and all three components move at nearly the same rate. This is called the 'coupling point'.

The torque multiplication or drive ratio varies until a one to one coupling point is reached.

To achieve the power required to climb a hill, the driver depresses the accelerator pedal and the torque converter reacts by increasing the torque multiplication.

When driving on a flat road at cruising speed, the power required is not as great and therefore, the torque converter stays at one to one.



M44 1622

Figure 137

- 1.To engine
- 2.Torque converter cover welded to the impeller
- 3.Lock-up clutch
- 4.Turbine

- 5.One-way clutch
- 6.Stator
- 7.Impeller
- 8.To gearbox

Torque converter lock-up mechanism

In a torque converter there is always a certain amount of slip between the impeller and turbine. This will contribute to a reduction in fuel economy especially during high speed cruising.

This is eliminated by the torque converter lock-up mechanism. The lock-up mechanism is attached to the turbine and controls a lock-up clutch which is integral with the torque converter.

The lock-up mechanism comprises a lock-up solenoid valve, a lock-up control valve and a lock-up clutch.

The lock-up control is provided by the EAT ECU which operates the lock-up solenoid valve. The EAT ECU controls lock-up clutch engagement and release according to the lock-up schedule programmed into the ECU and the vehicle speed and throttle angle.

The lock-up mechanism operates with the gearbox in 'D' (normal mode 4th and 5th gears) and in manual 4th and 5th gears. In an emergency condition when high fluid temperatures are reached, the EAT ECU can also operate the lock-up mechanism in 2nd and 3rd gears to help reduce fluid temperatures.

In addition to the lock and unlock conditions, the lock-up control can also initiate smooth lock-up, coast lock-up and lock-up prohibition control.

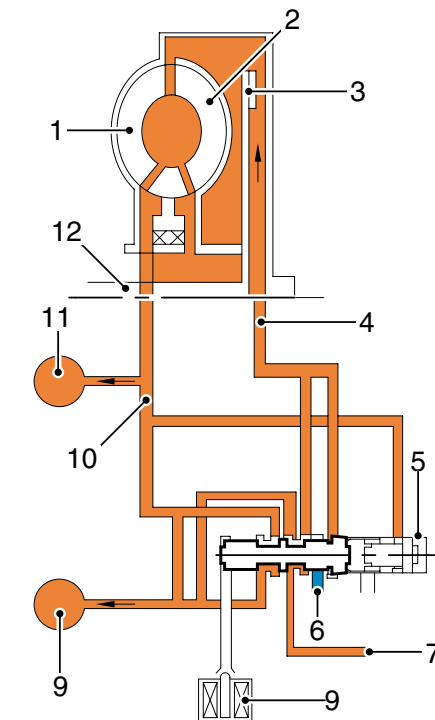
Smooth lock-up minimises lock-up shock by smoothly and slowly engaging the lock-up clutch.

Coast lock-up control maintains the lock-up condition after the throttle pedal has been released in the lock-up range at certain high speed driving. This prevents the lock-up control switching between the locked and unlocked condition caused by repeated on-off use of the throttle pedal.

Lock-up prohibition control prevents clutch lock-up within the range if the fluid temperature is below 40°C (104°F). This promotes faster warm-up of the gearbox fluid. This strategy is also used by the EAT ECU to prevent lock-up in 1st gear, park, reverse and neutral ranges.

Unlock condition

The unlock release pressure is supplied via the control valve to the lock-up clutch. The pressure forces the clutch mechanism away from the torque converter and moves the lock-up mechanism into the unlock condition. The torque converter pressure is decayed to the drain port, removing the applied pressure from the torque converter, allowing the clutch mechanism to move.



M44 1623

Figure 138

1. Impeller
2. Turbine
3. Lock-up clutch
4. Release pressure
5. Lock-up control valve
6. Drain port
7. Torque converter pressure
8. Lock-up solenoid
9. Fluid cooler
10. Torque converter applied pressure
11. Lubrication
12. Input shaft

Lock-up condition

The EAT ECU operates the lock-up solenoid, which in turn supplies pilot pressure to the control valve. The control valve moves under the influence of the pilot pressure, blocking the release pressure feed to the lock-up clutch and re-directing it to the other side of the clutch mechanism.

With the release pressure removed, the lock-up clutch moves and engages with the torque converter, moving the lock-up mechanism into the locked condition.

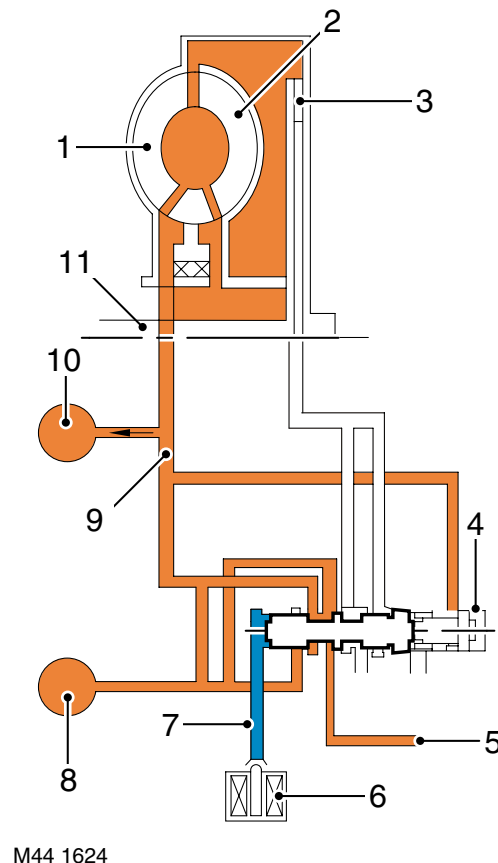


Figure 139

- 1. Impeller
- 2. Turbine
- 3. Lock-up clutch
- 4. Lock-up control valve
- 5. Torque converter pressure
- 6. Lock-up solenoid
- 7. Pilot pressure
- 8. Fluid cooler
- 9. Torque converter applied pressure
- 10. Lubrication
- 11. Input shaft

Smooth lock-up

Smooth lock-up occurs as the mechanism moves from the unlock to the locked condition. Torque converter release pressure is lowered gradually preventing a sudden lock-up clutch engagement, reducing lock-up shock.

The lock-up solenoid is a driven duty solenoid operating at 50Hz. The lock-up control valve has a pressure regulation device which reacts to torque converter release pressure and solenoid pilot pressure.

As the solenoid is operated, the pilot pressure is gradually applied to the control valve. This moves the valve, partially exposing the release pressure to a drain port.

The control valve is moved against an opposing spring by the increasing pilot pressure. The release pressure is decayed proportionally in response to the increasing pilot pressure allowing the clutch to smoothly engage with the torque converter.

Fluid cooling

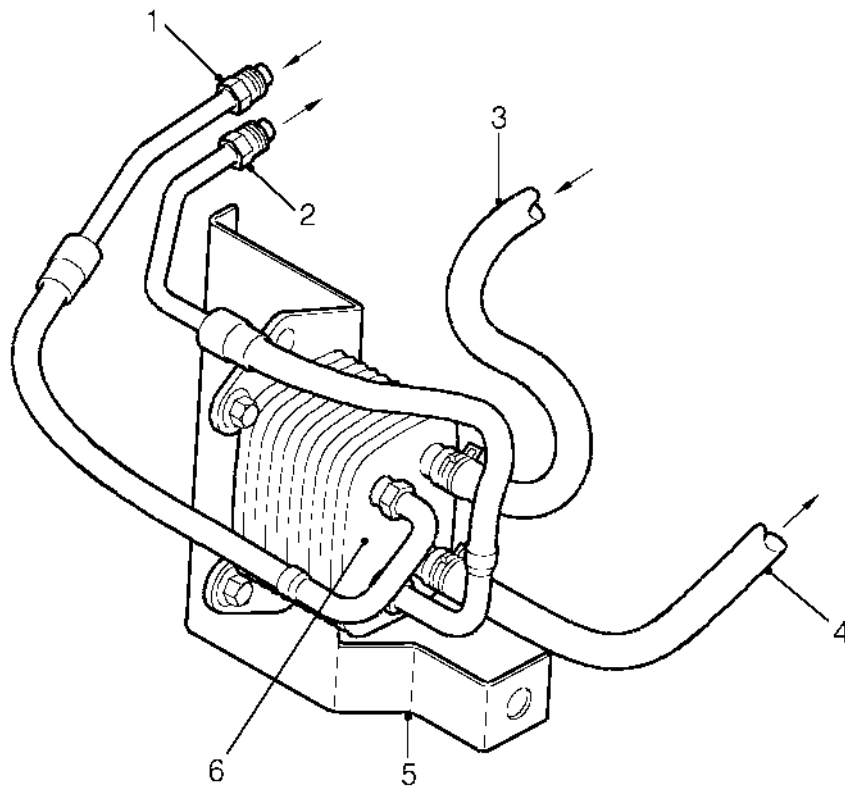
Fluid cooling is performed by a dedicated fluid cooler for the gearbox located on a bracket at the front of the gearbox.

The fluid cooler comprises cores which allow fluid to flow across from one side of the cooler to the other. Each core is surrounded by a water jacket which allows engine coolant to flow around the cooler.

The cooler is connected to the gearbox by metal pipes and flexible hoses. The engine coolant is connected from the heater matrix to the cooler and from the cooler to the thermostat housing with coolant hoses.

The gearbox fluid flows from the gearbox to the upper connection on the fluid cooler. The fluid then flows through the cores in the cooler which are surrounded by engine coolant which cools the gearbox fluid. The fluid exits the fluid cooler via the lower connection and is returned to the gearbox.

The engine coolant flows from the engine oil cooler into the upper coolant connection on the fluid cooler. The coolant exits the cooler via the lower connection and flows to the thermostat housing.

Blast air cooler

M44 1625

Figure 140

- 1. Gearbox fluid feed pipe
- 2. Gearbox fluid return pipe
- 3. Engine coolant feed hose
- 4. Engine coolant return hose
- 5. Bracket
- 6. Fluid cooler

Sensors

The EAT ECU sets correct gear change scheduling using three speed signal inputs: intermediate speed, turbine speed and vehicle speed in conjunction with a throttle position signal from the ECM.

Intermediate speed sensor

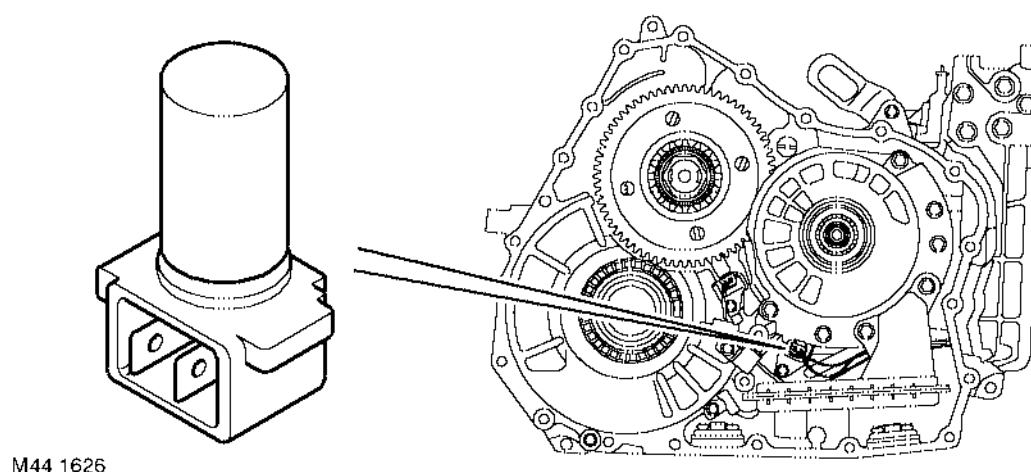


Figure 141

The intermediate speed sensor is located within the gearbox. The EAT ECU uses this sensor to ensure correct gear engagement and to monitor the amount of slip within the gearbox.

The EAT ECU calculates the slip within the gearbox by comparing the difference between the inputs from the intermediate speed sensor and the turbine speed sensor.

The intermediate speed sensor detects the output gear rotation speed and sends an electrical output to pin 51 of the EAT ECU which also supplies an earth path for the sensor on ECU pin 20.

The sensor is an inductive sensor that produces a sinusoidal output at a frequency of 54 pulses per revolution of the output gear.

The intermediate speed sensor can fail in the following ways: Sensor open circuit Short circuit to 12 or 5 volts Short circuit to earth. The EAT ECU will detect sensor failure if the vehicle speed exceeds 25 mph (40 km/h) and the sensor output is equivalent to less than 600 rev/min for two seconds.

In the event of an intermediate speed sensor signal failure any of the following symptoms may be observed:

- Upshift to 5th gear inoperative
- Torque reduction request from the EAT ECU to the ECM inoperative.

A failure of the sensor will generate a 'P' code which can be retrieved using TestBook or any Keyword 2000 diagnostic tool.

Turbine speed sensor

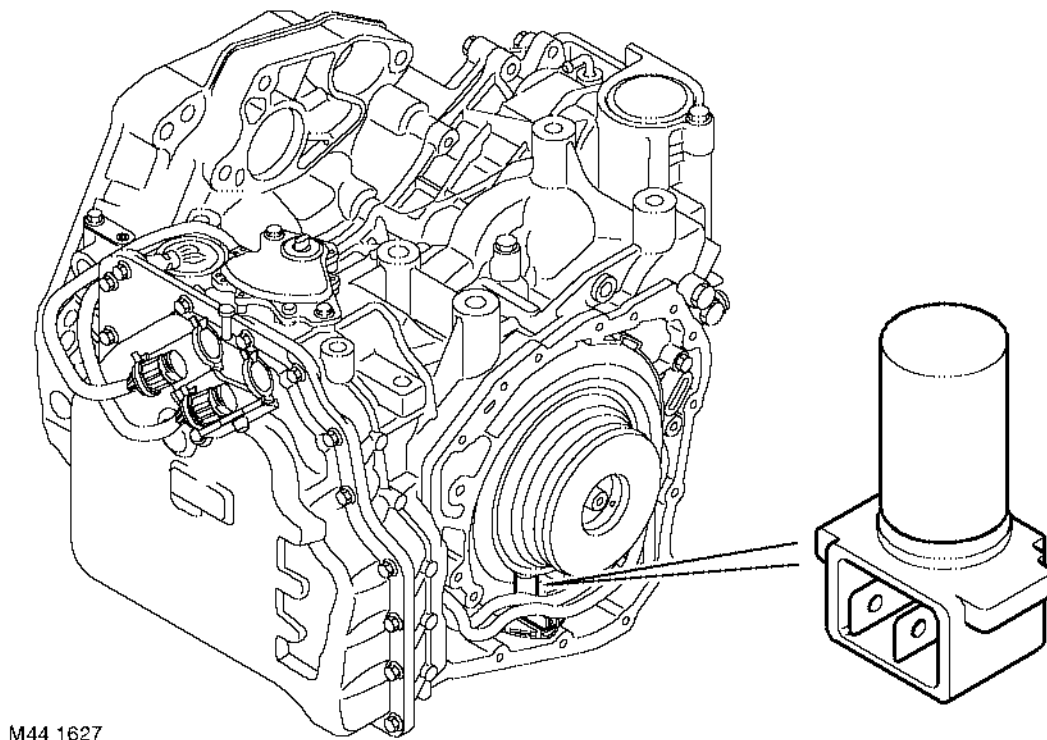


Figure 142

The turbine speed sensor is located within the gearbox and is used by the EAT ECU to monitor the input shaft speed. The EAT ECU uses this sensor to ensure the correct gear ratio is selected and to ensure that there is not excessive slip within the gearbox drive train.

The turbine speed sensor detects the input shaft speed (turbine speed) and sends an electrical output to pin 24 of the EAT ECU which also supplies an earth path for the sensor on ECU pin 20.

The sensor is an inductive sensor that produces a sinusoidal output at a frequency of 36 pulses per revolution of the input shaft.

The turbine speed sensor can fail in the following ways:

- Sensor open circuit
- Short circuit to 12 or 5 volts
- Short circuit to earth.

The EAT ECU will detect sensor failure if the vehicle speed exceeds 25 mph (40 km/h) and the engine speed is above 1300 rev/min, but the turbine speed is below 600 rev/min for two seconds.

In the event of a turbine speed sensor signal failure any of the following symptoms may be observed:

- Upshift to 5th gear inoperative
- Torque reduction request from the EAT ECU to the ECM inoperative.

A failure of the sensor will generate a 'P' code which can be retrieved using TestBook or any Keyword 2000 diagnostic tool.

Vehicle speed sensor

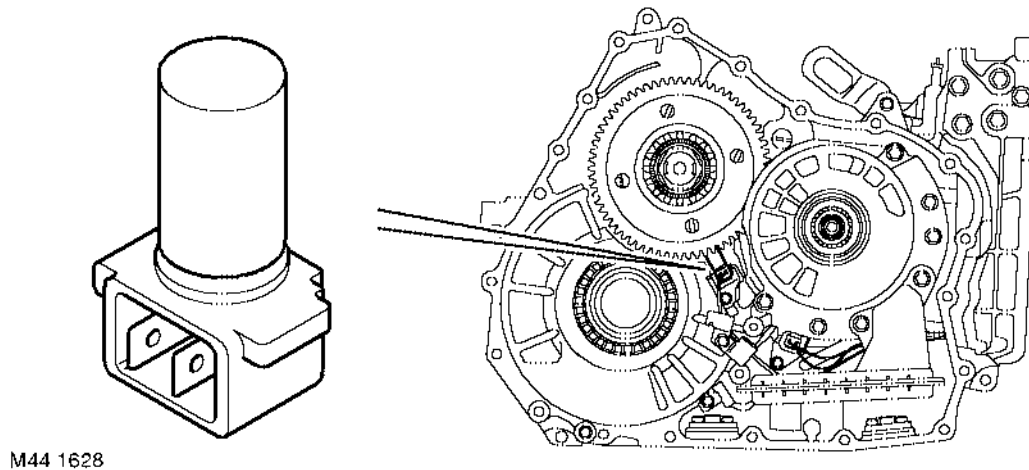


Figure 143

The vehicle speed sensor is located within the gearbox. The EAT ECU uses this sensor to monitor the rotational speed of the parking gear and calculate this reading into a vehicle speed. The EAT ECU also monitors the vehicle speed using a signal from the ABS ECU.

The vehicle speed sensor detects the parking gear rotation speed and sends an electrical output to pin 5 of the EAT ECU which also provides an earth path for the sensor.

The sensor is an inductive sensor that produces a sinusoidal output at a frequency of 18 pulses per revolution of the parking gear.

The EAT ECU uses the signal to calculate the following:

- Amount of engine torque reduction required during gear changes
- Notify the EAT ECU when the vehicle is stationary, for creep control.

The vehicle speed sensor can fail the following ways:

- Sensor open circuit
- Sensor short circuit to 12 or 5 volts
- Sensor short circuit to earth.

The EAT ECU will detect sensor failure if the ABS ECU speed signal is more than 25 mph (40 km/h) but the vehicle speed sensor reading is less than 3 mph (5 km/h) for more than two seconds.

In the event of a vehicle speed sensor signal failure any of the following symptoms may be observed: Upshift to 5th gear inoperative Torque reduction request from the EAT ECU to the ECM inoperative.

If a failure of the vehicle speed sensor occurs and the ABS ECU speed signal is functional, the EAT ECU will control gear shifting using the ABS ECU signal.

If both the vehicle speed sensor and the ABS ECU speed signals fail, the EAT ECU will lock the gearbox in fourth gear (fail-safe mode) and inhibit torque converter lock-up control.

Fluid temperature sensor

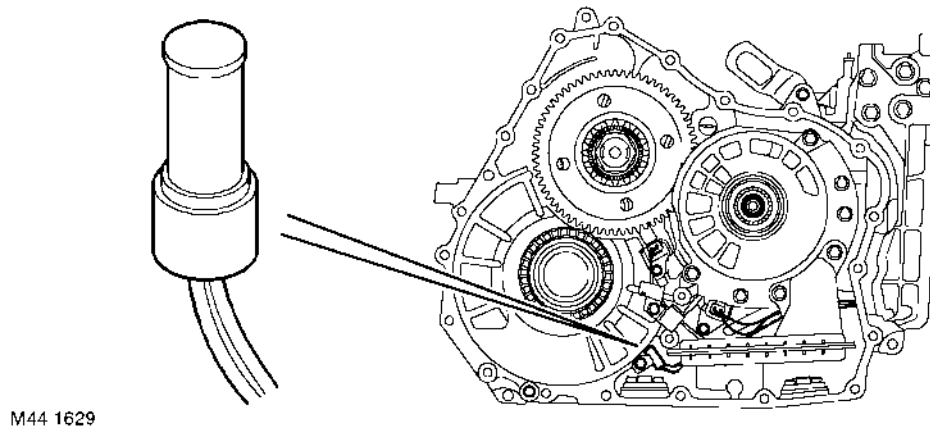


Figure 144

The fluid temperature sensor is located within the gearbox on the valve block. The EAT ECU uses this sensor to monitor the gearbox fluid temperature.

When the fluid is cold, the EAT ECU changes gear at higher engine speeds to promote faster fluid warm-up. If the fluid temperature becomes too high, the EAT ECU transmits a cooling request on the CAN link to the ECM to operate the cooling fans.

The fluid temperature sensor has an electrical output to pin 39 of the EAT ECU which also provides an earth path for the sensor.

The fluid temperature sensor is a negative temperature coefficient sensor. As the temperature rises, the resistance in the sensor decreases. As temperature decreases, the resistance in the sensor increases and the output voltage to the EAT ECU changes in proportion.

The output voltage from the sensor is in the range of 0 - 2.5 Volts with the lower voltage representing the highest temperature.

The change in resistance is proportional to the temperature of the gearbox fluid. From the resistance of the sensor, the EAT ECU calculates the temperature of the gearbox fluid. Should the fluid temperature sensor fail the EAT ECU uses the last recorded EAT ECU value as a default value.

Fluid temperature sensor resistance values

Temperature °C (°F)	Resistance kOhms Ω
-40 (-40)	54.90
-20 (-4)	16.70
0 (32)	6.02
20 (68)	2.50
40 (104)	1.16
60 (140)	0.59
80 (176)	0.33
100 (212)	0.19
120 (248)	0.12
140 (284)	0.08

The fluid temperature sensor can fail in the following ways:

- Sensor open circuit
- Short circuit to 12 or 5 volts
- Short circuit to earth.

The EAT ECU will detect temperature sensor failure when the vehicle speed exceeds 12.5 mph (20 km/h) and the temperature sensor provides a reading of less than -30°C (-22°F). In the event of a fluid temperature sensor signal failure any of the following symptoms may be observed:

- Upshift to 5th gear inoperative
- Torque reduction request from the EAT ECU to the ECM inoperative.

Selector and inhibitor switch

The selector and inhibitor switch is located on the selector shaft on top of the gearbox. The switch is connected via a 10 pin connector C0244 to the main harness. The switch receives battery voltage from the main relay via fuse 4 in the engine compartment fusebox.

The EAT ECU is provided with a voltage output from the selector and inhibitor switch that corresponds with the gear position the driver has selected.

The EAT ECU determines the position of the selector lever by monitoring seven sets of contacts in the selector and inhibitor switch which are operated by the selector shaft.

Each set of contacts corresponds to one of the seven selector lever positions (PRND421). Only one set of contacts will supply battery voltage to the EAT ECU at any one time. The EAT ECU monitors the switch output every 10 ms.

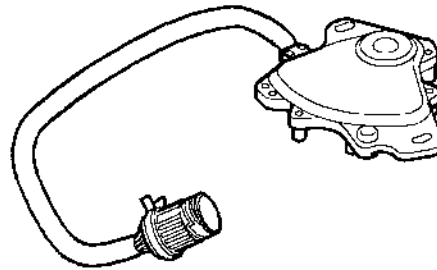
A pair of contacts are provided for the crank inhibit circuit. The contacts are only closed when the selector lever is in the 'P' and 'N' positions.

The two contacts are wired in series with the EWS3D immobilisation ECU. When the selector lever is in any position other than 'P' or 'N', the feed from the ignition switch to the immobilisation ECU is broken by the open contacts, preventing starter motor operation.

In the event of a selector and inhibitor switch signal failure, any of the following symptoms may be observed:

- Upshift to 5th gear inoperative
- Torque converter lock-up inoperative
- Torque reduction request from the EAT ECU to the ECM inoperative
- Cranking disabled if fault is on the two inhibitor switch contacts.

Selector position switch



M44 1630

Figure 145

Gear lever selector assembly

The gear selector lever assembly comprises a shift lock solenoid, a key interlock mechanism (if fitted), an LED module and a sport/manual switch.

A nylon cast plate provides the location for the selector lever components. The plate is secured to the floor pan with six integral studs and nuts. A rubber boot protects the assembly from dirt and moisture under the vehicle and also isolates vibrations from the lever.

The selector lever is attached to a gimbal mounting which allows gear selection of PRND421 in a forward and backward direction and selection between automatic and sport/manual in a left and right transverse direction. When sport/manual mode is selected, the lever can be moved in a forward or backward direction to select + or - for manual operation.

Gear selector assembly

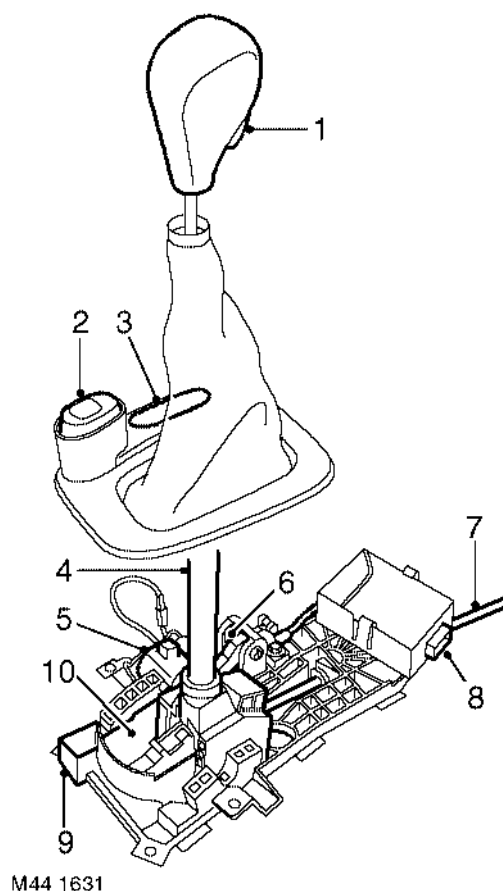


Figure 146

- 1. Park/Reverse release button
- 2. Hill descent control switch
- 3. LED Module
- 4. Selector lever
- 5. Shift interlock solenoid
- 6. Key interlock mechanism (Selected

- markets only)
- 7. Selector cable
- 8. Mirror fold ECU (if fitted - reference only)
- 9. Sport/manual switch connector
- 10. Sport/manual switch

There are seven selector lever positions:

- **P (Park)** - prevents the vehicle from moving by locking the gearbox.
- **R (Reverse)** - select only when vehicle is stationary and the engine is at idle.
- **N (Neutral)** - no torque transmitted to the drive wheels.
- **D (Drive)** - this position uses all five forward gears. Normal position selected for conventional driving.
- **4** - this position uses 1st to 4th gears only.
- **2** - this position uses 1st and 2nd gears only.
- **1** - this position uses 1st gear only.
- **S/M (Sport/Manual - Steptronic)** - this position uses all five gears as in 'D', but will shift up at higher engine speeds, improving acceleration.
- **+ and -** - movement of the selector lever in the +/- positions, when the selector lever is in the 'S/M' position, will operate the gearbox in manual (Steptronic) mode, allowing the driver to manually select all five forward gears.

The selector lever position is displayed to the driver on the LED module in the centre console and in the instrument pack and corresponds with the position of the selector lever. The LED module illumination and instrument pack display is determined by the selector and inhibitor switch assembly on the gearbox, with the exception of the 'S/M' LED and the 'Sport' instrument pack display which are operated by a hall effect sensor located on the sport/manual switch.

All vehicles with an automatic gearbox incorporate an interlock solenoid at the bottom of the lever, which prevents the lever being moved from P (Park) unless the ignition switch is in position II and the foot brake is applied.

In selected markets, a key interlock mechanism, operated by a Bowden cable from the ignition switch barrel assembly, is also operated by the selector lever park position. The mechanism prevents the ignition key from being removed from the ignition barrel when the selector lever is not in the park position. The mechanism also prevents the selector lever from moving from the 'P' position until the ignition switch is in position II.

Sport/Manual switch

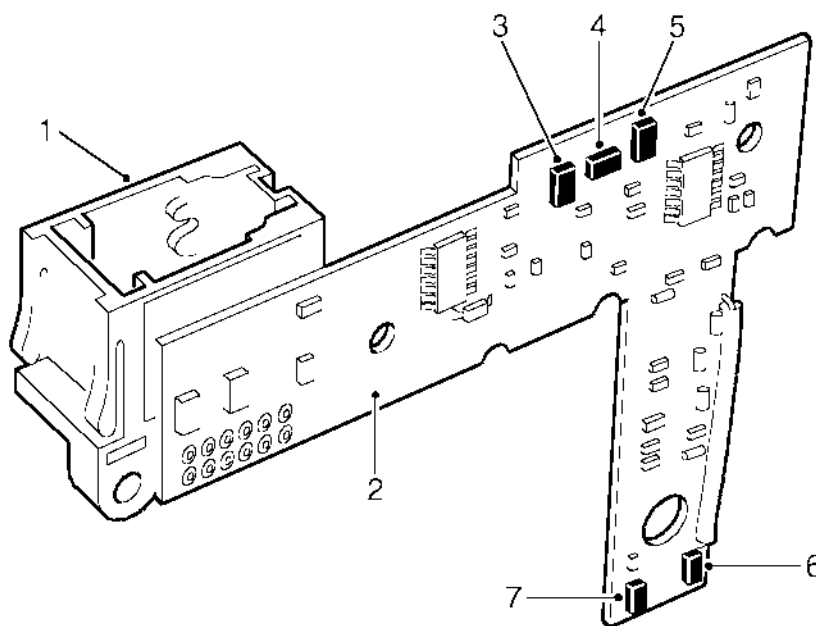


Figure 147

- 1.Connector
- 2.PCB
- 3.'4' sensor
- 4.'D' sensor
- 5.'N' sensor
- 6.'+' (plus) sensor
- 7.'-' (minus) sensor

The sport/manual switch comprises a PCB and connector socket which is located to the left of the selector lever and is an integral part of the selector lever assembly and cannot be serviced separately. The switch is connected to the main harness by a twelve pin connector.

The sport/manual switch has five proximity sensors which correspond to the D, N, 4 and +/- positions. The selector lever has two targets. An upper target is aligned with the DN4 sensors and the lower target is aligned with the +/- sensors.

When the selector lever is in the D position, the D sensor is aligned with the target and the EAT ECU receives a signal that D is selected. When the selector lever is moved to the S/M (sport) position, the target moves away from the sensor. This is sensed by the ECU which then initiates sport mode.

The sensors in the N and 4 positions inform the ECU that D has been deselected, but not to the S/M position, preventing the ECU from incorrectly initiating sport mode.

When the selector lever is moved to the S/M position, the target moves away from the D sensor. If the EAT ECU does not receive a signal from either the 4 or N sensors, it determines that sport has been selected. The lower target is positioned between the two sensors for +/- selection. If the selector lever is not moved to the +/- positions, the ECU keeps the gearbox in sport mode. If the ECU senses a signal from either the + or - sensor, it initiates manual mode and selects the manual gear selection requested. Manual mode will be maintained until the ECU senses a signal from the D sensor.

Shift interlock solenoid

The shift interlock solenoid is controlled by the EAT ECU. The solenoid receives a battery feed from the ignition switch position II.

When the ignition is switched to position II and the selector lever is in the park position, the EAT ECU provides a earth for the solenoid which energises, deploying a pin which locks the lever in park.

The brake switch receives a battery feed which is passed to the EAT ECU when the brake pedal is depressed. The ECU senses the brake switch signal and removes the earth path for the interlock solenoid, which retracts the pin and allows the selector lever to be moved from park.

LED module

The LED module is located in the selector lever surround and is secured with two integral clips. The module is connected to the main harness by a 12 pin connector C0675.

The LED module illuminates the applicable LED for the P, R, N, D, 4, 2, 1 and S/M positions. When the side lamps are switched on, all the LED's are illuminated at a low intensity, with the selected LED illuminated at a higher intensity.

Selector cable

The selector cable is a Bowden type cable that connects the selector lever to an input lever on the gearbox.

A 'C' clip secures the outer cable to the selector lever assembly; the gearbox end of the outer cable is secured to a bracket on the gearbox by an integral clip. The inner cable is adjustable at the connection with the gearbox input lever.

Brake switch

The brake switch is located on the pedal box below the fascia. The EAT ECU uses this switch to monitor brake pedal application status. The information is input to pin 43 of the EAT ECU on a hardwired connection from the switch.

The EAT ECU can allow the gearbox to apply more engine braking therefore slowing down the vehicle in a shorter distance and reducing brake pad wear. The EAT ECU achieves engine braking by applying the low and reverse clutches.

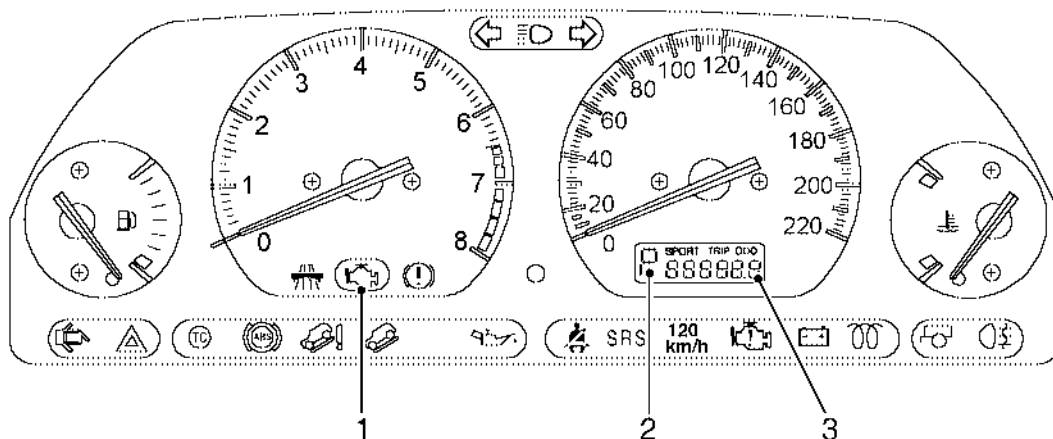
The brake switch can fail in the following ways:

- Switch open circuit
- Short circuit to 12 or 5 volts
- Short circuit to earth.

In the event of a brake switch signal failure, extra gearbox braking will not occur and shift lock solenoid (if fitted) will not function.

Instrument Pack

The instrument pack displays gearbox selection and fault information in the LCD and can illuminate the MIL for OBD emission related faults.



M44 1632

Figure 148

1. Malfunction Indicator Lamp (MIL)
2. Gearbox mode display
3. Liquid Crystal Display (LCD)

The gearbox related displays in the instrument pack are controlled by the ECM which transmits CAN message signals to operate the lamps and the LCD.

Malfunction Indicator Lamp (MIL)

The MIL is located in the instrument pack and is illuminated in an amber colour and shows a silhouette of an engine. The lamp is illuminated by a CAN message from the ECM on receipt of a CAN message from the EAT ECU.

Emission related faults are detected by the OBD feature in the EAT ECU and will illuminate the MIL in the instrument pack.

Liquid crystal display (LCD)

The LCD is located in a central position in the instrument pack. In addition to displaying the odometer and trip meter, the LCD also displays the current gearbox status. The following table shows the characters displayed and their definition.

Character	Description
P	Park
R	Reverse
N	Neutral
D	Drive
D ^{Sport}	Sport Mode
1	Manual 1st ratio
2	Manual 2nd ratio
3	Manual 3rd ratio
4	Manual 4th ratio
5	Manual 5th ratio
4 and F Flashing alternately	Severe fault detected - Limp home mode strategy initiated

The EAT ECU transmits the selector lever position through the CAN bus to the ECM. The ECM processes this information and passes it to the instrument pack in the form of CAN messages to display the gearbox status.

If the gearbox develops a fault and adopts the limp home mode, the LCD will alternately display 'F' and 4" to alert the driver that a fault has occurred and limp home mode is operational.

Electronic automatic transmission control unit

The EAT ECU is located in the environmental box (E-Box) in the engine compartment, adjacent to the ECM. The ECU is connected to the vehicle wiring by a 54 pin connector C0932.

The EAT ECU uses a 'flash' Electronic Erasable Programmable Read Only Memory (EEPROM). This enables a new or replacement EAT ECU to be externally configured. EEPROM also allows the EAT ECU to be updated with new information and market specific data.

To input new information and market specific data the EAT ECU must be configured using TestBook. The EEPROM allows the ECU to be reconfigured as many times as necessary to meet changing specifications and legislation.

The EAT ECU memorises the signal values of the gearbox sensors and actuators. These stored values ensure optimum gearbox performance is achieved at all times.

This information is lost if battery voltage is too low, for example if the battery becomes discharged. The EAT ECU reverts to default readings on first engine start after a battery discharge or disconnection. The EEPROM facility in the ECU allows the stored values to be re-learnt, ensuring optimum gearbox performance.

If these signals are not within the EAT ECU stored parameters, the ECU will make adjustments to the operation of the gearbox through the actuators to provide optimum drivability and performance.

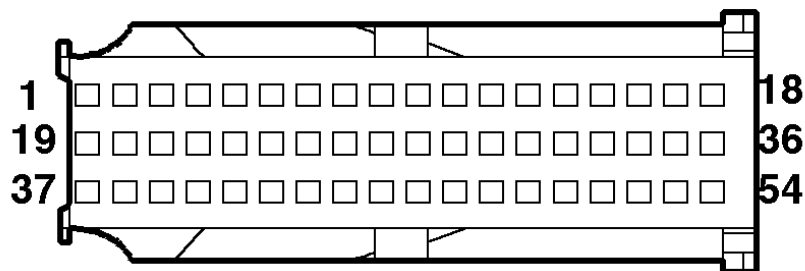
The inputs from the sensors constantly updates the EAT ECU with the current operating condition of both the gearbox and the engine. The ECU compares this current information with mapped information stored within its memory. The ECU will make any required adjustment to the operation of the gearbox through the following actuators:

- Gear control solenoid valves
- Lock-up solenoid valve
- Line pressure solenoid valve.

The EAT ECU also interfaces with the following:

- Engine Control Module (ECM) via the CAN
- Instrument pack via the CAN
- Diagnostic socket via the ISO 9141 K line.

Connector C0932 Pin Details



M44 1634

Figure 149

The following table shows the harness connector face view and pin numbers and input/output information.

Pin No.	Description	Input/Output
1	Diagnostic ISO9141 K Line	Input/Output
2	Not used	-
3	2/4 brake duty solenoid valve	Output
4	2/4 brake timing solenoid valve	Output
5	Vehicle speed sensor	Input
6	Not used	-
7	Selector 3rd range switch	Input
8	Selector 2nd range switch	Input
9	Earth	Input
10	Reduction timing solenoid valve	Output
11	Not used	-
12	CAN Bus - Low	Input/Output
13	CAN Bus - Low2	Input/Output
14	Shift solenoid valve B	Output
15	Shift solenoid valve A	Output
16	Lock-up duty solenoid valve	Output
17	Solenoid valves - Earth	Input
18	Line pressure duty solenoid	Output
19	Selector shift up (+) sensor	Input
20	Sensors - Earth	Input
21	Intermediate shaft speed sensor	Input
22	Not used	-
23	Not used	-
24	Turbine speed sensor	Input
25	Selector 'N' range switch	Input
26	Selector 'R' range switch	Input
27	Selector 'D' range switch	Input
28	Kick down inhibit	Input
29	Not used	-
30	Selector 'P' range switch	Input
31	Normal (drive) mode switch	Input
32	Not used	-
33	CAN Bus High	Input/Output
34	CAN Bus High2	Input/Output
35	Not used	-
36	12V Battery voltage from main relay	Input
37	Selector shift down (-) sensor	Input
38	Earth	Input
39	Fluid temperature sensor	Input
40	Not used	-
41	Sport / Manual hold switch	Input
42	Not used	-
43	Brake switch signal	Input
44	Not used	-
45	Selector 4th range switch	Input
46	Not used	-
47	Not used	-
48	Shift lock solenoid fault	Input

Pin No.	Description	Input/Output
49	Cruise switch signal (from cruise control ECU)	Input
50	Shift lock solenoid earth	Input
51	Not used	-
52	Shift solenoid valve C	Output
53	Low clutch timing solenoid valve	Output
54	12V Battery voltage from main relay	Input

Main relay

The main relay is located in the engine compartment fusebox and supplies battery voltage to the EAT ECU, in addition to other vehicle components. The main relay is energised by the ECM when the ignition is switched on.

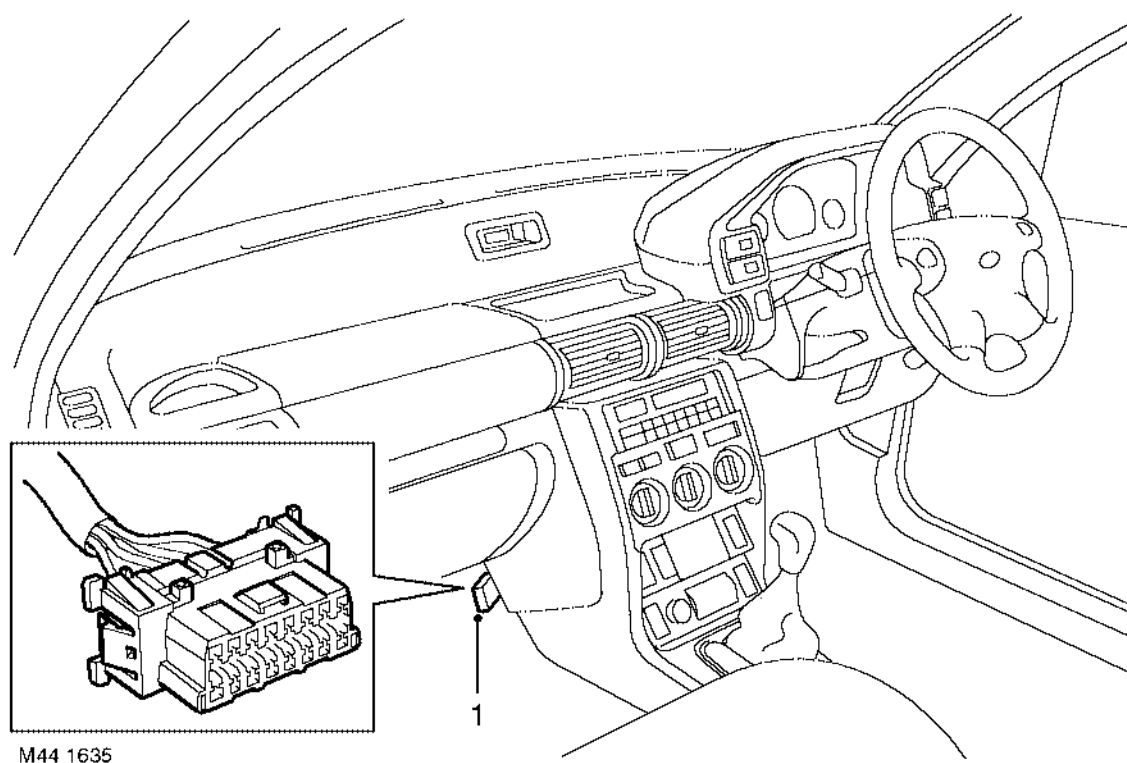
When the ignition is switched off, the ECM will maintain the main relay in an energised state for several minutes. This allows for cooling fan operation to continue after the engine has been switched off and allows other vehicle ECU's to remain active. The EAT ECU remains active for a short period after the ignition is switched off to allow EEPROM fault code data to be stored.

In the event of a main relay failure, any of the following symptoms may be observed:

- The gearbox will be locked in 4th gear (limp home mode)
- No CAN communications will be available.

Diagnostics

A diagnostic socket allows the exchange of information between the EAT ECU and TestBook. The diagnostic socket is located behind the centre console, in the passenger footwell.



M44 1635

Figure 150

1.Diagnostic socket

The diagnostic socket is connected to the EAT ECU on an ISO9141 K Line. The system uses a 'P' code diagnostic strategy and can record faults relating to the gearbox operation. The codes can be retrieved using TestBook or any diagnostic tool using Keyword 2000 protocol.

Diagnostic Trouble Codes (DTC)

The following table lists P codes, affected components and fault description.

The diagnostics related to diagnostic trouble codes introduced by ECD3 are disabled on vehicles built prior to the ECD3 compliance date.

P Code	Component	Description
P0702	GND return (Sensor earth)	Short circuit to battery
P0705	Selector and inhibitor switch input	Multiple signal or No signal
P0710	ATF temperature sensor	Signal out of range
P0715	Turbine speed sensor	No signal
P0720	Vehicle speed sensor	No signal
P0732	1st gear ratio	Out of range
P0732	2nd gear ratio	Out of range
P0733	3rd gear ratio	Out of range
P0734	4th gear ratio	Out of range
P0735	5th gear ratio	Out of range
P0736	Reverse gear ratio	Out of range

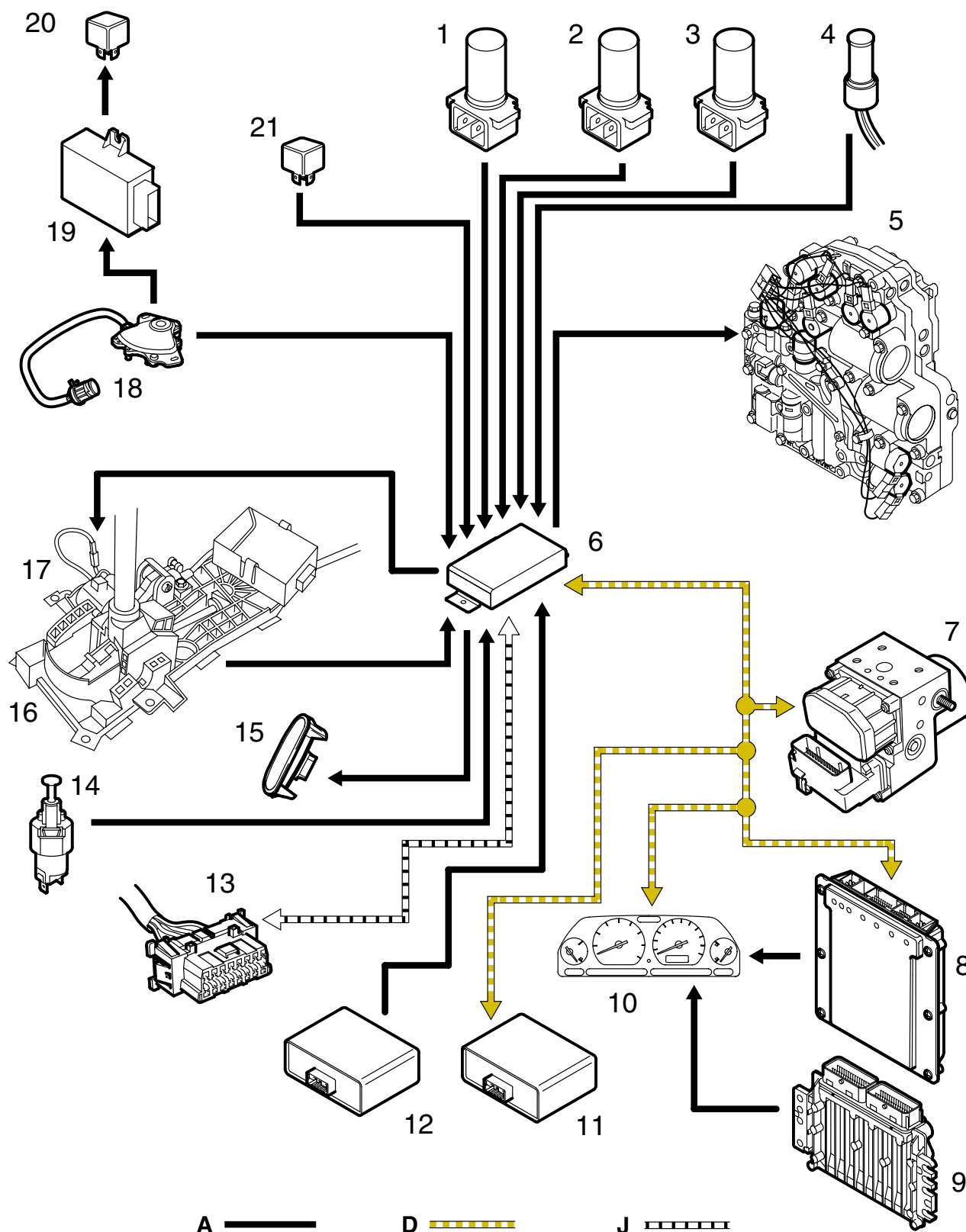
P Code	Component	Description
P0740	Lock-up clutch solenoid	Out of range
P0743	Lock-up duty solenoid	Short circuit to earth or battery
P0748	Line pressure duty solenoid	Short circuit to earth or battery
P0753	Shift solenoid A	Open circuit or short circuit to earth or battery
P0758	Shift solenoid B	Short circuit to earth or battery
P0763	Shift solenoid C	Short circuit to earth or battery
P0790	Mode switch input	Multiple signal
P1562	Power supply voltage	Out of range
P1605	EAT ECU EEPROM	Error flag set
P1715	Intermediate speed sensor	No signal
P1748	2-4 brake duty solenoid	Open circuit or short circuit to earth or battery
P1785	Low clutch timing solenoid	Short circuit to earth or battery
P1786	Reduction timing solenoid	Short circuit to earth or battery
P1787	2-4 brake timing solenoid	Open circuit or short circuit to earth or battery
P1815	Steptronic (manual) +/- switch input signals	Multiple signals/No signal
P1825	Shift interlock ECU	Shift interlock failure
P1840	CAN Bus	CAN Bus malfunction
P1841	CAN Bus monitoring	CAN Bus off
P1842	CAN level monitoring	Incompatible
P1843	CAN timeout monitoring	CAN Bus missing nodes detected
P1844	Engine RPM (Speed signal) Engine temperature signal Torque reduction signal Throttle angle signal Virtual throttle angle	Error flag set Error flag set Torque reduction volume not achieved Error flag set Error flag set

Operation

The EAT ECU controls the following functions:

- Gear shift scheduling
- Lock-up control
- Line pressure control
- Driving mode engagement
- Sport mode engagement
- Manual (Steptronic) mode engagement
- Reverse inhibit
- Hill mode strategy engagement
- Downhill recognition
- Cruise mode engagement
- Cooling strategy engagement
- Selector position display
- Driving mode display
- Fault status
- Fault code storage
- Emergency/Fail-safe program control

Transmission control diagram



M44 1615

Figure 151

A= Hardwired D= CAN Bus J= Diagnostic Bus

1.Intermediate speed sensor	12.Cruise control interface ECU - KV6 (Hardwired)
2.Vehicle speed sensor	13.Diagnostic socket
3.Turbine speed sensor	14.Brake switch
4.Fluid temperature sensor	15.PRND421S/M LED Module
5.Solenoid valves and valve block	16.Sport/manual switch
6.EAT ECU	17.Shift interlock solenoid
7.ABS ECU/Modulator	18.Selector and inhibitor switch
8.Engine Control Module (ECM) - M47R	19.EWS3D immobilisation ECU
9.Engine Control Module (ECM) - KV6	20.Starter relay
10.Instrument pack	21.Main relay
11.Cruise control interface ECU - M47R (CAN)	

Gear Shift Scheduling

The EAT ECU uses the relationship between the vehicle speed and the throttle position to carry out gear shift scheduling. Depending on these inputs, the EAT ECU controls gear selection using the three shift solenoid valves located in the valve block.

Lock-Up Control

The EAT ECU monitors the relationship between vehicle speed and throttle position to calculate when to lock-up the torque converter.

Lock-up control is possible in 4th and 5th gears. For example, lock-up is possible at high speed cruising with low throttle position. Torque converter lock-up is also provided in 2nd and 3rd gears when high fluid temperatures are detected by the ECU.

A refinement to the torque converter lock-up system is the reduction of harshness or shock during torque converter lock-up.

The EAT ECU controls the lock-up solenoid valve to provide a smooth lock-up function. The solenoid is operated slowly, and gradually varies the fluid pressure to the lock-up control valve. This causes the lock-up clutch to engage slowly, producing a smooth operation.

To promote engine warm-up at low temperatures, the EAT ECU will inhibit lock-up if the gearbox fluid temperature is below 40°C (104°F).

Line Pressure Control

Line pressure refers to the operating fluid pressure that is supplied to the multi-plate clutches, multi-plate brakes and brake band within the gearbox.

Line pressure control provides smooth vehicle operation and gear shift action. The line pressure control is continuously responding to current driving conditions to regulate and deliver the optimum operating pressure at all times. For example, line pressure is lower under normal operating conditions than it would be under hard acceleration.

The EAT ECU controls line pressure by actuating the line pressure solenoid valve in the valve block. The ECU calculates the line pressure required by using engine speed, vehicle speed and throttle position.

High line pressures will cause very harsh gearshifts and gear engagement. Low line pressure will cause gearshifts to take an excessive amount of time to change, which will quickly burn out the clutches, brakes and brake band within the gearbox.

Driving Modes

There are five different driving modes that the driver can select:

- Normal mode
- Sport mode
- Manual (Steptronic) mode
- Hill Descent Control (HDC) mode
- Cruise mode.

Normal, sport, cruise and HDC modes are selected manually by the driver. Fast off and stop go modes are controlled by the EAT ECU responding to driving conditions.

The different modes are selected by the gear selector lever or, in the case of cruise mode and HDC, a separate switch. The gear change scheduling is altered to correspond with the mode selected.

Normal mode

On power up the EAT ECU always initialises normal mode. In this mode all automatic/adaptive modes are active. Normal mode uses gear shift and lock-up maps which allows vehicle operation which is a compromise between performance, fuel consumption and emissions.

Sport mode

In sport mode the EAT ECU controls the gearbox to downshift more readily and use gear change schedules that hold the lower gears for longer at high engine speeds. This enhances acceleration and vehicle responsiveness. Sport mode is selected by moving the gear selector lever to the 'S/M' position. 'Sport' is displayed in the instrument pack LCD when this mode is selected.

Manual (Steptronic) mode

Manual mode allows the driver to operate the gearbox as a semi-automatic, Steptronic gearbox. The driver can change up and down the five gears with the freedom of a manual transmission.

Gearshift maps programmed in the EAT ECU protect the engine at high engine speeds by automatically changing up to prevent engine over speed and changing down to prevent stalling.

Manual mode is entered by moving the selector lever to the 'S/M' position and moving the lever to either the + or - positions to move the gearbox up and down the five gear ratios. Manual mode is exited by moving the selector to position 'D'.

HDC mode

The HDC mode assists the ABS in controlling the descent of the vehicle in either 1st gear ratio or reverse gear ratio. HDC mode is initiated by selecting 1 or R on the selector lever, depressing the HDC button adjacent to the selector lever and throttle pedal released (low demand position). The instrument pack illuminates the HDC warning lamp and the LCD will display the selected gear (1 or R).

The EAT ECU will maintain the selected gear ratio and apply engine braking the assist ABS in controlling the vehicle's descent.

Cruise mode

Cruise control is activated by depressing the cruise control switch in the centre console. When cruise control is active, the EAT ECU senses this as a hardwired input from the cruise control ECU (KV6 models) or interface unit (M47R models). In cruise mode the EAT ECU uses a dedicated gearshift map to control the gearbox and assist the cruise control ECU in maintaining the vehicle speed. The gearbox cruise mode is cancelled by applying the brake pedal or deselecting cruise control. Cruise mode is suspended when the throttle demand is increased and is reinstated when the pedal is released and the set speed resumed. Cruise mode is also suspended when the suspend switch on the steering wheel is pressed.

Reverse inhibit

If the vehicle exceeds 6 mph (10 km/h) in the forward direction, and Reverse (R) gear is selected, the EAT ECU switches on the low clutch timing solenoid valve in the valve block, which drains the fluid from the reverse clutch.

This function prevents the gearbox from engaging reverse gear when the vehicle is moving in a forward direction, so preventing damage to the gearbox.

Hill mode

Hill mode modifies the gearbox shift pattern to assist drivability on steep gradients. The EAT ECU detects the conditions to activate hill mode by monitoring the engine torque values, throttle angle and engine speed. This mode also assists driving at high altitudes and trailer towing.

Downhill recognition

On downhill slopes there is a tendency for automatic gearboxes to upshift due to the increase in vehicle speed and the decrease in throttle angle.

The reduction in engine braking causes the driver to use the brakes. A downhill slope is recognised by EAT ECU as an increase in vehicle speed with the decrease in throttle angle.

When a downhill slope is recognised and the brakes are applied, the shift pattern is over-ruled and the gearbox shifts down a gear if engine speed allows. The downhill mode is cancelled upon application of the throttle.

Cooling strategy

The purpose of the cooling strategy is to reduce engine and gearbox temperatures during high load conditions, for example when towing trailers. Under these conditions the engine and gearbox may generate excessive heat.

While in any gear other than 5th, or in 5th gear with the vehicle speed above 38 mph (61 km/h), if the gearbox fluid temperature increases to 127°C (260°F), the EAT ECU employs the cooling strategy.

This strategy consists of a separate shift and torque converter lock-up map that allows torque converter lock-up or gear changes to occur outside of their normal operating parameters.

This will reduce either the engine speed or the slip in the torque converter, therefore reducing the heat generated.

The EAT ECU cancels the cooling strategy when gearbox fluid temperature decreases to 120°C (248°F).

Engine cooling fan

If the gearbox fluid temperature increases to 110°C (230°F), the EAT ECU sends a cooling request message to the ECM on the CAN bus. The ECM then switches the engine cooling fan on, or if it is already on, keeps it on, to maintain the air flow through the fluid cooler.

The EAT ECU cancels the cooling request when the fluid temperature decreases to 100°C (212°F).

Diagnostics

If the EAT ECU detects a failure in an associated component, a fault code will be stored in the EAT ECU memory. TestBook is used to retrieve these fault codes to identify the cause of the failure.

Gearbox fault status

If the EAT ECU detects a fault with the gearbox system it will enter a fail safe mode. There are many fail safe modes the EAT ECU can adopt.

The EAT ECU will adopt the fail safe mode most acceptable for the driver and will ensure the least amount of damage to the gearbox.

When a fault is detected a CAN message is sent from the EAT ECU to the instrument pack and the MIL will be illuminated if the fault is related to OBD. If the ECU is able to implement a limp home mode, the instrument pack LCD will display '4' and 'F' alternately as the gearbox status display. Some faults may not display '4' and 'F' in the instrument pack, but the driver may notice a reduction in shift quality.

Engine speed and throttle monitoring

The ECM constantly supplies the EAT ECU with information on engine speed and throttle angle through messages on the CAN bus. This information is used by the EAT ECU to calculate the correct timing of gear changes.

If the messages are not received from the ECM, the EAT ECU will implement a back-up strategy to protect the gearbox from damage, whilst allowing the vehicle to be driven.

In the event of an engine speed signal failure any of the following symptoms may be observed:

- Decrease in fuel economy
- Increase in engine emissions.

In the event of a throttle position signal failure, any of the following symptoms may be observed:

- Harsh gear changes
- No kickdown
- Torque reduction request inhibited.

Getrag 283

General

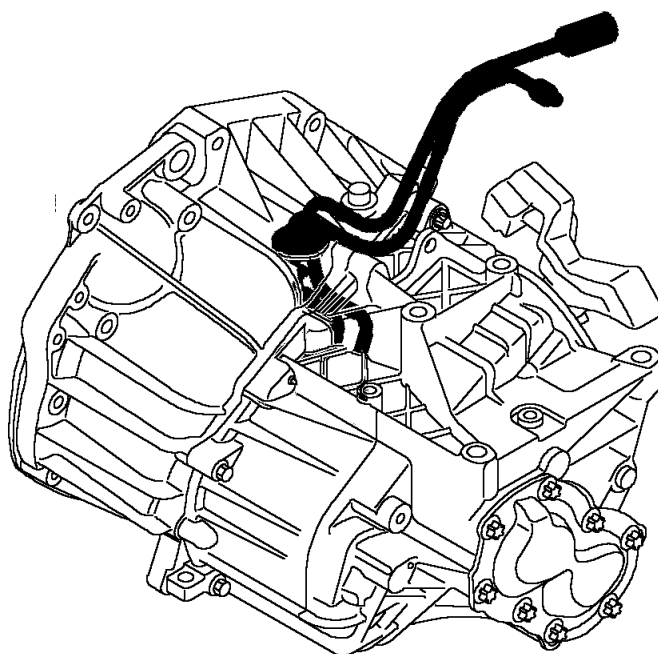


Figure 152

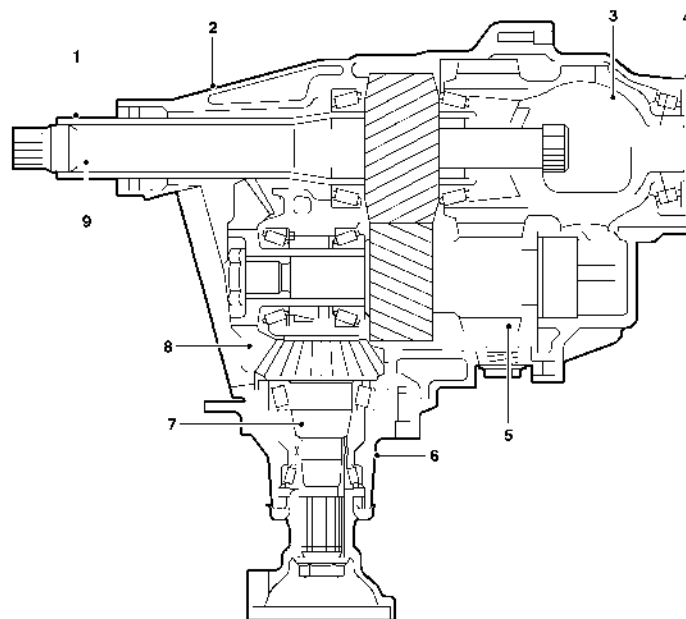
All M47R Diesel Freelanders with manual transmission feature a newly developed Getrag gearbox. The gearbox, named 283, is made in Italy in a brand new factory that meets the most demanding manufacturing and quality standards in the world.

The new gearbox has been designed to handle the high torque outputs of the M47R engine and has a capacity of 273Nm. It is 'fill for life', requiring no oil change.

Features of the Getrag 283 transmission are:

- Synchromesh is provided on reverse as well as all forward gears. The lack of reverse gear synchromesh can result in reverse gear crash and customer dissatisfaction
- First and second gears have two-cone synchromesh. This reduces gear change loads where the highest speed differences have to be overcome and the greatest forces endured
- The gear machining process reduces gear noise
- The hydraulically activated clutch and concentric slave cylinder together give a light pedal load and smooth travel
- First gear switch for hill descent control
- IRD differential necessitates the removal of the transmission differential

Intermediate reduction drive



M41 7883

Figure 153

- 1.Primary shaft
- 2.Main casing
- 3.Differential unit
- 4.RH Housing
- 5.Laygear
- 6.Pinion housing
- 7.Rear output pinion
- 8.Hypoid gear set
- 9.Intermediate shaft

The IRD is fitted in place of the conventional transfer box, and is attached to the manual or automatic gearbox. The combination of the two units provides drive to the front and rear wheels. The IRD incorporates a differential unit to control the proportion of drive delivered to each front wheel, and in addition, it operates in conjunction with the viscous coupling to give the vehicle a self-sensing four wheel drive system. The main casing, cover and pinion housing are manufactured from cast aluminium.

The unit comprises of a main casing, a RH housing, primary shaft, an intermediate shaft, a differential unit, a laygear, hypoid gear set, a rear output pinion and a pinion housing. An oil cooler, connected to the vehicle cooling system, is fitted to prevent overheating of the IRD lubricating fluid. The main casing also incorporates the oil level/drain plugs and a breather outlet. There are a total of seven taper roller bearings and one parallel roller bearing supporting the primary shaft, differential and output shaft assemblies.

Four seals, internal to the IRD, are used to prevent mixing of the IRD and gearbox lubricating fluids.

Clutch

The clutch system is a conventional diaphragm type clutch operated by a hydraulic master cylinder. The hydraulic system is manufactured from plastic. The system is sealed for life and can only be replaced in its entirety. The clutch requires no adjustment to compensate for clutch drive plate wear.

The hydraulic clutch comprises a master cylinder and a slave cylinder/hydraulic release bearing connected by a two piece plastic tube. The system is supplied as a two piece system, pre-filled with hydraulic fluid to ease replacement and minimize repair times. The master cylinder is manufactured from injection moulded thermoplastic which can operate in extremes of temperatures.

The master cylinder is located in the bulkhead in a specially designed hole which allows the cylinder to be installed at a 45° angle from vertical. Once located, the master cylinder is rotated to the vertical position and is automatically secured in this position. The master cylinder has a piston which moves in the cylinder. A rod is attached to the piston and to a spigot on the clutch pedal. A fluid reservoir is mounted on the engine compartment side of the master cylinder and is sealed with a removable rubber cap.

A nylon tube is connected to the master cylinder by a swivel coupling which aids installation and alignment. The tube is fitted with a self sealing, quick fit coupling which mates with a similar connection on the slave cylinder tube.

The slave cylinder is located inside the clutch housing and is integral with the release bearing. The assembly is located and supported on a tube which is fitted over the gearbox input shaft. The pipe from the slave cylinder passes through a sealing grommet in the gearbox clutch housing and is terminated with a self sealing, quick fit coupling, which mates with the coupling on the pipe connecting the master cylinder. A second pipe is also attached to the slave cylinder and emerges from the sealing grommet and is terminated with a bleed nipple.

A coil spring is located between the piston of the slave cylinder and the release bearing. The spring holds the release bearing against the pressure plate diaphragm.

Braking system

Foundation brakes

Vehicle braking is provided by disc brakes on the front wheels and drum brakes on the rear wheels. The foot brakes are operated by a diagonally split, dual circuit hydraulic system with vacuum servo power assistance. A cable operated handbrake operates on the two rear brakes.

The ABS features 4-wheel electronic traction control and hill descent functions as well as anti-lock braking and electronic brake distribution.

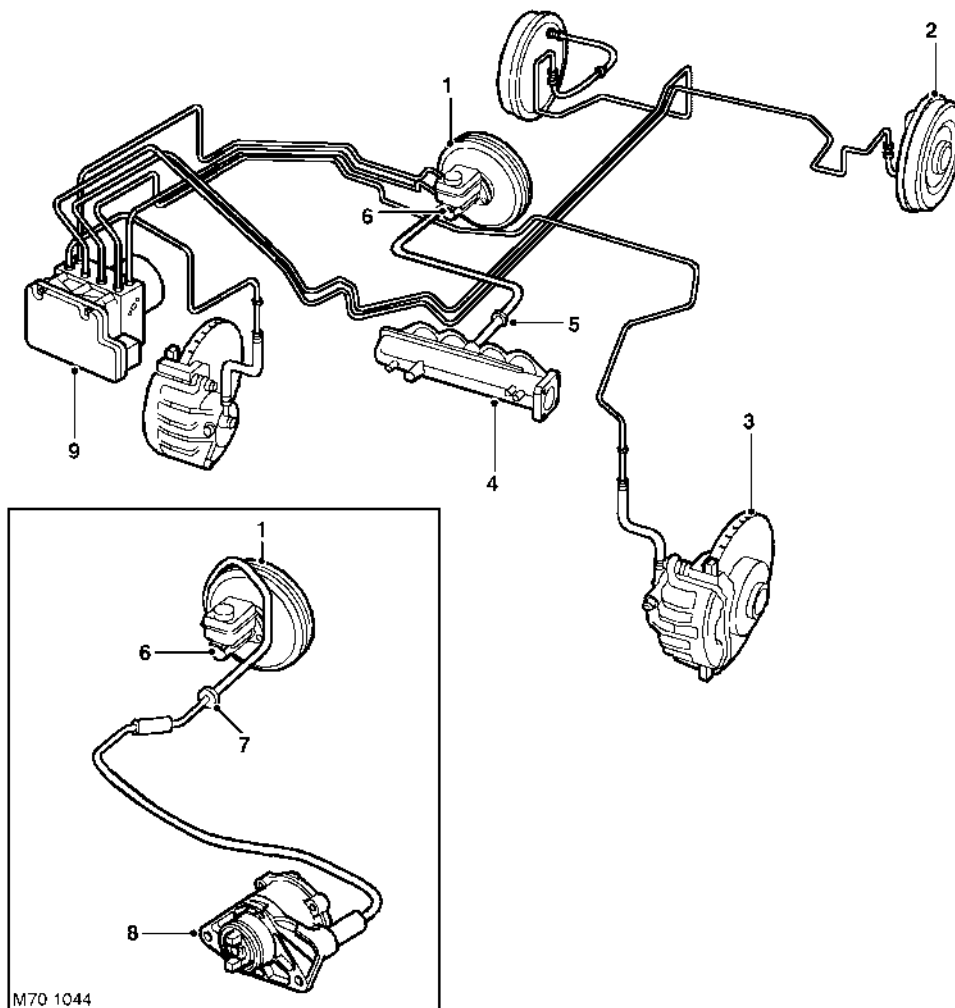


Figure 154

RHD shown, LHD similar

- 1.Brake servo assembly
- 2.Rear brake
- 3.Front brake
- 4.Engine inlet manifold (petrol models)
- 5.Vacuum check valve
- 6.Master cylinder assembly
- 7.Vacuum check valve (diesel)

- 8.Vacuum pump (diesel models)
- 9.ABS modulator/ECU

Anti lock braking system

Freelander 2001 will be available with a new ABS system: TEVES MK20 SCS system. The system comprises the following features:

- Anti-lock braking system
- Hill descent control
- Electronic traction control
- Electrical brake-force distribution
- CAN communication link

The system communicates via CAN with the engine management system, the instrument pack and, on automatic derivatives, with the transmission control unit. the system comprises the following components:

- Electronic control unit
- Modulator (attached to the ECU)
- Wheel speed sensors
- Mechanical brake switch
- Brake fluid level switch
- HDC relay and switch
- Longitudinal accelerometer

Electronic control unit

The Electronic Control Unit (ECU) determines the speed and acceleration of each wheel, controls appropriate hydraulic functions and monitors system operation for fault conditions and interfaces to other vehicle systems. The ECU is attached to the Modulator unit and is mounted underbonnet on the RHS valence behind the headlamp.

Under the following conditions the ECU is programmed to switch off the main driver which will result in the illumination of the ABS, TC, HDC and EBD warning lamps:

- If the IGN voltage drops to values, which are not sufficient to maintain a stabilised, supply voltage for the processors. This voltage is below the functional operating voltage of 8 volts. The controller will invariably switch on again when the minimum operating voltage of 10 volts is reached.
- If the following failures or errors are detected:
 - Valve failure
 - Two wheel speed sensor failure
 - Main driver failure
 - Redundancy error
 - Overvoltage

The ECU will also inhibit the ABS function, traction control, hill descent control and illuminate their respective warning lamps without switching off the main driver in the following circumstances:

- Supply voltage at pin 12 < 8 volts
- Failure of one or more of the wheel speed sensors
- Pump motor failure

Hydraulic modulator

The hydraulic unit of the modulator consists of a pump and 12 solenoid operated valves, accumulator and damper chambers. During normal braking where ABS intervention is not required, brake fluid passes straight through de-energised inlet valves (normally open). Where ABS intervention is required, pressure is maintained at a wheel by closing the appropriate inlet valve. When pressure needs to be released from a brake circuit, the appropriate outlet valve is opened (when output valve is opened the Inlet valve must be closed) and the brake fluid is allowed to flow into the reservoir. Brake fluid is returned, via the return pump, to the Master cylinder line via the damper chamber.

ABS hydraulic circuits



Figure 155

- 1.Front right cylinder
- 2.Rear left cylinder
- 3.Rear right cylinder
- 4.Front left cylinder
- 5.Low pressure accumulator
- 6.Damper chamber
- 7.Recirculation pump
- 8.Pulsation damper
- 9.Master cylinder
- 10.Reservoir
- 11.Modulator
- 12.Inlet valve
- 13.Outlet valve
- 14.Electric shuttle valve
- 15.Separation valve

Brake fluid pressure - (inlet)

The hydraulic circuit of the ABS modulator consists of the Primary and Secondary feeds from the Brake Master cylinder. These are fed into the modulator by two Ø 6 mm. brake pipes. The input pipes are easily distinguished by their size, compared to the four Ø 4.76 mm. outlet pipes.

The ECU can detect electrical failure of each the inlet valves and will generate relevant fault codes which can be accessed via TestBook.

Brake fluid pressure - (outlet)

The hydraulic outlet circuit of the ABS modulator consists of the four pipes leading to the front calipers and rear brake drums. The four pipes transmit the brake fluid usually at the pressure determined by the drivers brake application, but during ABS, EBD, TC and HDC intervention at the pressures modified by the ABS ECU. The pipes are attached by a series of clips into the body and terminate at the caliper/drum via a flexible hose.

The ECU can detect electrical failure of each the output valves and will generate relevant fault codes which can be accessed via TestBook.

Wheel speed sensor

A wheel speed sensor is fitted to each of the four Hub carriers. These sensors inform the ABS ECU about the speed of each of the road wheels. This measurement is fundamental to the operation of the braking features. The harness wires that connect the sensors to the ABS unit are twisted pairs. Since the sensors are reductor devices (Passive sensor) no output is available when the road wheels are not turning. Thus, the ABS ECU is unable to test the sensor or the pole wheel fully until the vehicle is moving.

Failures or malfunctions relating to the sensor, and sensor connections, are detected by the ABS ECU. In the event of failure of two or more of the sensors the ABS ECU switches off the system and illuminates the ABS, TC, EBD, and HDC warning lamps.

If a single sensor fails the ABS ECU maintains the minimum functions to provide safe operation and illuminates the ABS, TC, and HDC warning lamps.

Mechanical brake switch

A mechanical Pedal switch is used to illuminate the stop/brake lamps on the vehicle because of its high current carrying/switching capabilities. It is also used to input the status of the Brake pedal to the ABS ECU. This switch is double contact switch where the brake lamp switch (BLS) contact is open and the brake switch (BS) contact is closed when brake pedal is at rest. When pedal is depressed, the BLS contact closes and BS contact opens thus supplying 12 volts to the brake/stoplamps and indicating to the ABS ECU that the pedal has been operated. During the time pedal is depressed there is a time when both BLS and BS contacts will both be closed, this is required to do the plausibility check on the switch. The switch used is a carryover from the Range Rover.

Freelander 2001 also has a Hall effect brake pedal position sensor fitted adjacent to the mechanical brake switch. This is not used by the ABS system but by other system ECU's which are not compatible with mechanical switches.

Brake fluid level switch

The brake fluid level switch (BFLS) switch is a Reed switch, and is located within the Brake fluid reservoir. The brake fluid level switch is connected to the ABS ECU and is switched to ground. The BFLS is closed when there is correct fluid level. If the switch goes open circuit (low level of fluid), then the switch will send a CAN message to the ABS ECU to activate the Brake warning LED in the instrument pack. This also means that if the connector comes off or the wire breaks the brake warning lamp will be 'on'.

Hill descent control relay and switch

The HDC relay is located inside the engine compartment fusebox. The HDC switch is a latching switch mounted on the centre console for automatics vehicles and the gear lever for manual vehicles.

Longitudinal accelerometer

Longitudinal accelerometer

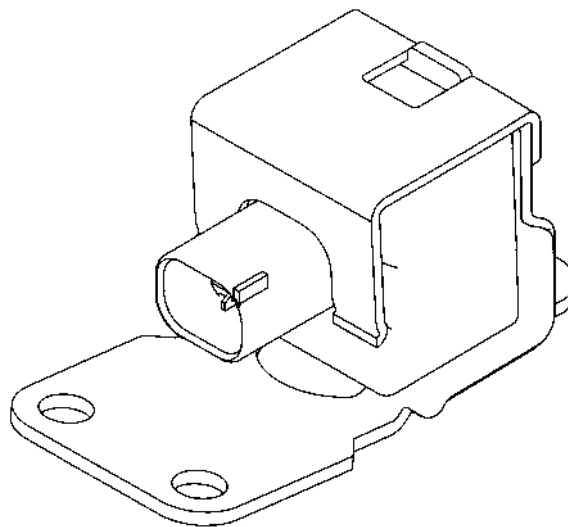


Figure 156

The longitudinal acceleration sensor (sometimes known as "G" sensor) is mounted in-cab near the centre-line of the vehicle alongside the handbrake lever. It provides additional information to the ABS ECU regarding vehicle motion, to corroborate inputs from the wheel speed sensors.

The signal produced by the longitudinal accelerometer is used by the ABS ECU to check the plausibility of the vehicle speed signal. Where the vehicle wheel speed sensors tell the ECU that the vehicle speed is faster than the actual vehicle body speed.

Anti-lock braking system

The ABS fitted to Freelander is a four channel system. It has independent control of all four wheels and works on all terrain.

The ABS ECU takes wheel speed information from sensors, located within the hub carrier, and monitors the relative deceleration/acceleration of each wheel at all times. These signals are used to calculate the rotational deceleration rates for each wheel during braking operation. In the event of a wheel slip occurring (i.e. rotational deceleration being outside of allowable limits), the hydraulic system will control the brake line pressure by operating the appropriate solenoid valves within the hydraulic modulator and thus removing some brake pressure from the locked wheel. Once the wheel deceleration has recovered to within allowable limits the modulator then allows pressure to be re-applied to the appropriate brake caliper.

If the ECU detects, via the wheel speed sensors, that any of the wheels are tending to lock, the inlet valves of those wheels are closed and the outlet valves are opened. This fills the low-pressure accumulators, enabling pressure to be released from the brakes. The activated re-circulation pump returns the brake fluid via the master cylinder to the fluid reservoir.

To increase pressure to the wheel brakes, the inlets are opened and outlets closed. The fluid is then replenished from the master cylinder, and if the low pressure accumulators contain fluid, additionally by the re-circulation pump. By restoring and shutting off the pressure, a pulsating pedal motion may be felt by the driver.

When ABS intervention is necessary the warning lamp will not illuminate but the driver may experience audible feedback from the modulator along with the brake pedal vibrating.

If a fault occurs with the system or any of its constituent components the relevant warning lamp in the IPK will illuminate to inform the driver of the fault.

The ABS warning lamp is 'on' under the following conditions:

- During the initialisation phase and a following test phase controlled by the microprocessor it then goes off for approximately 0.5 seconds (if there are no current or stored faults). It comes back on until the vehicle reaches speed of 7 kph. It then goes off provided there are good wheel speed sensor signals. The lamp will not flash off if there are stored or current faults.
- If there is a system fault which inhibits ABS operation.
- When the controller is switched off as long as voltage is applied at pin 12 (IGN), during diagnostics
- In the event of CAN communication failure between the IPK and the ABS ECU

Electronic brake-force distribution

This feature controls the front to rear balance of the braking system by electronic braking force distribution (EBD). This makes sure that under any conditions and loading, the rear wheels will not lock before the fronts, which would cause handling and stability problems.

EBD uses standard ABS hardware to optimise the braking distribution automatically, below the point where ABS control would be invoked. This task was previously performed by a pressure conscious reduction valve (PCRV), which allowed the braking loads to be apportioned between the front and rear axles under all vehicle-loading conditions.

The EBD warning lamp is the red brake warning lamp and is illuminated under the following conditions:

- During the initialisation phase and a following test phase controlled by the microprocessor
- When the controller is switched 'Off' as long as voltage is applied at pin 12 (IGN)
- When the handbrake is applied
- When the brake fluid level is low or when the brake fluid level switch is not connected
- If there is a CAN communication failure between IPK and the ABS ECU

Traction control

This feature uses brake intervention to prevent wheel slippage (i.e. wheel speed faster than vehicle reference speed) during attempts to accelerate or on a slippery road surface. This is done by the ECU, which monitors the speed of each wheel. If any wheel is spinning faster than others, brake pressure is applied to that wheel to slow it down, bringing it in line with other wheel speeds, thus providing the optimum traction between the road surface and each vehicle tyre.

If ETC is required and the brake pedal is not depressed, the ECU starts the re-circulation pump to draw fluid into the system from the master cylinder. Additional valves are required for the purpose of controlling the volumetric flow. The Continental TEVES system uses two additional solenoid valves in each brake circuit. As the pump starts up, the separation valve blocks the delivery line to the master cylinder and diverts the fluid flow to the pump circuit. The changeover, or electric shuttle valves, control fluid flow from the master cylinder and reservoir. Actual wheel control takes place in the same way as ABS via the control of the individual inlet and outlet valves. Excess volumetric flow of the pump is routed via the pressure relief valve, which is integrated into the separation valve on the Continental TEVES system.

The traction control warning lamp is amber in colour and is illuminated in the following circumstances/conditions:

- It illuminates for a minimum of 2 seconds when TC is active or longer if TC is active for longer than 2 seconds
- During the initialisation phase and a following test phase controlled by the microprocessor
- In the event of TC fault condition
- Fully 'on' when manual disable TC function is operated
- Flashing when Brakes are hot (over 350°C)
- When the controller is switched 'Off' as long as voltage is applied at pin 12 (IGN)
- During diagnostics

Disabling traction control

To allow the vehicle to be tested on two wheel rolling roads there is a feature which allows the traction control function to be disabled. To disable traction control the brake pedal has to be operated 10 times within first 10 seconds of turning 'on' the ignition. When TC is disabled, the TC warning LED will be illuminated in the instrument pack and no wheel braking will occur during this period. Also the road speed signal will be an average of the two rotating wheels, and no wheelspeed sensor faults or 'G' sensor faults will be registered during this period. To re-enable TC the vehicle must see a 7kph signal on all 4 wheels.

Should the ETC (or HDC) be active for long periods the temperature of the brakes may cause damage to the brake components (disks, drums, pads and shoes). To prevent this there is a safety feature that disables the ETC or HDC if it considers the system is overheating. The system functions by the ABS calculating the brake temperature. When the first temperature limit is reached (350°C) is reached the ETC warning lamp will start to flash (if HDC is also 'ON' then the HDC fault lamp will also flash). When the second temperature limit (400°C) has been reached the warning lights will continue to flash but the ETC and HDC functionality will become inactive. Should HDC be active as the second temperature limit is reached the HDC will fade out gradually. System functionality will return when the brakes have returned to the third limit (300°C).

Hill descent control

This feature allows the vehicle speed to be controlled during a hill descent using the vehicle Brakes. This feature has to be selected using the Hill descent switch with the selected gear being 'first' or 'reverse' and the brakes below 350°C.

When HDC is selected by operating the latching HDC switch the green LED is illuminated continuously to indicate HDC is available. If conditions are not met to enable HDC operation, after the switch is operated the green LED flashes. When going downhill and HDC is selected the vehicle will maintain a target speed of approximately 7kph by applying the brakes if the throttle pedal is not depressed. When the throttle pedal is depressed the target speed will be relative to the throttle pedal position and the vehicle will go down faster at the new target speed. If the slope is not steep enough and the speed is less than the target speed, the vehicle will not accelerate to reach the target speed. The HDC function is brakes intervention only. There are 2 LED's in the instrument pack for the HDC function. There is a green LED, which indicates the status of the HDC function and an amber LED which, indicates HDC system fault when illuminated fully.

Minimum target speeds with the throttle closed are 6 mph (9.6 km/h) in first gear and 4 mph (6.5 km/h) in reverse gear. The first gear target speed is decreased to 4.4 mph (7 km/h) if rough terrain or sharp bends (detected from ABS sensor inputs) are encountered while already travelling at the minimum target speed. Minimum target speeds are increased at cold idle to prevent conflict between the brakes and the engine caused by HDC trying to impose a lower vehicle speed than is normal for the increased engine speeds at cold idle. Minimum target speeds at cold idle are 7.5 mph (12 km/h) in first gear and 4.4 mph (7 km/h) in reverse gear.

During active braking, the brakes are operated in axle pairs on one or both axles. The braking effort is distributed between the front and rear axles as necessary to maintain vehicle stability. Distribution of the braking effort is dependant on direction of travel and braking effort being applied. To prevent wheel lock, anti-lock braking is also enabled during active braking.

The ABS ECU incorporates a fade out strategy that, if a fault occurs or HDC is deselected during active braking, provides a safe transition from active braking to brakes off. The fade out strategy increases the target speed at a low constant acceleration rate, independent of actual throttle position. If active braking is in operation, this causes the braking effort to be gradually reduced and then discontinued. The HDC information warning lamp flashes while fade out is in progress.

If the clutch is disengaged during active braking, the HDC information warning lamp flashes after a delay of 3 seconds. After 60 seconds, if the clutch is still disengaged, the HDC fault warning lamp flashes and active braking operation fades out.

To prevent the brakes overheating, the ABS ECU monitors the amount of active braking employed and, from this, calculates brake temperature. If the ABS ECU determines brake temperature has exceeded a preset limit, it extinguishes the HDC information warning lamp and flashes the HDC fault warning lamp to indicate that HDC should be deselected. If active braking continues and the ABS ECU determines that brake temperature has increased a further 50 C, it fades out active braking and disables HDC. After fade out, the HDC fault warning lamp continues to flash, while HDC is selected, until the ABS ECU calculates brake temperature to be at an acceptable level. This calculation continues even if the ignition is turned off, so turning the ignition off and back on will not reduce the disabled time. When the ABS ECU calculates the brake temperature to be acceptable, it extinguishes the HDC fault warning lamp and illuminates the HDC information warning lamp to indicate HDC is available again. The disabled time is dependant on vehicle speed; typical times at constant vehicle speeds are as follows:

Disabling of hill descent control and traction control after prolonged use

If the traction control or HDC has been active for a long time, the foundation brakes can get very hot and damage may occur to the brake components compromising braking efficiency. For this reason there is an ABS function which inhibits excessive use of traction control and hill descent control. The way this function works is that the ABS ECU calculates the temperature of the brakes using internal algorithms. If the first temperature threshold (350°C) is reached then the amber TC LED and the amber HDC fault LED will start to flash. The green HDC LED will extinguish. A flashing LED warns the driver that the brakes are getting hot (during this period the TC and HDC function is still available). If the second temperature threshold (400°C) is reached then the LED's continue to flash but the functionality is disabled for both TC and HDC. If HDC is operating at the time then the functionality fades out gradually when 400°C is reached. Vehicle functionality will return to normal after the brakes have cooled down to below 300°C.

Diagnostics

While the ignition is on, the diagnostics function of the ABS ECU monitors the system for faults. In addition, the return pump is tested by pulsing it briefly immediately after the engine starts provided vehicle speed exceeded 4.4 mph (7 km/h) during the previous ignition cycle. If a fault is detected at any time, the ABS ECU stores a related fault code in memory and illuminates the appropriate warning lamps in the instrument pack. If a fault exists in a warning lamp circuit, the lamp will not illuminate during the lamp check at ignition on, but, provided there are no other faults, the related function will otherwise be fully operational.

Checks performed by diagnostics

Fault	Status of warning lamps				Default strategy
	ABS	ETC	HDC Fault	HDC information	
ABS ECU internal failure	On	On	On	Off	ABS: Disabled. ETC: Disabled. HDC: Disabled.
ECM input failure	Off	On	On	Off*	ABS: Enabled. ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in active braking mode.
Sticking throttle	Off	Off	On	Off*	ABS: Enabled. ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in active braking mode.
Implausible gear position input	Off	Off	On	Off*	ABS: Enabled. ETC: Enabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in active braking mode.
No reference earth	On	On	On	Off	ABS: Disabled. ETC: Disabled. HDC: Disabled.
Failure of ABS sensor	On	On	On	Off†	ABS: Enabled. ETC: Enabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in active braking mode.
Failure of 2 ABS sensors	On	On	On	Off*	ABS: Enabled on unaffected hydraulic circuit (if applicable), disabled on affected hydraulic circuit(s). ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in braking mode.
Failure of more than 2 ABS sensors	On	On	On	Off	ABS: Disabled. ETC: Disabled. HDC: Disabled.
Failure of input valve	On	On	On	Off	ABS: Enabled on unaffected hydraulic circuit (if applicable), disabled on affected hydraulic circuit(s). ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in braking mode.
Failure of more than one input valve	On	On	On	Off*	ABS: Enabled on unaffected hydraulic circuit (if applicable), disabled on affected hydraulic circuit(s). ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in braking mode.
Failure of output valve	On	On	On	Off*	ABS: Enabled on unaffected hydraulic circuit (if applicable), disabled on affected hydraulic circuit(s). ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in braking mode.
Failure of more than one output valve	On	On	On	Off*	ABS: Enabled on unaffected hydraulic circuit (if applicable), disabled on affected hydraulic circuit(s). ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in braking mode.
Battery short in more than two input or output valve circuits	On	On	On	Off	ABS: Disabled. ETC: Disabled. HDC: Disabled.
Return pump or relay fault	On	On	On	Off	ABS: Disabled. ETC: Disabled. HDC: Disabled.

Fault	Status of warning lamps				Default strategy
	ABS	ETC	HDC Fault	HDC information	
Brake lamp relay fault	Off	Off	On	Off*	ABS: Enabled. ETC: Enabled. HDC: Enabled.
Supply voltage out of limits	On	On	On	Off*	ABS: Enabled. ETC: Disabled. HDC: Immediately disabled if not in active braking mode, faded out then disabled if in active braking mode.
* = Flashes if HDC faded out; † = Flashes if HDC in active braking mode					

Electrical data

Component resistance and voltage values are detailed below:

Component	Resistance, Ohms
ABS brake lamp relay coil	73 to 89
ABS pump relay coil	44.4 to 54.4
ABS sensor	950 to 1100
Shuttle valve switches, both open (brakes off)	2977 to 3067
Shuttle valve switches, both closed (brakes on)	1007 to 1037
Shuttle valve switches, one open, one closed	1992 to 2052
Inlet solenoid valve	5.9 to 7.3
Outlet solenoid valve	3.0 to 3.6

Component	Signal
First gear switch	Earth when first gear selected. Open circuit when first gear not selected.
HDC switch	Battery voltage when HDC selected. Open circuit when HDC not selected.
Reverse gear switch	Battery voltage when reverse gear selected. Open circuit when reverse gear not selected.

ABS system failure warning lights

Operating condition					
	Brake system (Red)	ABS (Amber)	Traction control (Amber)	HDC fault (Amber)	HDC Active (Green)
LED check (ABS flash 'Off' only occurs if there are no stored faults within ABS ECU)	'Off'	'On' for 1.7 sec 'Off' for 0.5 sec then 'on' until vehicle speed >7kph then turns 'Off'	'Off'	'Off'	'On' (if HDC selected)
Normal operation (With no failures and all conditions satisfied for all features)	'Off'	'Off' (After LED check lamp stays 'On' until vehicle speed >7kph then turns 'Off'	'Off'	'Off'	'On' (if HDC selected)
Hand brake 'On'	'On'	'Off'	'Off'	'Off'	'Off'
Low brake fluid	'On'	'Off'	'Off'	'Off'	'Off'
ABS failure only	'Off'	'On'	'On'	'Off'	'Off'
Traction failure only	'Off'	'Off'	'On'	'Off'	'Off'
ABS + EBD failure	'On'	'On'	'On'	'On'	'Off'
ABS ECU not connected	'On'	'On'	'On'	'On'	'Off'
Diagnostic mode	'On'	'On'	'On'	'On'	'On'
Traction disabled mode	'Off'	'Off'	'On'	'Off'	'On'
HDC selected (Conditions not met for HDC operation)	'Off'	'Off'	'Off'	'Off'	Flashing 2Hz
HDC selected (HDC is available and vehicle ready for descent)	'Off'	'Off'	'Off'	'Off'	'On'
HDC failure only	'Off'	'Off'	'Off'	'On'	'Off'
Brakes overheated	'Off'	'Off'	Flashing 2Hz (if activated by ATC)	Flashing 2Hz (if activated by HDC)	-