Freelander



Workshop Manual
System Description & Operation

Werkplaatshandboek
Systeem-beschrijving en werking

Manual d'Atelier
Description et fonctionnement du système

Werkstatthandbuch
Systembeschreibung und Functionsweise

Manuale d'Officina
Descrizione e funzionamento del sistema

Manual de Taller
Descripción y funcionamiento del sistema

Manual de Oficina
Funcionamento do Sistema

LAND ROVER

FREELANDER
2001MY ON

WORKSHOP MANUAL - SYSTEM DESCRIPTION AND OPERATION

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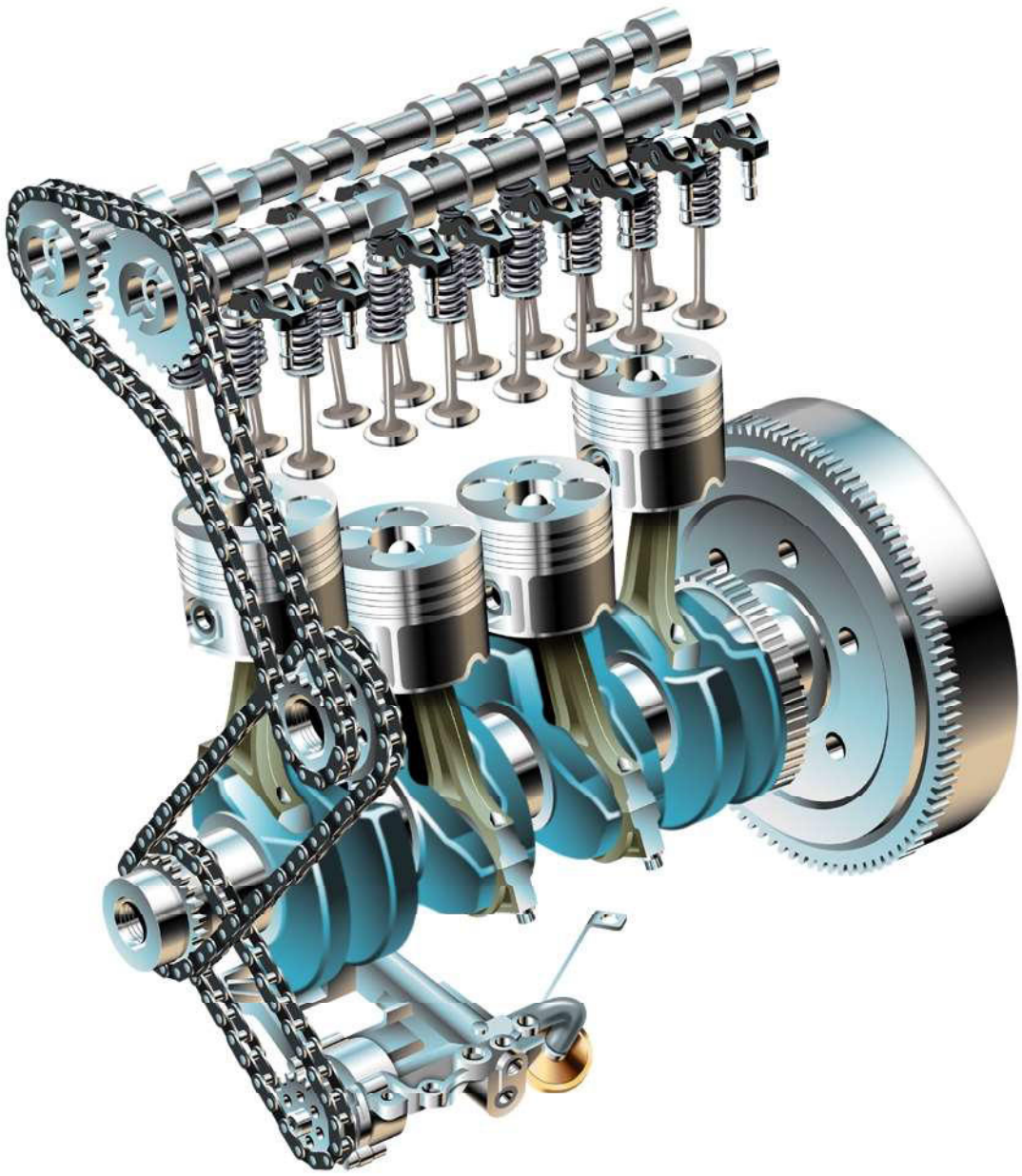
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Td4 Engine – General View



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Td4 Engine – Internal View



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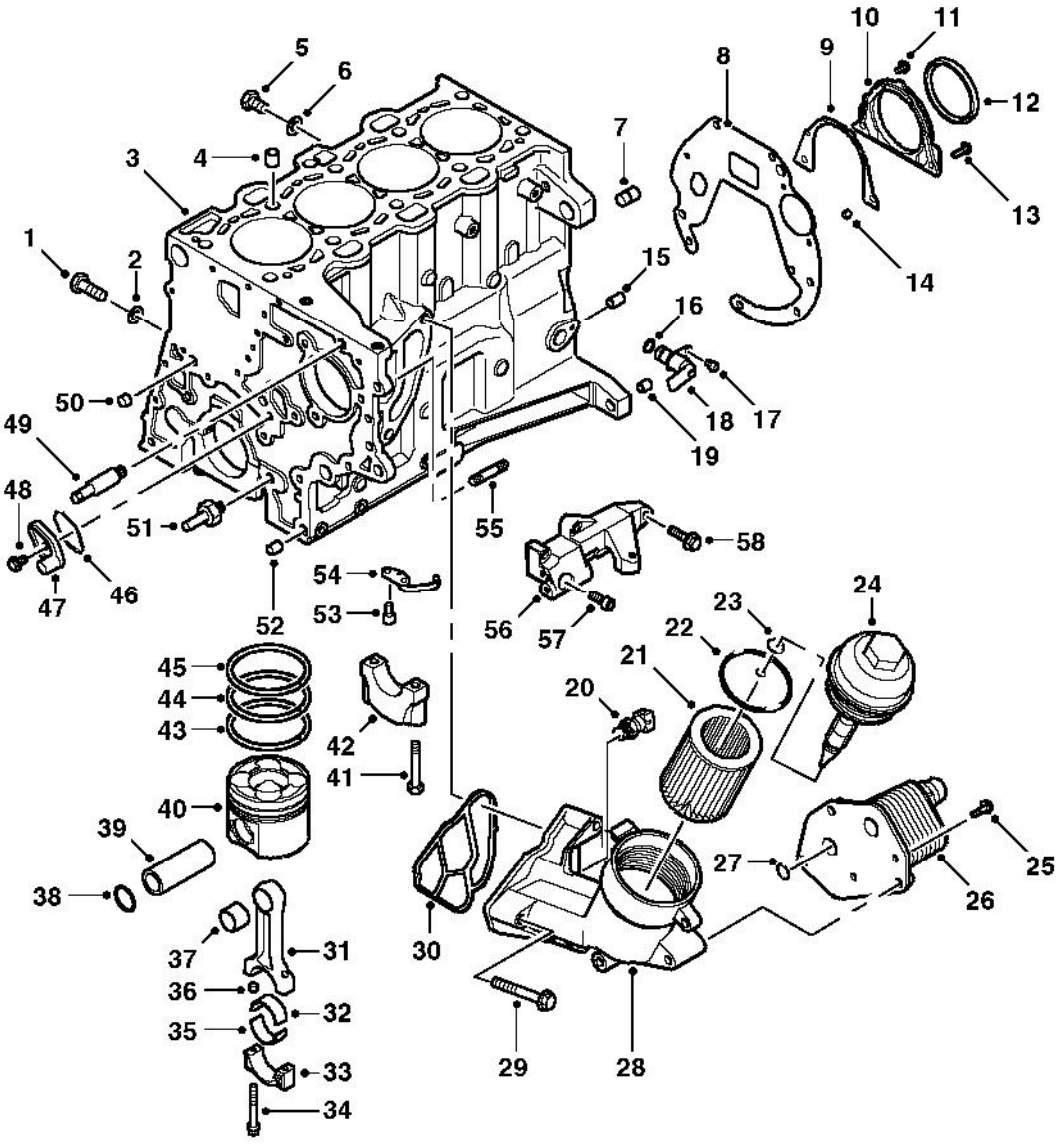
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Cylinder Block Components

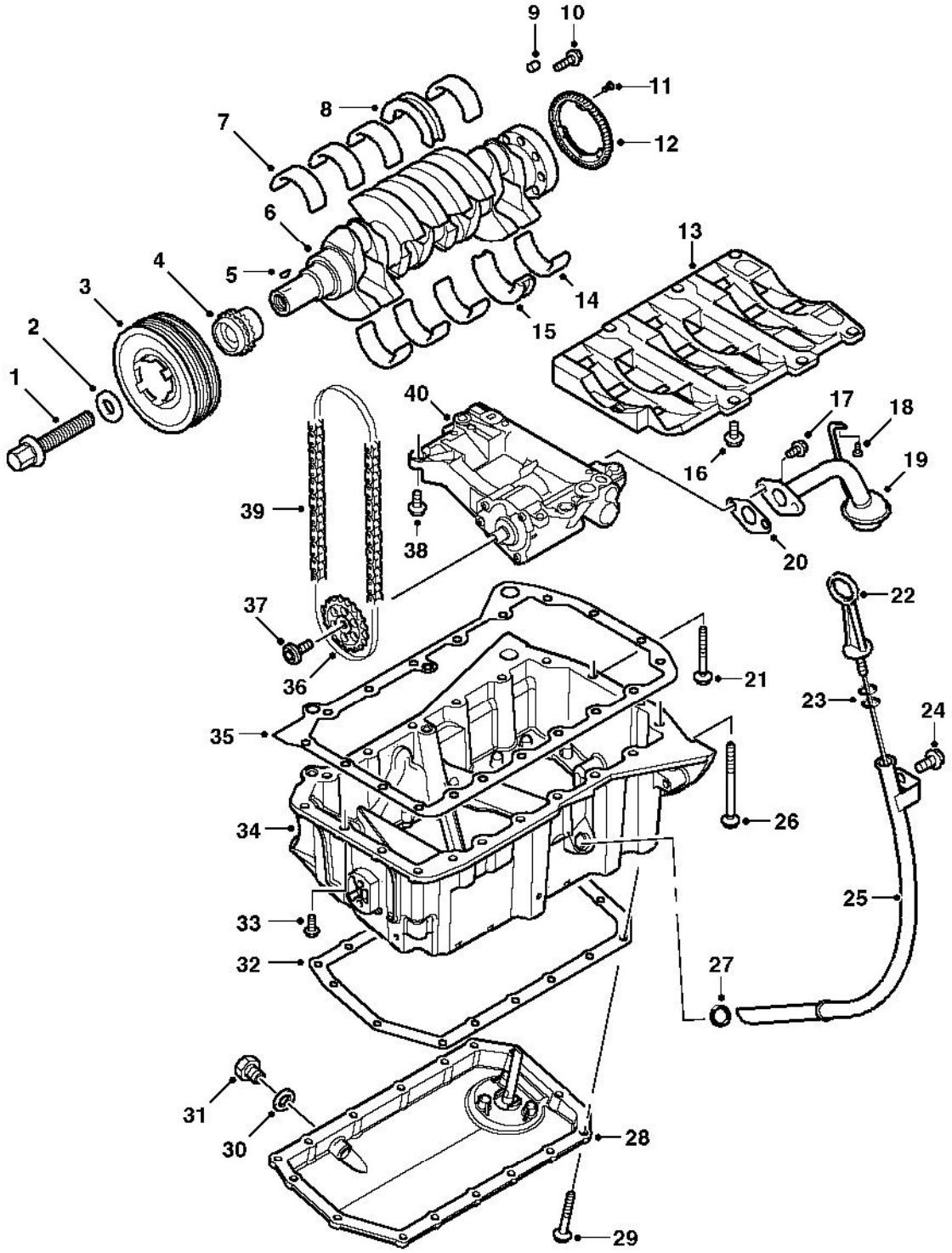


M12 6908



1 Banjo bolt – turbocharger oil supply
2 Copper washers – banjo bolt (2 off)
3 Cylinder block
4 Dowels – cylinder block to cylinder head (2 off)
5 Plug – coolant jacket
6 Sealing washer
7 Plug – rear engine block (2 off)
8 Gearbox closure assembly plate
9 Gasket – crankshaft rear seal housing to engine block
10 Crankshaft rear seal housing
11 Bolts – crankshaft rear seal housing to engine block (4 x M6)
12 Crankshaft rear seal
13 Bolts – crankshaft rear seal housing to engine block (2 x M8)
14 Dowel – crankshaft
15 Dowels – cylinder block rear (2 off)
16 'O' ring – crankshaft position sensor
17 Screw – crankshaft position sensor
18 Crankshaft position (CKP) sensor
19 Dowels – cylinder block rear (2 off)
20 Oil pressure switch
21 Oil filter element
22 Sealing ring – oil filter
23 Sealing washers – oil filter head (2 off)
24 Oil filter housing head assembly
25 Bolts – oil cooler assembly to oil filter housing (3 off)
26 Oil cooler assembly
27 'O' rings – oil cooler assembly to oil filter housing (2 off)
28 Oil filter housing
29 Bolts – oil filter housing to cylinder block (3 off)
30 Gasket – oil filter housing to cylinder block
31 Connecting rod (4 off)
32 Big-end bearing shell (upper)
33 Big-end bearing cap
34 Bolt – big-end bearing cap to connecting rod (2 off per connecting rod)
35 Big-end bearing shell (lower)
36 Dowels – big end bearing cap to connecting rod (2 off per connecting rod)
37 Small-end bush
38 Circlips (2 off per Gudgeon pin)
39 Gudgeon pin
40 Piston (4 off)
41 Bolts – main bearing cap (2 off per cap)
42 Main bearing cap (5 off)
43 Oil control ring
44 2nd compression ring
45 Top compression ring
46 'O' ring – cylinder block blanking plate
47 Cylinder block (front) blanking plate
48 Bolt – cylinder block blanking plate
49 Pin – cylinder block, front (drive chain guide)
50 Plug – cylinder block (front)
51 Pins – ancillary chain guide to cylinder block (2 off)
52 Dowels – cylinder block (front) to lower timing chain cover (2 off)
53 Bolts – piston cooling jet (4 off)
54 Piston cooling jets (4 off)
55 Studs – fuel injection pump to cylinder block mounting (3 off)
56 Alternator to engine block mounting bracket
57 Bolt (short) – alternator to engine block mounting bracket bolt
58 Bolt (long) – alternator to engine block mounting bracket (4 off)

Crankshaft, Sump and Oil Pump

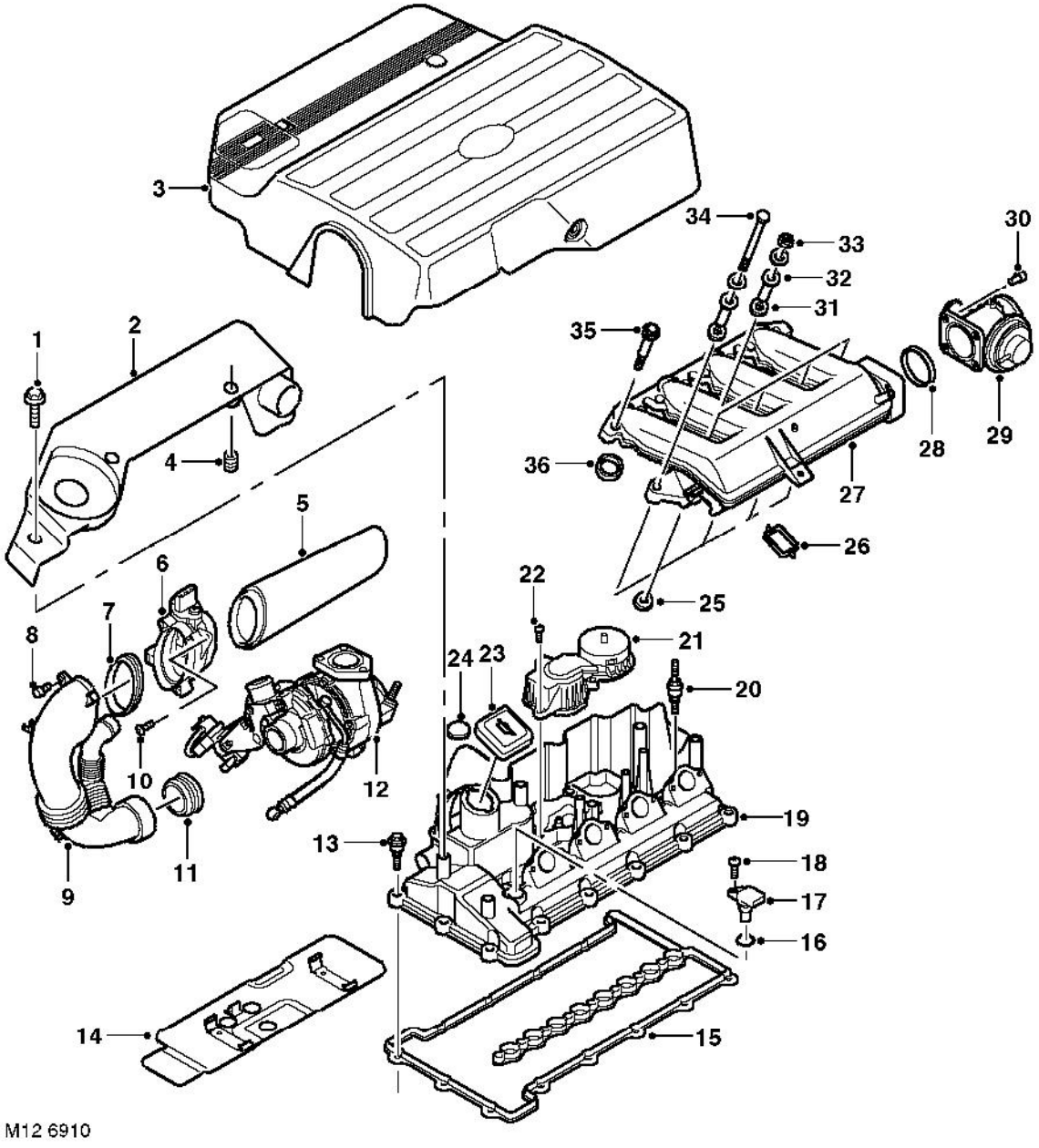


M12 6909



1 Bolt – TV damper/crankshaft pulley
2 Washer – crankshaft pulley bolt
3 TV damper and crankshaft pulley
4 Crankshaft sprocket
5 Woodruff key
6 Crankshaft
7 Main bearing shells (grooved) – upper halves (4 off)
8 No. 4 main bearing with integral thrust washers (grooved) – upper half
9 Dowel – flywheel to crankshaft
10 Bolts – flywheel to crankshaft (8 off)
11 Bolts – impulse wheel to crankshaft (4 off)
12 Crankshaft timing impulse wheel
13 Cylinder block stiffener plate
14 Main bearing shells (plain) – lower (4 off)
15 No. 4 main bearing shell (plain with integral thrust washers) – lower
16 Bolts – stiffener plate to cylinder block (6 off)
17 Bolts – oil pick-up pipe to oil pump assembly (2 off)
18 Bolt – oil pick-up pipe to stiffener plate
19 Oil pick-up pipe and strainer
20 Gasket – oil pick-up pipe to oil pump assembly
21 Bolts – sump to cylinder block – M6 x 40 mm (2 off)
22 Dipstick
23 'O' ring – dipstick to dipstick tube
24 Screw – dipstick tube to oil filter housing
25 Dipstick tube
26 Bolts – sump to cylinder block – M8 x 110 mm (2 off)
27 'O' ring – dipstick tube to sump
28 Sump bottom plate
29 Bolts – sump bottom plate to sump (16 off)
30 Washer – oil drain plug sealing
31 Plug – sump oil drain
32 Gasket – sump bottom plate to sump
33 Bolts – sump to cylinder block – M8 x 30 mm (15 off)
34 Sump
35 Gasket – sump to cylinder block
36 Oil pump sprocket
37 Bolt – oil pump sprocket
38 Bolts – oil pump assembly to cylinder block
39 Oil pump drive chain
40 Oil pump assembly

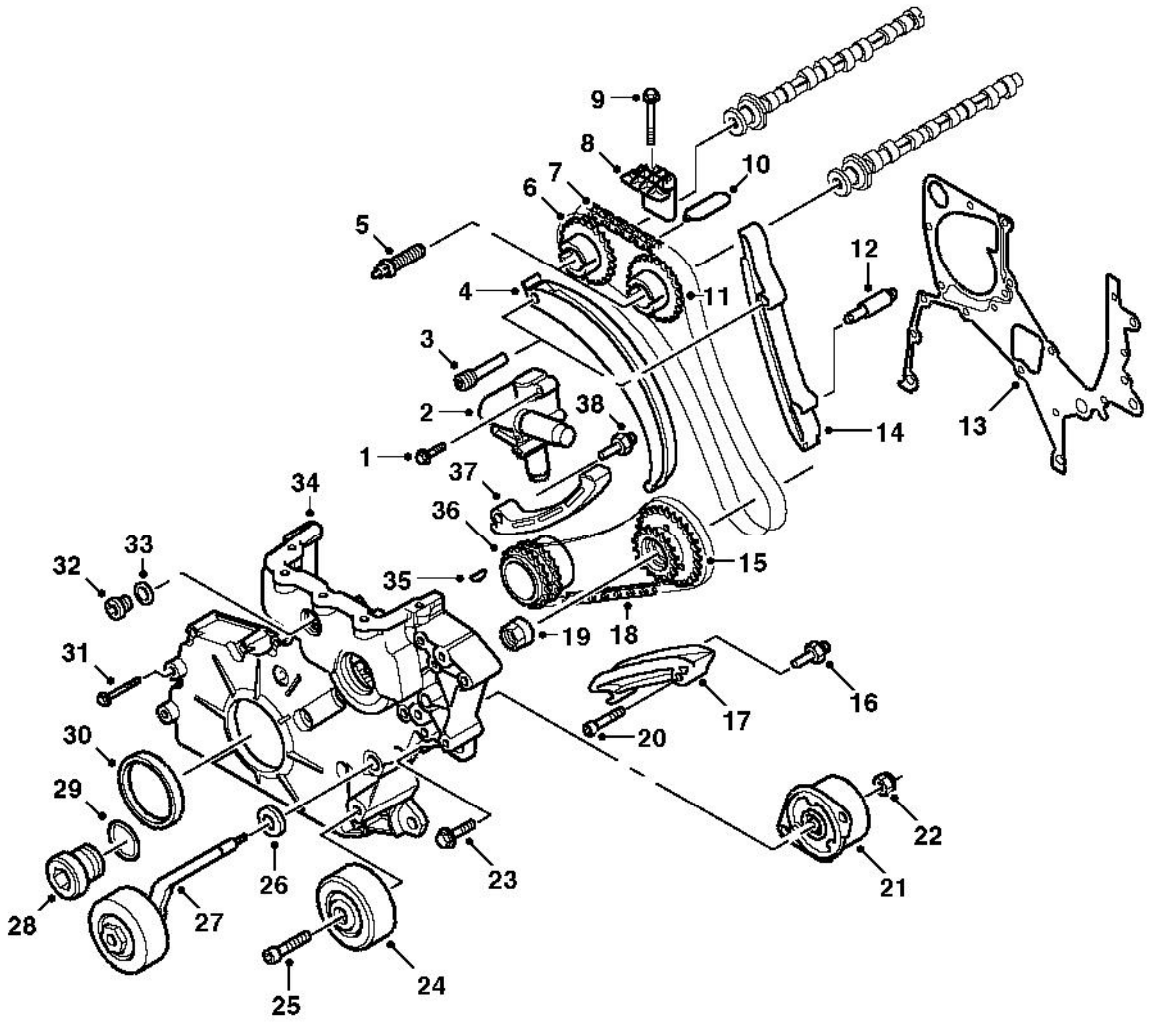
Camshaft Cover and Engine Cover





1 Bolts – air cleaner cover (3 off)
2 Air cleaner cover
3 Acoustic cover
4 Grommet
5 Air filter
6 Mass air flow (MAF) sensor assembly
7 Grommet – air cleaner upper
8 Fixings – duct to airflow sensor assembly (2 x clips + 2 x capscrews)
9 Duct – Air cleaner assembly to turbocharger
10 Screws – mass airflow (MAF) sensor assembly to air cleaner assembly (2 off)
11 Grommet – air cleaner lower
12 Turbocharger
13 Bolts – camshaft cover to cylinder head (14 off)
14 Camshaft cover blanking plate
15 Gasket – camshaft cover to cylinder head
16 'O' ring – camshaft sensor
17 Camshaft sensor
18 Screw – camshaft sensor to camshaft cover
19 Camshaft cover
20 Pillar bolts – camshaft cover to cylinder head (8 off)
21 Oil depression limiter (filter housing)
22 Screws – oil separator housing to camshaft cover (4 off)
23 Oil filler cap
24 Plugs – camshaft cover (3 off)
25 Inlet manifold cover (tangential port side) lower adaptors (5 off)
26 Gasket (tangential ports) – inlet manifold (4 off)
27 Inlet manifold assembly
28 Sealing ring – EGR valve to inlet manifold
29 EGR valve
30 Screws – EGR valve to inlet manifold (4 off)
31 Inlet manifold cover (tangential port side) inserts (8 off)
32 Inlet manifold cover (tangential port side) top adaptors (5 off)
33 Nuts – inlet manifold (tangential port side) to cylinder head (4 off)
34 Bolt – inlet manifold to cylinder head
35 Bolts – inlet manifold assembly (swirl port side) to camshaft cover (8 off)
36 Gasket (swirl ports) – inlet manifold (4 off)

Camshaft Timing Chain Components

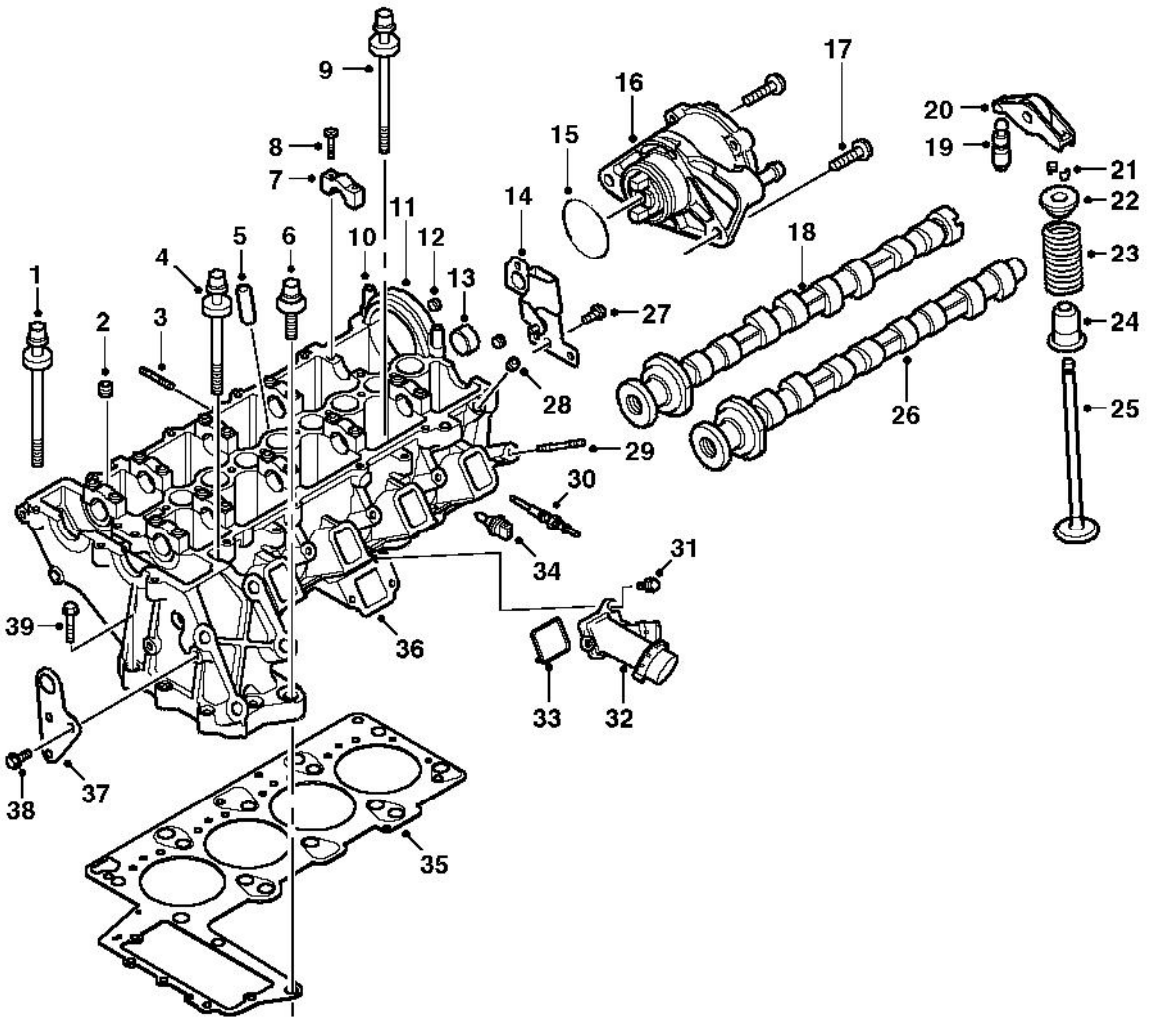


M12 6911



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

Cylinder Head Components

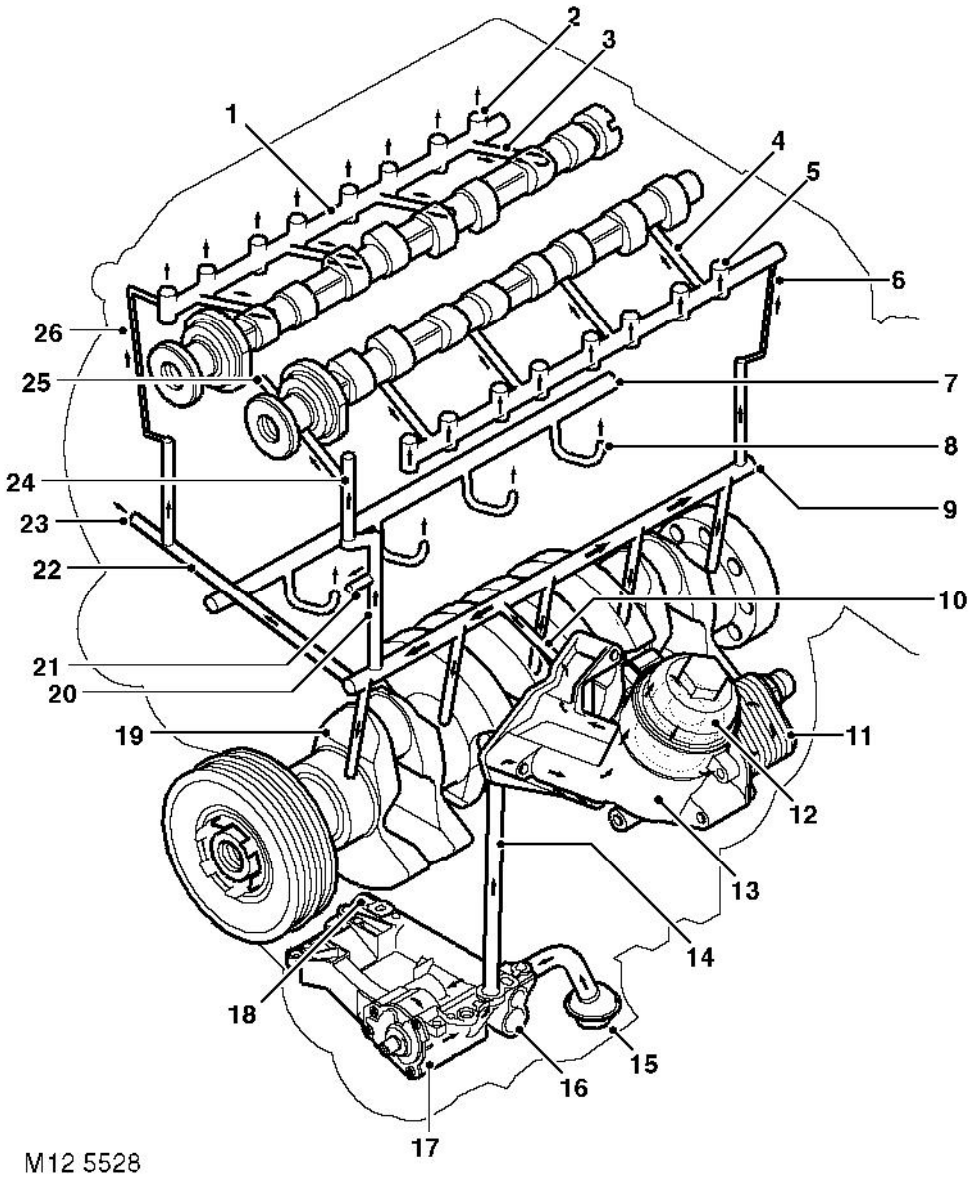


M12 6912



1 Bolt – cylinder head fixing
2 Plug – cylinder head oil channel
3 Studs – exhaust manifold to cylinder head mounting (8 off)
4 Bolt – cylinder head to cylinder block
5 Valve guides (16 off)
6 Bolt – cylinder head to cylinder block
7 Camshaft bearing caps (10 off, 5 per camshaft)
8 Screws – camshaft bearing cap (20 off; 2 per camshaft bearing cap)
9 Cylinder head bolts (10 off)
10 Pillar screws – vacuum pump bracket
11 Vacuum pump bracket
12 Plugs – cylinder head (rear) oil gallery (2 off)
13 Plug – cylinder head (rear) blanking
14 Engine lifting bracket (rear)
15 'O' ring – vacuum pump to cylinder head
16 Vacuum pump
17 Bolts – vacuum pump to cylinder head (2 off)
18 Exhaust camshaft
19 Hydraulic tappets (16 off)
20 Rockers (16 off)
21 Valve spring collets (32 off)
22 Valve spring retainers (16 off)
23 Valve springs (16 off)
24 Valve stem seals (16 off)
25 Valves (8 x inlet, 8 x exhaust)
26 Intake camshaft
27 Bolts – engine lifting bracket to cylinder head (rear) (2 off)
28 Screw – oil gallery blanking
29 Studs – intake manifold to cylinder head mounting (4 off)
30 Glow plugs (4 off)
31 Bolts – coolant outlet elbow (3 off)
32 Coolant outlet elbow
33 Gasket – coolant outlet elbow to cylinder block
34 Coolant temperature sensor
35 Cylinder head gasket
36 Cylinder head
37 Engine lifting bracket (front)
38 Bolts – engine lifting bracket (front) (2 off)
39 Bolts – cylinder head to lower timing cover (4 off)

Lubrication Circuit



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

Description

General
The Td4 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 EU-3 (European Commission Directive) legislative requirements and employs a 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 DDE 4.0 engine management system.
☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

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.

The engine utilises the following features:
- Direct fuel injection utilising a common rail and high pressure injectors controlled by an engine management system for precise fuel delivery under all prevailing operating conditions. A high pressure intermediary fuel pump is chain driven from the crankshaft to supply fuel to the common rail
- 4 valves per cylinder with centrally arranged injection nozzle
- Turbocharging which delivers compressed air via an intercooler to the combustion chambers for improved power output
- Exhaust gas recirculation to improve emissions through the reduction of NO2
- Oil cooler to keep engine lubrication oil cool under heavy loads and high ambient temperatures

Cylinder Block Components
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 RH 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.

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.

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.

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.

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 RH 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.

The oil filter is a disposable paper type. The filter is removed by unscrewing the cap of the oil filter housing.

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 LH side of the cylinder block. The pump is a 3 radial piston type controlled by the DDE 4.0 engine management system and chain driven from the crankshaft at 0.75 x engine speed.

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

Crankshaft Position (CKP) Sensor
The crankshaft position sensor is mounted on the rear LH side of the cylinder block. The sensor is a Hall-effect type which acts on a profiled target on the flywheel.

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

Sump, Crankshaft and Oil Pump Components
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.

A thermal oil level sensor is fitted through the bottom plate of the sump and is fixed to the bottom plate by means of three studs and nuts. The oil drain plug with sealing washer is also fitted to the RH 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 LH 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.

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.

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
The cylinder head components are described below:

Cylinder Head
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.

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 LH 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 LH side of the cylinder head.

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**
☞ **COOLING SYSTEM - Td4, DESCRIPTION AND OPERATION, Description.**



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.

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

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

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

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

Vacuum Pump

The vacuum pump is located on a support bracket at the rear RH 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.

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.

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.

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

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
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.

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.

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 RH 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.

☞ **INSTRUMENTS, DESCRIPTION AND OPERATION, Description.**



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 LH main oil gallery crosses to the RH 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.

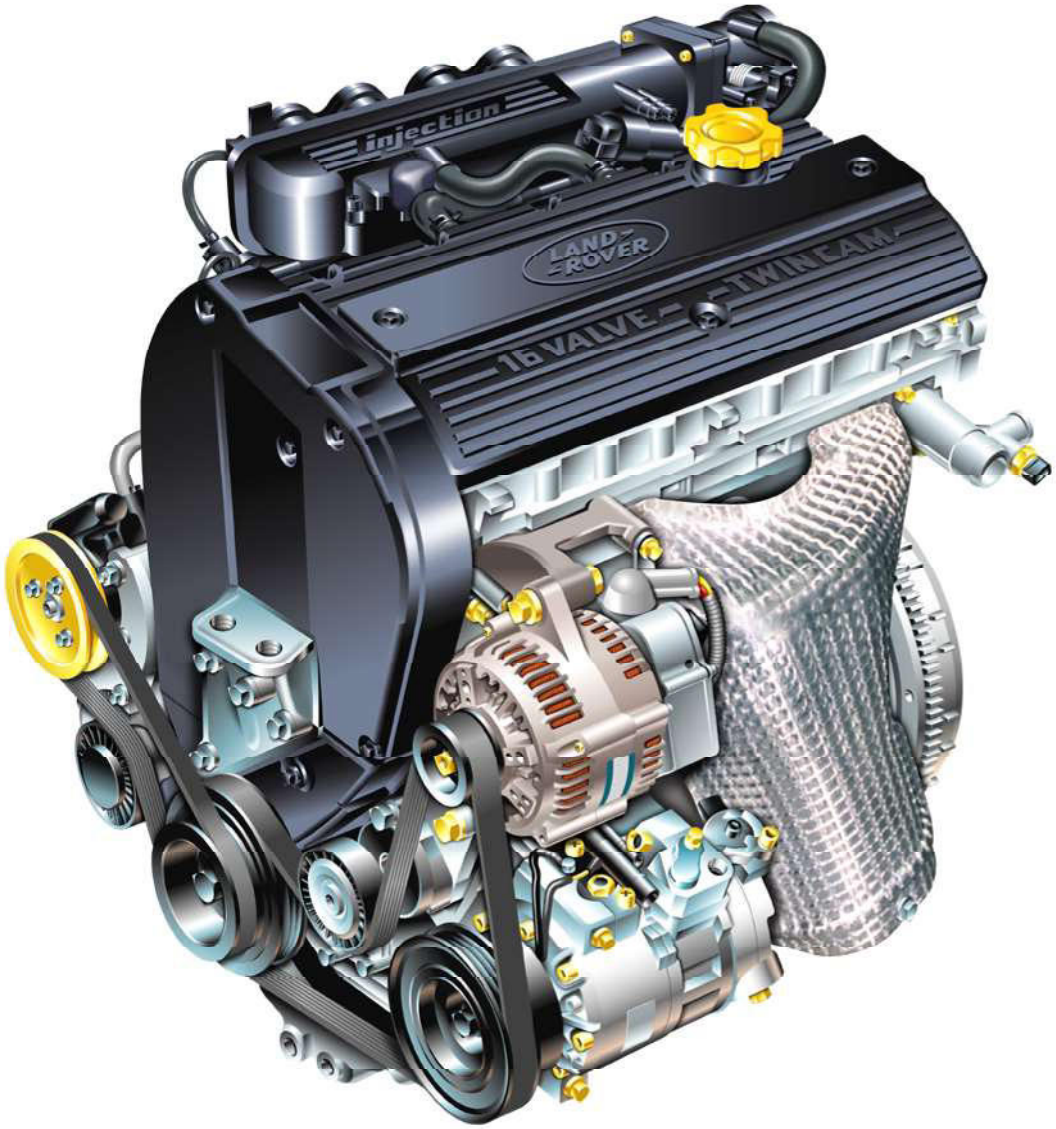
Riser channels at the front RH side and rear LH side of the cylinder block are used to channel oil to mating ports in the cylinder head and provide a source for cylinder head lubrication and operating pressure for the hydraulic tappets.

Oil is fed through oil galleries at the LH and RH side 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 RH gallery.

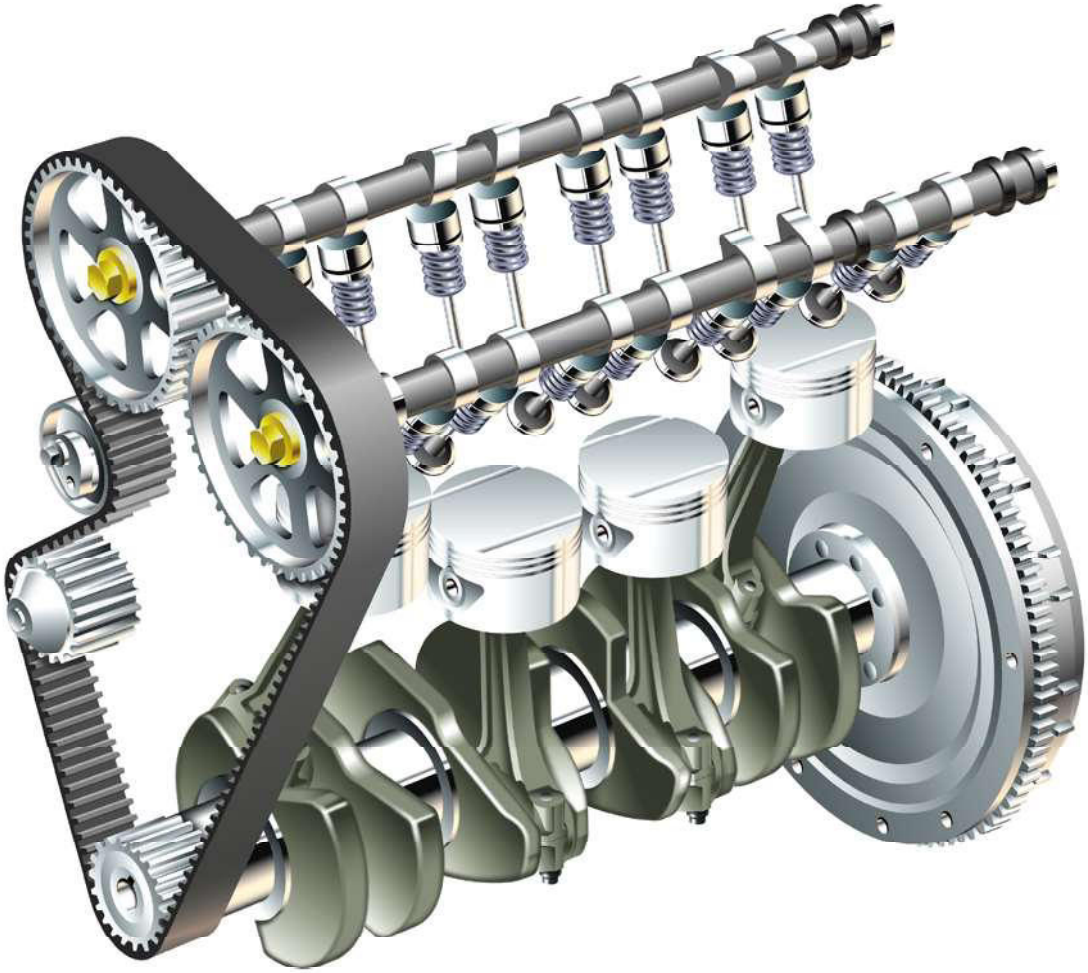
An additional riser channel from the cylinder block LH main oil gallery is used to supply lubrication to the timing chain system through several outlet ports at the front of the cylinder block and cylinder head.

External View



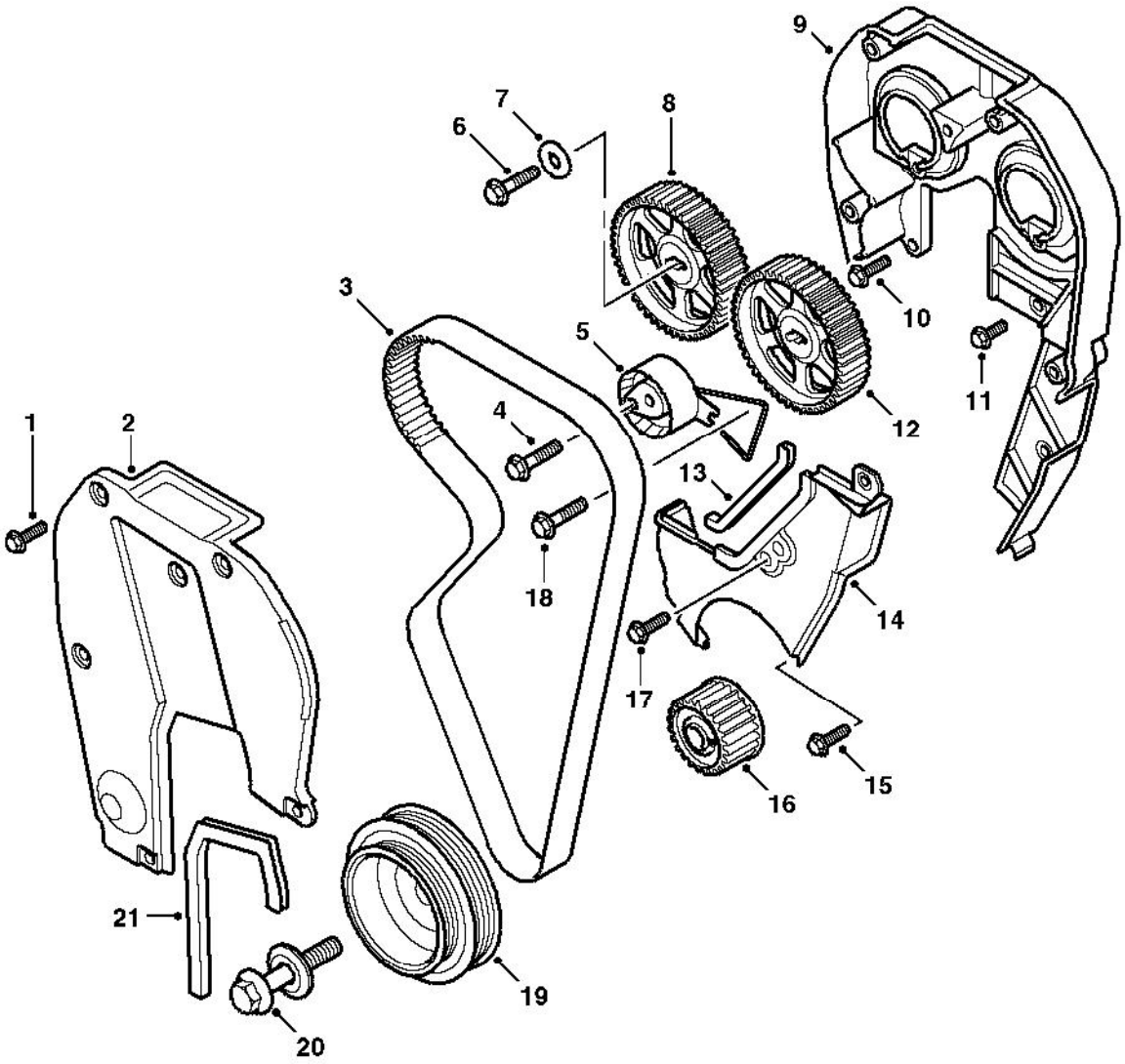
M12 6832

Internal View



M12 6833

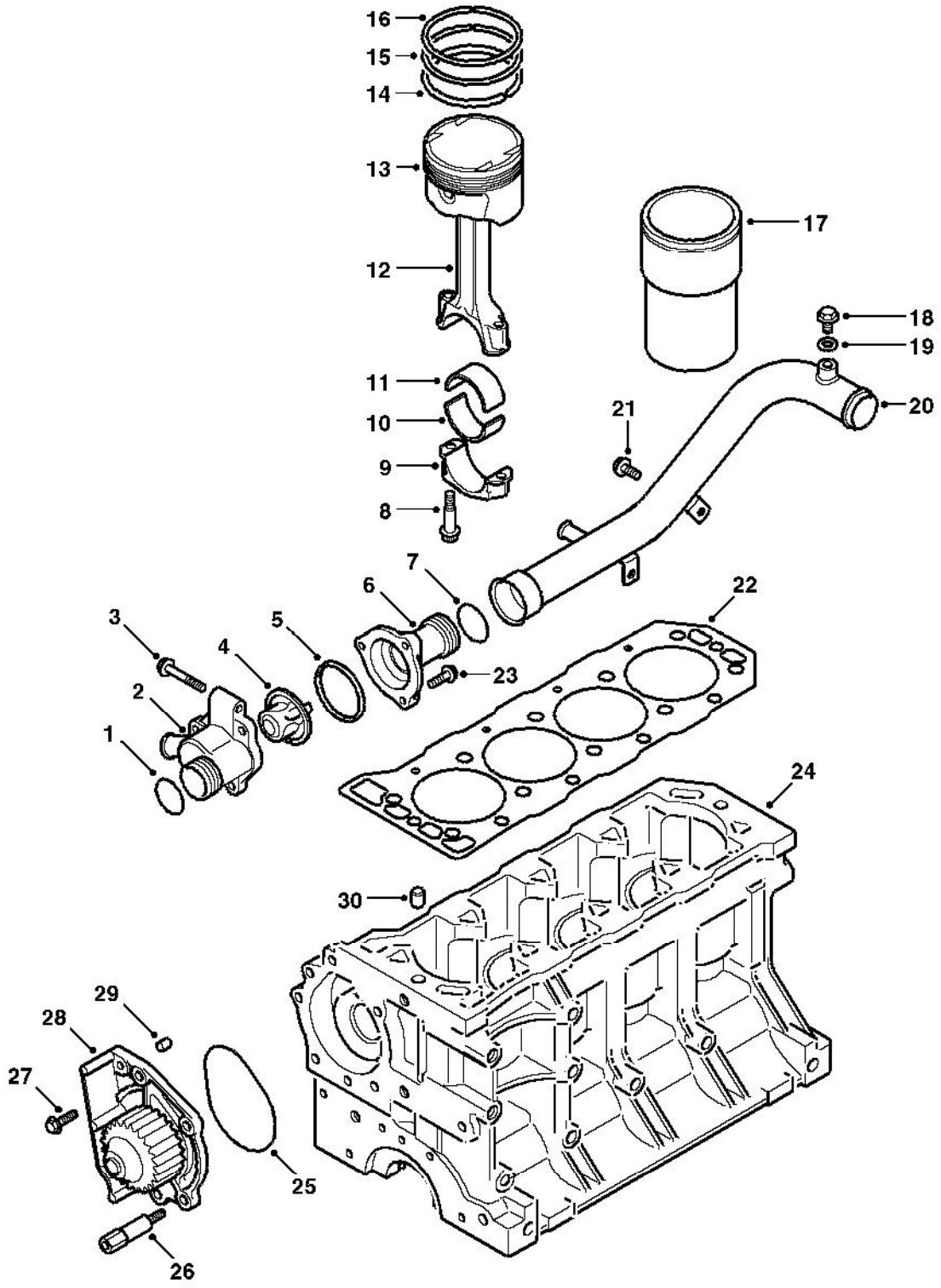
Timing Belt Components



M12 7051

1 Screws – upper front to upper rear drive belt cover (5 off)
2 Upper front drive belt cover
3 Drive belt
4 Bolt – tensioner to cylinder head
5 Tensioner
6 Bolt – camshaft drive gear to camshaft
7 Washer – camshaft drive gear to camshaft
8 Inlet camshaft drive gear
9 Upper rear drive belt cover assembly
10 Screw (long) – upper rear drive belt cover to cylinder block
11 Screws (short) – upper rear drive belt cover to cylinder block (4 off)
12 Exhaust camshaft drive gear
13 Seal – lower front drive belt cover
14 Lower front drive belt cover assembly
15 Screw – lower front drive belt cover to oil pump
16 Crankshaft drive gear
17 Screw – lower front drive belt cover to upper rear drive belt cover
18 Screw – tensioner index wire stop to cylinder head
19 Crankshaft pulley
20 Bolt and washer – crankshaft pulley
21 Seal – upper front drive belt cover

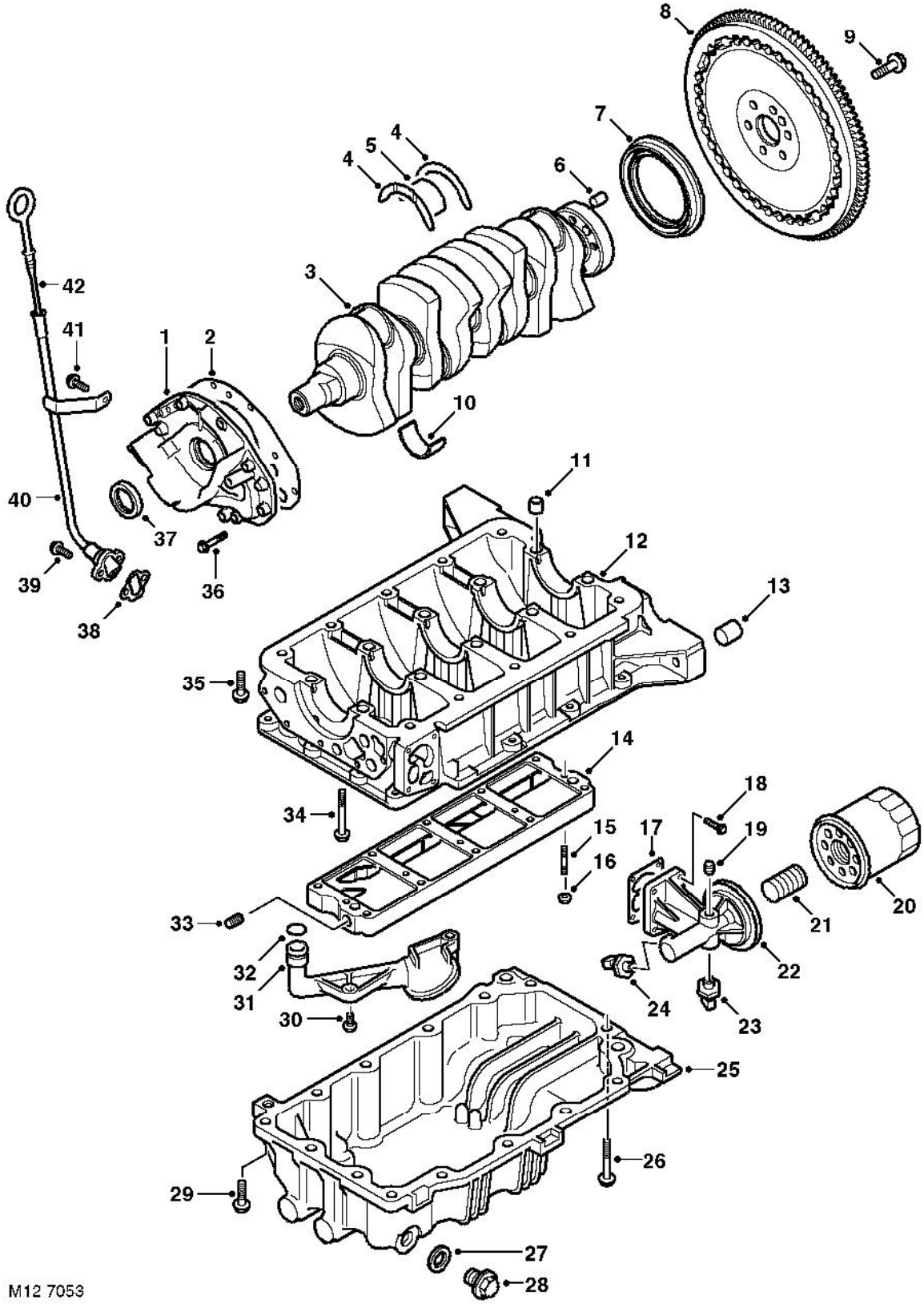
Cylinder Block Components



M12 7052

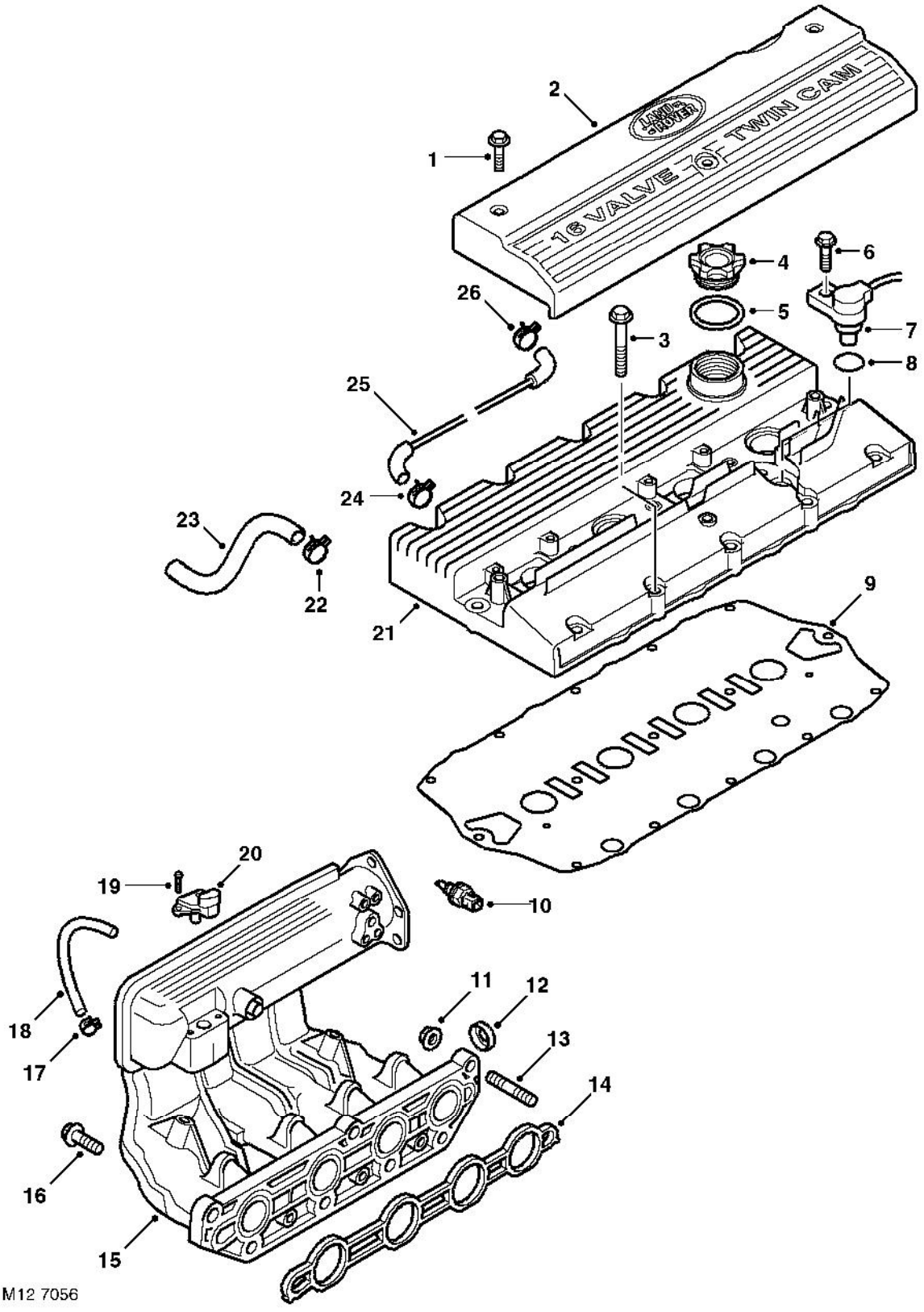
1 'O' ring – thermostat housing to coolant pump
2 Thermostat housing
3 Screw – dipstick tube and thermostat housing to cylinder block
4 Thermostat
5 Seal – thermostat
6 Cover – thermostat
7 'O' ring – thermostat to coolant pipe
8 Bolt – connecting rod (2 off per connecting rod)
9 Big-end bearing cap
10 Big-end bearing shell (lower)
11 Big-end bearing shell (upper)
12 Connecting rod (4 off)
13 Piston (4 off)
14 Oil control ring
15 2nd compression ring
16 Top compression ring
17 Sealing washer – vent screw to coolant pipe
18 Cylinder liner (4 off)
19 Vent screw
20 Coolant pipe
21 Screw – coolant pipe to cylinder block
22 Cylinder head gasket
23 Bolts – thermostat cover to housing (3 off)
24 Cylinder block
25 'O' ring –coolant pump
26 Pillar bolt – coolant pump to cylinder block (coolant pump belt cover support)
27 Screws – coolant pump to cylinder block (4 off)
28 Coolant pump
29 Dowels – coolant pump to cylinder block (2 off)

Crankshaft, Sump and Oil Pump Assembly



1 Oil pump assembly
2 Gasket – oil pump
3 Crankshaft
4 Thrust washers (2 off at No.3 main bearing)
5 Main bearing shells (upper) – (5 off; plain in No.1 and 5, grooved in No.2, 3 and 4)
6 Dowel
7 Crankshaft rear oil seal
8 Flywheel assembly
9 Bolts – flywheel to crankshaft (6 off)
10 Main bearing shells (lower) – (5 off)
11 Dowels – bearing ladder to cylinder block
12 Bearing ladder
13 Dowels – bearing ladder to transmission case (2 off)
14 Oil rail
15 Studs – bearing ladder to oil rail (2 off)
16 Nuts – bearing ladder to oil rail (2 off)
17 Gasket – oil filter adapter to bearing ladder
18 Screws – oil filter adapter to bearing ladder (4 off)
19 Taper plug
20 Oil filter cartridge
21 Oil filter adapter insert
22 Oil filter head
23 Oil temperature sensor
24 Oil pressure switch
25 Sump
26 Bolts (long) – sump to bearing ladder (2 off)
27 Sealing washer – sump plug
28 Plug – sump oil drain
29 Screws (short) – sump to bearing ladder (12 off)
30 Screw – oil suction pipe to bearing ladder
31 Oil suction pipe
32 Seal – oil suction pipe
33 Oil rail core plug
34 Bolts (long) – bearing ladder to cylinder block
35 Bolts (short) – bearing ladder to cylinder block (9 off)
36 Bolts – oil pump to cylinder block
37 Crankshaft front oil seal
38 Gasket – dipstick tube to bearing ladder
39 Screws – dipstick tube to bearing ladder (2 off)
40 Dipstick tube
41 Bolt – dipstick tube to thermostat and cylinder block
42 Dipstick

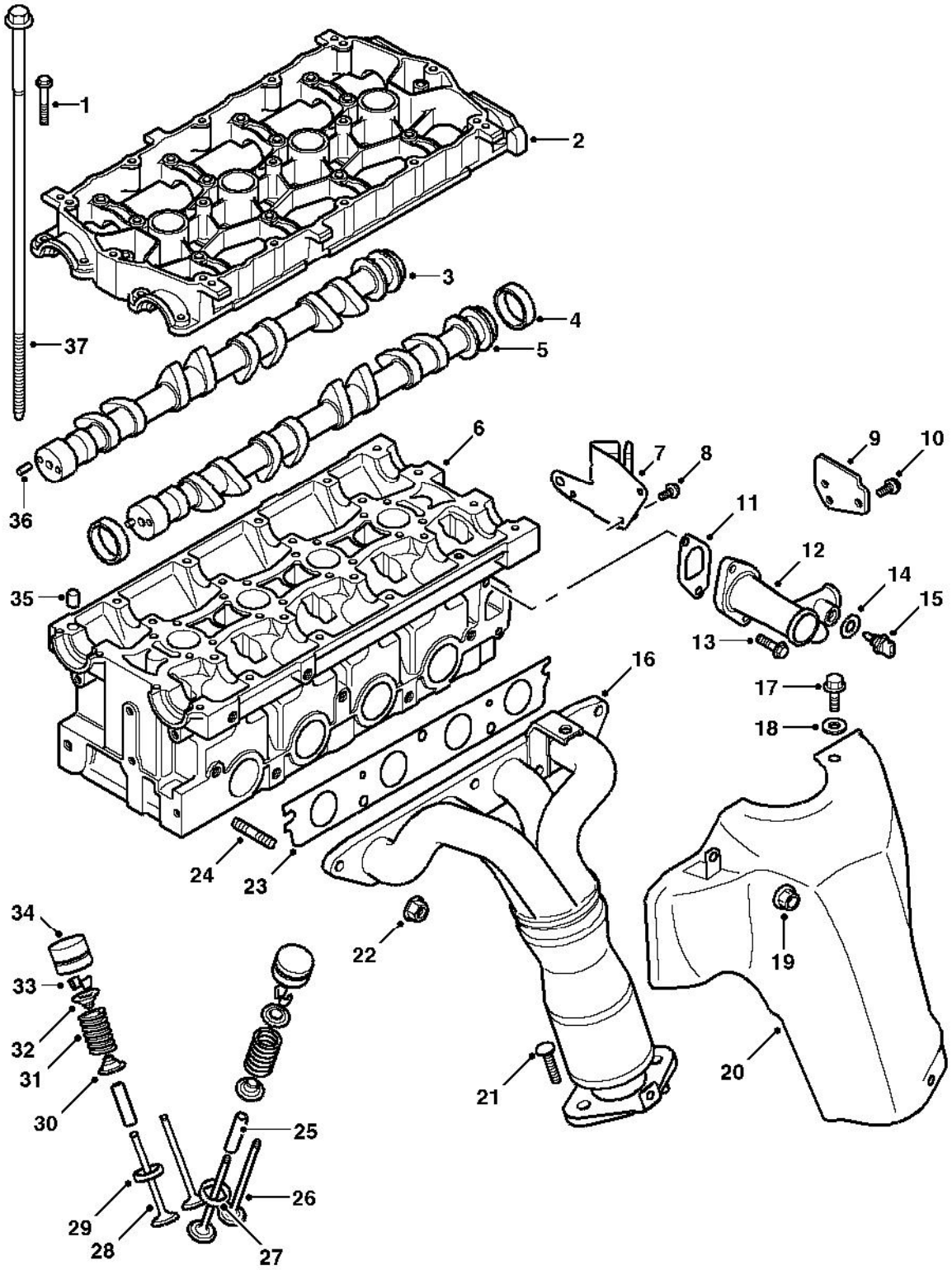
Camshaft Cover, Engine Cover and Inlet Manifold





1 Bolts – spark plug cover to camshaft cover (3 off)
2 Spark plug cover
3 Bolts – camshaft cover to camshaft carrier (15 off)
4 Oil filler cap
5 Oil filler cap seal
6 Bolt – camshaft sensor to camshaft cover
7 Camshaft sensor
8 'O' ring – camshaft sensor
9 Gasket – camshaft cover to camshaft carrier
10 Inlet air temperature (IAT) sensor
11 Nuts – inlet manifold to cylinder head studs (3 off)
12 Copper washer – IAT sensor to inlet manifold
13 Studs – inlet manifold to cylinder head (3 off)
14 Gasket – inlet manifold to cylinder head
15 Inlet manifold
16 Bolts – inlet manifold to cylinder head (4 off)
17 Spring clip – vacuum regulator to inlet manifold pipe
18 Pipe – vacuum regulator to inlet manifold
19 Cap screws – Manifold Absolute Pressure (MAP) sensor to inlet manifold (2 off)
20 Manifold Absolute Pressure (MAP) sensor
21 Camshaft cover assembly
22 Spring clip – breather hose to camshaft cover
23 Hose – camshaft cover to inlet manifold breather
24 Spring clip – breather hose to camshaft cover
25 Hose – camshaft cover to throttle body breather
26 Spring clip – breather hose to throttle body

Cylinder Head Components



M12 7054

1 Bolts – camshaft carrier to cylinder head (26 off)
2 Camshaft carrier
3 Inlet camshaft
4 Oil seal – camshaft (4 off)
5 Exhaust camshaft
6 Cylinder head
7 Cover plate – inlet camshaft
8 Screws – cover plate to camshaft cover (2 off)
9 Cover plate – exhaust camshaft
10 Screws – cover plate to camshaft cover (2 off)
11 Gasket – coolant outlet elbow
12 Coolant outlet elbow
13 Screws – coolant outlet elbow to cylinder head (2 off)
14 Washer – coolant temperature sensor
15 Coolant temperature sensor
16 Exhaust manifold
17 Bolts – exhaust heat shield (2 off)
18 Washer – exhaust heat shield
19 Nut – exhaust heat shield
20 Exhaust heat shield
21 Bolts – exhaust manifold to exhaust down pipe
22 Nuts – exhaust manifold to cylinder head studs (5 off)
23 Gasket – exhaust manifold to cylinder head
24 Studs – exhaust manifold to cylinder head
25 Valve guides (16 off)
26 Exhaust valves (8 off – 2 per cylinder)
27 Exhaust valve seat inserts (8 off)
28 Inlet valves (8 off – 2 per cylinder)
29 Inlet valve seat inserts (8 off)
30 Valve stem oil seal (16 off)
31 Valve spring (16 off)
32 Valve spring cap (16 off)
33 Collets – cap (16 off)
34 Hydraulic tappets (16 off)
35 Ring dowel – cylinder head to camshaft carrier (2 off)
36 Drive pin – camshaft (2 off, 1 per camshaft)
37 Bolts – cylinder head (10 off)

Operation

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.

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.

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.

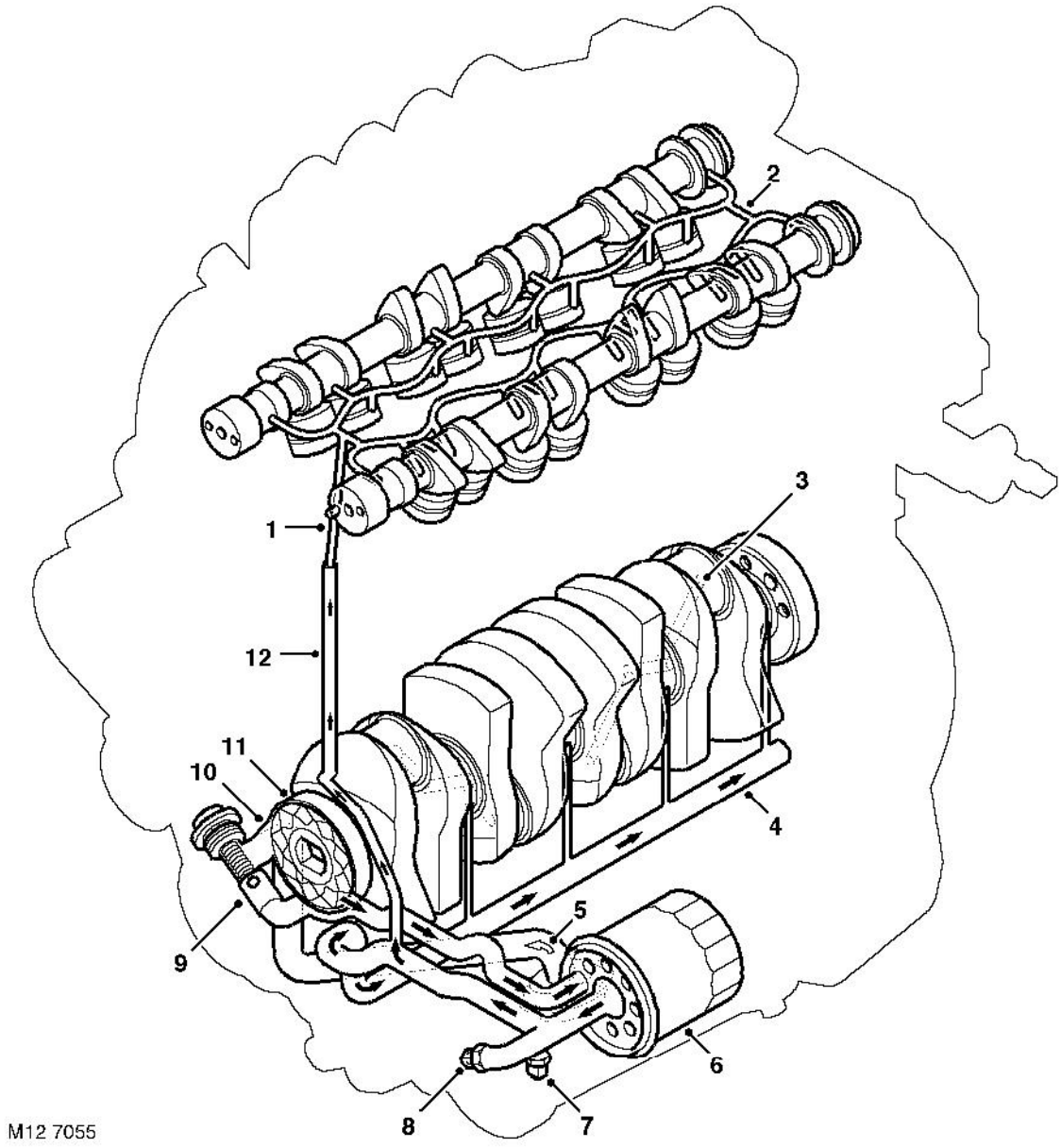
The stainless steel cylinder head gasket has moulded seals around all coolant, breather and oil apertures and has steel cylinder bore eyelets. Limiters at each end of the gasket control compression of the gasket.

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.

Engine Lubrication System



The lubrication system is of the full-flow filtration, forced fed type. The oil sump is of either pressed steel or alloy manufacture. Pressed steel sumps are sealed to the bearing ladder using a positively located gasket incorporating compression limiters. Alloy sumps are sealed to the bearing ladder with a bead of sealant applied to the sump flange.

Oil is drawn, via a strainer and suction pipe (1) in the sump, into the crankshaft driven oil pump (2) of the trochoid type which has an integral pressure relief valve (3), excess oil is diverted into the intake (4) of the oil pump. Oil is pumped through the full-flow cartridge-type oil filter (5), mounted on an adapter attached to the oil pump housing. The low-oil pressure sensor (6) is also screwed into the adapter and registers the oil pressure in the main oil gallery on the outflow side of the filter.

The main oil gallery (7) is fed through the oil rail below the main bearing ladder in which drillings direct the oil to the main bearings. Cross drillings in the crankshaft from No. 2 and 4 main bearings carry the oil to the big-end bearings. A passage in the oil pump housing connects to a drilling (8) in the cylinder block to oil ways (9) in the cylinder head.

Oil is fed through the cylinder head to twin full-length oil ways (10) in the camshaft carrier to supply oil to each hydraulic tappet and camshaft bearing.

Crankcase Ventilation
A positive crankcase ventilation system is used to vent blow-by gas from the crankcase to the air intake system.

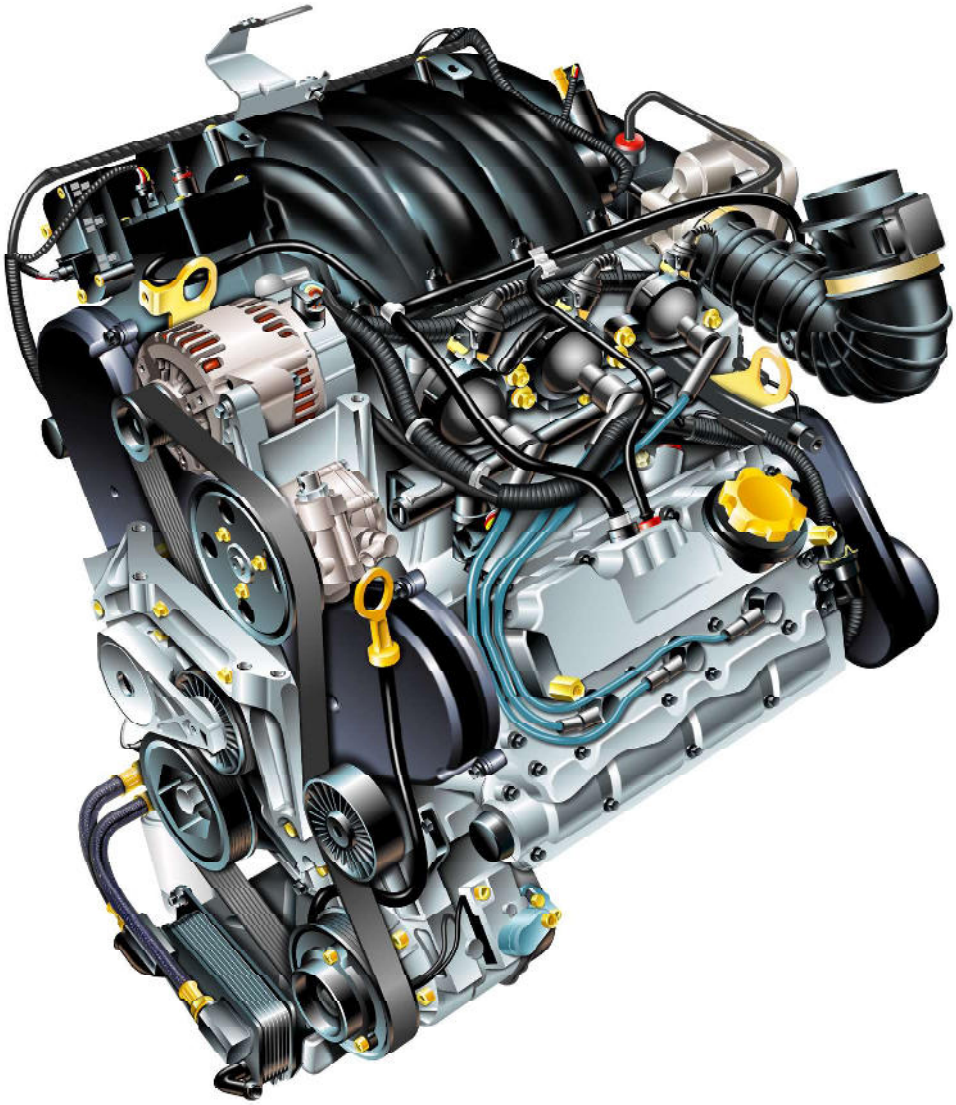
Crankcase gas is drawn through a gauze oil separator in the camshaft cover and passes via hoses into the throttle housing.

KV6 Engine – General View (All Except NAS)



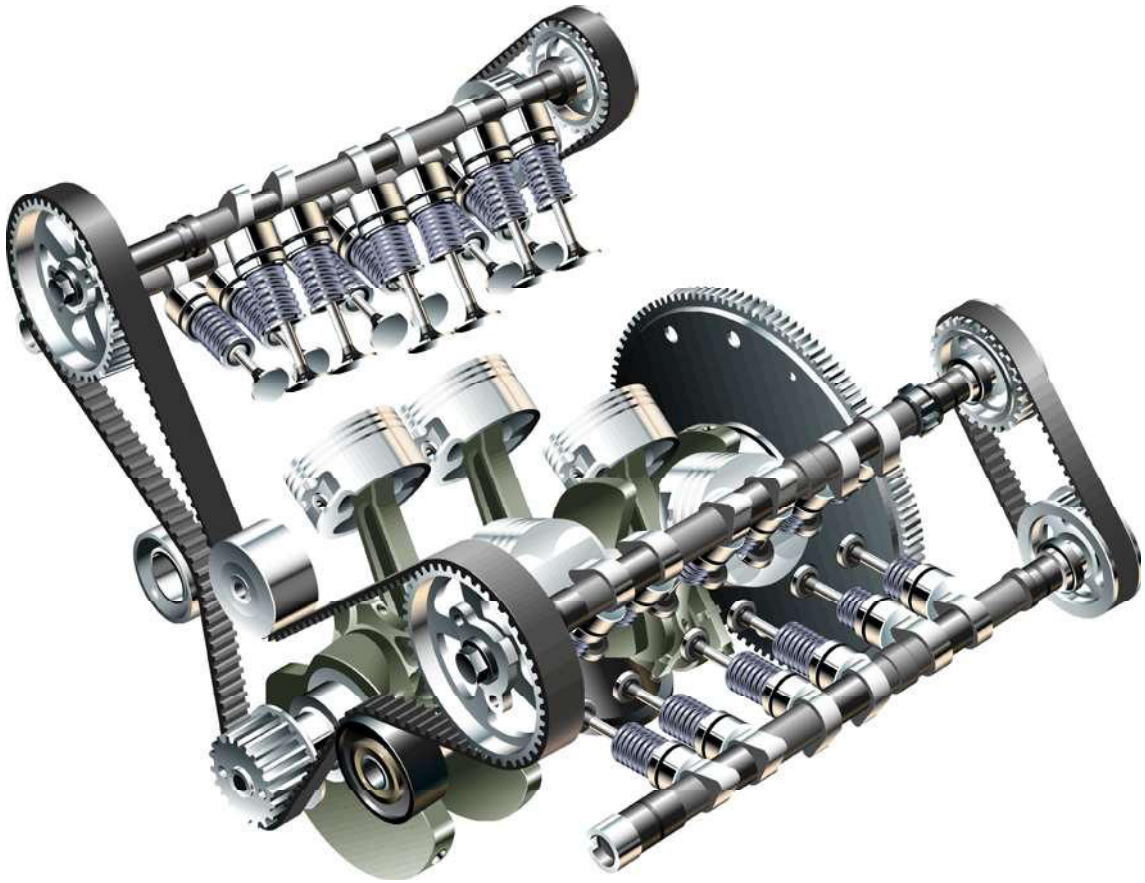
M12 6812

KV6 Engine – General View (NAS)



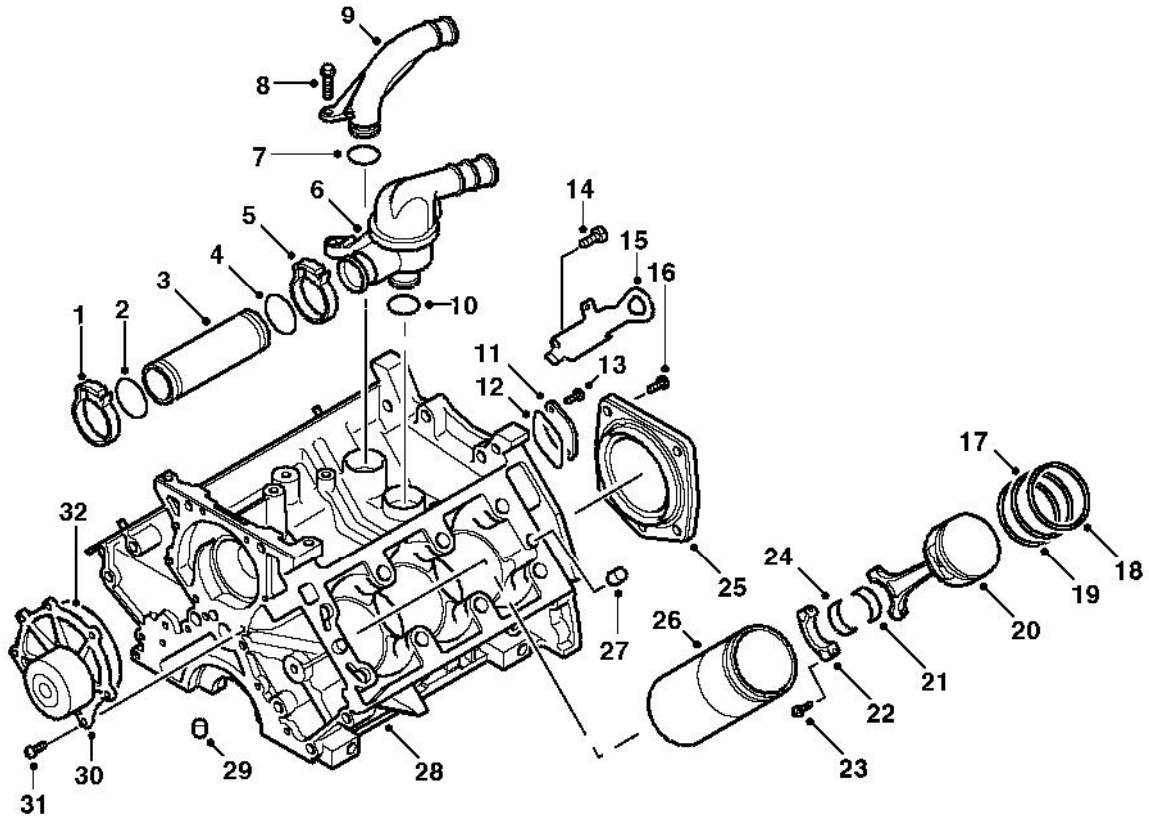
M12 7452

KV6 Engine – Internal View



M12 6813

KV6 Engine – Cylinder Block Components



M12 6644

1 Clip – 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 – coolant pump to thermostat pipe
6 Thermostat housing
7 'O' ring – coolant outlet elbow to cylinder block
8 Bolt – coolant outlet elbow to cylinder block
9 Coolant outlet elbow
10 'O' ring – thermostat housing to cylinder block
11 Blanking plate – coolant outlet
12 Seal – blanking plate
13 Screw – blanking plate (2 off)
14 Bolt – engine lifting bracket, rear (2 off)
15 Engine lifting bracket – rear
16 Screw – crankshaft rear oil seal (5 off)
17 2nd compression ring
18 Top compression ring
19 Oil control ring
20 Piston
21 Big-end upper bearing shell
22 Big-end bearing cap
23 Bolt – big-end bearing cap to connecting rod (2 off per piston)
24 Big-end lower bearing shell
25 Crankshaft rear oil seal
26 Cylinder liner (6 off)
27 Dowel – cylinder block to cylinder head (4 off)
28 Cylinder block
29 Dowel – cylinder block to lower crankcase (4 off)
30 Engine coolant pump
31 Screw – coolant pump to cylinder block (7 off)
32 Seal – coolant pump to cylinder block



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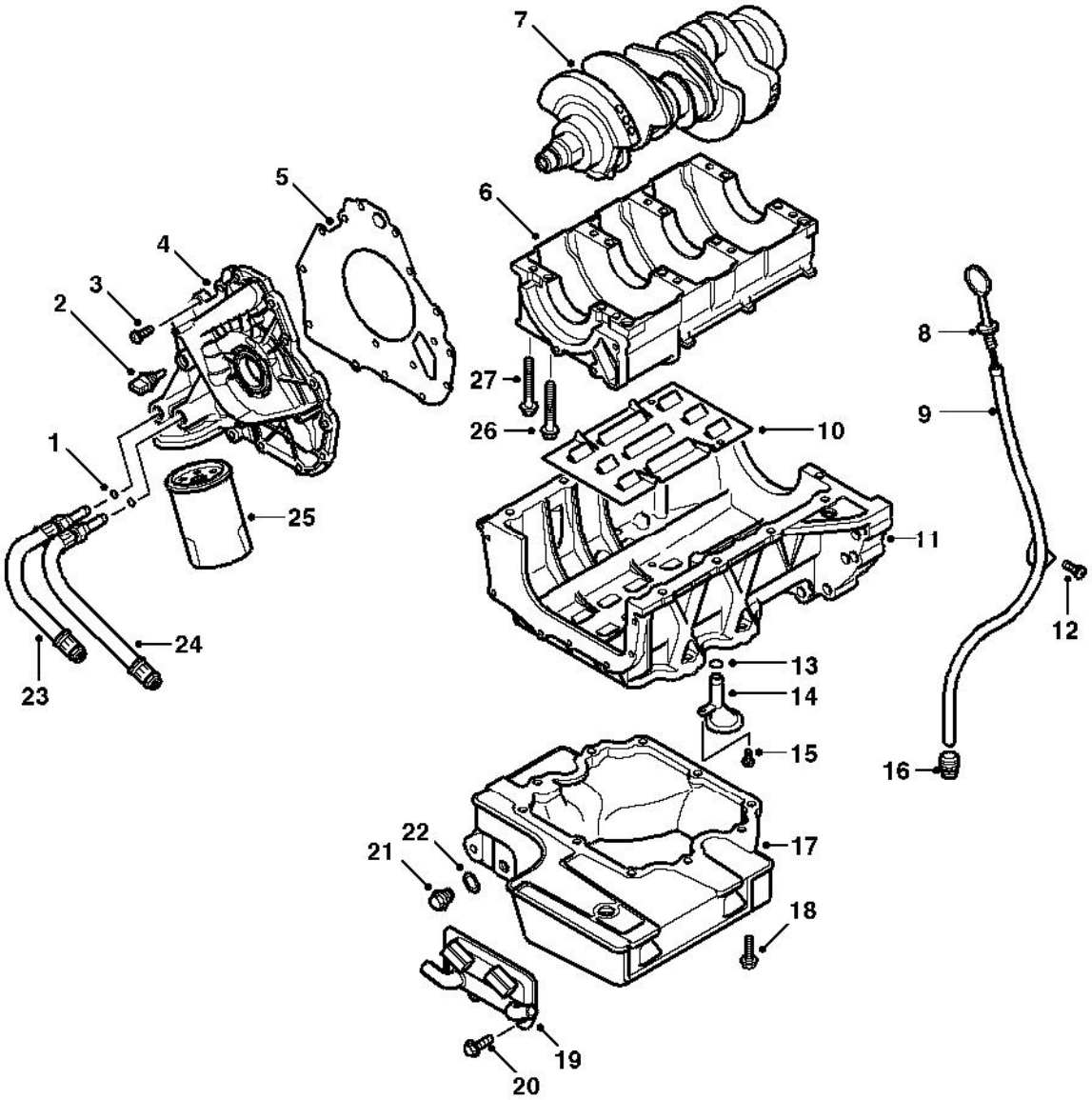
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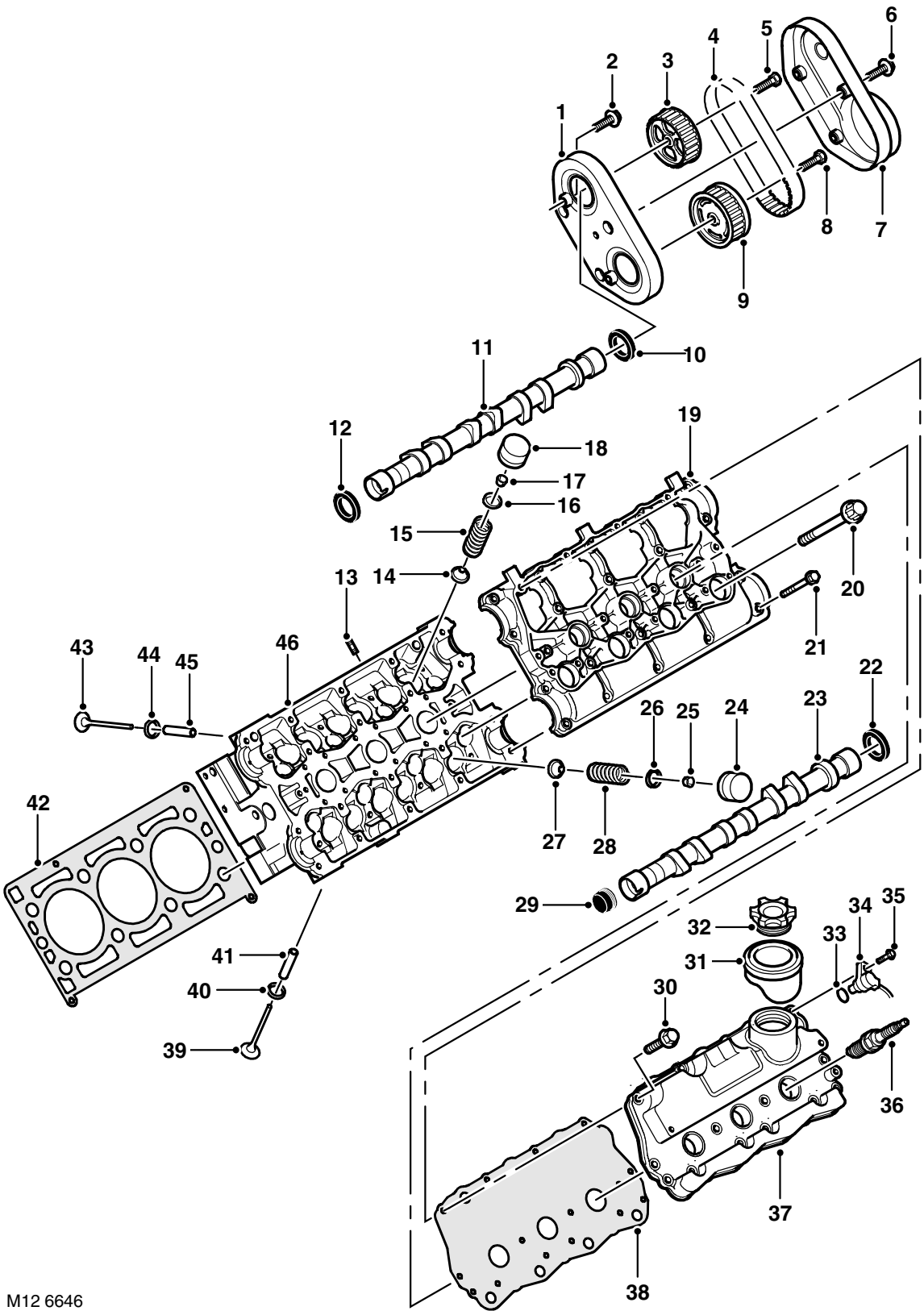
KV6 Engine – Crankshaft, Sump and Oil Pump Assembly



M12 6645

1 'O' rings – oil filter housing to oil cooler pipes
2 Oil pressure switch
3 Screw – oil pump to cylinder block (16 off)
4 Oil pump and oil filter housing assembly
5 Gasket – oil pump housing
6 Bearing ladder
7 Crankshaft
8 Dipstick
9 Dipstick tube
10 Baffle plate – lower crankcase extension
11 Lower crankcase extension
12 Screw – dipstick tube to cylinder block
13 'O' ring – oil pick-up pipe
14 Oil pick-up pipe with integral strainer
15 Screw – oil pick-up pipe to lower crankcase
16 Connector (quick fit) – dipstick tube to sump
17 Sump
18 Bolt – sump to lower crankcase (10 off; 5 x short, 5 x long)
19 Oil cooler
20 Bolt – oil cooler to sump (3 off)
21 Oil drain plug
22 Seal – oil drain plug
23 Pipe – oil cooler to oil filter housing
24 Pipe – oil filter housing to oil cooler
25 Oil filter cartridge
26 Bolt (long) – bearing ladder to cylinder block (8 off)
27 Bolt (short) – bearing ladder to cylinder block (8 off)

KV6 Engine – Cylinder Head Components

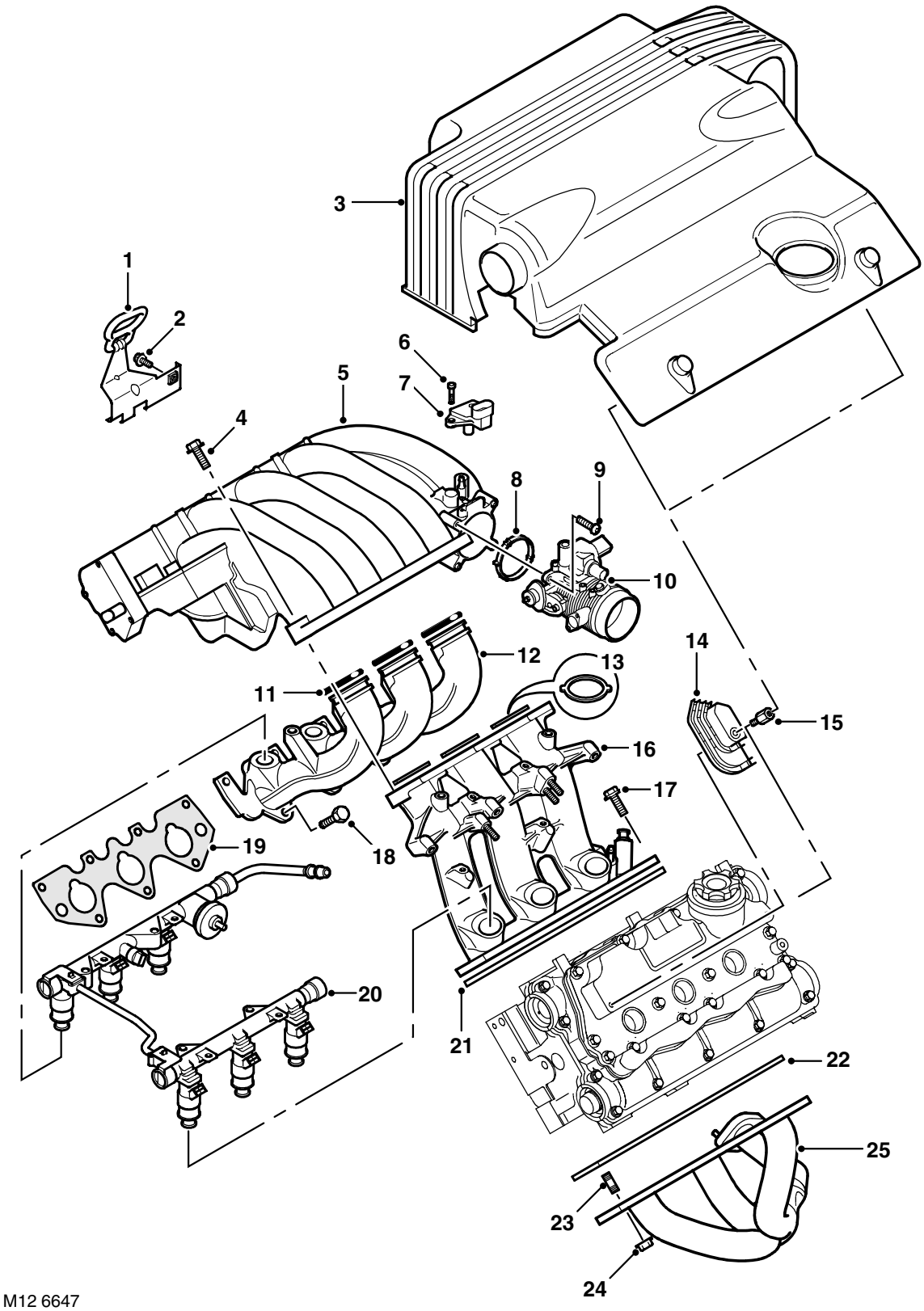


LH cylinder bank shown, RH cylinder bank similar



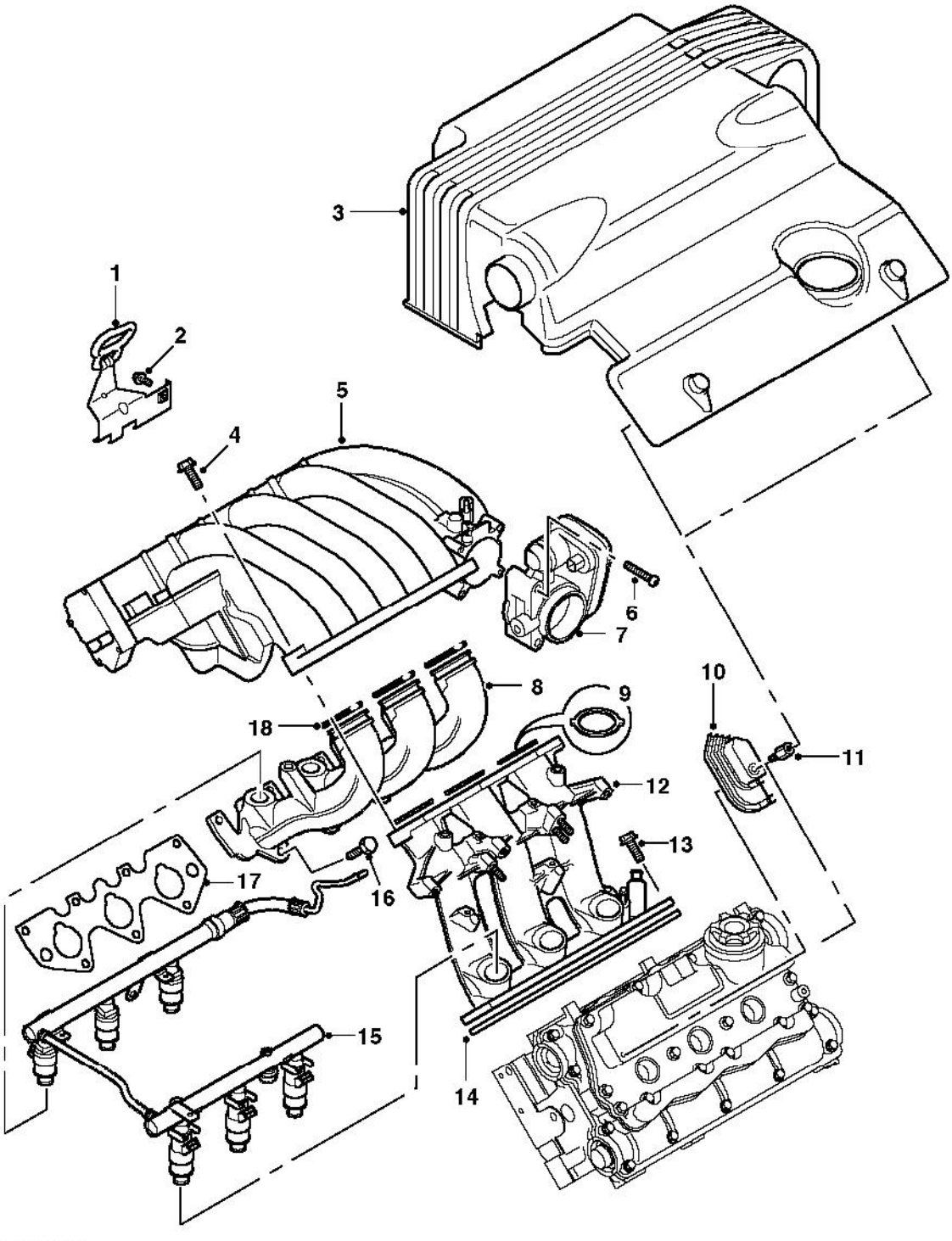
1 Rear drive belt inner cover
2 Bolt – camshaft rear drive belt inner cover (4 off)
3 Camshaft gear – rear inlet
4 Drive belt – rear camshaft
5 Bolt – inlet camshaft gear
6 Bolt – camshaft rear drive belt outer cover (3 off)
7 Rear drive belt outer cover
8 Bolt – exhaust camshaft gear
9 Camshaft gear – rear exhaust
10 Seal – inlet camshaft, rear oil
11 Inlet camshaft
12 Seal – inlet camshaft, front oil
13 Stud – cylinder head to intake manifold (2 off)
14 Valve stem oil seal – inlet (6 off)
15 Valve spring – inlet (6 off)
16 Valve spring cap – inlet (6 off)
17 Collet – inlet valve (12 off)
18 Tappet – inlet valve (6 off)
19 Camshaft carrier
20 Bolt – cylinder head (8 off)
21 Bolt – camshaft carrier to cylinder head (22 off)
22 Seal – exhaust camshaft, rear oil
23 Exhaust camshaft
24 Tappet – exhaust valve (6 off)
25 Collet – exhaust valve (12 off)
26 Valve spring cap – exhaust (6 off)
27 Valve stem oil seal – exhaust (6 off)
28 Valve spring – exhaust (6 off)
29 Seal – exhaust camshaft, front oil
30 Bolt – camshaft cover (14 off)
31 Seal – oil filler cap
32 Oil filler cap
33 'O' ring – CMP sensor
34 CMP sensor
35 Bolt – CMP sensor
36 Spark plug (3 off)
37 Camshaft cover
38 Gasket – camshaft cover
39 Inlet valve (6 off)
40 Valve seat insert – inlet (6 off)
41 Valve guide – inlet (6 off)
42 Gasket – cylinder head
43 Exhaust valves (6 off)
44 Valve seat insert – exhaust (6 off)
45 Valve guides – exhaust (6 off)
46 Cylinder head

KV6 Engine – Manifolds and Engine Cover Components (All Except NAS)



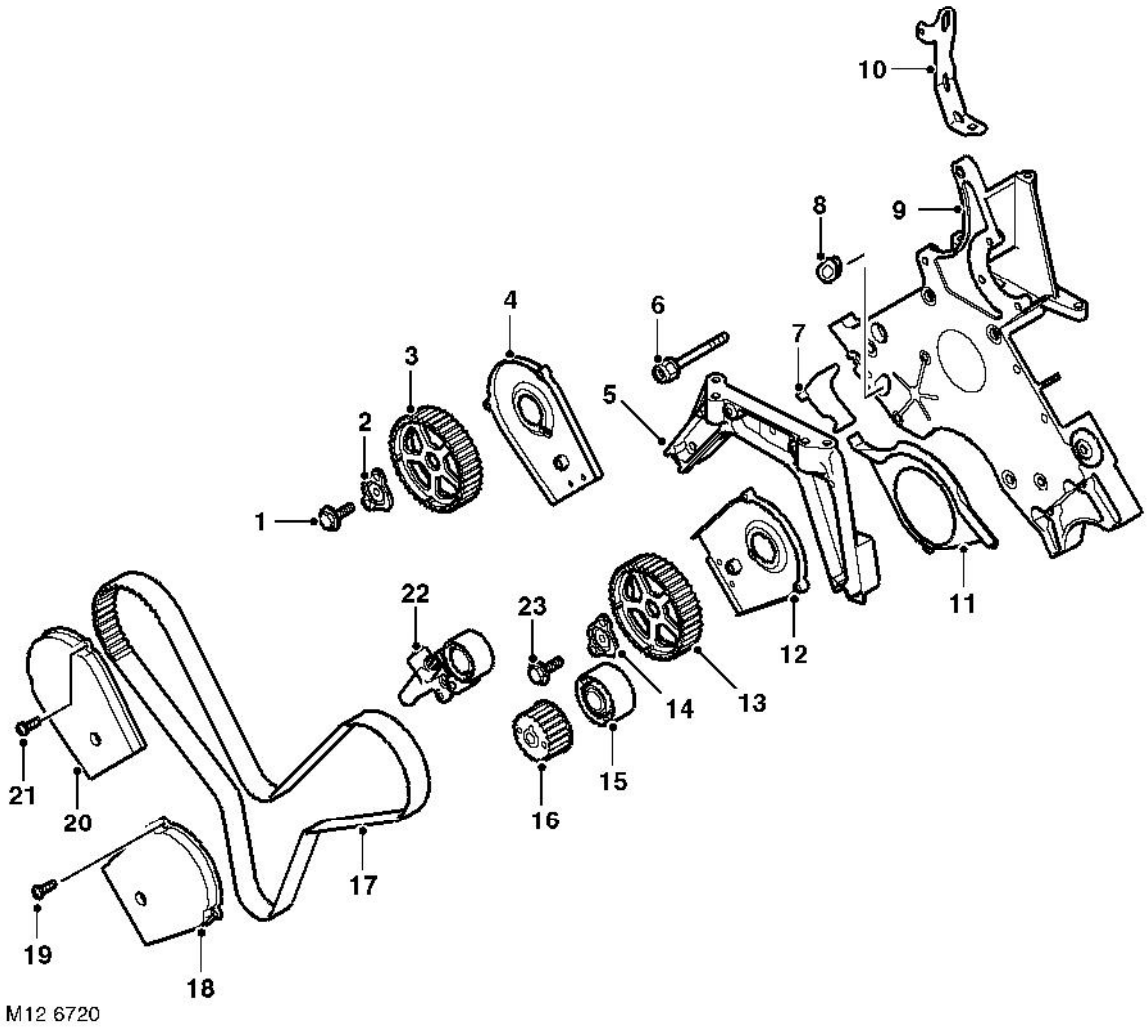
1 Strap – engine acoustic cover
2 Bolt – engine acoustic cover strap to manifold chamber
3 Engine acoustic cover
4 Bolt – manifold chamber to RH inlet manifold (4 off)
5 Manifold chamber
6 Screw – IAT/MAP sensor to manifold chamber (2 off)
7 IAT/MAP sensor
8 Seal – throttle body assembly to manifold chamber
9 Bolt – throttle body assembly to manifold chamber (4 off)
10 Throttle body assembly
11 'O' rings – inlet manifold to top cover, RH (3 off)
12 Inlet manifold, RH
13 Seal – manifold chamber to LH inlet manifold (3 off)
14 Guide block – HT lead
15 Stud – HT lead guide block/acoustic cover fixing
16 Inlet manifold, LH
17 Bolt – inlet manifold to cylinder head, LH (7 off)
18 Bolt – inlet manifold to cylinder head, RH
19 Gasket – inlet manifold to cylinder head, RH
20 Fuel rail
21 Gasket – inlet manifold to cylinder head, LH
22 Gasket – exhaust manifold to cylinder head, LH
23 Stud – exhaust manifold to cylinder head, LH (4 off)
24 Nut – exhaust manifold to cylinder head, LH (4 off)
25 Exhaust manifold, LH

KV6 Engine – Manifolds and Engine Cover Components (NAS)



1 Strap – engine acoustic cover
2 Bolt – engine acoustic cover strap to manifold chamber
3 Engine acoustic cover
4 Bolt – manifold chamber to RH inlet manifold (4 off)
5 Manifold chamber
6 Bolt – throttle body assembly to manifold chamber (4 off)
7 Throttle body assembly
8 Inlet manifold, RH
9 Seal - manifold chamber to LH inlet manifold (3 off)
10 Guide block – HT lead
11 Stud – HT lead guide block/acoustic cover fixing
12 Inlet manifold, LH
13 Bolt – inlet manifold to cylinder head LH (7 off)
14 Gasket - inlet manifold to cylinder head (LH)
15 Fuel rail
16 Bolt – inlet manifold to cylinder head
17 Gasket – inlet manifold to cylinder head, RH
18 'O' ring - inlet manifold to top cover RH (3 off)

KV6 Engine – Camshaft Drive Belt Components



1 Bolt – timing gear to inlet camshaft (RH)
2 Hub – camshaft front timing gear (RH)
3 Camshaft front timing gear (RH)
4 Drive belt (front) backplate cover – RH
5 Engine mounting bracket
6 Bolt – engine mounting bracket to front plate (4 off)
7 Cover plate – drive belt
8 Blanking plug
9 Engine front plate
10 Engine lifting bracket – front
11 Cover – lower drive belt
12 Drive belt (front) backplate cover – LH
13 Camshaft front timing gear (LH)
14 Hub – camshaft front timing gear (LH)
15 Idler pulley – drive belt
16 Crankshaft timing gear
17 Drive belt – front
18 Front drive belt outer cover (LH)
19 Screw – front drive belt outer cover to inner cover, LH (3 off)
20 Front drive belt outer cover (RH)
21 Screw – front drive belt outer cover to inner cover, RH (3 off)
22 Tensioner assembly – front drive belt
23 Bolt – timing gear to inlet camshaft (LH)

Description

General
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 engine management system utilising a range of sensors to constantly monitor and optimise engine performance.

☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**

Cylinder Block Components
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 main bearing ladder is manufactured from special alloy A357TF as used in manufacturing components in the aerospace 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 jointing compound, and secured 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, are offset to the thrust side and 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
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 (SG) iron, 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. A baffle plate is fitted in the lower crankcase extension to minimise the effects of oil slosh.

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 though 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 the oil pump housing 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 pump housing. Hoses from the engine cooling system are connected to two pipes on the oil cooler for the supply and return of coolant.

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
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 (CMP) sensor to measure engine position. The CMP sensor is bolted to the LH camshaft cover.

☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**

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 fluro-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.

Camshaft Cover and Engine Cover Components

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.

The acoustic cover is located on the engine by two rubber studs on the underside of the acoustic cover. A rubber strap, at the rear of the engine, and two quick release fasteners, at the front of the acoustic cover, secure the acoustic cover in position.

Resonators and part of the engine intake duct are integrated into the acoustic cover, and the engine air filter is installed in a compartment below a lid secured with two Torx bolts.

In NAS markets, a metal foil heatshield is installed on the underside of the acoustic cover.

A rubber duct connects the engine intake duct in the acoustic cover to the RH inner wing. In all except NAS markets, engine air is drawn from the space between the inner and outer wings. In NAS markets, a further duct is installed between the inner and outer wings to draw engine air from the base of the A post.

Throttle Body Assembly

All markets except NAS

The throttle body is attached to the inlet manifold chamber and comes in one of two variants, with and without cruise control. The housing of the throttle body incorporates ports for crankcase ventilation and the idle air control valve.

NAS markets

The throttle body is an electrically actuated unit controlled by the Engine Control Module (ECM). The position of the throttle plate is controlled by a DC motor and a return spring integrated into the throttle body. Two feedback potentiometers supply throttle plate position signals to the ECM for closed loop control.

Four Torx bolts secure the throttle body to the inlet manifold chamber. A rubber seal, keyed to a groove in the inlet manifold chamber, ensures the joint is air tight.

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, controlled by an electric 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.

☞ **MANIFOLD AND EXHAUST SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

Operation

Lubrication Circuit
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.

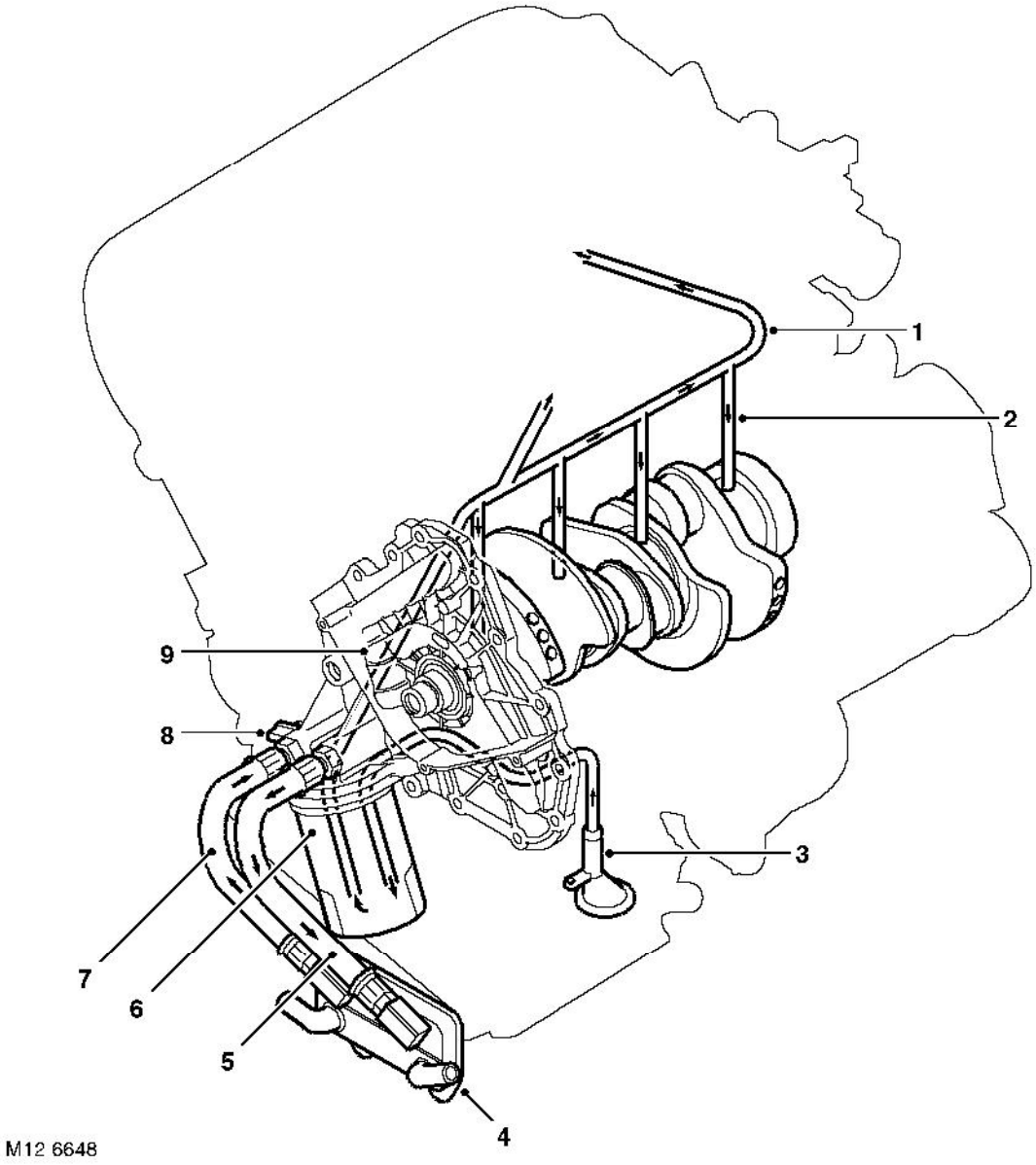
The oil pressure switch is located at the outlet side of the oil filter housing to sense the oil pressure level before the oil flow enters the main gallery in the engine block. A warning lamp in the instrument pack is illuminated if low oil pressure is detected.

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 directed via separate galleries to the camshaft bearings and hydraulic tappet housings. Return oil from the cylinder head drains into 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.

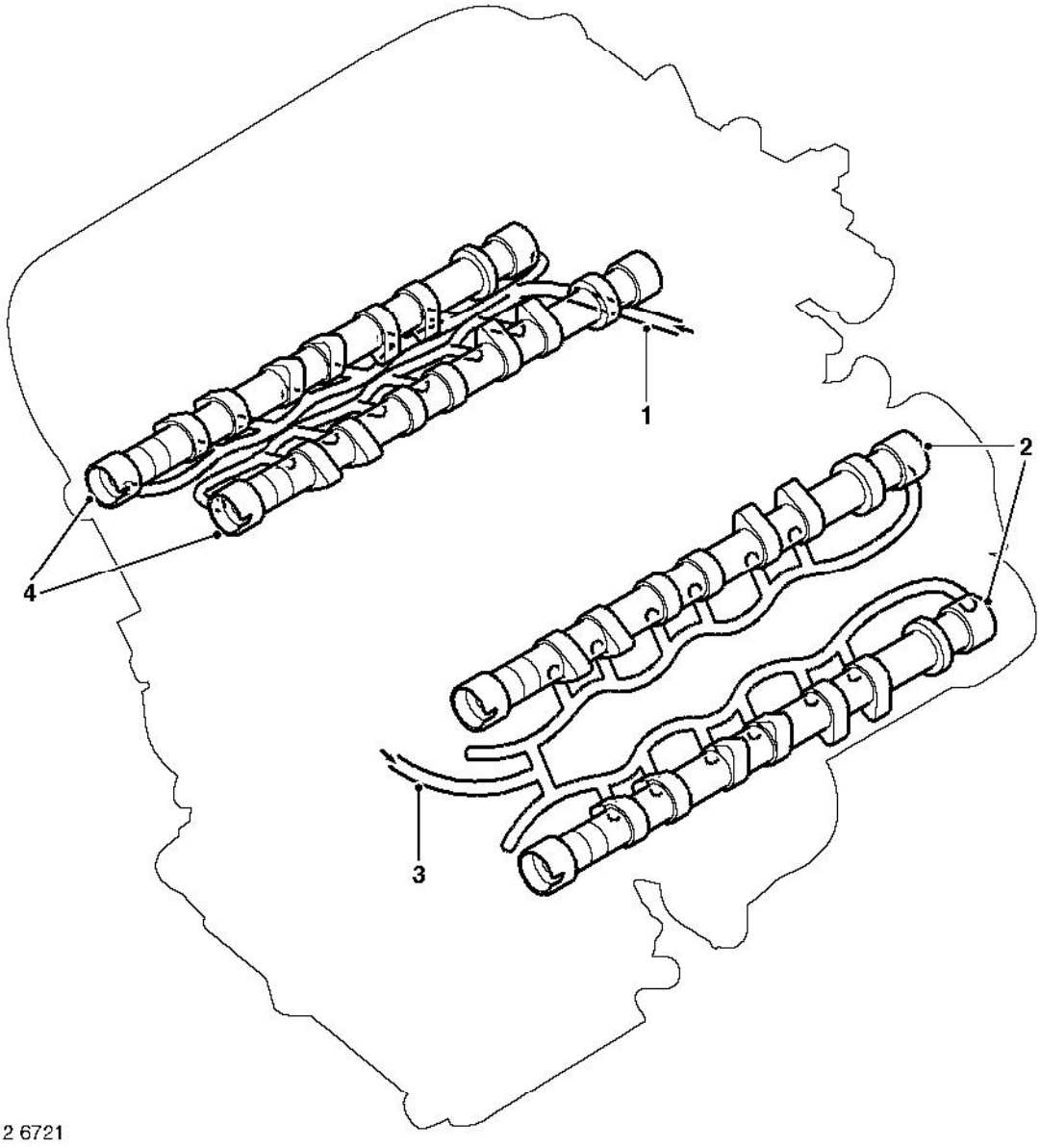
☞ **EMISSION CONTROL - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

Crankshaft Oil Supply



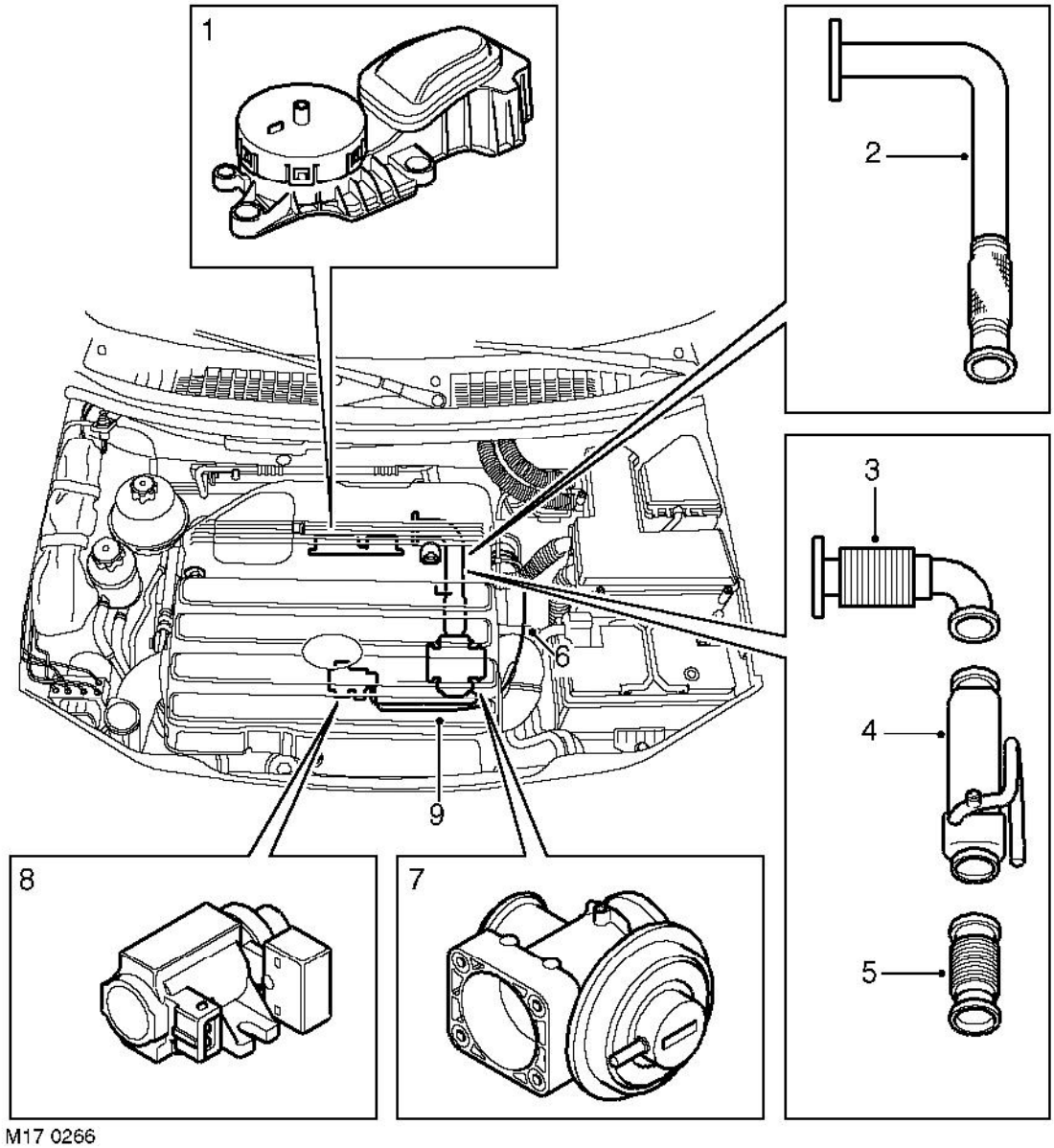
1 Cylinder block main oil gallery
2 Cross drillings to crankshaft main bearings
3 Oil pick-up pipe with integral strainer
4 Oil cooler
5 Oil cooler supply pipe
6 Oil filter cartridge
7 Oil cooler return pipe
8 Oil pressure switch
9 Oil pump with integral oil pressure relief valve

Cylinder Head Component Oil Supply



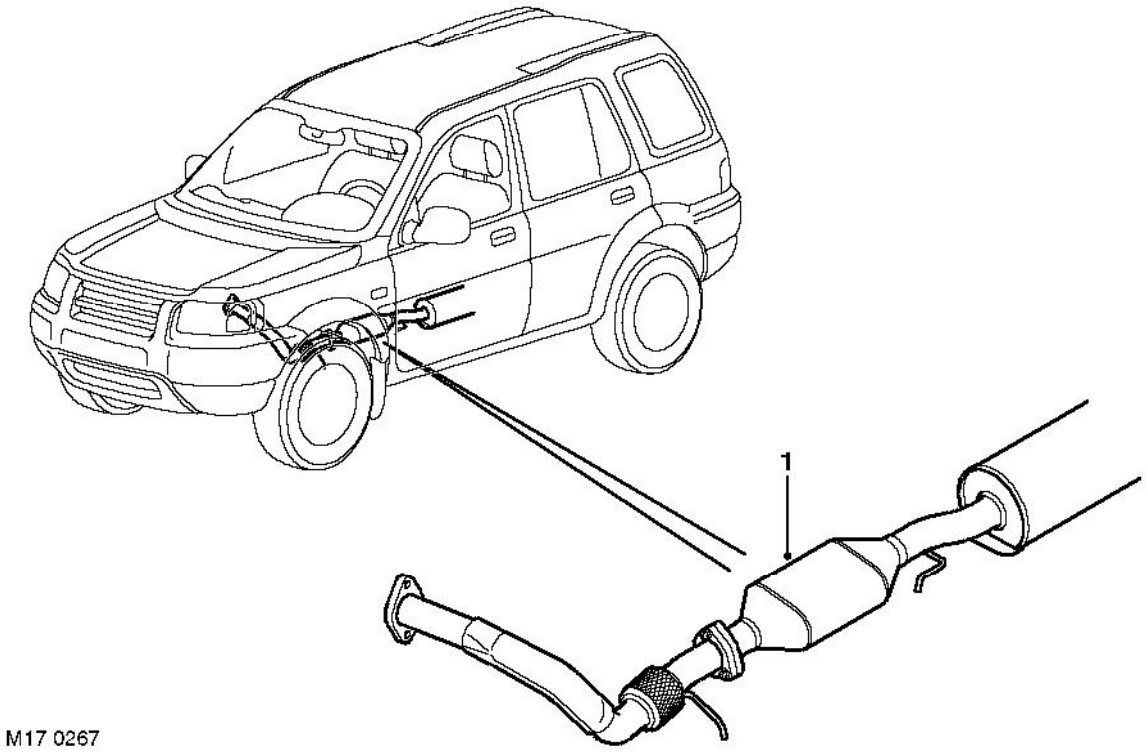
1 From RH cylinder block main gallery
2 LH cylinder head camshafts
3 From LH cylinder block main gallery
4 RH cylinder head camshafts

Emission Control Component Layout – Crankcase and EGR



1 Depression limiter valve
2 EGR pipe (manual gearbox models)
3 EGR rear pipe (automatic gearbox models)
4 EGR cooler (automatic gearbox models)
5 EGR front pipe (automatic gearbox models)
6 Vacuum pipe from brake servo vacuum to EGR solenoid
7 EGR valve
8 EGR solenoid
9 Vacuum pipe from EGR solenoid to EGR valve

Emission Control Component Layout – Exhaust



1 Catalytic converter

Description

General

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

- Crankcase emission control.
- Exhaust gas recirculation.
- Exhaust emission control.

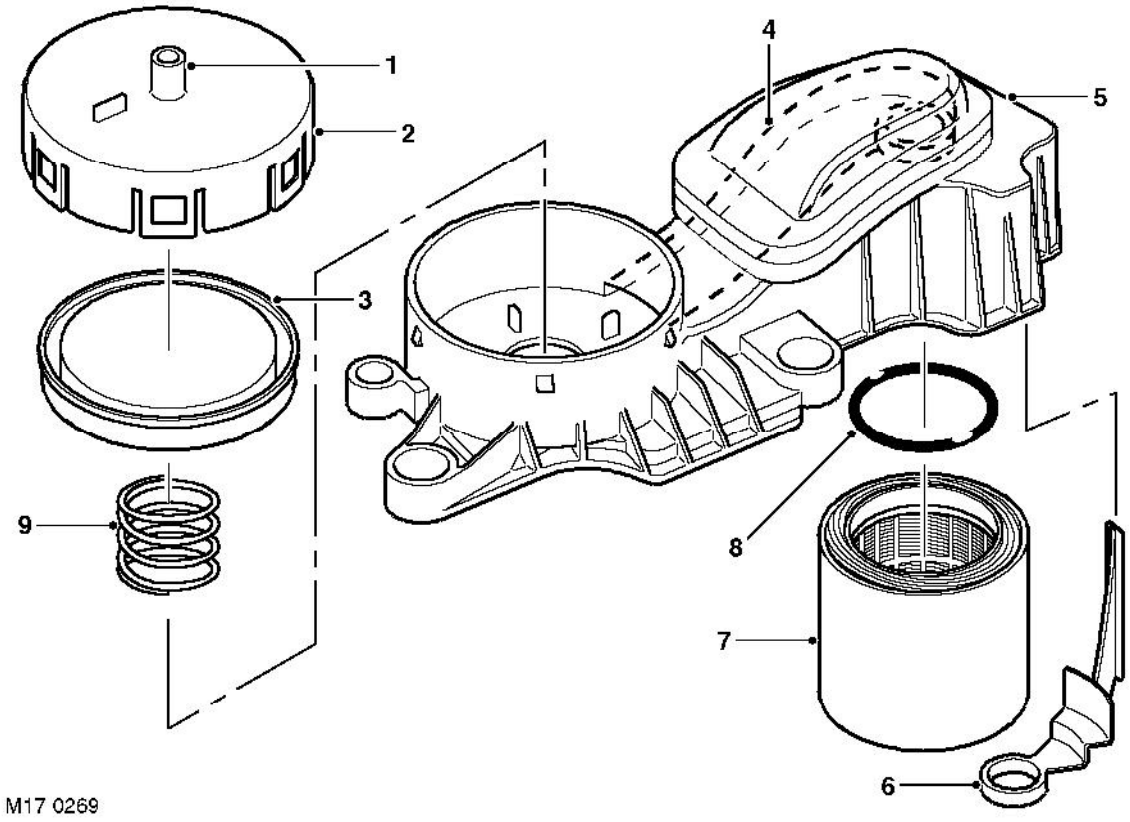
CAUTION: In many countries it is against the law for a vehicle owner or an unauthorised dealer to modify or tamper with emission control equipment. In some cases, the vehicle owner and/or the dealer may even be liable for prosecution.

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.

Depression Limiter Valve



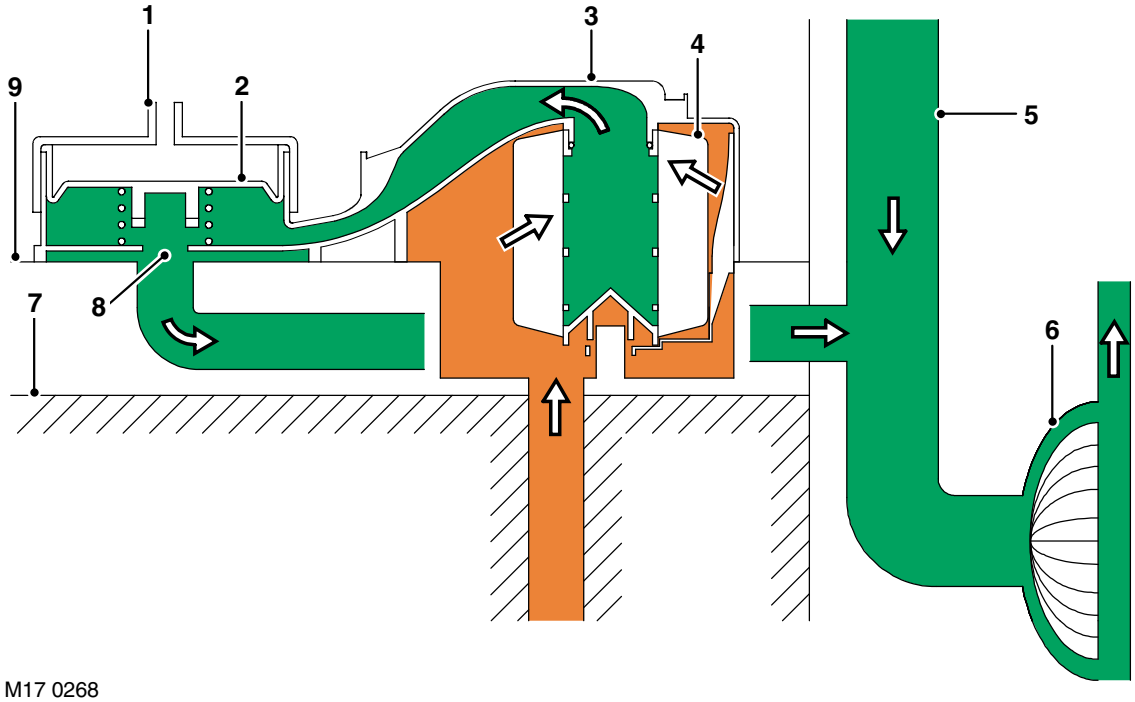
1 Ambient pressure vent
2 Cap
3 Diaphragm valve
4 Integral passageway
5 Housing
6 Locating arm
7 Oil separator
8 'O' ring
9 Spring

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. A vent in the cap allows ambient pressure into the upper part of the chamber, above the diaphragm valve.

Crankcase Emissions Schematic



M17 0268

1 Ambient pressure vent
2 Diaphragm valve
3 Depression limiter valve
4 Oil separator
5 Turbocharger inlet duct
6 Turbocharger
7 Cylinder head
8 Outlet port
9 Camshaft cover

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 Nitrous Oxide (NOx) emissions.



A vacuum operated EGR valve on the inlet manifold controls the flow of recirculated exhaust gases. The exhaust gases are supplied to the EGR valve through an EGR pipe connected to the LH end of the exhaust manifold. On automatic gearbox models, a cooler, cooled by the engine cooling system, is installed between front and rear sections of the EGR pipe. From the EGR valve, the gases flow into the inlet manifold and the turbocharger inlet.

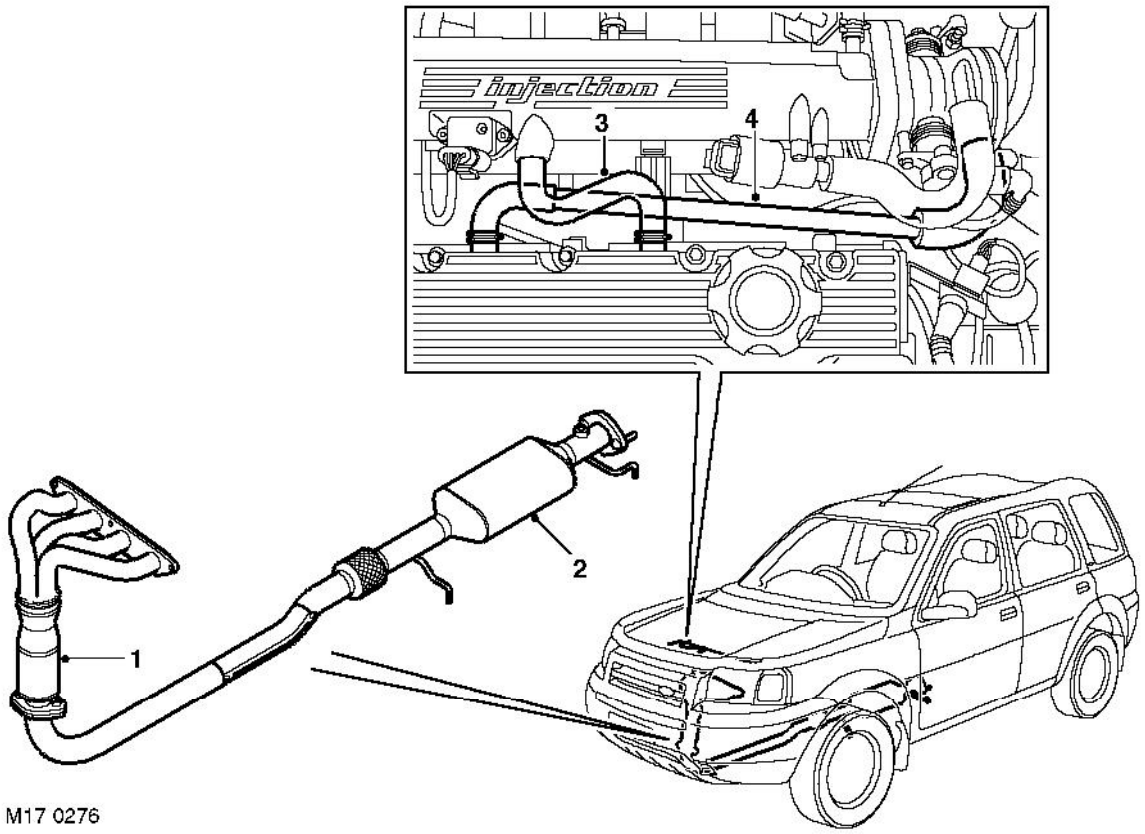
The EGR valve is controlled by an EGR solenoid, on the front of the cylinder block, which modulates a vacuum supply from the brake servo vacuum pump. The EGR solenoid is controlled by the ECM. The ECM uses the input from the air flow meter to monitor EGR operation, using the principle that an increase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

Exhaust 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.

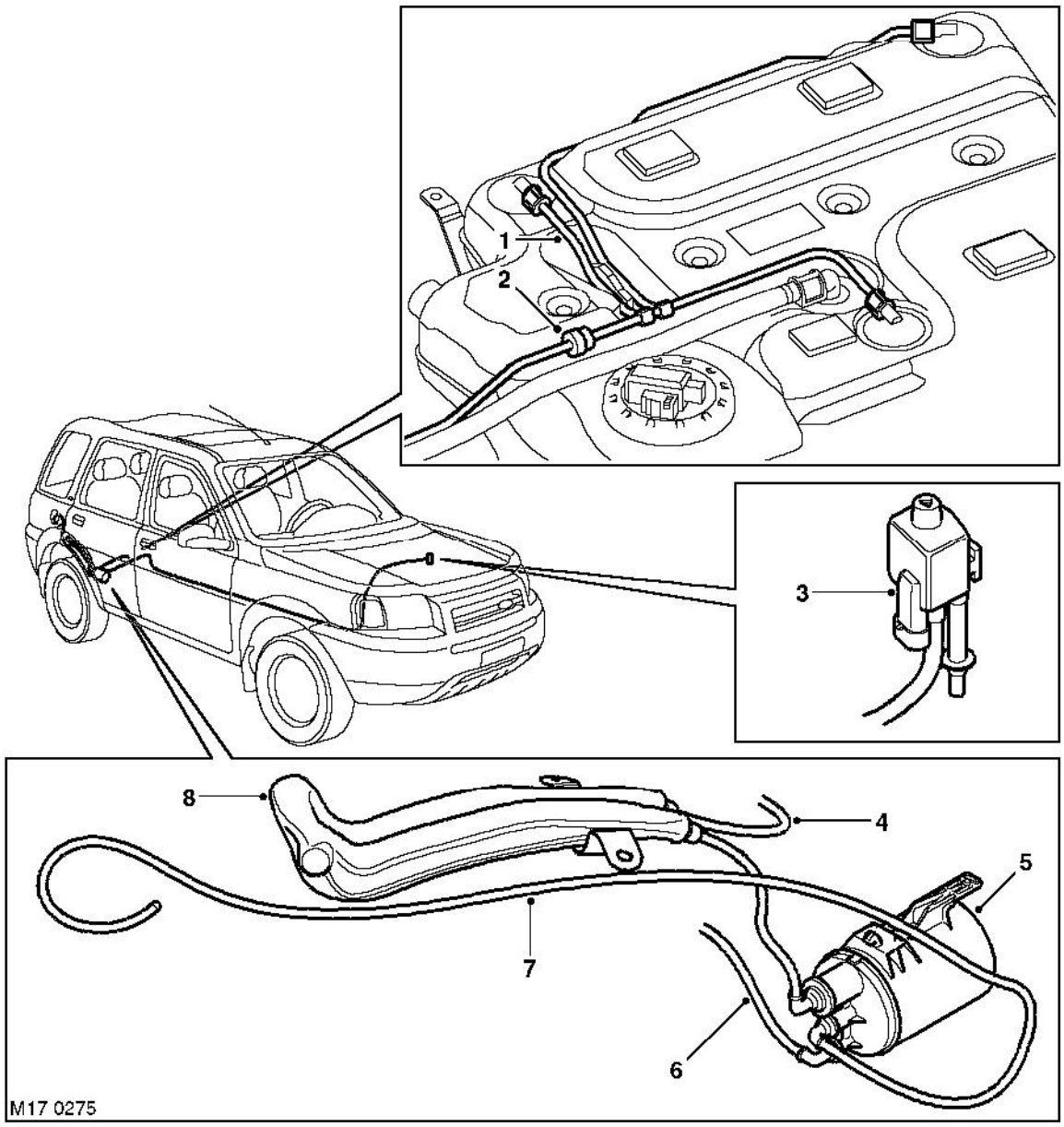
In the catalytic converter the exhaust gases are passed through honeycombed ceramic elements coated with a special surface treatment called 'washcoat'. The washcoat increases the surface area of the ceramic elements by a factor of approximately 7000. On top of the washcoat is a coating containing platinum, 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.

Emission Control Component Layout – Crankcase and Exhaust



1 Starter (Upstream) catalytic converter
2 Main (Downstream) catalytic converter
3 Crankcase breather hose to inlet manifold
4 Crankcase breather hose to throttle body

Emission Control Component Layout – EVAP



1 Fuel tank vent lines
2 Two-way valve
3 EVAP purge valve
4 Vent line from fuel tank
5 EVAP canister
6 Vent line to purge valve
7 Vent line to atmosphere
8 Vapour separator

Description

General

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.

CAUTION: In many countries it is against the law for a vehicle owner or an unauthorised dealer to modify or tamper with emission control equipment. In some cases, the vehicle owner and/or the dealer may even be liable for prosecution.

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

While the engine is running, blow-by gases from the crankcase are mixed with inlet air and burned in the combustion chambers.

The crankcase is vented via the oil drain passages in the cylinder block and cylinder head and two ports in the camshaft cover. The larger port in the camshaft cover is connected to the throttle body, on the upstream side of the throttle disc, by a plastic pipe and rubber elbow connections. The smaller port in the camshaft cover is connected to the inlet manifold by a rubber hose. The smaller port incorporates a restrictor and a gauze oil separator to prevent oil being drawn out of the camshaft cover.

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 port in the camshaft cover. Clean air, from the upstream side of the throttle disc, is drawn into the crankcase through the larger port in the camshaft cover 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 the camshaft cover, are subjected to similar, relatively weak, depression levels. Crankcase gases are then drawn out of both ports in the camshaft cover, with the majority being drawn out of the unrestricted larger port 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.

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. In European Union markets, to reduce the carbon monoxide and hydrocarbons content of the exhaust gases, two catalytic converters are installed in the exhaust system. A 'starter' catalytic converter is integrated into the exhaust manifold and a main catalytic converter is integrated into the exhaust system front pipe.

In the catalytic converters 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. The active constituents consist of palladium and platinum, which add oxygen to the carbon monoxide and the hydrocarbons in the exhaust gases, to convert them into carbon dioxide and water respectively.

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 a Heated Oxygen Sensor (HO2S) upstream of the starter catalytic converter. The ECM also monitors the condition of the catalytic converters using an input from a HO2S downstream of the main catalytic converter.

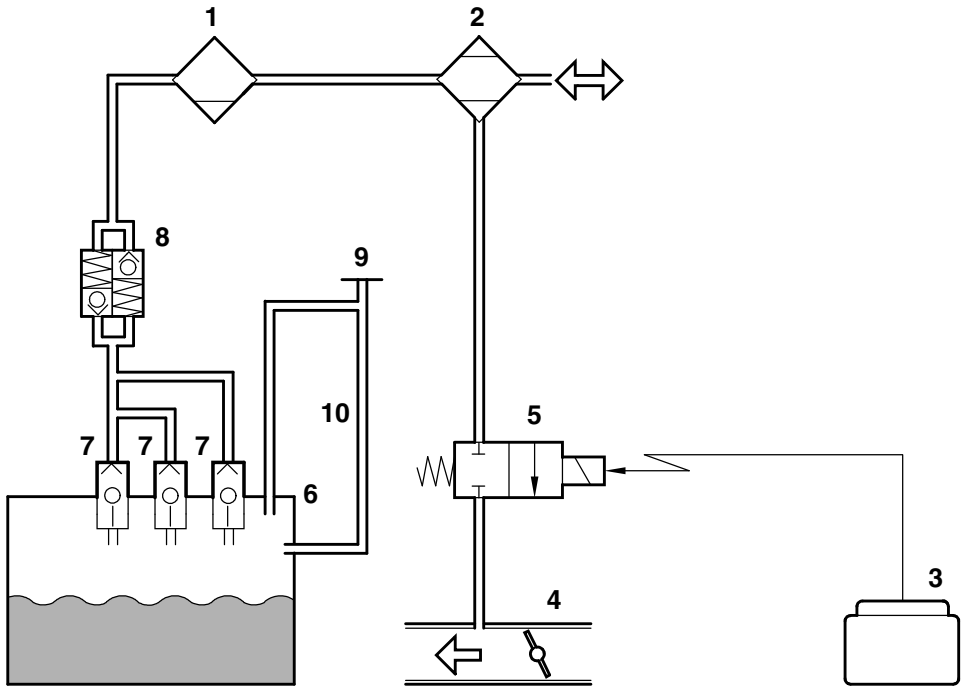
EVAP Control

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, a vapour separator, an EVAP canister, a purge valve and interconnecting vent pipes. The vent pipes are connected to the system components and the fuel tank by quick release connectors. On the fuel tank, the vent lines are connected to three roll over valves. The roll over valves are float valves that prevent fuel from entering the vent pipes due to fuel slosh or if the vehicle overturns.

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 pressure is released through the vapour separator and the EVAP canister to atmosphere. The vapour separator and the EVAP canister remove fuel from the vapour and relatively fuel free air vents to atmosphere. When the fuel tank cools and vapour pressure decreases below ambient pressure, the two-way valve opens and outside air is drawn through the EVAP canister and vapour separator into the tank.

Some of the fuel removed from the vapour vented from the fuel tank is stored in the EVAP canister. Since there is a limit to the volume of fuel that can be stored in the EVAP canister, when the engine is running fuel is purged from the EVAP canister, through the purge valve, and burned in the engine.

EVAP System Schematic



M17 0311

1 Vapour separator
2 EVAP canister
3 ECM
4 Throttle
5 Purge valve
6 Fuel tank
7 Roll over valve
8 Two-way valve
9 Fuel filler cap
10 Filler tube

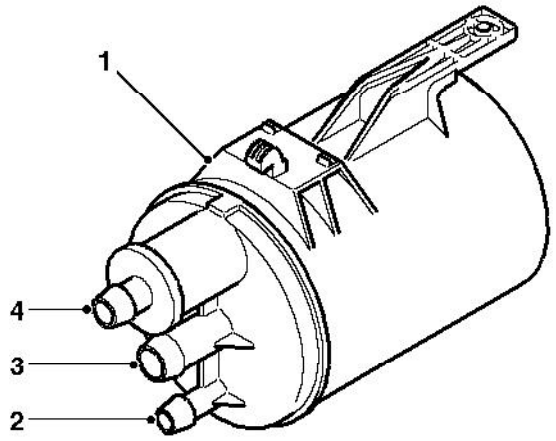
Two-way Valve

The two-way valve is installed in the vent pipe from the tank, next to the fuel tank pump unit. The two-way valve opens, to release pressure from the fuel tank, at 0.018 to 0.050 bar (0.26 to 0.73 lbf/in^2). Air 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.

Vapour Separator

The vapour separator is installed at the front of the RH rear wheel arch, behind the wheel arch liner. The vapour separator prevents the charcoal in the EVAP canister being saturated with fuel, by condensing out some of the fuel in the vapour vented from the fuel tank. Condensed fuel from the vapour separator drains back to the fuel tank through the vent pipe.

EVAP Canister



M17 0273

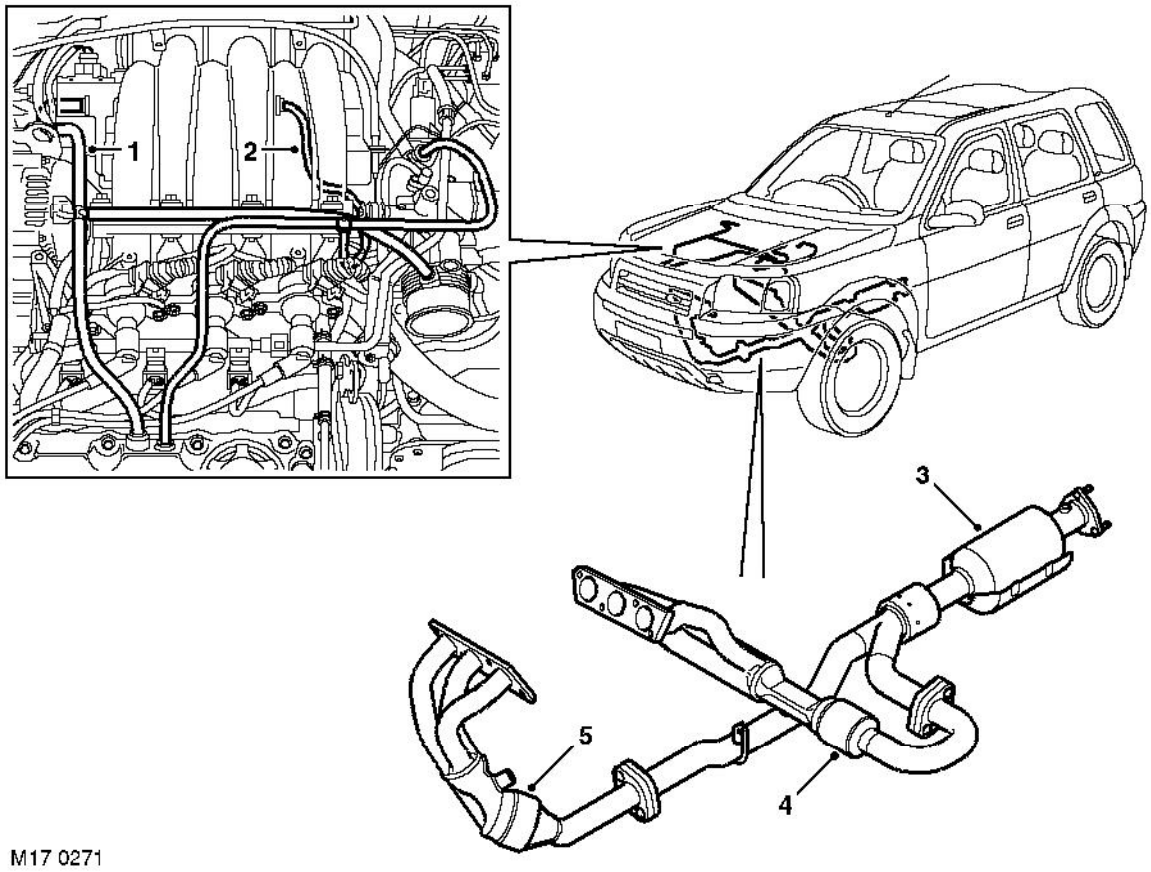
1 Canister housing
2 Vapour separator connection
3 Atmospheric vent connection
4 Purge valve connection

The EVAP canister is installed at the front of the RH rear wheel arch, behind the wheel arch liner. Charcoal in the EVAP canister absorbs and stores fuel from the vapour vented from the fuel tank. When the engine is running, fuel is purged from the EVAP canister by outside air being drawn through the charcoal and the outlet to the purge valve.

Purge Valve

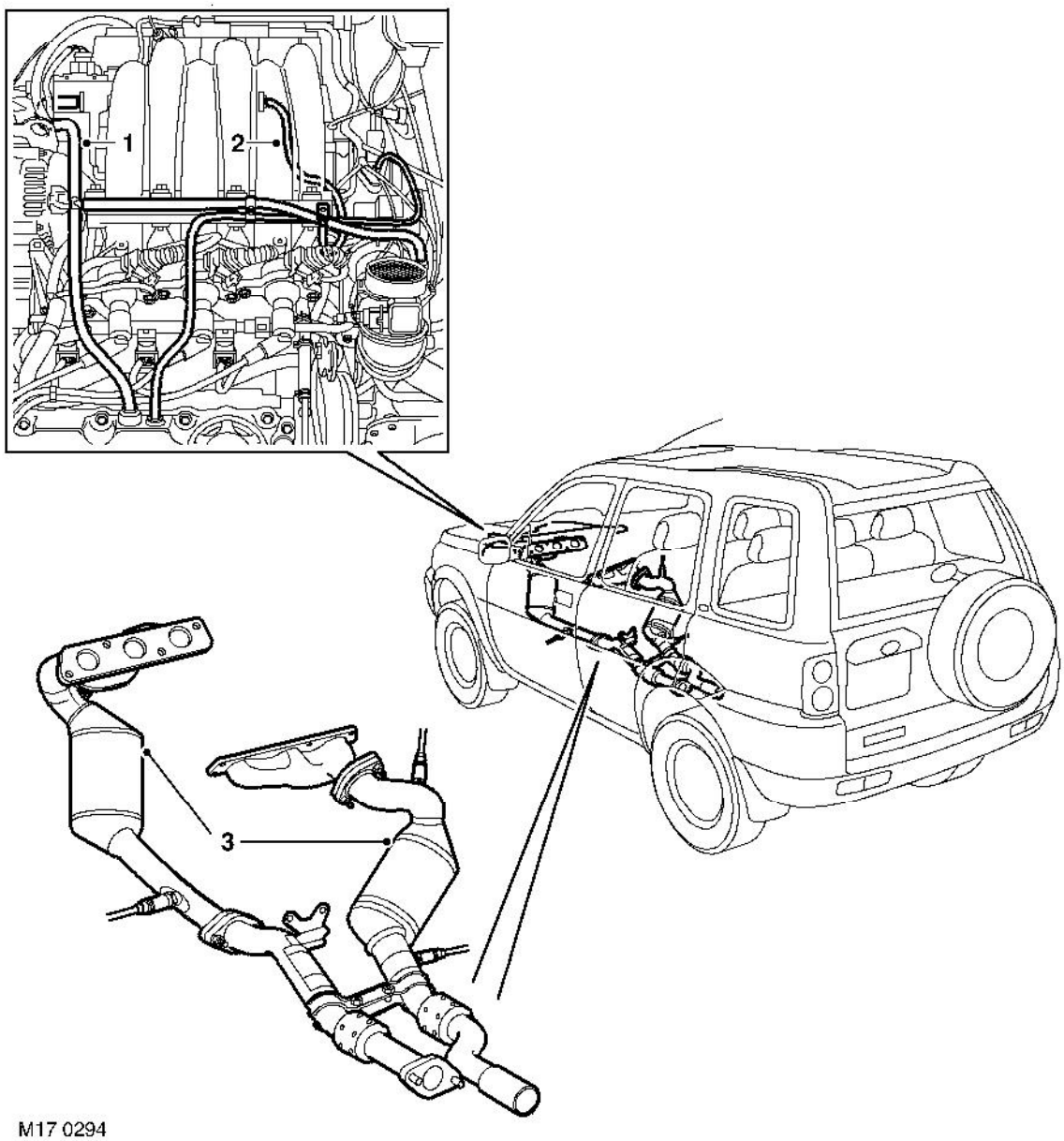
The purge valve is installed on the LH suspension turret in the engine compartment, and connected to the EVAP canister by a vent pipe installed on the underside of the vehicle, next to the fuel delivery pipe. A second vent pipe connects the purge valve to the inlet manifold. The purge valve is controlled by the Engine Control Module (ECM) and remains closed below a preset coolant temperature and engine speed, 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 engine operating conditions are suitable, the ECM opens the purge valve and the depression in the inlet manifold draws fuel vapour from the EVAP canister.

Emission Control Component Layout – Crankcase and Exhaust (All Except NAS)



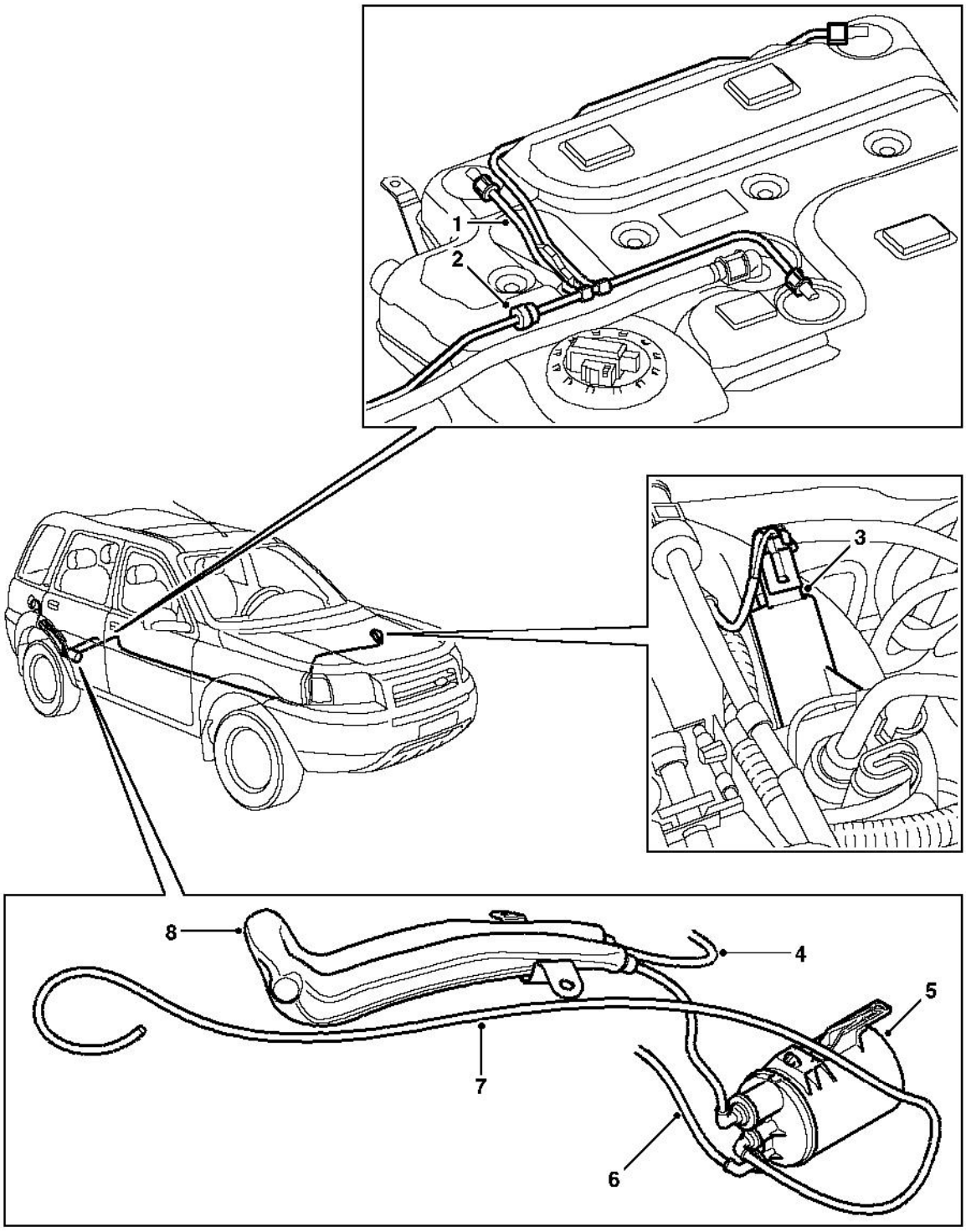
1 Crankcase breather hose to throttle body
2 Crankcase breather hose to inlet manifold chamber
3 Main (downstream) catalytic converter
4 RH starter (upstream) catalytic converter
5 LH starter (upstream) catalytic converter

Emission Control Component Layout – Crankcase and Exhaust (NAS)



1 Crankcase breather hose to intake duct
2 Crankcase breather hose to inlet manifold
3 Catalytic converters

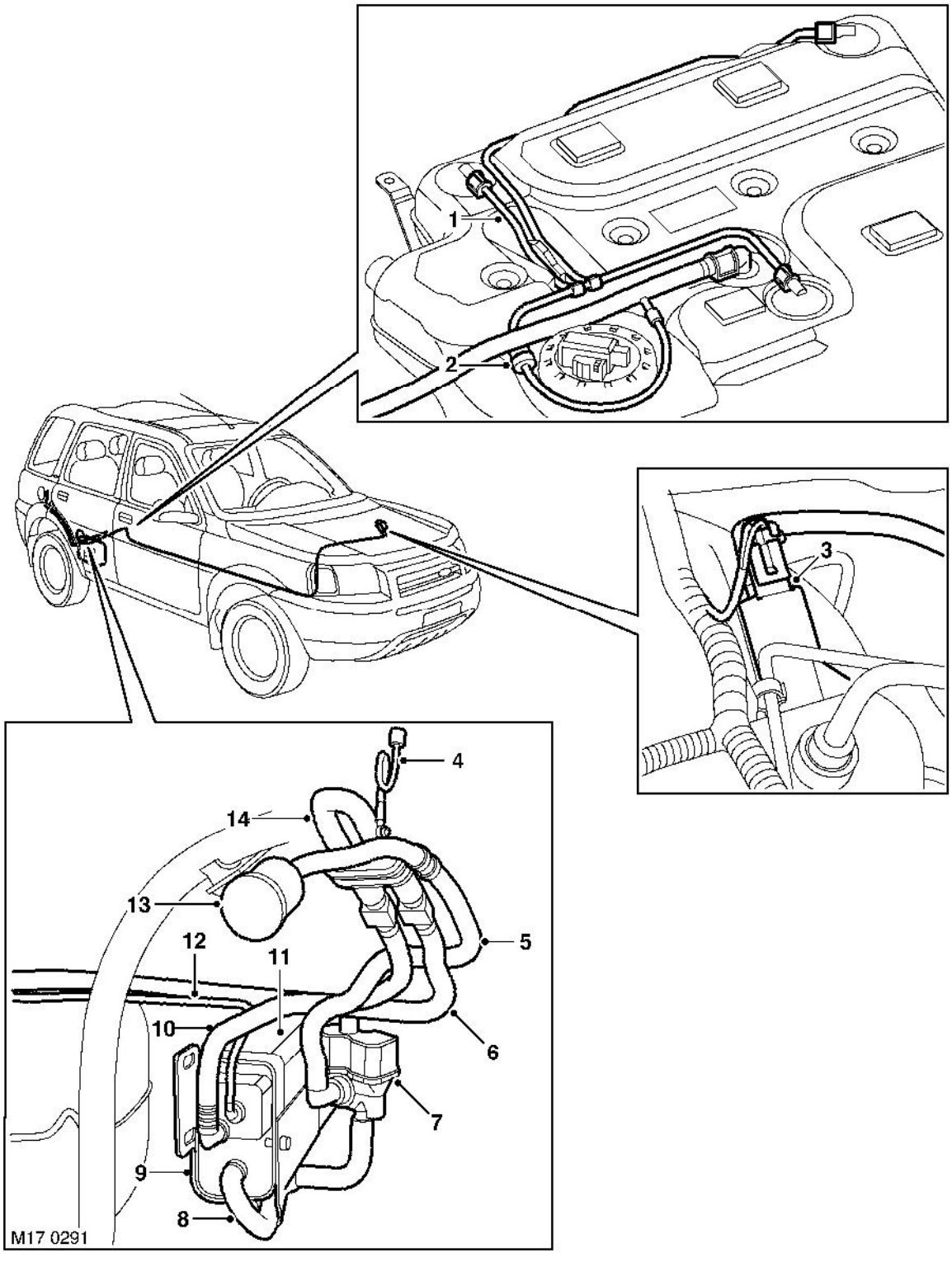
Emission Control Component Layout – EVAP (All Except NAS)



M17 0270

1 Fuel tank vent lines
2 Two-way valve
3 Purge valve
4 Vent line from fuel tank
5 EVAP canister
6 Vent line to purge valve
7 Vent line to atmosphere
8 Vapour separator

Emission Control Component Layout – EVAP (NAS)



1 Fuel tank vent pipes
2 Two-way valve
3 Purge valve
4 Recirculation pipe
5 DMTL to air filter vent pipe
6 Fuel tank to vapour separator vent pipe
7 DMTL
8 Canister to DMTL vent pipe
9 Canister support bracket
10 Vapour separator to canister vent pipe
11 EVAP canister
12 Canister to purge valve vent pipe
13 Air filter
14 Vapour separator

Description

General

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

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

CAUTION: In many countries it is against the law for a vehicle owner or an unauthorised dealer to modify or tamper with emission control equipment. In some cases, the vehicle owner and/or the dealer may even be liable for prosecution.

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 and the fuel system components are correctly maintained and in good mechanical condition.

Crankcase Emission Control System

The crankcase is vented via the oil drain passages in the cylinder blocks and cylinder heads and two ports in each camshaft cover. Plastic pipes connect the larger ports in the camshaft covers to either the throttle body (all except NAS) or the intake duct (NAS), on the upstream side of the throttle disc. The smaller ports in the camshaft covers are connected to the inlet manifold, 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.

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. In some markets, to reduce the carbon monoxide and hydrocarbons content of the exhaust gases, catalytic converters are installed in the exhaust system. Where catalytic converters are fitted:

- In all except NAS markets, a 'starter' catalytic converter is integrated into each exhaust manifold and a main catalytic converter is integrated into the exhaust system front pipe.
- In NAS markets, a catalytic converter is integrated into each downpipe close to the exhaust manifolds.

In the catalytic converters 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. The active constituents consist of platinum and rhodium. Platinum adds 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 Nitrous Oxides (NOx) to convert them into nitrogen.



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.

EVAP Control

The EVAP control system reduces the level of hydrocarbons released into the atmosphere by fuel vapour venting from the fuel tank. On NAS models, a positive pressure leak detection function is incorporated to monitor the integrity of the system. The EVAP control system comprises:

- A two way valve.
- A vapour separator.
- An EVAP canister.
- A purge valve.
- A Diagnostic Module for Tank Leakage (DMTL) (NAS only).
- An air filter (NAS only).
- Interconnecting vent pipes.

The EVAP control system is connected to the Onboard Refuelling Vapour Recovery (ORVR) valve (NAS only) and/or the roll over valves in the fuel tank. The ORVR valve and the roll over valves are float valves that allow inward and outward venting of the fuel tank, but prevent the escape of fuel into the vent pipes due to fuel slosh or if the vehicle overturns. The ORVR valve is normally closed when the fuel tank is full and normally open at all other fuel levels. The roll over valves are normally open at all fuel levels.

On all except NAS vehicles, venting occurs through the roll over valves and the two-way valve with changes of tank pressure.

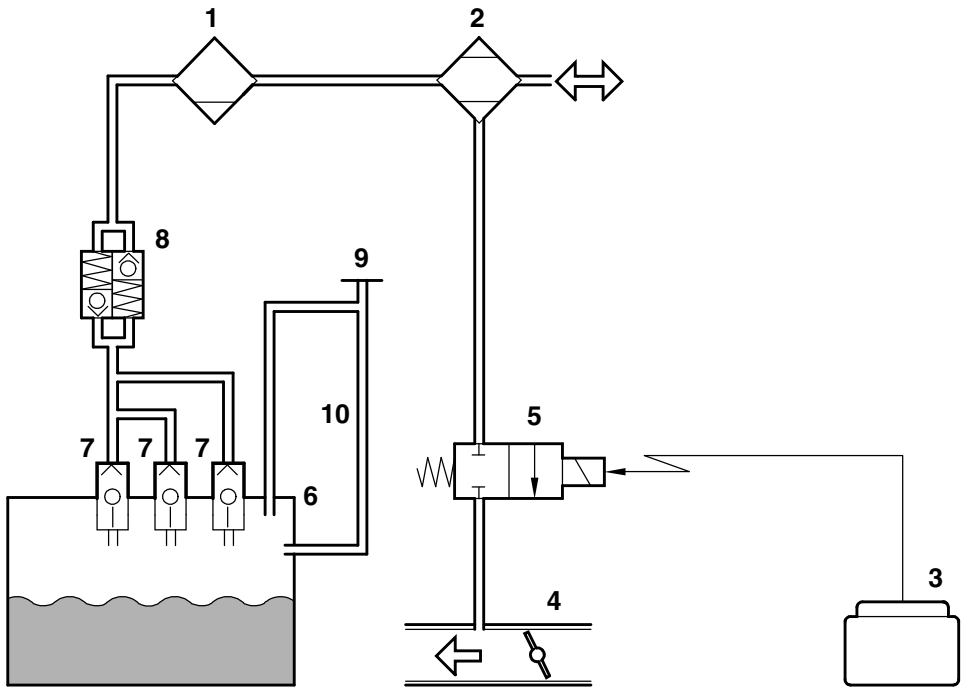
On NAS vehicles, when the fuel tank is less than full, venting is unrestricted through the ORVR valve. Only when the fuel tank is full does venting occur, with changes of tank pressure, through the roll over valves and the two-way valve.

Vapour vented from the fuel tank passes through the EVAP control system to atmosphere. The EVAP canister absorbs fuel from the vapour and relatively fuel free air vents to atmosphere. Since there is a limit to the storage capacity of the EVAP canister, when the engine is running fuel is purged from the EVAP canister and burned in the engine.

On NAS vehicles, to reduce the load on the EVAP canister during refuelling, a proportion of the air expelled from the tank is recirculated through a pipe connected between the top of the vapour separator and the filler tube. The recirculation flow is induced by fuel in the filler tube flowing past a restrictor installed in the recirculation pipe connection on the filler tube. With the recirculation flow present, less fresh air enters the tank, which reduces the volume of vapour generated and fuel deposited in the EVAP canister.

On NAS vehicles, the DMTL periodically checks the EVAP control system and fuel tank for leaks when the ignition is switched off.

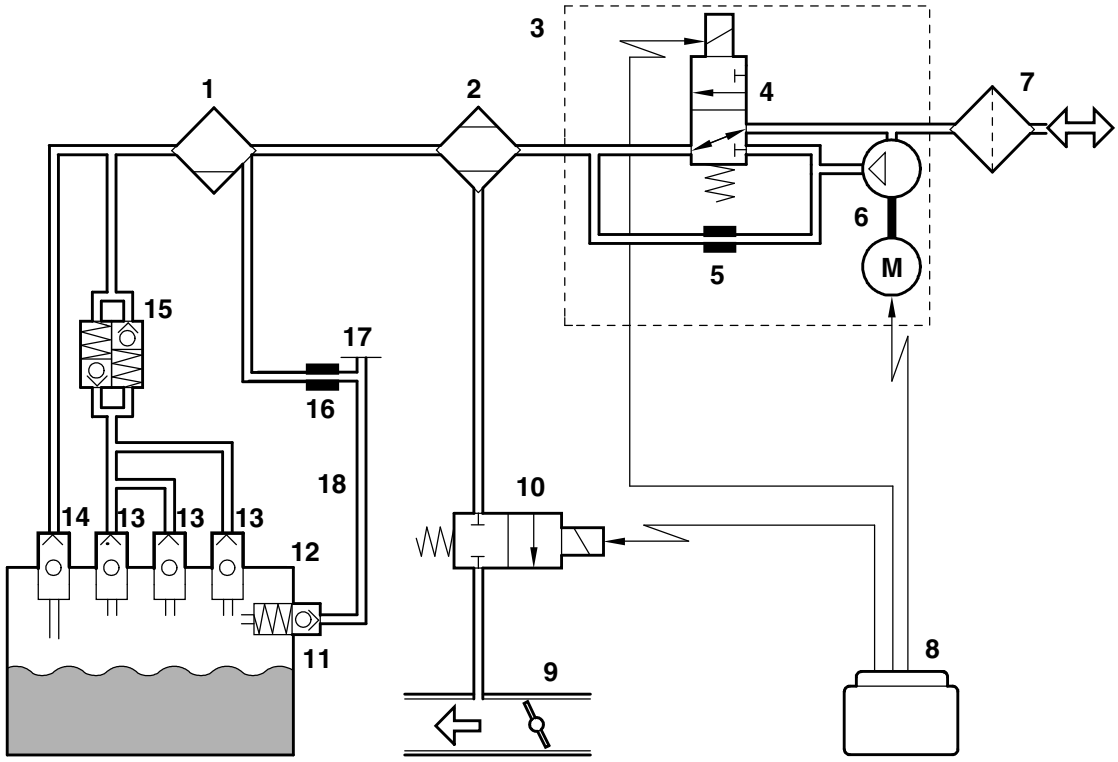
EVAP System Schematic (All Except NAS)



M17 0311

1 Vapour separator
2 EVAP canister
3 ECM
4 Throttle
5 Purge valve
6 Fuel tank
7 Roll over valve
8 Two-way valve
9 Fuel filler cap
10 Filler tube

EVAP System Schematic (NAS)



M17 0292

1 Vapour separator
2 EVAP canister
3 DMTL
4 Change-over valve
5 0.5 mm (0.020 in) reference orifice
6 Air pump and motor
7 Air filter
8 ECM
9 Throttle body
10 Purge valve
11 Flap valve
12 Fuel tank
13 Roll over valve
14 ORVR valve
15 Two-way valve
16 Restrictor
17 Fuel filler cap
18 Filler tube

Two-way Valve

The two-way valve limits the pressure and depression in the fuel tank and, during refuelling, induces automatic cut-off in the refuelling nozzle when the fuel in the tank reaches the full level. The two-way valve is installed in the vent pipe from the tank, next to the fuel pump assembly.

The two-way valve is a normally closed valve that opens, to release pressure from the fuel tank, at 18 to 50 mbar (0.26 and 0.73 lbf/in^2). Air 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. The nominal opening pressure of the non return valve is 1 mbar (0.015 lbf/in^2).

During refuelling, if the fuel in the tank reaches the full level outward venting becomes restricted, which creates a back pressure in the filler tube and automatically closes the refuelling nozzle. On all except NAS vehicles, the restriction is caused by the fuel covering the outlet to the vent pipe connected to the top of the filler tube. On NAS vehicles, the restriction is caused by the fuel closing the ORVR valve.

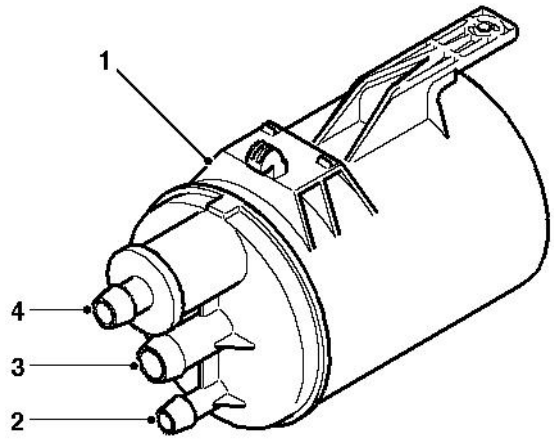
Vapour Separator

The vapour separator is installed at the front of the RH rear wheel arch, behind the wheel arch liner. The vapour separator prevents the charcoal in the EVAP canister being saturated with fuel, by separating any liquid from the vapour vented from the fuel tank. Separated fuel from the vapour separator drains back to the fuel tank through the vent pipe.

EVAP Canister

The EVAP canister is installed at the front of the RH rear wheel arch, behind the wheel arch liner. Charcoal in the EVAP canister absorbs and stores fuel from the vapour vented from the fuel tank. When the engine is running, fuel is purged from the EVAP canister when the purge valve opens and clean air is drawn through the charcoal.

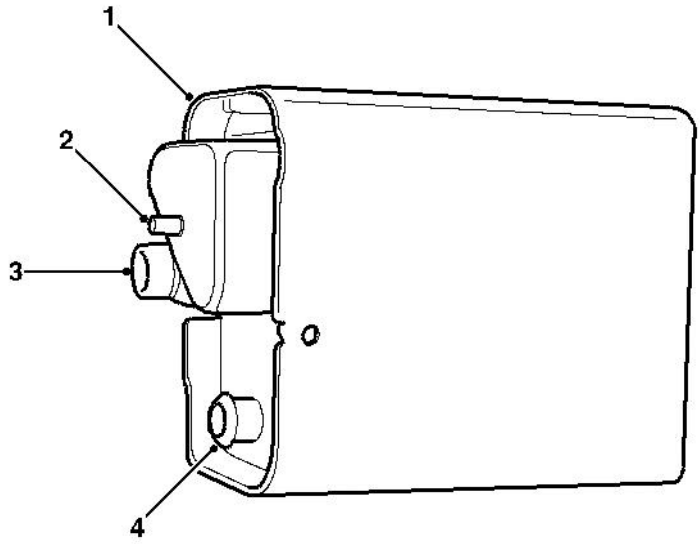
EVAP Canister (All Except NAS)



M17 0273

1 Canister housing
2 Vapour separator connection
3 Atmospheric vent connection
4 Purge valve connection

EVAP Canister (NAS)



M17 0312

1 Canister housing
2 Purge valve connection
3 Vapour separator connection
4 DMTL connection

Purge Valve

The purge valve is installed on the inlet manifold chamber, next to the throttle body, and connected to the EVAP canister by a vent pipe installed on the underside of the vehicle, next to the fuel delivery pipe.

The purge valve is controlled by the Engine Control Module (ECM) and remains closed below a preset coolant temperature and engine speed, to protect engine tune and catalytic converter performance. When engine operating conditions are suitable, the ECM opens the purge valve and the depression in the inlet manifold draws fuel vapour from the EVAP canister.



DMTL (NAS Only)

The DMTL is connected to the atmospheric vent of the charcoal canister and incorporates an electric air pump, a normally open change-over valve and a 0.5 mm (0.020 in) reference orifice. The DMTL operates only after the ignition is switched off and is controlled by the ECM, which also monitors the air pump and the change-over valve for faults.

Air Filter (NAS Only)

The air filter prevents dust being drawn into the EVAP system. A breather tube connects the DMTL to the air filter, which is located above the RH rear wheelarch liner, immediately below the fuel filler cap.

Leak Diagnostic Operation (NAS Only)

To check the fuel tank and EVAP system for leaks, the ECM operates the air pump in the DMTL and monitors the current draw. Initially, the ECM establishes a reference current by pumping air through the reference orifice and back to atmosphere. Having established a reference current, the ECM then closes the change-over valve, which seals the EVAP system (the purge valve already being closed), and diverts the output from the air pump around the reference orifice and into the EVAP system.

When the change-over valve is first closed, the load on the pump drops to zero, then, provided there are no leaks, the pump begins to pressurise the EVAP system and the load and current draw of the pump begin to increase. By monitoring the rate and level of current increase, the ECM can determine if there is a leak in the system.

During the leak check, the ECM energises a heating element in the air pump to prevent condensation forming and producing an incorrect current reading.

Leaks are classified as minor (equivalent to hole diameter of 0.5 to 1.0 mm (0.02 to 0.04 in) or major (equivalent to hole diameter of 1.0 mm (0.04 in) or greater).

The ECM conducts a check for major leaks each time the ignition is switched off, provided the following baseline conditions are met:

- The ECM is in power down mode more than 3 seconds after the ignition is switched off.
- The vehicle speed is zero.
- The engine speed is zero.
- The pressure altitude (derived from engine load calculations) is below 1830 m (6000 ft).
- The engine coolant temperature is more than 2.25 °C (36 °F).
- The ambient temperature is between 0 and 40 °C (32 and 104 °F).
- The EVAP canister load factor is 3 or less (the load factor is a measure, between –1 and +30, of the amount of fuel vapour stored in the EVAP canister, where –1 is 0% fuel vapour, 0 is stoichiometric fuel vapour level and +30 is 100% saturated with fuel vapour).
- The fuel tank level is valid and between 15 and 85 % of the nominal capacity.
- The engine running time during the previous ignition on cycle was more than 20 minutes.
- Battery voltage is between 10.94 and 14.52 volts.
- The last engine off time was more than 150 minutes.
- No errors with the following functions or components:
  - Road speed.
  - EVAP system load monitoring.
  - Engine coolant temperature.
  - Ambient air temperature.
  - Fuel level.
  - Purge valve.
  - DMTL.

A check for minor leaks is only conducted after every 14th major leak check or after refuelling is detected.

At the end of the leak check the ECM stops the air pump and opens the change-over valve.

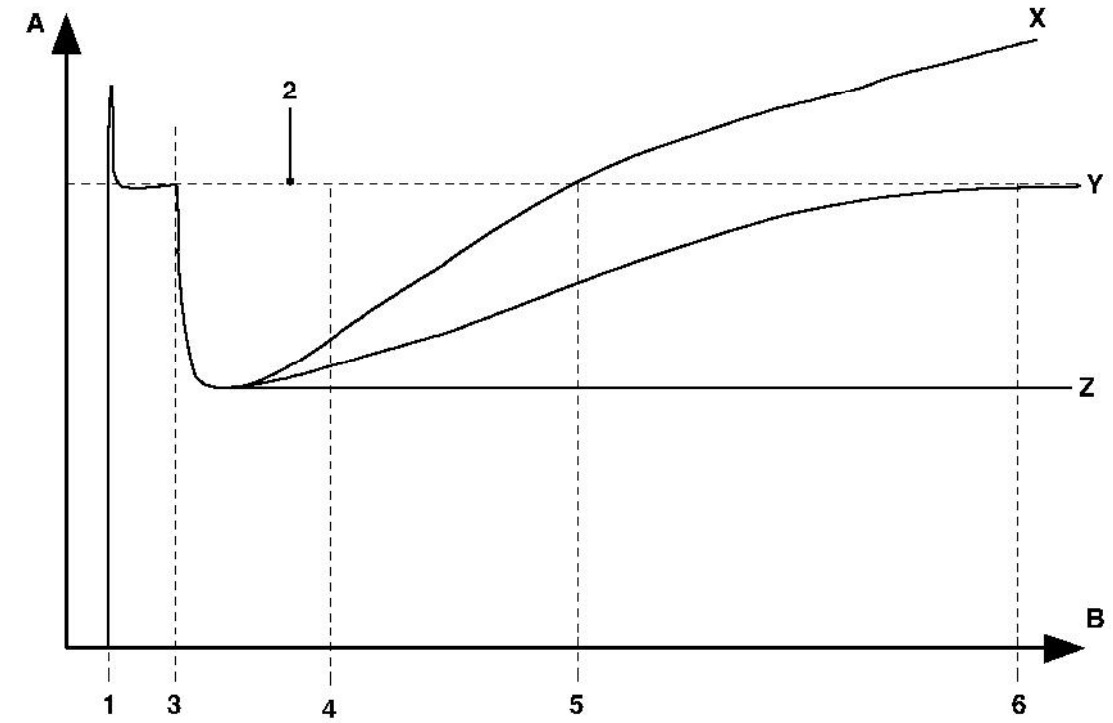
If the fuel filler cap is opened or refuelling is detected during the leak check, by a sudden drop in the current draw or rise in fuel level, the leak check is aborted.

If a leak is detected during the check, the ECM stores an appropriate fault code in memory. If a leak is detected on two consecutive checks, the ECM illuminates the MIL on the next drive cycle.

The duration of the leak check is between 40 and 270 seconds, depending on results and the level of fuel in the tank.

A leak test can be invoked using TestBook/T4, which overrides the baseline conditions requirement.

Leak Check Sequence



M17 0293

A = Pump motor current; B = Time

X = Current draw for tight system; Y = Current draw for minor leak; Z = Current draw for major leak

1 Pump motor energised: Air directed through reference orifice to atmosphere, to establish reference current.
2 Reference current.
3 Change-over valve energised: Air directed through EVAP canister into fuel tank.
4 Major leak check completed: If current is above stored value, no major leak present; if current is below stored value, major leak present.
5 Minor leak check completed, with no minor leak detected, when current exceeds reference value.
6 Minor leak check completed, with minor leak detected, when current stabilises at or below reference current.



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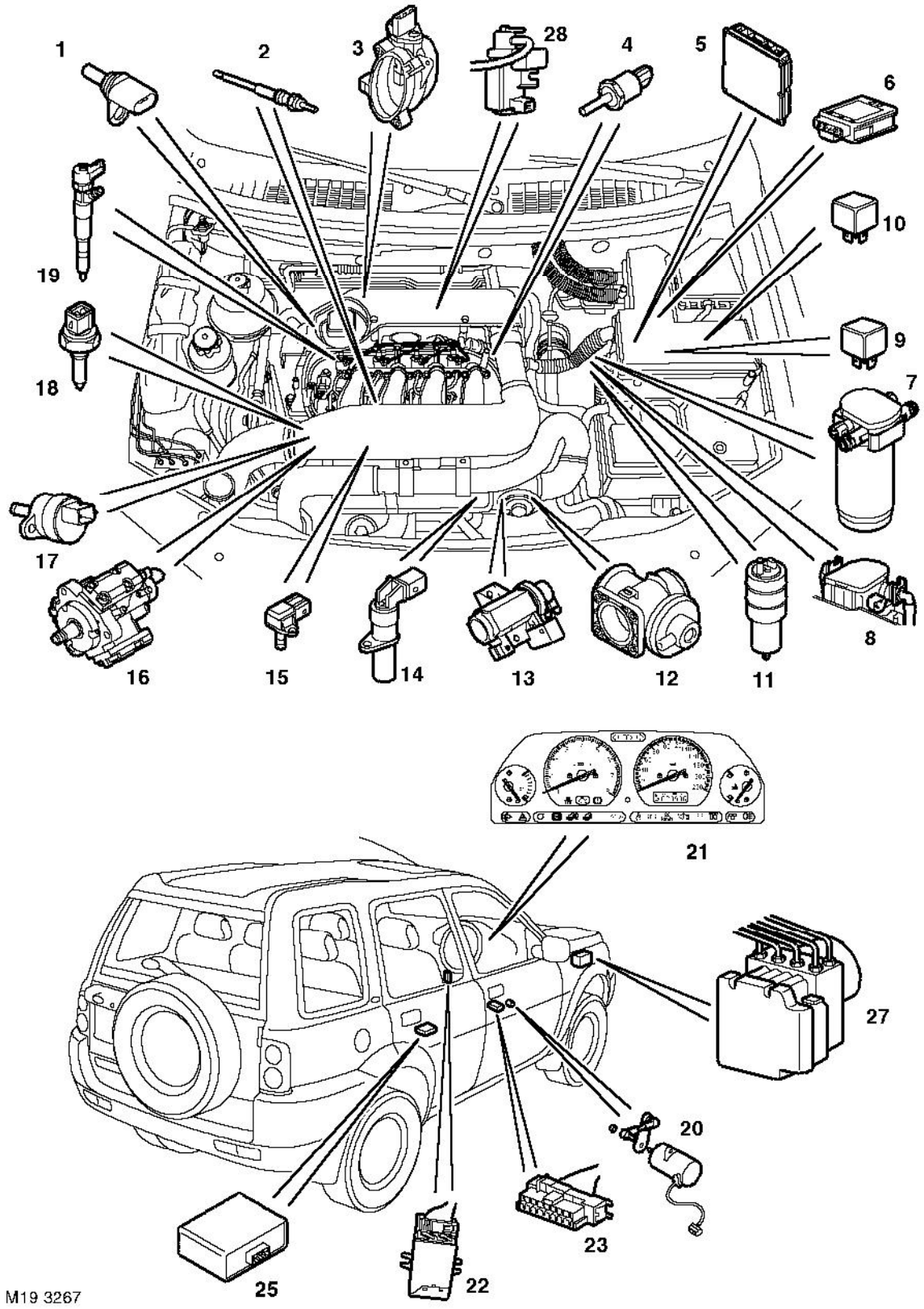
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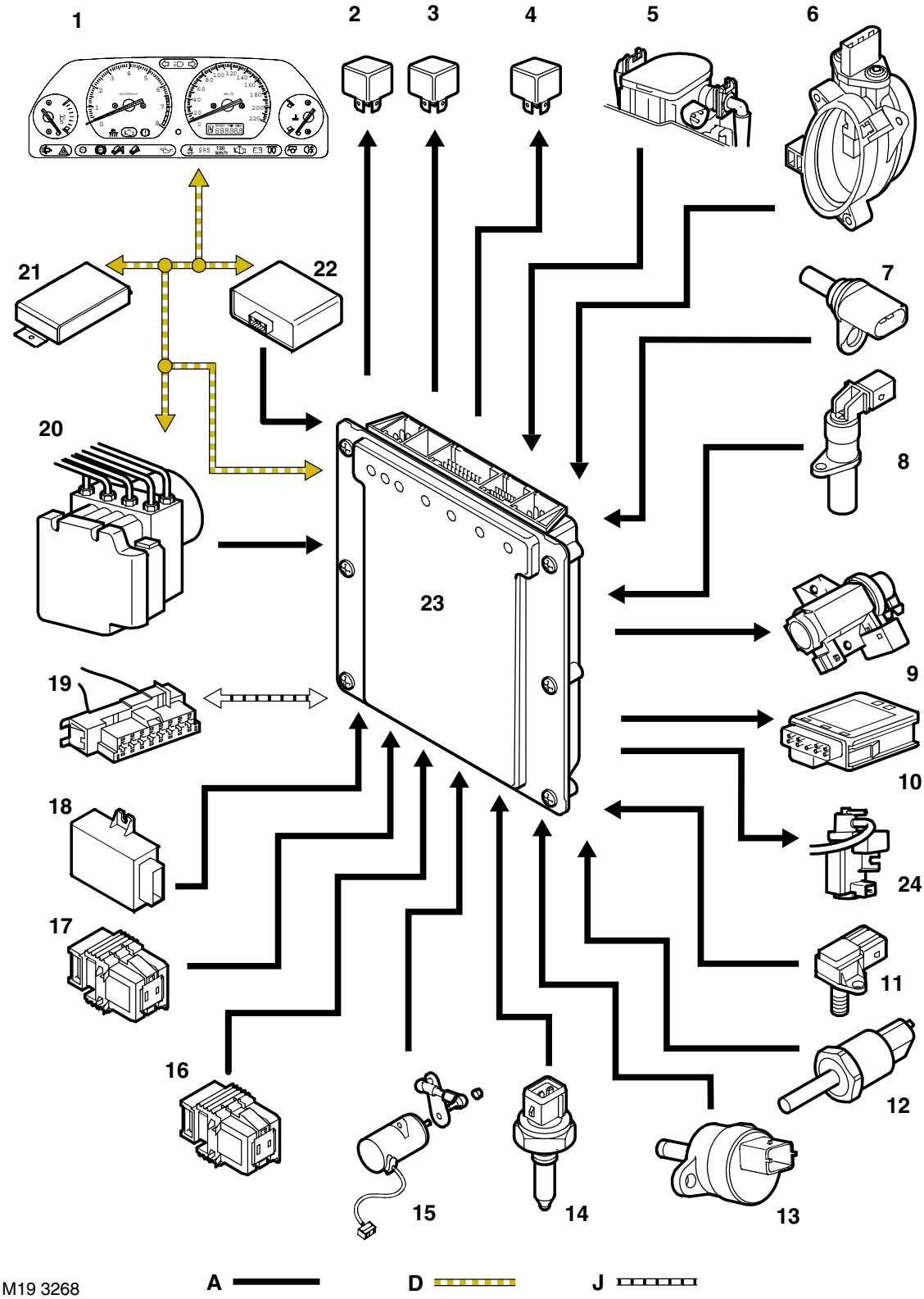
Engine Management Component Layout



RHD shown, LHD similar

1 CMP sensor
2 Glow plug
3 MAF/ IAT sensor
4 HP fuel sensor
5 ECM
6 Glow plug ECU
7 Fuel filter
8 LP fuel sensor
9 Main relay
10 A/C compressor clutch relay
11 Secondary low pressure fuel pump
12 EGR control valve
13 EGR modulator
14 CKP sensor
15 Boost pressure sensor
16 HP fuel injection pump
17 Fuel pressure regulator
18 ECT sensor
19 Fuel injector
20 Throttle Position sensor
21 Instrument pack
22 Immobilisation ECU
23 Diagnostic socket
24 EAT ECU
25 Cruise control interface ECU
26 BCU
27 ABS ECU/modulator

Engine Management Control Diagram



A = Hardwired connection; D = CAN bus; J = Diagnostic ISO 9141-2 K line bus



1 Instrument pack
2 Fuel pump relay
3 Main relay
4 A/C compressor clutch relay
5 LP fuel sensor
6 MAF/ IAT sensor
7 CMP sensor
8 CKP sensor
9 EGR modulator
10 Glow plug ECU
11 Boost pressure switch
12 HP fuel sensor
13 Fuel pressure regulator
14 ECT sensor
15 Throttle Position sensor
16 Clutch switch
17 Brake switch
18 Immobilisation ECU
19 Diagnostic socket
20 ABS ECU/modulator
21 EAT ECU
22 Cruise control interface ECU
23 ECM

Description

General
The Td4 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 throttle potentiometer, 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.
  ☞ **BRAKES, DESCRIPTION AND OPERATION, Description.**
- 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).
  ☞ **COMMUNICATION DATA BUSES, DESCRIPTION AND OPERATION, Description.**

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:

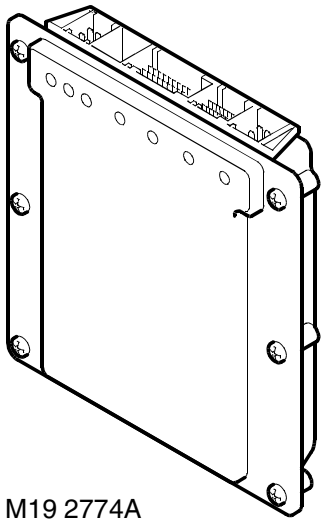
- EGR modulator.
- Glow-plug relay.
- Fuel pressure regulator valve.
- Electronic fuel injectors.
- Cooling fan relay.
- A/C compressor clutch relay.
- Vacuum control module

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.
  ☞ **AUTOMATIC GEARBOX - JATCO, DESCRIPTION AND OPERATION, Description.**
- Glow-plug relay.
- Instrument pack.
  ☞ **INSTRUMENTS, DESCRIPTION AND OPERATION, Description.**
- Immobilisation ECU.
  ☞ **SECURITY, DESCRIPTION AND OPERATION, Description.**
- Cruise control interface ECU.
  ☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

Engine Control Module (ECM)



M19 2774A

The ECM has a steel casing to provide protection from electromagnetic radiation and is located in the E-box.

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.

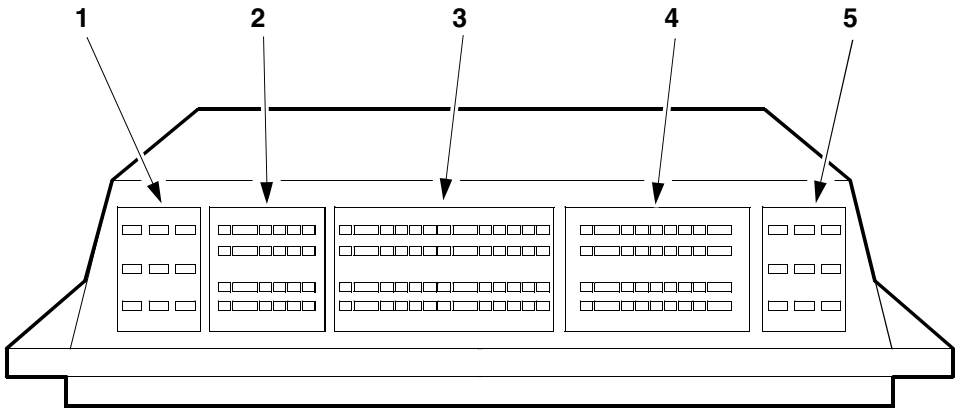
The ECM cannot be tested directly, diagnosis must be performed by ensuring that inputs and outputs conform to specifications. TestBook is available for this purpose. If the ECM is to be replaced, the new ECM will be supplied 'blank' and must be configured to the vehicle using TestBook. When the ECM is fitted to the vehicle it must also be synchronised to the immobilisation ECU using TestBook. Engine control modules cannot 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.

ECM Harness Connectors



M19 2747

1 9 pin connector (C0603)
2 24 pin connector (C0604)
3 52 pin connector (C0606)
4 40 pin connector (C0331)
5 9 pin connector (C0332)



ECM Harness Connector Pin Details (C0331)

Pin No.	Description	Input/Output
1	Charge check alternator	Output
2 and 3	Not used	-
4	Engine fan control	Output
5 and 6	Not used	-
7	Throttle potentiometer earth	-
8	Throttle potentiometer signal	Input
9	Throttle potentiometer supply	Output
10	Fuel pump	Output
11	Oil pressure sensor	Output
12	Throttle potentiometer earth	-
13	Throttle potentiometer signal	Input
14	Throttle potentiometer supply	Output
15 to 21	Not used	-
22	Vehicle speed signal	Input
23	Clutch switch	Input
24	Brake switch main circuit	Input
25	Not used	-
26	Ignition voltage	Input
27	Cruise control ECU MFL signal	Input
28	Brake switch test circuit	Input
29	Compressor relay	Output
30 and 31	Not used	-
32	Diagnostic interface	Input/Output
33	Immobilisation	Input/Output
34 and 35	Not used	-
36	CAN bus high	Input/Output
37	CAN bus low	Input/Output
38 to 40	Not used	-

ECM Harness Connector Pin Details (C0332)

Pin No.	Description	Input/Output
1	Supply electronic fuel injector cylinders 2 and 4	Input
2	Not used	-
3	Electronic fuel injector cylinder 2	Input
4	Supply electronic fuel injector cylinders 1 and 3	Input
5	Electronic fuel injector cylinder 1	Output
6	Electronic fuel injector cylinder 4	Output
7	Not used	-
8	Electronic fuel injector cylinder 3	Output
9	Not used	-

ECM Harness Connector Pin Details (C0603)

Pin No.	Description	Input/Output
1	Battery voltage	Input
2 and 3	Not used	-
4	Earth	-
5	Earth	-
6	Earth	-
7	Ignition voltage	Input
8	Main relay supply	Input
9	Main relay earth	Output

ECM Harness Connector Pin Details (C0604)

Pin No.	Description	Input/Output
1 to 8	Not used	-
9	Fuel pressure sensor supply	Output
10	Fuel pressure sensor earth	-
11 to 16	Not used	-
17	Fuel pressure sensor signal	Input
18 to 24	Not used	-

ECM Harness Connector Pin Details (C0606)

Pin No.	Description	Input/Output
1	MAF sensor supply	Output
2	MAF sensor signal	Input
3	MAF sensor earth	-
4	CMP signal	Input
5	Not used	-
6	CKP signal	Input
7 to 9	Not used	-
10	EGR	Output
11	Not used	-
12	Glow plug control	Output
13	Not used	-
14	Boost pressure sensor supply	Output
15	Boost pressure sensor signal	Input
16	Boost pressure sensor earth	-
17	CMP earth	-
18	Not used	-
19	Speed signal screen earth	-
20	Fuel rail pressure sensor earth	-
21 to 27	Not used	-
28	ECT signal	Input
29	IAT signal	Input
30	Not used	-
31	CKP earth	-
32	ECT earth	-
33	Fuel rail pressure sensor signal	Input
34	Not used	-
35	Fuel rail pressure sensor supply	Output

Pin No.	Description	Input/Output
36 and 37	Not used	-
38	Fuel pressure regulator	Output
39 and 40	Not used	-
41	Oil pressure switch	Input
42 to 49	Not used	-
50	Charge check alternator	Input
51	Not used	-
52	Fault status glow plug relay	Input

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.
- Implementation of idle strategy when vehicle is stationary.

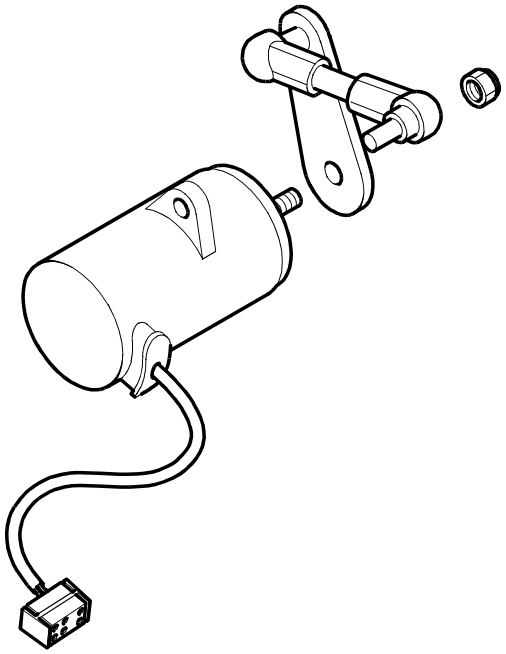
Communication

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 data bus.

There are two data bus 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



M19 2761A

The throttle potentiometer 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 throttle potentiometer, 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 throttle potentiometer 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

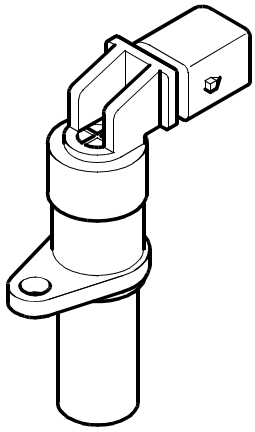
The ECM supplies the throttle potentiometer with a regulated 5 volts supply and an earth path for the resistive tracks. The output signals vary according to the position of the accelerator pedal. The throttle potentiometer earth also acts as a screen to protect the integrity of the signal.

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 (unless the brake is activated):

- No accelerator response.
- Failure of emission control.
- Automatic gearbox kickdown inoperative.

Crankshaft Position (CKP) Sensor



M19 2772A

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:

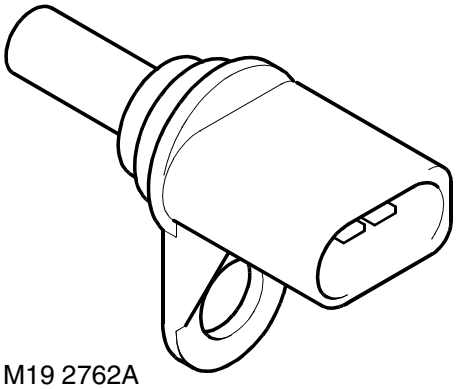
- To determine fuel injection timing.
- To enable the fuel pump relay circuit (after the priming period).
- To produce an engine speed message for broadcast on the CAN bus for use by other systems.

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



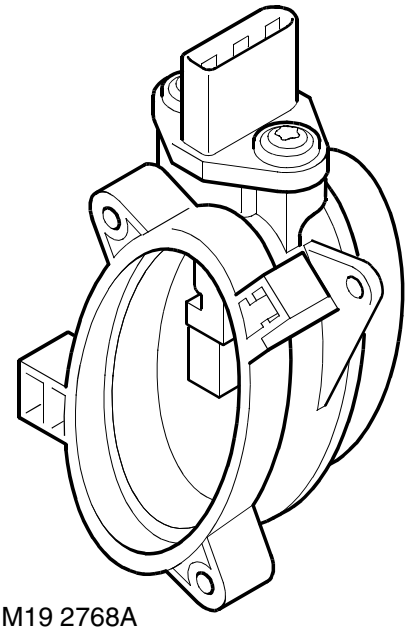
M19 2762A

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



M19 2768A

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.

Normal operating parameters of the MAF/ IAT sensor are as follows:

MAF

Air mass, kg/h	Current draw, μA
15	1.4255
30	1.7616
50	2.0895
60	2.2270
120	2.8356
220	3.4558
250	3.5942
370	4.0291
480	4.3279
640	4.6601

IAT

Temperature, °C (°F)	Resistance, kΩ
-30 (-22)	22.960
-20 (-4)	13.850
-10 (14)	8.609
0 (32)	5.499
10 (50)	3.604
20 (68)	2.420
30 (86)	1.662
40 (104)	1.166
50 (122)	0.835
60 (140)	0.609
70 (158)	0.452
80 (176)	0.340
90 (194)	0.261
100 (212)	0.202
110 (230)	0.159
120 (248)	0.127
130 (266)	0.102

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:

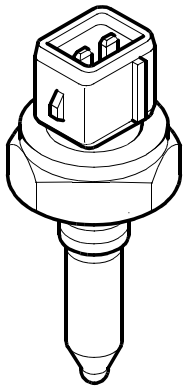
- To maintain manifold boost pressure.
- To reduce exhaust smoke emissions while driving at high altitude.
- Control of the EGR system.
- Control of the vacuum control module

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/in^2).

Engine Coolant Temperature (ECT) Sensor



M19 2773A

The ECT sensor is located in the engine block 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.

ECT Sensor Resistance

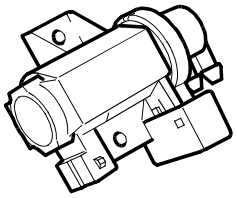
Temperature, °C (°F)	Resistance, kΩ
-30 (-22)	4.916
-20 (-4)	4.853
-10 (14)	4.745
0 (32)	4.584
10 (50)	4.354
20 (68)	4.046
30 (86)	3.660
40 (104)	3.220
50 (122)	2.751
60 (140)	2.267
70 (158)	1.862
80 (176)	1.490
90 (194)	1.182
100 (212)	0.938
110 (230)	0.738
120 (248)	0.581
130 (266)	0.464

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.
- 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



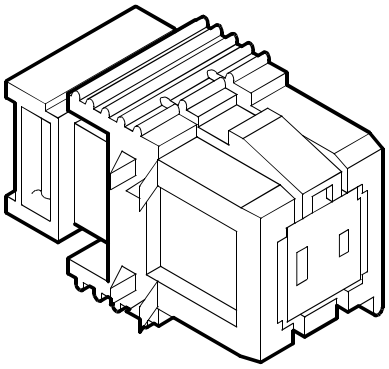
M19 2956

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



M19 2826A

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.

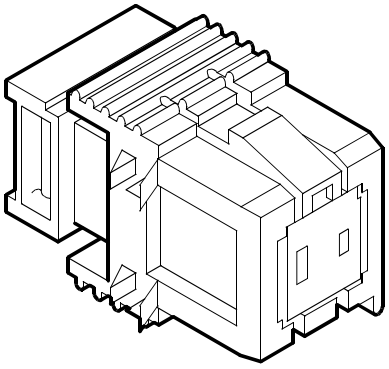
The brake switch includes two separate circuits, one normally open and one normally closed, connecting to earth. The two circuits are referred to as main brake and brake test.

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



M19 2826A

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 E-box in the engine compartment. 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.

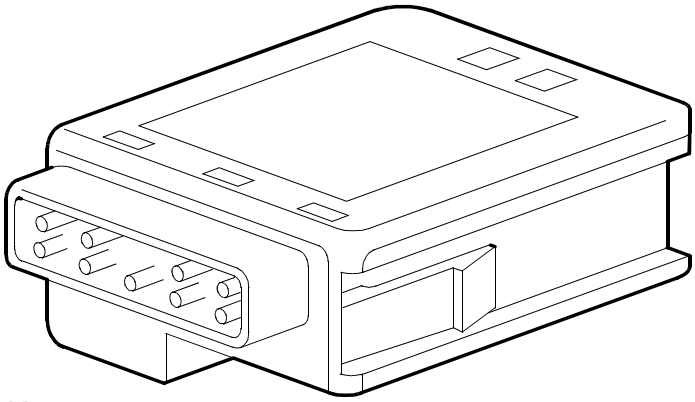
The main relay contact supplies battery voltage to the following components:
- ECM.
- MAF/ IAT sensor.
- CMP sensor.
- Fuel pressure regulator.
- EGR modulator.
- Glow plug relay.

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



M19 2769

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.

Glow Plug Relay Harness Connector (C0215) Pin Details

Pin No.	Description	Input/Output
1	Battery supply	Input
2	Glow plug cylinder 3	Output
3	Glow plug cylinder 4	Output
4	Not used	-
5	Module earth	Output
6	Not used	-
7	Not used	-
8	Glow plug cylinder 2	Output
9	Glow plug cylinder 1	Output
10	Glow plug operation control from ECM	Input
11	Glow plug heater feedback to ECM	Output
12	Switched power ignition position II	Input

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/in^2).

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/in^2) during cranking and 300 bar (4350 lbf/in^2) 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/in^2). When energised, the valve is closed, allowing maximum fuel pressure in the fuel rail. This pressure can reach approximately 1300 bar (18,854 lbf/in^2). 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.

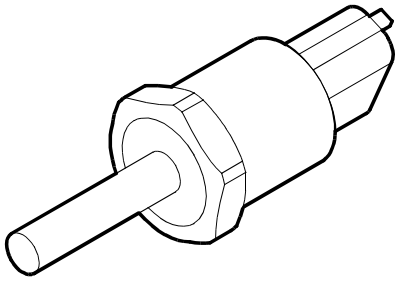
Electronic Fuel Injector
There are four electronic fuel injectors (one for each cylinder), each located in the centre of a cylinder's four valves. The electronic fuel injectors are supplied with fuel from the fuel rail and deliver finely atomised fuel directly into the combustion chambers. Each injector is controlled individually by the ECM according to the firing order. The injectors are provided with a 12 volt power supply from the main relay. 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



M19 2763

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.

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.

Operation

General
The ECM controls the operation of the engine using information stored within memory in the form of maps. The maps contain data which is used to determine the most efficient fuelling for any given driving condition. The ECM also has maps for the operation of sub systems such as EGR. The ECM is an adaptive unit which 'learns' the characteristics of the vehicle components. This feature allows the ECM to compensate for any variations in components fitted to the vehicle in production, and to adapt to changes which may occur in service. The ability to compensate for 'wear and tear' and environmental changes during the life of the vehicle ensures that the ECM can comply with the emission control legislation over extended periods. The ECM is programmed with a 'strategy', this controls the decisions about 'when' to turn specific functions on and off. The inputs to this decision making process are supplied by sensors, mounted at various locations on the vehicle, which supply information to the ECM. If a sensor fails to supply information, the ECM will use the remaining sensors, and insert a default value for the missing information. This is not always possible, in which case the vehicle will be disabled. Where a default is used, this may result in reduced driveability, or an increase in fuel consumption and exhaust emissions. The ECM is programmed with vehicle specific information known as a 'calibration', this is the data required to calculate the 'outputs'. This information along with sensor inputs and interfaced data determines actuator output signals.

The ECM facilitates strategies such as:
- Smoke limitation.
- Active surge damping.
- Automatic gear change.
- Fuel reduction.
- Engine cooling.
- Combustion noise limitation.

During idle and wide open 'throttle' conditions the ECM uses mapped information to respond to the input from the Throttle Position sensor. To implement the optimum fuelling strategy for idle and wide open 'throttle' the ECM requires input information from the following:
- CKP sensor.
- Throttle Position sensor.
- ECT sensor.
- MAF/ IAT sensor.
- High pressure fuel sensor.

This information is then compared to mapped information within the ECM to facilitate acceleration using the following actuators and controllers:
- EGR modulator - closed for cleaner combustion.
- Fuel pressure regulator - increase fuel pressure to injector rail.
- Electronic fuel injectors - injection duration longer.
- A/C compressor clutch relay - de-energised during wide-open 'throttle' to reduce engine load.
- EAT ECU - kickdown (automatic gearbox models).

During cold start conditions the ECM uses ECT information to determine if cold start strategy is required. During cold start conditions the ECM will inject more fuel into the cylinders and will initiate glow plug timing strategy for effective cold starting. Normal fuel strategy is used during hot starts.

Injection Control
The purpose of the injection control is to deliver a precise quantity of finely atomised fuel into the combustion chambers at the correct times in the engine cycle.

To precisely control fuel injection quantity and timing, the following information must be available to the ECM:
- Crankshaft speed and position: This information enables the ECM to determine the volume of air induced into the cylinders and the position of the crankshaft for timing purposes.
- Camshaft position: This information enables the ECM to determine the relative positions of the crankshaft and camshaft for timing purposes.
- Injection timing map information: This information provides the basic data which is used by the ECM when calculating the injection timing and quantity.



- Engine coolant temperature: This information is used, in conjunction with the CKP and the fuelling map, to set the injection quantity to the correct value.
- Injector rail pressure: This information is used during fuelling calculations to correct the electrical opening times (injector duty cycle) to compensate for variations in fuel pressure.
- Mass air flow: This information is used by the ECM to calculate the mass of air which has entered the cylinders, and hence the amount of oxygen available for combustion of the fuel. It also allows the ECM to monitor EGR flow when the system is active.
- Intake air temperature: This information is required by the ECM to provide a correction factor for differing intake air temperatures. Cold air contains more oxygen than hot air for any given volume, therefore the fuelling must be adjusted to suit the prevailing conditions.
- Accelerator pedal position: This information is vital to the operation of the ECM and the vehicle. The ECM interprets the electrical signal from the throttle potentiometer as 'throttle' demand and controls the power output of the engine accordingly.

Pilot Fuel Injection
Pilot fuel injection helps to reduce engine clatter and vibration. The ECM provides this feature by opening the electronic fuel injectors briefly before injecting the main charge of fuel. This makes the flame front propagation through the main charge less abrupt, giving reduced levels of diesel knock.

Smoke Limitation
This requires high injection pressure to improve the atomisation of the fuel injected into the cylinders. By maintaining high fuel pressures at low engine speeds the ECM maximises the atomisation of the fuel for conditions where turbulence in the combustion chamber is reduced. The strategy contained in the ECM does not allow more fuel to be injected than there is oxygen available in the cylinders.

Active Surge Damping
Active surge damping is implemented to prevent the engine surging when the EAT ECU changes gear, or the clutch switch indicates that the clutch pedal is depressed. The ECM will reduce fuelling to lower the engine torque output, thereby preventing engine surge.

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 module 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).

Air Conditioning (A/C)
The A/C system is dependent on the ECM for actuation of the compressor clutch. While the engine is running, the ECM receives a compressor on/off request on the CAN bus every 10 seconds, and each time that the A/C is turned on or off. When the request is for the compressor to be turned on, the ECM will engage the compressor clutch providing the following conditions exist:
- All engine sensors are functioning.
- The engine is not under heavy load (i.e. accelerator pedal is not fully down).
- The coolant temperature is not more than 118 °C (244 °F).
- Evaporator temperature not less than -7 °C (25 °F).
- Engine speed over 500 rev/min.
- A/C refrigerant pressure within the limits required by the trinary switch.

The ECM engages the compressor clutch by providing an earth path for the A/C compressor clutch relay winding. The contacts in the relay close and supply a 12 volt feed to engage the compressor clutch. When the compressor clutch request has been granted a confirmation message is broadcast on the CAN bus.

If any of the conditions necessary to engage the compressor clutch cease to exist, the ECM will disengage the compressor. The ECM broadcasts a confirmation that the A/C clutch has been disengaged on the CAN bus.

Cooling Strategy
The ECM controls cooling fan operation for the engine, automatic gearbox and A/C condenser. With the ECM controlling cooling fan operation, it can adjust injection duration and timing to compensate for additional engine load imposed by the alternator during cooling fan operation. The ECM can request one of three fan speeds depending on coolant temperature, EAT ECU and A/C requests. These fan speeds are:

- Low: 250 rev/min.
- Medium: 800 rev/min.
- High: 1750 rev/min.

Priority will be given to the highest fan speed request. When A/C is requested, fan speed is set to low, unless the EAT ECU or ECT requires a higher fan speed. If the cooling request circuit of the trinary switch is open the fan speed is then set to medium. High speed fan operation will be selected by one of the following conditions:

- Engine temperature is greater than 119 °C (246 °F).
- EAT ECU request for increased cooling.

The ECM achieves fan speeds by sending a 140 Hz PWM signal to a PWM converter located within the fan relay module. The PWM converter is connected to three relays, also located within the fan relay module, and determines which relays to energise by the duty cycle of the pulse:

- 13%: Relay one energised to give low fan speed.
- 40%: Relays one and two energised to give medium fan speed.
- 86%: Relays one, two and three energised to give high fan speed.

Electronic Automatic Transmission (EAT) ECU Strategy
On automatic gearbox models, the EAT ECU implements an idle neutral strategy, which is part of the fuel reduction strategy. Neutral is selected, reducing engine load and fuel consumption, when all of the following conditions are met:

- ECM confirms engine at idle.
- 'D' selected on gear selector lever.
- Foot brake applied.

Should one of these conditions change, after neutral has been selected, 'D' will be reselected automatically.

When the EAT ECU requests, via the CAN bus, a reduction in engine torque, the ECM reduces engine torque by cutting back fuel delivery. This ensures smooth gear changes throughout the engine speed and load ranges, and reduces exhaust emissions.

Information sent from the ECM to the EAT ECU using the CAN bus is as follows:

- Accelerator pedal position.
- Engine torque.
- Engine speed.
- Coolant temperature.
- Ignition key position.
- Virtual 'throttle' angle.

Information sent from the EAT ECU to the ECM using the CAN bus is as follows:

- Torque reduction requests.
- Gear lever position.
- Current gear.
- Gear change in progress.
- Additional cooling request.

Immobilisation System
The ECM plays a major role in the immobilisation of the vehicle. The ECM inhibits engine fuelling until the ECM receives a valid coded signal from the immobilisation ECU. The coded signal from the immobilisation ECU comes in the form of a rolling code. This code cannot be copied or bypassed in any way.

When new, the immobilisation ECU is blank and is programmed with a starting code known as a 'seed'. The seed is then used as a base point for the rolling code when the immobilisation ECU is synchronised to the ECM during manufacture.

Once synchronised, the ECM and immobilisation ECU are not interchangeable and work as a matching pair.

When a new ECM is fitted to a vehicle during service, the new ECM must be in a blank condition. The blank ECM must be re-synchronised to the immobilisation ECU using TestBook.

When a new immobilisation ECU is fitted to a vehicle during service, the new immobilisation ECU must be supplied with a seed that matches the vehicle. This information is held by Rover. The rolling codes in the new immobilisation ECU and the existing ECM must then be synchronised using TestBook.

The immobilisation ECU receives engine speed information from the ECM to inhibit starter motor operation when the engine is running, to prevent damage to the starter drive pinion and ring-gear. Engine speed information is broadcast on the CAN bus by the ECM. The instrument pack converts and broadcasts the engine speed signal on the K bus where it is received by the immobilisation ECU.

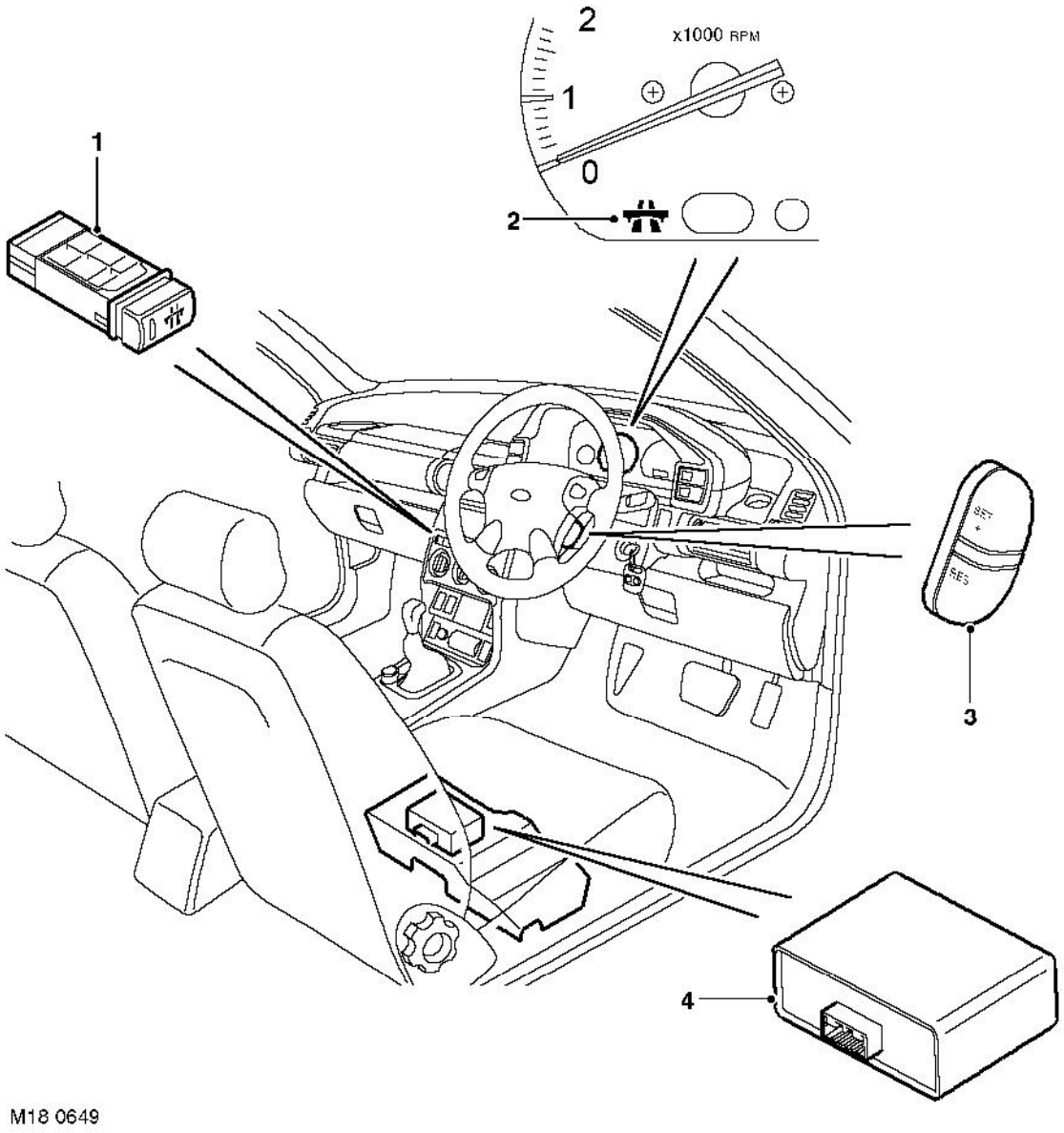
Cruise Control

The ECM incorporates a cruise control program which is activated and deactivated by an input from the cruise control interface ECU.

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

During cruise control operation, the ECM controls vehicle speed by adjusting fuel injection duration and timing. On automatic gearbox models, when the accelerator pedal is released during cruise control the ECM outputs a calculated 'throttle' angle signal to the EAT ECU in place of the actual 'throttle' angle signal derived from the Throttle Position sensor. The calculated 'throttle' angle is derived from fuel demand.

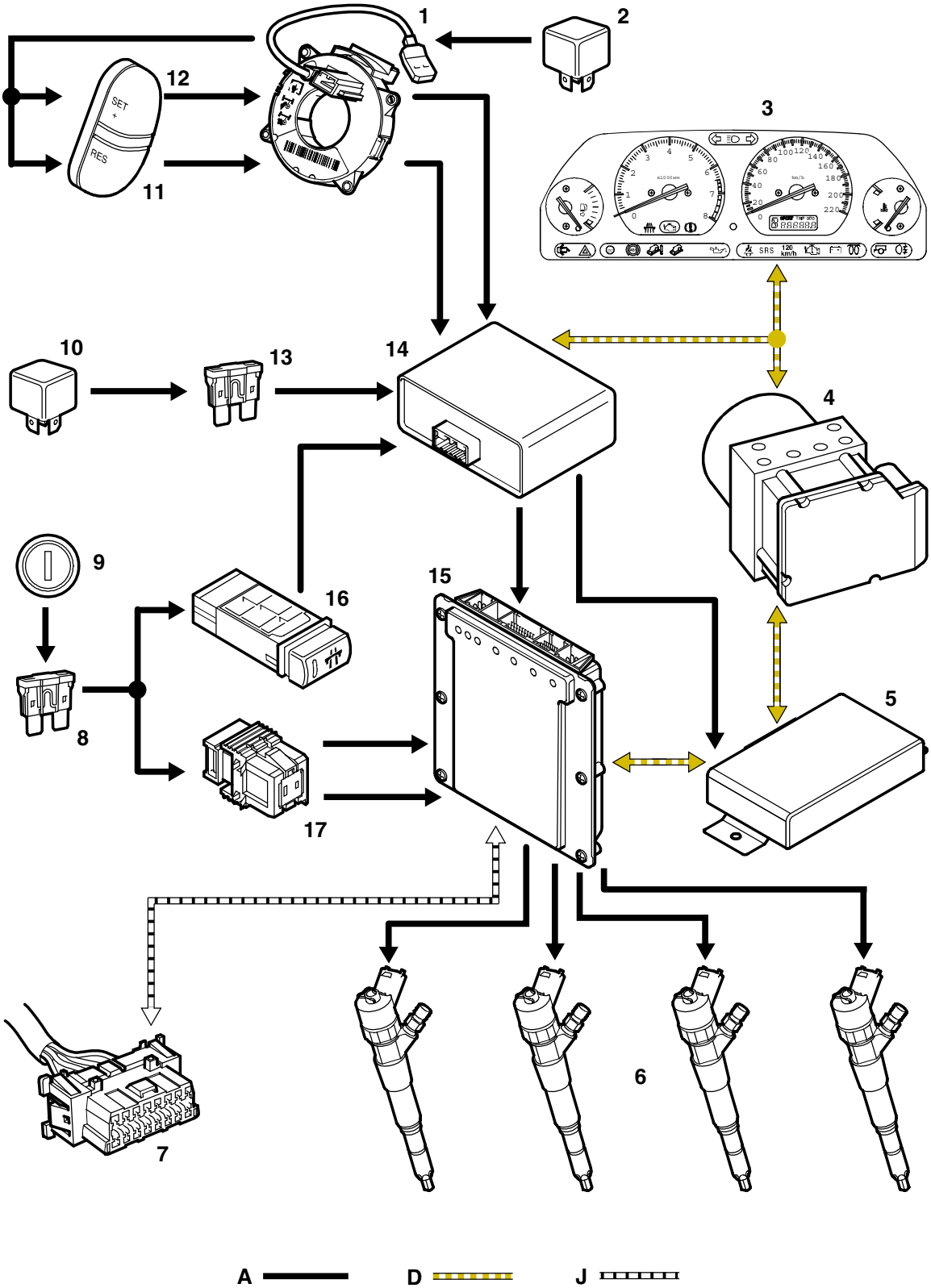
Cruise Control Component Layout



RHD shown, LHD similar

1 Master switch
2 Warning lamp
3 Steering wheel switches
4 Interface ECU

Cruise Control, Control Diagram



M18 0650

A = Hardwired connection; D = CAN bus; J = Diagnostic ISO 9141 K line bus

1 Rotary coupler
2 Horn relay
3 Instrument pack
4 ABS modulator
5 EAT ECU
6 Fuel injector
7 Diagnostic socket
8 Fuse 35, passenger compartment fusebox
9 Ignition switch
10 Main relay
11 RES switch
12 SET+ switch
13 Fuse 4, engine compartment fusebox
14 Interface ECU
15 ECM
16 Master switch
17 Brake pedal position sensor

Description

General
The cruise control system is integrated with the engine management system and uses fuelling intervention to automatically maintain a set vehicle speed. Once engaged, the system can also be used to accelerate the vehicle without using the accelerator pedal. The cruise control system consists of:

- A master switch.
- SET+ and RES steering wheel switches.
- An interface ECU.
- A warning lamp.

The system also uses:

- Inputs from the brake pedal position sensor and the Anti-lock Braking System (ABS) modulator.
  ☞ **BRAKES, DESCRIPTION AND OPERATION, Description.**
- The Engine Control Module (ECM).
  ☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

The Controller Area Network (CAN) bus is used by the cruise control system for the exchange of data between the interface ECU, ECM, EAT ECU, ABS modulator and instrument pack.

Cruise control is enabled when the master switch is pressed. Once enabled, the cruise control system is operated using the steering wheel switches. The steering wheel switches output signals to the interface ECU, which then signals the ECM. In the cruise control mode, the ECM adjusts the pulse width of the fuel injector signals to adjust the fuel supply as necessary to maintain the vehicle at the set speed.

The cruise control warning lamp provides a visual indication of when the system is engaged.

Master Switch
The master switch controls an ignition feed to the interface ECU to enable the system. The switch is a mechanically latching push switch installed in the centre console switch panel. A green LED in the switch remains illuminated while the switch is latched.

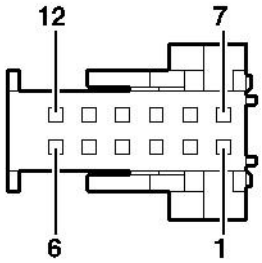
Steering Wheel Switches
The steering wheel switches, SET+ and RES, are non latching push switches that engage and disengage cruise control and adjust the set speed. While pressed, the switches connect a power feed from the battery, via the coil of the horn relay and the rotary coupler, to the interface ECU.

Interface ECU
The interface ECU converts the analogue signals from the steering wheel switches into serial data messages, known as Multi-Function Logic (MFL) messages, which are interpreted by the ECM to operate cruise control. The interface ECU also controls the output of a cruise engaged signal to the EAT ECU. The interface ECU is installed below the RH front seat, under a plastic protective cover.

MFL Messages
The ignition power supply from the master switch activates the interface ECU, which then monitors the inputs from the steering wheel switches and the cruise control status message from the CAN bus. From these, the interface ECU determines when to output one of three MFL messages, RESUME, SET or OFF, on the serial link to the ECM. Each time the interface ECU is enabled by the power feed from the master switch, the output of the RESUME message is automatically inhibited until after the first engagement of cruise control.

Cruise Engaged Signal
When cruise control is engaged, the interface ECU outputs battery voltage on a connection to the EAT ECU to provide a cruise control engaged signal. The EAT ECU uses the signal to switch between normal and cruise control modes of operation.

Interface ECU Harness Connector (C0895)



M18 0651

Interface ECU Harness Connector Pin Details

Pin No.	Description	Input/Output
1	System earth	-
2	MFL signal	Output
3	SET+ switch	Input
4	RES. switch	Input
5	CAN bus low (L line)	Input/Output
6	CAN bus high (K line)	Input/Output
7	Cruise control master switch	Input
8	Ignition power supply	Input
9	Cruise control engaged signal	Output
10 to 12	Not used	-

Warning Lamp

The warning lamp indicates the status of the cruise control system. Located in the instrument pack, the warning lamp illuminates when cruise control is engaged, and consists of a motorway graphic on a yellow background.

CAN System

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.

Brake Pedal Position Sensor

Outputs from the brake pedal position sensor are supplied to the ECM 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. 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.

ECM

The ECM incorporates a software module and associated components to enable cruise control operation by direct control of the fuel injectors. In addition to controlling the fuel injectors, the software module monitors hardwired and CAN bus inputs to the ECM and prevents or suspends cruise control operation when the vehicle is not in the correct driving configuration.

Operation

General
When the ignition is switched on, the interface ECU receives a power feed from the main relay and initialises the MFL serial link to the ECM. The ECM is in the normal fuelling mode and outputs the cruise control inactive message on the CAN bus. The interface ECU ignores inputs from the steering wheel switches.

When the master switch is pressed, the LED in the master switch illuminates and a second power feed is connected to the interface ECU to enable the system.

Engagement
Cruise control is engaged by pressing the SET+ steering wheel switch. On receipt of the input from the SET+ switch, the interface ECU outputs a SET MFL message. Provided the vehicle is in the correct driving configuration, when the ECM receives the SET message it stores the current vehicle speed in memory as the set speed. The ECM then adjusts the fuel delivery from the injectors as necessary to maintain the vehicle at the set speed, and changes the CAN bus message of cruise control status to active.

The vehicle is in the correct driving configuration, when:
- The brakes are off.
- The gearbox is in drive.
- The vehicle is moving at a road speed between 22 and 125 mph (35 and 200 km/h).
- Electronic Traction Control (ETC) is not active.

On receipt of the cruise control active message on the CAN bus, the instrument pack illuminates the cruise control warning lamp and the interface ECU outputs the cruise control engaged signal to the EAT ECU. On receipt of the cruise control engaged signal, the EAT ECU adopts the cruise control mode, which uses a gear change map less sensitive to changes of (virtual) accelerator pedal position to prevent unnecessary gear changes. This improves operating refinement for a minor loss of performance.

Acceleration
While cruise control is engaged, the vehicle can be accelerated using either the SET+ switch or the accelerator pedal. Each momentary press (less than 0.5 second) of the SET+ switch causes the interface ECU to output a SET MFL message to the ECM, which then increments the set speed by 1 mph (1.6 km/h) and accelerates the vehicle to the new set speed. If the switch is held on, the interface ECU repeatedly sends the SET MFL message until the switch is released. While it receives the messages, the ECM keeps incrementing the stored set speed and accelerating the vehicle. When the switch is released and the messages stop, the ECM adopts the increased vehicle speed as the new set speed.

If the accelerator pedal is used to accelerate the vehicle, the ECM reverts to normal fuelling control when it detects the demand from the accelerator pedal position sensor exceeds that of the virtual accelerator pedal position. Provided the demand from the accelerator pedal position sensor does not increase vehicle speed by more than 10 mph (16 km/h) above the set speed, for more than 30 seconds, cruise control remains engaged and the set speed is resumed once the accelerator pedal is released. If the SET+ switch is pressed before the accelerator pedal is released, the higher speed is adopted as the new set speed.

Suspend/Resume
Cruise control can be manually suspended and resumed (at the previous set speed) using the RES steering wheel switch. The ECM automatically suspends cruise control if one of the conditions required to enable the system is no longer present, e.g. the brakes are applied. Cruise control is also automatically suspended by the ECM if:
- The vehicle speed increases to more than 10 mph (16 km/h) above the set speed for more than 30 seconds, e.g. when travelling downhill or using the accelerator pedal to override cruise control.
- Engine speed increases too rapidly, e.g. if their is a fault in the gearbox or the gearbox goes into neutral.
- The vehicle decelerates too rapidly, e.g. when the brakes are applied.



Suspend

When the RES switch is pressed, the interface ECU outputs the OFF MFL message to the ECM. On receipt of the OFF MFL message, and when automatically suspending cruise control, the ECM reverts to normal fuelling control and changes the cruise control message on the CAN bus to inactive. The set speed is retained in memory by the ECM. On receipt of the cruise control inactive CAN bus message, the instrument pack extinguishes the cruise control warning lamp and the interface ECU switches off the cruise control engaged signal to the EAT ECU. The EAT ECU then returns to its previous operating mode.

Resume

While cruise control is suspended, when the RES switch is pressed the interface ECU outputs the MFL RESUME message to the ECM. Provided the vehicle is in the correct driving configuration, on receipt of the RESUME MFL message the ECM engages cruise control at the previous set speed and changes the CAN bus cruise control message back to active. The instrument pack then illuminates the cruise control warning lamp again and the interface ECU outputs the cruise engaged signal to switch the EAT ECU back to the cruise control mode.

Cancelling

Cruise control is cancelled by pressing the master switch. When cruise control is cancelled, the LED in the master switch extinguishes and the power feed to the interface ECU is disconnected to disable the system. If cruise control is engaged when the master switch is pressed, the interface ECU and the ECM respond in the same way as when cruise control is suspended, except that the interface ECU no longer reacts to inputs from the steering wheel switches.

During the same ignition cycle, if the master switch is pressed again, the interface ECU is re-enabled. Since the output of the RESUME MFL message is inhibited until after the first engagement of cruise control, the interface ECU will not react to an input from the RES switch, and the set speed in the ECM memory is effectively lost to the system. Cruise control only re-engages if the SET+ switch is pressed, when, provided the vehicle is in the correct driving configuration, the ECM adopts the current vehicle speed as the new set speed.

Diagnostics

Diagnostics are incorporated into the interface ECU for self monitoring and for checking of the CAN bus message from the ECM. If a fault is detected, the interface ECU uses the MFL serial link to communicate this to the ECM, which disables cruise control for the remainder of the ignition cycle and stores a related fault code in memory.

The MFL signal contains a toggle bit which the interface ECU changes to a different state every second to indicate that the interface ECU is operating correctly and receiving a valid CAN bus signal. If a fault occurs with the CAN bus signal or the interface ECU, the toggle bit remains unchanged to advise the ECM that a fault exists. If the interface ECU fails to output the MFL signal, the ECM also interprets the lack of a signal as a fault. The fault codes can be accessed using TestBook, which communicates with the ECM via an ISO 9141-2 K line from the diagnostic socket.

The ECM monitors the two inputs from the brake pedal position sensor and disables cruise control if a fault is detected. Both inputs 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 ECM can detect open circuits and implausible inputs. However, simultaneous short circuits to 0 volt in both inputs cannot be detected and, if this occurs, cruise control operates but does not suspend operation when the brake pedal is pressed.

The ECM resets the cruise control system at the beginning of each ignition cycle and operates normally if a previously detected fault is no longer present.

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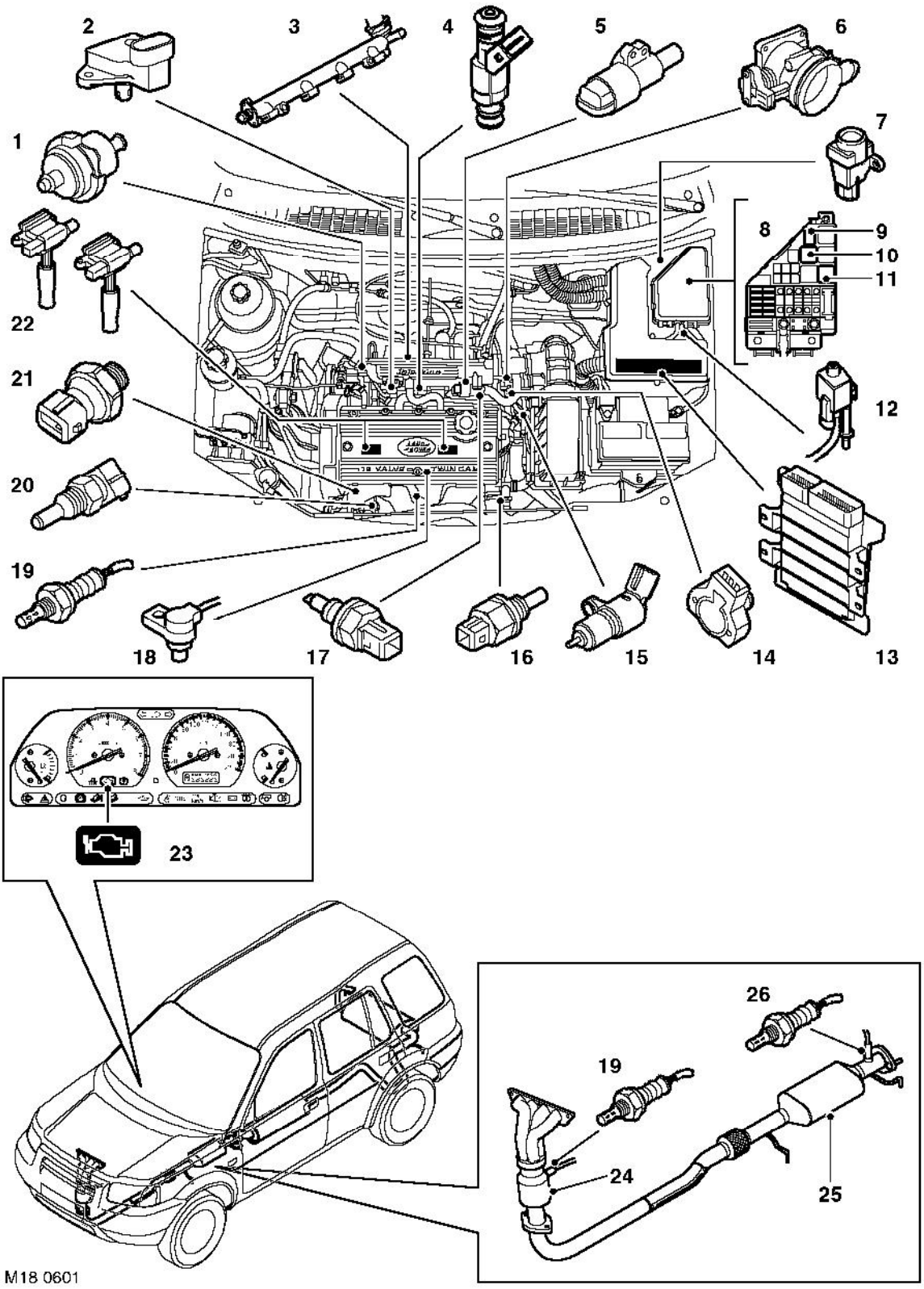
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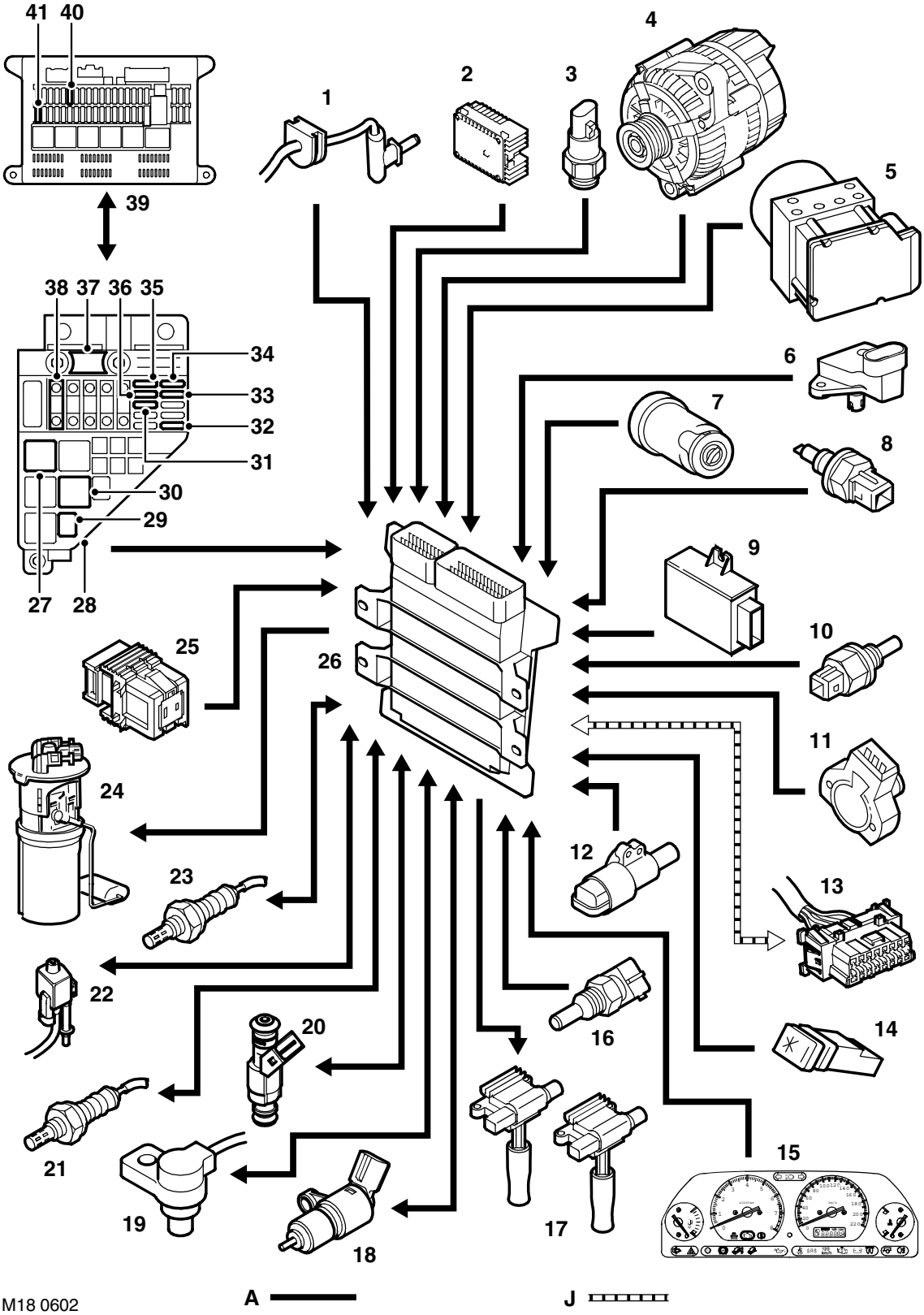
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Engine Management Component Layout



1 Fuel pressure regulator
2 Manifold Absolute Pressure (MAP) sensor
3 Fuel rail
4 Injector (4 off)
5 Idle Air Control Valve (IACV)
6 Throttle housing
7 Fuel shut-off switch
8 Engine compartment fusebox
9 Air Conditioning (A/C) relay
10 Main relay
11 Fuel pump relay
12 EVAP purge valve
13 Engine Control Module (ECM)
14 Throttle Position (TP) sensor
15 Crankshaft Position (CKP) sensor
16 Engine Coolant Temperature (ECT) sensor
17 Intake Air Temperature (IAT) sensor
18 Camshaft Position (CMP) sensor
19 Upstream oxygen sensor (HO2S)
20 Engine oil temperature sensor
21 Engine oil pressure switch
22 Ignition coils
23 Malfunction Indicator Lamp (MIL)
24 Starter catalyst
25 Main catalyst
26 Downstream oxygen sensor (HO2S)

MEMS3 Control Diagram



A = Hardwired; B = Serial link; J = Diagnostic ISO 9141 'K' Line

1 Evaporator temperature sensor
2 Cooling fan ECU
3 A/C pressure sensor
4 Alternator
5 ABS modulator ECU (road speed signal)
6 MAP sensor
7 Ignition switch
8 IAT sensor
9 EWS3D immobilisation ECU
10 ECT sensor
11 TP sensor
12 IACV
13 Diagnostic socket
14 A/C on/off switch
15 Instrument pack (fuel tank level, MIL and tachometer)
16 Engine oil temperature sensor
17 Ignition coils
18 CKP sensor
19 CMP sensor
20 Fuel injector (4 off)
21 HO2S upstream (pre-catalyst)
22 EVAP purge valve
23 HO2S downstream (post catalyst)
24 Fuel pump and level sensor
25 Throttle pedal switch
26 ECM
27 Fuel pump relay
28 Engine compartment fusebox
29 A/C relay
30 Main relay
31 Fuse 5 (10A) ECM permanent feed
32 Fuse 10 (20A) Inertia switch/fuel pump relay
33 Fuse 4 (15A) A/C relay coil feed
34 Fuse 2 (20A) ECM 12V supply from main relay/ fuel injectors supply/ignition coils supply
35 Fuse 1 (15A) HO2S downstream (post catalyst)/EVAP purge valve
36 Fuse 3 (15A) HO2S upstream (pre catalyst)/ CMP sensor
37 Fusible link 1 (150A) Alternator
38 Fusible link 2 (60A) Ignition switch
39 Passenger compartment fusebox
40 Fuse 6 (10A) ECM ignition signal
41 Fuse 19 (10A) Alternator ignition feed

Description

General

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

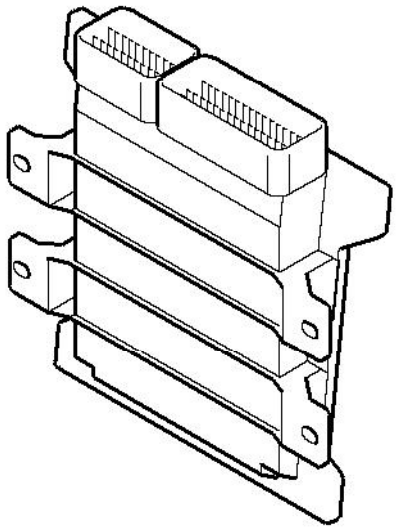
The ECM controls the operation of the fuel system, ignition system, evaporative emission control, cooling system and the air conditioning system.

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

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 E-box is a lidded container that provides a protected environment for the ECM and the EAT ECU. An open hub, centrifugal fan powered by an electric motor ventilates the E-box with air from the passenger compartment. Exhaust 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 colder 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.

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

Two harness connectors, C0913 and C0914 are used to connect the ECM to the main harness. The ECM is connected to earth using three wires. Pins 59, 66 and 73 of ECM connector C0913 are connected to a body earth at connector C1964, C1947 and C1413 respectively. 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 pin 80 of ECM connector C0913.

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 pin 61 of ECM connector C0913. The ECM energises the main relay by completing the earth path for the relay coil which is connected to the ECM at pin 54 of connector C0913. The main relay provides battery voltage to various peripheral components and also to the ECM at pin 19 of connector C0914.

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 at pin 68 of connector C0913. The ECM references the sensors and the IACV stepper motor prior to start-up.

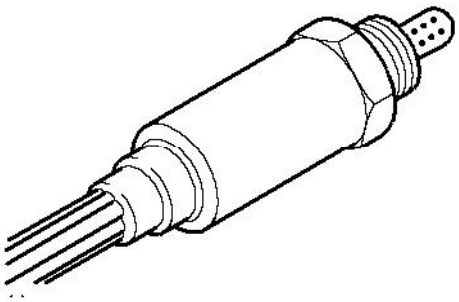
Security code information is exchanged between the ECM and the immobilisation ECU via a wire connected from pin 72 of connector C0913 on the ECM.

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 IACV 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 Sensors (HO2S)



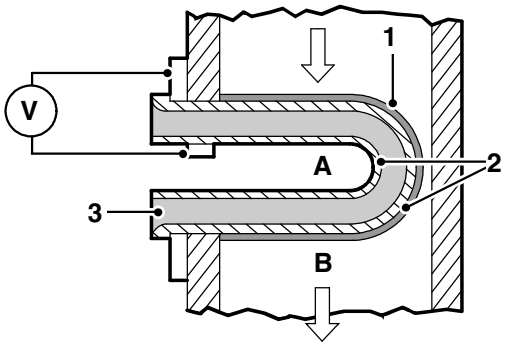
M18 0604

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 catalytic converter 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, whilst the inner surface is exposed to ambient air. The sensor has a ceramic coating to protect the sensing element from contamination and heat damage.



M18 0605

A = Ambient Air; B = Exhaust Gases

1 Protective ceramic coating
2 Electrodes
3 Zirconium Oxide

CAUTION: HO2 sensors are easily damaged by dropping, excessive heat or contamination. Care must be taken not to damage the sensor housing or tip.

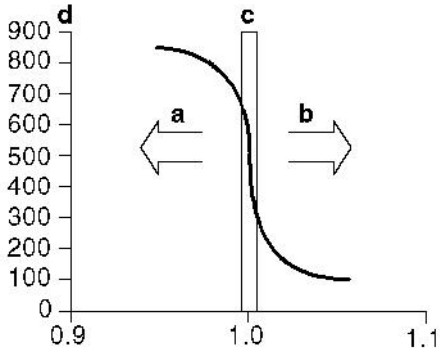
- **The HO2S becomes very hot, take care when working near it.**
- **Do not measure the resistance of the sensing element.**
- **Observe the correct torque tightening value when installing the HO2S.**
- **Do not subject the HO2S to mechanical shocks.**
- **The HO2S may be contaminated if fuel with added lead is used.**

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).

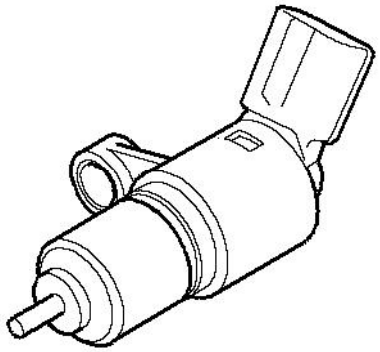


M18 0606

a Rich AFR
b Lean AFR
c Lambda window (0.97 to 1.03 mV)
d HO2S Output in mV.

Crankshaft Position (CKP) Sensor

The variable reluctance CKP sensor is mounted at the rear of the engine with the sensor tip facing the engine side 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.



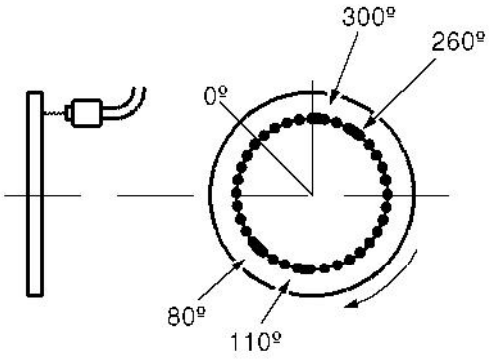
M18 0676

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 value.

The CKP sensor is a variable reluctance sensor and provides an analogue voltage output to pins 4 and 30 of ECM connector C0914, 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 (e.m.f.).

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.



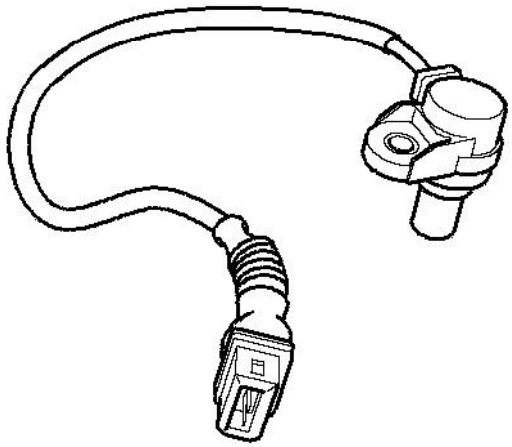
M18 0607

Camshaft (CMP) Sensor

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 provides an output to pin 16 of the ECM connector C0914. The ECM provides an earth for the sensor on pin 42 of ECM connector C0914.

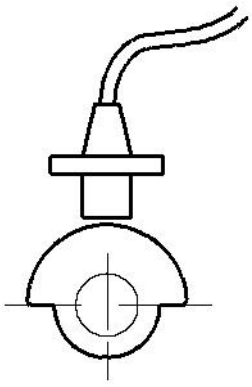
The CMP sensor is located on the camshaft cover (under the plastic cover) at the opposite end to the camshaft drive and reads off a reluctor on the exhaust camshaft.

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 an digital signal by the ECM.



M18 0608

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.



M18 0609

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.

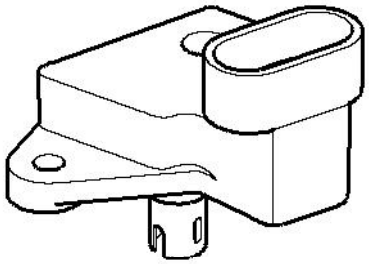
If the CMP sensor signal is missing, the engine will still start and run, but the fuel injection may be out of phase. This will be noticeable by a reduction in performance and drivability, together with an increase in fuel consumption and emissions.

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 (MAP) Sensor
The 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 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.

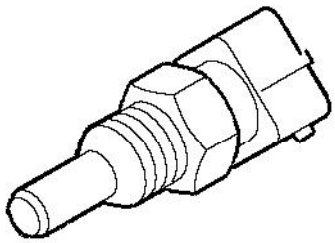
The MAP sensor receives a 5V ±4% supply voltage from pin 8 of ECM connector C0914 and provides an analogue signal to pin 45 of ECM connector C0914, which relates to the absolute manifold pressure and allows the ECM to calculate engine load. The ECM provides an earth for the sensor via pin 31 of ECM connector C0914. Pin 10 of connector C0914, although connected is not used by the ECM and is provided for future development.



M18 0610

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 (ECT) Sensor



M18 0611

The ECT sensor is located in the cooling system outlet elbow from the cylinder head and provides a signal to pin 33 of ECM connector C0914 which allows the engine temperature to be determined. The ECM provides an earth for the sensor via pin 7 of ECM connector C0914.

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

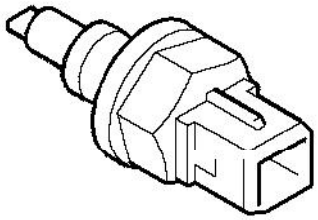
☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Operation.**

The ECT sensor consists of an encapsulated Negative Temperature Coefficient (NTC) thermistor which is in contact with the engine coolant. The ECM uses engine coolant 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 also 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.

☞ **COOLING SYSTEM - K SERIES 1.8, DESCRIPTION AND OPERATION, Description.**

Intake Air Temperature (IAT) Sensor



M18 0612

The 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.

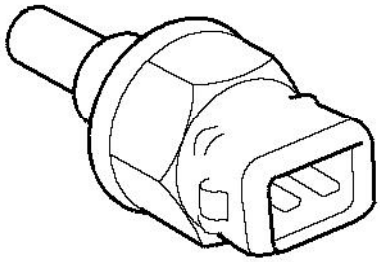
The IAT sensor provides a signal to pin 44 of ECM connector C0914, which enables the ECM to adjust ignition timing and fuelling quantity according to the intake air temperature, thus ensuring optimum performance, drivability and low emissions. The ECM provides an earth for the sensor via pin 18 of ECM connector C0914.

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



M18 0613

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.

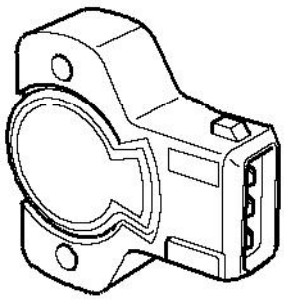
The use of an engine oil temperature sensor allows the ECM to provide optimum engine performance and minimum emissions during the engine warm up phase. The sensor provides a signal to pin 32 of ECM connector C0914. The ECM provides an earth for the sensor on pin 6 of ECM connector C0914.

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 (TP) Sensor



M18 0614

The 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.

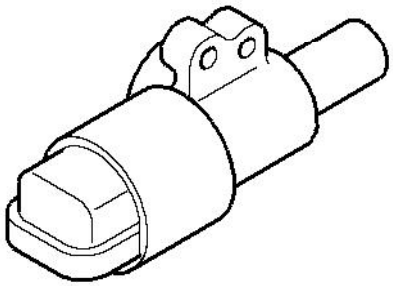
The TP sensor is a potentiometer which acts as a voltage divider in an external ECM circuit. The potentiometer consists of a 4kΩ ±20% resistive track and a wiper arm, driven by the throttle spindle, which sweeps over the track.

The track receives a regulated 5 V ±4% supply from pin 46 of ECM connector C0914, together with an earth path from pin 34 of ECM connector C0914. 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 pin 20 of ECM connector C0914, 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 (IACV)



M18 0615

The IACV 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 IACV 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.

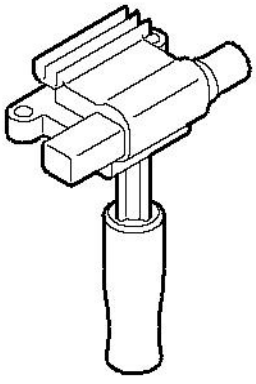
Each of the four connections can be connected to 12 volts or earth, enabling four 'phases' to be obtained. The ECM drives the four phases, known as 'A', 'B', 'C' and 'D', from pins 39, 13, 50 and 24 respectively of ECM connector C0914, to obtain the desired idle speed.

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

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



M18 0616

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 is connected to earth via pin 52 of ECM connector C0914 and coil No. 2 is connected to earth via pin 26 of ECM connector C0914. 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.

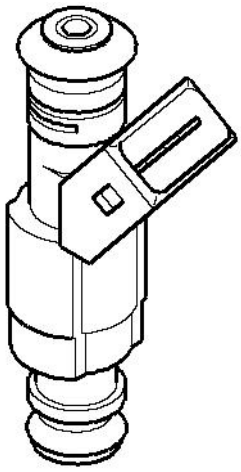
WARNING: The HT voltage of the ignition system is in excess of 50 kV and the LT voltage is in excess of 400 volts. Voltages this high can cause serious injury and may even be fatal. Never touch any ignition components while the engine is running or being cranked.

CAUTION: Never crank or run the engine with the HT leads disconnected from the ignition coils; failure of the ECM and/or the coil will result. Always disable the ignition system by disconnecting the LT connectors from the coil.

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 kΩ.

Fuel Injectors

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.



M19 3315

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 - 16Ω at 20°C (68°F). The fuel injectors operate at a regulated pressure of 3.5 bar (50 lbf/in^2). The regulator is located on the end of the fuel rail and excess fuel is returned to the swirl pot via a return line to the tank.

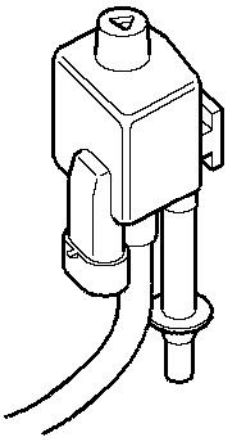
The injectors receive fuel under pressure from the fuel rail and a 12 volts supply from the main relay. To deliver fuel to the engine, the ECM has to lift the needle off the injector seat by energising the solenoid.

To energise the solenoid the ECM supplies an earth path from connector C0914 to the winding of each injector on the following pins:

- Injector No. 1 - pin 25.
- Injector No. 2 - pin 51.
- Injector No. 3 - pin 14.
- Injector No. 4 - pin 40.

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 (EVAP) Purge Valve



M18 0618

The 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 on pin 48 of connector C0914. The purge valve receives a battery feed from the main relay via fuse 1 in the engine compartment fusebox.

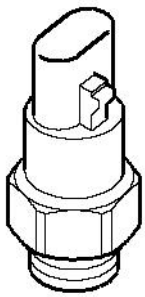
The EVAP purge valve controls the flow of fuel vapours from the EVAP canister to the intake manifold of the engine. When the vehicle is being driven the ECM will purge the EVAP canister by opening the purge valve, this allows the vacuum present in the intake manifold to draw fuel vapour from the canister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

Air Conditioning (A/C) Refrigerant Pressure Sensor



M18 0619

The pressure sensor is located in an A/C pipe from the condensor on the front RH side of the engine compartment. For further information on the air conditioning system and pressure sensor switching pressures:

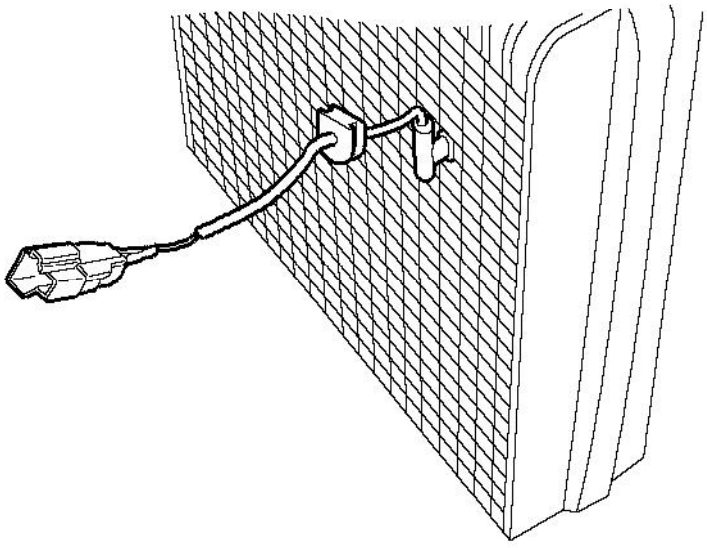
☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

The sensor is used by the ECM, in conjunction with the evaporator sensor, to calculate the loads applied to the engine by the variable load A/C compressor for engine load calculations and idle speed control. The sensor is connected to ECM pins 57, 70 and 71 of connector C0913. Pin 57 is a 5V sensor supply, pin 70 is the return signal from the sensor and pin 71 is for the sensor earth.

The ECM uses the signals from the sensor to disengage the compressor electro-mechanical clutch should the pressure become too low or too high and to switch the cooling fans to high or low speed at predetermined pressures.

☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

Air Conditioning (A/C) Evaporator Temperature Sensor



M18 0620

The evaporator temperature sensor is a NTC thermistor located in the evaporator. This is used by the ECM, in conjunction with the A/C pressure sensor, to monitor evaporator temperature and calculate the loads applied to the engine by the variable load compressor for engine load calculations and idle speed control.

The evaporator temperature sensor is connected to ECM pins 37 and 47 of connector C0914. Pin 37 supplies the sensor earth and pin 47 supplies the sensor signal to the ECM.

If evaporator temperature falls low enough for ice to form on the evaporator fins, the ECM will disengage the compressor electro-mechanical clutch until evaporator temperature rises sufficiently.

☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

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 to pin 35 of ECM connector C0914 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.

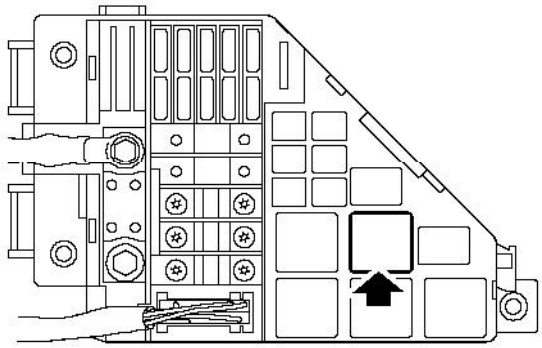
The ECM uses the load signal to provide idle speed compensation and to reduce engine speed fluctuations. If the load signal fails, the ECM uses a default value and stores a fault code which can be retrieved using TestBook.

Ignition Switch Signal

A hardwired digital input to pin 61 of ECM connector C0913 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



M18 0621

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

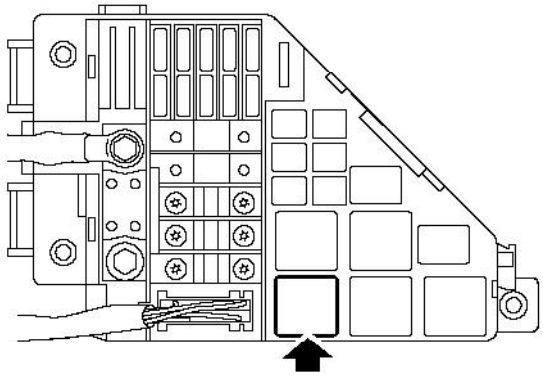
The main relay is normally open when the ignition is off. When the ignition is switched on to position II, the ECM provides an earth path for the relay coil which energises, closing the contacts.

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

- ECM connector C0914 pin 19
- 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



M18 0622

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 switch is in position II (ignition on), the ECM provides an earth path for the relay coil on pin 68 of connector C0913. 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 position III (crank), the ECM will energise the relay when the engine starts cranking and will remain energised until the engine stops.

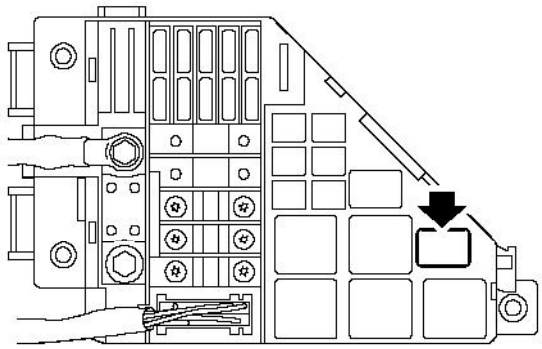
If the engine stalls and the ECM stops receiving a signal from the CKP sensor, the ECM will remove the earth path for the relay, stopping the fuel pump.

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.

WARNING: Ensure there are no fuel leaks and confirm the integrity of the fuel system before resetting the fuel shut-off 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.

A/C Compressor Clutch Relay



M18 0623

On vehicles fitted with air conditioning, an A/C relay is located in the engine compartment fusebox. When the engine is running and the driver requests A/C on, the ECM receives an earth signal from the A/C switch to pin 56 of ECM connector C0913.

If conditions are correct, the ECM grants the A/C request by completing an earth path from pin 53 of ECM connector C0913 to the A/C clutch relay coil. The relay coil receives a battery feed from the main relay and, when the earth path is granted, the coil will energise closing the relay contacts.

A permanent battery supply, via fusible link 1 and fuse 9 in the engine compartment fusebox, passes through the relay contacts and operates the compressor clutch.

The ECM will remove the earth path from the relay coil, disengaging the A/C compressor clutch if:

- Engine coolant temperature exceeds a predetermined level and will re-engage the A/C compressor clutch when the coolant temperature falls to a predetermined level.
- If the A/C refrigerant pressure becomes too low or too high. For details on refrigerant pressures:
  ☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

If the A/C clutch relay fails, A/C will be inoperative and the ECM will store fault codes which can be retrieved using TestBook.

Engine Cooling Fans

On vehicles without 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 A/C, both fans operate in parallel controlled by the ECM via a cooling fan ECU.

Cooling Fan Operation - Vehicles 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 Operation - Vehicles With A/C

The engine cooling fan and the condensor fan are operated in parallel by the ECM via a cooling fan ECU. The cooling fan ECU, 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 cooling fan ECU to determine the output voltage supplied to the fan motors.

Fan operation is also dependent on vehicle road speed. The ECM will adjust 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 cooling fan ECU will not supply any power to the fan motors. At a duty cycle of 50%, the ECU supplies 6 volts to the fan motors to operate them at a minimum speed of approximately 1300 rev/min. As the duty cycle increases above 50%, the ECU 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 a maximum speed of approximately 3000 rev/min.

When the main relay is energised, the cooling fan ECU 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 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

☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

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 bus 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 (MIL)

The 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 switching 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.

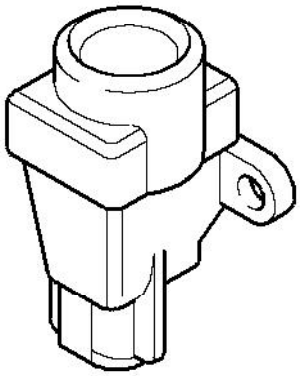
☞ **SECURITY, DESCRIPTION AND OPERATION, Description.**

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 to ECM pins 65 and 79 on the CAN bus. 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.

Fuel Shut-off Switch



M18 0624

The fuel shut-off switch is located in the engine compartment to the rear of the LH suspension turret. 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.

WARNING: Ensure there are no fuel leaks and confirm the integrity of the fuel system before resetting the fuel shut-off switch.

Throttle Pedal Switch

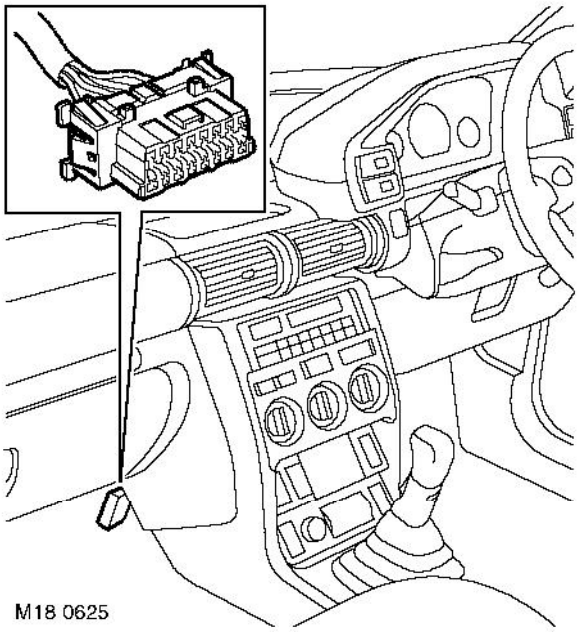
The throttle pedal switch is located at the top of the pedal box and secured in a cut-out hole in the fabrication. The switch is a proximity type Hall effect switch which senses a target located on the throttle pedal. The switch is connected on a single wire to pin 77 of ECM connector C0913.

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 (OBD)
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.

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 and 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.

Diagnostic Trouble Codes (DTC)
The following table lists P codes, affected components and fault description.

P Code	Component	Description
P0106	Manifold pressure input	Circuit fault
P0107	Manifold pressure input	Circuit fault
P0108	Manifold pressure input	Circuit fault
P0111	Inlet Air Temperature (IAT) input	Circuit fault
P0112	Inlet Air Temperature (IAT) input	Circuit fault
P0113	Inlet Air Temperature (IAT) input	Circuit fault
P0116	Coolant temperature input	Circuit fault
P0117	Coolant temperature input	Circuit fault
P0118	Coolant temperature input	Circuit fault
P0121	Throttle Potentiometer (TP) input	Circuit fault
P0123	Throttle Potentiometer (TP) input	Circuit fault
P0130	Upstream (pre-catalyst) oxygen sensor input	Switching frequency too low
P0131	Upstream (pre-catalyst) oxygen sensor input	Electrical fault
P0132	Upstream (pre-catalyst) oxygen sensor input	Electrical fault
P0133	Upstream (pre-catalyst) oxygen sensor input	Signal out of range
P0135	Upstream (pre-catalyst) oxygen sensor input	Electrical fault
P0136	Downstream (post-catalyst) oxygen sensor input	Signal implausable
P0137	Downstream (post-catalyst) oxygen sensor input	Electrical fault
P0138	Downstream (post-catalyst) oxygen sensor input	Electrical fault
P0140	Downstream (post-catalyst) oxygen sensor input	Signal missing
P0141	Downstream (post-catalyst) oxygen sensor input	Electrical fault
P0170	Fuel system	Adaptions out of range
P0197	Oil temperature input	Circuit fault
P0198	Oil temperature input	Circuit fault
P0261	Injector 1 drive	Circuit fault
P0262	Injector 1 drive	Circuit fault
P0264	Injector 2 drive	Circuit fault
P0265	Injector 3 drive	Circuit fault
P0267	Injector 3 drive	Circuit fault
P0268	Injector 3 drive	Circuit fault
P0270	Injector 4 drive	Circuit fault
P0271	Injector 4 drive	Circuit fault
P0301	Cylinder 1	Misfire
P0302	Cylinder 2	Misfire
P0303	Cylinder 3	Misfire
P0304	Cylinder 4	Misfire
P0335	Crankshaft Position (CKP) sensor	No signal
P0340	Camshaft Position (CMP) sensor	No signal
P0351	Ignition coil 1	Signal missing
P0352	Ignition coil 2	Signal missing
P0420	Main catalytic converter	Catalyst general failure
P0444	Purge valve drive	Circuit fault
P0445	Purge valve drive	Circuit fault
P0462	Fuel tank level input	Circuit fault
P0463	Fuel tank level input	Circuit fault
P0480	Radiator fan drive	Circuit fault
P0481	Condensor fan drive	Circuit fault
P0500	Vehicle speed sensor	Signal fault

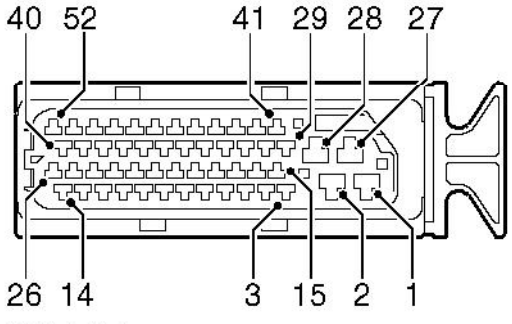
P Code	Component	Description
P0501	Vehicle road speed input	Signal implausable
P0505	Idle speed stepper motor (IACV)	Short circuit to battery or earth or open circuit
P0532	Air conditioning pressure sensor	Circuit fault
P0533	Air conditioning pressure sensor	Circuit fault
P0562	Battery voltage input	Circuit fault
P0563	Battery voltage input	Circuit fault
P0650	Malfunction Indicator Lamp (MIL)	Circuit fault
P1185	Upstream (pre-catalyst) oxygen heater sensor	Electrical fault
P1186	Upstream (pre-catalyst) oxygen sensor heater	Electrical fault
P1191	Downstream (post catalyst) oxygen sensor heater	Electrical fault
P1192	Downstream (post catalyst) oxygen heater sensor	Electrical fault
P1231	Fuel pump relay	Circuit fault
P1232	Fuel pump relay	Circuit fault
P1300	Main catalytic converter	Misfire causing catalyst damage
P1316	Cylinder block	Misfire causing increased emissions
P1506	Idle Air Control Valve (IACV) stepper motor drive	Circuit fault
P1507	Idle Air Control Valve (IACV) stepper motor drive	Circuit fault
P1508	Idle Air Control Valve (IACV) stepper motor drive	Circuit fault
P1537	Air conditioning drive	Circuit fault
P1538	Air conditioning drive	Circuit fault
P1590	Rough road sensor	Signal fault
P1610	Main relay drive	Circuit fault
P1611	Main relay drive	Circuit fault
P1640	CAN Bus	CAN message failure

ECM Harness Connector Details

The following tables give input/output information for the two harness connectors used on the ECM.

Connector C0914 (black) - 52 pin

Connector C0914 is used to provide inputs and outputs from and to the ECM for engine sensor operation.



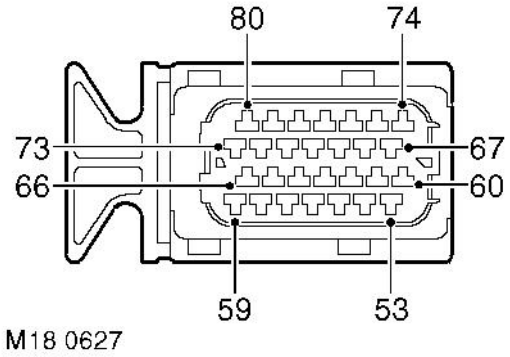
M18 0626

Pin No.	Description	Input/Output
1	HO2S (pre-catalyst) heater drive	Output
2	Not used	-
3	HO2S (post catalyst) positive	Output
4	CKP sensor positive	Output

Pin No.	Description	Input/Output
5	Not used	-
6	Engine oil temperature sensor earth	Input
7	ECT sensor earth	Input
8	MAP sensor supply +5V	Output
9	Not used	-
10	MAP sensor intake air temperature signal	Not used
11	Not used	-
12	Not used	-
13	IACV stepper motor phase B	Input/Output
14	Injector 3 earth	Input
15	HO2S (pre catalyst) positive	Output
16	CMP sensor signal	Input
17	CKP sensor screened earth	Input
18	IAT sensor earth	Earth
19	Main relay 12V supply	Input
20	TP sensor signal	Input
21	Not used	-
22	Not used	-
23	Not used	-
24	IACV stepper motor phase D	Input/Output
25	Injector 1 earth	Input
26	Ignition coil 2 earth	Input
27	HO2S (post catalyst) heater drive	Output
28	HO2S (post catalyst) screened earth	Input
29	HO2S (post catalyst) negative	Input
30	CKP sensor negative	Input
31	MAP sensor earth	Input
32	Engine oil temperature sensor signal	Input
33	ECT sensor signal	Input
34	TP sensor earth	Input
35	Alternator load signal	Input
36	Not used	-
37	A/C evaporator temperature sensor earth	Input
38	EVAP Purge valve drive	Output
39	IACV stepper motor phase A	Input/Output
40	Injector 4 earth	Input
41	HO2S (pre-catalyst) negative	Input
42	CMP sensor earth	Input
43	Not used	-
44	IAT sensor signal	Input
45	MAP sensor signal	Input
46	TP sensor supply +5V	Output
47	A/C evaporator temperature sensor signal	Input
48	Not used	-
49	Not used	-
50	IACV stepper motor phase C	Input/Output
51	Injector 2 earth	Input
52	Ignition coil 1 earth	Input

Connector C0913 (black) - 28 pin

Connector C0913 is used to provide inputs and outputs from and to the ECM for A/C, immobilisation, ABS ECU and diagnostic information.



Pin No.	Description	Input/Output
53	A/C clutch relay coil earth	Input
54	Main relay coil earth	Input
55	Not used	
56	Not used	-
57	A/C pressure sensor supply +5V	Output
58	Diagnostic ISO 9141 K Line	Input/Output
59	Main earth 1	Input
60	Cooling fan relay coil earth (non A/C)	Input
61	Ignition switch signal	Input
62	Not used	-
63	Not used	-
64	Not used	-
65	CAN Positive	Input/Output
66	Main earth 3	Input
67	PWM fan drive (A/C only)	Input
68	Fuel pump relay coil earth	Input
69	Not used	-
70	A/C pressure sensor signal	Input
71	A/C pressure sensor earth	Input
72	EWS3D Immobilisation coded signal	Input
73	Main earth 2	Input
74	Not used	-
75	Not used	-
76	Not used	-
77	Throttle pedal switch	Input
78	Not used	-
79	CAN Negative	Input/Output
80	Battery permanent supply - Engine compartment fusebox Fuse 2	Input

Operation

Acceleration Enrichment
When the throttle pedal is depressed, the ECM receives a rising voltage from the TP sensor and detects a rise in manifold pressure from the MAP sensor. The ECM provides additional fuel by increasing the normal injector pulse width and also provides a number of extra additional pulses on rapid throttle openings.

Over-Run Fuel Cut-Off
The ECM implements over-run fuel cut-off when the engine speed is above 1600 rpm with the engine at normal operating temperature and the TP sensor in the closed position, i.e. when ECM senses that the vehicle is 'coasting' with the throttle pedal released. The ECM indexes the IACV open slightly to increase the air flow through the engine to maintain a constant manifold depression to keep emissions low.

Fuel is immediately reinstated if the throttle is opened. If the engine speed drops below 1600 rpm on over-run, fuel is progressively reinstated.

Over-Speed Fuel Cut-Off
To prevent damage at high engine speeds the ECM will implement fuel cut-off at engine speeds above approximately 7000 rpm. Fuel is reinstated as the engine speed falls.

Ignition Switch Off
In the first 10 seconds after the ignition is switched off, the ECM drives the IACV to its power down position (ready for the next engine start), and stores any required information.

The ECM also monitors engine coolant temperature using the ECT sensor. Refer to Engine Cooling Fans - Description in this section for cooling fan switching temperatures.

Fuel Quantity
The ECM controls fuel quantity by providing sequential injection to the cylinder head intake ports. Sequential injection allows each injector to deliver a precise amount of fuel to the cylinder intake ports, during the induction stroke, in cylinder firing order.

The CMP sensor and reluctor allows the ECM to synchronise injection at cranking speed for starting. The precise quantity of fuel delivered is controlled by adjusting the duration of the injector open time.

To achieve optimum performance the ECM is able to 'learn' the individual characteristics of an engine and adapt the fuelling strategy to suit. This capability is known as adaptive fuel strategy.

Adaptive fuel strategy must be maintained under all throttle positions except:
- Cold start.
- Hot start.
- Wide open throttle.

All of the above throttle positions are deemed to be 'open loop'. Open loop fuelling does not rely on information from the HO2S, but sets the air/fuel ratio (AFR) according to the stored data in the ECM.

During a cold start, the ECM references the ECT sensor to calculate the appropriate amount of fuel required to support combustion and adjusts the idle speed to the correct 'fast idle' value. This strategy is maintained until the HO2S is hot enough to provide an accurate feedback signal.

The specific nature of the other open loop conditions means that the HO2S feedback is unsuitable as a control value for fuelling. Adaptive strategy also allows the ECM to compensate for wear in engine components and allow for production tolerances in mass produced components such as sensors.

To calculate the amount of fuel to be injected into each cylinder, the ECM has to determine the quantity of oxygen available in the cylinder to burn it. This can be calculated by processing information from the following sensors:
- MAP sensor.
- CKP sensor.
- ECT sensor.
- TP sensor.

During one engine revolution, 2 of the 4 cylinders draw in air. The ECM uses the CKP sensor signal to determine the potential air intake volume in the cylinders.

The oxygen content of the air contained in the cylinders can be calculated by the ECM using information from the MAP sensor and the IAT sensor. The pressure of the air in the intake manifold will vary according to the following factors:

- The position of the throttle valve (driver input).
- The atmospheric pressure (altitude and weather conditions).
- The mechanical condition of the engine (volumetric efficiency).

The pressure in the intake manifold, downstream of the throttle valve, indicates how much air has flowed into the cylinders. This will decrease at higher altitudes as the air becomes 'thinner' or less dense. This will also mean that there will be less oxygen contained in the air which will be available for combustion of fuel.

The temperature of the air will also affect the oxygen content. Air which is cool has molecules packed closer together than hot air, therefore; cooler air contains more oxygen for any given volume than hotter air.

From the above information, the ECM can calculate how much air has been induced into the cylinders. By comparing these values to a fuelling map stored in the ECM memory, the amount of oxygen induced into the cylinders can be calculated. The values obtained from the ECT sensor, engine oil temperature sensor and TP sensor provide 'fine tuning' to the calculations.

To deliver the fuel the ECM completes an earth path to the injector coil, opening the injector for the precise amount of time required for the quantity determined. The correct cylinder order is determined by referencing the CMP sensor during start up to synchronise the CMP sensor signal to the CKP sensor signal. The fuel is injected into the inlet ports of the intake manifold and is drawn into the cylinder as an air and fuel mixture.

The ECM ensures that the amount of fuel injected is not affected by the variations in inlet manifold pressure. The ECM corrects the injector duration time, using MAP sensor information.

The ECM references battery voltage to adjust opening times to suit the state of battery charge. This is required because low battery voltage will mean slower response from the injectors, and could give a leaner AFR than intended.

Ignition Timing

The ignition timing is an important part of the ECM adaptive strategy. The ignition system consists of two double ended coils, mounted on the cam cover directly over the spark plugs, which operate using the wasted spark principle. Each coil is connected to a pair of spark plugs, 1 and 4, 2 and 3.

The spark plugs are connected in series with the secondary winding of the coil so a spark occurs in both cylinders at the same time. When a spark occurs in the two cylinders which are on the compression stroke the air/fuel charge is ignited. The spark has no effect on the two cylinders at the end of the exhaust stroke, hence the term 'wasted spark'.

The major advantage of this system is that a distributor cap and rotor arm are eliminated thereby improving performance and reliability. The timing of the spark will affect the quality of combustion and the power produced.

The ECM will reference all relevant sensors to achieve the optimum timing for any given condition. This electronically increases the primary coil charging time (dwell angle) as engine speed increases to maintain coil HT voltage at high engine speeds.

The ECM calculates ignition timing using inputs from the following:

- CKP sensor.
- TP sensor.
- ECT sensor.
- IAT sensor.

The ECM calculates dwell angle using inputs from the following:

- CKP sensor.
- Battery voltage.

At start up the ECM sets ignition timing by referencing the ECT sensor. After start up, the ignition timing will be controlled according to maps stored in the memory and modified according to additional sensor inputs.

The choice of ignition point is critical in maintaining engine power output with low emissions. Advancing the ignition may increase power output under certain conditions, but it also increases the amount of oxides of nitrogen (NOx) and carbon monoxide (CO) produced in the combustion chamber.

There is a narrow range of ignition points for all engine conditions which give an acceptable compromise between power output and emission control.

The ignition mapping contained within the ECM memory keeps the ignition timing within this narrow band. The ignition timing is used to control engine idle speed in conjunction with the IACV stepper motor.

As the MEMS 3 system does not have a knock sensor, ignition timing advance is controlled using different mapping at high engine and intake air temperatures in order to avoid detonation (pinking).

Idle Speed Control

The ECM regulates the engine speed at idling. The ECM uses two methods of idle speed control:

- Ignition timing adjustment
- IACV stepper motor.

When the engine idle speed fluctuates and there are no additional loads on the engine, the ECM will vary the ignition timing and the IACV to regulate the idle speed. This allows very rapid correction of out of tolerance idle speeds. When an additional load is placed on the engine, such as when the power steering is turned on full lock, the ECM uses the IACV stepper motor to control the idle speed to specification.

The idle speed is determined from the CKP sensor, but there are also inputs to the ECM from the following:

- Alternator
- A/C system Cooling fan status
- A/C compressor on/off status.

If the ECM receives information from the above inputs that an extra load is being placed on the engine, it can immediately compensate and avoid engine poor idle or stall conditions.

The IACV stepper motor is mounted on the inlet manifold and controls a throttle valve air bypass port. To increase the idle speed, the stepper motor allows more air to bypass the throttle and enter the cylinders. To decrease the idle speed, the stepper motor allows less air to enter the cylinders.

The stepper motor is a bi-polar type which consists of two windings controlled by Pulse Width Modulated (PWM) signals from the ECM.

The position of the stepper motor is always referenced on power down of the ECM, this may take from three to five seconds. The stepper motor is also used to reduce manifold vacuum during deceleration to control emissions.

Evaporative Emission (EVAP) Control System

The hydrocarbon vapour given off by petrol is harmful to health and the environment. Legislation limits the amount of hydrocarbons (HC) which can be emitted to atmosphere by a motor vehicle.

To meet the limits imposed, a charcoal canister is fitted to the fuel system to absorb fuel vapour from the tank when the vehicle is not in use. The charcoal canister has a finite capacity and therefore needs to be purged when the vehicle is driven.

This is achieved by drawing the fuel vapours out of the canister and into the cylinders of the engine. The HC vapours are converted into carbon dioxide (CO_2) and water (H_2O) by the combustion process and catalytic converter.



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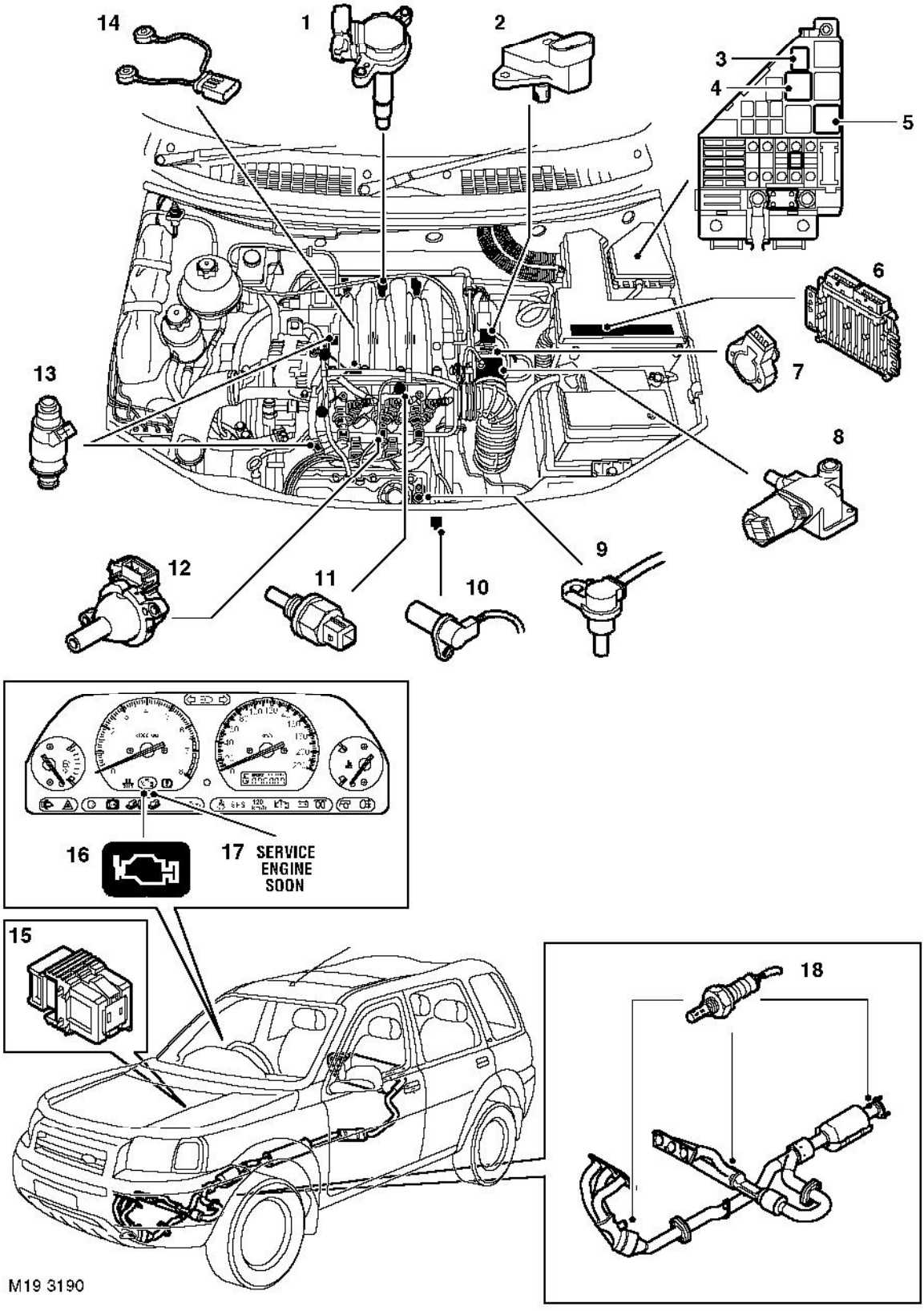
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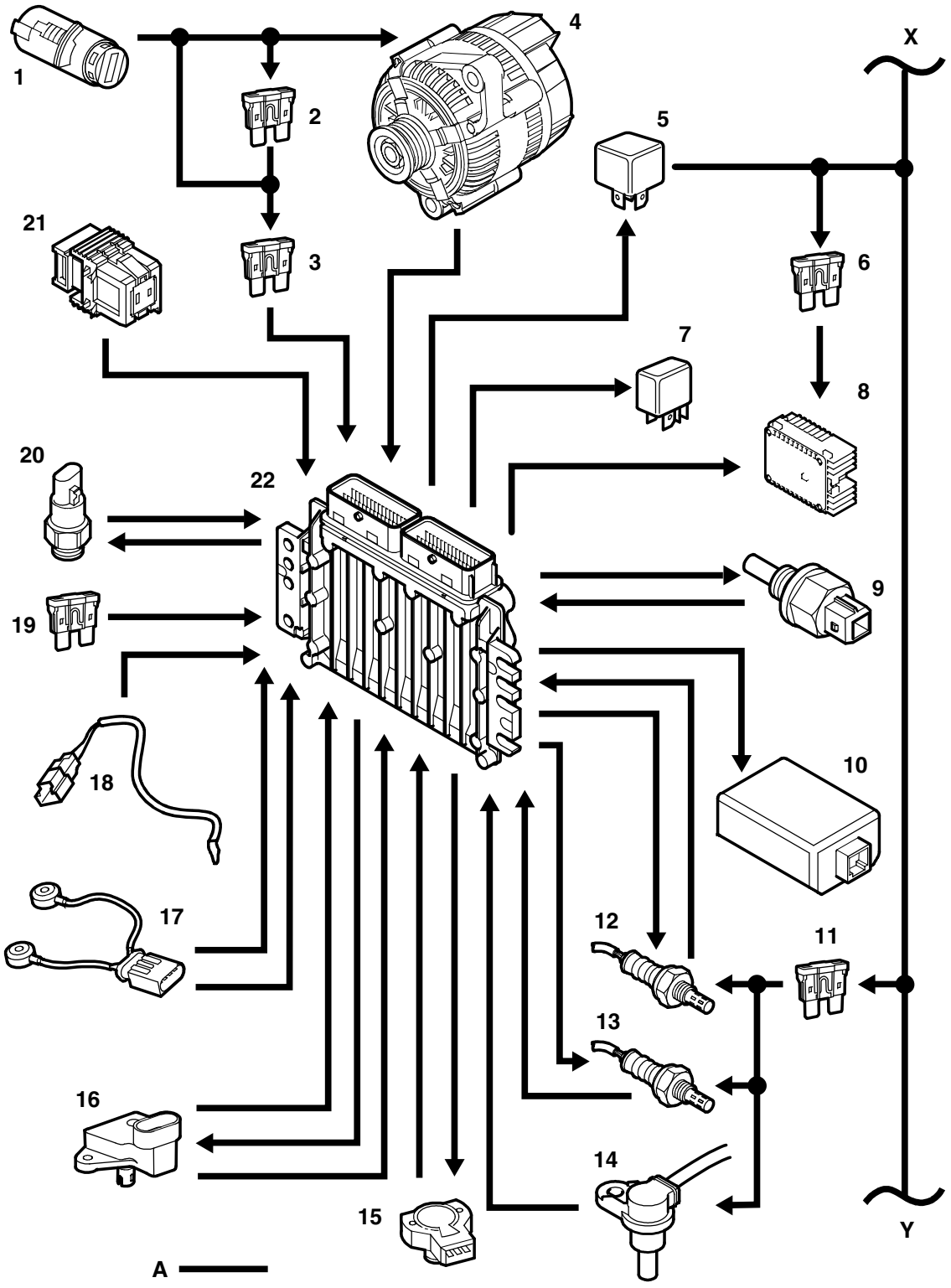
Engine Management System Component Layout



RHD shown, LHD similar

1 RH bank ignition coil (x 3)
2 IAT/MAP sensor
3 A/C compressor clutch relay
4 Main relay
5 Fuel pump relay
6 ECM
7 TP sensor
8 IAC valve
9 CKP sensor
10 CMP sensor
11 ECT sensor
12 LH bank ignition coil (x 3)
13 Fuel injector (x 6)
14 Knock sensors
15 Accelerator pedal position sensor
16 MIL (all except NAS)
17 MIL (NAS)
18 HO2S (x 3)

Engine Management System Control Diagram – Sheet 1 of 2

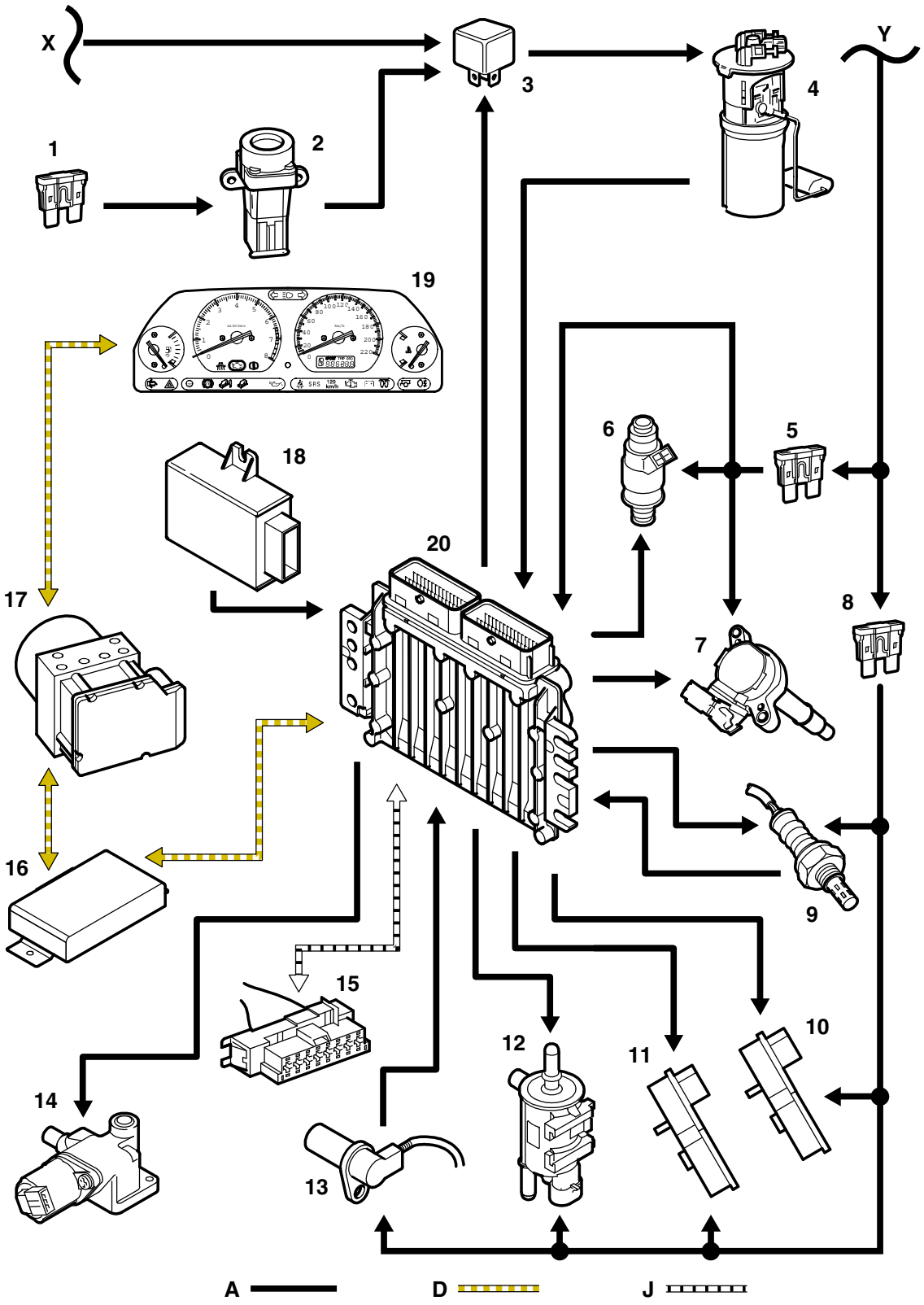


M19 3191

A = Hardwired connection

1 Ignition switch
2 Fuse 19, passenger compartment fusebox
3 Fuse 6, passenger compartment fusebox
4 Alternator
5 Main relay
6 Fuse 4, engine compartment fusebox
7 A/C compressor relay
8 Cooling fan ECU
9 ECT sensor
10 Cruise control interface ECU
11 Fuse 3, engine compartment fusebox
12 LH front HO2S
13 RH front HO2S
14 CMP sensor
15 TP sensor
16 IAT/MAP sensor
17 Knock sensors
18 A/C evaporator temperature sensor
19 Fuse 5, engine compartment fusebox
20 A/C refrigerant pressure sensor
21 Accelerator pedal position sensor
22 ECM

Engine Management System Control Diagram – Sheet 2 of 2



M19 3192

A = Hardwired connection; D = CAN bus; J = Diagnostic ISO 9141 K line

1 Fuse 10, engine compartment fusebox
2 Inertia fuel cut-off switch
3 Fuel pump relay
4 Fuel tank unit
5 Fuse 2, engine compartment fusebox
6 Fuel injector (x 6)
7 Ignition coil (x 6)
8 Fuse 1, engine compartment fusebox
9 Rear HO2S
10 VIS balance valve motor
11 VIS power valves motor
12 EVAP canister purge valve
13 CKP sensor
14 IAC valve
15 Diagnostic socket
16 EAT ECU
17 ABS modulator
18 Immobilisation ECU
19 Instrument pack
20 ECM

Description

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.
  ☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**
- Cooling fans.
- Evaporative emissions (EVAP) canister purge valve.
  ☞ **EMISSION CONTROL - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**
- Fuel pump.
  ☞ **FUEL DELIVERY SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**
- Variable Intake System (VIS).
  ☞ **MANIFOLD AND EXHAUST SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

The EMS interfaces with the:

- Immobilisation ECU, for re-mobilisation of the engine fuel supply.
  ☞ **SECURITY, DESCRIPTION AND OPERATION, Description.**
- Cruise control interface ECU, to enable the system.
  ☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**
- Electronic Automatic Transmission (EAT) ECU, to assist with control of the gearbox.
  ☞ **AUTOMATIC GEARBOX - JATCO, DESCRIPTION AND OPERATION, Description.**

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.

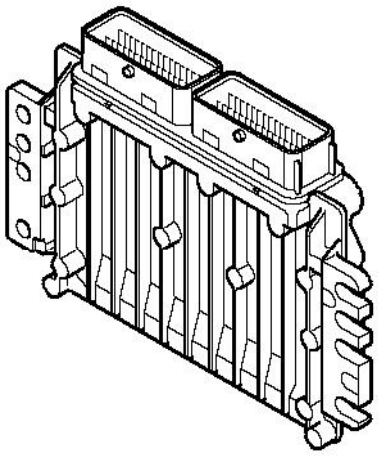
A 'flash' Electronic Erasable Programmable Read Only Memory (EEPROM) allows the ECM to be externally configured, using TestBook, with market specific or new information.

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. After battery reconnection or recharging, 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.

ECM



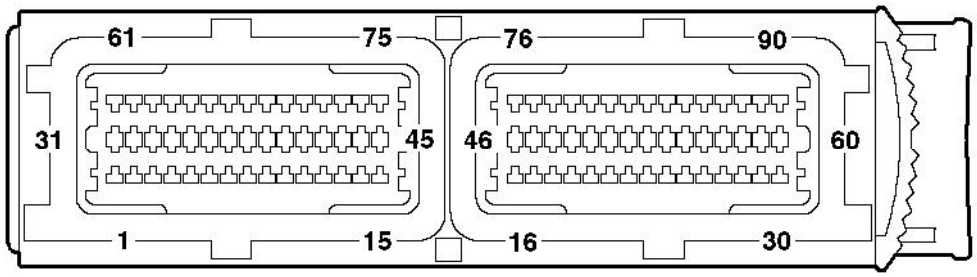
M19 3199

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.

The E-box is a lidded container that provides a protected environment for the ECM and the EAT ECU. An open hub, centrifugal fan powered by an electric motor ventilates the E-box with air from the passenger compartment. Exhaust 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 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, the thermostatic switch opens and stops the fan. To prevent the fan seizing up in colder climates, where it may not operate for long periods of time, the fan also receives a power feed direct from the starter circuit so that it runs each time the engine is cranked.

Inputs and Outputs
The ECM inputs and outputs are detailed in the Table below:

ECM Harness Connector (C0371)



M19 3200

ECM Harness Connector Pin Details

Pin No.	Description	Input/Output
1	Ignition coil 4	Output
2	Ignition coil 3	Output
3	ECM earth	-
4	EVAP canister purge valve	Output
5 and 6	Not used	-
7	Main relay	Output
8	VIS balance valve motor supply	Output
9	Fuel pump relay	Output
10	Cruise control enable (where fitted)	Output
11	Not used	-
12	IAT/MAP sensor earth	-
13	LH front HO2S signal	Input
14	RH front HO2S signal	Input
15	ECT sensor earth	Input
16	Rear HO2S signal	Input
17	A/C pressure sensor signal	Input
18	CKP sensor earth	-
19	CMP sensor earth	-
20	LH knock sensor signal	Input
21 and 22	Not used	-
23	VIS power valve motor position feedback	Input
24 to 26	Not used	-
27	CAN bus high	Input/Output
28	ECM earth	-
29	Ignition power supply	Input
30	Permanent battery power supply	Input
31	Ignition coil 6	Output
32	Ignition coil 5	Output
33	ECM earth	-
34	RH front HO2S heater	Output
35	Rear HO2S heater	Output
36	LH front HO2S heater	Output
37	Not used	-
38	VIS power valve motor supply	Output
39 to 41	Not used	-
42	IAC valve stepper motor (step 3)	Output
43	Not used	-
44	Throttle position sensor signal	Input



Pin No.	Description	Input/Output
45	ECT sensor signal	Input
46	Evaporator temperature sensor signal	Input
47	IAT/MAP sensor (IAT signal)	Input
48	Not used	-
49	Accelerator pedal position sensor	Input
50	RH knock sensor signal	Input
51	Alternator (engine running signal)	Input
52	Mobilisation signal	Input
53	Sensor earth (A/C pressure and evaporator temperature sensors)	-
54	CKP sensor signal	Input
55	Not used	-
56	Diagnostic ISO 9141 K line	Input/Output
57	CAN bus low	Input/Output
58	Fuel injector 4	Output
59	Fuel injector 2	Output
60	Fuel injector 1	Output
61	Ignition coil 1	Output
62	Ignition coil 2	Output
63	ECM earth	-
64	A/C compressor relay	Output
65	Not used	-
66	Power supply from main relay	Input
67	ECM earth	-
68	Not used	-
69	Cooling fan PWM signal	Output
70	IAC valve stepper motor (step 2)	Output
71	IAC valve stepper motor (step 1)	Output
72	IAC valve stepper motor (step 4)	Output
73	IAT/MAP sensor (MAP signal)	Input
74	Throttle position sensor reference supply	Output
75	Throttle position sensor earth	-
76	Rear HO2S heater earth	-
77	LH and RH front HO2S heater earth	-
78	IAT/MAP sensor reference supply	Output
79	Not used	-
80	Knock sensors earth	-
81	A/C pressure sensor supply	Output
82	CMP sensor signal	Input
83	Not used	-
84	VIS balance valve motor position feedback	Input
85 to 87	Not used	-
88	Fuel injector 3	Output
89	Fuel injector 5	Output
90	Fuel injector 6	Output

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.

ECM CAN Messages

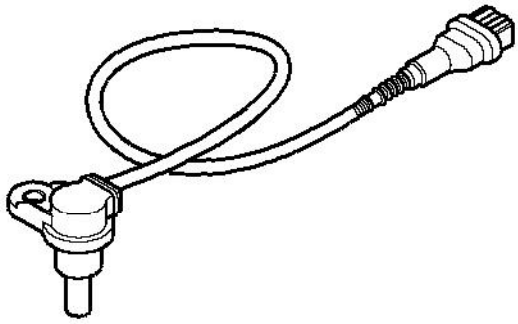
Inputs	Outputs
A/C request. Instrument pack requests A/C on when A/C switch and blowers are on. Used for condenser clutch and cooling fan control.	Actual engine torque. Current engine torque including any torque reduction. Expressed as a percentage of maximum engine torque. Used by EAT ECU for gear change scheduling.
Cooling request. Request by EAT ECU for additional cooling of the transmission fluid. The ECM switches on, or increases the speed of, the cooling fans.	Engine coolant temperature. Used by EAT ECU for diagnostic functions and to detect when the engine has completed a 'warm up' cycle. Used by instrument pack to drive engine temperature gauge.
Current/Target gear. EAT ECU informs the ECM what gear is currently engaged or, if a gear change is in progress, the gear to which the gearbox is changing. Used for engine load change prediction.	Engine friction. Informs the EAT ECU of the current frictional torque losses within the engine. Expressed as a percentage of maximum engine torque. Used for gear change scheduling.
Fuel level. Instrument pack informs the ECM of the level of fuel in the tank. Used for misfire monitoring.	Engine management fault. Indicates that a non emissions related fault has been detected.
Gear selector lever position. EAT ECU informs the ECM of the gear selector lever position selected by the driver. Used for idle speed control.	Engine speed. Used by EAT ECU to calculate gearbox oil pressure to assist with gear change scheduling. Also used by instrument pack to drive tachometer.
Gear change in progress. EAT ECU informs the ECM when a gear change is in progress. Used at idle speed to compensate for engine load changes during the gear change.	Engine speed error. Informs the EAT ECU if there is a fault with the engine speed calculation. If necessary, the EAT ECU adjusts gearbox operation to prevent possibility of mechanical damage.
Gearbox fault. EAT ECU informs the ECM there is a transmission fault that requires the MIL to be illuminated.	Engine torque error. Informs the ABS modulator and EAT ECU if there is an engine torque measurement error.
Rough road signal. From ABS modulator for use in misfire monitoring.	Fuel consumption. Used by instrument pack to calculate service intervals. Derived from fuel injection dwell times. Broadcast every 10 milli-seconds as cumulative volume used. Measured in micro-litres and begins counting from zero again when value reaches 65535 micro-litres.
Torque reduction request. ABS modulator requests the ECM to reduce engine torque to assist with traction control. Amount of torque reduction required expressed as a percentage of maximum engine torque.	Ignition switch status. Used to initiate the EAT ECU power-down routine at ignition off.
Torque reduction request. EAT ECU requests the ECM to reduce engine torque for a gear change (equivalent to lifting off the throttle in manual gearbox models). Amount of torque reduction required expressed as a percentage of maximum engine torque.	Indexed engine torque. Theoretical maximum engine torque for current engine operating conditions. Expressed as a percentage of maximum engine torque. Used by ABS modulator and EAT ECU for torque reduction request calculations and gear change scheduling.
Torque increase request. ABS modulator requests a minor increase in engine torque when brakes are off and ABS function is triggered by engine braking. Amount of torque reduction required expressed as a percentage of maximum engine torque.	MIL status. Indicates to instrument pack if MIL should be on or off. Used by EAT ECU to discontinue emissions related OBD.
Vehicle speed. Current vehicle speed as calculated by ABS modulator using mean wheel speeds.	Throttle angle. Used by EAT ECU for gear change scheduling (kickdown) and ABS modulator for hill descent control.
Brake intervention activity status. ABS modulator informs ECM when ABS, ETC or HDC functions use brake intervention. ECM suspends misfire detection during brake intervention.	

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.

Camshaft Position (CMP) Sensor



M19 3201

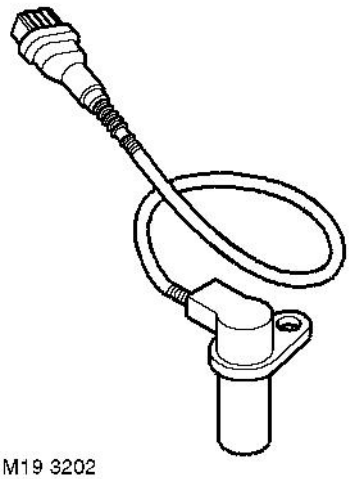
The CMP sensor provides a signal which enables the ECM to determine the position of the camshaft relative to the crankshaft. This allows the ECM to synchronise fuel injection for start and run conditions.

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.

Crankshaft Position (CKP) Sensor



M19 3202

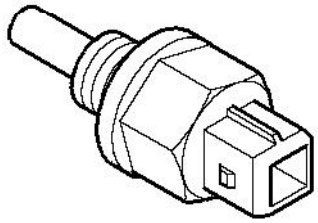
The CKP sensor provides the ECM with a digital signal of the rotational speed and angular position of the crankshaft, for use in ignition timing, fuel injection timing and fuel quantity calculations. To determine the exact position of the crankshaft in the engine cycle, the ECM must also use the input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

Engine Coolant Temperature (ECT) Sensor



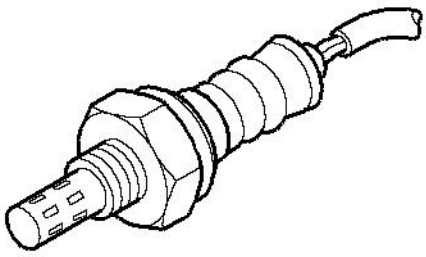
M19 3203

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.

Heated Oxygen Sensors (HO2S)



M19 3204

The EMS has three HO2S:

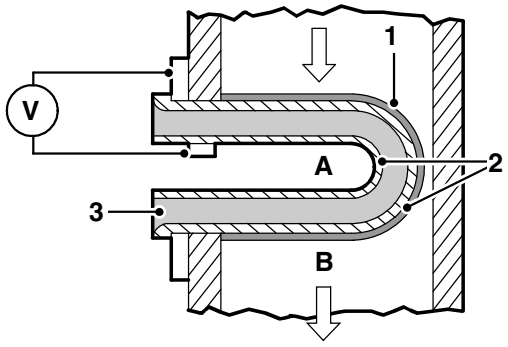
- One in each exhaust manifold, upstream of the starter catalytic converter, identified as LH and RH front HO2S.
- One in the exhaust front pipe immediately downstream of the main catalytic converter, identified as the rear HO2S.

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 (for explanation of lambda window, see ***Closed loop fuelling*** in **Operation**).

Sectioned View of HO2S



M19 3205

A = Ambient air; B = Exhaust gases

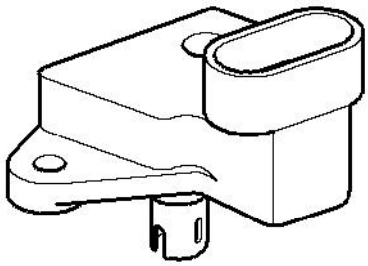
1 Protective ceramic coating
2 Electrodes
3 Zirconium oxide

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.

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



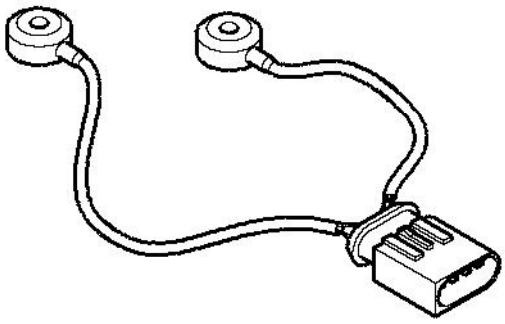
M19 3206

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



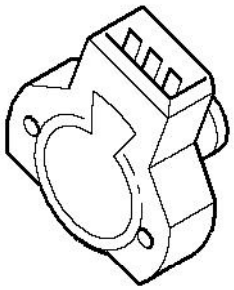
M19 3207

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



M19 3208

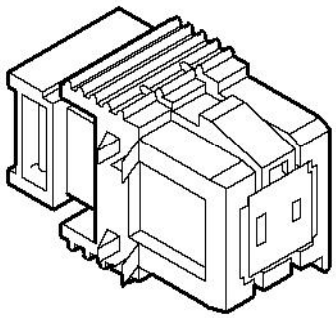
The TP sensor provides the ECM with a throttle plate position signal. The TP sensor is located on the throttle body.

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 0.14 V at closed throttle to 4.36 V 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.

Accelerator Pedal Position Sensor



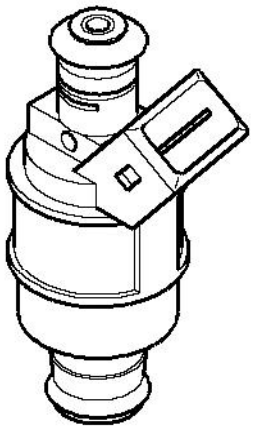
M19 3209

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).

Fuel Injectors



M19 3314

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.

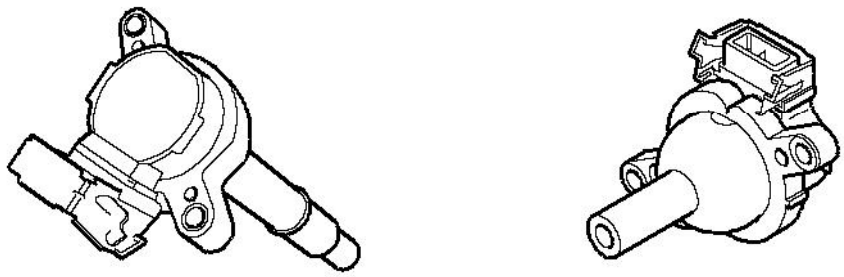
Each injector delivers fuel once per engine cycle, during the inlet stroke. The ECM calculates the open time (duty cycle) of the injectors from:

- 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/in^2) by a pressure regulator incorporated into the pump unit in the fuel tank. An accumulator is attached to the fuel rail on the RH 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).

Ignition Coils



M19 3211

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.

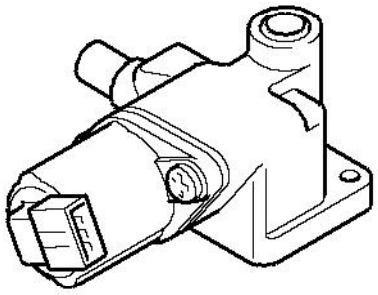
The ECM calculates dwell angle using inputs from the following:

- 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.

Idle Air Control (IAC) Valve



M19 3212

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 the 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.

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.

Operation

General

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.

Fuelling Control

The ECM controls the amount of fuel injected into the engine by adjusting the duty cycle of the fuel injectors. The amount of fuel required is a rolling process determined from maps of engine speed against mass air flow. The value from the map is then corrected for engine coolant temperature, throttle position, vehicle speed and any adaptive value stored in memory.

Mass air flow is calculated using engine speed, inlet air temperature and inlet air pressure. The engine speed indicates the volume of air flowing into the cylinders; the inlet air temperature and inlet air pressure indicate the density of the air. The pressure of the inlet air varies according to the following:

- The position of the throttle valve (driver input).
- The atmospheric pressure (altitude and weather conditions).
- The mechanical condition of the engine (volumetric efficiency).

To ensure the accuracy of the amount of fuel injected, the ECM monitors the fuel injector power supplies and, if necessary, adjusts the fuel injector duty cycle to compensate for low battery voltage. At lower voltages, fuel injector response is slower and, unless compensated for, results in a leaner AFR than intended.

The ECM operates the fuel injectors during their related cylinder's induction stroke, in cylinder firing order. Fuel injector timing is determined from the CMP and CKP sensor inputs.

Fuelling control operates in either closed loop or open loop.

Closed Loop Fuelling

Closed loop fuelling is used for the following conditions:

- Idle.
- Lower mass air flows.
- Cruise.



During closed loop fuelling the ECM maintains the AFR within a lambda window of 1.00 ± 0.03, where lambda 1.00 is equivalent to an AFR of 14.7 : 1 by weight. The ECM uses the inputs from the two front HO2S to monitor the engine's AFR and, if necessary, adds a correction to maintain the AFR within the lambda window. If, over a number of ignition cycles, a significant correction is consistently applied, the ECM stores the correction as an adaptive value.

The efficient operation of the catalytic converters relies on the ECM cycling the AFR from rich to lean within the lambda window, i.e. between lambda 0.97 and 1.03. The continuous cycling within the lambda window allows the catalytic converters to absorb and release oxygen for optimum efficiency.

Open Loop Fuelling

The ECM uses open loop fuelling when it is not possible or desirable to use feedback from the front HO2S to monitor the AFR. During open loop fuelling the ECM uses information from the engine sensors and fuelling maps to determine the required fuel quantity.

Open loop fuelling is used for the following conditions:

- Cold start.
- Warm up.
- Maximum mass air flow.
- Wide open throttle.
- Hot start.
- HO2S failure.

Cold Start: During cold starting the engine temperature is low enough to promote fuel condensation on the cold surfaces of the inlet manifold and cylinder walls. This would leave the AFR lean and the fuel content too poorly distributed to provide a readily combustible mixture. To overcome this the ECM increases the amount of fuel injected to produce a rich AFR and adjusts the idle speed to a 'fast idle' value.

Warm Up: Once the engine has fired, the ECM references the ECT, IAT/MAP, TP and CMP sensors to modify the fuelling as the engine warms up. As the engine temperature rises, the AFR is leaned off until the HO2S are functional and the ECM adopts closed loop fuelling.

Maximum Mass Air Flow/ Wide Open Throttle : For maximum power output on sudden opening of the throttle or continuous wide open throttle, the ECM switches to open loop fuelling and enriches the AFR to 12 : 1.

Hot Start: When a hot engine is turned off, the fuel in the injectors and injector rail absorbs heat, which causes the characteristics of the fuel to change. A hot start becomes more demanding due to difficulties in achieving the correct AFR and an even mixture distribution. To overcome this the ECM references the ECT sensor and enriches the AFR.

HO2S Failure: If the input from one of the front HO2S is missing, or outside tolerances, the ECM adopts open loop fuelling.

Overrun Fuel Cut-off

During overrun, if engine speed is sufficiently above stalling speed the ECM temporarily inhibits fuel injection. Fuel injection is reinstated when the throttle opens or engine speed approaches stalling speed. The engine speeds at which the ECM inhibits and reinstates fuel injection varies with coolant temperature; the lower the coolant temperature the higher the engine speeds.

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 the 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.

Catalytic Converter Monitoring

The ECM monitors the operating efficiency of the catalytic converters by comparing the input of the rear HO2S with the inputs from the two front HO2S.

Cooling Fans

The ECM controls the operation of the variable speed cooling fans via a Pulse Width Modulated (PWM) signal to the cooling fan ECU. The cooling fan ECU regulates the voltage of a common power feed to the two fans, and relates the voltage to the duty cycle of the PWM signal. The ECM varies the duty cycle of the PWM signal between 10 and 90% to vary the fan speed. If the PWM signal is outside the 10 to 90 % range, the cooling fan ECU interprets the signal as an open or short circuit and runs the fans at maximum speed to ensure the engine and gearbox do not overheat.

The ECM operates the fans in response to inputs from:

- The ECT sensor, for engine cooling. With the engine running, the fans come on at maximum speed if the coolant temperature increases to 105 °C (221 °F). The fans go off when the coolant temperature decreases to 102 °C (216 °F).
- The instrument pack and the A/C pressure sensor, for refrigerant system cooling (see **Air Conditioning (A/C)**, below).
- The EAT ECU, for gearbox cooling.

☞ **AUTOMATIC GEARBOX - JATCO, DESCRIPTION AND OPERATION, Description.**

If there is a conflict between requested fan speeds from the different inputs, the ECM adopts the highest requested speed.



As part of the power down routine, when the ignition is switched off the ECM samples the engine coolant temperature. If the coolant temperature is below 102 °C (216), the fans remain off. If the coolant temperature is between 102 and 105 °C (216 and 211 °F) the fans run at 8% of full speed for 5 minutes and then go off. If the coolant temperature is 105 °C (221 °F) or above, the fans run at 20% of full speed for 5 minutes and then go off.

Air Conditioning (A/C)

When the CAN bus message from the instrument pack requests A/C, the ECM grants the request by energising the A/C compressor clutch relay provided that:

- Driver demand is less than wide open throttle.
- The engine coolant temperature is within limits.
- There is no engine running problem.
- The engine is running below the maximum permitted continuous speed.
- The input from the A/C pressure switch indicates that refrigerant system pressure is within limits.
- The input from the evaporator temperature sensor indicates that the temperature of the air from the evaporator is above the minimum limit, i.e. the evaporator is free from ice.

When it energises the A/C compressor clutch relay, the ECM also operates the cooling fans. The fans run continuously while the compressor clutch is engaged. The speed of the cooling fans depends on refrigerant system pressure, with stepped changes of speed as refrigerant pressure increases and decreases.

Cooling Fan Speed Versus Refrigerant Pressure

Refrigerant pressure, bar (lbf/in²)	Fan speed, % of maximum
<16 (232)	43
16 to <20 (232 to <290)	55
20 to <23 (290 to <334)	63
23 to <30 (334 to <435)	67
30> (435>)	100

While the A/C is on, if the throttle position or engine coolant temperature exceed preset limits the ECM de-energises the A/C compressor clutch relay to suspend A/C operation and reduce the load on the engine. When the parameter returns within limits the ECM re-energises the A/C compressor clutch relay to restore A/C. Similarly, to protect the refrigerant system, the ECM suspends A/C operation if the refrigerant system pressure is not within the high and low limits.

A/C Compressor Clutch Switching Points

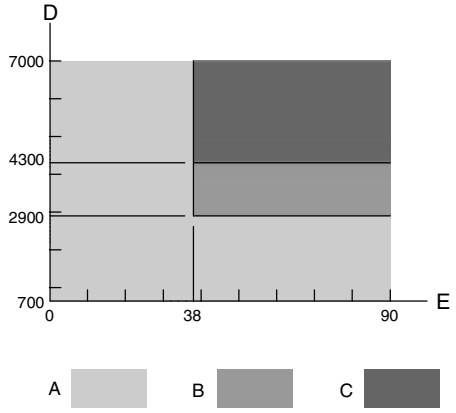
Input component	Compressor clutch	
	Disengaged	Engaged
TP sensor	Accelerating at maximum load	Stable at maximum load and below
ECT sensor	More than 118 °C (244 °F)	Less than 112 °C (234 °F)
A/C pressure sensor – low limit	1.6 bar (23.2 lbf/in²)	2.0 bar (29.0 lbf/in²)
A/C pressure sensor – high limit	29 bar (421 lbf/in²)	23 bar (334 lbf/in²)

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.

VIS Valve Operating Strategy



M19 3213

A = Balance valve open; power valves open; B = Balance valve closed; power valves open; C = Balance valve open; power valves closed; D = Engine speed, rev/min; E = Throttle opening, degrees

Gear Change Torque Reduction
The ECM retards the ignition timing to reduce engine torque during a gear change. Once the gear change is completed the ignition timing is returned to normal control.

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.

Diagnostic Trouble Codes

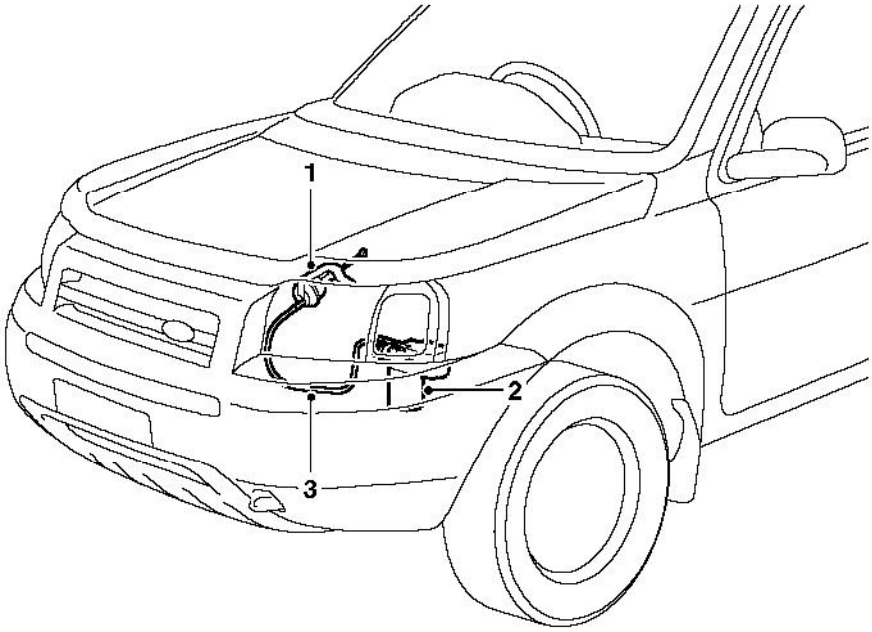
P Code	Component	Description	MIL
P0107	Manifold air pressure sensor (IAT/ MAP sensor pressure signal)	Short to battery or open circuit	Y
P0108	Manifold air pressure sensor (IAT/ MAP sensor pressure signal)	Short to earth	Y
P0112	Air intake temperature sensor (IAT/ MAP sensor temperature signal)	Short to battery or open circuit	Y
P0113	Air intake temperature sensor (IAT/ MAP sensor temperature signal)	Short to earth	Y



P Code	Component	Description	MIL
P0117	Coolant temperature sensor	Short to battery or open circuit	Y
P0118	Coolant temperature sensor	Short to earth	Y
P0122	Throttle position sensor	Short to battery or open circuit	Y
P0123	Throttle position sensor	Short to earth	Y
P0131	Upstream O2 sensor odd bank (LH front HO2S)	Air leakage, short to earth or open circuit	Y
P0132	Upstream O2 sensor odd bank (LH front HO2S)	Short to battery	Y
P0133	Upstream O2 sensor odd bank (LH front HO2S)	Slow response	Y
P0135	Upstream O2 sensor heater odd bank (LH front HO2S heater)	Short to battery, short to earth or open circuit	Y
P0137	Downstream O2 sensor (rear HO2S)	Air leakage, short to earth or open circuit	Y
P0138	Downstream O2 sensor (rear HO2S)	Short to battery	Y
P0140	Downstream O2 sensor (rear HO2S)	No activity detected	Y
P0141	Downstream O2 sensor (rear HO2S)	Short to battery, short to earth or open circuit	Y
P0151	Upstream O2 sensor even bank (RH front HO2S)	Air leakage, short to earth or open circuit	Y
P0152	Upstream O2 sensor even bank (RH front HO2S)	Short to battery	Y
P0153	Upstream O2 sensor even bank (RH front HO2S)	Slow response	Y
P0155	Upstream O2 sensor heater even bank (RH front HO2S heater)	Short to battery, short to earth or open circuit	Y
P0171	Fuelling odd bank (LH cylinder bank)	Lean limit	Y
P0172	Fuelling odd bank (LH cylinder bank)	Rich limit	Y
P0174	Fuelling even bank (RH cylinder bank)	Lean limit	Y
P0175	Fuelling even bank (RH cylinder bank)	Rich limit	Y
P0261	Injector 6	Short to earth or open circuit	Y
P0262	Injector 6	Short to battery	Y
P0264	Injector 5	Short to earth or open circuit	Y
P0265	Injector 5	Short to battery	Y
P0267	Injector 4	Short to earth or open circuit	Y
P0268	Injector 4	Short to battery	Y
P0270	Injector 3	Short to earth or open circuit	Y
P0271	Injector 3	Short to battery	Y
P0273	Injector 2	Short to earth or open circuit	Y
P0274	Injector 2	Short to battery	Y
P0276	Injector 1	Short to earth or open circuit	Y
P0277	Injector 1	Short to battery	Y
P0300	Cylinder banks	Misfire, increased emissions	Y
P0301	RH cylinder bank	Misfire detected cylinder 6	Y
P0302	LH cylinder bank	Misfire detected cylinder 5	Y
P0303	RH cylinder bank	Misfire detected cylinder 4	Y
P0301	RH cylinder bank	Misfire detected cylinder 6	Y
P0302	LH cylinder bank	Misfire detected cylinder 5	Y
P0303	RH cylinder bank	Misfire detected cylinder 4	Y
P0325	Knock sensor odd bank (RH knock sensor)	Noise level too low	Y
P0325	Knock sensor odd bank (RH knock sensor)	Noise level too low	Y

P Code	Component	Description	MIL
P0335	Crankshaft sensor	No signal	Y
P0336	Crankshaft sensor	Signal not plausible	Y
P0340	Camshaft sensor	No signal	Y
P0341	Camshaft sensor	Signal not plausible	Y
P0351	Ignition control signal coil A - cylinder 6	Short to battery, short to earth or open circuit	Y
P0352	Ignition control signal coil B - cylinder 5	Short to battery, short to earth or open circuit	Y
P0353	Ignition control signal coil C - cylinder 4	Short to battery, short to earth or open circuit	Y
P0354	Ignition control signal coil D - cylinder 3	Short to battery, short to earth or open circuit	Y
P0355	Ignition control signal coil E - cylinder 2	Short to battery, short to earth or open circuit	Y
P0356	Ignition control signal coil F - cylinder 1	Short to battery, short to earth or open circuit	Y
P0420	Catalytic converter	Malfunction	Y
P0444	Purge valve	Open circuit	Y
P0445	Purge valve	Short to battery or short to earth	Y
P0505	Idle speed stepper motor (IAC valve)	Short to battery, short to earth or open circuit	Y
P0562	System relay	Open circuit	Y
P0563	System relay	Short to battery	Y
P1230	Fuel pump relay	Open circuit	Y
P1231	Fuel pump relay	Short to earth	Y
P1232	Fuel pump relay	Short to battery	Y
P1319	Cylinder banks	Misfire at low fuel level	Y
P1320	CKP sensor	Flywheel adaption for misfire detection, adaption limit	Y
P1321	CKP sensor	Flywheel adaption for misfire detection, tooth error	Y
P1470	Variable intake balance valve	Always open	Y
P1471	Variable intake balance valve	Always closed	Y
P1472	Variable intake butterfly (power) valves	Always open	Y
P1473	Variable intake butterfly (power) valves	Always closed	Y
P1474	Variable intake balance valve	Short to battery	Y
P1475	Variable intake balance valve	Short to earth or open circuit	Y
P1476	Variable intake butterfly (power) valves	Short to battery	Y
P1477	Variable intake butterfly (power) valves	Short to earth or open circuit	Y
P1510	Cruise control enable (interface ECU)	Short to battery	Y
P1511	Cruise control enable (interface ECU)	Short to earth or open circuit	Y
P1537	A/C compressor clutch relay	Short to earth or open circuit	N
P1538	A/C compressor clutch	Short to battery	N
P1610	Main relay	Short to battery	Y
P1611	Main relay	Short to earth or open circuit	Y
P1630	Immobilisation ECU	Security code not received	N
P1631	Immobilisation ECU	Security code incorrect	N
P1641	CAN bus	Bus failure	Y
P1646	CAN bus	Automatic transmission message fault	Y
P1775	CAN bus	Auto gearbox ECU MIL request	Y

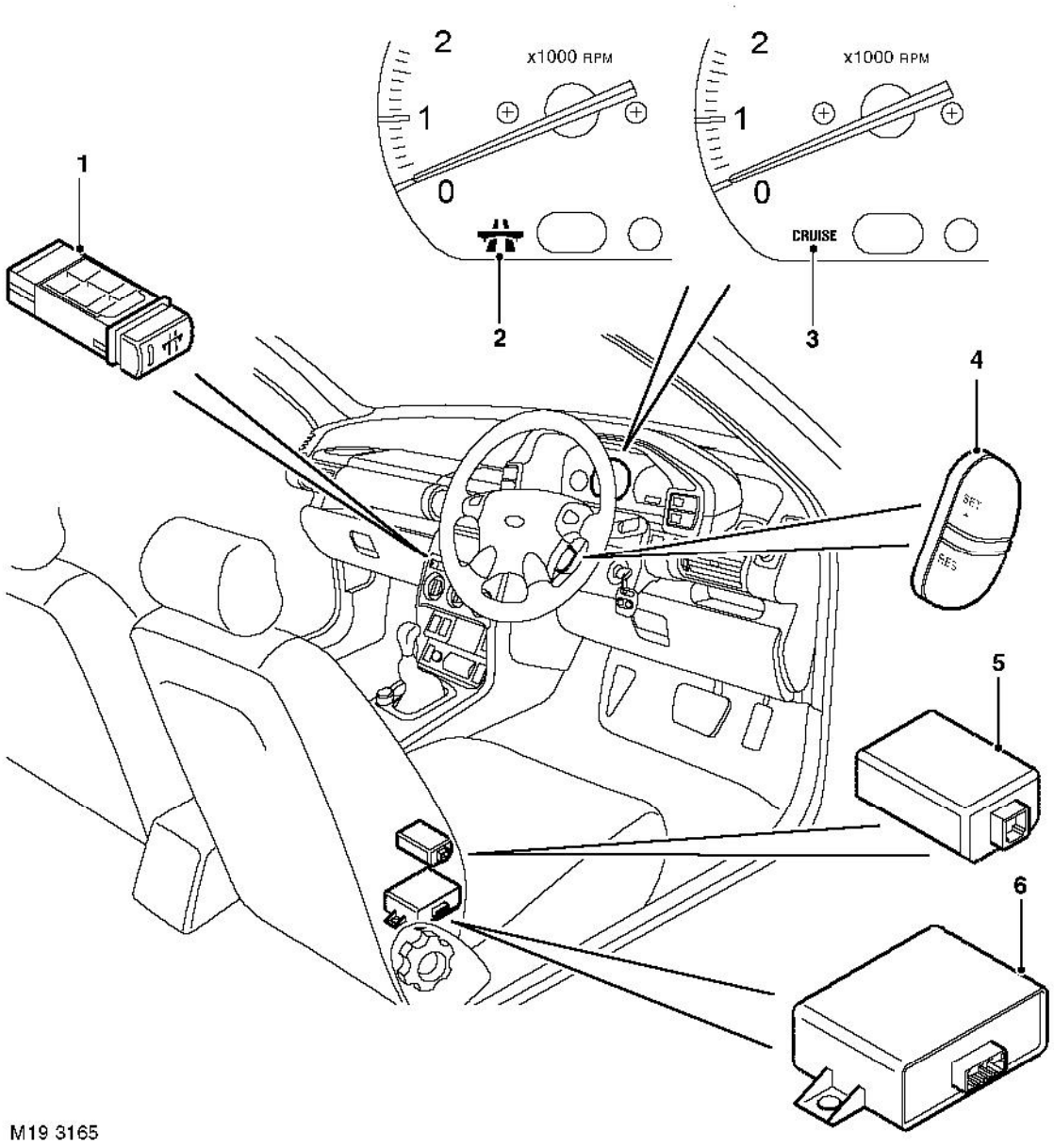
Cruise Control System Component Layout - Sheet 1 of 2



M19 3164

1 Vacuum actuator
2 Vacuum pump assembly
3 Pipe

Cruise Control System Component Layout - Sheet 2 of 2



RHD shown, LHD similar

1 Master switch
2 Warning lamp (all except NAS)
3 Warning lamp (NAS only)
4 Steering wheel switches
5 Interface ECU
6 Cruise control ECU



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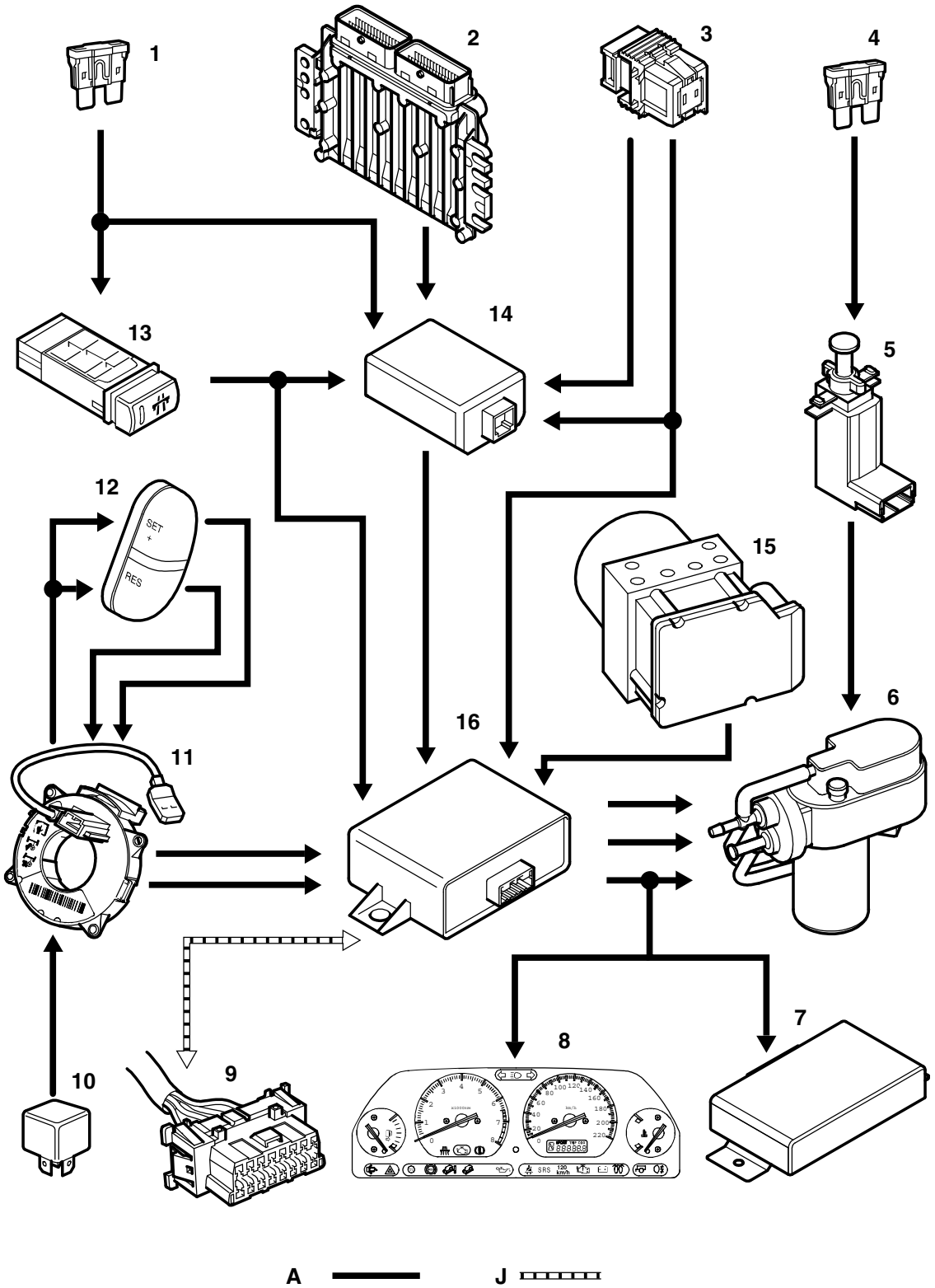
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Cruise Control System Control Diagram



A = Hardwired connection; J = Diagnostic ISO 9141 K line bus

1 Fuse 35, passenger compartment fusebox
2 ECM
3 Brake pedal position sensor
4 Fuse 2, passenger compartment fusebox
5 Brake pedal switch
6 Vacuum pump assembly
7 EAT ECU
8 Instrument pack
9 Diagnostic socket
10 Horn relay
11 Rotary coupler
12 Steering wheel switches
13 Master switch
14 Interface ECU
15 ABS modulator
16 Cruise control ECU

Description

General

The cruise control system is an electro-pneumatic system that uses throttle intervention to automatically maintain a set vehicle speed. Once engaged, the system can also be used to accelerate the vehicle without using the accelerator pedal. The cruise control system consists of:

- A master switch.
- SET+ and RES steering wheel switches.
- An interface ECU.
- A cruise control ECU.
- A warning lamp.
- A vacuum pump assembly.
- A vacuum actuator.

The system also uses inputs from:

- The brake pedal position sensor, brake pedal switch and Anti-lock Braking System (ABS) modulator.
  ☞ **BRAKES, DESCRIPTION AND OPERATION, Description.**
- The Engine Control Module (ECM).
  ☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**

Cruise control is enabled when the master switch is pressed and the vehicle is in a suitable driving configuration. Once enabled, the cruise control system is engaged using the steering wheel switches. The steering wheel switches output signals to the cruise control ECU, which runs the vacuum pump assembly to operate the vacuum actuator and produce the required control of the throttle.

The cruise control warning lamp provides a visual indication of when the system is engaged.

Master Switch

The master switch controls an ignition feed to the interface ECU and the cruise control ECU to enable the system. The switch is a mechanically latching push switch installed in the centre console switch panel. A green LED in the switch remains illuminated while the switch is latched.

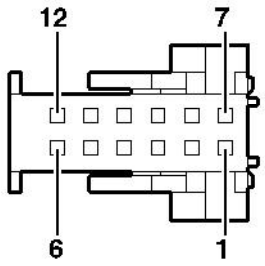
Steering Wheel Switches

The SET+ and RES steering wheel switches are non latching push switches that engage and disengage cruise control and adjust the set speed. While pressed, the switches connect a power feed from the battery, via the coil of the horn relay and the rotary coupler, to the cruise control ECU.

Interface ECU

The interface ECU controls the output of a power supply which is used by the cruise control ECU to operate the vacuum pump assembly. The interface ECU is installed below the front RH seat, adjacent to the cruise control ECU, below a plastic protective cover. The power supply is output to the cruise control ECU when the system is enabled by the master switch.

Interface ECU Harness Connector (C0895)



M18 0651

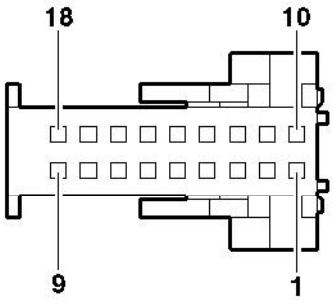
Interface ECU Harness Connector Pin Details

Pin No.	Description	Input/Output
1	Earth	-
2 and 3	Not used	-
4	Brake pedal position sensor	Input
5	ECM cruise enable	Input
6	Brake pedal position sensor	Input
7	Not used	Input
8	Ignition power supply	Input
9	Cruise control ECU power supply	Output
10	Not used	Output
11	Earth	-
12	Master switch	Input

Cruise Control ECU

The cruise control ECU controls the operation of the vacuum pump in response to inputs from the steering wheel switches. The cruise control ECU is installed below the front RH seat, adjacent to the interface ECU, below a plastic protective cover.

Cruise Control ECU Harness Connector (C0239)



M19 3167

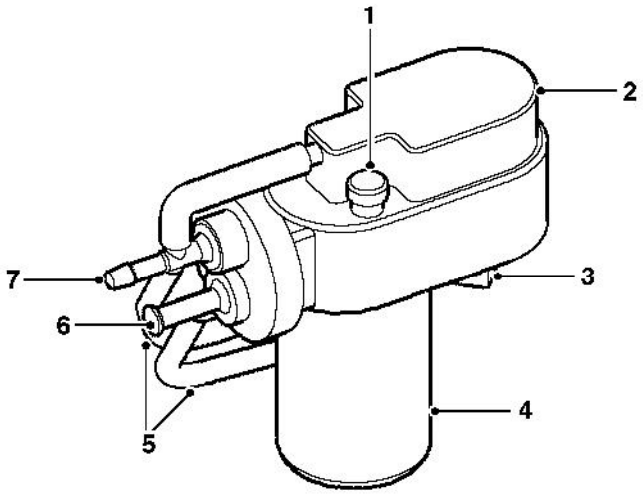
Cruise Control ECU Connector Pin Details

Pin No.	Description	Input/Output
1	Power supply (from interface ECU)	Input
2	RES switch	Input
3	Not used	-
4	SET+ switch	Input
5	Brake pedal position sensor	Input
6	Not used	-
7	Vacuum pump control	Output
8	Master switch	Input
9 and 10	Not used	-
11	Vacuum pump and valves supply	Output
12 to 14	Not used	-
15	Road speed	Input
16	Diagnostic ISO 9141 K line	Input/Output
17	Control valve signal	Output
18	System earth	-

Warning Lamp

The warning lamp indicates the status of the cruise control system. Located in the instrument pack, the warning lamp illuminates when cruise control is engaged, and consists of a motorway graphic on a yellow background (all except NAS) or a yellow CRUISE legend (NAS only).

Vacuum Pump Assembly

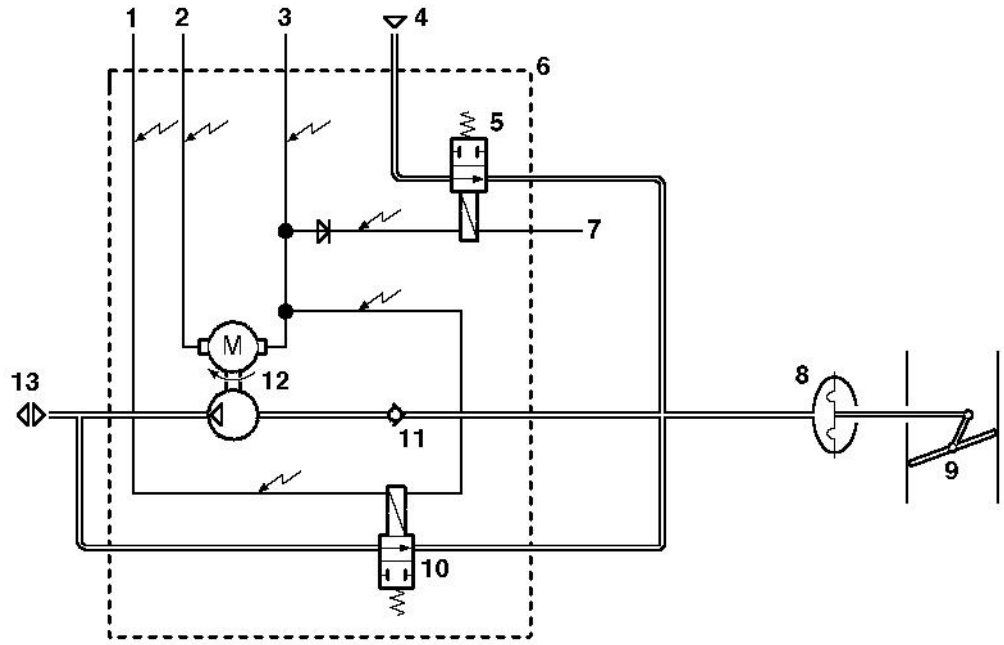


M19 3168

1 Vent
2 Valve housing
3 Electrical connector
4 Motor housing
5 Connecting hoses
6 Vent
7 Vacuum actuator connection

The vacuum pump assembly controls the operation of the vacuum actuator. The assembly is installed in the LH front corner of the engine compartment, on mounting rubbers attached to the front of the battery box. The assembly consists of a vacuum pump, driven by an electric motor, and two normally open solenoid valves: a control valve and a dump 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.

Vacuum System Schematic



M19 3169

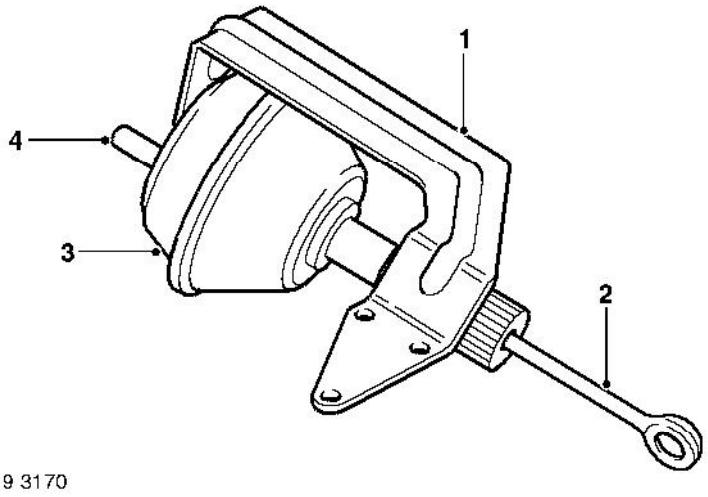
1 Control valve control signal
2 Vacuum pump control signal
3 Vacuum pump and valves supply
4 Vent
5 Dump valve
6 Vacuum pump assembly
7 Dump valve control signal
8 Vacuum actuator
9 Throttle
10 Control valve
11 Non return valve
12 Vacuum pump
13 Vent

When cruise control is selected and the vehicle is in the correct driving configuration, the cruise control ECU outputs the pump and valves power supply. The cruise control ECU also closes the control and dump valves, and runs the vacuum pump, using individual Pulse Width Modulated (PWM) control signals.

When the vacuum pump runs, it draws air through the non return valve and creates a depression on one side of the diaphragm in the vacuum actuator, which moves to open the throttle. When the vehicle is at the set speed, the cruise control ECU stops the vacuum pump, and the non return valve closes to maintain the depression in the vacuum actuator and hold the throttle in position. If vehicle speed decreases below the set speed, or a higher set speed is required, the cruise control ECU starts the vacuum pump again to increase the depression in the vacuum actuator and increase the throttle angle. If the vehicle speed increases above the set speed, the cruise control ECU opens the control valve to reduce the depression in the vacuum actuator and reduce the throttle angle.

When cruise control is disengaged, the cruise control ECU removes the pump and valves power supply from the vacuum pump assembly, to disable the vacuum pump and open the control and dump valves. The open valves allow atmospheric pressure into the vacuum actuator, which moves to close the throttle. The dump valve provides additional safety for the system, by ensuring the vacuum is released from the vacuum actuator even if the control valve remains closed or the control valve vent line is obstructed.

Vacuum Actuator



1 Mounting bracket
2 Actuating rod
3 Diaphragm chamber
4 Vacuum pipe connection

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.

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.

Brake Pedal 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.



ABS Modulator
The ABS modulator supplies a road speed signal to the cruise control ECU. The signal is supplied as a 12 volt square wave with a frequency of 8000 pulses/mile.

ECM
The ECM supplies a cruise control enable signal to the interface ECU when the vehicle is in a driving configuration suitable for cruise control operation. The ECM suspends the cruise control enable signal immediately the vehicle is not in the correct driving configuration or if an engine or gearbox fault occurs.

Operation

General
When the ignition is switched on, the interface ECU and the master switch receive a power feed from the passenger compartment fusebox. When the master switch is pressed, the LED in the master switch illuminates and further power feeds are connected to the interface ECU and the cruise control ECU to enable the system.

Cruise control is enabled provided the interface ECU is in receipt of a cruise enable signal from the ECM and the system inputs indicate that:
- The brakes are off.
- The vehicle is moving at a road speed between 22 and 125 mph (35 and 200 km/h).

The ECM outputs the cruise enable signal to the interface ECU, when:
- The engine is running and vehicle speed is above 3 mph (5 km/h).
- Engine speed does not exceed 6496 rpm.
- The gearbox is not in Park, Neutral or Reverse.
- Electronic Traction Control (ETC) is not active.

While the system is enabled, the interface ECU outputs the power supply to the cruise control ECU for operation of the vacuum pump assembly.

Engagement
When the system is enabled, cruise control is engaged by pressing the SET+ steering wheel switch. On receipt of the input from the SET+ switch, the cruise control ECU stores the current vehicle speed as the set speed and outputs the pump and valve power supply to the vacuum pump assembly. The cruise control ECU also outputs signals to operate the vacuum pump and control valves in the vacuum pump assembly. The vacuum pump and control valves regulate the vacuum sensed by the vacuum actuator, to adjust the throttle as necessary to maintain the vehicle at the set speed.

When cruise control is engaged, the pump and valve power supply is also connected to the EAT ECU and the instrument pack. On receipt of the power supply, the EAT ECU adopts the cruise control mode, which uses a gear change map less sensitive to changes of throttle opening to prevent unnecessary gear changes, which improves operating refinement for a minor loss of performance. In the instrument pack, the power supply illuminates the cruise control warning lamp.

Acceleration
While cruise control is engaged, the vehicle can be accelerated using either the SET+ switch or the accelerator pedal. A momentary press (less than 0.5 second) of the SET+ switch causes the cruise control ECU to increment the stored set speed by 1 mph (1.6 km/h) and operate the vacuum pump assembly to accelerate the vehicle to the new set speed. If the switch is held on, the cruise control ECU keeps incrementing the stored set speed and accelerating the vehicle until the switch is released. When the switch is released, the cruise control ECU adopts the increased vehicle speed as the new set speed.

If the accelerator pedal is used to accelerate the vehicle, the cable from the accelerator pedal overrides the vacuum actuator and increases the throttle opening to meet driver demand. Cruise control remains engaged and the set speed is resumed once the accelerator pedal is released. If the SET+ switch is pressed before the accelerator pedal is released, the cruise control ECU adopts the higher speed as the new set speed.

Suspend/Resume
Cruise control can be manually suspended and resumed (at the previous set speed) using the RES steering wheel switch. The interface ECU, the cruise control ECU and the ECM automatically suspend cruise control if one of the conditions required to enable the system is no longer present, e.g. the brakes are applied or ETC activates. Cruise control is also automatically suspended by the cruise control ECU if the vehicle speed decreases to less than 75% of the set speed, e.g. when travelling up a steep hill.



Suspend

When the RES switch is pressed, the cruise control ECU disconnects the pump and valve power supply output from the vacuum pump, EAT ECU and instrument pack. The set speed is retained in memory by the interface ECU. When the pump and valve power supply is disconnected:

- The vacuum pump assembly vents the vacuum actuator and control of the throttle returns to the accelerator pedal.
- The EAT ECU returns to its previous operating mode.
- The cruise control warning lamp in the instrument pack is extinguished.

If the interface ECU or the ECM suspend cruise control, the power supply from the interface ECU to the cruise control ECU is disconnected. Since the power supply is used to operate the vacuum pump assembly, system operation is automatically suspended. If the cruise control ECU detects the brakes being applied, it disconnects the pump and valve power supply output even if the power supply from the interface ECU is still present.

Resume

Provided the system is enabled, pressing the RES switch causes the cruise control ECU to output the pump and valve power supply to resume operation of the vacuum pump assembly and accelerate or decelerate the vehicle to the stored set speed. The EAT ECU returns to the cruise control mode and the cruise control warning lamp in the instrument pack illuminates.

Cancelling

Cruise control is cancelled by pressing the master switch. When cruise control is cancelled, the LED in the master switch extinguishes and the power feeds from the switch to the cruise control ECU and the interface ECU are disconnected. The set speed is lost from the memory of the cruise control ECU and the power supply from the interface ECU to the cruise control ECU is disconnected. If cruise control is engaged when the master switch is pressed:

- The cruise control ECU stops operating the vacuum pump assembly and control of the throttle returns to the accelerator pedal.
- The EAT ECU returns to its previous operating mode.
- The cruise control warning lamp in the instrument pack is extinguished.

Diagnostics

While the system is active, the cruise control ECU performs self-checks and plausibility checks of the outputs to the vacuum pump assembly and the input from the brake pedal position sensor. If a fault is detected, a related fault code is stored in the non volatile memory of the cruise control ECU and cruise control is disabled for the remainder of the ignition cycle. Codes are retrieved using TestBook, which communicates with the cruise control ECU via an ISO 9141 K line connection from the diagnostic socket.

The interface ECU monitors the two inputs from the brake pedal position sensor and disables cruise control for the remainder of the ignition cycle if a fault is detected. The interface ECU can detect open circuits and implausible inputs. However, simultaneous short circuits to 0 or 12 volts in both inputs cannot be detected and, if this occurs, cruise control operates but does not suspend operation when the brake pedal is pressed.

The system is reset at the beginning of each ignition cycle and operates normally if a previously detected fault is no longer present.



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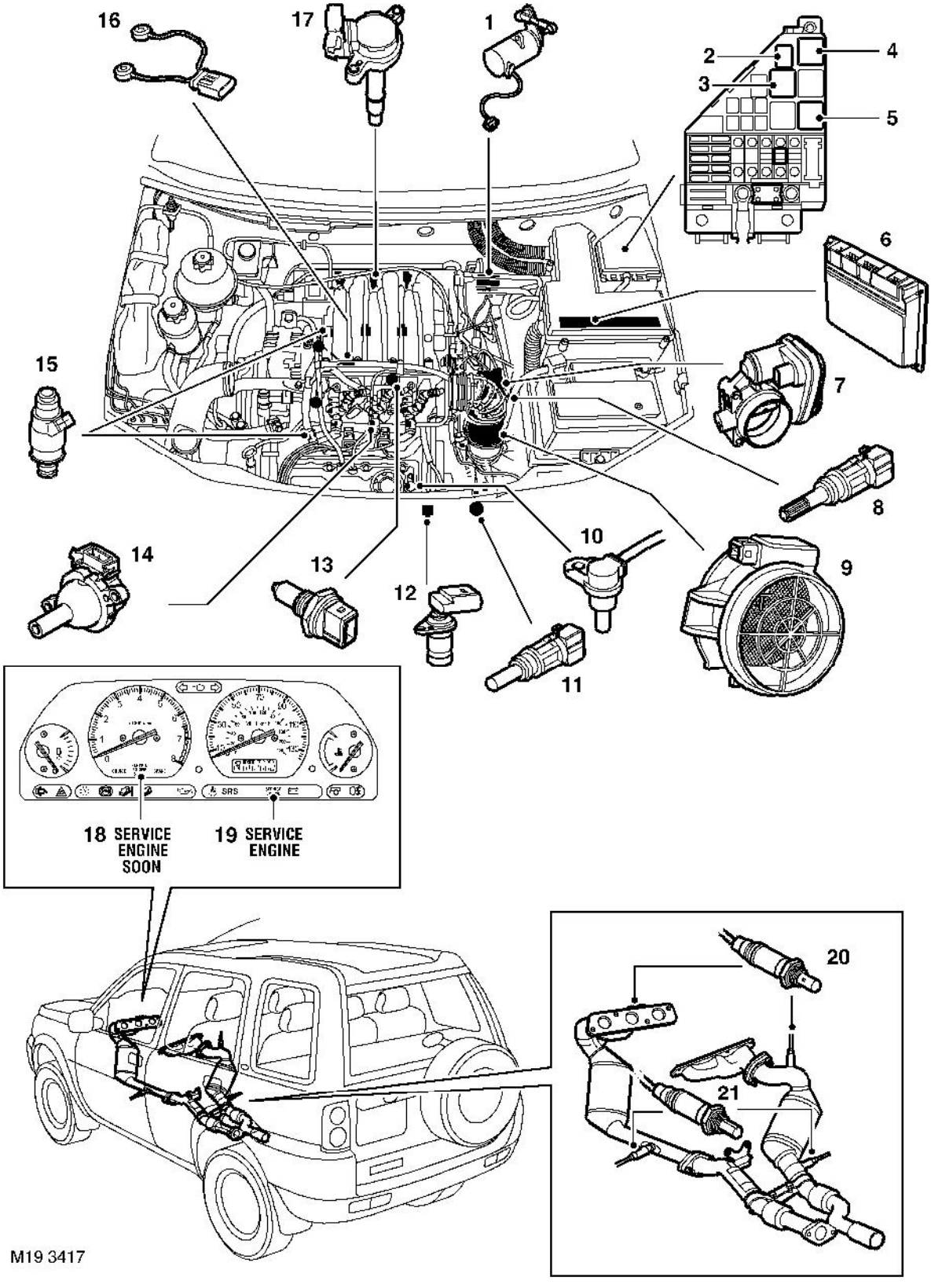
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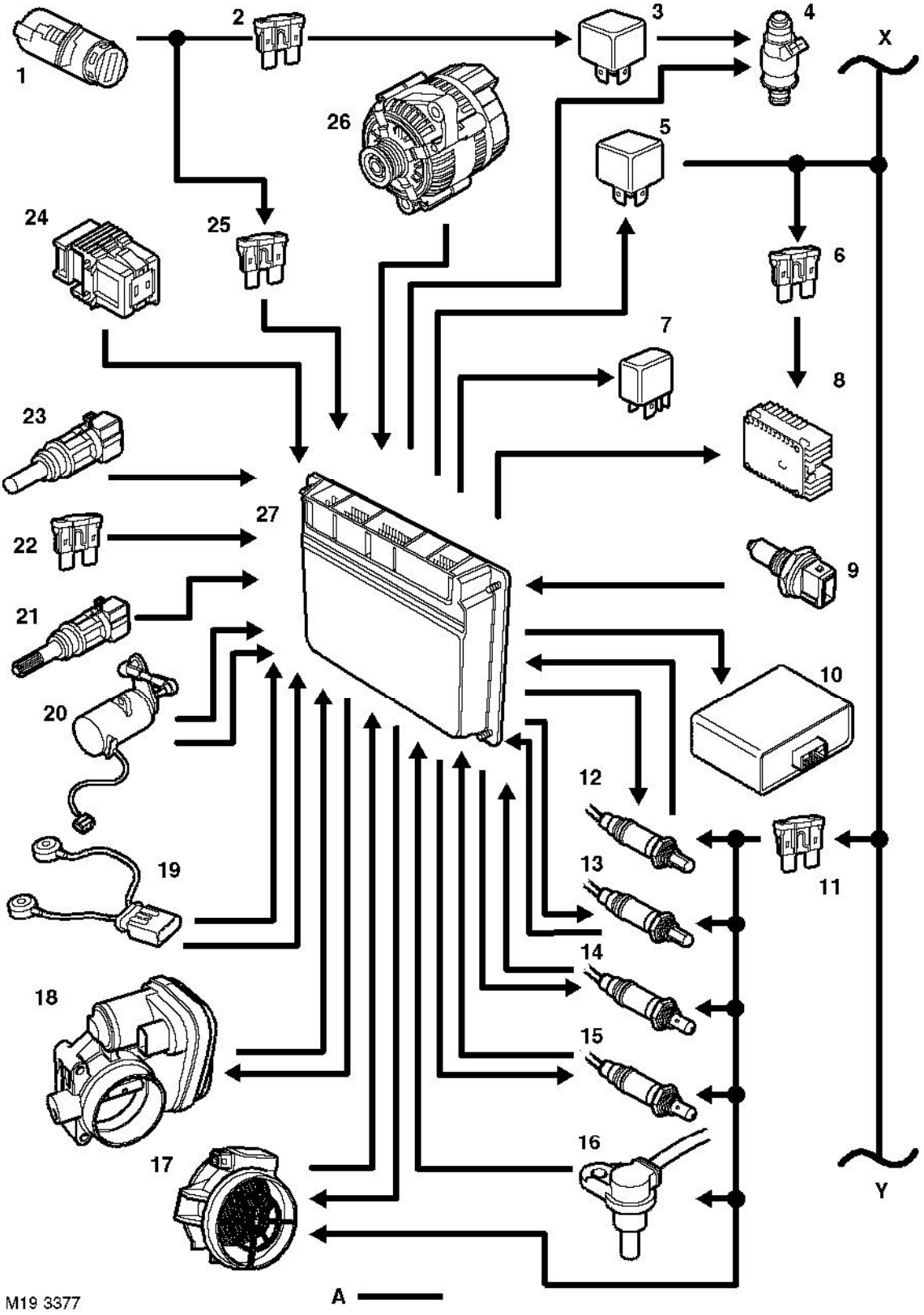
Engine Management System Component Location





1 APP sensor
2 A/C compressor clutch relay
3 Main relay
4 ECM relay
5 Fuel pump relay
6 ECM
7 Electric throttle
8 IAT sensor
9 MAF sensor
10 CMP sensor
11 Thermostat monitoring sensor
12 CKP sensor
13 ECT sensor
14 LH bank ignition coil (x 3)
15 Fuel injector (x 6)
16 Knock sensors
17 RH bank ignition coil (x 3)
18 MIL
19 Engine malfunction lamp
20 Front HO2S (x 2)
21 Rear HO2S (x 2)

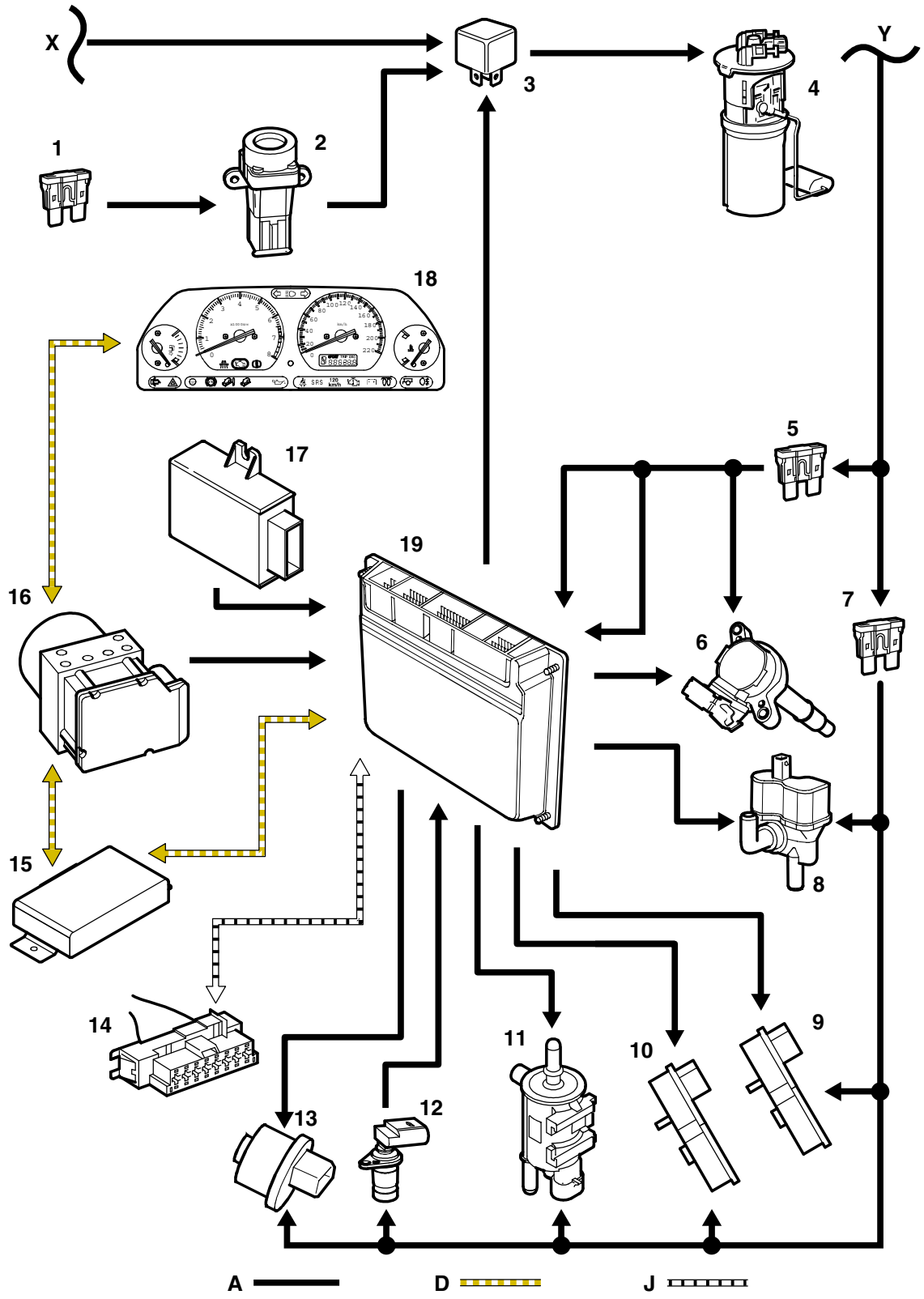
Engine Management System Control Diagram – Sheet 1 of 2



A = Hardwired connection

1 Ignition switch
2 Fuse 35, passenger compartment fusebox
3 ECM relay
4 Fuel injector (x 6)
5 Main relay
6 Fuse 4, engine compartment fusebox
7 A/C compressor relay
8 Cooling fan ECU
9 ECT sensor
10 Cruise control interface ECU
11 Fuse 3, engine compartment fusebox
12 LH front HO2S
13 RH front HO2S
14 LH rear HO2S
15 RH rear HO2S
16 CMP sensor
17 MAF sensor
18 Electric throttle
19 Knock sensors
20 APP sensor
21 IAT sensor
22 Fuse 5, engine compartment fusebox
23 Thermostat monitoring sensor
24 Brake pedal sensor
25 Fuse 6, passenger compartment fusebox
26 Alternator
27 ECM

Engine Management System Control Diagram – Sheet 2 of 2



M19 3378

A = Hardwired connection; D = CAN bus; J = Diagnostic ISO 9141 K line

1 Fuse 10, engine compartment fusebox
2 Inertia fuel cut-off switch
3 Fuel pump relay
4 Fuel tank unit
5 Fuse 2, engine compartment fusebox
6 Ignition coil (x 6)
7 Fuse 1, engine compartment fusebox
8 DMTL
9 VIS balance valve motor
10 VIS power valves motor
11 EVAP canister purge valve
12 CKP sensor
13 Vacuum enhancer solenoid valve
14 Diagnostic socket
15 EAT ECU
16 ABS modulator
17 Immobilisation ECU
18 Instrument pack
19 ECM

Description

General

The KV6 engine is fitted with a Siemens MS43 Engine Management System (EMS), which is an adaptive system that maintains engine performance at the optimum level throughout the life of the engine.

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

- Air Conditioning (A/C) compressor.
  ☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**
- Engine cooling fans.
  ☞ **COOLING SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**
- Evaporative emissions (EVAP) purge valve and Diagnostic Module for Tank Leakage (DMTL).
  ☞ **EMISSION CONTROL - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**
- Fuel pump.
  ☞ **FUEL DELIVERY SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**
- Variable Intake System (VIS).
  ☞ **MANIFOLD AND EXHAUST SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

The ECM also interfaces with the:

- Immobilisation ECU, for re-mobilisation of the engine fuel supply.
  ☞ **SECURITY, DESCRIPTION AND OPERATION, Description.**
- Cruise control interface ECU, to operate cruise control.
  ☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Cruise Control Description.**
- Electronic Automatic Transmission (EAT) ECU, to assist with control of the gearbox.
  ☞ **AUTOMATIC GEARBOX - JATCO, DESCRIPTION AND OPERATION, Description.**

Sensor inputs and engine performance are monitored by the ECM, which illuminates the SERVICE ENGINE SOON (MIL) and/or the SERVICE ENGINE warning lamps in the instrument pack if a fault is detected.

As part of the security system's immobilisation function, a vehicle specific security code is programmed into the ECM and the 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/T4 to learn the vehicle security code from the immobilisation ECU.

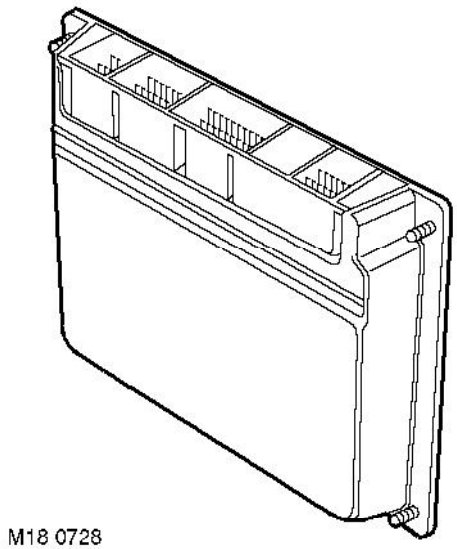
A 'flash' Electronic Erasable Programmable Read Only Memory (EEPROM) allows the ECM to be externally configured, using TestBook/T4, with market specific or new information.

The ECM memorises the position of the crankshaft and the camshaft when the engine stops. During cranking on the subsequent start the ECM confirms their positions from sensor inputs before initiating fuel injection and ignition.

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

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

ECM

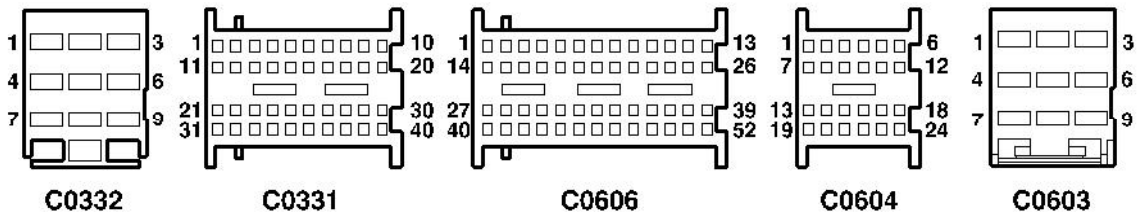


M18 0728

The ECM is located in the engine compartment, in the E-box. Five connectors provide the interface between the ECM and the vehicle wiring.

The E-box is a lidded container that provides a protected environment for the ECM and the EAT ECU. An open hub, centrifugal fan powered by an electric motor ventilates the E-box with air from the passenger compartment. Exhaust 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 (81 °F), the thermostatic switch opens and stops the fan. To prevent the fan seizing up in colder climates, where it may not operate for long periods of time, the fan also receives a power feed direct from the starter circuit so that it runs each time the engine is cranked.

ECM Harness Connectors



M19 3379

Connector C0331 Pin Details

Pin No.	Description	Input/Output
1 to 3	Not used	–
4	Engine cooling fan control	Output
5 and 6	Not used	–
7	APP sensor earth 2	–
8	APP sensor signal 2	Input
9	APP sensor supply 2	Output
10	Fuel pump relay coil	Output
11	Not used	–
12	APP sensor earth 1	–
13	APP sensor signal 1	Input
14	APP sensor supply 1	Output
15 to 19	Not used	–
20	DMTL pump motor	Output
21	Alternator load sensing	Input
22	Vehicle speed	Input
23	VIS balance valve position feedback	Input
24	Brake pedal sensor, Brake Lamp Switch (BLS) signal	Input
25	Not used	–
26	Ignition sense	Input
27	Cruise control MFL signal	Input
28	Brake pedal sensor, Brake Test Switch (BTS) signal	Input
29	A/C compressor clutch relay coil	Output
30	DMTL change-over valve	Output
31	Not used	–
32	Diagnostic ISO 9141 K line	Input/Output
33	Immobilisation ECU	Input
34	VIS power (butterfly) valves position feedback	Input
35	Not used	–
36	CAN bus high	Input/Output
37	CAN bus low	Input/Output
38	Thermostat monitoring sensor earth	–
39	Thermostat monitoring sensor signal	Input
40	Not used	–



Connector C0332 Pin Details

Pin No.	Description	Input/Output
1	Ignition coil 5	Output
2	Ignition coil 3	Output
3	Ignition coil 1	Output
4	Not used	–
5	Ignition earth	–
6	Not used	–
7	Ignition coil 4	Output
8	Ignition coil 6	Output
9	Ignition coil 2	Output

Connector C0603 Pin Details

Pin No.	Description	Input/Output
1	Ignition sense	Input
2 and 3	Not used	–
4	Electronic earth	–
5	Fuel injector earth	–
6	Power stage earth	–
7	Battery power supply	Input
8	Ignition power supply	Input
9	Ignition power supply	Input

Connector C0604 Pin Details

Pin No.	Description	Input/Output
1	LH bank front HO2S heater drive	Output
2 to 6	Not used	–
7	LH bank rear HO2S heater drive	Output
8 to 12	Not used	–
13	RH bank front HO2S heater drive	Output
14	LH bank front HO2S signal	Input
15	RH bank front HO2S signal	Input
16	LH bank rear HO2S signal	Input
17	Not used	–
18	RH bank rear HO2S signal	Input
19	RH bank rear HO2S heater drive	Output
20	LH bank front HO2S earth	–
21	RH bank front HO2S earth	–
22	LH bank rear HO2S earth	–
23	Main relay coil	Output
24	RH bank rear HO2S earth	–

Connector C0606 Pin Details

Pin No.	Description	Input/Output
1	MAF sensor signal	Input
2	Not used	–
3	Vacuum enhancer solenoid valve	Output
4	Not used	–
5	CMP sensor signal	Input
6	Not used	–
7	Throttle feedback potentiometer supply	Output
8	CKP sensor signal	Input
9	Not used	–
10	Throttle feedback potentiometer 2 signal	Input
11	VIS balance valve motor drive	Output
12 to 16	Not used	–
17	MAF sensor earth	–
18	CMP sensor earth	–
19	Throttle feedback potentiometer 1 signal	Input
20	Throttle feedback potentiometer earth	–
21	CKP sensor earth	–
22	IAT sensor signal	Input
23	IAT sensor earth	–
24	ECT sensor signal	Input
25	ECT sensor earth	–
26 and 28	Not used	–
29	LH bank knock sensor	Input
30	LH bank knock sensor	Input
31	RH bank knock sensor	Input
32	RH bank knock sensor	Input
33	Fuel injector 1	Output
34	Fuel injector 3	Output
35	Fuel injector 5	Output
36	Fuel injector 2	Output
37	Fuel injector 6	Output
38	Fuel injector 4	Output
39 to 41	Not used	–
42	EVAP purge valve drive	Output
43	Throttle motor open drive	Output
44	Throttle motor close drive	Output
45 to 47	Not used	–
48	Knock sensors screen	Input
49	VIS power (butterfly) valves motor drive	Output
50	Not used	–
51	DMTL heater drive	Output
52	Not used	–

Controller Area Network (CAN) Bus

The ECM is connected to the Anti-lock Braking System (ABS) modulator, EAT ECU and the instrument pack by the CAN bus.

Electric Throttle

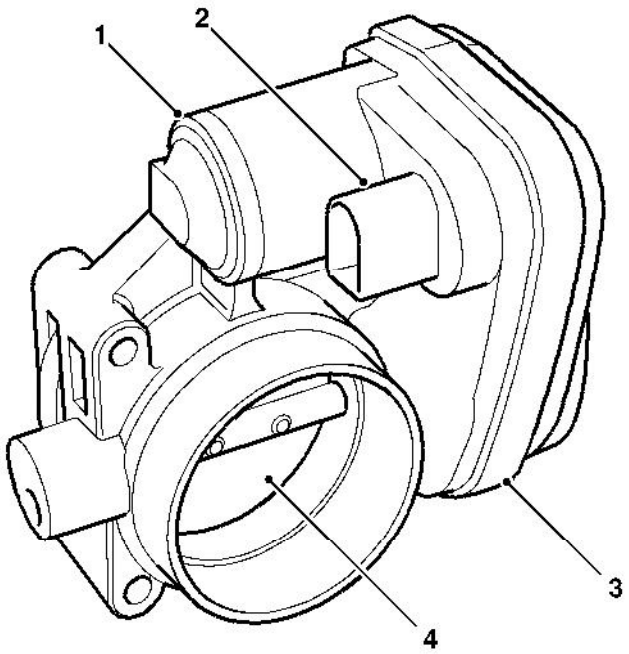
The electric throttle controls the air flow into the engine. In addition to the normal engine power control function, the electric throttle allows the cruise control, idle speed control and engine speed limiting functions to be performed without the need for additional hardware.

The electric throttle consists of a throttle body which incorporates a throttle plate driven by a DC motor via reduction gears. A return spring biases the throttle plate in the closed direction.

Operation of the DC motor is controlled by the ECM, which outputs two Pulse Width Modulated (PWM) signals to an H bridge drive circuit in the motor. The ECM varies the speed and direction of the motor by varying the duty cycle of the PWM signals.

To enable closed loop control, the position of the throttle plate is supplied to the ECM by two feedback potentiometers in the throttle body. The feedback potentiometers have a common 5 volt supply and a common ground connection from the ECM, and produce separate linear signal voltages to the ECM proportional to the position of the throttle plate. The ECM uses the signal from feedback potentiometer 1 as the primary signal of throttle plate position, and the signal from feedback potentiometer 2 for plausibility checks.

- The signal from feedback potentiometer 1 varies between 0.5 volt (0% throttle open) and 4.5 volts (100% throttle open)
- The signal from feedback potentiometer 2 varies between 4.5 volts (0% throttle open) and 0.5 volt (100% throttle open)



M18 0709

1 DC motor
2 Electrical connector
3 Reduction gear/ feedback potentiometer
4 Throttle plate

While the ignition is on, the ECM continuously monitors the two feedback potentiometers for short and open circuits and checks the feedback potentiometer signals, against each other and the inputs from the Accelerator Pedal Position (APP) sensor, for plausibility. If a fault is detected in the feedback potentiometer signals or the DC motor, the ECM:

- Stores a related fault code in memory.
- Illuminates the SERVICE ENGINE warning lamp in the instrument pack.
- Adopts a throttle limp home mode or disables throttle control, depending on the nature of the fault.

The throttle limp home mode adopted depends on the nature of the fault:

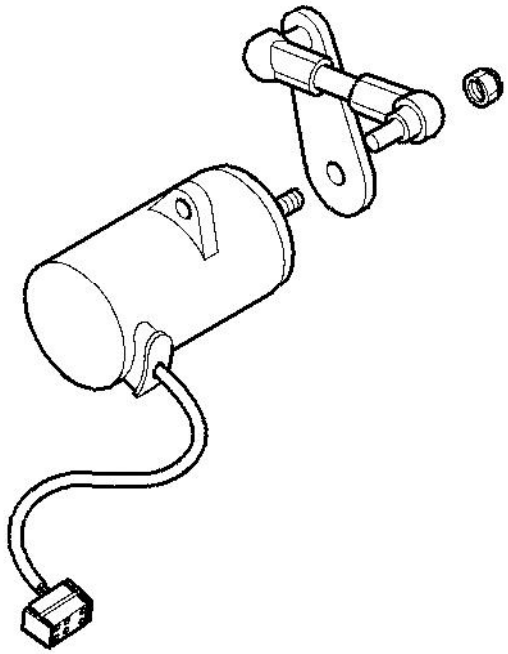
- If there is a fault with one feedback potentiometer, or the throttle position controller in the ECM, the ECM limits vehicle acceleration by limiting throttle plate opening.
- If there is a fault with both feedback potentiometers, the ECM uses fuel injection cut-off to limit engine speed to 1300 rev/min maximum.

EMS Sensors

The EMS incorporates the following sensors:

- An APP sensor.
- A Crankshaft Position (CKP) sensor.
- A Camshaft Position (CMP) sensor.
- A Mass Air Flow (MAF) sensor.
- An Intake Air Temperature (IAT) sensor.
- An Engine Coolant Temperature (ECT) sensor.
- A thermostat monitoring sensor.
- Four Heated Oxygen Sensors (HO2S).
- Two knock sensors.

APP Sensor



M19 3383

The APP sensor enables the ECM to determine the throttle position requested by the driver on the accelerator pedal.

The APP sensor is installed on the pedal box and consists of a twin track potentiometer with wipers driven by a linkage connected to the accelerator pedal. Each potentiometer track has a 5 volt supply and ground connection from the ECM, and produces a linear signal voltage to the ECM proportional to the position of the accelerator pedal. The signal voltage from track 1 of the potentiometer is approximately double that of the signal voltage from track 2.

From the sensor signals, the ECM determines driver demand as a percentage of pedal travel, where 0% is with the pedal released and 100% is with the pedal fully depressed. Driver demand is then used to calculate throttle angle, fuel quantity and ignition timing. The ECM also outputs driver demand on the CAN system, for use by the brake and gearbox control systems.

The ECM stores the signal values that correspond with closed and wide open throttle, and adapts to new values to accommodate component wear or replacement.

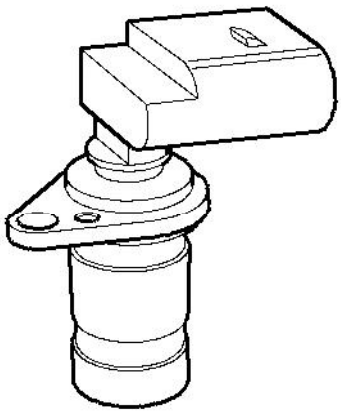
The signals from the APP sensor are monitored by the ECM for short and open circuits and plausibility. If a fault is detected, the ECM:

- Stores a related fault code in memory.
- Illuminates the SERVICE ENGINE warning lamp in the instrument pack.
- Inhibits the driver demand message on the CAN bus, which disables the Hill Descent Control (HDC) function of the ABS modulator and reduces the performance of the automatic gearbox (harsh gear changes and loss of kickdown).
- Adopts a throttle limp home mode.

The throttle limp home mode adopted depends on the nature of the fault:

- If a fault is detected with one potentiometer track, the ECM limits vehicle acceleration by limiting throttle plate opening.
- If a fault is detected with both potentiometer tracks, the ECM uses the throttle plate to run the engine at a fixed speed of 1472 rev/min while the brake pedal is released, and idle speed (750 rev/min) while the brake pedal is pressed or if there is a brake pedal sensor fault.
- If there is a process fault in the ECM, the ECM either uses fuel injection cut-off to limit engine speed to 1300 rev/min or disables fuel injection to stop the engine.

CKP Sensor



M18 0711

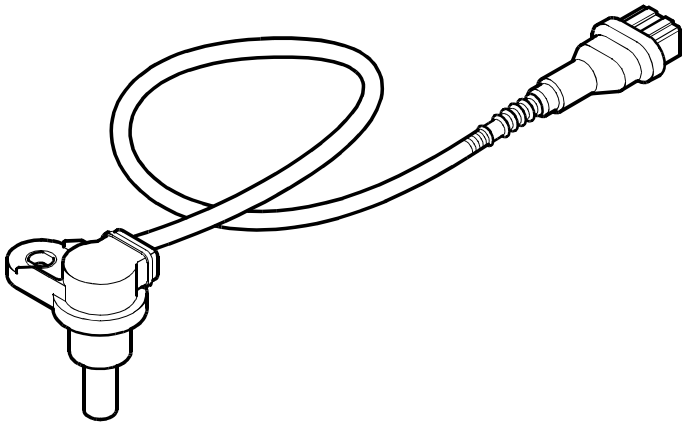
The CKP sensor provides the ECM with a digital signal of the rotational speed and angular position of the crankshaft, for use in ignition timing, fuel injection timing and fuel injection quantity calculations. To determine the exact position of the crankshaft in the engine cycle, the ECM must also use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

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

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

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

CMP Sensor



M19 2837A

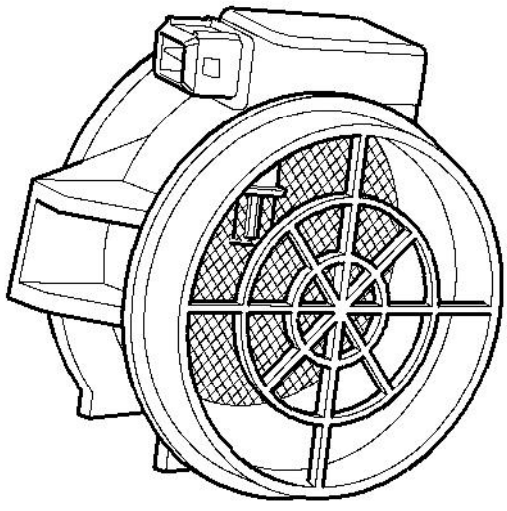
The CMP sensor provides a signal which enables the ECM to determine the position of the camshaft relative to the crankshaft. This allows the ECM to synchronise fuel injection for start and run conditions.

The CMP sensor is located on the camshaft cover of the LH (front) cylinder bank, at the opposite end to the camshaft drive, in line with a 'half moon' reluctor on the exhaust camshaft. The reluctor 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.

MAF Sensor



M18 0712

The MAF sensor provides a signal which the ECM uses for engine load calculations.

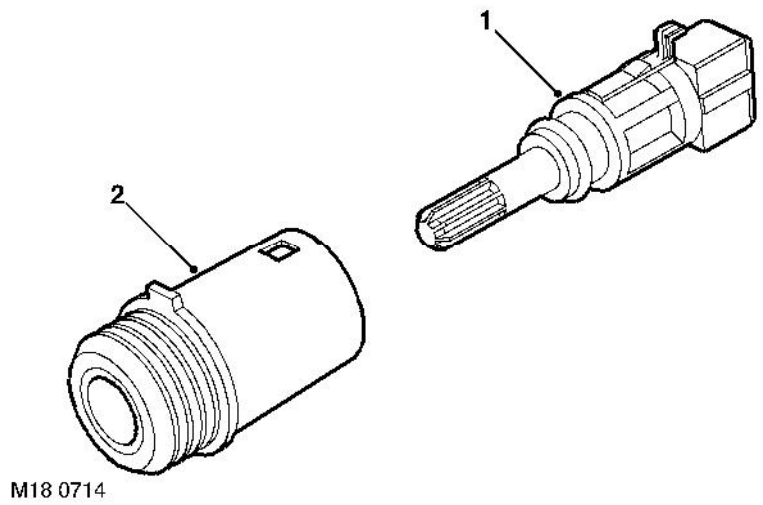
The MAF sensor is a hot film type, and is located in the intake system between the air filter housing and the throttle body.

A closed-loop control circuit in the MAF sensor maintains a thick film resistor at a constant 200 °C (392 °F) above ambient temperature. The current required to maintain the temperature of the thick film resistor, against the cooling effect of the air flowing through the sensor, provides a precise, non-linear, measure of the air mass entering the engine.

The MAF sensor receives a battery voltage power supply and generates an output signal to the ECM, between 0 and 5 volts, which is proportional to the air mass drawn into the engine.

In the event of a MAF sensor signal failure, the following symptoms may be apparent:
- During driving engine speed may dip before recovering.
- Difficult starting.
- Engine stalls after starting.
- Delayed throttle response.
- Reduced engine performance.

IAT Sensor



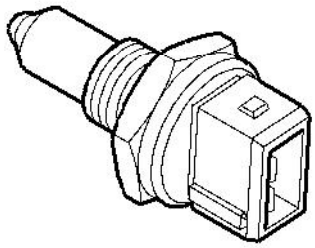
1 Sensor **2** Housing

The IAT sensor provides a signal that enables the ECM to adjust ignition timing and fuelling quantity according to the intake air temperature, thus ensuring optimum performance, driveability and emissions.

The IAT sensor is a Negative Temperature Coefficient (NTC) thermistor located in a plastic housing installed in the intake duct between the MAF sensor and the throttle body. The sensor is a push fit in the housing and sealed by an 'O' ring. A clip is integrated into the sensor to secure it in the housing.

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

ECT Sensor



M18 0713

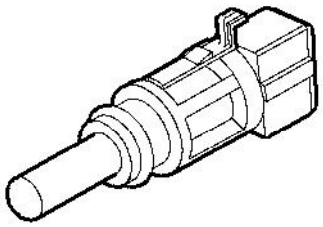
The ECT sensor provides the ECM with a signal voltage that varies with coolant temperature, to enable the ECM to adapt the fuelling quantity and ignition timing with changes of engine temperature.

The ECT sensor is located between the cylinder banks, between cylinders 3 and 6.

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

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

Thermostat Monitoring Sensor

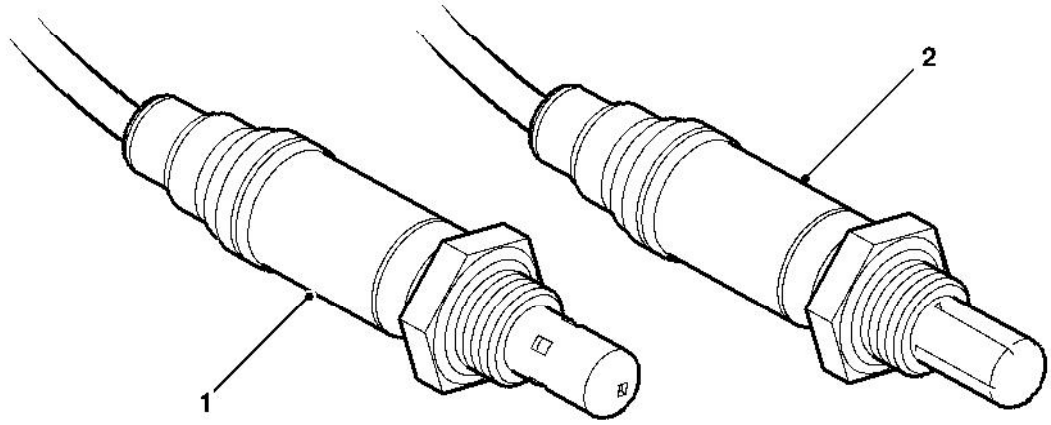


M18 0715

The input from the thermostat monitoring sensor is used by the ECM to monitor the operation of the cooling system thermostat and to control the operation of the engine cooling fans.

The thermostat monitoring sensor is a NTC thermistor installed in a plastic 'T' piece in the radiator bottom hose. The sensor is a push fit in the T piece and sealed by an 'O' ring. A clip is integrated into the sensor to secure it in the T piece.

HO2S



M18 0716

1 Rear HO2S

2 Front HO2S

The EMS has four HO2S:

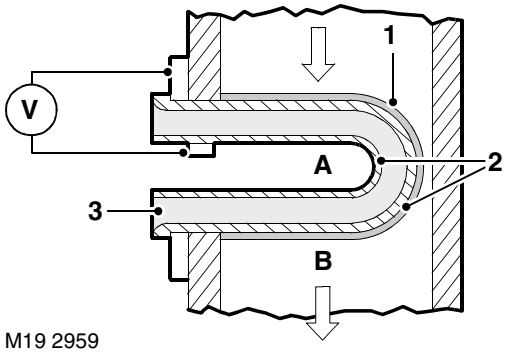
- One upstream of each catalytic converter, identified as LH and RH front HO2S.
- One downstream of each catalytic converter, identified as LH and RH rear HO2S.

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

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

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

Sectioned View of HO2S



M19 2959

A = Ambient air; B = Exhaust gases

1 Protective ceramic coating

2 Electrodes

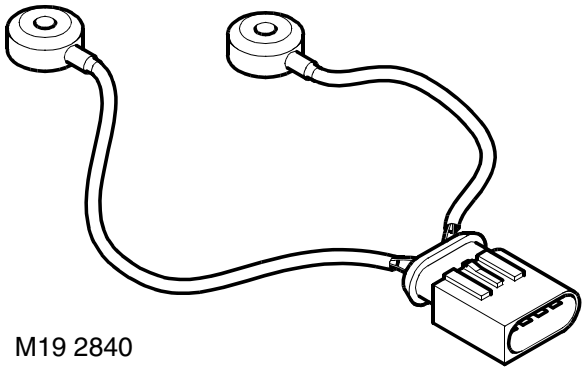
3 Zirconium oxide

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 and low load conditions, each HO2S contains a heating element powered by a supply from the main relay. The earth paths for the heating elements are controlled by the ECM. On start up, the current supplied to the heating elements is increased gradually to prevent sudden heating from damaging the ceramic coating. After the initial warm up period the ECM modulates the earth of the heating elements, from a map of engine speed against mass air flow, to maintain the HO2S at the optimum operating temperature.

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

If an HO2S fails, the ECM illuminates the MIL. If a front HO2S fails the ECM also adopts open loop fuelling and catalytic converter monitoring is disabled. If a rear HO2S fails, catalytic converter and front HO2S monitoring is disabled.

Knock Sensors



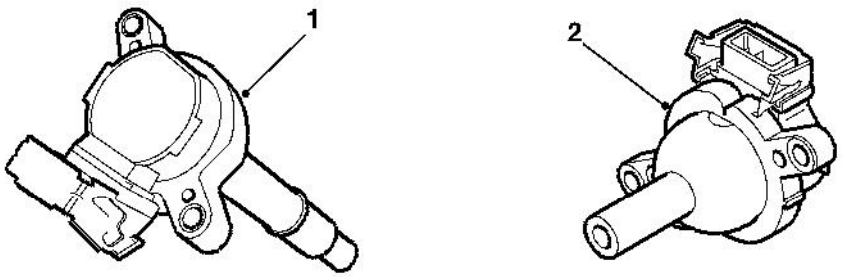
M19 2840

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

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

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

Ignition Coils



M19 3384

1 RH bank ignition coil

2 LH bank ignition coil



The ECM uses a separate ignition coil for each spark plug. The ignition coils for the LH bank spark plugs are positioned on the forward tracts of the 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 the dwell period using inputs from the following:
- Battery voltage (main relay).
- CKP sensor.
- Ignition coil primary current (internal ECM connection).

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

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

Ignition Timing

The ECM calculates ignition timing using inputs from the following sensors:
- CKP sensor.
- MAF sensor.
- Knock sensors.
- TP sensor (idle only).
- ECT sensor.

At start up and idle the ECM sets ignition timing by referencing the ECT and CKP sensors. Once above idle the ignition timing is controlled according to maps stored in the ECM memory and modified according to additional sensor inputs and any adaptive value stored in memory. The maps keep the ignition timing within a narrow band that gives an acceptable 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 fuelling, ignition timing and the electric throttle.

When the engine idle speed fluctuates the ECM initially varies the ignition timing, which produces rapid changes of engine speed. If this fails to correct the idle speed, the ECM also adjusts the electric throttle and fuelling.

Misfire Detection

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

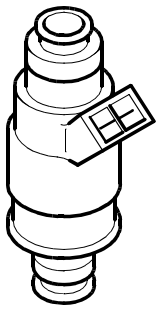
Low fuel level:

When the fuel tank is almost empty there is a risk that air may be drawn into the fuel system, due to fuel 'slosh', causing fuel starvation and misfires. To prevent false misfire faults being logged, the ECM disables misfire detection if it receives a low fuel level message on the CAN bus. Fuel tank content is monitored by the instrument pack, which transmits the low fuel level message if the fuel tank content decreases to less than 15% (8.85 litres; 2.34 US galls).

Rough road disable:

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

Fuel Injectors



M19 2845A

A split stream, air assisted fuel injector is installed for each cylinder. The injectors are located in the 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 ECM relay in the engine compartment fusebox. 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 intake duct via a plastic tube and tracts formed in the gasket face of the intake manifolds.

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

- Engine speed.
- Mass air flow.
- Engine temperature.
- Accelerator pedal position (i.e. driver demand).

The fuel in the fuel rail is maintained at a pressure of 3.5 bar (51 lbf/in 2) by a pressure regulator incorporated into the pump unit in the fuel tank. An accumulator is attached to the LH fuel rail, to damp out pressure pulses from the pump and ensure that the pressure in the fuel rail is constant. A Schraeder valve is installed in the fuel rail, above the accumulator, to provide a pressure test connection for maintenance.

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



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

When the purge valve is open fuel vapour is drawn from the EVAP canister into the 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.

Warning Lamps
Two warning lamps in the instrument are used to indicate faults with the engine management system. The engine malfunction lamp consists of an amber SERVICE ENGINE legend and is illuminated to indicate the detection of a non emissions related fault. The Malfunction Indicator Lamp (MIL) consists of an amber SERVICE ENGINE SOON legend and is illuminated to indicate the detection of an emissions related fault. The ECM operates the warning lamps, by communicating with the instrument pack on the CAN bus. If a fault that can cause catalytic converter damage is detected, the warning lamps flash. For other faults the warning lamps are continuously illuminated.

Diagnostics
The ECM incorporates On Board Diagnostics (OBD) software that complies with market legislation current at the time of manufacture. During engine operation the ECM performs self test and diagnostic routines to monitor the performance of the engine and the EMS. If a fault is detected the ECM stores a related Diagnostic Trouble Code (DTC, also known as a 'P' code) in a non volatile memory and, for most faults, illuminates the engine SERVICE ENGINE and/or the SERVICE ENGINE SOON warning lamps. Codes are retrieved using TestBook/T4, which communicates with the ECM via an ISO 9141 K line connection from the diagnostic socket.

P Code No.	Component/Signal	Fault Description	Warning Lamp	
			MIL	Engine Fault
0100	MAF sensor signal	Open circuit	No	No
0102	MAF sensor signal	Short circuit to earth	No	No
0103	MAF sensor signal	Short circuit to battery	No	No
0105	ECM internal ambient pressure sensor	Circuit malfunction	No	No
0107	ECM internal ambient pressure sensor	Short circuit to earth	No	No
0108	ECM internal ambient pressure sensor	Open circuit or short circuit to battery	No	No
0109	ECM internal ambient pressure sensor	Circuit intermittent	No	No
0112	IAT sensor	Short circuit to earth	No	No
0113	IAT sensor	Open circuit or short circuit to battery	No	No
0116	ECT sensor	Signal implausible	No	No
0117	ECT sensor	Short circuit to earth	No	No
0118	ECT sensor	Open circuit or short circuit to battery	No	No
0122	Throttle potentiometer 1	Open circuit or short circuit to earth	Yes	Yes
0123	Throttle potentiometer 1	Short circuit to battery	Yes	Yes
0125	ECT sensor	Open circuit, short circuit to ground or signal implausible	No	No

P Code No.	Component/Signal	Fault Description	Warning Lamp	
			MIL	Engine Fault
0128	Thermostat monitoring sensor	Low coolant temperature – thermostat stuck open	No	No
0131	LH bank front HO2S signal	Short circuit to earth	Yes	No
0132	LH bank front HO2S signal	Short circuit to battery	Yes	No
0133	LH bank front HO2S signal	Slow response	Yes	No
0134	LH bank front HO2S signal	Open circuit	Yes	No
		Signal not switching	No	No
0135	LH bank front HO2S heater circuit	Open circuit or short circuit to battery or earth	No	No
0136	LH bank rear HO2S signal	Open circuit	No	No
0137	LH bank rear HO2S signal	Short circuit to earth	No	No
0138	LH bank rear HO2S signal	Short circuit to battery	No	No
0139	LH bank rear HO2S signal	Slow response	Yes	No
0140	LH bank rear HO2S signal	No activity	No	No
0141	LH bank rear HO2S heater circuit	Open circuit or short circuit to battery or earth	No	No
0151	RH bank front HO2S signal	Short circuit to earth	Yes	No
0152	RH bank front HO2S signal	Short circuit to battery	Yes	No
0153	RH bank front HO2S signal	Slow response	Yes	No
0154	RH bank front HO2S signal	Open circuit	Yes	No
		Signal not switching	No	No
0155	RH bank front HO2S heater circuit	Open circuit or short circuit to battery or earth	No	No
0156	RH bank rear HO2S signal	Open circuit	No	No
0157	RH bank rear HO2S signal	Short circuit to earth	No	No
0158	RH bank rear HO2S signal	Short circuit to battery	No	No
0159	RH bank rear HO2S signal	Slow response	Yes	No
0160	RH bank rear HO2S signal	No activity	No	No
0161	RH bank rear HO2S heater circuit	Open circuit or short circuit to battery or earth	No	No
0171	LH bank lambda control	Fuelling too lean	Yes	No
0172	LH bank lambda control	Fuelling too rich	Yes	No
0174	RH bank lambda control	Fuelling too lean	Yes	No
0175	RH bank lambda control	Fuelling too rich	Yes	No
0201	Fuel injector 1	Open circuit	Yes	No
0202	Fuel injector 2	Open circuit	Yes	No
0203	Fuel injector 3	Open circuit	Yes	No
0204	Fuel injector 4	Open circuit	Yes	No
0205	Fuel injector 5	Open circuit	Yes	No
0206	Fuel injector 6	Open circuit	Yes	No
0222	Throttle potentiometer 2	Open circuit or short circuit to earth	Yes	Yes
0223	Throttle potentiometer 2	Short circuit to battery	Yes	Yes
0261	Fuel injector 1	Short circuit to earth	Yes	No
0262	Fuel injector 1	Short circuit to battery	Yes	No
0264	Fuel injector 2	Short circuit to earth	Yes	No
0265	Fuel injector 2	Short circuit to battery	Yes	No
0267	Fuel injector 3	Short circuit to earth	Yes	No
0268	Fuel injector 3	Short circuit to battery	Yes	No
0270	Fuel injector 4	Short circuit to earth	Yes	No
0271	Fuel injector 4	Short circuit to battery	Yes	No
0273	Fuel injector 5	Short circuit to earth	Yes	No



P Code No.	Component/Signal	Fault Description	Warning Lamp	
			MIL	Engine Fault
0274	Fuel injector 5	Short circuit to battery	Yes	No
0276	Fuel injector 6	Short circuit to earth	Yes	No
0277	Fuel injector 6	Short circuit to battery	Yes	No
0301	Cylinder 1	Misfire detected	Yes	No
0302	Cylinder 2	Misfire detected	Yes	No
0303	Cylinder 3	Misfire detected	Yes	No
0304	Cylinder 4	Misfire detected	Yes	No
0305	Cylinder 5	Misfire detected	Yes	No
0306	Cylinder 6	Misfire detected	Yes	No
0313	Misfire detection	Misfire detected at low fuel level	Yes	No
0327	LH bank knock sensor	Open circuit	No	No
0332	RH bank knock sensor	Open circuit	No	No
0335	CKP sensor	Signal implausible	No	No
0337	CKP sensor	Short circuit to earth	No	No
0338	CKP sensor	Short circuit to battery	No	No
0339	CKP sensor	Open circuit/no signal	No	No
0340	CMP sensor	Open circuit/no signal	No	No
0341	CMP sensor	Signal implausible	No	No
0351	Ignition coil 1	No spark	Yes	No
0352	Ignition coil 2	No spark	Yes	No
0353	Ignition coil 3	No spark	Yes	No
0354	Ignition coil 4	No spark	Yes	No
0355	Ignition coil 5	No spark	Yes	No
0356	Ignition coil 6	No spark	Yes	No
0420	LH bank catalytic converter	Efficiency below threshold – light off too long	No	No
0430	RH bank catalytic converter	Efficiency below threshold – light off too long	No	No
0441	Diagnostics	EVAP purge flow test failure	Yes	No
0443	Purge valve	Circuit malfunction	Yes	No
0444	Purge valve	Open circuit	Yes	No
0445	Purge valve	Short circuit to battery or earth	Yes	No
0455	EVAP system	Major leak	Yes	No
0456	EVAP system	Minor leak	Yes	No
0500	Vehicle speed signal	Signal implausible	No	No
0505	ECM idle speed control	System malfunction	No	No
0606	ECM	Processor fault	Yes	No
1101	MAF sensor	Signal implausible for throttle angle	No	No
1113	ECM internal ambient pressure sensor	Automatic section failure	No	No
1115	Thermostat monitoring sensor	Coolant temperature stuck high	No	No
1118	Thermostat monitoring sensor	Open circuit or short circuit to battery	No	No
1119	Thermostat monitoring sensor	Short circuit to earth	No	No
1122	APP sensor potentiometer 1	Open circuit or short circuit to earth	No	Yes
1123	APP sensor potentiometer 1	Short circuit to battery	No	Yes
1132	LH bank front HO2S	Heating defective	No	No
1133	RH bank front HO2S	Heating defective	No	No
1141	Throttle potentiometer 1	Ratio of throttle potentiometer 1 signal to air flow implausible	Yes	Yes
1142	Throttle potentiometer 2	Ratio of throttle potentiometer 2 signal to air flow implausible	Yes	Yes

P Code No.	Component/Signal	Fault Description	Warning Lamp	
			MIL	Engine Fault
1146	LH bank lambda control	Downstream fuel trim above lean delay time	No	No
1147	RH bank lambda control	Downstream fuel trim above lean delay time	No	No
1148	LH bank lambda control	Downstream fuel trim above rich delay time	No	No
1149	RH bank lambda control	Downstream fuel trim above rich delay time	No	No
1150	LH bank lambda control	Downstream fuel trim fault at low fuel level	No	No
1151	RH bank lambda control	Downstream fuel trim fault at low fuel level	No	No
1155	LH bank rear HO2S	Heating defective	No	No
1160	RH bank rear HO2S	Heating defective	No	No
1165	LH bank lambda control	HO2S fault detected at low fuel level	Yes	No
1166	RH bank lambda control	HO2S fault detected at low fuel level	Yes	No
1167	LH bank rear HO2S	Signal implausible	No	No
1168	RH bank rear HO2S	Signal implausible	No	No
1180	LH bank rear HO2S	Slow response	No	No
1227	APP sensor potentiometer 2	Open circuit or short circuit to earth	No	Yes
1228	APP sensor potentiometer 2	Short circuit to battery	No	Yes
1231	Fuel pump relay	Short circuit to earth	No	No
1232	Fuel pump relay	Short circuit to battery	No	No
1320	Misfire detection	Reluctor adaption fault	No	No
1321	Misfire detection	Reluctor tooth pattern fault	No	No
1322	Ignition system	Ignition fault on more than two cylinders	No	No
1351	Ignition coil 1	Short circuit to battery	Yes	No
1352	Ignition coil 2	Short circuit to battery	Yes	No
1353	Ignition coil 3	Short circuit to battery	Yes	No
1354	Ignition coil 4	Short circuit to battery	Yes	No
1355	Ignition coil 5	Short circuit to battery	Yes	No
1356	Ignition coil 6	Short to battery	Yes	No
1383	Ignition feedback resistor	Open circuit	No	No
1391	Ignition coil 1	Spark duration too short	Yes	No
1392	Ignition coil 2	Spark duration too short	Yes	No
1393	Ignition coil 3	Spark duration too short	Yes	No
1394	Ignition coil 4	Spark duration too short	Yes	No
1395	Ignition coil 5	Spark duration too short	Yes	No
1396	Ignition coil 6	Spark duration too short	Yes	No
1450	DMTL pump motor	Reference current above limit	Yes	No
1451	DMTL pump motor	Reference current below limit	Yes	No
1452	DMTL pump motor	Reference current unstable	Yes	No
1453	DMTL pump motor	Change-over valve stuck	Yes	No
1454	DMTL change-over valve	Short circuit to battery	No	No
1455	DMTL change-over valve	Short to earth	No	No
1456	DMTL change-over valve	Open circuit	No	No
1470	VIS balance valve motor	Valve always open	No	No
1471	VIS balance valve motor	Valve always closed	No	No
1472	VIS power/ butterfly valves motor	Valves always open	No	No
1473	VIS power/ butterfly valves motor	Valves always closed	No	No
1474	VIS balance valve motor	Short circuit to battery	No	No



P Code No.	Component/Signal	Fault Description	Warning Lamp	
			MIL	Engine Fault
1475	VIS balance valve motor	Open circuit or short circuit to earth	No	No
1476	VIS power/ butterfly valves motor	Short circuit to battery	No	No
1477	VIS power/ butterfly valves motor	Open circuit or short circuit to earth	No	No
1488	DMTL pump motor	Open circuit or short circuit to earth	Yes	No
1489	DMTL pump motor	TBD	Yes	No
1490	DMTL pump motor	Short circuit to battery	Yes	No
1537	A/C compressor clutch relay	Short circuit to earth	No	No
1538	A/C compressor clutch relay	Short circuit to battery	No	No
1540	APP sensor	Both signals implausible	Yes	Yes
1541	APP sensor	Signal implausible	No	Yes
1564	Cruise control interface ECU	MFL signal bit pattern implausible	No	No
1565	Cruise control interface ECU	MFL signal switch state implausible, circuit high voltage	No	No
1566	Cruise control interface ECU	MFL signal period time error, circuit low voltage	No	No
1572	Brake pedal sensor	BLS signal defective or BTS signal active	No	No
1573	Brake pedal sensor	BTS signal defective	No	No
1574	Brake pedal sensor	Signals implausible	No	No
1575	Brake pedal sensor	APP sensor to brake sensor inputs implausible	No	Yes
1576	Brake pedal sensor	APP sensor to brake sensor inputs high	No	Yes
1577	Brake pedal sensor	APP sensor to brake sensor inputs low	No	Yes
1621	Serial link with immobilisation ECU	Timeout	No	No
1624	Serial link with immobilisation ECU	Code not accepted	No	No
1625	ECM, throttle monitoring/ self test	Internal fault	Yes	Yes
1626	ECM, throttle monitoring/ self test	Engine torque monitoring problem	Yes	Yes
1627	ECM, throttle monitoring/ self test	Engine speed monitoring problem	Yes	Yes
1628	ECM, throttle monitoring/ self test	PWM signal 1 duty cycle threshold exceeded for <1 second	No	No
1629	ECM, throttle monitoring/ self test	PWM signal 2 duty cycle threshold exceeded for >1 second	Yes	Yes
1630	ECM, throttle monitoring/ self test	Throttle position control deviation	Yes	Yes
1631	Throttle	Motor power stage fault	Yes	Yes
1636	ECM, throttle monitoring/ self test	Throttle motor adaption not completed	Yes	Yes
1637	ECM, throttle monitoring/ self test	Throttle motor lower adaption not plausible	Yes	Yes
1638	ECM, throttle monitoring/ self test	Throttle motor upper adaption not plausible	Yes	Yes
1639	ECM, throttle monitoring/ self test	Throttle motor spring test not completed	Yes	Yes
1641	CAN bus	Bus off	No	No
1645	CAN bus link with ABS ECU	Timed out	No	No
1646	CAN bus link with EAT ECU	Timed out	No	No
1647	CAN bus link with instrument pack	Timed out	No	No
1666	Serial link with immobilisation ECU	Wrong code	No	No
1669	ECM cooling fan signal	Open circuit or short to battery	No	No
1670	ECM cooling fan signal	Open circuit	No	No
1671	ECM cooling fan signal	Short to battery	No	No
1672	Serial link with immobilisation ECU	Code implausible	No	No

P Code No.	Component/Signal	Fault Description	Warning Lamp	
			MIL	Engine Fault
1676	ECM, throttle monitoring/ self test	Engine torque versus driver demand implausible	No	Yes
1677	ECM, throttle monitoring/ self test	Engine speed versus driver demand implausible	No	No
1678	Throttle	Potentiometer 1 defective	Yes	Yes
1679	Throttle	Potentiometer 2 defective	Yes	Yes
1689	Brake vacuum enhancer solenoid valve	Short circuit to battery	No	No
1690	Brake vacuum enhancer solenoid valve	Short circuit to earth	No	No
1691	Brake vacuum enhancer solenoid valve	Open circuit	No	No
1692	Main relay	Main relay fault	No	No

Operation

Engine Starting
When the ignition switch is in position II a power feed is connected from the ignition switch to the ECM relay and the ECM. The ECM then initiates 'wake up' routines and energises the main and fuel pump relays.

When the engine cranks, provided a valid mobilisation signal is received from the immobilisation ECU, the ECM initiates throttle control, fuelling and ignition to start and maintain control of the engine as necessary to meet driver demand. If no mobilisation code is received from the immobilisation ECU, or the code is invalid, the ECM inhibits fuel injection and ignition to prevent the engine from starting.

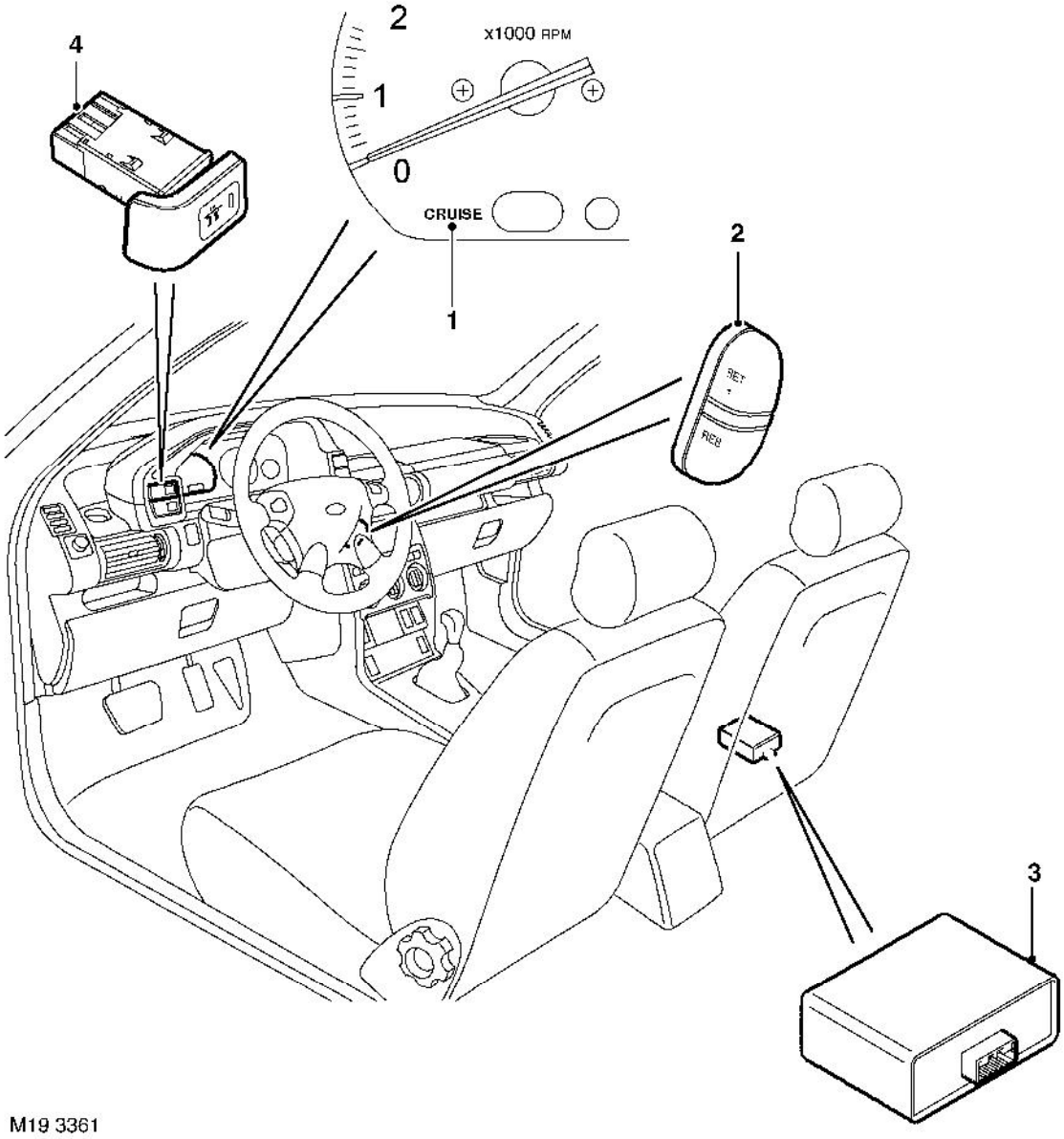
The electrical circuit from the fuel pump relay to the fuel pump is routed through the fuel cut-off inertia switch, located below the E-box in the engine compartment. In the event of a collision the switch breaks the circuit to prevent further fuel being delivered to the engine. The switch is reset by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

During the start sequence, the ECM also illuminates the MIL, as a bulb check. While the ignition switch is in position II the MIL is continuously illuminated. The MIL is extinguished when the ignition switch turns to position III and the engine starts.

Engine Stopping
When the ignition switch is turned to position I, the ECM switches off the ignition coils and fuel pump to stop the engine and the ECM relay de-energises to disconnect the power feed to the fuel injectors. The ECM continues to energise the main relay until the power down functions are completed. Power down functions include the fuel tank leak check, engine cooling and memorising data for the next start up. If neither a fuel tank lank check nor engine cooling are required, the power down process takes approximately 10 seconds.

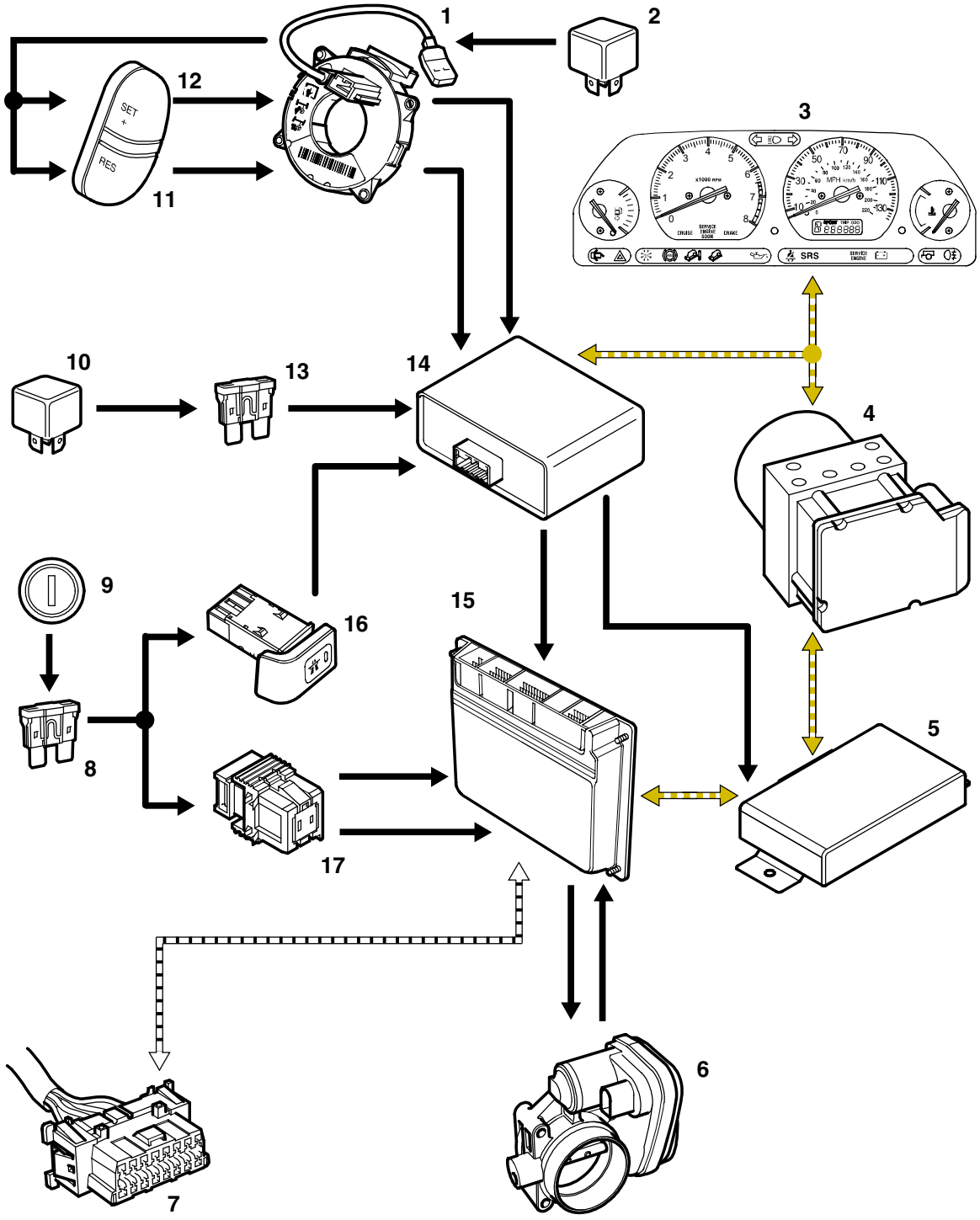
When the power down process is completed, the ECM de-energises the main relay and enters a low power mode. In the low power mode, maximum quiescent drain is 0.5 mA.

Cruise Control Component Location



1 Warning lamp
2 Steering wheel switches
3 Interface ECU
4 Master switch

Cruise Control System Control Diagram



M18 0720

A = Hardwired connection; D = CAN bus; J = Diagnostic ISO 9141 K line bus



1 Rotary coupler
2 Horn relay
3 Instrument pack
4 ABS modulator
5 EAT ECU
6 Electric throttle
7 Diagnostic socket
8 Fuse 8, passenger compartment fusebox
9 Ignition switch
10 Main relay
11 RES switch
12 SET+ switch
13 Fuse 7, passenger compartment fusebox
14 Interface ECU
15 ECM
16 Master switch
17 Brake pedal sensor

Cruise Control Description

General

The cruise control system is integrated with the engine management system and uses throttle intervention to automatically maintain a set vehicle speed. Once engaged, the system can also be used to accelerate the vehicle without using the accelerator pedal. The cruise control system consists of:

- A master switch.
- SET+ and RES steering wheel switches.
- An interface ECU.
- A warning lamp.

The system also uses:

- Inputs from the brake pedal sensor and the Anti-lock Braking System (ABS) modulator.
- The Engine Control Module (ECM).

The Controller Area Network (CAN) bus is used by the cruise control system for the exchange of data between the interface ECU, ECM, EAT ECU, ABS modulator and instrument pack.

Cruise control is enabled when the master switch is pressed. Once enabled, the cruise control system is operated using the steering wheel switches. The steering wheel switches output signals to the interface ECU, which then signals the ECM. The ECM then adjusts the throttle to maintain the vehicle at the set speed.

The cruise control warning lamp provides a visual indication of when the system is engaged.

Master Switch

The master switch controls an ignition feed to the interface ECU to enable the system. The switch is a mechanically latching push switch installed on the outboard side of the instrument pack. An amber LED in the switch remains illuminated while the switch is latched.

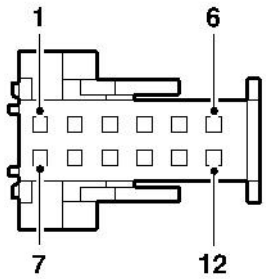
Steering Wheel Switches

The steering wheel switches, SET+ and RES, are non latching push switches that engage and disengage cruise control and adjust the set speed. While pressed, the switches connect a power feed from the battery, via the coil of the horn relay and the rotary coupler, to the interface ECU.

Interface ECU

The interface ECU converts the analogue signals from the steering wheel switches into serial data messages, known as Multi-Function Logic (MFL) messages, which are interpreted by the ECM to operate cruise control. The interface ECU also controls the output of a cruise engaged signal to the EAT ECU. The interface ECU is installed below the RH front seat, under a plastic protective cover.

Interface ECU Harness Connector (C1959)



M18 0762

Pin No.	Description	Input/Output
1	System earth	-
2	MFL signal	Output
3	SET+ switch	Input
4	RES switch	Input
5	CAN bus low (L line)	Input/Output
6	CAN bus high (K line)	Input/Output
7	Cruise control master switch	Input
8	Ignition power supply	Input
9	Cruise control engaged signal	Output
10 to 12	Not used	-

MFL Messages

The interface ECU outputs one of three MFL messages, RESUME, SET or OFF, on a serial link to the ECM. The power feed from the main relay to the interface ECU drives the MFL messages. While the master switch is selected off, only the OFF MFL message can be transmitted. When the master switch is selected on, the power feed from the switch enables the interface ECU to send either the SET or RESUME MFL messages, depending on the inputs from the steering wheel switches and the cruise control status message from the CAN bus. When the master switch is first switched on, the output of the RESUME message is automatically inhibited until after the first engagement of cruise control.

Cruise Engaged Signal

When cruise control is engaged, the interface ECU outputs battery voltage on a connection to the EAT ECU to provide a cruise control engaged signal. The EAT ECU uses the signal to switch between normal and cruise control modes of operation.

Warning Lamp

The warning lamp indicates the status of the cruise control system. Located in the instrument pack, the warning lamp illuminates when cruise control is engaged, and consists of an amber CRUISE legend.

CAN System

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.
- Accelerator pedal position, from the ECM. Used by the EAT ECU for gear change control.
- Gear lever position, from the EAT ECU. Used by the ECM to ensure the vehicle is in drive for cruise control operation.

Brake Pedal Sensor

Outputs from the brake pedal sensor are supplied to the ECM to enable the system to detect when the brakes are applied. The brake pedal sensor is a Hall effect sensor that produces two outputs. Both outputs should be 0 to 2 volts while the brake pedal is released. When the brake pedal is pressed, the Brake Lamp Switch (BLS) output increases to between 6 and battery volts, the Brake Test Switch (BTS) output increases to between 10 and battery volts.

ECM

The ECM incorporates a software module and associated components to enable cruise control operation by direct control of the electric throttle. In addition to controlling the throttle, the software module monitors hardwired and CAN bus inputs to the ECM and prevents or suspends cruise control operation when the vehicle is not in the correct driving configuration.

Cruise Control Operation

General
When the ignition is switched on, the interface ECU receives a power feed from the main relay and initialises the MFL serial link to the ECM. The ECM is in the normal fuelling mode and outputs the cruise control inactive message on the CAN bus. The interface ECU ignores inputs from the steering wheel switches.

When the master switch is pressed, the LED in the master switch illuminates and a second power feed is connected to the interface ECU to enable the system.

Engagement
Cruise control is engaged by pressing the SET+ steering wheel switch. On receipt of the input from the SET+ switch, the interface ECU outputs a SET MFL message. Provided the vehicle is in the correct driving configuration, when the ECM receives the SET message it stores the current vehicle speed in memory as the set speed. The ECM then adjusts the throttle as necessary to maintain the vehicle at the set speed, and changes the CAN bus message of cruise control status to active.

The vehicle is in the correct driving configuration, when:
- The brakes are off.
- The gearbox is in drive.
- The vehicle is moving at a road speed between 22 and 125 mph (35 and 200 km/h).
- Electronic Traction Control (ETC) is not active.

On receipt of the cruise control active message on the CAN bus, the instrument pack illuminates the cruise control warning lamp and the interface ECU outputs the hardwired cruise control engaged signal to the EAT ECU. On receipt of the cruise control engaged signal, the EAT ECU adopts the cruise control mode, which uses a gear change map less sensitive to changes of accelerator pedal position, to prevent unnecessary gear changes. This improves operating refinement for a minor loss of performance.

Acceleration
While cruise control is engaged, the vehicle can be accelerated using either the SET+ switch or the accelerator pedal. Each momentary press (less than 0.5 second) of the SET+ switch causes the interface ECU to output a SET MFL message to the ECM, which then increments the set speed by 0.6 mph (1 km/h) and accelerates the vehicle to the new set speed. If the switch is held on, the interface ECU repeatedly sends the SET MFL message until the switch is released. While it receives the messages, the ECM keeps incrementing the stored set speed and accelerating the vehicle. When the switch is released and the messages stop, the ECM adopts the increased vehicle speed as the new set speed.

If the accelerator pedal is used to accelerate the vehicle, the ECM reverts to normal throttle control when it detects the demand from the accelerator pedal sensor exceeds that of the current throttle setting. Provided the demand from the accelerator pedal sensor does not increase vehicle speed by more than 10 mph (16 km/h) above the set speed, for more than 30 seconds, cruise control remains engaged and the set speed is resumed once the accelerator pedal is released. If the SET+ switch is pressed before the accelerator pedal is released, the higher speed is adopted as the new set speed.

Suspend/Resume
Cruise control can be manually suspended and resumed (at the previous set speed) using the RES steering wheel switch. The ECM automatically suspends cruise control if one of the conditions required to enable the system is no longer present, e.g. the brakes are applied. Cruise control is also automatically suspended by the ECM if:
- The vehicle speed increases to more than 10 mph (16 km/h) above the set speed for more than 30 seconds, e.g. when travelling downhill or using the accelerator pedal to override cruise control.
- Engine speed increases too rapidly, e.g. if their is a fault in the gearbox or the gearbox goes into neutral.
- The vehicle decelerates too rapidly, e.g. when the brakes are applied.



Suspend

When the RES switch is pressed, the interface ECU outputs the OFF MFL message to the ECM. On receipt of the OFF MFL message, and when automatically suspending cruise control, the ECM reverts to normal fuelling control and changes the cruise control message on the CAN bus to inactive. The set speed is retained in memory by the ECM. On receipt of the cruise control inactive CAN bus message, the instrument pack extinguishes the cruise control warning lamp and the interface ECU switches off the cruise control engaged signal to the EAT ECU. The EAT ECU then returns to its previous operating mode.

Resume

While cruise control is suspended, when the RES switch is pressed the interface ECU outputs the MFL RESUME message to the ECM. Provided the vehicle is in the correct driving configuration, on receipt of the RESUME MFL message the ECM engages cruise control at the previous set speed and changes the CAN bus cruise control message back to active. The instrument pack then illuminates the cruise control warning lamp again and the interface ECU outputs the cruise engaged signal to switch the EAT ECU back to the cruise control mode.

Cancelling

Cruise control is cancelled by pressing the master switch. When cruise control is cancelled, the LED in the master switch extinguishes and the power feed to the interface ECU is disconnected to disable the system. If cruise control is engaged when the master switch is pressed, the interface ECU and the ECM respond in the same way as when cruise control is suspended, except that the interface ECU no longer reacts to inputs from the steering wheel switches.

During the same ignition cycle, if the master switch is pressed again, the interface ECU is re-enabled. Since the output of the RESUME MFL message is inhibited until after the first engagement of cruise control, the interface ECU will not react to an input from the RES switch, and the set speed in the ECM memory is effectively lost to the system. Cruise control only re-engages if the SET+ switch is pressed, when, provided the vehicle is in the correct driving configuration, the ECM adopts the current vehicle speed as the new set speed.

Diagnostics

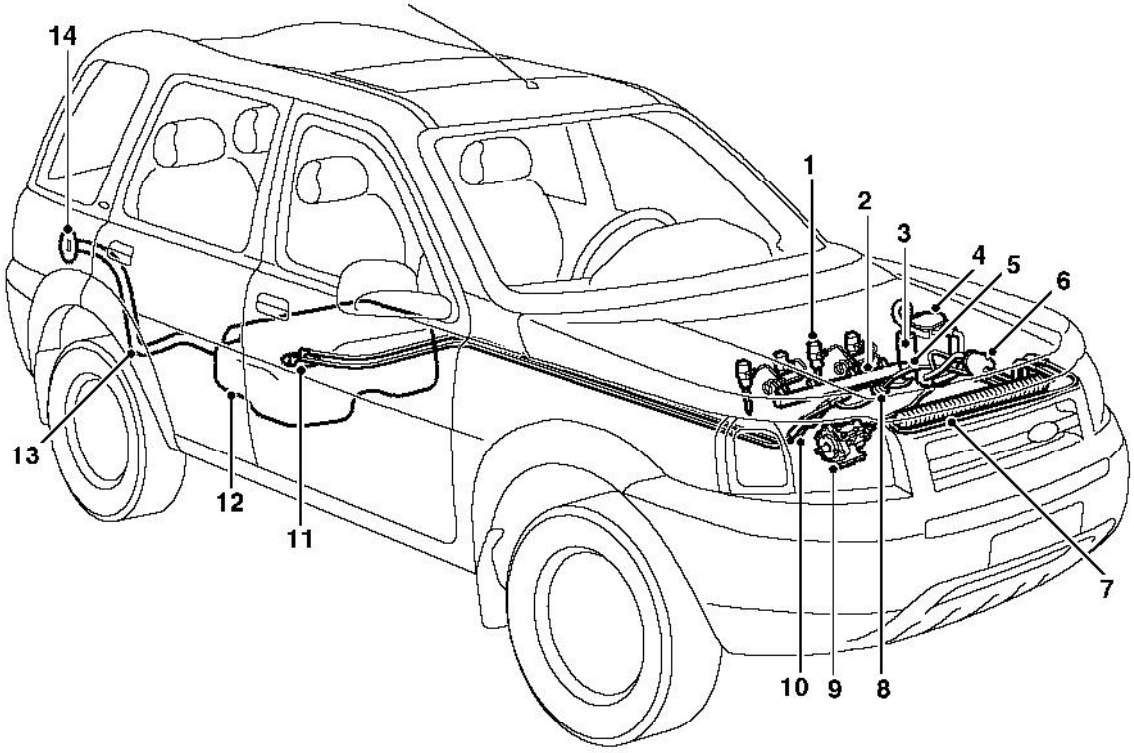
The ECM monitors the MFL serial link to check for faults with the interface ECU. The MFL signal contains a toggle bit which the interface ECU changes to a different state every second to indicate that the interface ECU is operating correctly and receiving a valid CAN bus signal. If a fault occurs with the CAN bus signal or the interface ECU, the toggle bit remains unchanged and the ECM interprets the unchanged toggle bit as a fault. If the interface ECU fails to output the MFL signal, the ECM also interprets the lack of a signal as a fault.

If a fault is detected, the ECM disables cruise control for the remainder of the ignition cycle and stores a related fault code in memory. The fault codes can be accessed using TestBook/T4, which communicates with the ECM via an ISO 9141-2 K line from the diagnostic socket.

The ECM monitors the two inputs from the brake pedal position sensor and disables cruise control if a fault is detected. The ECM can detect open circuits and implausible inputs. However, simultaneous short circuits to 0 volt in both inputs cannot be detected and, if this occurs, cruise control operates but does not suspend operation when the brake pedal is pressed.

The ECM resets the cruise control system at the beginning of each ignition cycle and operates normally if a previously detected fault is no longer present.

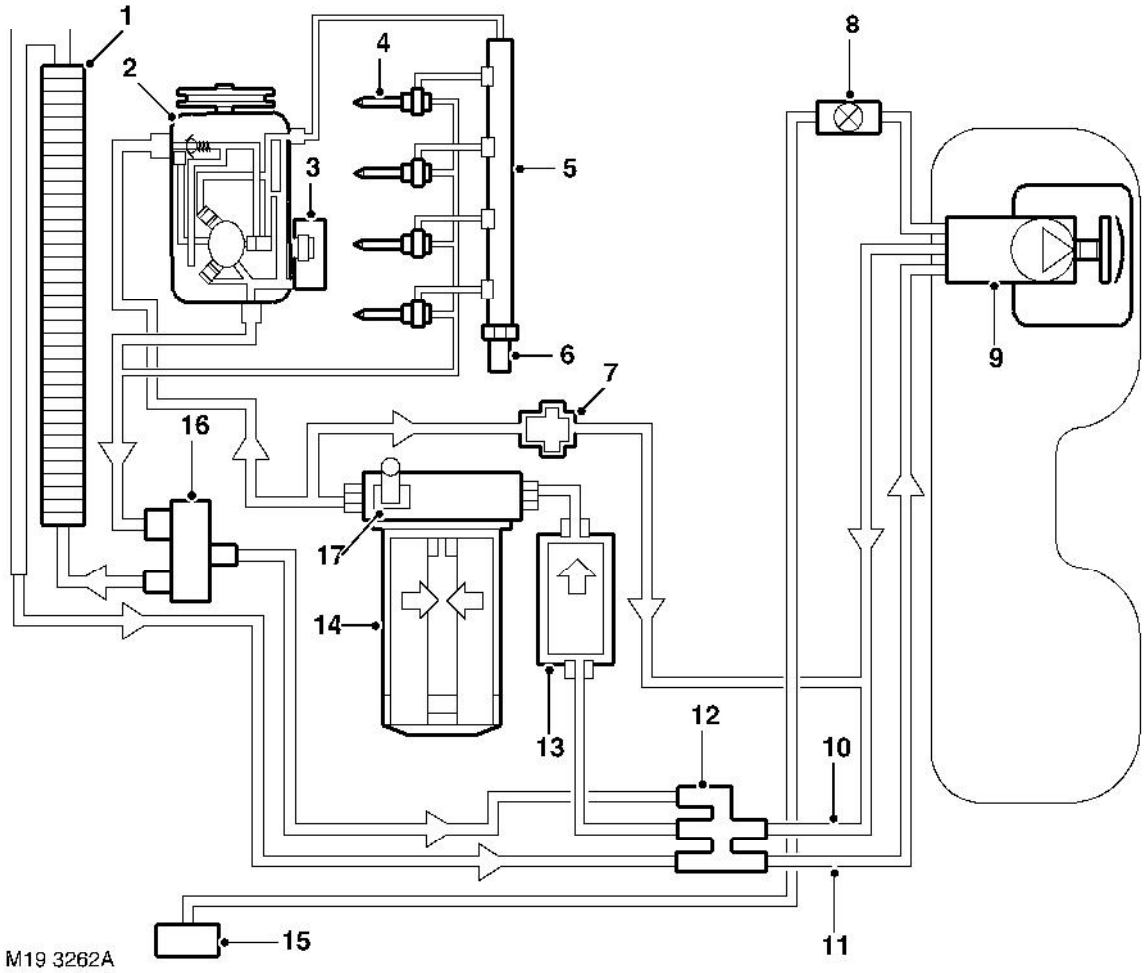
Fuel Delivery System Component Layout



M19 3261

1 Injector (4 off)
2 Fuel rail
3 Secondary Low Pressure (LP) fuel pump
4 Fuel filter
5 Pressure sensor
6 Bi-metallic valve
7 Fuel cooler
8 Pressure relief valve
9 High Pressure (HP) fuel injector pump
10 Five way valve
11 Primary LP fuel pump
12 Fuel tank
13 Filler tube
14 Filler cap

Fuel Delivery System Schematic Diagram



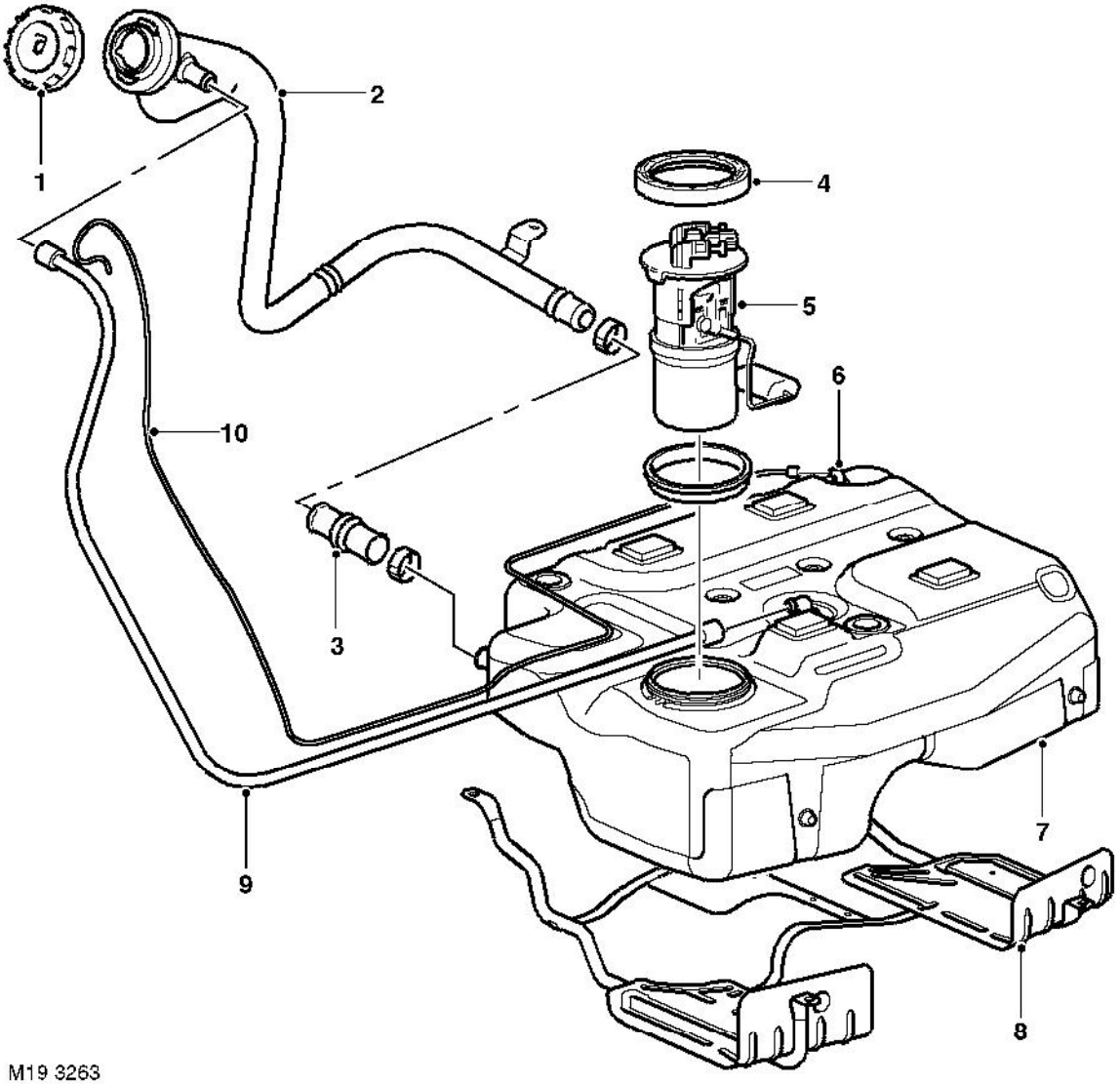
1 Fuel cooler
2 Fuel injection pump
3 Fuel pressure regulator
4 Fuel injector (4 off)
5 Fuel rail
6 Fuel pressure sensor
7 Pressure relief valve
8 Fuel Burning Heater (FBH) pump
9 Primary LP fuel pump
10 Supply pipe
11 Return pipe
12 Five way valve
13 Secondary LP fuel pump
14 Fuel filter
15 FBH
16 Bi-metallic valve
17 LP fuel sensor

Description

General

The major components of the fuel delivery system comprise a fuel tank, a HP fuel injection pump, a primary LP fuel pump, a secondary LP fuel pump, a fuel rail and four injectors, a fuel filter and fuel cooler. The low pressure (LP) fuel pumps pass fuel from the tank to the injection pump which delivers fuel at high pressure to the fuel rail and equally to each of the injectors.

Fuel Tank



M19 3263

1 Filler cap
2 Filler tube
3 Flexible tube
4 Locking ring
5 Primary LP fuel pump and fuel gauge potentiometer
6 Roll over valve
7 Fuel tank
8 Cradle
9 Vent pipe
10 Atmospheric vent

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 with a tubular cradle which is secured to the vehicle floorpan with four bolts. The tank has a capacity of 60 litres (13.2 gallons).

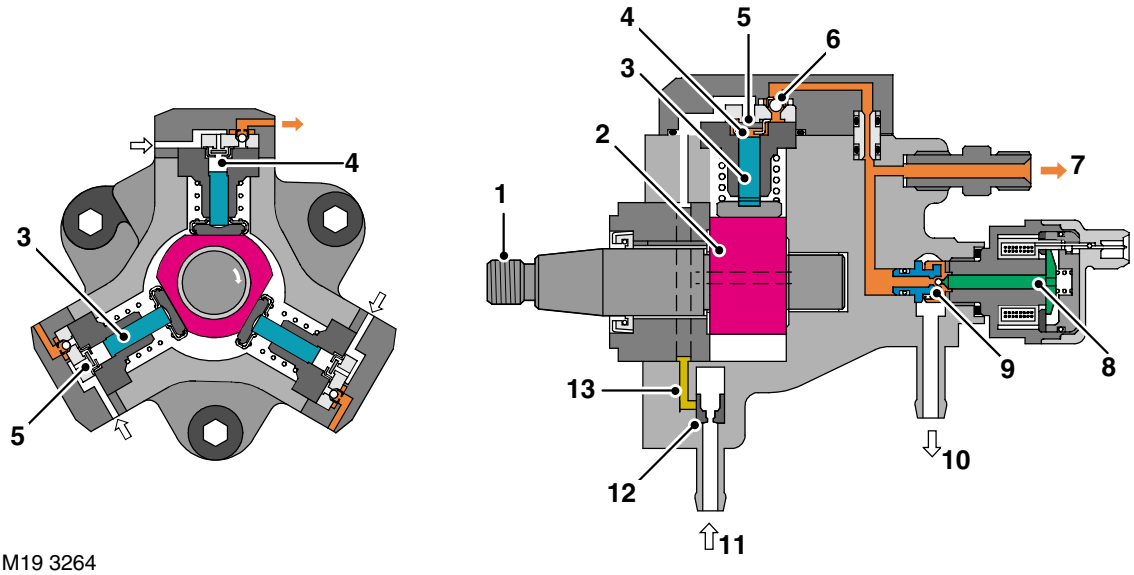
A reflective metallic shield protects the tank from heat generated from the exhaust system on the LH side and a fire shield is located on the RH side.

An aperture in the top surface of the tank allows for the fitment of the primary LP fuel pump. The pump is secured with a special locking ring and is sealed with a rubber seal ring.

The fuel tank filler is located on the RH 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 diameter vent pipe allows air and vapour displaced by the fuel to escape to atmosphere during filling of the tank.

The tank incorporates a Roll Over Valve (ROV) to allow vapour in the tank to escape to atmosphere. The tank must not be over-filled to ensure that a vapour space above the fuel level is maintained which allows 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.

HP Fuel Injection Pump



M19 3264

1 Drive shaft
2 Cam
3 Piston
4 Chamber
5 Inlet valve
6 Pressure valve
7 HP supply to fuel rail
8 Pressure control valve
9 Ball valve
10 HP return
11 LP fuel supply
12 Safety valve with throttle bore
13 LP fuel gallery

The high pressure fuel injection pump is located on the front right hand end of the engine and is driven via a chain from the crankshaft. The pump has a variable output which is controlled by the ECM via a pressure control valve. The ECM maintains the pump output pressure to the fuel rail at a level appropriate to the current operating conditions. The output pressure is measured by a pressure sensor located in the end of the fuel rail.

The pump receives a fuel supply from the fuel filter which is supplied by the primary and secondary LP pumps at a pressure of approximately 2 to 2.4 bar (29 to 35 lbf/in^2). This pressure is controlled by the pressure relief valve.

The injection pump uses the fuel as a lubricant and coolant for the pump internal components. The pump has an integral control valve which ensures that fuel delivery to the internal components is maintained in the event of a drop of fuel supply pressure. If the supply pressure falls to below 0.5 bar (7.25 lbf/in^2), the valve closes and diverts all fuel to the lubrication and coolant passages within the pump in preference to supplying the injectors, preventing irreparable damage to the pump.

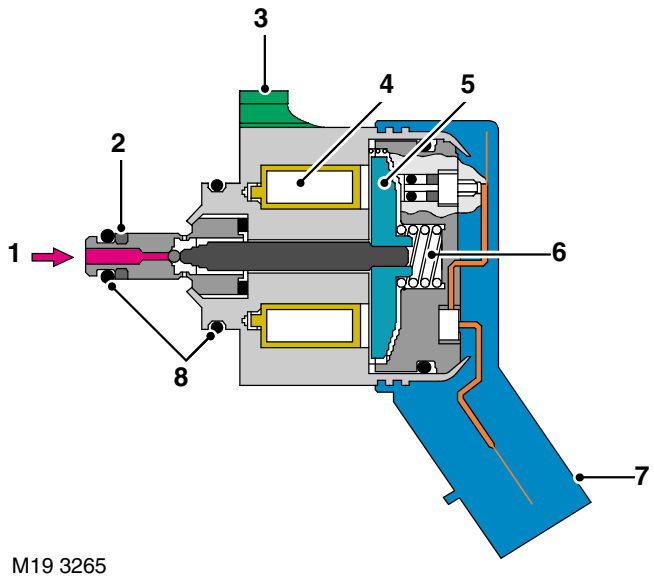
The ECM monitors the fuel pressure by a fuel pressure sensor located in the fuel filter. This sensor detects fuel pressure emerging from the filter and can detect low fuel supply pressure to the injector pump immediately. If the pressure falls to below 0.8 bar (11.6 lbf/in^2), the ECM changes the fuelling strategy to the engine. In this instance there will be a gradual drop in engine power because the ECM will limit the injector pulse times to preserve fuel pressure in the rail and allow the vehicle to be driven safely to a stop.

The injection pump delivers a high output which is not required by the engine at all times. Excess fuel is passed from the pump to the fuel tank via the pressure control valve. At fuel temperatures above 76°C (169°F), a bi-metallic valve diverts the fuel through a fuel cooler, located above the engine cooling radiator, to cool the fuel before it returns to the tank.

The engine requires a minimum output of 200 bar (2900 lbf/in^2) at start up and 300 bar (4350 lbf/in^2) at idle. The pump can deliver a maximum output pressure of up to 1300 bar (18850 lbf/in^2) to cover all operating conditions.

The pump has three external connections; a LP supply, a HP output and a HP return. The connections have tapered seats which accept the coned seats of the connecting pipes which are secured with ferrule nuts. The fuel flowing through the pump is also used to cool and lubricate the pump internal components.

Pressure Control Valve



M19 3265

1 HP fuel input
2 Support ring
3 Body
4 Coil
5 Armature
6 Spring
7 Electrical connector
8 O-ring seals

The pressure control valve is located on the pump and directly controls the pressure of fuel delivered to the fuel rail via an integral solenoid valve. The valve is sealed in the pump housing with two O-ring seals. The inner seal, which is exposed to HP fuel, has a support ring to aid sealing against the high fuel pressure.

When the ball valve is in its closed position, the coil is energised, forcing the armature to hold the ball valve on its seat against the HP output from the pump, assisted by the coil spring.

When the ball valve is in its open position, the coil is de-energised. This allows the ball valve to push the armature, against the coil spring pressure and allow the valve to open. This allows the HP pump output to pass through the open ball valve into the fuel return pipe.

The ECM controls the opening and closing of the valve using PWM signals to control the solenoid. When the solenoid is de-energised, the valve is open and fuel pressure is diverted into the fuel return line. When the solenoid is energised the valve is closed allowing the fuel pressure to rise. The ECM controls the fuel pressure by adjusting the duty cycle of the solenoid via the PWM signals.

The ECM determines the required fuel pressure by monitoring signals corresponding to the following parameters:

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

If the pressure control valve fails the engine may not start, power loss may occur and the engine will stall.

Primary LP 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 fitment and removal. Access to the pump is via an access panel located below the RH rear seat.

An electrical connector on the 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 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 the cool fuel in the tank. The pump is capable of a maximum output of 165 litres/hour at a pressure of 2.0 bar (29 lbf/in^2) and a power supply of 11.5V.

A float operated potentiometer is also located on the pump and provides a variable resistance to earth for an output from the fuel gauge in 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 remaining fuel.

The pump has a connection for a fuel supply to the fuel burning heater pump, located in the RH wheel arch, on vehicles fitted with this option. For further details refer to Heating and Ventilation.

☞ **HEATING AND VENTILATION, DESCRIPTION AND OPERATION, Description.**

Secondary LP Fuel Pump

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

The pump is a secondary in-line screw pump designed to aid fuel flow through the filter in cold conditions. The pump is capable of a maximum output of 210 litres/hour at a pressure of 1.8 bar (26 lbf/in^2) and a power supply of 12V.

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.

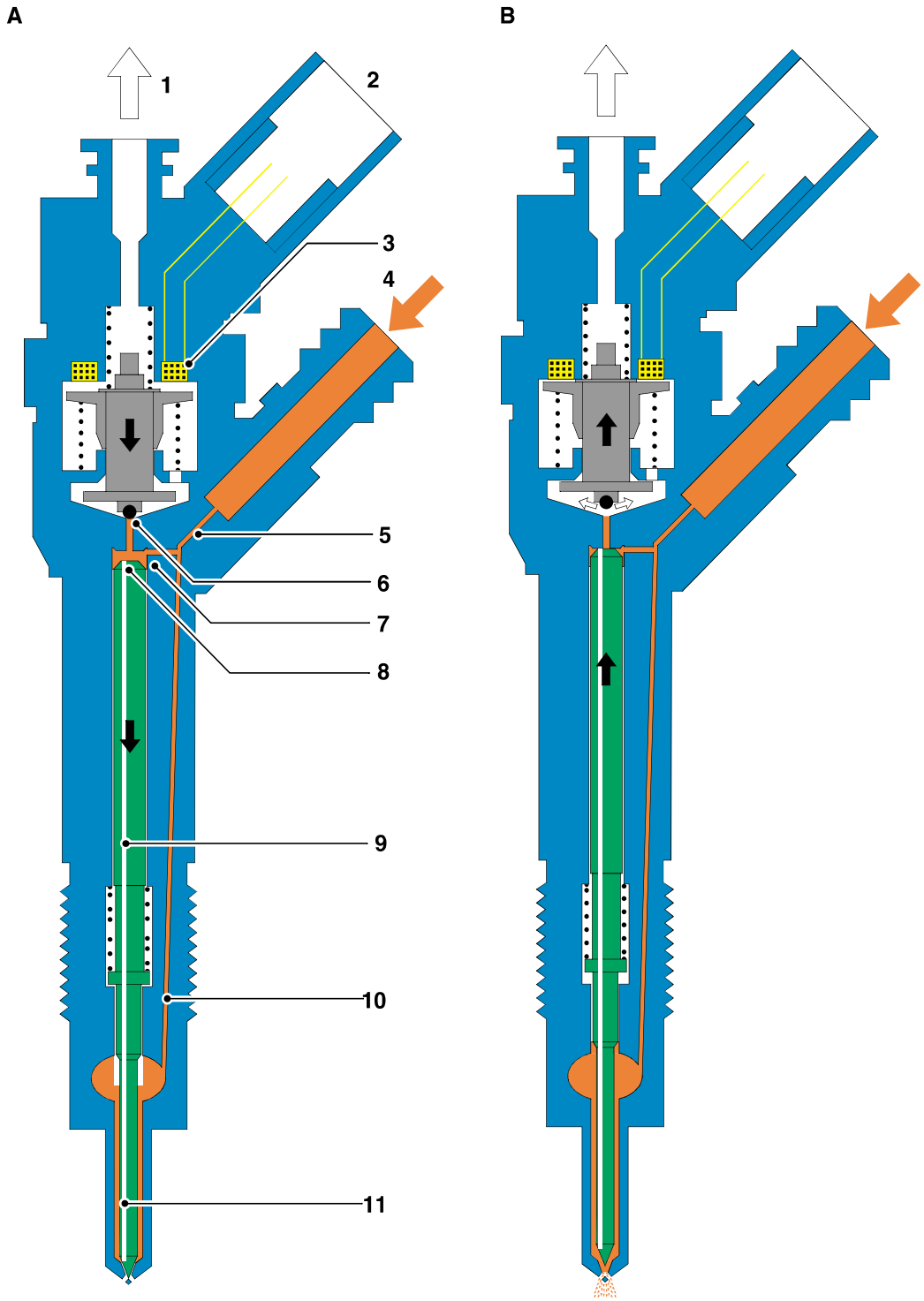
The pump recirculates warm fuel returning from the injection pump through the fuel filter to prevent waxing of the fuel in cold conditions. This is directed into the pump feed hose from the five port valve when the fuel is below 76°C (169°F) and the bi-metallic valve is closed, by-passing the fuel cooler.

Fuel Pump Relay

The primary and secondary low pressure pumps are controlled by the ECM via a relay which is located on a bracket on the 'A' post, adjacent to the passenger compartment fusebox.

The relay coil receives a permanent battery supply via the fuel shut-off switch. The coil is energised when required by the ECM which provides an earth path. In the event of the fuel shut-off switch being tripped, the power supply to the relay coil is removed, de-energising the coil and removing the power supply to the primary and secondary low pressure pump.

Injectors



M19 3266

A = Injector closed
B = Injector open

1 Fuel return
2 Electrical connector
3 Solenoid valve
4 HP Fuel supply inlet
5 Valve control chamber
6 Ball valve
7 Inlet port
8 Outlet port
9 Valve control piston
10 HP fuel supply gallery to nozzle
11 Nozzle needle valve

The four injectors are located in the cylinder head, between the four valves in each cylinder. Each injector is sealed into the cylinder head with a copper washer. Two studs in the head locate a plate on the injector which is secured with two nuts on the studs. Each stud has an external Torx fitting on the end, which allows the stud to be wound from the head and simultaneously extract the injector from its bore.

Each injector has an electrical connector for power supply and connections to the ECM. The top of each injector is fitted with a fuel return pipe which allows fuel used in the operation of the injector to return to the tank. Each injector only uses approximately 50% of the fuel delivered to it. The remaining 50% is used to cool the injector and is passed to return via the fuel return pipe. The injectors are sensitive to fuel pressure and if pressure in the fuel rail falls to below 0.6 bar (8.7 lbf/in^2) the injectors will not deliver the correct fuel requirements resulting in poor emissions and driveability.

Each electronic injector has a solenoid valve which, when energised, allows a ball valve to lift off its seat. This allows pressurised fuel to lift a needle valve in the injector nozzle and spray a finely atomised jet of fuel into the cylinder. Fuel which spills past the ball valve is directed into a return line which is connected to the fuel return from the HP injector pump.

Each injector has an electrical connector which provides a 12V direct supply from the main relay and connections to the ECM. If the battery voltage falls to between 6V and 9V, the operation of the injector solenoid will be impaired affecting, acceleration, maximum speed and idle. Battery voltage below 6V will result in the injectors not operating.

Each injector solenoid is controlled separately by the ECM which provides an earth path to open the injector nozzle at the correct time and for a calculated period to provide a metered injection of fuel into the cylinder. The ECM uses signals from other sensors and a programmed fuelling strategy to ensure that the precise amount of fuel is injected at the correct timing for maximum fuel efficiency and minimum emissions.

Fuel Rail

The metal fuel rail is a forged steel tube mounted on the cylinder head and secured with two cap screws. The rail has five threaded bosses with machined taper seats. The central threaded boss is for the HP fuel feed pipe from the injector pump. The four remaining bosses are for connection to each injector. Each pipe has a cone end which seals with the tapered seat in the rail and a similar seat on the injector.

A fuel rail pressure sensor is fitted into a threaded bore in the LH end of the rail. The sensor is connected to ECM connector C0606 via the engine harness which supplies a 5V power supply, earth and signal connections. The sensor is a diaphragm type sensor with a resistive element attached to the diaphragm. The diaphragm changes shape as the fuel pressure increases or decreases, causing the element to deflect, changing the resistive characteristics of the sensor. The sensor uses the 5V supply through the resistor to produce an analogue signal to the ECM which corresponds to the fuel pressure. The ECM compares this signal to values stored in its memory to calculate the actual fuel pressure present in the rail.

Bi-metallic Valve

The bi-metallic valve is located at the front of the engine compartment at the LH end of the fuel cooler. The valve has three connections and is connected via rubber hoses to the HP injector pump return pipe and the fuel cooler feed pipe and to the tank return line at the five-port valve.

The valve contains a bi-metallic strip which moves in relation to the temperature of the fuel flowing over it. At fuel temperatures below 76°C (169°F), the valve is closed and fuel returning from the injector pump is directed into the tank return line to the five-port valve, where it is directed into the secondary LP pump feed line. At temperatures above 76°C (169°F), the bi-metallic valve closes the return line and fuel is directed through the fuel cooler.

Pressure Relief Valve

The pressure relief valve is located below the fuel filter. A tee connection in the outlet hose from the filter is connected back into a tee connection in the fuel feed hose, upstream of the secondary LP pump. The relief valve is located in this line and controls the pressure of fluid delivered to the fuel injection pump to between 2 and 2.4 bar (29 to 35 lbf/in^2). At pressures above this, the relief valve opens allowing fuel to flow back to the fuel feed hose, decaying the pressure delivered to the injection pump. The primary reason for the relief valve is to protect the injection pump from high fuel input pressure from the secondary pump if a high voltage condition occurs.

Five Port Valve

The five-port valve is located at the bottom of the LH inner wing, near the bulkhead. 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 LP supply to the secondary LP pump. A connection to this line joins the fuel return line from the bi-metallic valve to the fuel cooler return line to allow returning fuel to recirculate through the secondary pump.

The valve intersects the return to tank hose from the fuel cooler and the fuel supply hose from the primary LP pump to the secondary LP pump. A fifth connection directs fuel from the injection pump, when the bi-metallic valve is closed, to pass into the valve. This warm fuel from the injection pump is mainly directed back into the feed hose to the secondary LP pump, although some fuel is allowed to flow to the tank return hose via a 2.8 mm restrictor.

Fuel Cooler

The fuel cooler is located below the bonnet locking platform. The cooler has two brackets which locate on captive studs on the locking platform and is secured with two nuts.

The cooler comprises a tube which is bent through 180° to form two parallel connected pipes. One pipe run has aluminium loops attached which are exposed to air flow from the front of the vehicle. The loops act as heat exchangers, conducting heat from the fuel as it passes through the tube. Each end of the tube is flanged. The inlet to the cooler is connected to the bi-metallic valve by a flexible hose. The outlet from the cooler is connected by a flexible hose to the five-port valve.

Fuel Filter

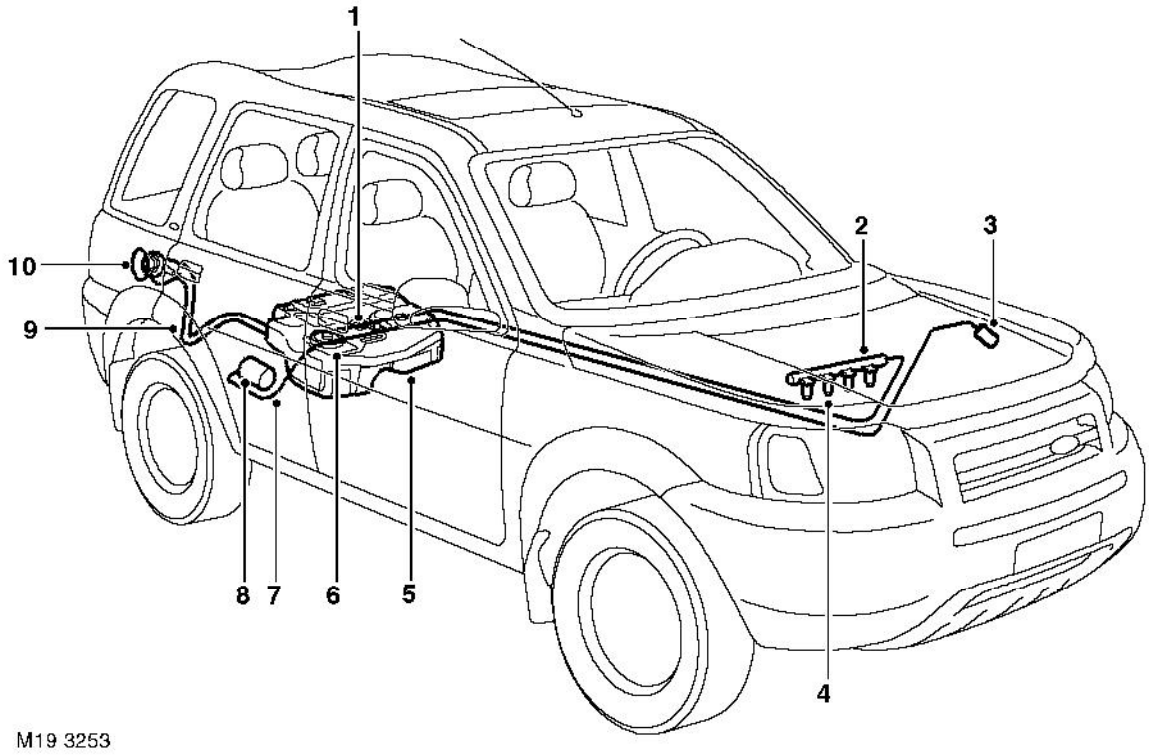
The fuel filter is located in a plastic housing, adjacent to the secondary LP fuel pump, in the engine compartment on the LH inner wing. The filter assembly comprises a filter canister, a filter head unit and a low pressure sensor.

The filter is accessible by removing the filter unit from the housing. The filter canister is removed from the filter head unit by unscrewing. The filter has no water trap installed. This is because the primary LP pump operates at high speed emulsifying water in the fuel and preventing accumulations in the filter. The paper filter has an increased filter area and pore size when compared to conventional filters. These characteristics help resist the potential for waxing to occur at low temperatures.

The low fuel pressure sensor is screwed into a port in the side of the filter head unit and is connected by three wires to ECM connector C0604, pins 9, 10 and 17. Pin 9 supplies a 5V supply to the sensor, pin 10 supplies an earth and pin 17 supplies a variable signal back to the ECM which corresponds to the fuel pressure.

The sensor measures the pressure on the output side of the filter and therefore can detect a blockage within the filter or failure of the LP fuel supply. The ECM will monitor the LP sensor and, in the event of very low pressure, will stop the engine to prevent damage to the HP injector pump. Refer to HP Fuel Injection Pump description in this section for further details.

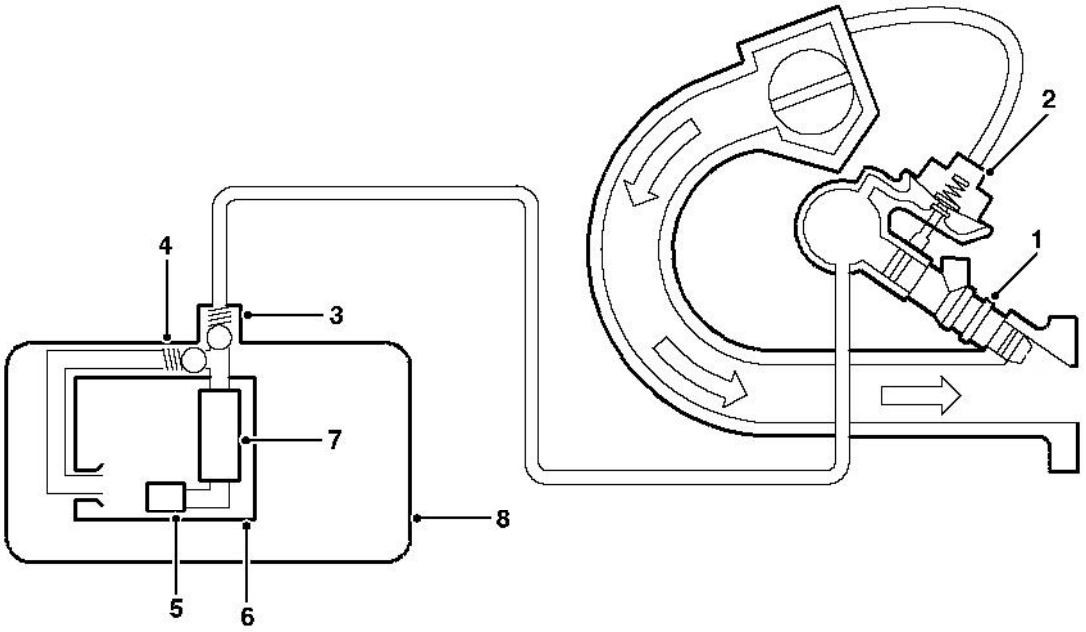
Fuel Delivery System Component Layout



M19 3253

1 Fuel feed pipe
2 Fuel rail
3 Purge valve
4 Injector (4 off)
5 Fuel tank
6 Fuel pump
7 Evaporative Emissions (EVAP) canister vent pipe
8 EVAP canister
9 Filler tube
10 Filler cap

Fuel Delivery System Schematic Diagram



M19 3254

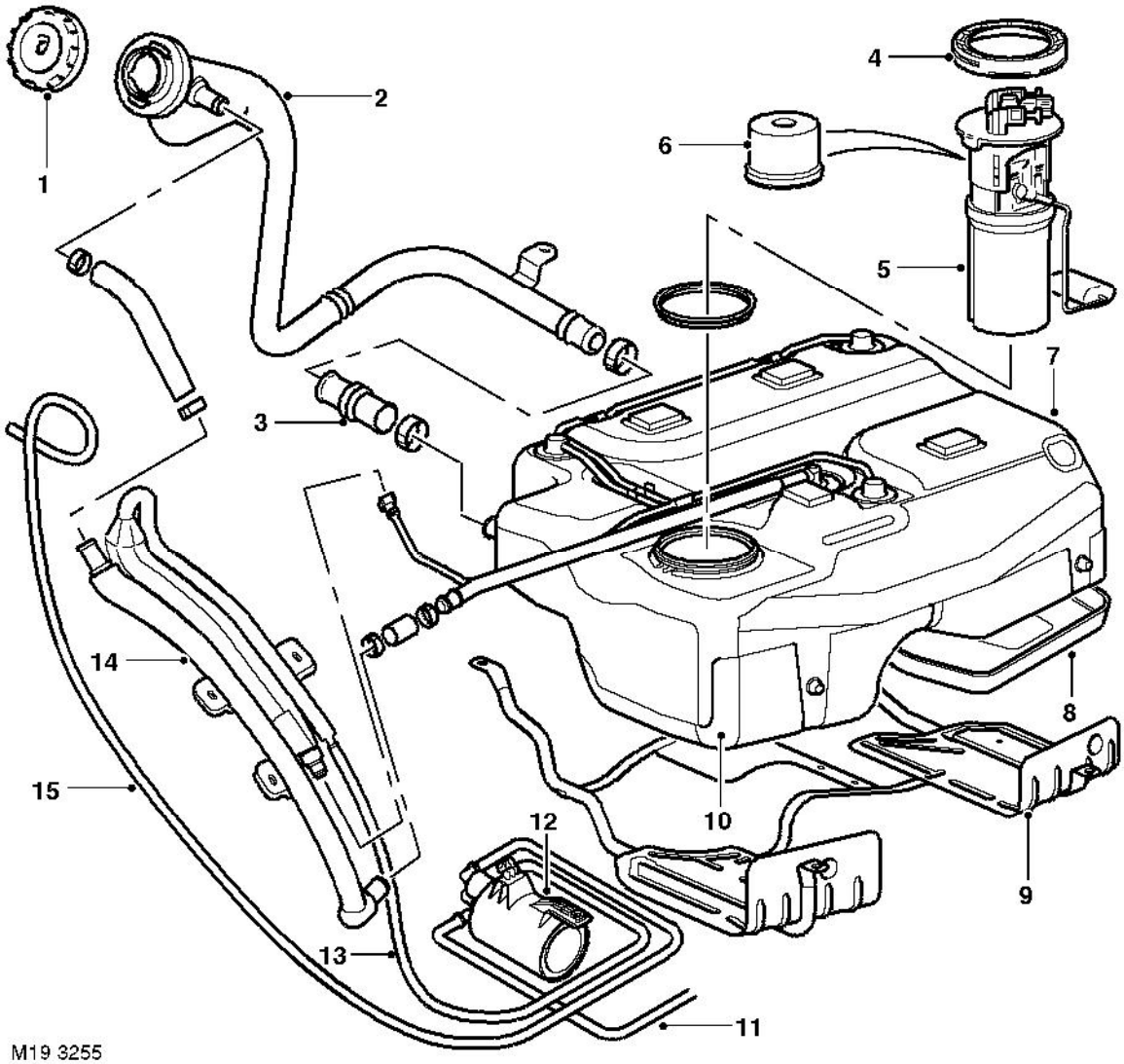
1 Injectors
2 Accumulator
3 Non return valve
4 Fuel pressure regulator
5 Fuel filter
6 Swirl pot
7 Fuel pump
8 Fuel tank

Description

General

The major components of the fuel delivery system comprise a fuel tank, a fuel pump, a fuel rail and four injectors. The fuel pump supplies fuel from the tank at a constant pressure, via a pipe routed along the underside of the vehicle, to the fuel rail. The fuel rail distributes the fuel equally to each of the four injectors.

Fuel Tank



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 astmospheric vent

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

A reflective metallic heat shield protects the tank from heat generated from the exhaust system on the LH side and a fire shield is located on the RH side.

An aperture in the top surface of the tank allows for the fitment of the fuel pump. The pump is secured with a special locking ring and is sealed with a rubber O-ring seal.

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 vent pipe is connected to the neck of the filler to allow air and fuel vapour displaced from the tank when filling to vent to atmosphere via the filler neck. A smaller vent pipe is also connected to the tank and vents fuel vapour from the tank to the EVAP canister which is located in the RH wheel arch, behind the liner.

☞ **EMISSION CONTROL - K SERIES 1.8, DESCRIPTION AND OPERATION, Description.**

The tank incorporates Roll Over Valves (ROV) to allow vapour in the tank to escape to the EVAP canister. The tank must not be over-filled to maintain a vapour space above the fuel level and allow the tank to 'breathe'. The ROV's are welded onto the top surface of the tank and connected via a pipe to the EVAP canister. During normal operation each ROV is open allowing vapour to pass to the canister. In the event of the vehicle being overturned the ROV's shut-off, sealing the tank and preventing fuel flowing down the vent pipe.

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. The fuel pump is housed in a plastic body which incorporates coarse and fine filters. The fine mesh filter should be renewed at the prescribed service intervals. The fuel pump is located in a larger housing which is the swirl pot. The swirl pot maintains a constant fuel level at the pump pick-up.

A pressure regulator which regulates the pressure output of the pump to 3.5 bar (51 lbf.in^2) is located in the pump housing. If the pressure exceeds this setting the regulator relieves excess pressure back to the swirl pot. This ensures that the fuel rail and the injectors are supplied with a constant pressure.

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 which supplies power and ground for 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 prevents fuel draining from the feed pipe into the tank after the pump has stopped.

Injectors

Four injectors are held between the fuel rail and the inlet manifold. The injectors are sealed to the fuel rail and the inlet manifold by O-ring seals. Each injector supplies one cylinder with fuel. The injectors receive pressurized fuel from the fuel pump via the fuel rail. The Engine Control Module (ECM) is responsible for the timed injection duration of each injector. The injectors supply a finely atomized spray of fuel into the cylinder which is mixed with the air prior to ignition. Refer to Engine Management System - MEMS for further details.

☞ **ENGINE MANAGEMENT SYSTEM - MEMS, DESCRIPTION AND OPERATION, Description.**

Fuel Rail

The fuel rail is located at the rear of the engine and secured to the inlet manifold with two bolts. The four injectors are located in holes in the rail, sealed with O-ring seals and secured with spring clips. The location of the fuel rail secures the injectors between the rail and the inlet manifold.

A flange with two threaded holes on the LH end of the fuel rail provides attachment for the fuel feed pipe. The fuel feed pipe has a metal flanged end which is locates on the fuel rail. A seal prevents leakage and the flange is secured with two screws. An accumulator is located on the RH end of the fuel rail.

Accumulator

The accumulator is attached to the right hand end of the fuel rail. The accumulator acts as a damper to damp pulses from the pump and ensure that the fuel pressure in the rail and to the injectors is constant. The accumulator is connected by a pipe to the inlet manifold from which it receives a vacuum to aid the damping process.

Operation

The fuel pump is controlled by the Engine Control Module (ECM) via a fuel pump relay located in the engine compartment fusebox.

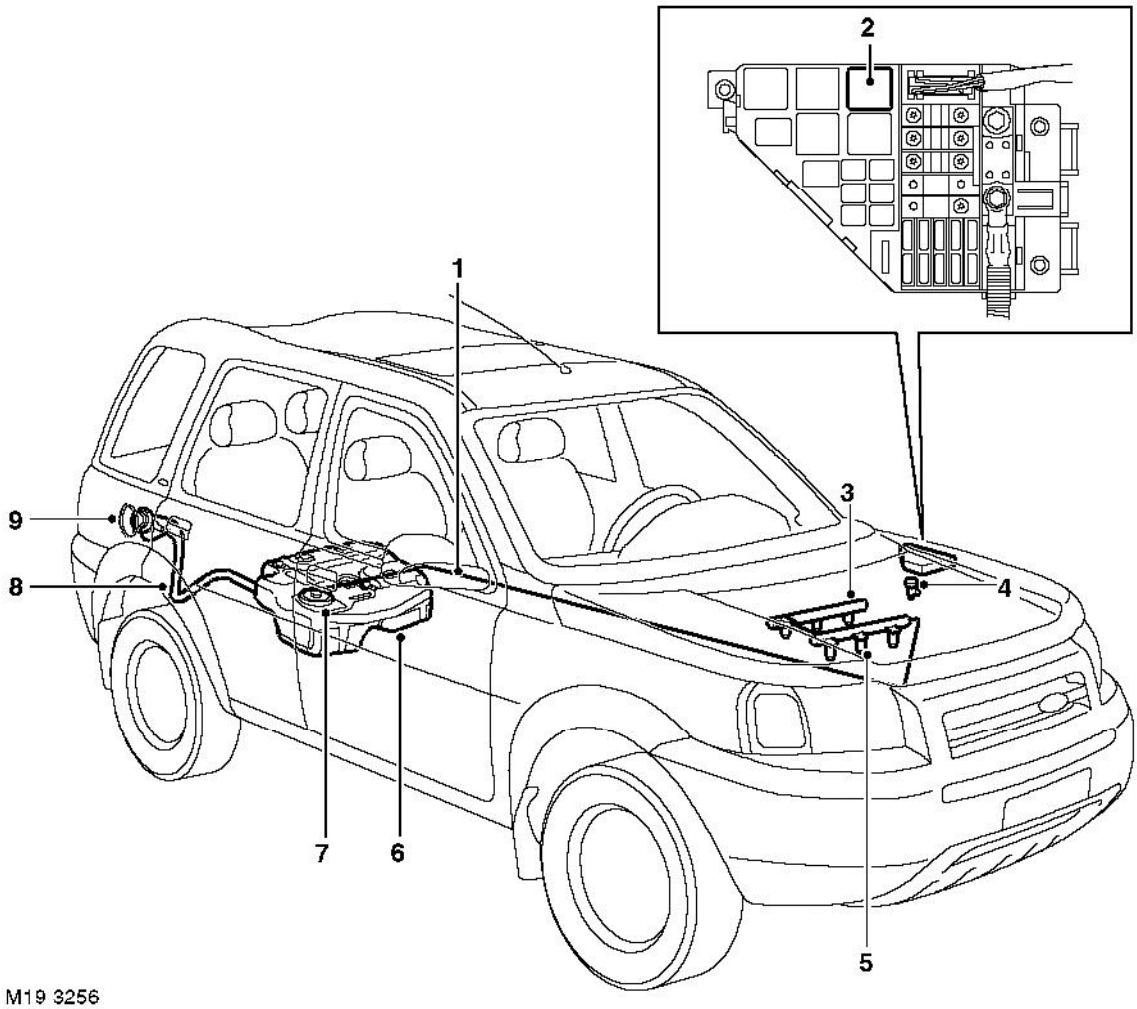
When the ignition is switched to position II, the ECM provides an earth path for the coil of the fuel pump relay on pin 68 of ECM connector C0913. The relay is energised for a short period to pressurise the fuel system. When the ECM senses that the engine has started by receipt of a valid signal from the CKP sensor, the ECM energises the fuel pump relay for as long as the engine is running.

The fuel shut-off switch is located in the power supply from the battery to the relay contacts. If the fuel shut-off switch is tripped the supply to the relay will be broken, preventing pump operation. The switch, located in the LH side of the engine compartment, below the E-box, breaks the circuit if a predetermined deceleration speed is exceeded, i.e. in the event of a collision. The fuel shut-off switch can be reset by depressing the rubber cap on the top of the switch.

WARNING: Ensure there are no fuel leaks and confirm the integrity of the fuel system before resetting the fuel shut-off switch.

The fuel pump, when running, outputs fuel at a constant pressure to the fuel rail. The pressure is controlled by the pressure regulator located in the pump. Excess fuel from the pressure regulator circuit is directed back to the pump swirl pot. The controlled pressure provides more fuel to the fuel rail than the maximum requirement of the engine, therefore a constant pressure is maintained in the rail under all operating conditions.

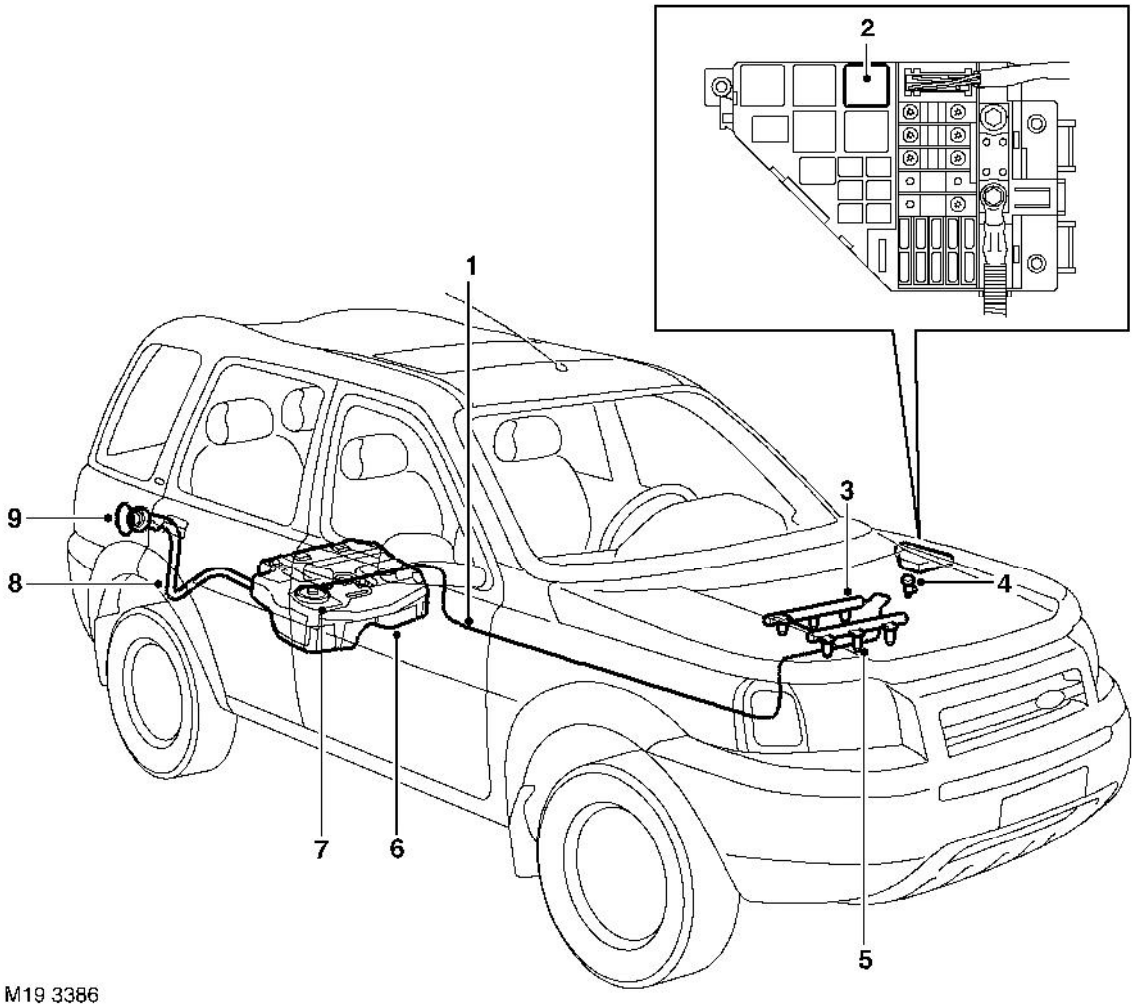
Fuel Delivery System Component Layout (All Except NAS)



M19 3256

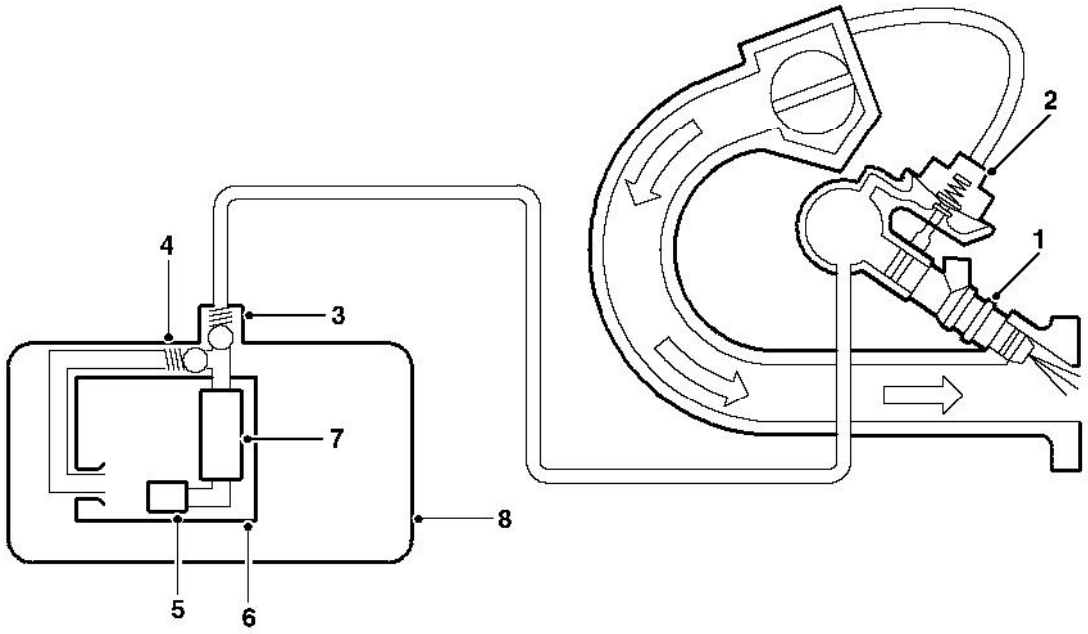
1 Fuel feed pipe
2 Fuel pump relay
3 Fuel rail
4 Inertia fuel cut-off switch
5 Fuel injector
6 Fuel tank
7 Fuel pump
8 Filler tube
9 Filler cap

Fuel Delivery System Component Layout (NAS)



1 Fuel feed pipe
2 Fuel pump relay
3 Fuel rail
4 Inertia fuel cut-off switch
5 Fuel injector
6 Fuel tank
7 Fuel pump
8 Filler tube
9 Fuel filler cap

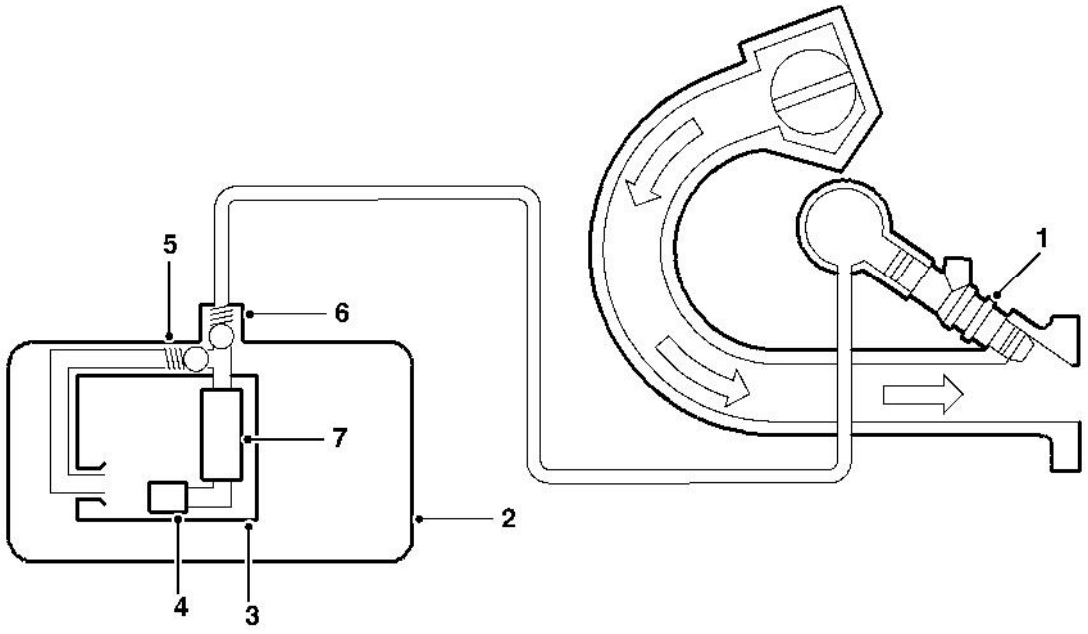
Fuel Delivery System Schematic (All Except NAS)



M19 3254

1 Injectors
2 Accumulator
3 Non return valve
4 Fuel pressure regulator
5 Fuel filter
6 Swirl pot
7 Fuel pump
8 Fuel tank

Fuel Delivery System Schematic (NAS)



M19 3387

1 Fuel injector
2 Fuel tank
3 Swirl pot
4 Fuel filter
5 Pressure regulator valve
6 Non return valve
7 Fuel pump

Description

General
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 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 LH side of the support cradle to protect the tank from heat radiated by the exhaust system. A fire shield is installed on the RH side of the support cradle.

The fuel tank has a nominal 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 top of the fuel tank filler tube is located in the RH rear wing panel and is closed by a lockable filler cap. The bottom of the filler tube is connected to the tank by a flexible tube secured with clamps. On NAS vehicles, a flap valve in the fuel tank, at the connection point with the filler tube, prevents vapour from escaping once refuelling is completed and also prevents fuel from escaping if the filler cap or filler tube are damaged in an accident.

On all except NAS vehicles, a vent pipe between the tank and the neck of the filler tube allows air to escape from the tank during refuelling. With the fuel filler cap installed, the tank is ventilated to atmosphere through vent pipes that connect three roll over valves in the tank to the Evaporative emissions (EVAP) system.

☞ **EMISSION CONTROL - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

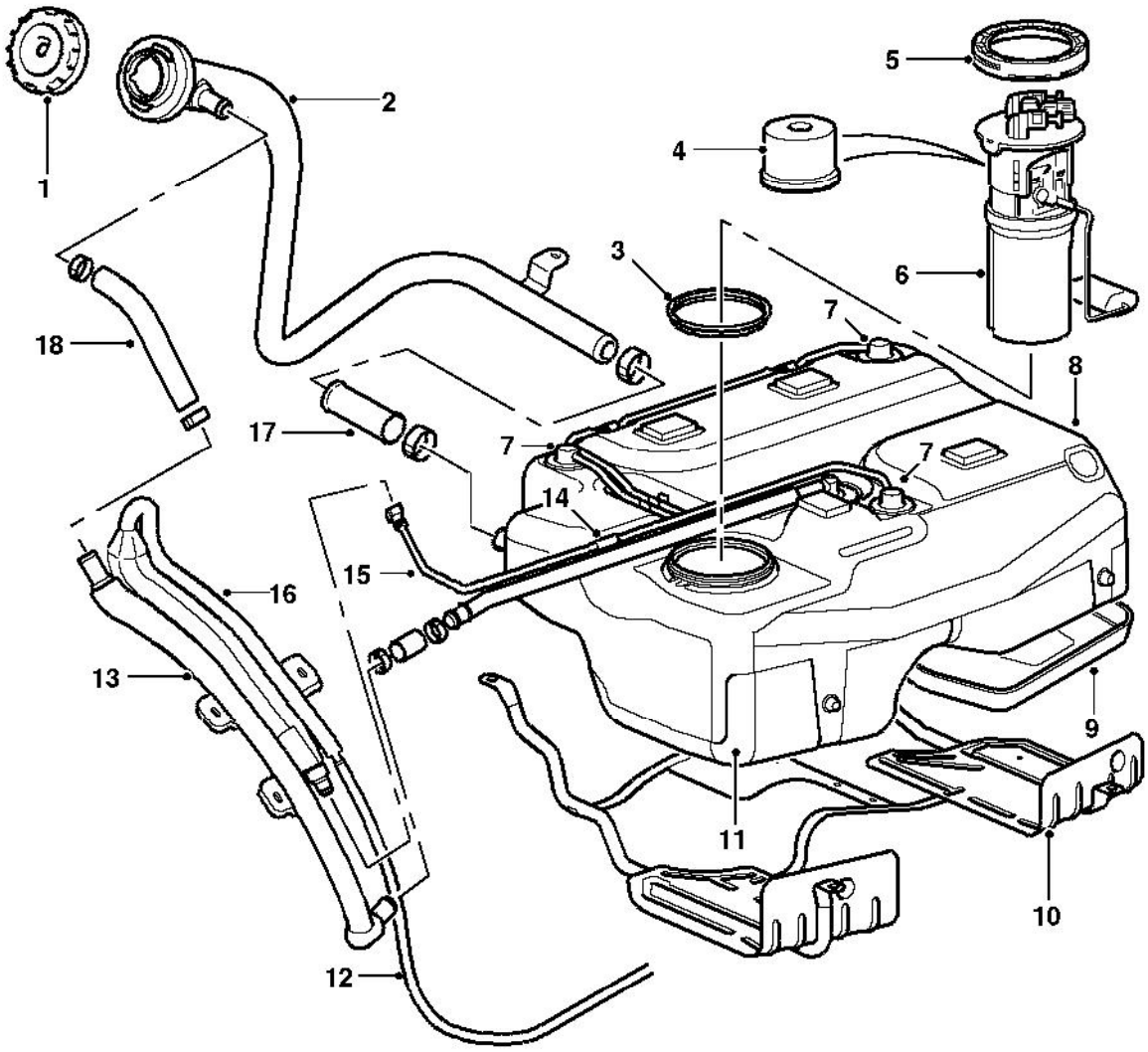
On NAS vehicles, during refuelling and with the fuel filler cap installed, the tank is ventilated to atmosphere through vent pipes that connect an Onboard Refuelling Vapour Recovery (ORVR) valve and the three roll over valves in the tank to the Evaporative emissions (EVAP) system.

☞ **EMISSION CONTROL - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

The location of the vent pipe connections on the fuel tank ensures an air space remains in the tank after filling, to allow for heat expansion of the fuel.

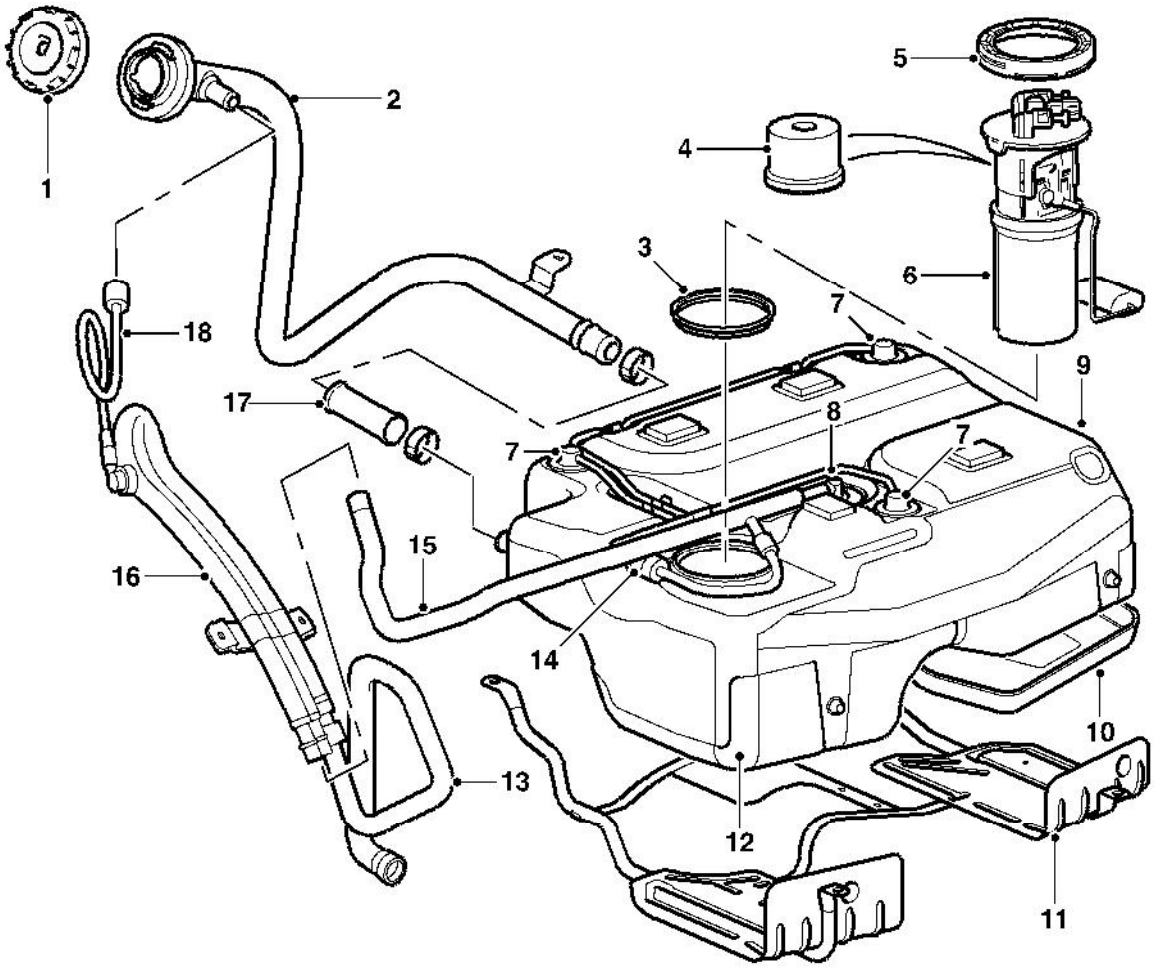
The ORVR valve and roll over valves are float valves that prevent fuel from entering the EVAP system vent pipes due to fuel slosh or if the vehicle overturns.

Fuel Tank and Fuel Pump (All Except NAS)



1 Fuel filler cap
2 Filler tube
3 Seal
4 Fuel filter
5 Locking ring
6 Fuel pump assembly
7 Roll over valve
8 Fuel tank
9 Fire shield
10 Cradle
11 Heat shield
12 Vent pipe from vapour separator to EVAP canister
13 Vent pipe from fuel tank to filler tube
14 Two-way valve
15 Vent pipe from fuel tank to vapour separator
16 Vapour separator
17 Flexible tube
18 Flexible tube

Fuel Tank and Fuel Pump (NAS)



M19 3362

1 Fuel filler cap
2 Filler tube
3 Seal
4 Fuel filter
5 Locking ring
6 Fuel pump assembly
7 Roll over valve
8 ORVR valve
9 Fuel tank
10 Fire shield
11 Cradle
12 Heat shield
13 Vent pipe from vapour separator to EVAP canister
14 Two-way valve
15 Vent pipe from fuel tank to vapour separator
16 Vapour separator
17 Flexible tube
18 Recirculation pipe

Fuel Pump

The fuel pump is a submersible electric pump 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/in^2). The regulator relieves excess fuel from the pump outlet back to the swirl pot.

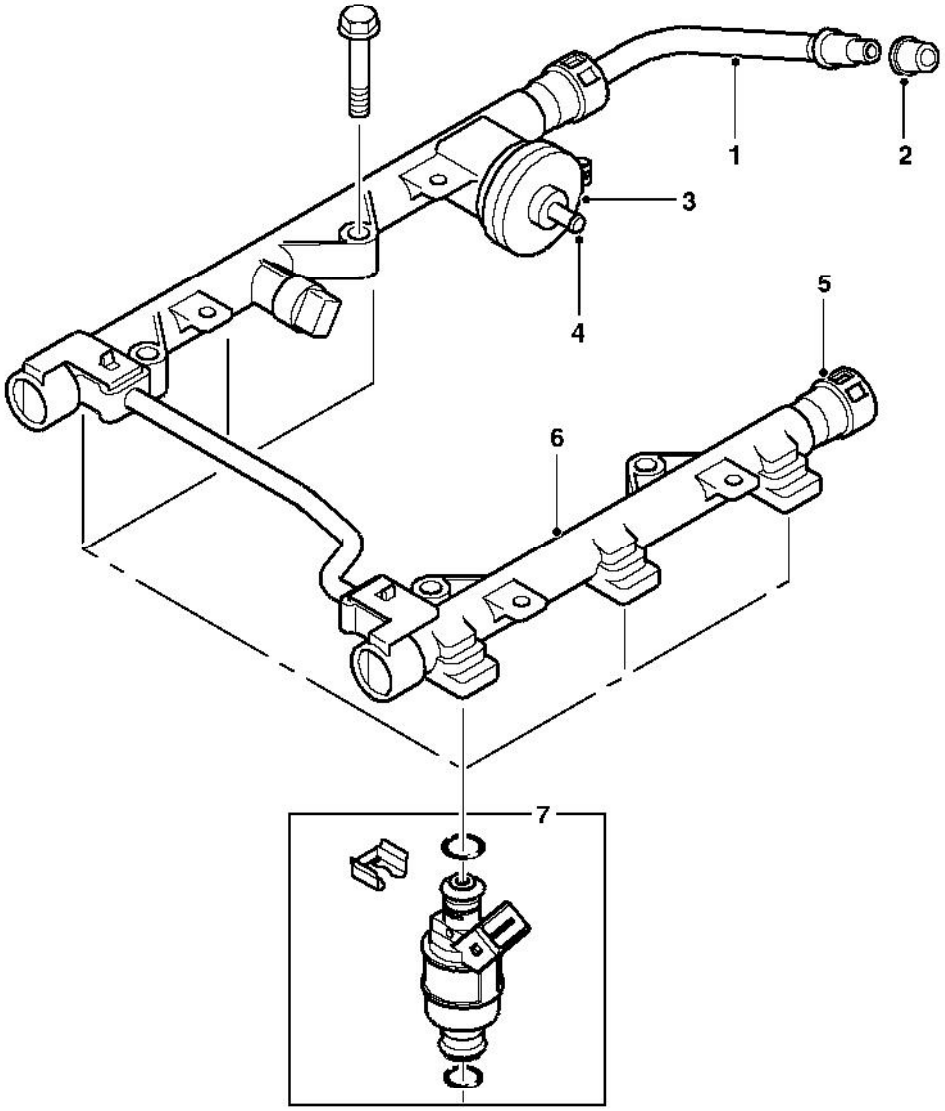
Fuel Rail

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 fuel rail.

An accumulator is attached to the fuel rail, to damp out pressure pulses from the pump and ensure that the pressure in the fuel rail is constant. On all except NAS vehicles, a vacuum pipe connects the accumulator to the inlet manifold to aid the damping process.

A Schraeder valve is installed in the 'fuel return' pipe (on all except NAS vehicles) or above the accumulator (on NAS vehicles) to provide a pressure test connection for maintenance.

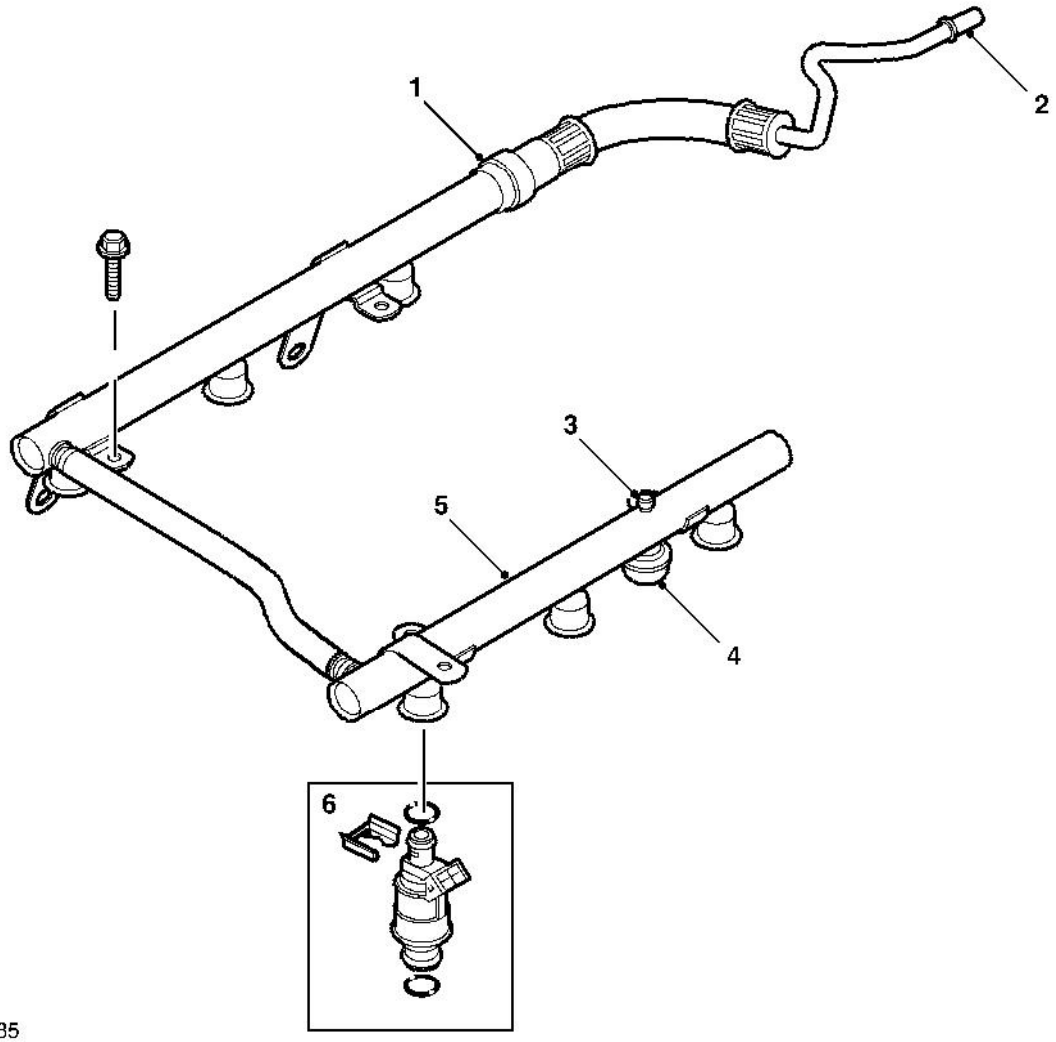
Fuel Rail and Injectors (All Except NAS)



M19 3257

1 'Fuel return' pipe
2 Dust cap
3 Accumulator
4 Vacuum pipe connection
5 Feed pipe quick release coupling
6 Fuel rail
7 Fuel injector

Fuel Rail and Injectors (NAS)



1 Quick release coupling
2 To fuel feed pipe
3 Dust cap and Schraeder valve
4 Accumulator
5 Fuel rail
6 Fuel injector

Operation

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 electrical circuit for the fuel pump incorporates an inertia fuel cut-off switch attached to the LH front suspension turret. In a collision above a preset deceleration speed, the 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.

WARNING: Ensure there are no fuel leaks and confirm the integrity of the fuel system before resetting the fuel shut-off switch.

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.



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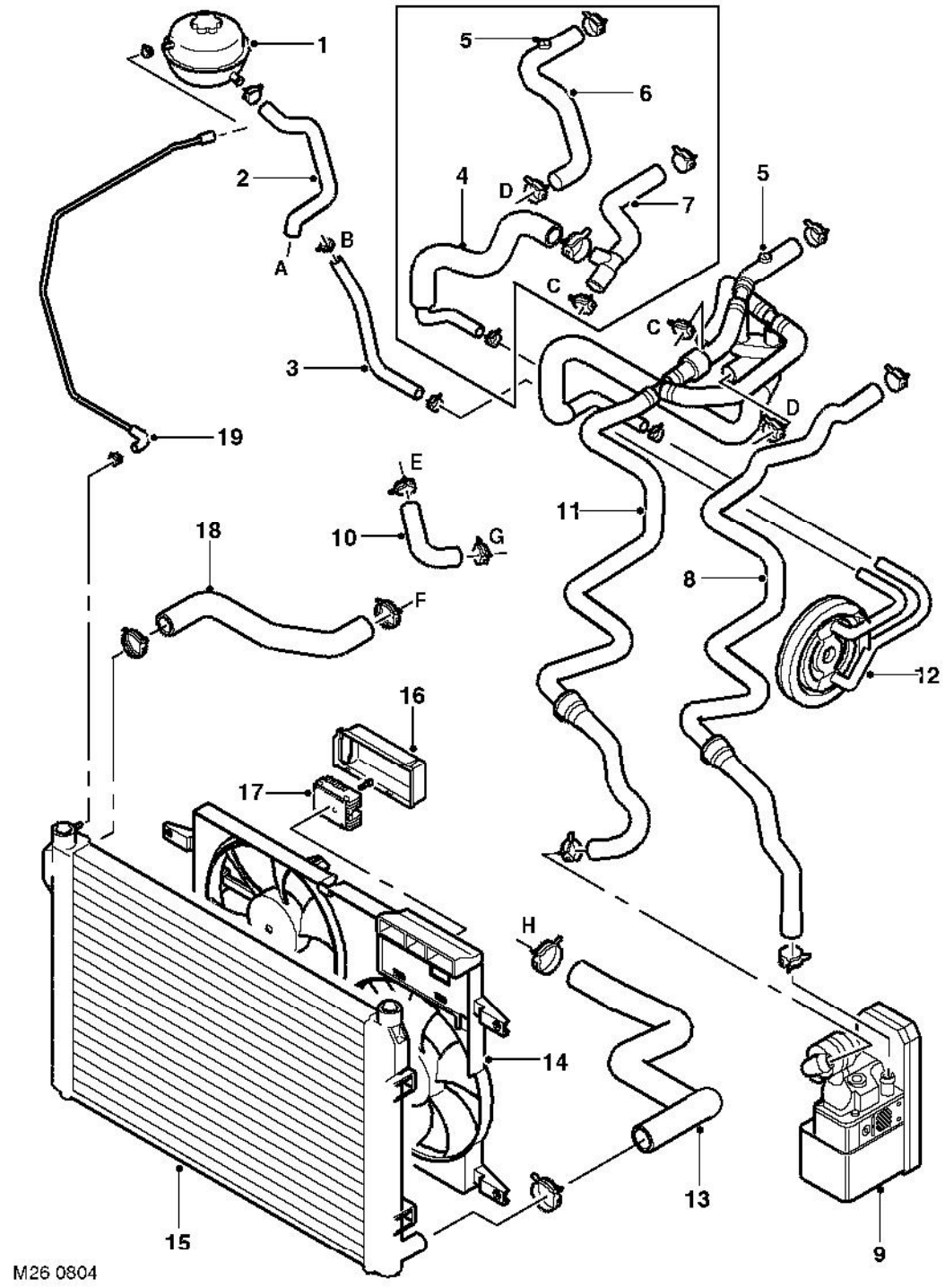
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Cooling System Component Layout – Manual Gearbox, Sheet 1 of 2

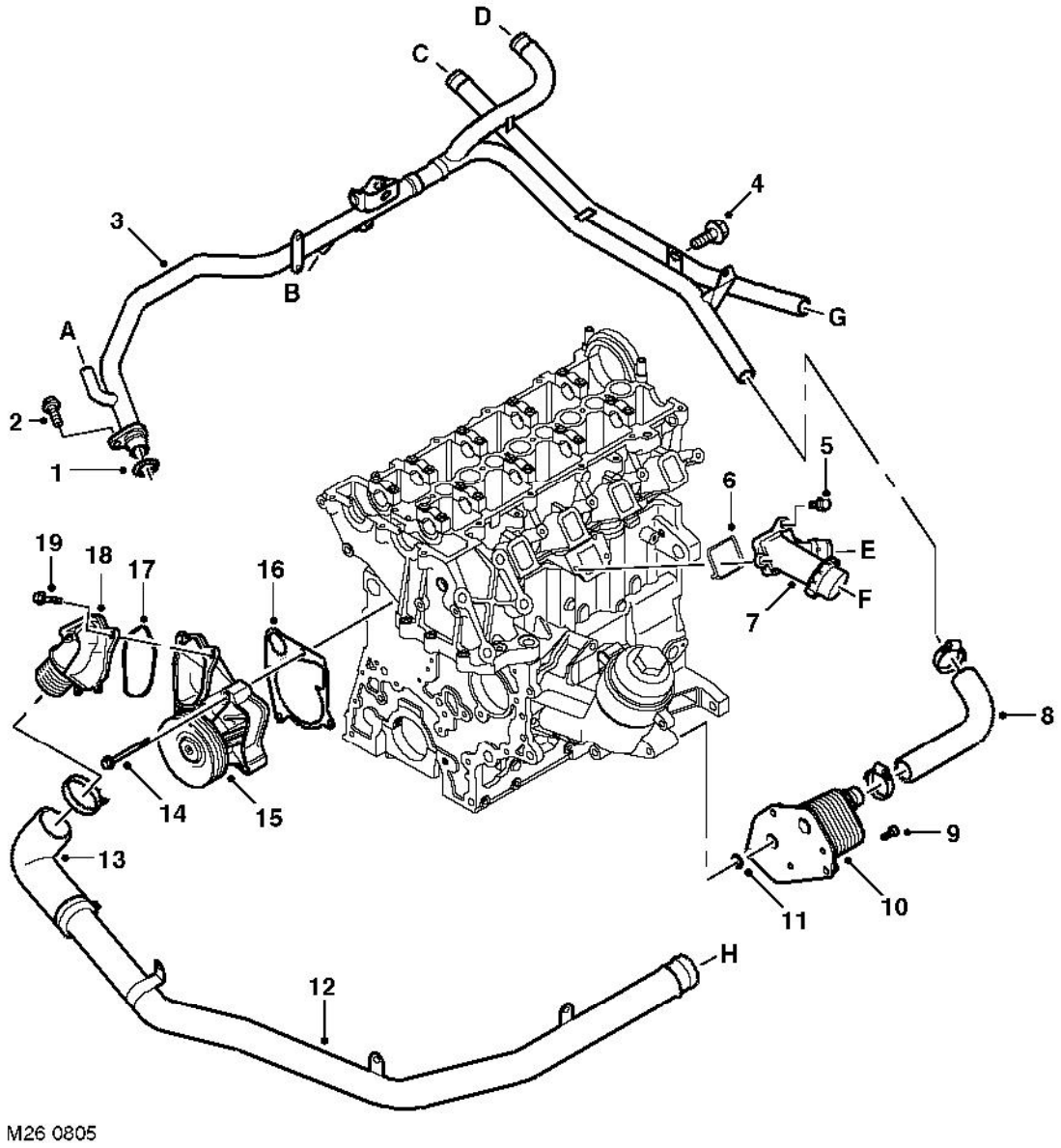


For connections A to H, see sheet 2



1 Expansion tank
2 Hose - expansion tank to coolant rail
3 Hose - IRD cooler outlet
4 Hose - IRD cooler inlet (models without FBH)
5 Bleed screw
6 Hose - heater outlet (models without FBH)
7 Hose - heater inlet (models without FBH)
8 Hose - heater inlet (models with FBH)
9 FBH (where fitted)
10 Hose - engine outlet to coolant rail
11 Hose - heater outlet (models with FBH)
12 IRD cooler
13 Radiator bottom hose
14 Cooling fans
15 Radiator
16 Cooling fan ECU cover
17 Cooling fan ECU
18 Radiator top hose
19 Expansion pipe

Cooling System Component Layout – Manual Gearbox, Sheet 2 of 2



For connections A to H, see sheet 1

1 'O' ring
2 Bolt - M6 x 18
3 Coolant rail
4 Bolt - M8 x 16
5 Bolt - M6 x 22 (4 off)
6 Gasket
7 Coolant outlet elbow
8 Hose - engine oil cooler to coolant rail
9 Torx screw (3 off)
10 Engine oil cooler
11 'O' ring
12 Coolant pipe
13 Hose - coolant pipe to thermostat housing
14 Bolt - coolant pump (4 off)
15 Coolant pump
16 Gasket
17 Gasket
18 Thermostat housing
19 Bolt - M6 x 22 (4 off)



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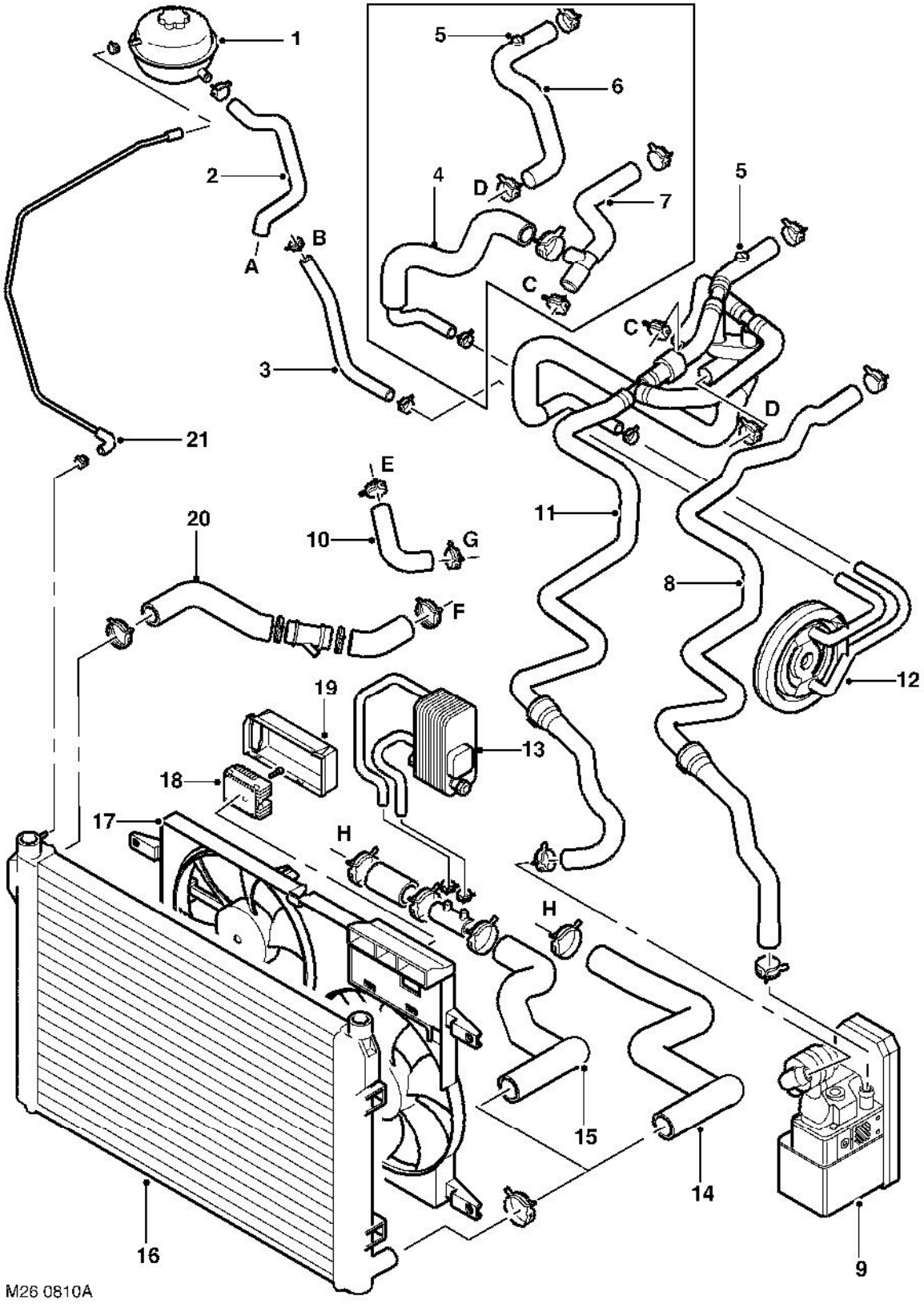
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Cooling System Component Layout – Automatic Gearbox, Sheet 1 of 2

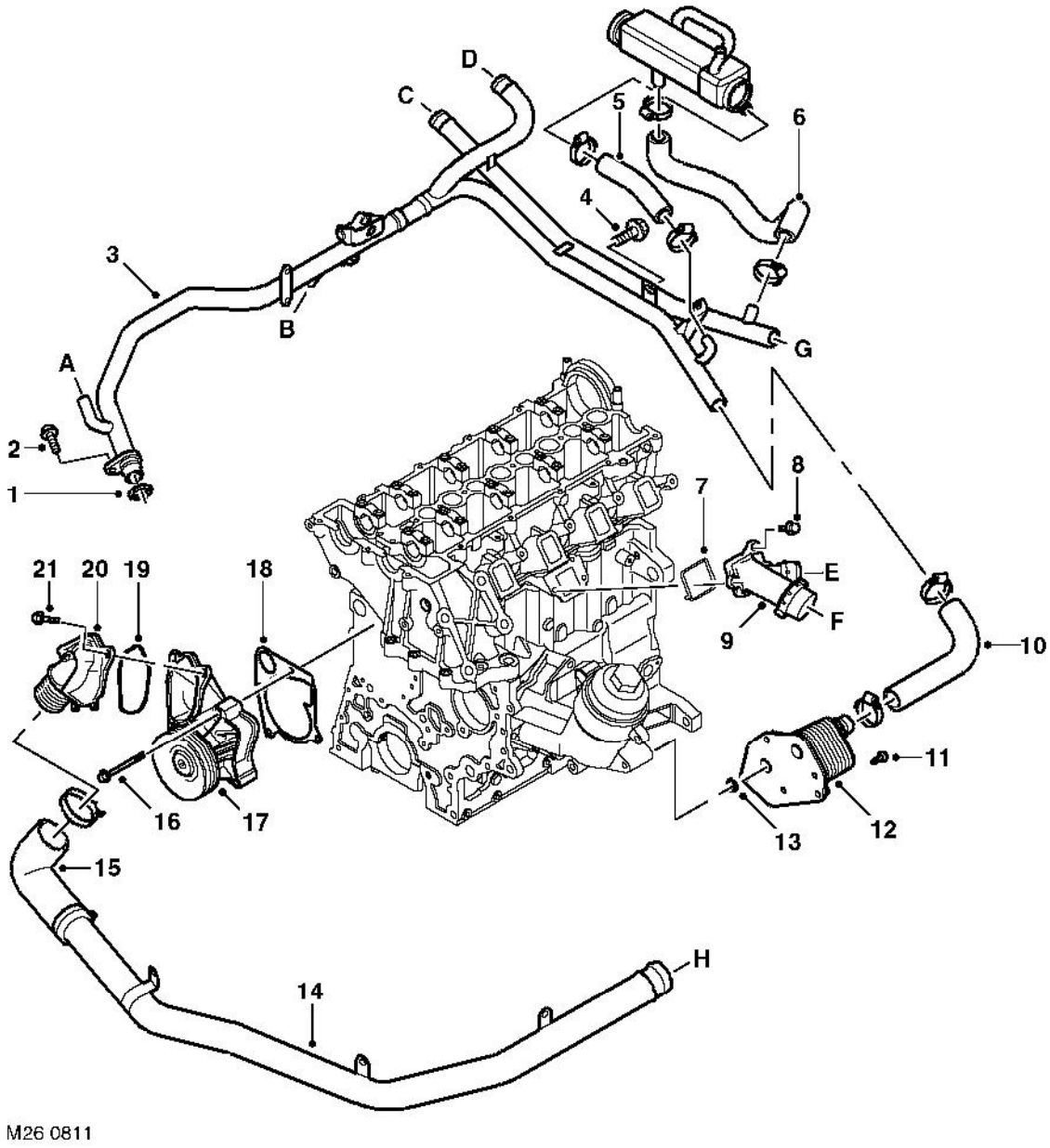


For connections A to H, see sheet 2



1 Expansion tank
2 Hose - expansion tank to coolant rail
3 Hose - IRD cooler outlet
4 Hose - IRD cooler inlet (models without FBH)
5 Bleed screw
6 Hose - heater outlet (models without FBH)
7 Hose - heater inlet (models without FBH)
8 Hose - heater inlet (models with FBH)
9 FBH (where fitted)
10 Hose - engine outlet to coolant rail
11 Hose - heater outlet (models with FBH)
12 IRD cooler
13 Transmission fluid cooler (where fitted)
14 Radiator bottom hose (models with air blast transmission cooler)
15 Radiator bottom hose assembly (models with coolant fluid cooler)
16 Radiator
17 Cooling fans
18 Cooling fan ECU
19 Cooling fan ECU cover
20 Radiator top hose assembly
21 Expansion pipe

Cooling System Component Layout – Automatic Gearbox, Sheet 2 of 2

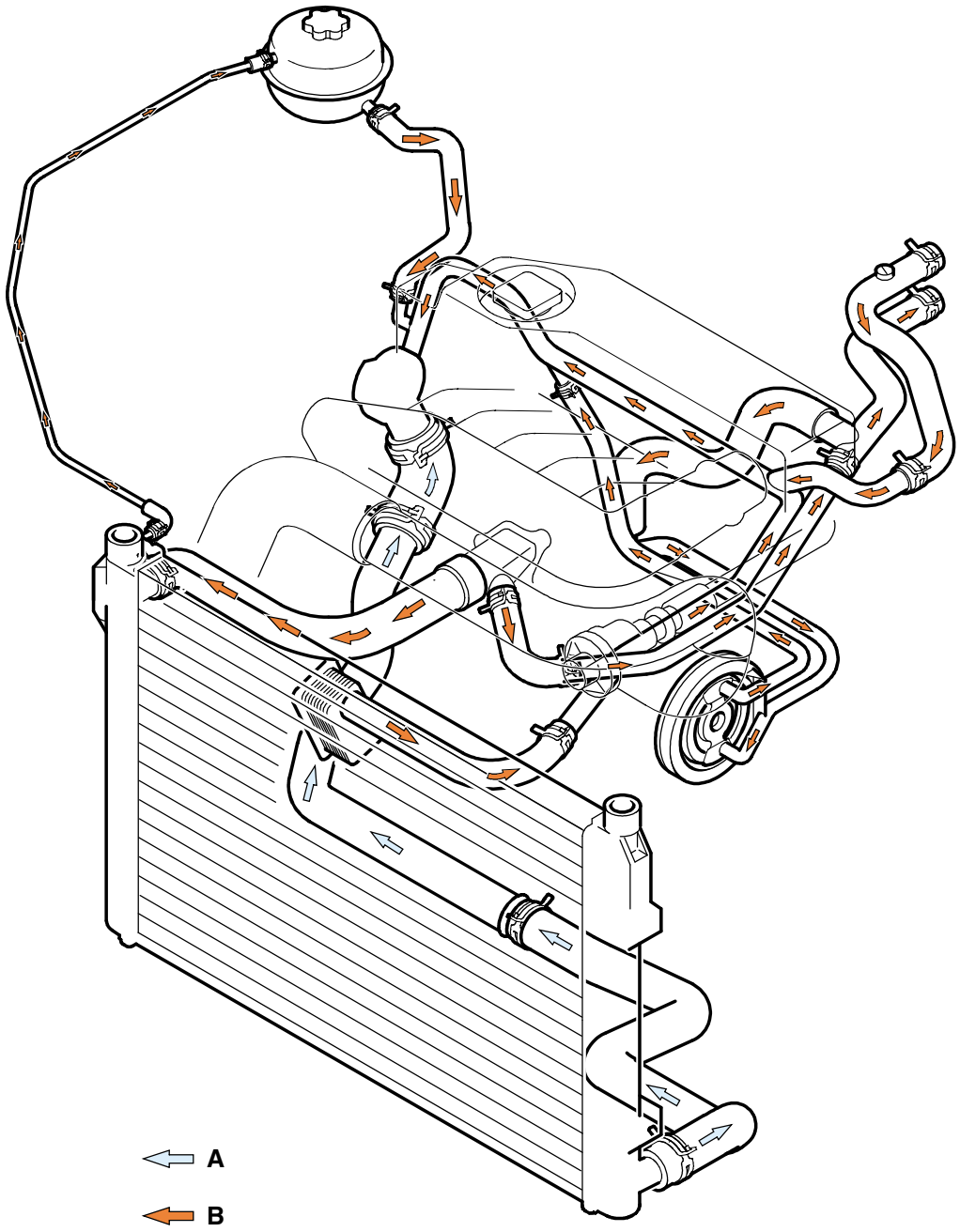


For connections A to H, see sheet 1



1 'O' ring
2 Bolt - M6 x 18
3 Coolant rail
4 Bolt - M8 x 16
5 Hose - EGR cooler inlet
6 Hose - EGR cooler outlet
7 Gasket
8 Bolt - M6 x 22 (4 off)
9 Coolant outlet elbow
10 Hose - engine oil cooler to coolant rail
11 Torx screw (3 off)
12 Engine oil cooler
13 'O' ring
14 Coolant pipe
15 Hose - coolant pipe to thermostat housing
16 Bolt - coolant pump (4 off)
17 Coolant pump
18 Gasket
19 Gasket
20 Thermostat housing
21 Bolt - M6 x 22 (4 off)

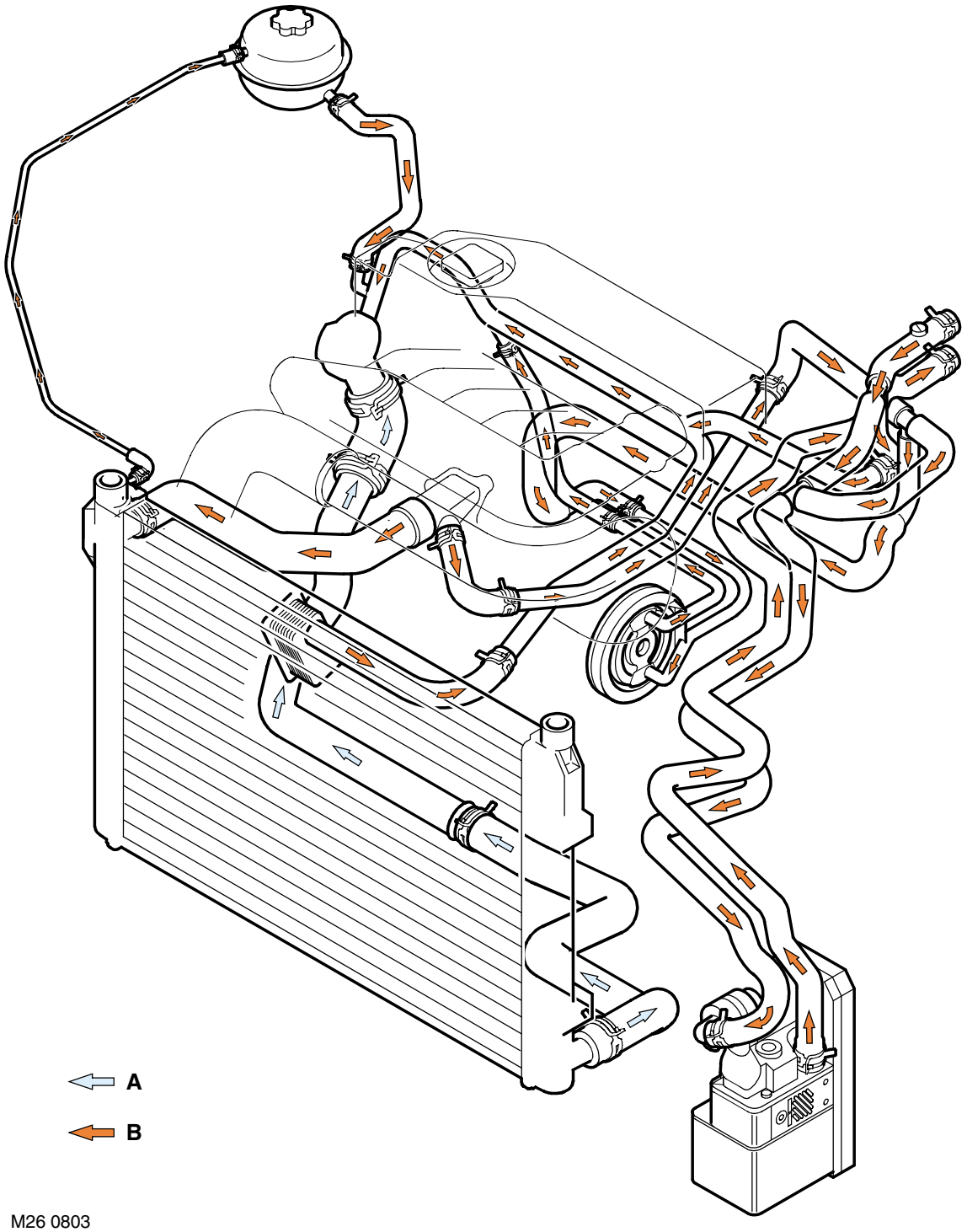
Cooling System Coolant Flow – Manual Gearbox Without FBH



M26 0829

A = Cold
B = Hot

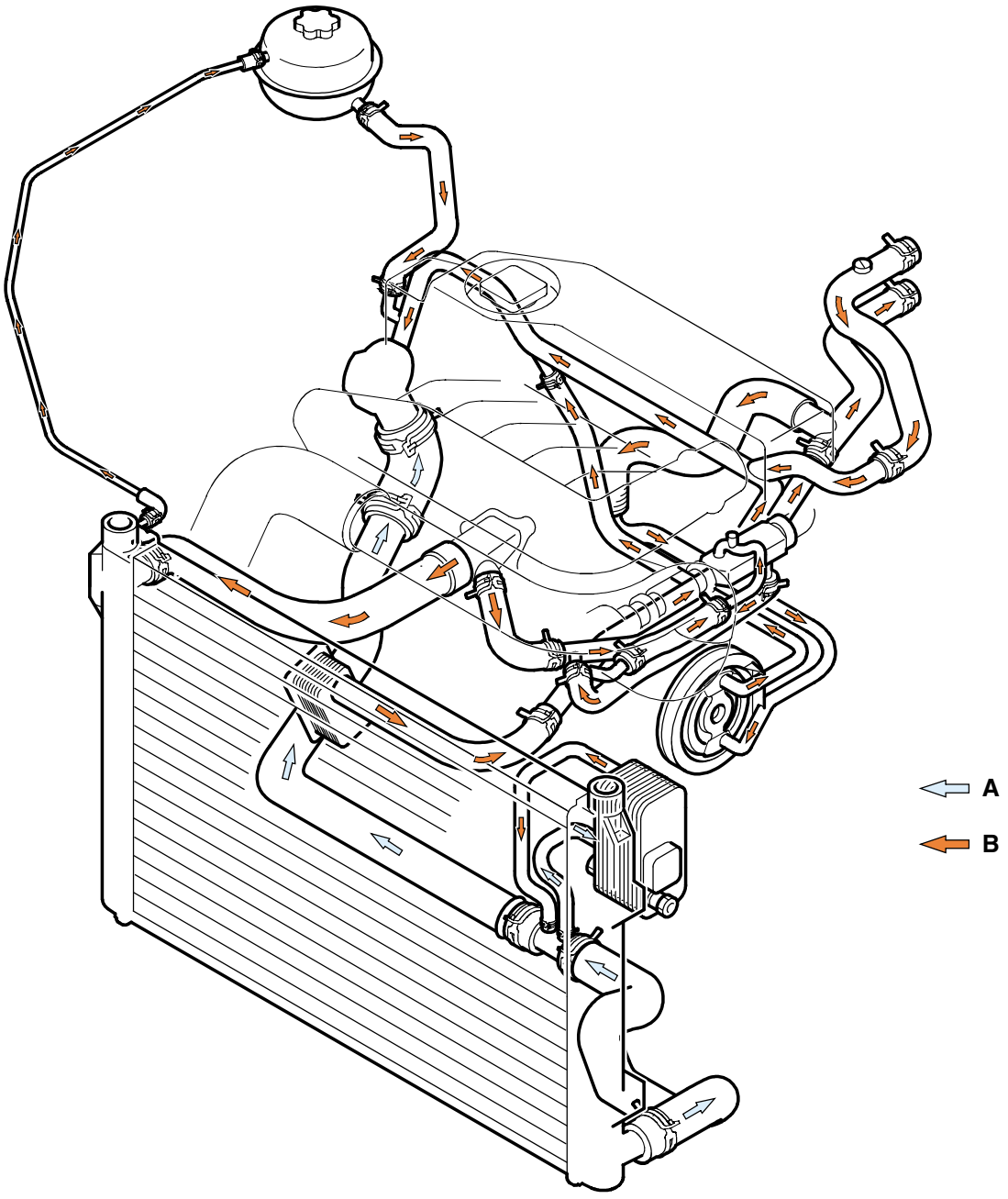
Cooling System Coolant Flow – Manual Gearbox With FBH



M26 0803

A = Cold
B = Hot

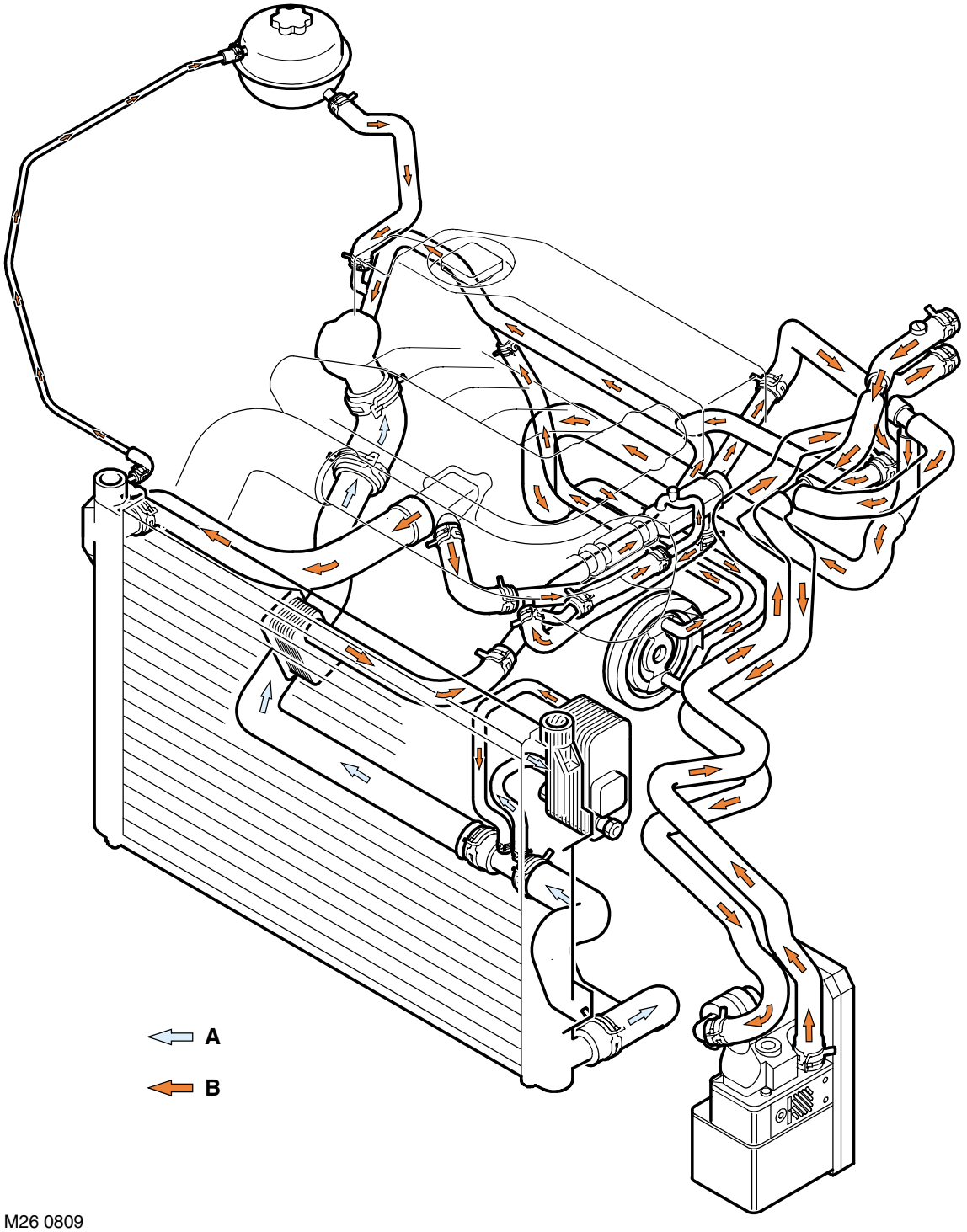
Cooling System Coolant Flow – Automatic Gearbox Without FBH



M26 0830

A = Cold
B = Hot

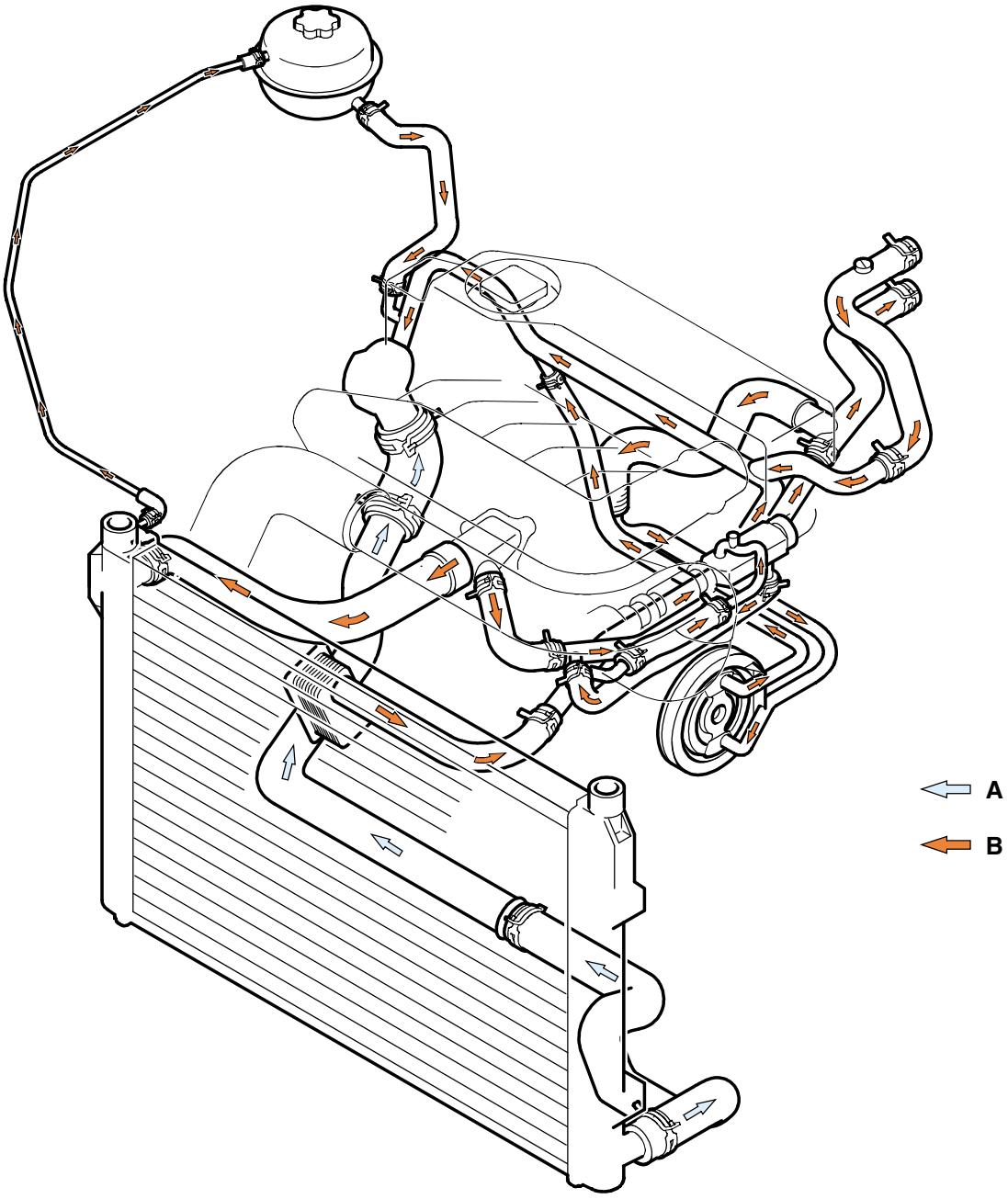
Cooling System Coolant Flow – Automatic Gearbox With FBH



M26 0809

A = Cold
B = Hot

Cooling System Coolant Flow – Automatic Gearbox With Air Blast Transmission Cooler



M26 0858

A = Cold
B = Hot



Description

General

The cooling system employed is the bypass type, which allows coolant to circulate around the engine and the heater circuit while the thermostat is closed. The primary function of the cooling system is to maintain the engine within an optimum temperature range under changing ambient and engine operating conditions. Secondary functions are to provide heating for the passenger compartment and cooling for the Intermediate Reduction Drive (IRD), engine oil and, on automatic gearbox models, the Exhaust Gas Recirculation (EGR) system and transmission fluid.

The cooling system comprises:

- A radiator
- A passenger compartment heater matrix
- An IRD cooler
- An EGR cooler (automatic gearbox models only)
- A transmission fluid cooler (some automatic gearbox models)
- Engine oil 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, IRD cooler, heater matrix and, where fitted, the EGR and transmission fluid coolers, via the coolant hoses. A bleed screw is installed in the return hose from the heater matrix to bleed air from the cooling system during filling.

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.

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 heater matrix via the coolant rail on the side of the engine. The radiator bottom hose is connected to a pipe which is routed around the front of the engine and connected to the coolant pump housing.

An expansion tank is fitted to the RH suspension turret in the engine compartment. The expansion tank allows for expansion of the coolant when the engine is hot and replaces the coolant into the system as the engine cools down.

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.

The EGR cooler, fitted to automatic gearbox models, is located in the coolant return line from the engine oil cooler to the coolant pump. The fluid cools the exhaust gases returning to the inlet manifold, which improves emissions. The cooler incorporates a bleed screw to bleed air from the cooler when filling the cooling system.

On automatic gearbox models fitted with a liquid cooled transmission fluid cooler, the cooler is located at the front of the gearbox. The cooler receives coolant from the radiator bottom hose, which passes through the cooler and is returned into the bottom hose.

Where fitted, the Fuel Burning Heater (FBH) is located behind the front of the LH wheelarch liner. The unit is connected in series with the coolant supply to the heater matrix. For further details refer to Heating and Ventilation.

☞ **HEATING AND VENTILATION, DESCRIPTION AND OPERATION, Description.**

For additional airflow through the radiator matrix, particularly when the vehicle is stationary, two electric cooling fans are fitted to the rear of the radiator. The fans are used for engine cooling and, if fitted, for air conditioning system cooling. Both fans operate in parallel at variable speeds controlled by the Engine Control Module (ECM) via a cooling fan ECU. The cooling fan ECU is located behind the radiator, below the bonnet closing panel. The temperature of the cooling system is monitored by the ECM via signals from an Engine Coolant Temperature (ECT) sensor, which is mounted in the cylinder head.



Operation

With the engine running, the coolant pump pulley is driven by the ancillary drive belt. When the engine is cold, the thermostat is closed and coolant is prevented from circulating through the radiator. Coolant is able to circulate through the bypass, heater matrix and coolers.

As the temperature increases, at 88 °C (190 °F) the thermostat begins to open, 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.

On automatic gearbox models with a liquid cooled transmission fluid cooler, the coolant from the radiator bottom hose is diverted through the cooler and back into the bottom hose. The bottom hose incorporates a valve which opens and closes dependent on system pressure to divert the flow through the cooler when applicable.

The increased coolant volume, created by heat expansion, is directed to the expansion tank through a bleed hose from the top of the radiator. The expansion tank has an outlet hose which is connected into the coolant circuit. This outlet hose returns the coolant to the system when the engine cools.

Coolant flows through the radiator from the top right hand tank to the bottom left hand tank and is cooled by air passing through the matrix. The temperature of the cooling system is monitored by the ECM via a temperature sensor located in the cylinder head. The ECM uses signals from this sensor to control the cooling fan operation and adjust fuelling according to engine temperature.

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Engine Management Component Layout.**

To control the cooling fans, the ECM sends a Pulse Width Modulated (PWM) signal to the cooling fan ECU. The frequency of the PWM signal, which is varied by the ECM, is used by the ECU to determine the output voltage supplied to the fan motors.

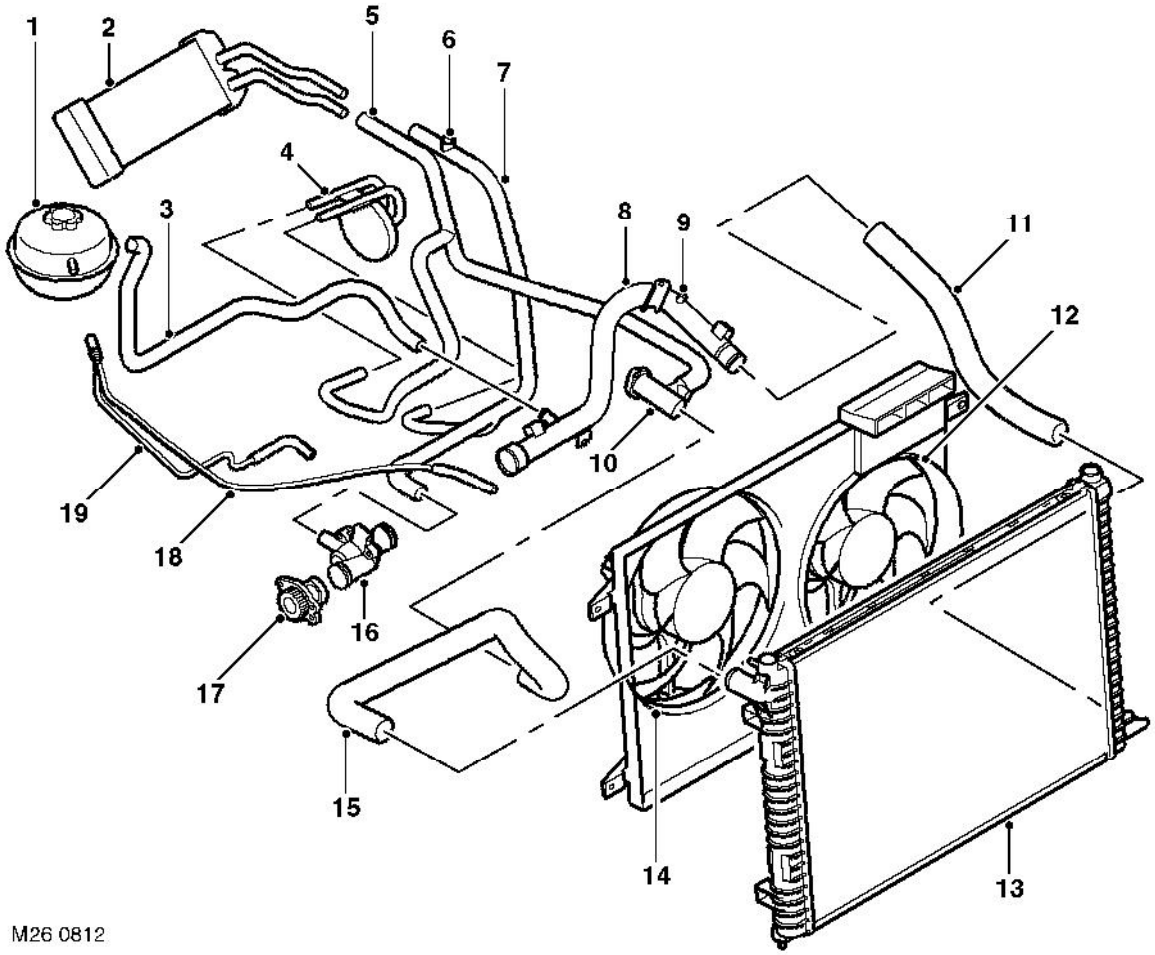
The ECM operates the fans in response to inputs from the ECT sensor, the A/C switch and the A/C pressure sensor. Refer to the A/C system for details.

☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

The speed of the cooling fans is also influenced by vehicle road speed. The ECM adjusts the speed of the cooling fans, to compensate for the ram effect of vehicle speed, using the CAN road speed signal received from the ABS ECU.

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.

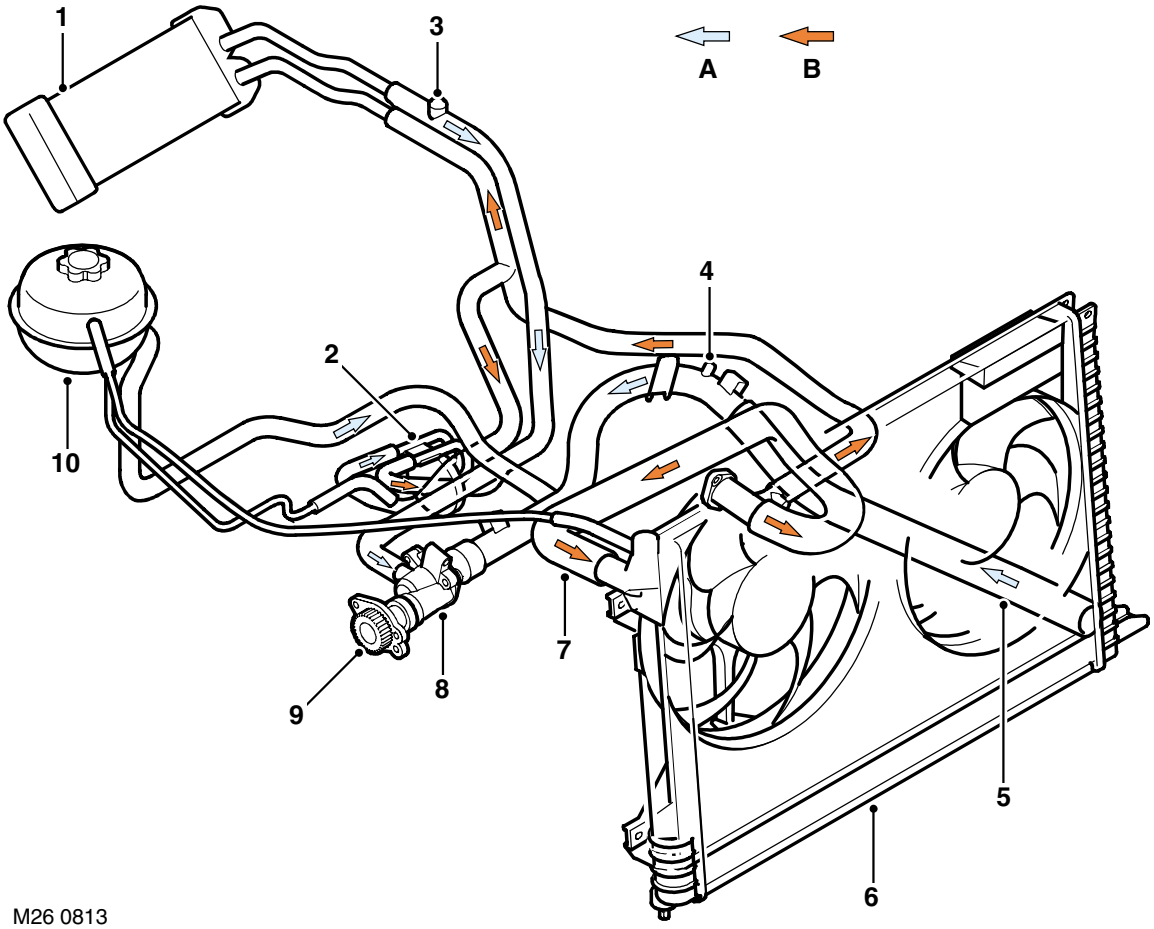
Cooling System Component Layout



M26 0812

1 Expansion tank
2 Heater matrix
3 Hose - expansion tank to coolant pipe
4 IRD cooler
5 Hose - heater inlet
6 Bleed screw
7 Hose - heater outlet
8 Coolant inlet pipe
9 Bleed screw
10 Coolant outlet pipe
11 Hose - radiator bottom
12 A/C condensor fan (if fitted)
13 Radiator
14 Engine cooling fan
15 Hose - radiator top
16 Thermostat housing
17 Water pump
18 Hose - bleed
19 Hose - bleed

Cooling System Operation



A = Cold
B = Hot

1 Heater matrix
2 IRD Cooler
3 Bleed screw
4 Bleed screw
5 Radiator bottom hose
6 Radiator
7 Radiator top hose
8 Thermostat housing
9 Water pump
10 Expansion tank



Description

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 system's 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 compartment.

The cooling system comprises:

- A radiator
- A passenger compartment heater matrix
- An IRD cooler
- A coolant pump
- A thermostat
- An expansion tank
- One or two cooling fans
- Connecting hoses and pipes.

The thermostat is installed in a housing which is attached to the coolant pump. The thermostat is located in the inlet side of the cooling circuit, which provides a more stable control of the coolant temperature in the engine.

When cold, the thermostat is closed and coolant is prevented from circulating through the radiator. Coolant is able to circulate through the bypass and heater circuits.

As the temperature increases, the thermostat gradually opens, bleeding cool fluid from the radiator bottom hose into the cylinder block and allowing hot coolant to flow to the radiator through the radiator 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.

An expansion tank is fitted to the right hand shock absorber mounting. Any excess coolant, created by heat expansion, is returned to the expansion tank through bleed lines from the top of the radiator and from the cylinder block. The expansion tank has an outlet pipe which is connected into the coolant circuit. The outlet pipe supplies coolant into the system when the engine is cool. This replaces coolant displaced to the expansion tank due to heat expansion.

The coolant is circulated by a rotor type pump. The pump is mounted at the rear of the engine and is driven by a geared pulley from the camshaft timing belt. The pump draws coolant from the radiator bottom hose and circulates it through the engine and heater circuit.

The radiator, positioned at the front of the vehicle, is an aluminium cross - flow type with moulded plastic end tanks. The radiator is mounted in rubber bushes; the bottom of the radiator is located in the front body cross member, and the top is located in the bonnet locking platform. The top hose from the radiator is connected to the temperature sensor housing and the bottom hose is connected, via a pipe, to the thermostat housing. For additional air flow through the radiator matrix, particularly when the vehicle is stationary, one or 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 a temperature sensor, which is mounted in a housing attached to the cylinder head.

The cooling system is also used to cool the Intermediate Reduction Drive (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 which contains waterways which cool the IRD oil and recirculates the coolant via the heater circuit.

Bleed screws are installed in the top hose of the heater matrix and the feed pipe to the coolant pump. These are used to bleed air from the cooling system during system filling.

The cooling system can have one or two cooling fans. Vehicles without air conditioning (A/C) have one cooling fan and vehicles with A/C have two cooling fans.

On vehicles without A/C, the single cooling fan is controlled by the ECM via a remote 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 A/C, both fans operate in parallel at variable speeds controlled by the ECM via a cooling fan ECU. The cooling fan ECU is located behind the radiator, below the bonnet closing panel.



Operation

Cooling System Operation
With the engine running, the coolant pump is driven via a pulley from the cam belt. When the engine is cold the thermostat is closed and coolant is prevented from circulating through the radiator. The coolant is directed around the by-pass, heater and IRD circuit.

As the engine temperature increases, the thermostat gradually opens allowing cool fluid from radiator bottom hose to flow through the pump and into the cylinder block. This cool fluid displaces the hot fluid in the cylinder block which flows to the radiator via the top hose. With the thermostat fully open the full coolant flow passes through the radiator, the IRD cooler and heater circuits.

Cooling Fan Operation - Vehicles Without Air Conditioning (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 Operation - Vehicles With Air Conditioning (A/C)
The engine cooling fan and the condensor fan are operated in parallel by the ECM via a cooling fan ECU. The cooling fan ECU, 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 ECU 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 cooling fan ECU will not supply any power to the fan motors. At a duty cycle of 50%, the ECU supplies 6 volts to the fan motors to operate them at a minimum speed of approximately 1300 rev/min. As the duty cycle increases above 50%, the ECU 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 a maximum speed of approximately 3000 rev/min.

When the main relay is energised, the cooling fan ECU 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 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
☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

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.



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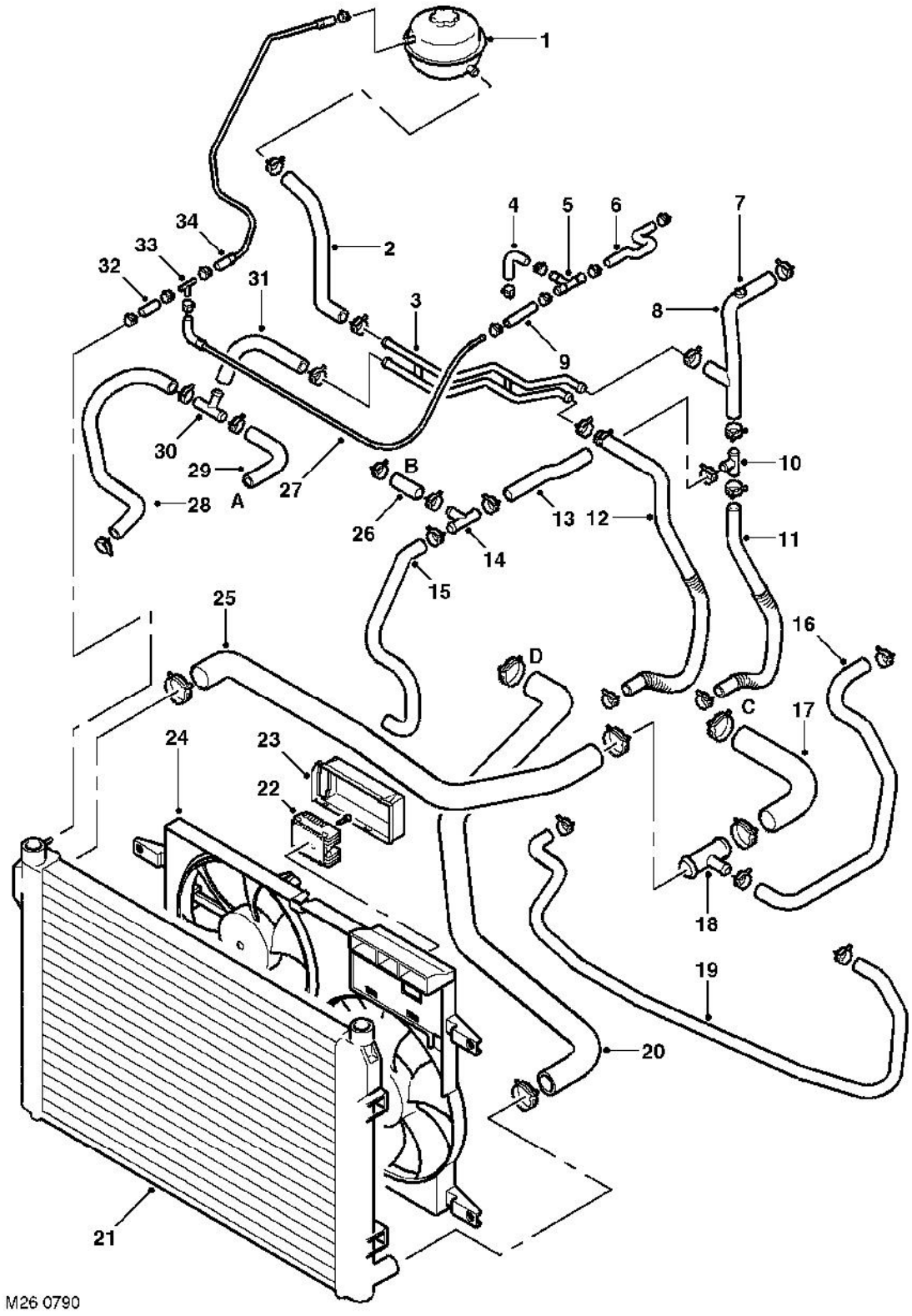
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Cooling System Component Layout - Sheet 1 of 2 (All Except NAS and Gulf States)

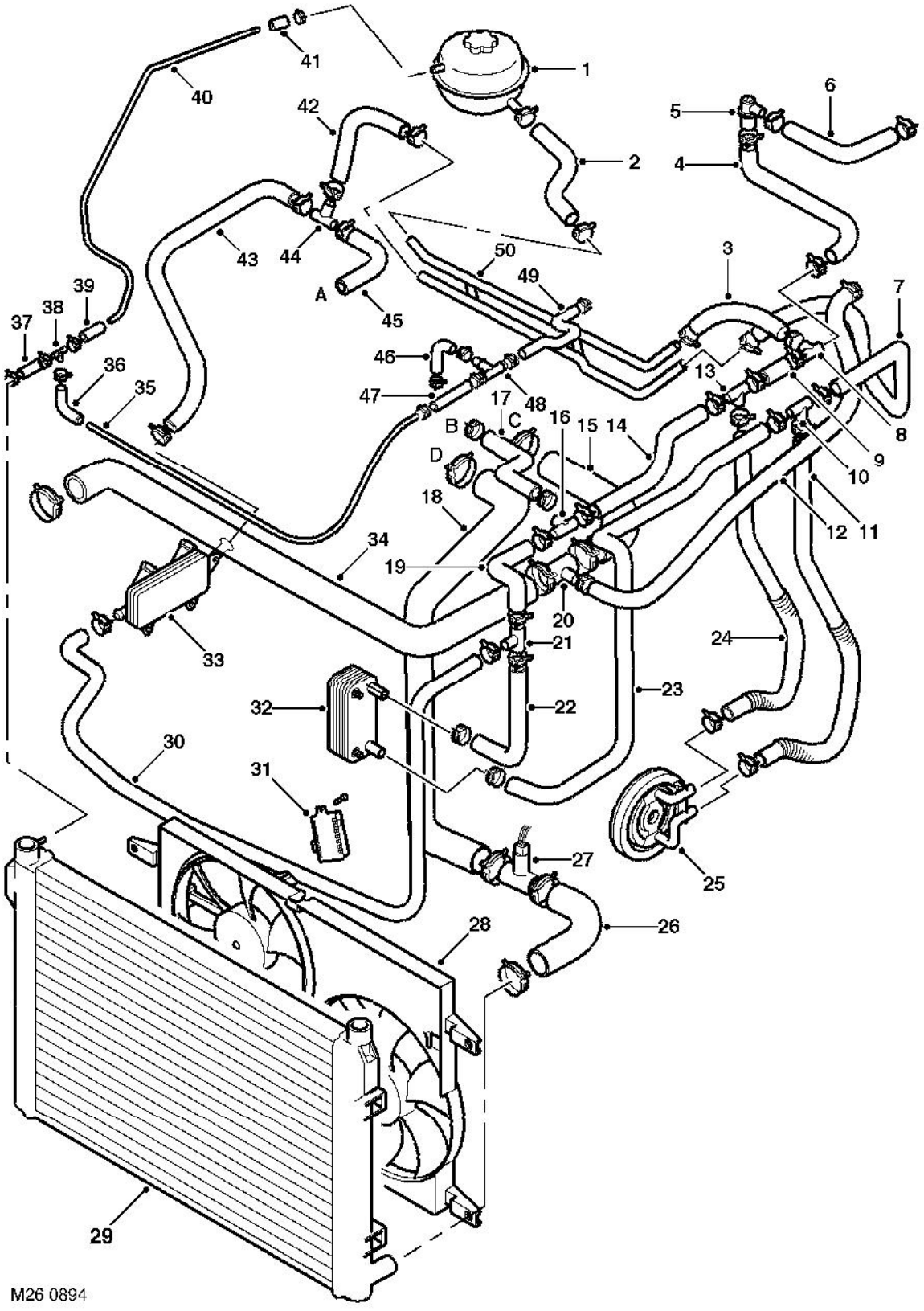


For connections A to D, see sheet 2



1 Expansion tank
2 Expansion tank return hose
3 Coolant rail
4 LH inlet manifold expansion hose
5 Inlet manifolds expansion hose 'T' connector
6 RH inlet manifold expansion hose
7 Bleed screw
8 Heater matrix return hose
9 Inlet manifolds expansion pipe to 'T' connector hose
10 Return hose 'T' connector
11 IRD cooler return hose
12 IRD cooler supply hose
13 'T' connector return hose
14 Return hose 'T' connector
15 Transmission fluid cooler return hose
16 Heater matrix supply hose
17 Engine to 'T' connector top hose
18 Top hose 'T' connector
19 Engine oil cooler to transmission fluid cooler hose
20 Bottom hose
21 Radiator
22 Cooling fan ECU
23 ECU cover
24 Cooling fans
25 'T' connector to radiator top hose
26 'T' connector to thermostat housing bypass hose
27 Inlet manifolds expansion pipe
28 Engine oil cooler supply hose
29 Cylinder block outlet hose
30 Cylinder block outlet 'T' connector
31 Cylinder block outlet to coolant rail hose
32 Radiator expansion hose
33 Expansion pipe 'T' connector
34 Radiator and inlet manifolds expansion pipe

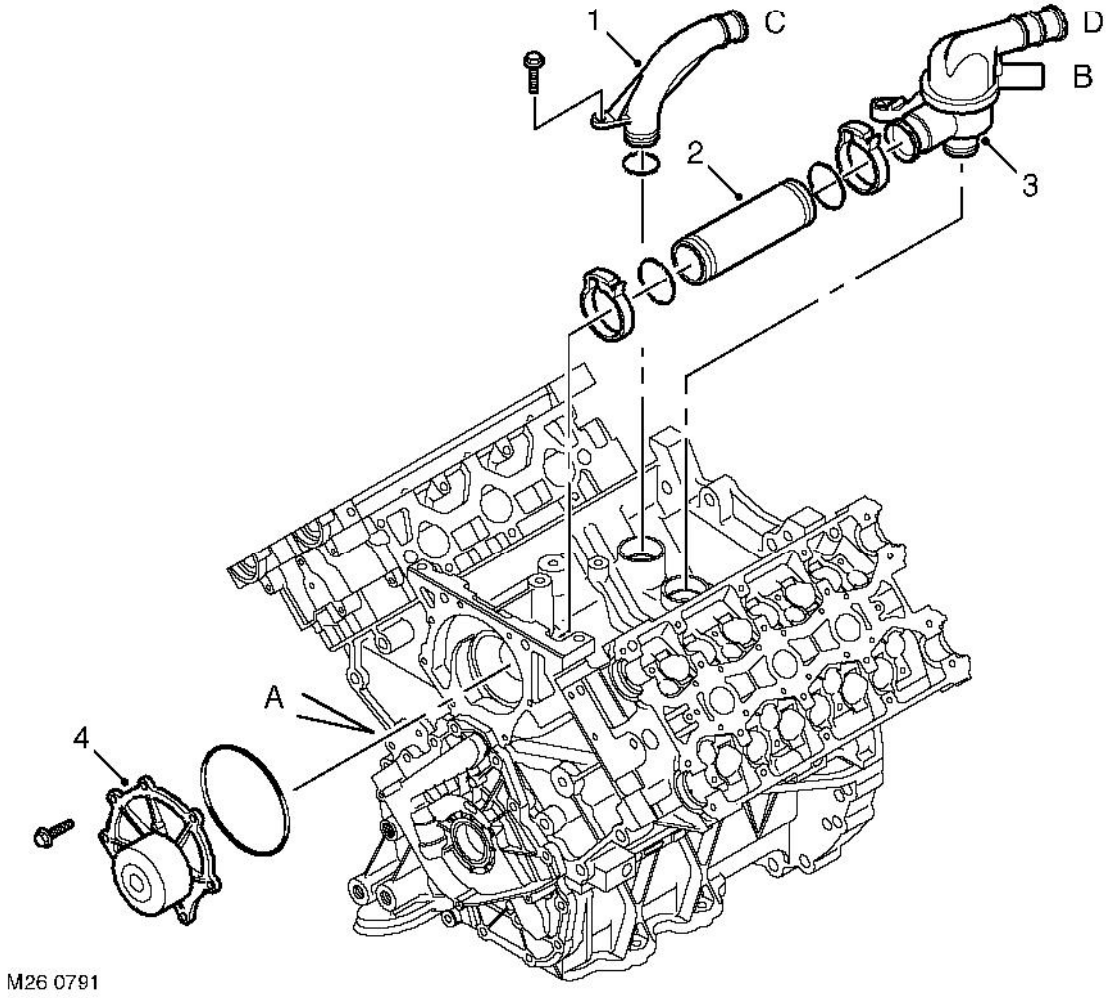
Cooling System Component Layout - Sheet 1 of 2 (NAS and Gulf States)





1 Expansion tank
2 Expansion tank return hose
3 Coolant rail to heater matrix return hose
4 Heater matrix return hose
5 Bleed screw elbow
6 Heater matrix return hose
7 Coolant rail to IRD cooler supply hose
8 Heater matrix return 'T' connector
9 Heater matrix return hose
10 IRD cooler supply 'T' connector
11 IRD cooler supply hose
12 Heater matrix supply hose
13 Heater matrix return 'T' connector
14 Heater matrix return hose
15 Engine to 'T' connector top hose
16 Heater matrix return 'T' connector
17 Thermostat housing bypass hose
18 Sensor housing to engine bottom hose
19 Fluid cooler return hose
20 Top hose 'T' connector
21 Fluid cooler return 'T' connector
22 Transmission fluid cooler return hose
23 Transmission fluid cooler supply hose
24 IRD cooler return hose
25 IRD cooler
26 Radiator to sensor housing bottom hose
27 Thermostat monitoring sensor housing
28 Cooling fans
29 Radiator
30 Engine oil cooler return hose
31 Cooling fan ECU
32 Transmission fluid cooler
33 Engine oil cooler
34 'T' connector to radiator top hose
35 Inlet manifolds expansion pipe
36 Expansion pipe connector hose
37 Radiator expansion hose
38 Expansion pipe 'T' connector
39 Expansion pipe connector hose
40 Radiator and inlet manifolds expansion pipe
41 Expansion pipe connector hose
42 Cylinder block outlet to coolant rail hose
43 Engine oil cooler supply hose
44 Cylinder block outlet 'T' connector
45 Cylinder block outlet hose
46 LH inlet manifold expansion hose
47 Expansion pipe connector hose
48 Expansion pipe 'T' connector
49 RH inlet manifold expansion hose
50 Coolant rail

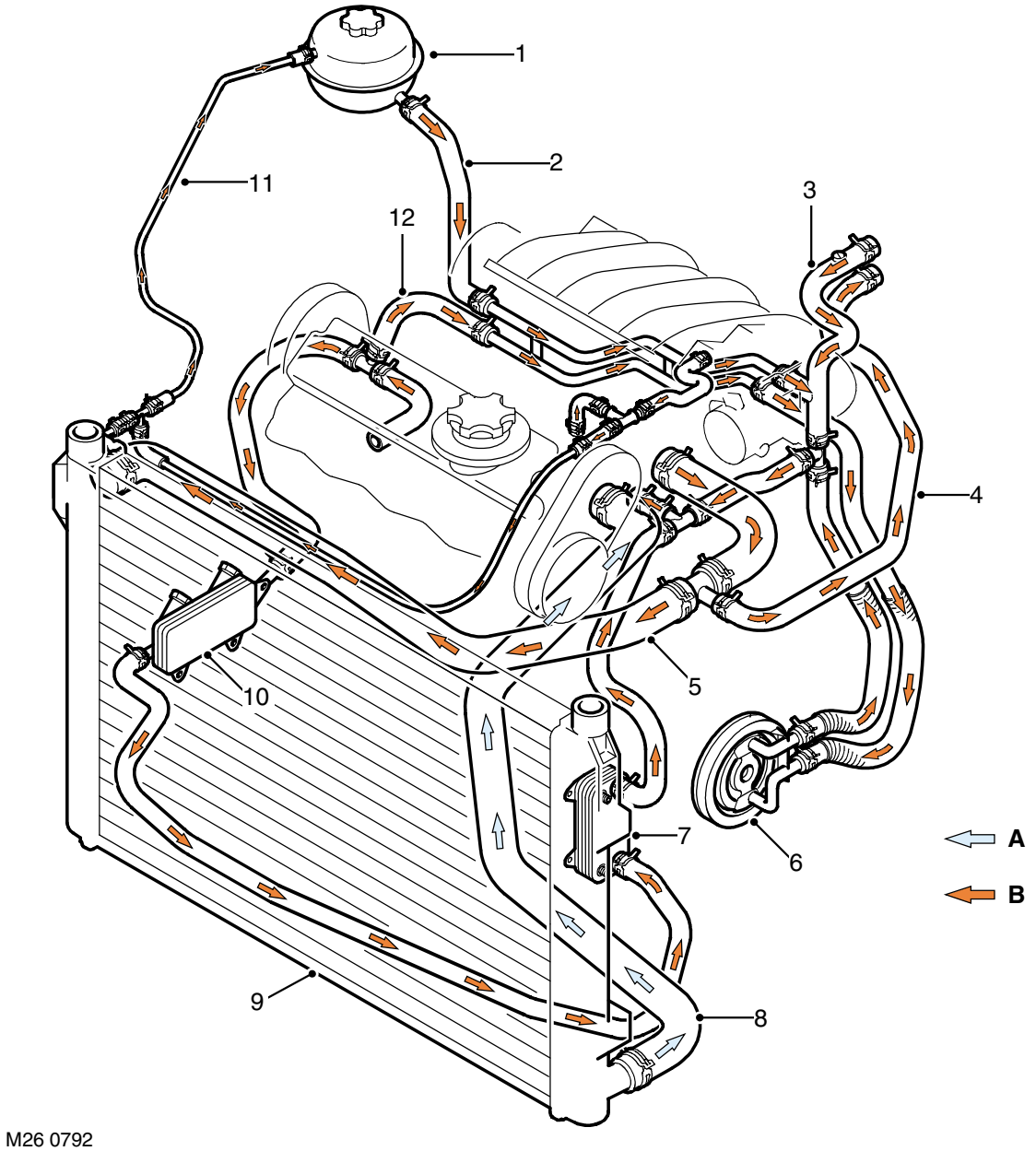
Cooling System Component Layout - Sheet 2 of 2



For connections A to D, see sheet 1

1 Outlet elbow
2 Pipe - thermostat to pump
3 Thermostat housing assembly
4 Coolant pump

Cooling System Coolant Flow (All Except NAS and Gulf States)

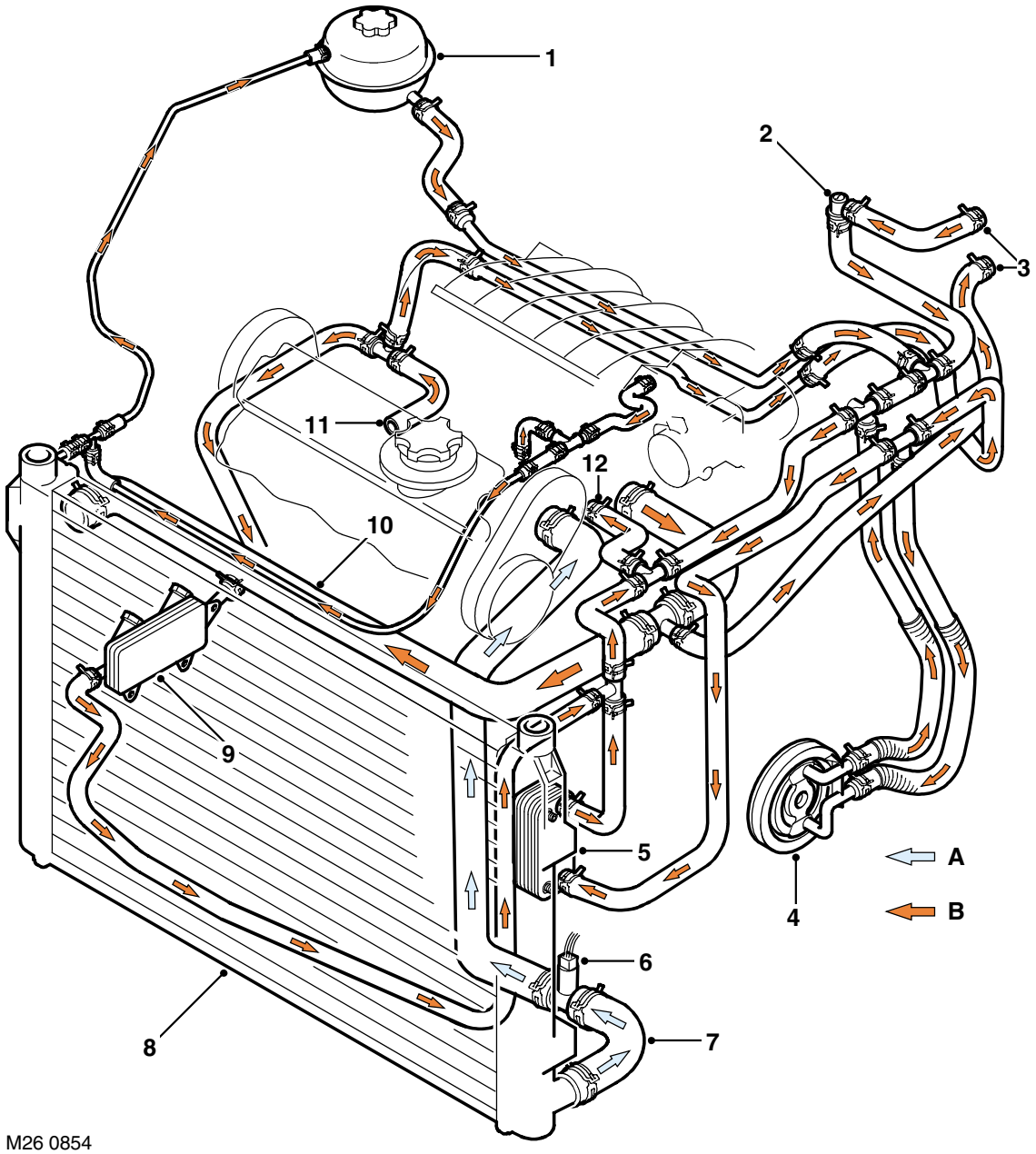


M26 0792

A = Cold; B = Hot

1 Expansion tank
2 Expansion tank return hose
3 Heater matrix return hose
4 Heater matrix supply hose
5 Top hose
6 IRD cooler
7 Transmission fluid cooler
8 Bottom hose
9 Radiator
10 Engine oil cooler
11 Expansion pipe
12 Cylinder block outlet hose assembly

Cooling System Coolant Flow (NAS and Gulf States)



A = Cold; B = Hot

1 Expansion tank
2 Bleed screw
3 Heater matrix connections
4 IRD cooler
5 Transmission fluid cooler
6 Thermostat monitoring sensor (NAS only)
7 Bottom hose
8 Radiator
9 Engine oil cooler
10 Top hose
11 Cylinder block outlet connection
12 Thermostat bypass connection



Description

General
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.

Radiator
The radiator is a cross flow type with an aluminium matrix and moulded plastic end tanks. The bottom of the radiator is located in rubber bushes on the front lower crossmember. The top of the radiator is secured to the bonnet locking platform by threaded retainers. The top hose connects the radiator to a coolant outlet elbow in the cylinder block. The bottom hose connects the radiator to the thermostat housing.

Thermostat
The thermostat is installed in a housing located in a coolant outlet port in the cylinder block, between the cylinder banks. The thermostat housing incorporates inlet connections for the bottom hose and the return hose from the IRD cooler/ heater/ transmission cooler. A pipe connects the outlet side of the thermostat housing to the coolant pump inlet.

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/in^2). 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 the outlets at the right front corner of the cylinder block and the top hose to the return hose connection on the thermostat housing. The hoses connected to the IRD cooler are covered by heat shielding to protect them from heat radiated by the exhaust system. A bleed screw in the heater outlet hose enables air to be bled from the system during filling.

Cooling Fans
The two 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 powered by a supply from 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.

Operation

General

When the engine is running, the coolant pump draws coolant through the pipe connected to the thermostat housing and pumps it through the outlet at the right front corner of the cylinder block and through the cooling jackets in the cylinder block, cylinder heads and inlet manifolds. From the outlet at the right front corner of the cylinder block, the coolant flows through the hoses and the coolant rail to the IRD cooler, the engine oil cooler and the transmission fluid cooler. From the top of the cylinder block, coolant flows through the outlet elbow and the top hose to the heater matrix. Coolant returning to the thermostat housing, from the cylinder block, the coolers and the heater matrix, bypasses the thermostat and flows back to the coolant pump inlet to begin the cycle again.

Coolant also flows through the expansion pipes to the expansion tank, from where it is drawn back into the system through the expansion tank outlet hose connected to the coolant rail. The increase in coolant volume, created by heat expansion, reduces the air space in the expansion tank, which pressurises the system and raises the boiling point of the coolant.

When the temperature of the coolant bypassing the thermostat is below 82 °C (180 °F), the thermostat remains closed and prevents coolant from circulating through the radiator. When the temperature of the bypassing coolant reaches 82 °C (180 °F), the thermostat begins to open, allowing 'cold' coolant from the radiator bottom hose into the pump inlet and hot coolant from the cylinder block to flow to the radiator through the top hose. The thermostat then regulates the flow through the radiator to maintain the engine at the optimum temperature. Maximum opening of the thermostat, and therefore maximum flow through the radiator, occurs if the coolant temperature reaches 102 °C (216 °F).

On NAS vehicles, operation of the thermostat is monitored by the Engine Control Module (ECM) using an input from the thermostat monitoring sensor in the bottom hose.

Coolant flows through the radiator, from the top of the RH end tank to the bottom of the LH end tank, and is cooled by air passing through the radiator. When required, the two cooling fans provide additional air flow through the radiator, particularly when the vehicle is stationary. Operation of the cooling fans is controlled by the ECM via the cooling fan ECU. The temperature of the cooling system is monitored by the ECM using inputs from the thermostat monitoring sensor (NAS only) and the Engine Coolant Temperature (ECT) sensor located in the cylinder block, to the left of the thermostat housing.

☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**

Cooling Fan Control

The ECM controls the operation of the variable speed cooling fans via a Pulse Width Modulated (PWM) signal to the cooling fan ECU. The cooling fan ECU regulates the voltage of a common power feed to the two fans, and relates the voltage to the duty cycle of the PWM signal.

All Except NAS

The ECM varies the duty cycle of the PWM signal between 10 and 90% to vary the fan speed. If the PWM signal is outside the 10 to 90 % range, the cooling fan ECU interprets the signal as an open or short circuit and runs the fans at maximum speed to ensure the engine and gearbox do not overheat.

The ECM operates the fans in response to inputs from:

- The ECT sensor, for engine cooling. With the engine running, the fans come on at maximum speed if the coolant temperature increases to 105 °C (221 °F). The fans go off when the coolant temperature decreases to 102 °C (216 °F).
- The instrument pack and the A/C pressure sensor, for refrigerant system cooling.
  ☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**
- The EAT ECU, for gearbox cooling.
  ☞ **AUTOMATIC GEARBOX - JATCO, DESCRIPTION AND OPERATION, Description.**

If there is a conflict between requested fan speeds from the different inputs, the ECM adopts the highest requested speed.



As part of the power down routine, when the ignition is switched off the ECM samples the engine coolant temperature. If the coolant temperature is below 102 °C (216), the fans remain off. If the coolant temperature is between 102 and 105 °C (216 and 211 °F) the fans run at 8% of full speed for 5 minutes and then go off. If the coolant temperature is 105 °C (221 °F) or above, the fans run at 20% of full speed for 5 minutes and then go off.

As the engine cools after the ignition is switched off, the coolant volume decreases and coolant is drawn from the expansion tank through the outlet hose connected to the coolant rail. The air space in the expansion tank increases and the pressure in the coolant system decreases to approximately ambient pressure.

NAS

The ECM varies the duty cycle of the PWM signal between 3 and 90 % to vary the cooling fan speed. At duty cycles between 3 and 9 % the cooling fans are off. When the duty cycle goes above 9 % the cooling fans come on at minimum speed, then increase in speed, in proportion to the increase in the duty cycle, up to maximum speed at a duty cycle of 90 %. If the duty cycle is less than 3 % or more than 90 %, the cooling fan ECU interprets the signal as an open or short circuit and runs the cooling fans at maximum speed to ensure the engine and gearbox do not overheat.

The speed of the cooling fans varies between a minimum of 750 rev/min, at 6 volts and a maximum of 4000 rev/min at nominal battery voltage. To reduce the noise from the cooling fans they are driven at slightly different speeds, except when running at minimum and maximum speeds. Stepped speed changes occur at 1500 rev/min (RH cooling fan), 1450 and 2600 rev/min (LH cooling fan) to improve refinement.

Control Inputs

While the engine is running, the ECM adjusts the speed of the cooling fans in response to inputs from:

- The thermostat monitoring sensor, for engine cooling. The fans come on at minimum speed if the coolant temperature goes above 90 °C (194 °F), and progressively increase to maximum speed at a coolant temperature of 102 °C (216 °F).
- The A/C system, via the instrument pack and the CAN bus, for refrigerant system cooling.
- The EAT ECU, via the CAN bus, for gearbox cooling.

If there is a conflict between requested cooling fan speeds from the different inputs, the ECM adopts the highest requested speed.

As part of the power down routine, when the ignition is switched off, if the ambient air temperature is more than 15 °C (59 °F) the ECM samples the coolant temperature using the input from the Engine Coolant Temperature (ECT) sensor. If the coolant temperature is more than 106 °C (223 °F), the ECM signals for the cooling fans to come on. The speed of the cooling fans is in proportion to the coolant temperature, from minimum speed at >106 °C (>223 °F) to maximum speed at 115 °C (239 °F). The cooling fans are switched off after 5 minutes or when the coolant temperature decreases to 106 °C (223 °F), whichever occurs first.

Motor Protection

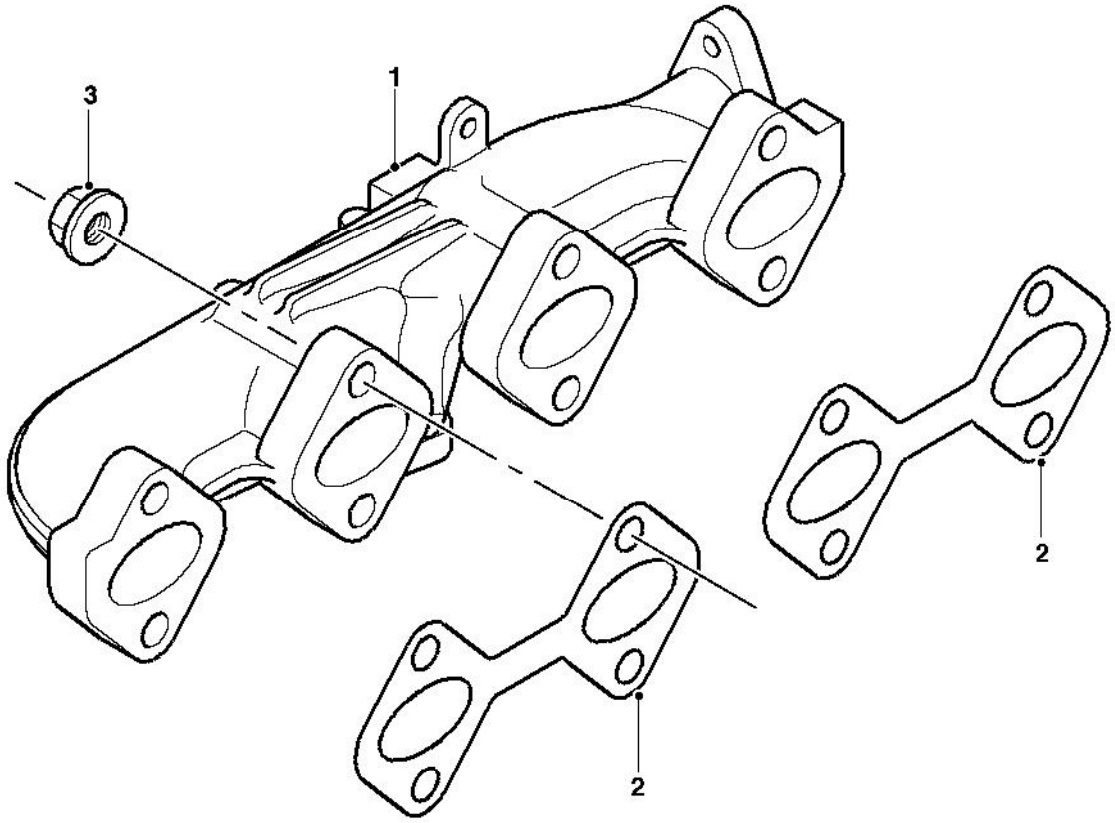
The cooling fan ECU monitors the speed of the cooling fans, from the current draw of the motors, and incorporates strategies to protect the motors from electrical overload if the fans are seized or heavily loaded (e.g. by debris or during wading).

When the duty cycle of the PWM signal indicates the cooling fans should be switched on, the cooling fan ECU initially outputs 2.5 volts to the motors to produce a 'soft' start. When the cooling fan ECU detects the motors are running satisfactorily, it then increases the outputs to the appropriate voltages for the required cooling fan speeds. If a motor fails to start within 3 seconds, the cooling fan ECU switches off the output to the affected motor, waits for 5 seconds and then tries another soft start. If the second soft start fails, after a further wait of 5 seconds the cooling fan ECU outputs 6 volts to the motor in an attempt to get it started. If the motor starts, the cooling fan ECU then increases the output to the appropriate voltage for the required cooling fan speed. If the motor fails to start within 4 seconds, the cooling fan ECU switches the output off, then, provided the cooling fans are still requested on, periodically invokes the start routine in an attempt to get the motor running.

If a cooling fan is already running and then seizes or becomes heavily loaded, the cooling fan ECU switches off the output to the affected motor, then periodically invokes the start routine, while the cooling fans are still requested on, in an attempt to get the motor running again.

When one of the cooling fans is not running, the cooling fan ECU runs the other cooling fan at maximum speed.

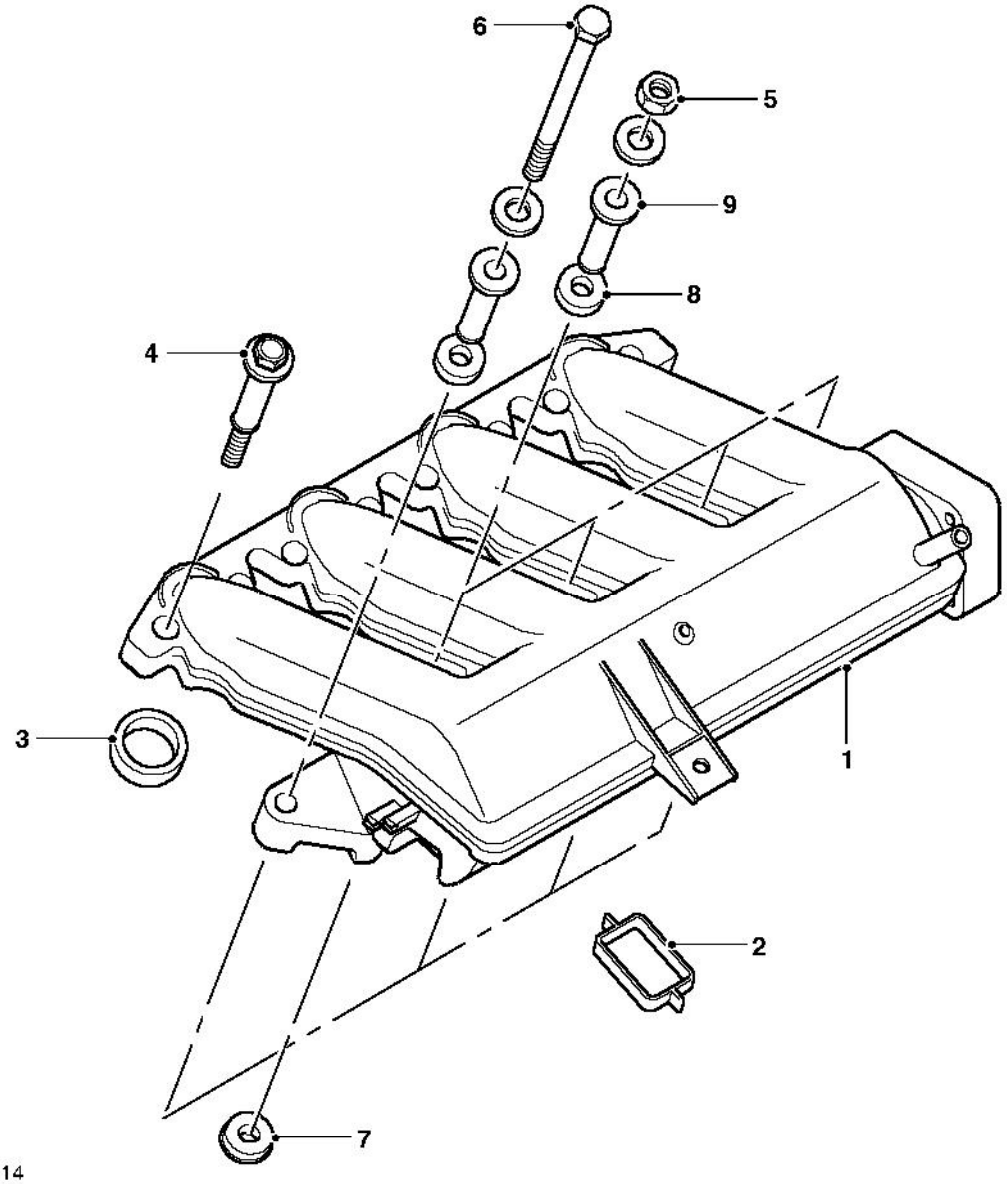
Exhaust Manifold Component Layout



M30 1013

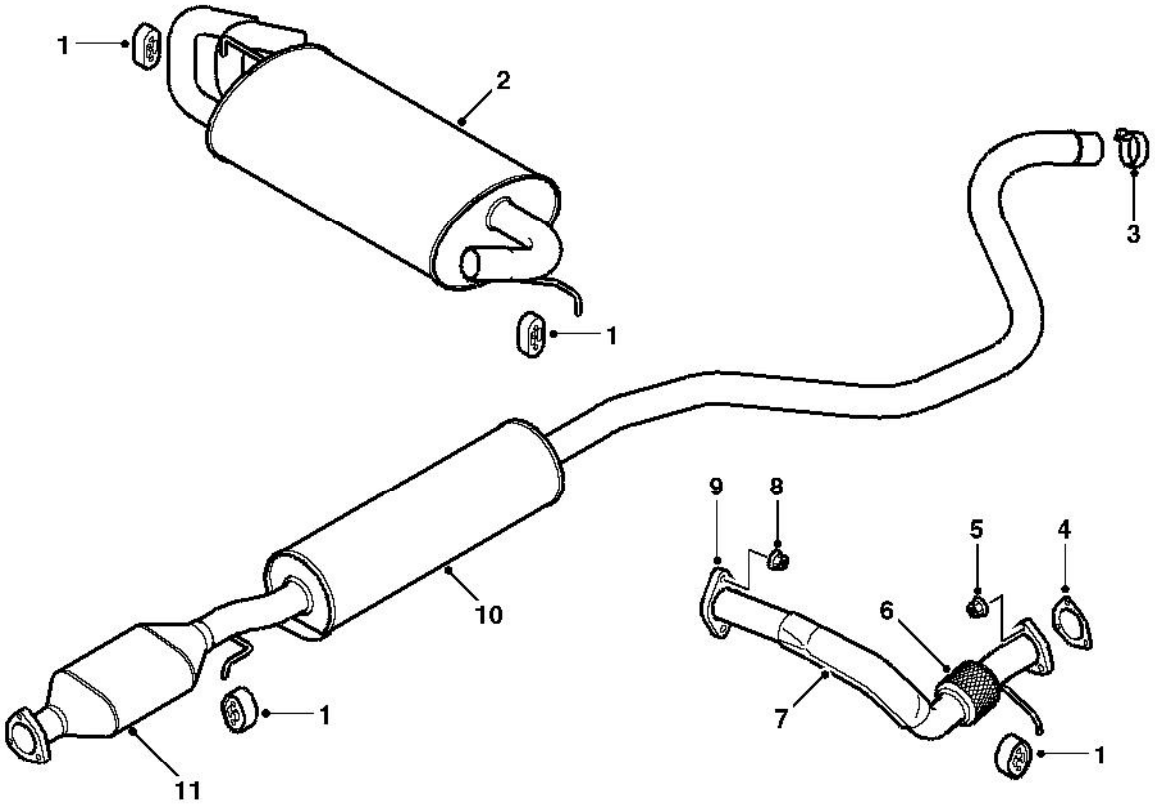
1 Exhaust manifold
2 Gasket (2 off)
3 Flanged nut (8 off)

Inlet Manifold Component Layout



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)

Exhaust System Component Layout



M30 1019

1 Mounting rubber (4 off)
2 Tail pipe assembly
3 Clamp
4 Gasket (front pipe to intermediate pipe)
5 Nut (3 off)
6 Flexible pipe
7 Front pipe assembly
8 Nut (2 off)
9 Flange
10 Intermediate pipe assembly
11 Catalytic converter

Description

General
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.

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.

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.

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.

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

Downpipe Assembly
The downpipe assembly is a tubular fabricated and welded construction. The downpipe is attached to the turbocharger by a flange which is secured with two lock nuts. The downpipe connects to an integral flexible pipe which terminates with a flange. The flange connects to the intermediate pipe and is sealed with a metal gasket. The downpipe is supported between the flexible pipe and the lower flange by a welded support bracket and a mounting rubber.

The flexible pipe is formed into a concertina shape with woven metal strands around its outer diameter. The flexible pipe allows for ease of exhaust system alignment and also absorbs engine vibrations. The woven metal strands increase the longevity of the flexible pipe.

Intermediate Pipe Assembly
The intermediate pipe has a flange at its forward end with three captive studs which mate with the flange on the downpipe assembly.



The catalytic converter is located between the forward flange and the silencer and is integral with the intermediate pipe.

☞ **EMISSION CONTROL - Td4, DESCRIPTION AND OPERATION, Description.**

CAUTION: Ensure the exhaust system is free from leaks. Exhaust gas leaks upstream of the catalytic converter could cause internal damage to the catalytic converter.

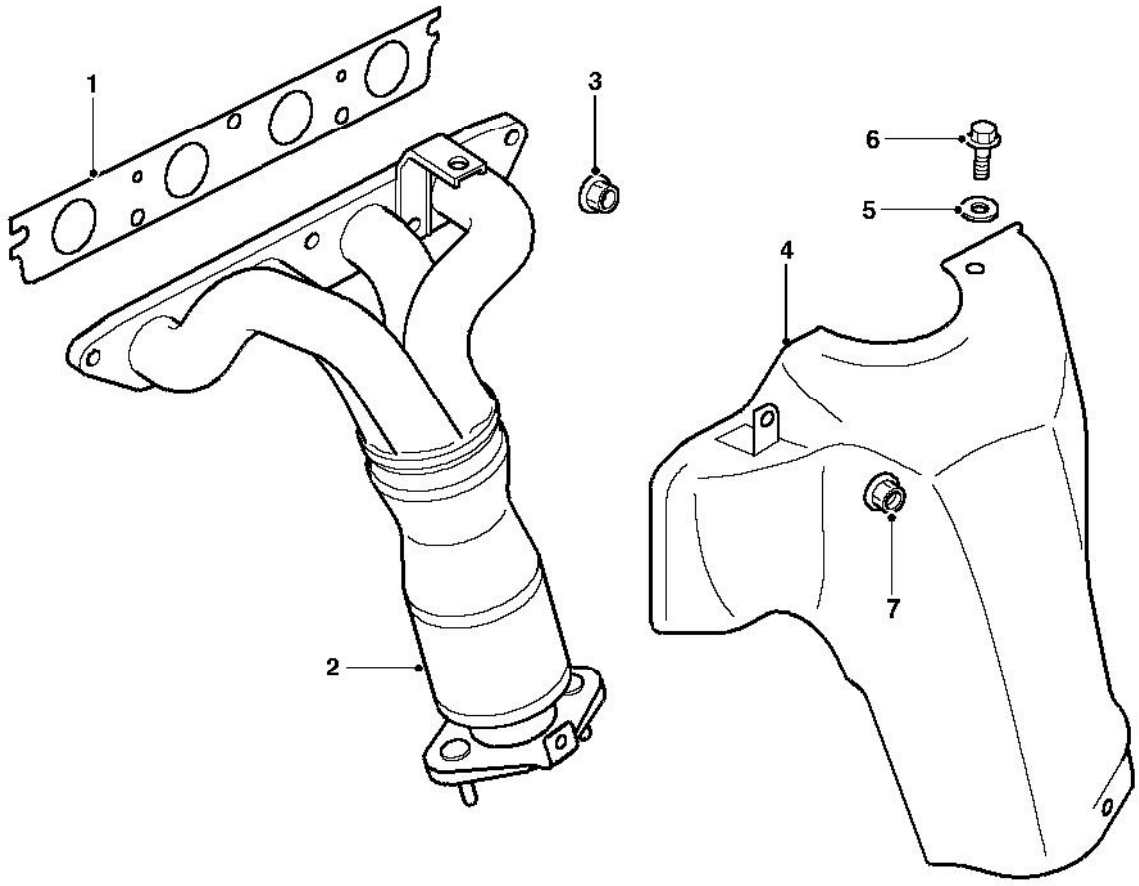
An oval section silencer is located behind the catalytic converter and is braced to the pipe at either end to resist bending. The pipe has a series of bends to allow clearance for the suspension and terminates in an open end which mates with the tailpipe assembly. The intermediate pipe is supported between the catalytic converter and the silencer by a welded support bracket and a mounting rubber.

Tailpipe Assembly

The tailpipe 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.

The 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 rear bumper.

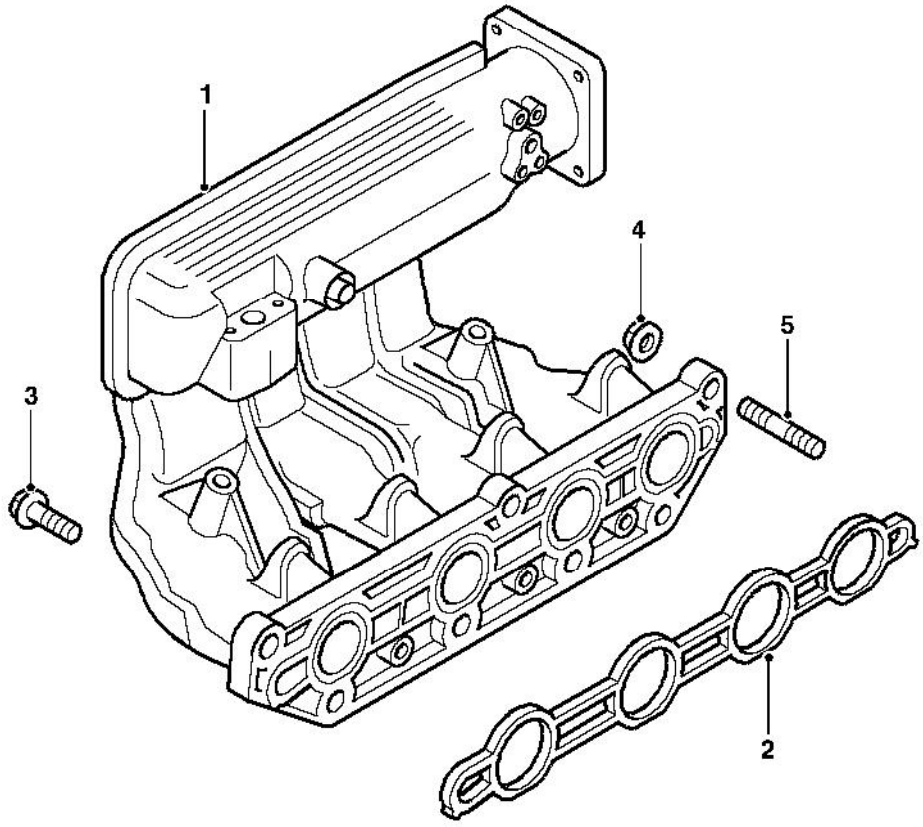
Exhaust Manifold



M30 1022

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

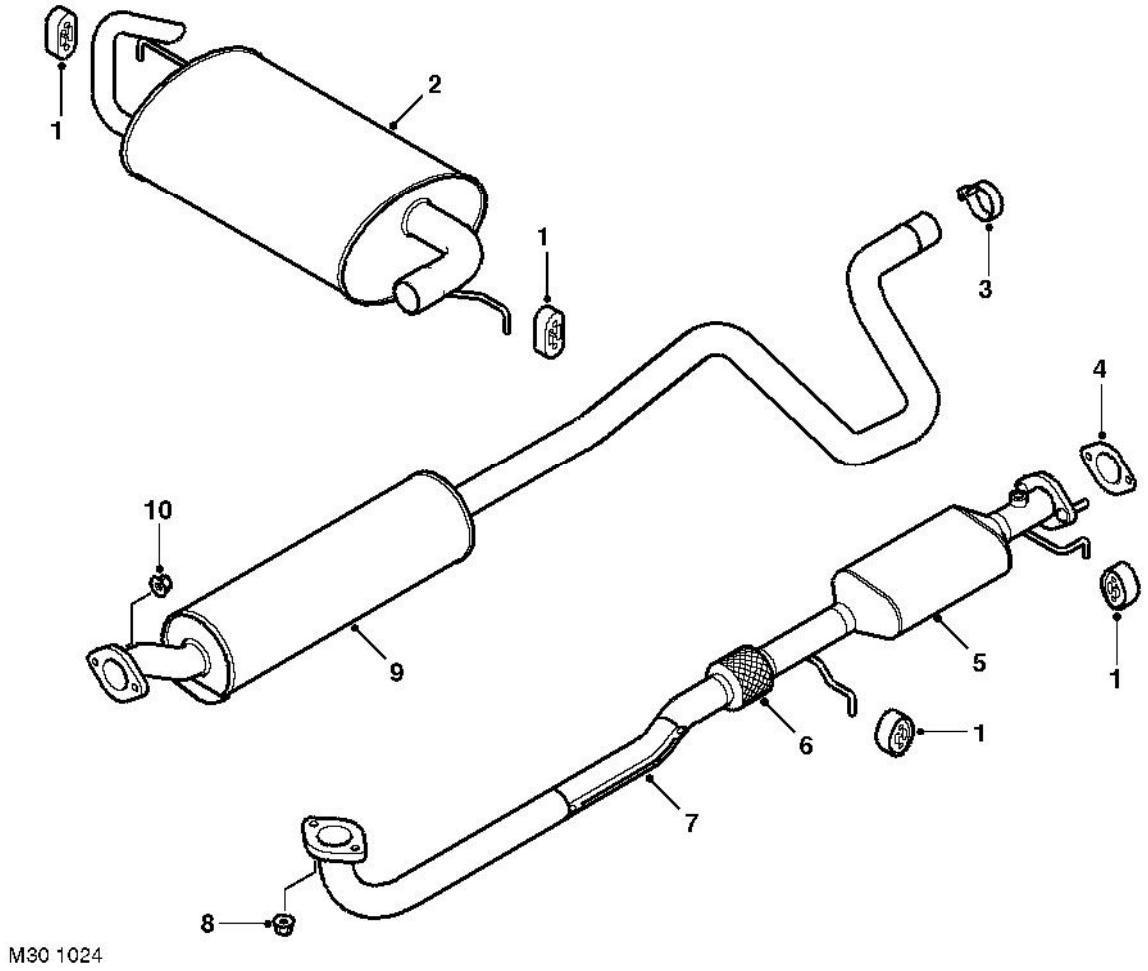
Inlet Manifold



M30 1023

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

Exhaust System



1 Mounting rubber (4 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)

Description

Inlet Manifold
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
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.

Front Pipe Assembly
The front pipe assembly is of welded and fabricated tubular construction and is connected to the exhaust manifold flange studs with two nuts and sealed with a metal gasket. A single pipe from the flange is positioned below the engine and connects into an integral flexible pipe section.

The flexible pipe is formed into a concertina shape with a metal shroud around its outer diameter. The flexible pipe allows for ease of exhaust system alignment and also absorbs engine vibration.

From the flexible pipe a short section of pipe is welded to the main catalytic converter. A second piece of pipe is welded to the outlet from the catalytic converter and incorporates a flange with two captive studs which mate with the intermediate pipe assembly.

☞ **EMISSION CONTROL - K SERIES 1.8, DESCRIPTION AND OPERATION, Description.**

CAUTION: Ensure the exhaust system is free from leaks. Exhaust gas leaks upstream of the catalytic converter could cause internal damage to the catalytic converter.

Two support brackets are welded to the pipe and support the front pipe assembly via mounting rubbers to brackets on the body.

Intermediate Pipe Assembly
A flange at the forward end of the intermediate pipe connects to the front pipe flange and is secured with two nuts and sealed with a metal gasket. A fabricated, circular silencer is mounted at the forward end of the intermediate pipe assembly. The rear pipe from the silencer is shaped to go around and over the rear subframe and terminates in an open end which mates with the tail pipe assembly. The intermediate pipe assembly is not attached to the vehicle body, but is retained by the flanged joint on the front pipe and the clamp on the tail pipe assembly.



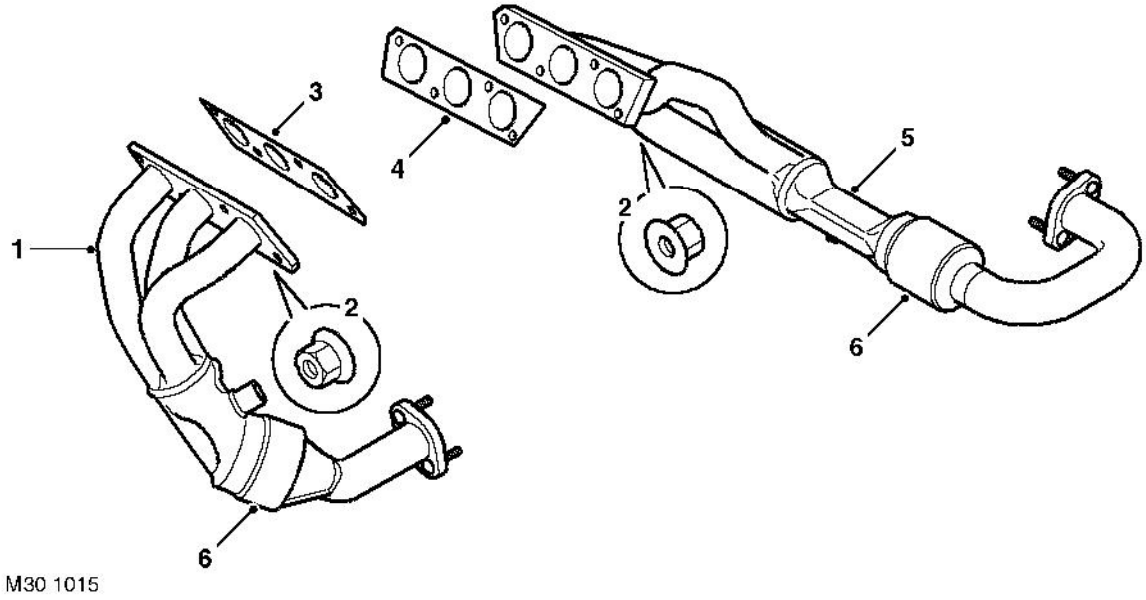
Tailpipe Assembly

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

The tail pipe is welded to the right hand end of the silencer and directs exhaust emissions downwards from the right hand end of the rear bumper.

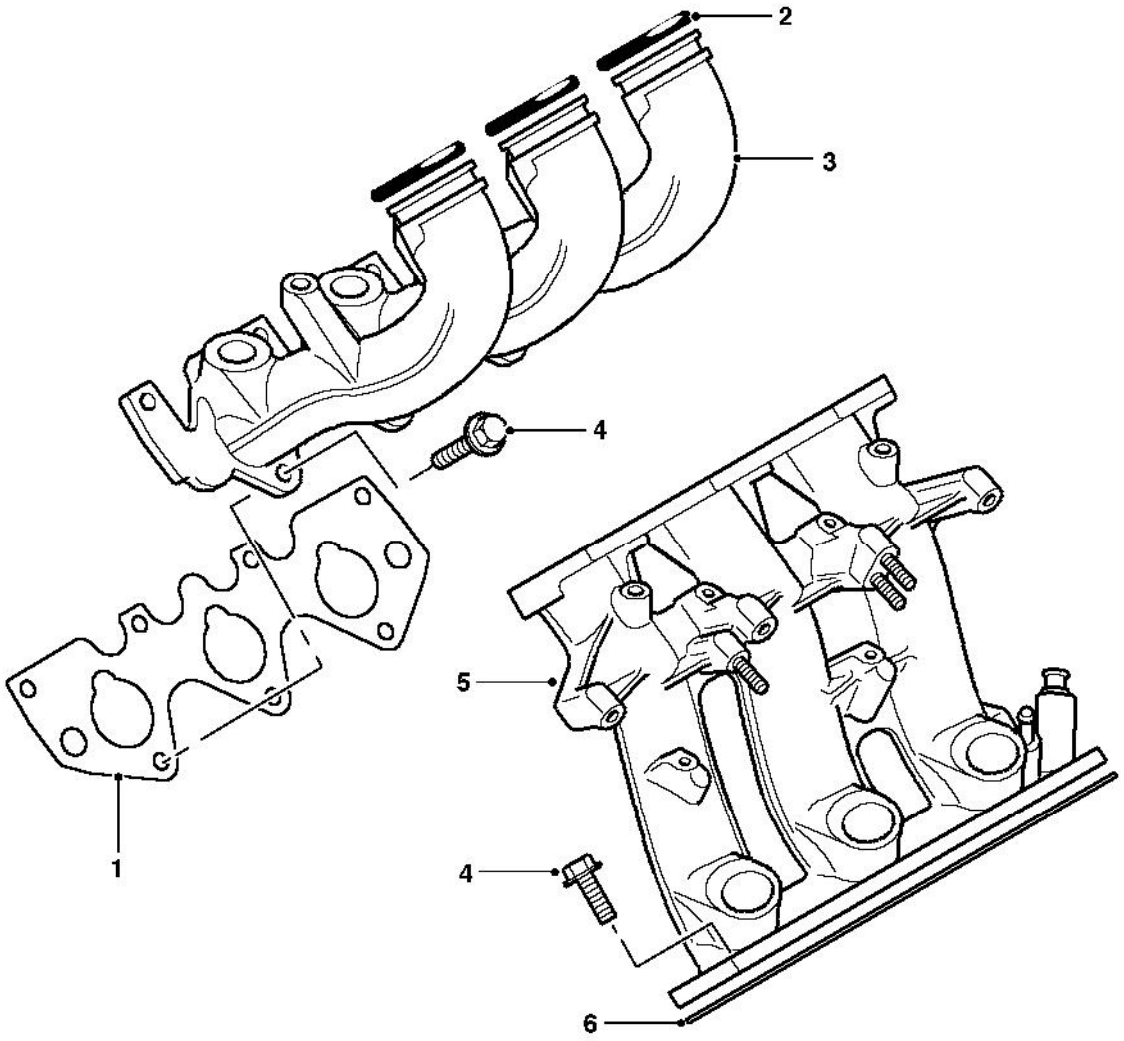
Attachment bars are welded to each end of the tailpipe assembly and provide attachment points for the tailpipe to the body via mounting rubbers.

Exhaust Manifold Component Layout (All Except NAS)



1 Exhaust manifold LH
2 Flanged nut (8 off)
3 Gasket LH
4 Gasket RH
5 Exhaust manifold RH
6 Starter catalyst

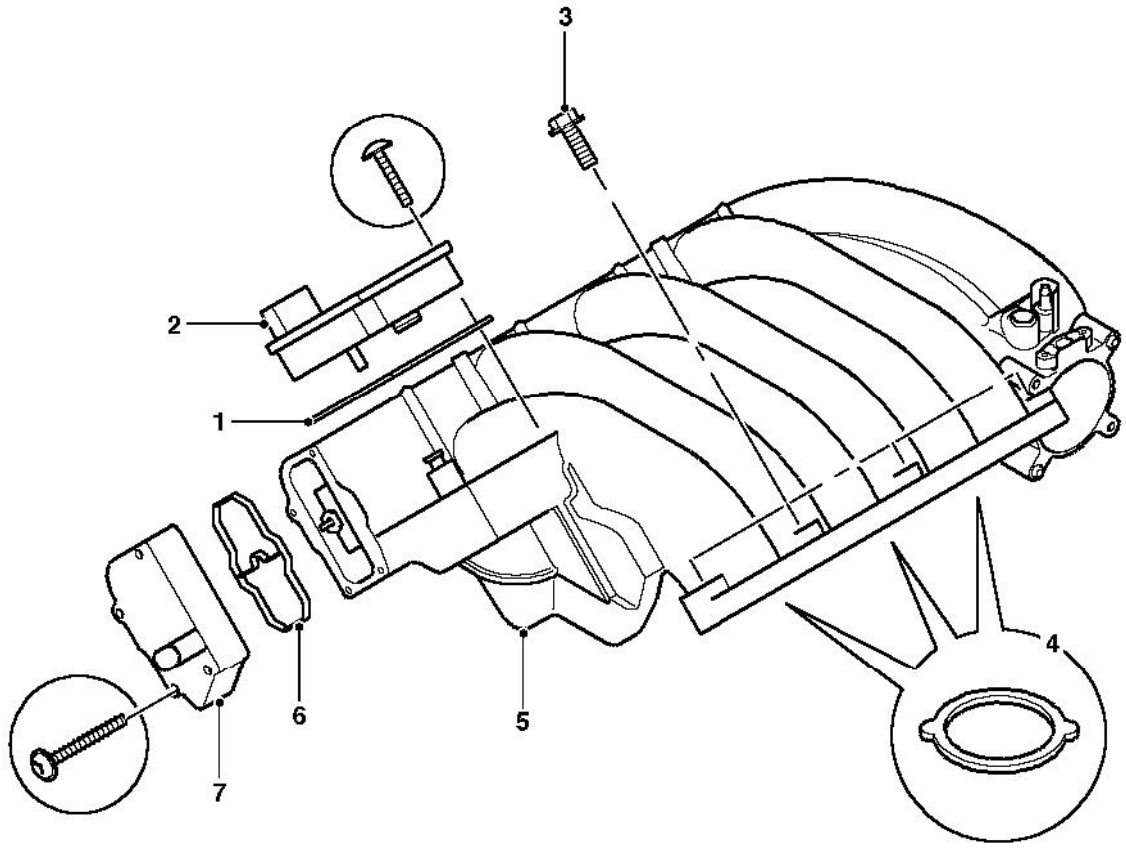
Inlet Manifold Component Layout



M30 1016

1 Gasket RH
2 'O' ring (3 off)
3 Inlet manifold RH
4 Flanged bolt (14 off)
5 Inlet manifold LH
6 Gasket LH

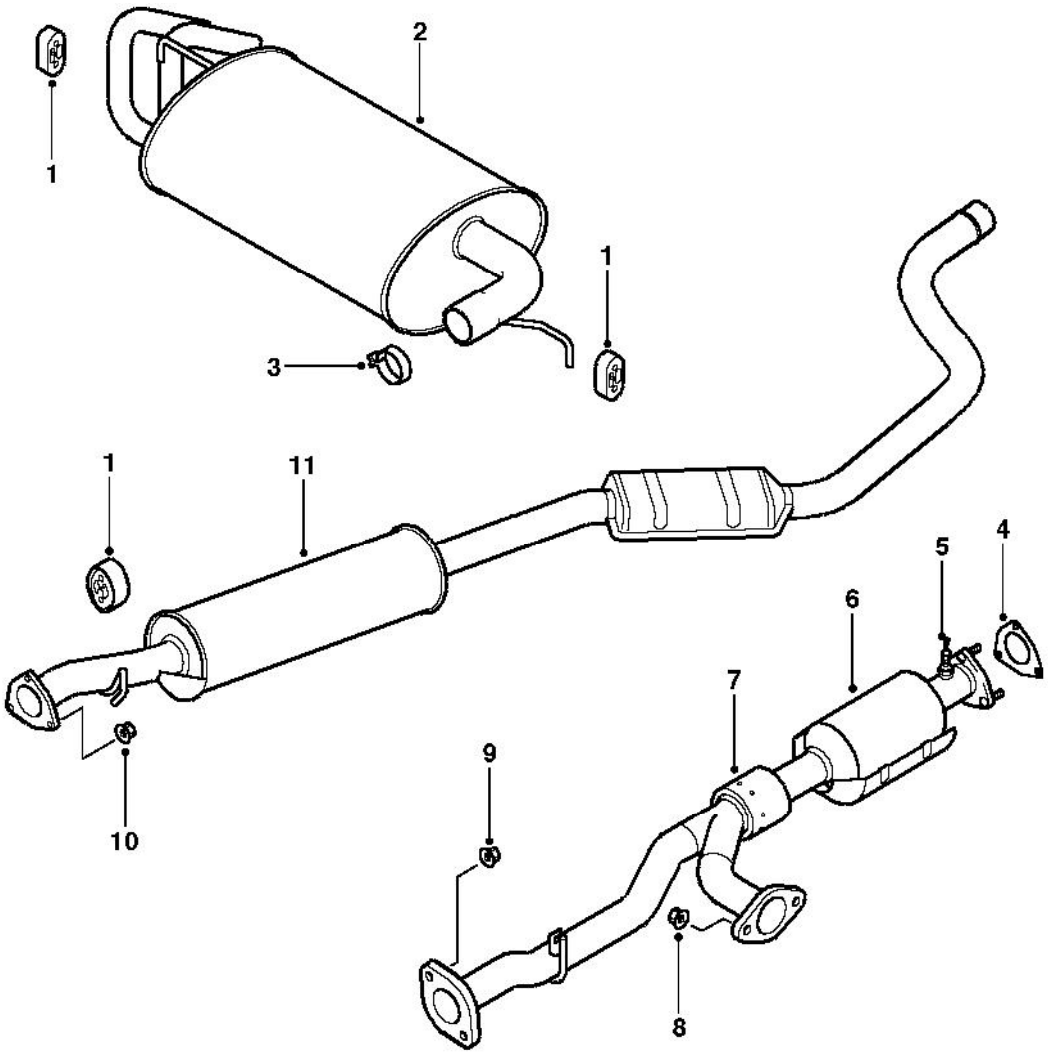
Inlet Manifold Chamber Component Layout



M30 1017

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

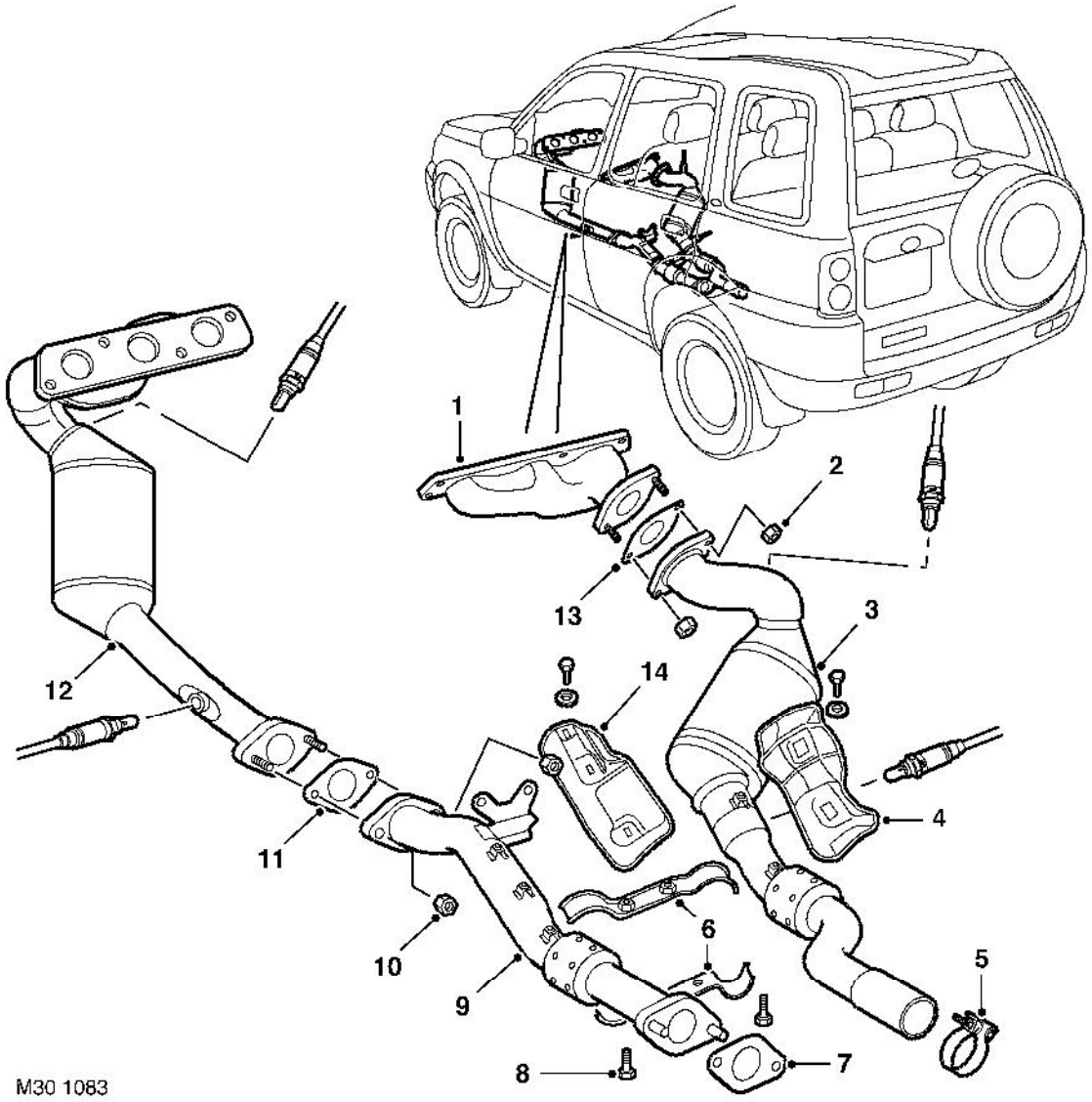
Exhaust System Component Layout (All Except NAS)



M30 1020

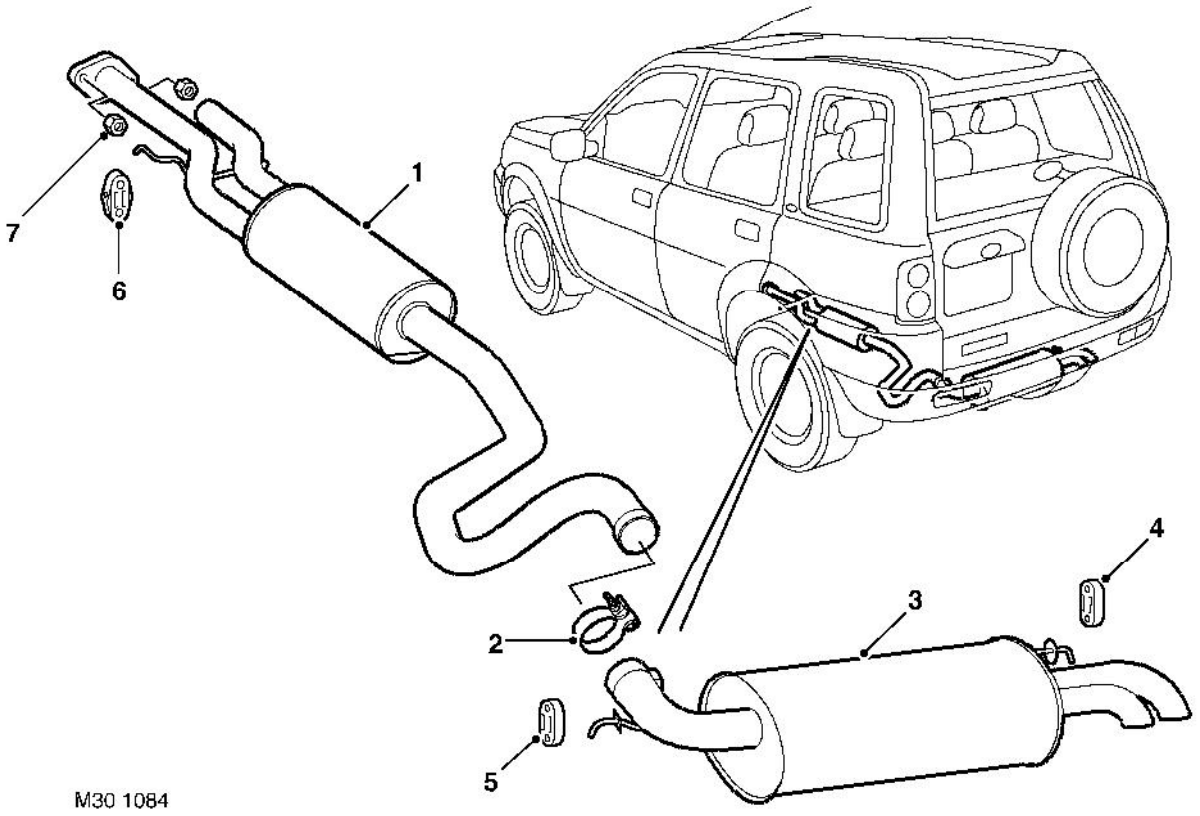
1 Mounting rubber (3 off)
2 Tail silencer
3 Clamp
4 Gasket
5 Post catalyst HO2S
6 Main catalytic converter
7 Front pipe assembly
8 Nut (2 off)
9 Nut (2 off)
10 Nut (3 off)
11 Intermediate pipe assembly

Exhaust System Component Layout – Sheet 1 of 2 (NAS)



1 RH manifold
2 Nut – RH catalytic converter and downpipe to manifold (x 2)
3 RH catalytic converter and downpipe
4 Heatshield
5 Pipe clamp
6 Bracing clamp
7 Gasket
8 Bolt – bracing clamp (x 2)
9 LH downpipe
10 Nut – LH downpipe to manifold and catalytic converter (x 2)
11 Gasket
12 LH manifold and catalytic converter
13 Gasket
14 Heatshield

Exhaust System Component Layout – Sheet 2 of 2 (NAS)



1 Intermediate pipe
2 Pipe clamp
3 Tail silencer
4 Mounting rubber
5 Mounting rubber
6 Mounting rubber with restraint
7 Nut – intermediate pipe to downpipes (x 2)

Description

Inlet Manifolds
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
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.

Exhaust Manifolds (All Except NAS)
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. Refer to the Emissions section for details of catalyst and HO2S operation.
☞ **EMISSION CONTROL - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

Exhaust System (All Except NAS)
The exhaust system comprises three major parts; a front pipe assembly incorporating a catalytic converter, an intermediate pipe assembly and a tail 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.
☞ **EMISSION CONTROL - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

CAUTION: Ensure the exhaust system is free from leaks. Exhaust gas leaks upstream of the catalytic converter could cause internal damage to the catalytic converter.

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.

Exhaust System (NAS)
The manifolds and exhaust system is of welded steel construction and consists of five main parts;
- A RH (rear) manifold.
- A LH (front) manifold and catalytic converter.
- A RH downpipe and catalytic converter.
- A LH downpipe.
- An intermediate pipe.
- A tail silencer.

Close coupled catalytic converters are incorporated into the system to achieve fast converter light-off times after starting the engine. Heated Oxygen Sensors (HO2S) are installed upstream and downstream of each catalytic converter, to enable the ECM to exercise closed loop control of the air:fuel ratio and to monitor catalytic converter performance.

To reduce heat loss, the exhaust manifolds, the pipes between the exhaust manifolds and the catalytic converters, and the ends of the catalytic converters, are double walled with an air gap between the walls.

The system is suspended from the underside of the vehicle on mounting rubbers and a bracket on the downpipe and rear catalytic converter.

RH Manifold
The three branch manifold is fitted to the RH cylinder head. A composite gasket seals the manifold to the cylinder head and four studs and nuts secure the manifold in position.

LH Manifold and Catalytic Converter
The front manifold and catalytic converter consists of a three branch manifold and a catalytic converter integrated into a common assembly. A composite gasket seals the manifold to the LH cylinder head and four studs and nuts secure the manifold in position. Threaded bosses are welded into the pipe at each end of the catalytic converter to accommodate the HO2S.

RH Downpipe and Catalytic Converter
The RH downpipe and catalytic converter is connected between the RH manifold and the intermediate pipe. The flanged connection with the RH manifold is sealed with a metal gasket. The slip joint connection with the intermediate pipe is secured with a clamp. Threaded bosses are welded into the downpipe at each end of the catalytic converter to accommodate the HO2S. A flexible joint is incorporated into the downpipe, near the connection with the intermediate pipe, to absorb engine vibration. Brackets welded to the top of the downpipe accommodate anchor nuts for the attachment of a heatshield.



LH Downpipe

The LH downpipe connects the LH manifold and catalytic converter to the intermediate pipe. Flanged connections at each end of the downpipe are sealed with metal gaskets. A flexible joint is incorporated into the downpipe, near the connection with the intermediate pipe, to absorb engine vibration. A bracing clamp attaches the LH downpipe to the RH downpipe and catalytic converter. A bracket on the LH downpipe attaches the system to the Intermediate Reduction Drive (IRD). Additional brackets welded to the top of the downpipe accommodate anchor nuts for the attachment of a heatshield.

Intermediate Pipe

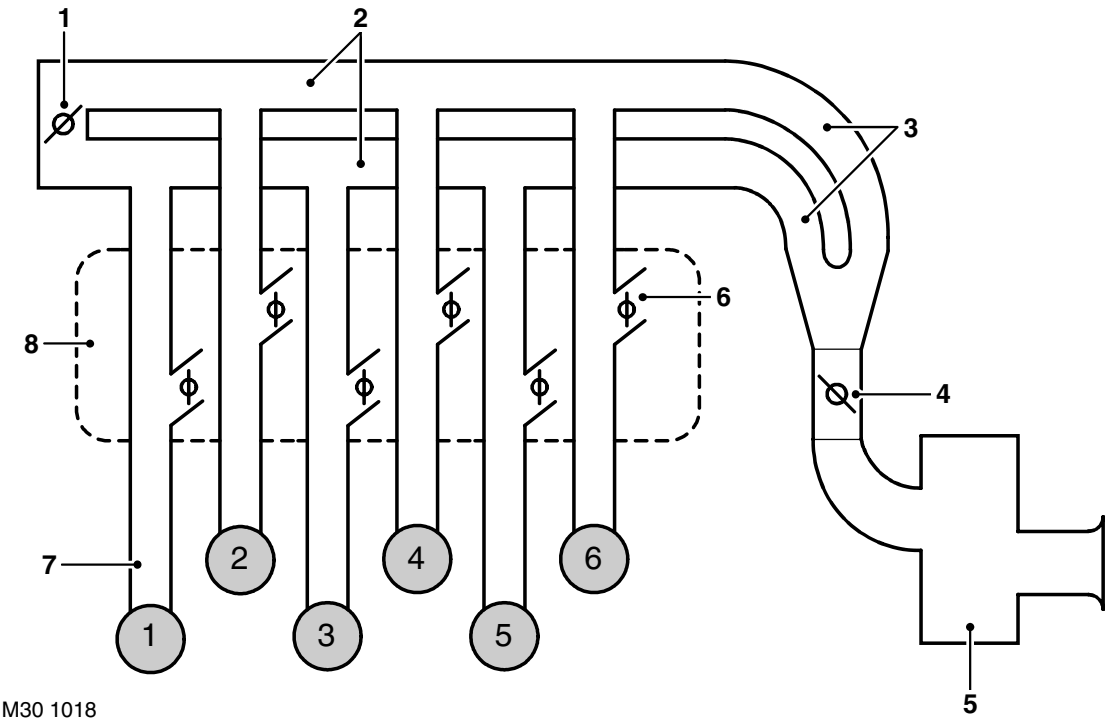
The intermediate pipe connects the downpipes to the tail silencer. A silencer is incorporated into the front of the intermediate pipe, and the rear end of the pipe is formed to pass over the rear suspension.

Tail Silencer

The tail silencer comprises a 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 slip joint between the tail silencer and the intermediate pipe is secured with a clamp.

Operation

Inlet Manifold Chamber – Variable Intake System (VIS)



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

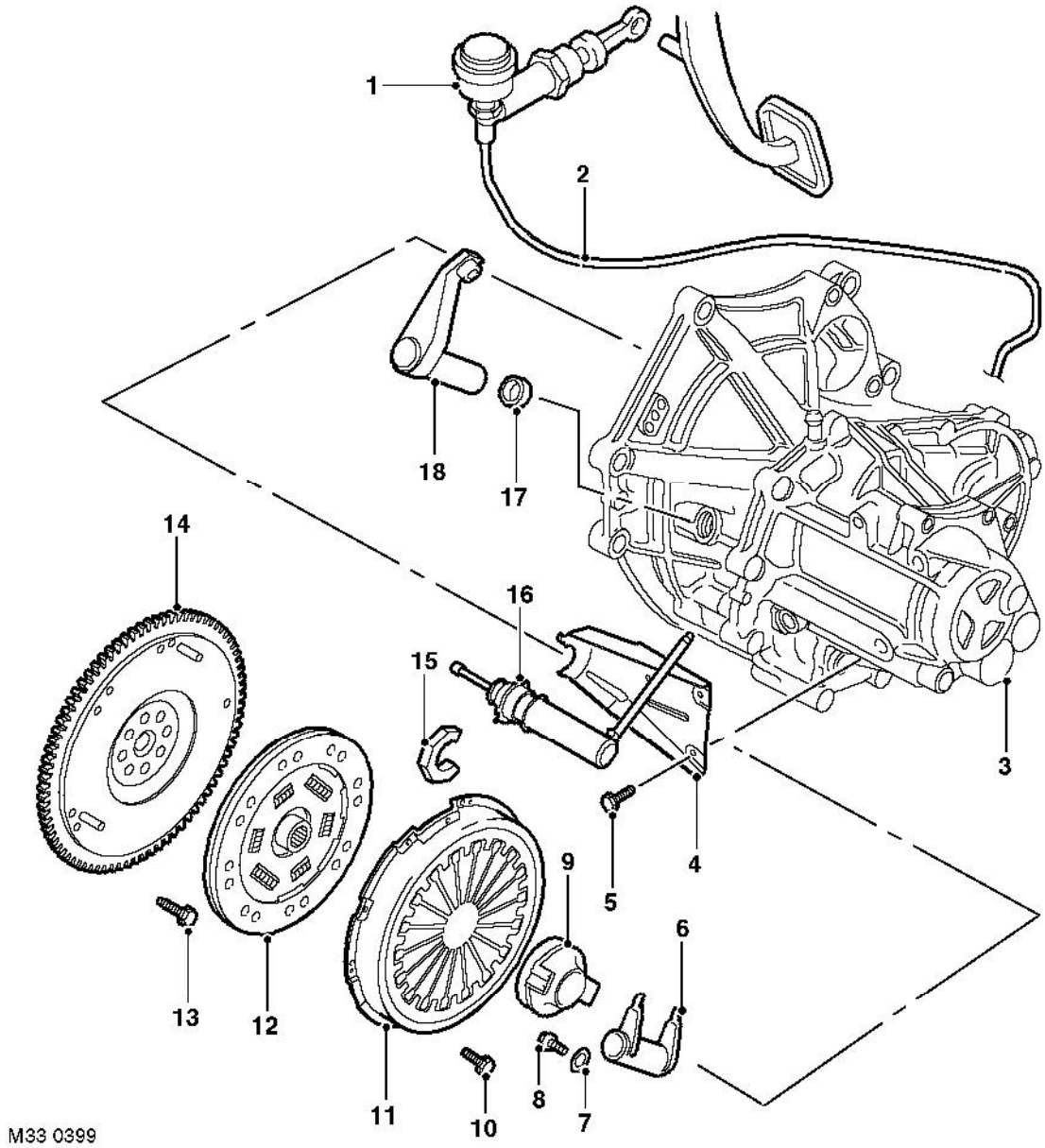
For increased mid-range torque performance, the plenums are connected using the balance valve. The power valves remain closed. This allows the engine to use the long primary tract length, which is tuned with the balance valve to produce maximum torque at 3750 rev/min.

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.

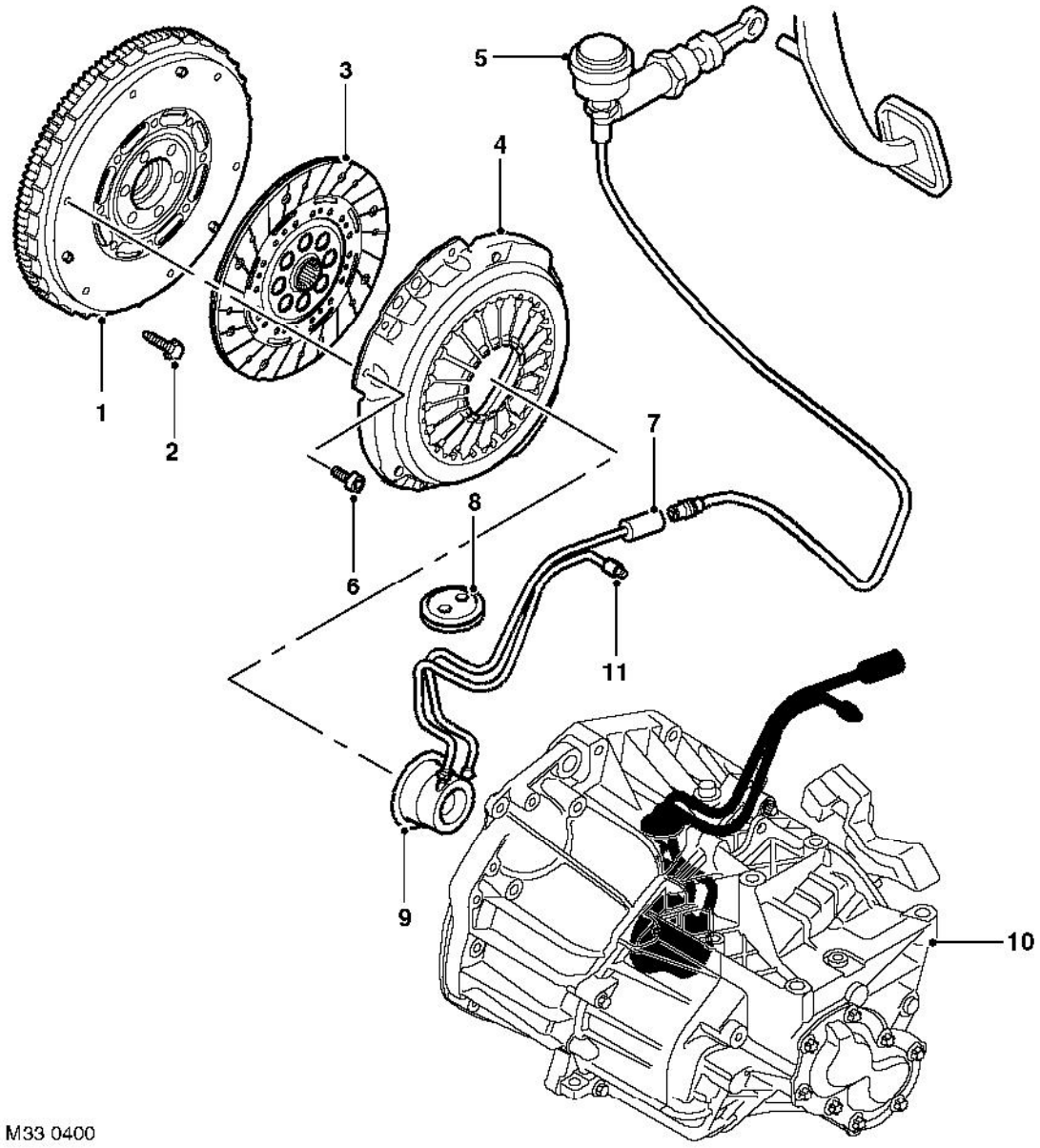
The manifold also gives an improvement in part load fuel consumption. At part load, throughout the emissions cycle the manifold operates as at high speed. The pressure dynamics significantly reduce the pump losses below 4000 rev/min resulting in improved fuel consumption.

Clutch Components – K1.8 Engines



1 Master cylinder
2 Tube
3 Gearbox (PG1)
4 Bracket
5 Bolt (3 off)
6 Release fork
7 Spring washer
8 Bolt
9 Release bearing
10 Bolt (6 off)
11 Clutch cover assembly
12 Clutch driven plate
13 Bolt (6 off)
14 Flywheel
15 Clip
16 Slave cylinder
17 Release shaft oil seal
18 Release lever

Clutch Components – Td4 Engines



1 Flywheel
2 Bolt (6 off)
3 Clutch driven plate
4 Clutch cover assembly
5 Master cylinder
6 Bolt (6 off)
7 Quick fit connector
8 Grommet
9 Slave cylinder/release bearing assembly
10 Gearbox (Getrag)
11 Bleed nipple

Description

Clutch System Description
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.

Hydraulic Clutch – K1.8 Engines
The hydraulic clutch comprises a master cylinder and a slave cylinder connected by a one piece plastic tube. The system comes as a complete assembly, pre-filled with hydraulic fluid to ease replacement and minimize repair times. The master and slave cylinders are 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 other end of the tube is connected to the slave cylinder, also using a swivel coupling. The nylon tube is flexible to allow ease of routing and absorbs engine movements and vibrations.

The slave cylinder comprises a cylinder with a piston and rod. The piston rod is fully extended when the clutch pedal is depressed and almost fully retracted when the pedal is at rest.

A new slave cylinder has the piston locked in the retracted position by a plastic clip. When the clutch is first operated, the hydraulic action of the clutch system breaks the plastic clip and allows the rod to extend. Care should be taken to ensure that the rod is correctly located in the release arm after the first operation of the clutch pedal. The plastic clip locates in a spherical seat in the release lever. The slave cylinder is attached to a bracket which is bolted to the gearbox. A specially shaped slot in the bracket locates the slave cylinder and a plastic clip secures it in position.

Hydraulic Clutch – Td4 Engines
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.

Clutch Mechanism – K1.8 Engines

The clutch mechanism comprises a flywheel, clutch driven plate, clutch cover assembly, release lever, release fork and a release bearing. The clutch mechanism is fully enclosed at the end of the engine by a bell housing formed by the gearbox casing.

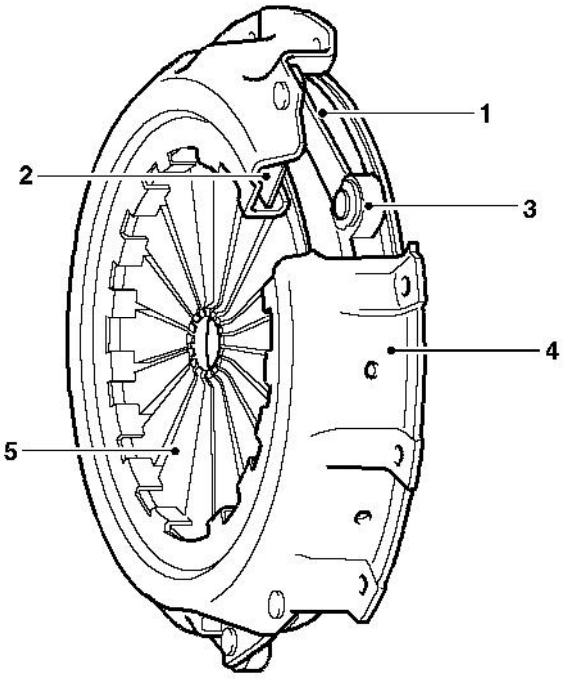
The spindle of the release lever is located through machined bores in the gearbox casing. The release fork fits on the release lever spindle and is secured to the spindle with a bolt and spring washer. An oil seal is located at the outer face of the gearbox casing and seals against the release lever spindle preventing the ingress of dirt and moisture.

A release bearing is operated by the release fork. The bearing has two lugs which clip onto the arms of the release fork.

The flywheel is bolted to the flange of the engine crankshaft with six bolts. A dowel ensures that the flywheel is correctly located. A ring gear is located on the outside diameter of the flywheel and is seated against a flange. The ring gear is an interference fit on the flywheel and is installed by heating the ring gear and cooling the flywheel. The ring gear is a serviceable item and can be replaced if damaged or worn.

The operating face of the flywheel is machined to provide a smooth surface for the clutch driven plate to engage on. Three dowels are fitted to the outer diameter of the flywheel and provide for the location of the clutch cover assembly. Six threaded holes provide for the attachment of the clutch cover assembly. The flywheel is balanced to ensure that it does not produce vibration when rotating.

Clutch Cover Assembly



M33 0401

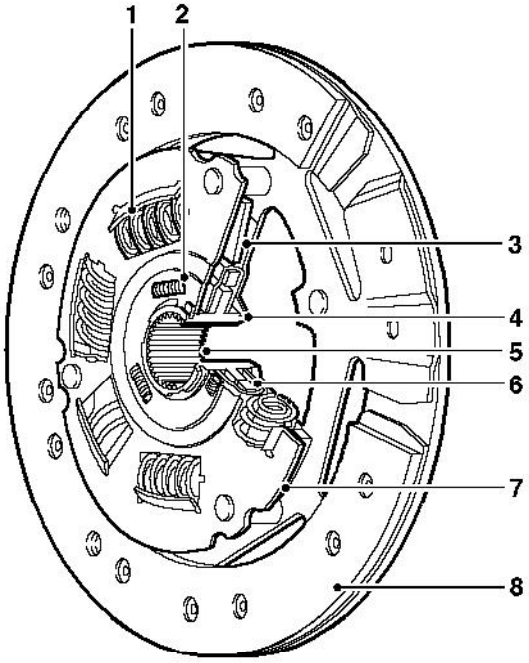
1 Drive straps
2 Fulcrum rings
3 Pressure plate
4 Cover
5 Diaphragm spring

The clutch cover assembly comprises a diaphragm spring, pressure plate and cover. The clutch cover assembly is mounted on and rotates with the flywheel. Three dowels locate the cover and six bolts secure it to the flywheel.

The 228 mm (9.0 in) diameter pressure plate is forged from cast iron and machined to provide a smooth surface for the drive plate to engage on. Three lugs on the outer diameter of the pressure plate connect it via drive straps to the cover. The drive straps have three tempered steel leaves and pull the pressure plate away from the drive plate when the clutch pedal is depressed. The cover is made from pressed steel.

The diaphragm spring comprises a cast ring with eighteen fingers on its inner diameter. Two circular steel fulcrum rings are attached to the cover and allows the diaphragm spring to pivot between them. The diaphragm spring is not physically attached to the pressure plate. When pressure is applied to the diaphragm spring fingers from the release bearing, the diaphragm spring pivots between the fulcrum rings and moves away from the pressure plate. The drive straps attaching the pressure plate to the cover move the pressure plate away from the clutch driven plate.

Clutch Driven Plate



M33 0406

1 Damper springs
2 Pre-damper springs
3 Inner plate
4 Friction damper
5 Splined hub
6 Central plate
7 Outer plate
8 Friction material

The clutch driven plate is sandwiched between the flywheel and the pressure plate of the clutch cover assembly. The clutch driven plate has a splined hub which engages with the splines on the primary shaft from the gearbox. The splined hub is located in an inner plate which contains four compression pre-damper springs. The inner plate is retained by the springs which can compress in both directions to cushion engine vibration at idle speed. The inner plate is located on eight larger compression springs which are located in a central plate. The hub is sandwiched between the central plate and the friction damper. The friction damper comprises friction washers located between the hub and the central plate. The friction washers reduce transmission noises and vibrations.

The drive from the inner plate is transferred to the central plate through the larger compression springs. Two outer plates are located either side of the central plate. The central plate is connected to the outer plate in slots and retained with rivets. The slots allow the central plate to move and compress the springs absorbing shock loads when the clutch is engaged or when the engine is decelerating. One of the outer plates is marked 'flywheel side'. This outer plate must face the flywheel when installed.

One of the outer plates has a spring steel plate riveted to it. The plate provides the attachment surface for the clutch driven plate friction facing material.

The facing material comprises two discs which are riveted to each side of the spring steel plate. The rivets are secured through recessed holes in the facing material and emerge in clearance holes in the opposite disk.

The clutch driven plate used is of the spring centre type. The spring centre drive plate allows angular movement of the hub at low torque levels and rotational forces are damped by the springs. The K Series drive plate is 228 mm (9.0 in) diameter and has a facing material manufactured from Valeo F808.

Clutch Mechanism – Td4 Engines

The clutch mechanism comprises a dual mass flywheel, clutch driven plate, clutch cover assembly and a hydraulically operated release bearing. The clutch mechanism is fully enclosed at the end of the engine by a bell housing formed by the gearbox casing.

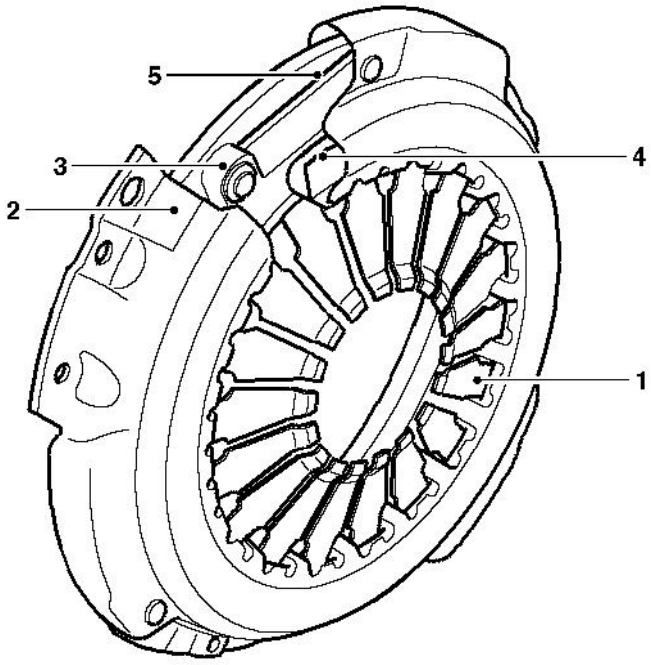
The release bearing is located on a tube which covers the gearbox input shaft and is connected by a pipe to the master cylinder. The release bearing is kept in contact with the pressure plate diaphragm by a spring which is located on the slave cylinder piston.

The dual mass flywheel comprises a primary mass and a secondary mass which, via the clutch driven plate, transmit drive to the gearbox. The secondary mass is located on a roller bearing in the primary mass. The primary mass is secured on the flanged end of the crankshaft with six bolts. The drive between the secondary and primary masses is achieved by a torsional spring damper. The flywheel insulates the gearbox from torsional and transient vibrations produced by the engine, giving an improved drive train refinement.

The operating face of the flywheel is machined to provide a smooth surface for the clutch driven plate to engage on. Three dowels in the secondary mass provide location for the clutch cover assembly which is secured with six bolts. The flywheel is balanced to ensure that it does not produce vibration when rotating.

A ring gear is located on the outer diameter of the flywheel. The ring gear is not serviceable and a new flywheel is necessary if the gear becomes worn or damaged.

Clutch Cover Assembly



M33 0402

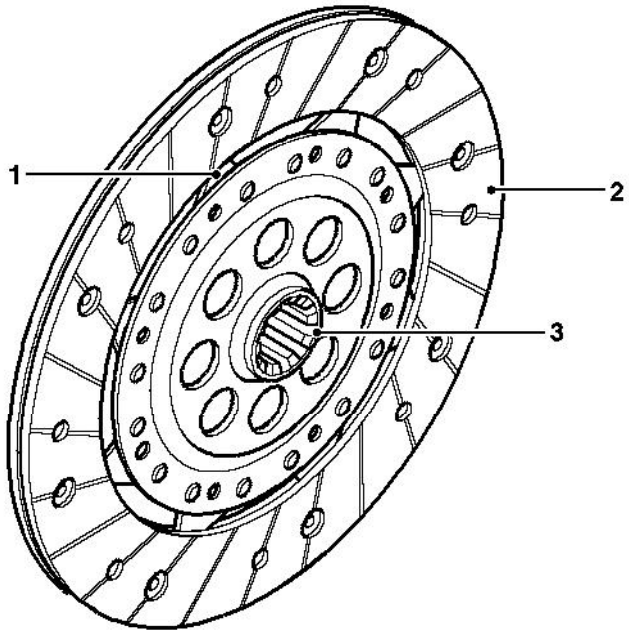
1 Diaphragm spring
2 Cover
3 Pressure plate
4 Fulcrum rings
5 Drive straps

The clutch cover assembly comprises a diaphragm spring, pressure plate and cover. The clutch cover assembly is mounted on and rotates with the flywheel and is located with three dowels and secured with six bolts.

The pressure plate is forged from cast iron and machined to provide a smooth surface for the clutch driven plate to engage on. Three lugs on the outer diameter of the pressure plate connect it via drive straps to the cover. The drive straps have three tempered steel leaves and pull the pressure plate away from the clutch driven plate when the clutch pedal is depressed. The cover is made from pressed steel.

The diaphragm spring comprises a cast ring with eighteen fingers on its inner diameter. Two circular steel fulcrum rings are attached to the cover and allow the diaphragm spring to pivot between them. The diaphragm spring is not physically attached to the pressure plate. When pressure is applied to the diaphragm spring fingers from the release bearing, the diaphragm spring pivots between the fulcrum rings and moves away from the pressure plate. The drive straps attaching the pressure plate to the cover also move away from the clutch driven plate.

Clutch Driven Plate



M33 0403

1 Cushion spring segments
2 Friction material
3 Splined hub

The drive plate is sandwiched between the flywheel and the pressure plate of the clutch cover assembly. The clutch driven plate has a splined hub which engages with the splines on the input shaft from the gearbox. One side of the drive plate is marked 'gearbox side' and must face the gearbox when installed. The hub is attached to a plate which also provides the attachment surface for the cushion spring segments which have the friction discs riveted to them.

The friction material comprises two discs which are riveted to each side of the cushion spring segments. The rivets are secured through recessed holes in the friction material and emerge in clearance holes in the opposite disc.

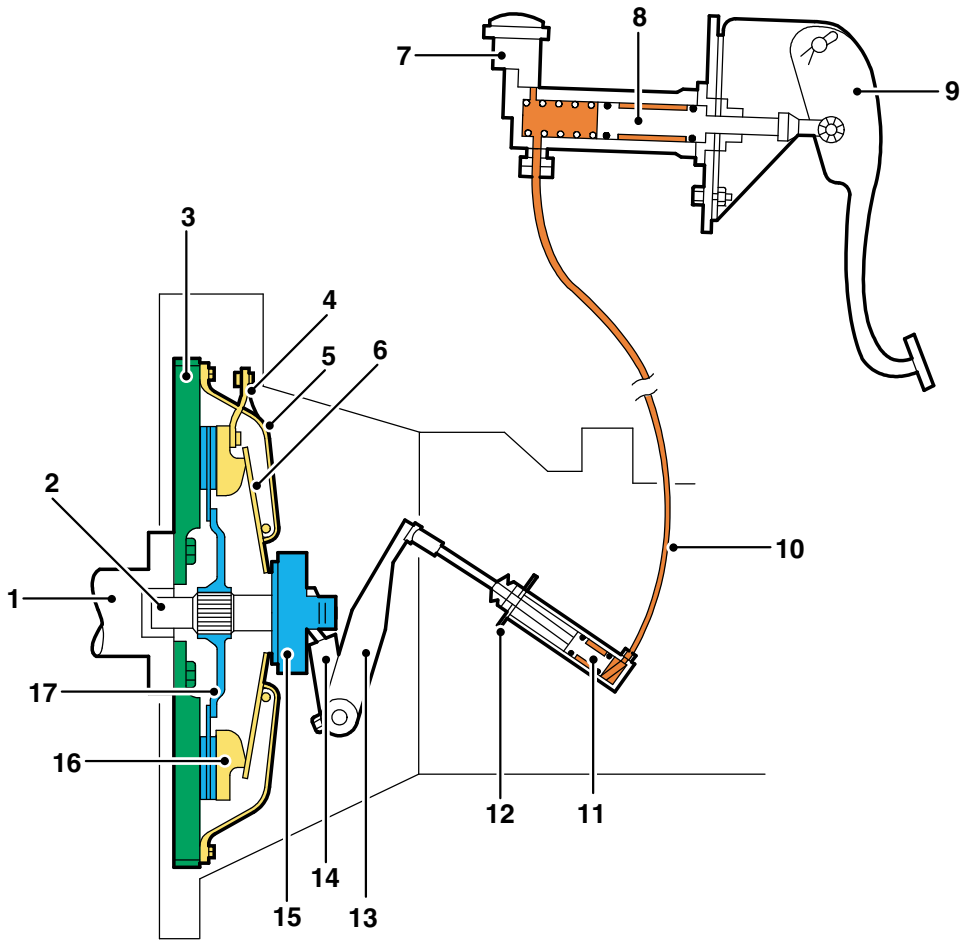
The clutch driven plate used is of the rigid centre type. The rigid centre drive plate allows angular movement of the hub at low torque levels with rotational movement cushioned by the dual mass flywheel. The Td4 drive plate is 228 mm (9.0 in) diameter and has a facing material manufactured from Valeo F808.

Operation

Clutch System Operation

The following illustrations show hydraulic and mechanical operation for K1.8 and Td4 clutch systems.

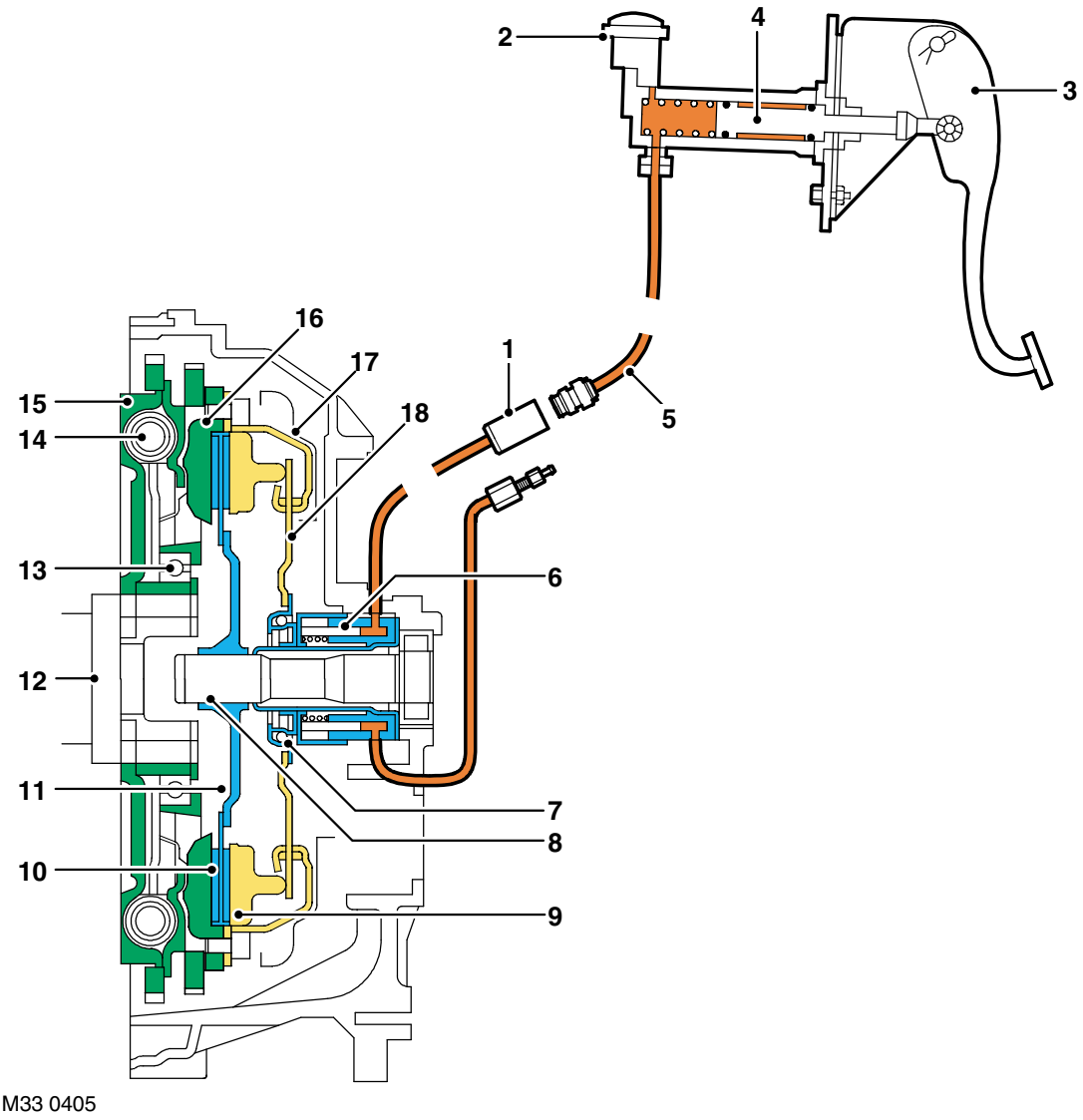
K1.8 Engines



M330404

1 Engine crankshaft
2 Gearbox primary shaft
3 Flywheel
4 Drive strap
5 Clutch cover
6 Diaphragm spring
7 Master cylinder assembly
8 Piston
9 Clutch pedal
10 Hydraulic tube
11 Piston
12 Slave cylinder
13 Release lever
14 Release fork
15 Release bearing
16 Pressure plate
17 Clutch driven plate

Td4 Engines



M33 0405

1 Quick fit connector
2 Master cylinder assembly
3 Clutch pedal
4 Piston
5 Hydraulic pipe
6 Piston
7 Release bearing
8 Gearbox input shaft
9 Pressure plate
10 Friction material
11 Clutch driven plate
12 Crankshaft
13 Roller bearing
14 Arc spring
15 Primary mass
16 Secondary mass
17 Clutch cover
18 Diaphragm spring

Hydraulic Operation

When the clutch pedal is depressed, the piston is pushed into the master cylinder. The piston pressurizes the fluid in the master cylinder forcing the pressurized fluid along the hydraulic pipe. The pressure is felt at the piston of the slave cylinder which moves under the hydraulic force applied.

K1.8 Engines: When the clutch pedal is released, force from the compressed fingers of the diaphragm spring pushes against the release fork through the release bearing. The release fork rotates which in turn rotates the release lever and pushes the piston back into the slave cylinder. This returns hydraulic fluid back up the hydraulic tube and into the master cylinder.

Td4 Engines: When the clutch pedal is released, force from the compressed fingers of the diaphragm spring pushes against the release bearing. The release bearing in turn pushes the piston back into the slave cylinder which returns hydraulic fluid back up the clutch pipe to the master cylinder.

Mechanical Operation

When the clutch pedal is depressed, the hydraulic pressure extends the piston in the slave cylinder.

K1.8 Engines: The extension of the piston rod pushes the release lever which transfers its rotary movement to the release fork to which it is connected. The release fork pivots towards the engine and converts its rotary movement into linear movement of the release bearing.

Td4 Engines: The extension of the piston is transferred into linear movement of the release bearing.

All Models: The release bearing pushes on the fingers of the diaphragm spring which pivots about its fulcrum on the clutch cover. As the diaphragm spring is deflected, its force is removed from the pressure plate. The three drive straps pull the pressure plate away from the clutch driven plate.

The removal of force from the pressure plate on the clutch driven plate reduces the friction between the clutch driven plate and the flywheel. The clutch driven plate slips against the flywheel and cannot transfer the drive from the flywheel to the gearbox primary shaft. When the clutch pedal is released, hydraulic pressure is removed from the piston in the slave cylinder. Removal of the pressure allows the release bearing to be pushed back along the gearbox primary shaft by the fingers of the diaphragm spring.

K1.8 Engines: The linear movement of the release bearing is transferred to rotary movement of the release fork and the release lever which pushes the piston into the slave cylinder.

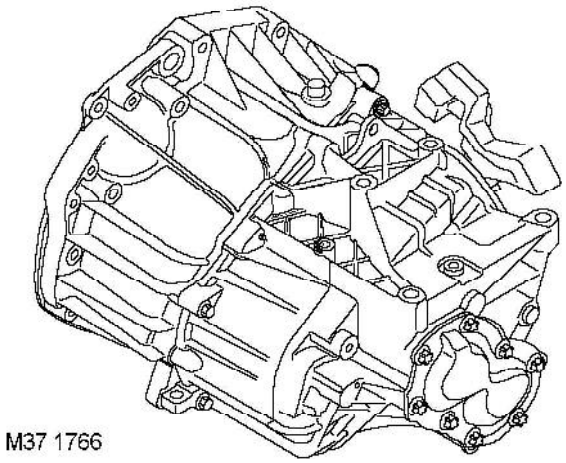
Td4 Engines: The linear movement of the release bearing pushes the piston into the slave cylinder.

All Models: The diaphragm spring pivots on its fulcrum on the clutch cover. This applies force to the pressure plate and overcomes the opposing force applied by the drive straps. The pressure plate moves towards the flywheel and applies force to the clutch driven plate.

The force applied to the clutch driven plate by the pressure plate increases the friction between the clutch driven plate and the flywheel. As the clutch pedal is released the friction increases and rotary movement of the flywheel is transferred to the clutch driven plate, which in turn rotates the primary shaft of the gearbox.

When the pedal is released fully, the force applied to the pressure plate by the diaphragm spring forces the clutch driven plate onto the flywheel with no slippage.

Getrag 5 Speed Transmission



M37 1766

Description

General
The Getrag 283 manual transmission incorporates a three shaft configuration, including a dual mass flywheel and a concentric slave cylinder, designed and manufactured in conjunction with Getrag. The gearbox is assembled in a purpose built factory in Bari, Italy.

The gearbox is of a 5 speed constant mesh type with all gears being of helical form.

Reverse gear noise quality matches the forward gear performance by including helical gearing. The dual mass flywheel is used to eliminate torsional vibration noise.

Unusual compactness is achieved by utilising the 3 shaft arrangement, this allows 1st/2nd and 5th/rev synchronisers to overlap as well as 1st and reverse gears to share components and take half the length usually required.

The Getrag 283 gearbox benefits from increased refinement for several reasons including the fact that all gears are power honed or ground after heat treatment in order to reduce distortion and optimise gear geometry achieving smooth quiet running.

To help improve the overall gear change quality, double cone synchronisers are used for 1st and 2nd gears to reduce load and improve smoothness into gear, whilst 3rd/4th and 5th employ single cone synchromesh, Reverse gear synchromesh is also specified.

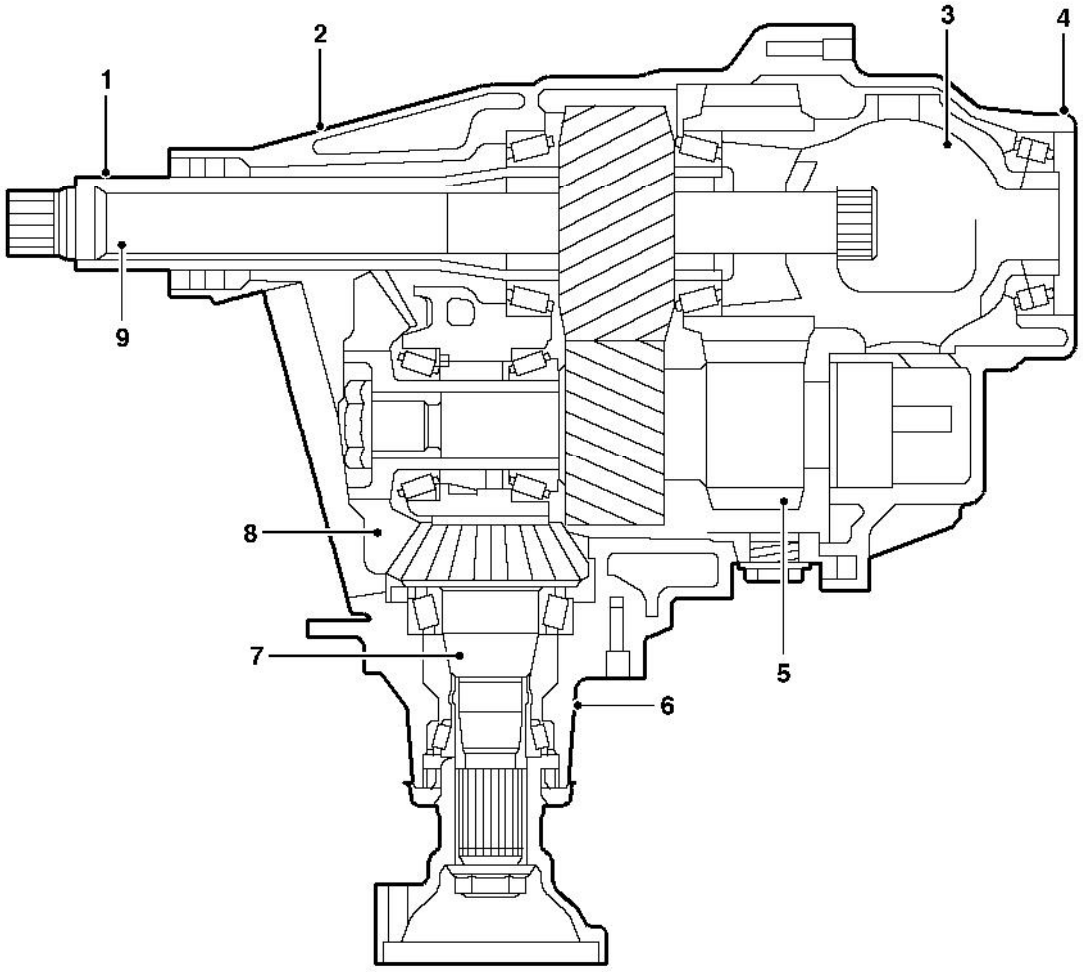
The oil used in the gearbox is MTF94 which is exceptionally stable under wide thermal extremes and has a very high service life of 100,00 miles giving it improved durability.

For the Freelander a more efficient rod type gear change is specified.

There are also switches located on first and reverse gears to electronically let the gearbox know that 'Hill Decent Control' (HDC) is enabled if engaged by the driver.

To allow the application of four wheel drive the output from the gearbox is transferred to the Intermediate Reduction Drive, (IRD) by means of a final drive carrier.

Intermediate Reduction Drive



M41 7683

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

Description

Intermediate Reduction Drive (IRD)
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.
☞ **COOLING SYSTEM - Td4, DESCRIPTION AND OPERATION, Cooling System Component Layout – Manual Gearbox, Sheet 1 of 2.**
☞ **COOLING SYSTEM - K SERIES 1.8, DESCRIPTION AND OPERATION, Cooling System Component Layout.**
☞ **COOLING SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Cooling System Component Layout - Sheet 1 of 2 (All Except NAS and Gulf States).**

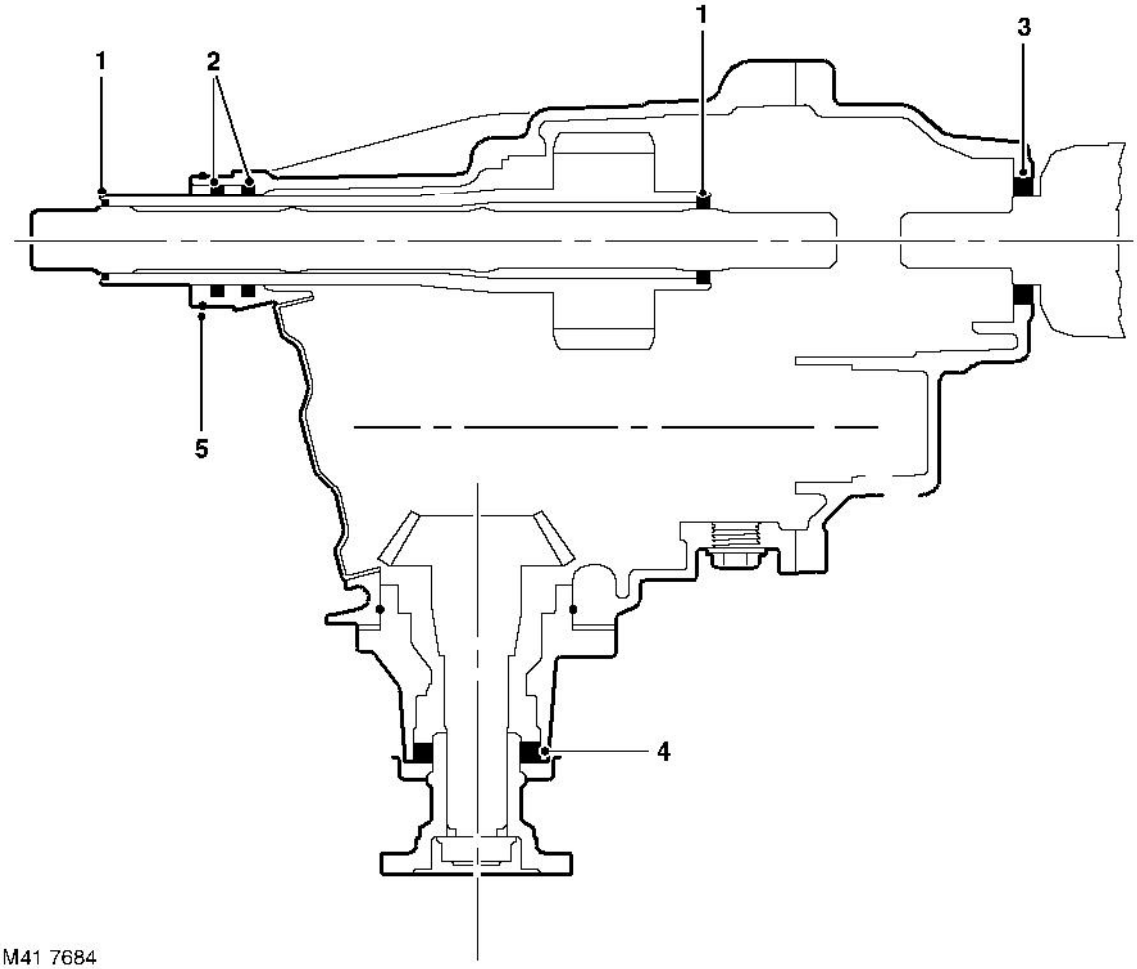
The main casing also incorporates the oil level/drain plugs and a breather outlet. There are a total of seven taper roller bearings and one parallel roller bearing supporting the primary shaft, differential and output shaft assemblies.

Four seals, internal to the IRD, are used to prevent mixing of the IRD and gearbox lubricating fluids.

Operation

Drive is transmitted from the gearbox to the IRD primary shaft via the splined hub in the gearbox final drive gear carrier. The drive is then transmitted from the primary shaft gear, which is integral with the primary shaft, to the layshaft which in turn drives the differential for the front driveshafts, and via a bevel drive gear and pinion to drive the rear axle. The intermediate shaft passes through the centre of the IRD primary shaft, and is the drive link between the IRD differential, and the left-hand front driveshaft, passing through the centre of the final drive carrier.

Oil Seals



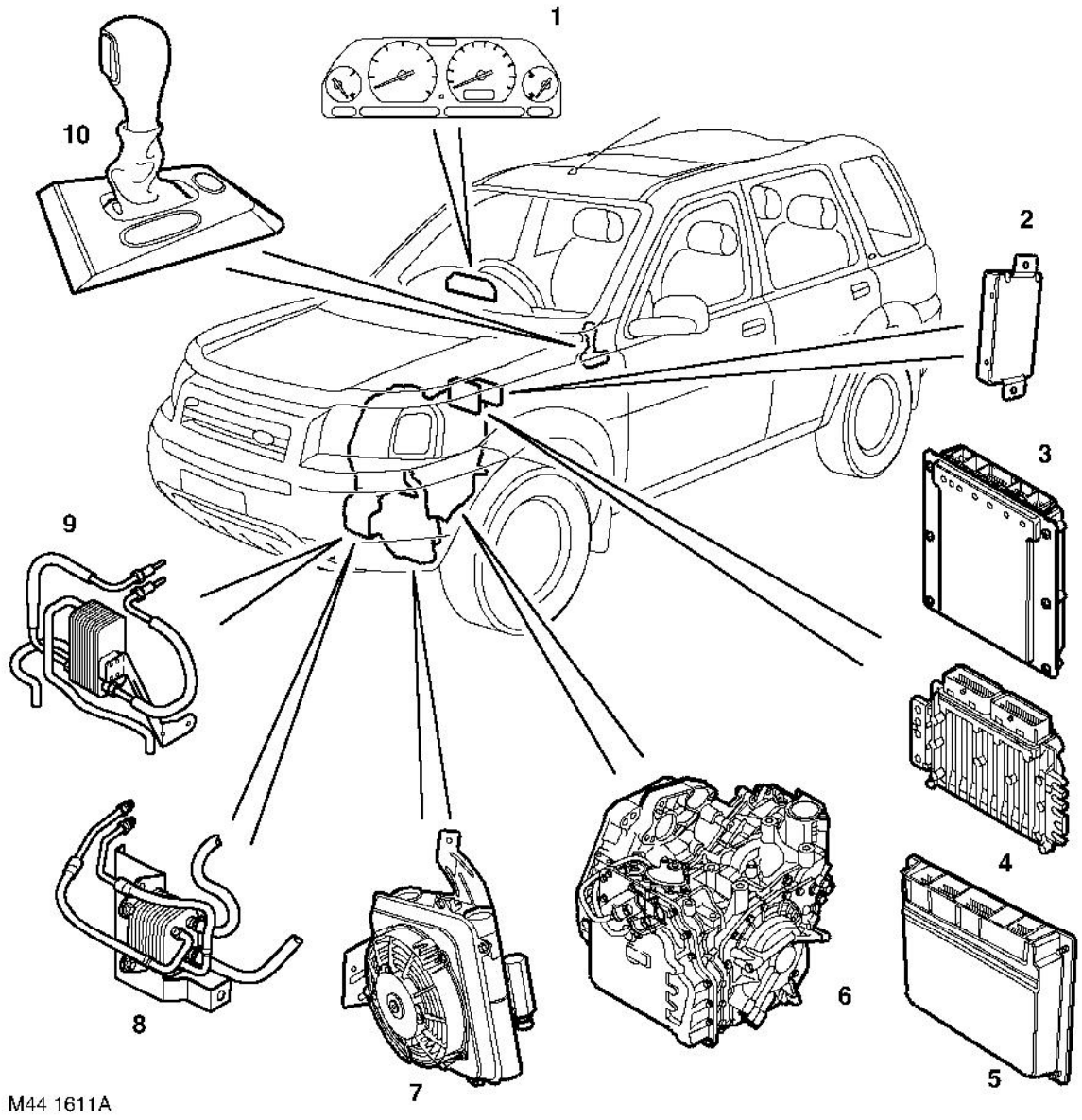
1 Primary shaft outer oil seal
2 Primary shaft inner oil seals
3 RH drive shaft oil seal
4 Pinion housing oil seal
5 'O' ring seal

Externally, three oil seals prevent lubricating oil escaping from the gearbox and the IRD unit. The gearbox gear case houses the oil seal for the left-hand front driveshaft, and the RH housing on the IRD unit houses the oil seal for the right-hand front driveshaft, with the remaining oil seal located in the pinion housing of the IRD.

There are also four internal oil seals in the IRD unit. Two smaller diameter oil seals are fitted internally at each end of the primary shaft. These prevent oil ingress along the intermediate shaft from the IRD unit at the differential end. At the opposite end, the seal prevents oil ingress from the gearbox along the intermediate shaft. Two larger oil seals are fitted in the main casing where the IRD unit enters the gearbox. The inner oil seal prevents oil ingress from the IRD primary shaft entering into the area between the two seals, and the outer oil seal prevents oil ingress from the gearbox entering the same area.

On the underside of the main casing is a 'tell-tale' drilling which is positioned between the inner and outer primary shaft oil seals. Oil leakage from the drilling will indicate either a faulty inner or outer primary shaft oil seal. An 'O' ring seal, fitted in a machined groove, seals the IRD main casing to the gearbox housing.

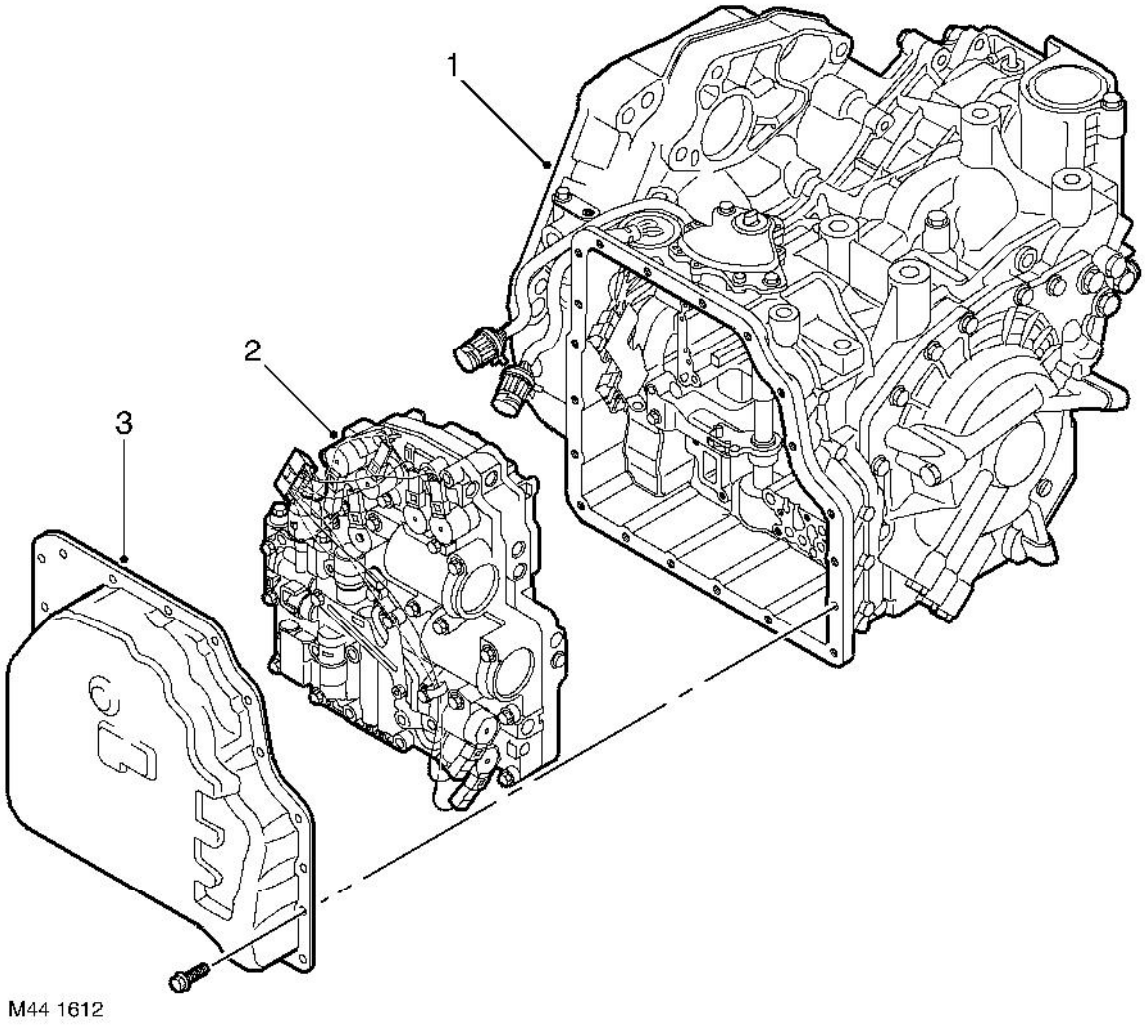
JATCO Automatic Gearbox Component Location



RHD model shown

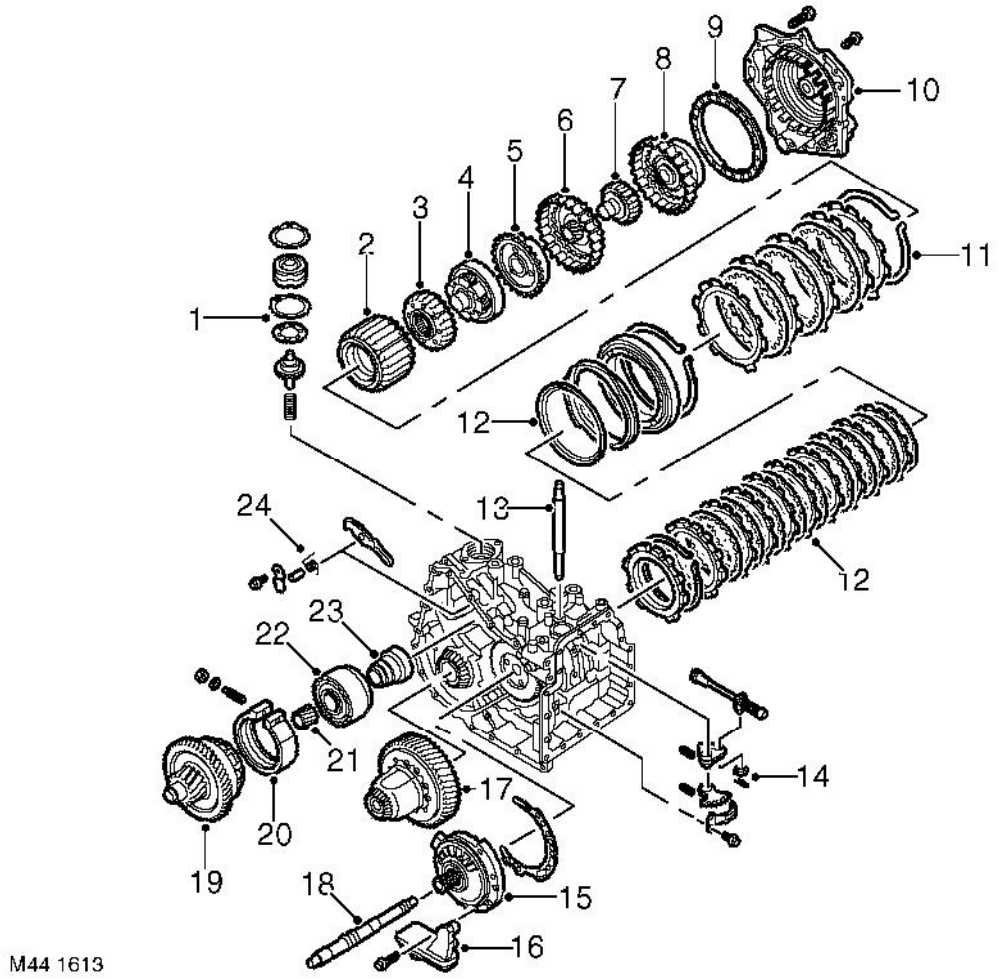
1 Instrument pack
2 Electronic Automatic Transmission (EAT) ECU
3 Engine Control Module (ECM) - Td4
4 Engine Control Module (ECM) - Non NAS KV6
5 Engine Control Module (ECM) – NAS KV6
6 JATCO Steptronic gearbox
7 Air blast fluid cooler (Td4 hot climate models)
8 Fluid cooler (KV6 models)
9 Fluid cooler (Td4 cold climate models)
10 Selector lever assembly

JATCO Automatic Gearbox



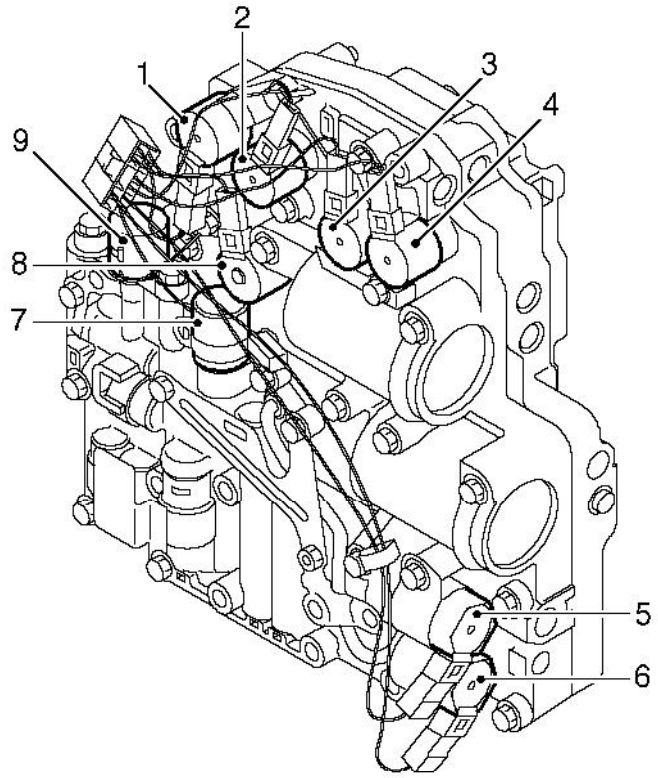
1 Gearbox
2 Solenoid valves and valve block
3 Fluid pan

JATCO Automatic Gearbox - Exploded View



1 Band servo
2 Low clutch
3 Internal gear
4 Rear planetary carrier
5 Front planetary carrier
6 Low clutch hub
7 High clutch hub
8 Reverse and high clutch assembly
9 Return spring
10 Side cover
11 2-4 brake
12 Low and reverse brake
13 Manual shaft
14 Parking component
15 Oil pump
16 Oil strainer
17 Differential gear
18 Input shaft
19 Reduction gear
20 Reduction brake band
21 Sun gear
22 Direct clutch
23 One way clutch inner race
24 Parking mechanism

JATCO Automatic Gearbox - Valve Block and Solenoid Valves



M441614

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

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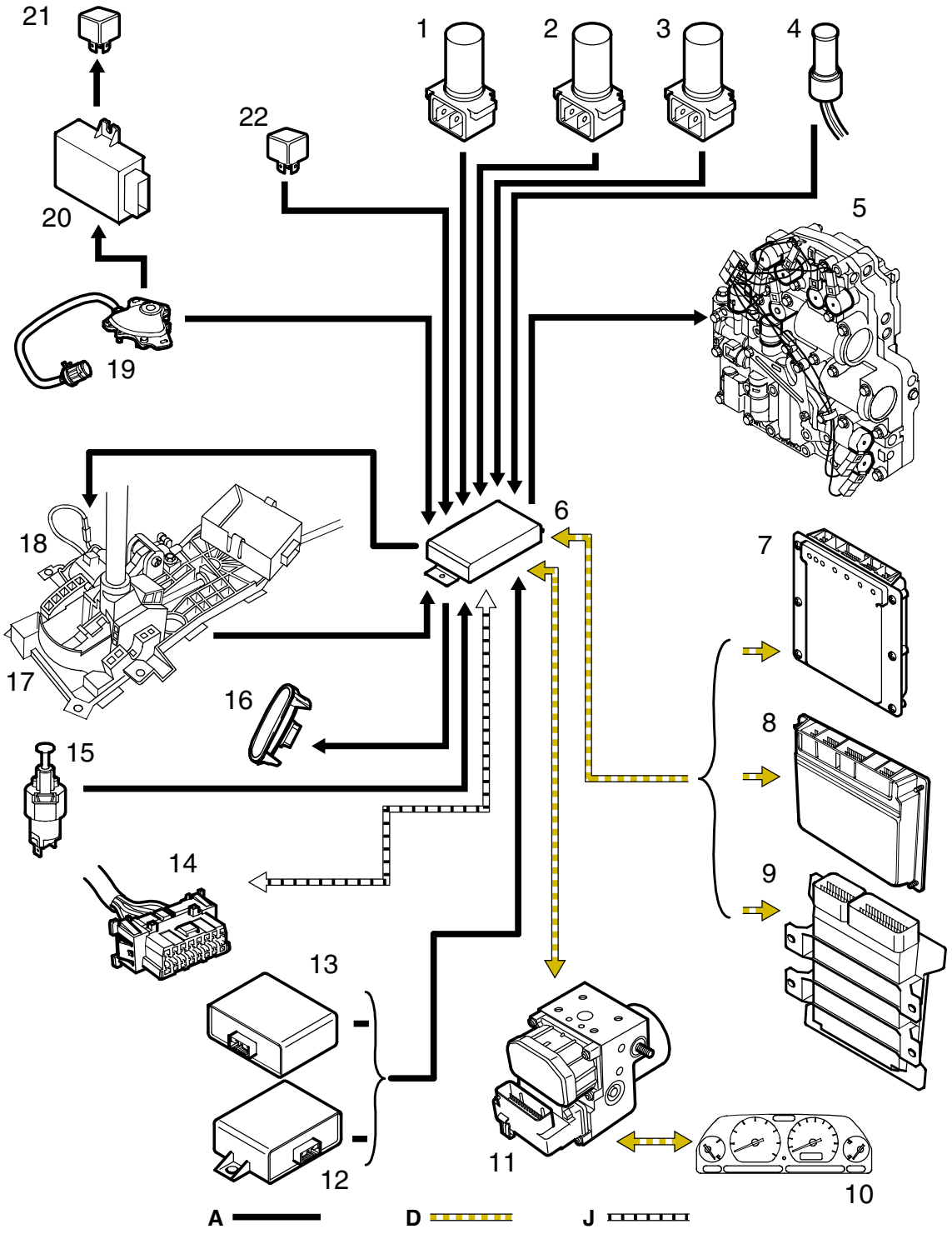
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JATCO Automatic Gearbox Control Diagram



M44 1615A

A = Hardwired; D = CAN Bus; J = Diagnostic ISO 9141 K Line

1 Intermediate speed sensor
2 Vehicle speed sensor
3 Turbine speed sensor
4 Fluid temperature sensor
5 Solenoid valves and valve block
6 EAT ECU
7 ECM – Td4
8 ECM – NAS KV6
9 ECM – Non NAS KV6
10 Instrument pack
11 ABS ECU/modulator
12 Cruise control ECU (non NAS KV6)
13 Cruise control interface ECU (Td4 and NAS KV6)
14 Diagnostic socket
15 Brake switch
16 PRND421S/M LED Module
17 Sport/manual switch
18 Shift interlock solenoid
19 Selector and inhibitor switch
20 Immobilisation ECU
21 Starter relay
22 Main relay

Description

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.

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 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 assembles. Torque is transmitted from the gearbox to the final drive through a reduction gear.

Gearbox Casing
Refer to JATCO Automatic Gearbox illustration.

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.

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	Td4
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

Refer to JATCO Automatic Gearbox - Valve Block and Solenoids illustration.

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.

Each solenoid valve is controlled separately by the EAT ECU. All nine solenoid valves can be classified into two types by their operating mode. 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.

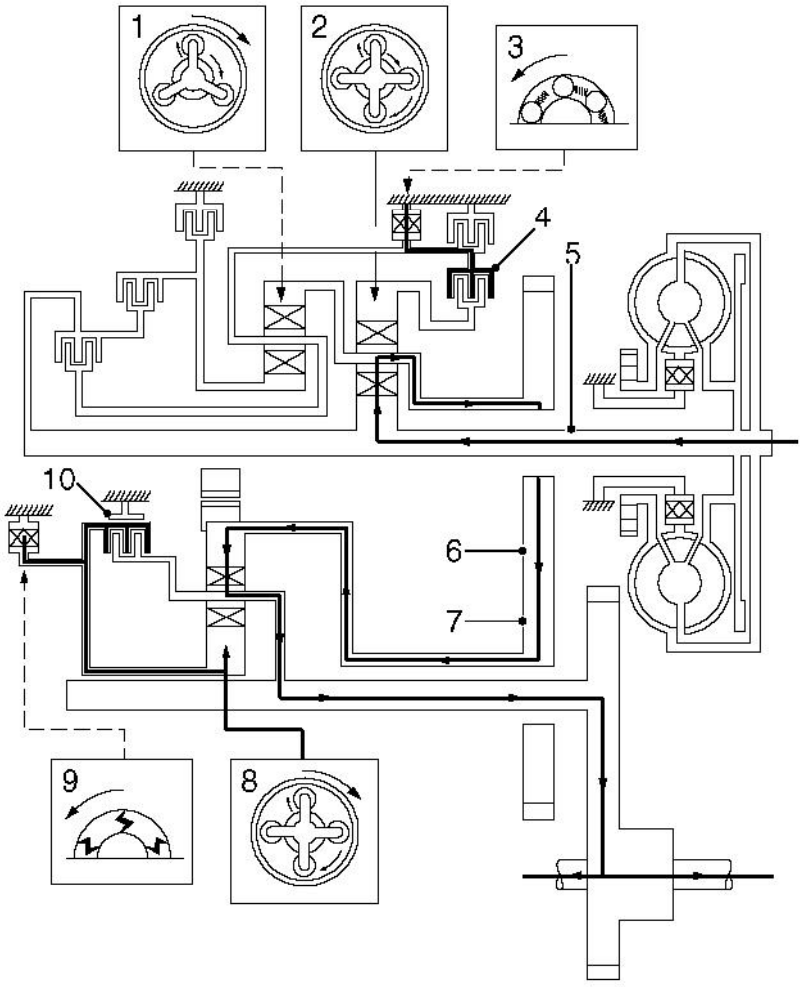
In the event of a solenoid valve failure any of the following symptoms may be observed:

- 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).

Power Flows

The following figures show the power flow in the gearbox for each forward gear and reverse.

1st Gear (D selected)

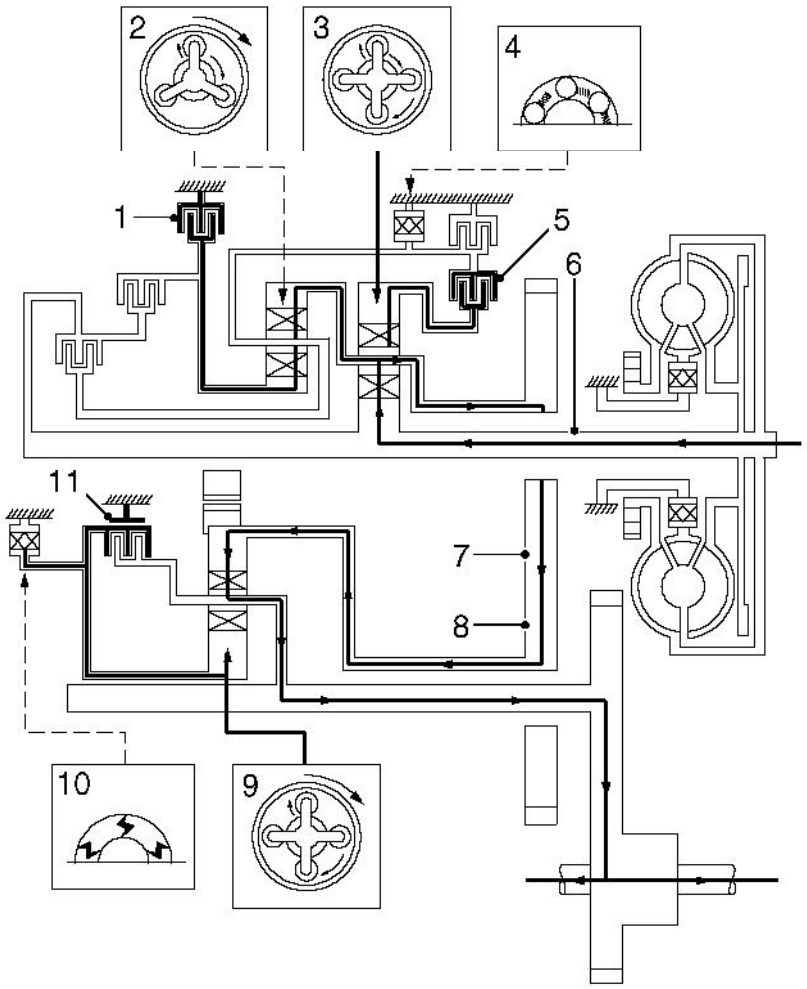


M44 1616

1 Front planetary gear
2 Rear planetary gear
3 Low one-way clutch
4 Low clutch
5 Input shaft
6 Output gear
7 Idler gear
8 Reduction planetary gear
9 Reduction one-way clutch
10 Reduction brake

On 1st gear selection, the low clutch and the reduction brake are engaged. During acceleration in 1st gear, the low one-way clutch and the reduction clutch are locked. Power flows from the input shaft to the rear sun gear to rotate it clockwise and the rear pinion gear rotates anti-clockwise. The rear internal gear tries to rotate clockwise. However, because the internal gear is connected to the low one-way clutch through the low clutch, the rear internal gear cannot rotate. Consequently, the rear planetary carrier and the output gear rotate clockwise. The output gear rotation is transmitted to the reduction internal gear by the idler gear. The reduction brake locks the reduction sun gear. The reduction gear rotates clockwise and makes the reduction planetary carrier rotate clockwise simultaneously. The reduction gear rotates clockwise and transmits the power to the final drive and out to the road wheels.

2nd Gear (D selected)

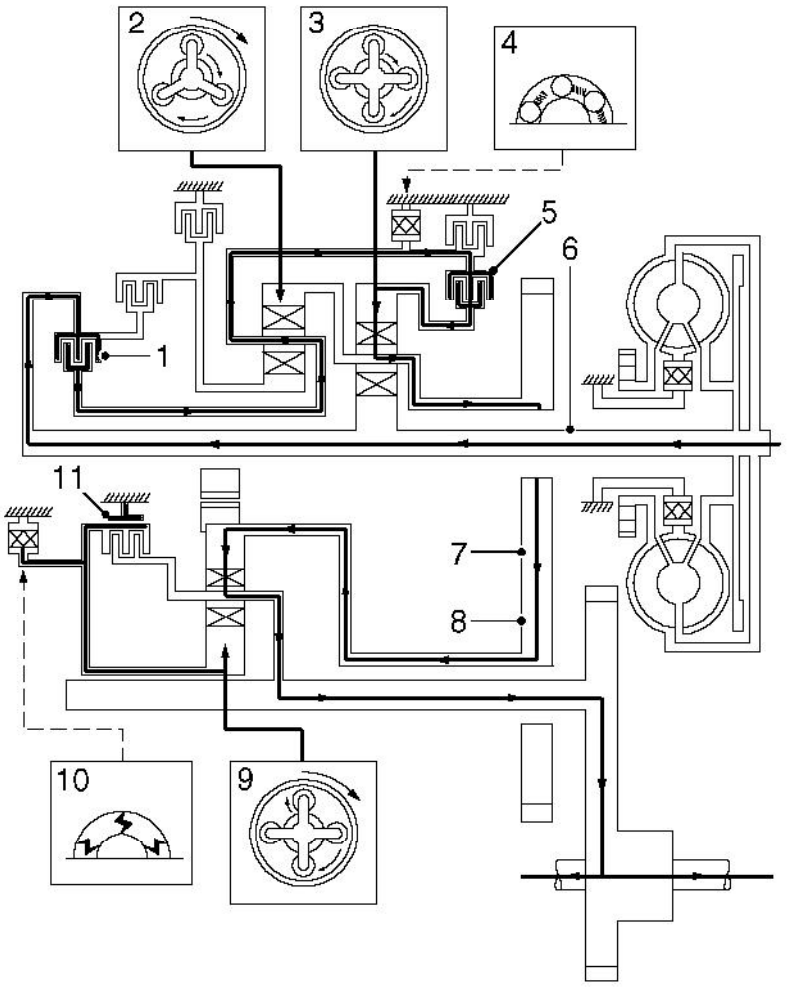


M44 1617

1 2-4 brake
2 Front planetary gear
3 Rear planetary gear
4 Low one-way clutch
5 Low clutch
6 Input shaft
7 Output gear
8 Idler gear
9 Reduction planetary gear
10 Reduction one-way clutch
11 Reduction brake

On 2nd gear selection, the low clutch, the 2-4 brake, and the reduction brake are engaged. During acceleration in 2nd gear, the reduction one-way clutch is locked. Power flows from the input shaft to the rear sun gear to rotate it clockwise and the rear pinion gear rotates anti-clockwise. The 2-4 brake locks the front sun gear. The front pinion gear rotates clockwise to force the front planetary carrier to rotate clockwise. The driven power rotates the front internal gear clockwise. The output gear rotates faster due to the front internal gear rotation. The output gear rotation is transmitted to the reduction gear. The reduction gear rotates clockwise and transmits the power to the road wheels in the same way as 1st gear.

3rd Gear (D selected)

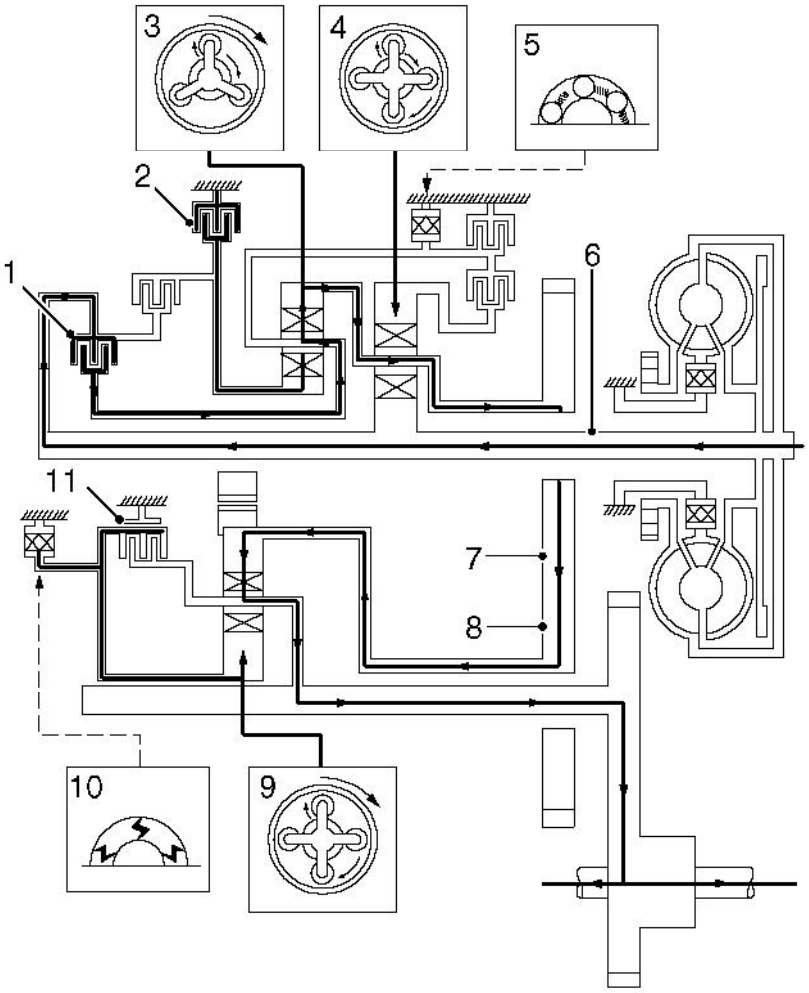


M44 1618

1 High clutch
2 Front planetary gear
3 Rear planetary gear
4 Low one-way clutch
5 Low clutch
6 Input shaft
7 Output shaft
8 Idler gear
9 Reduction planetary gear
10 Reduction one-way clutch
11 Reduction brake

On 3rd gear selection, the high clutch, the low clutch, and the reduction brake are engaged. During acceleration in 3rd gear, the reduction one-way clutch is locked. Power flows from the input shaft in a clockwise direction to the high clutch through the front planetary carrier. The front planetary carrier is connected to the rear internal gear by the low clutch. The rear internal gear rotates clockwise at the same speed as the input shaft. The rear sun gear rotates clockwise at the same speed because it is connected to the input shaft and the rear internal gear. The rear pinion does not rotate. The rear planetary carrier rotates in the same direction and speed as the input shaft. The power flow from the rear planetary carrier is transmitted to the reduction gear via the output gear, idler gear, reduction internal gear, and the reduction planetary carrier. The power is then transmitted to the road wheels in the same way as 1st gear.

4th Gear (D selected)

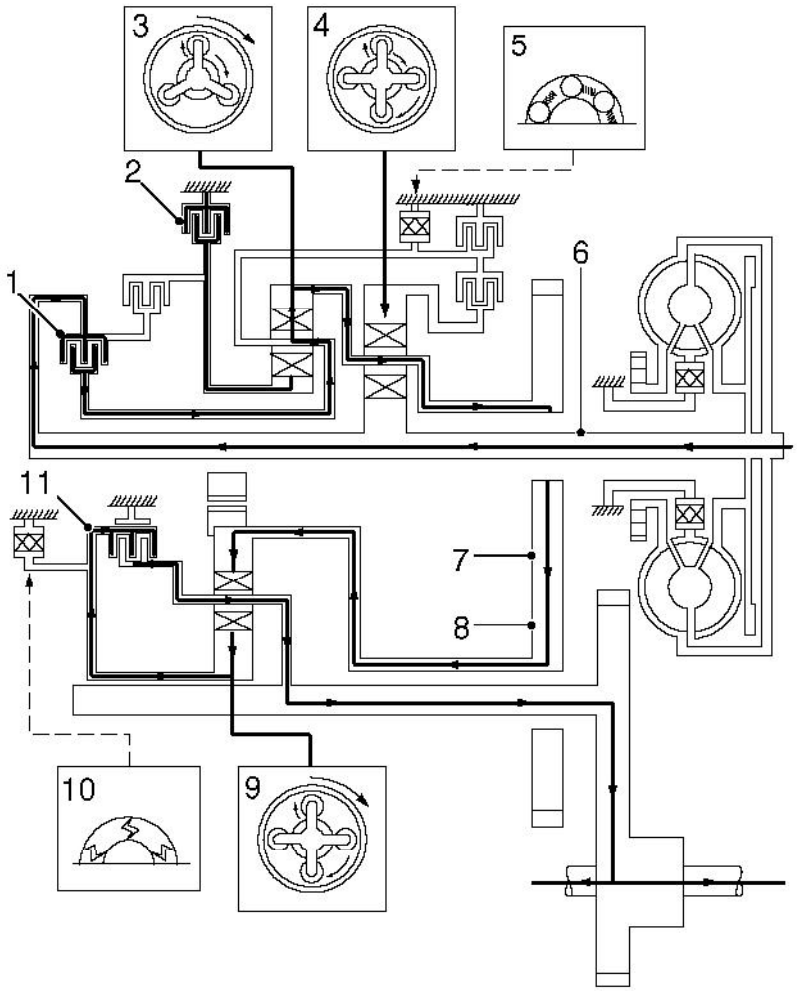


M44 1619

1 High clutch
2 2-4 brake
3 Front planetary gear
4 Rear planetary gear
5 Low one-way clutch
6 Input shaft
7 Output shaft
8 Idler gear
9 Reduction planetary gear
10 Reduction brake
11 Reduction one-way clutch

On 4th gear selection, the high clutch, 2-4 brake, and the reduction brake are engaged. During acceleration in 4th gear, the reduction one-way clutch is locked. Power flows from the input shaft to the front planetary carrier to rotate clockwise by the high clutch. The 2-4 brake locks the front sun gear. The front pinion gear rotates clockwise and forces the front planetary carrier to rotate clockwise simultaneously. This allows the front internal gear to rotate clockwise and transmit power to the reduction internal gear via the output gear and idler gear. The rotational speed of the planetary carrier is faster than 3rd gear because of the rotation of the internal gear. Power is then transmitted to the road wheels in the same way as 1st gear.

5th Gear (D selected)

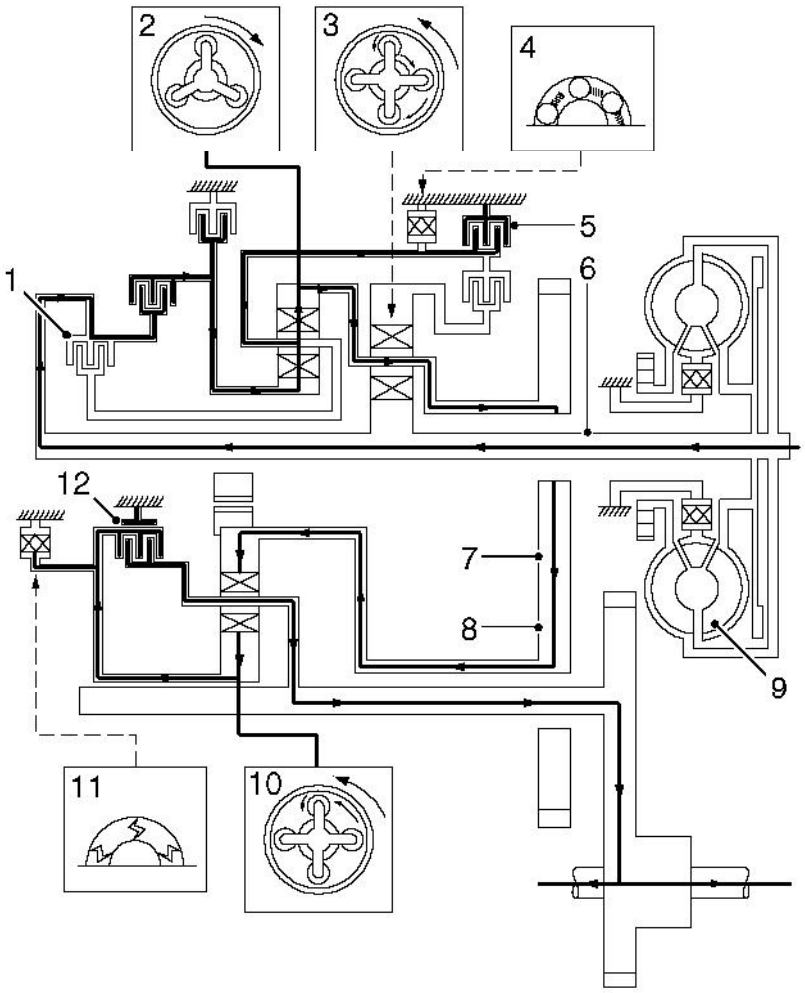


M44 1620

1 High clutch
2 2-4 brake
3 Front planetary gear
4 Rear planetary gear
5 Low one-way clutch
6 Input shaft
7 Output shaft
8 Idler gear
9 Reduction planetary gear
10 Reduction one-way clutch
11 Direct clutch

On 5th gear selection, the high clutch, direct clutch, and the 2-4 brake are engaged. Power flows from the input shaft and is transmitted to the reduction internal gear by the high clutch in the same way as in 4th gear. This power is transmitted through the reduction sun gear, final drive and direct clutch to drive the road wheels.

Reverse Gear

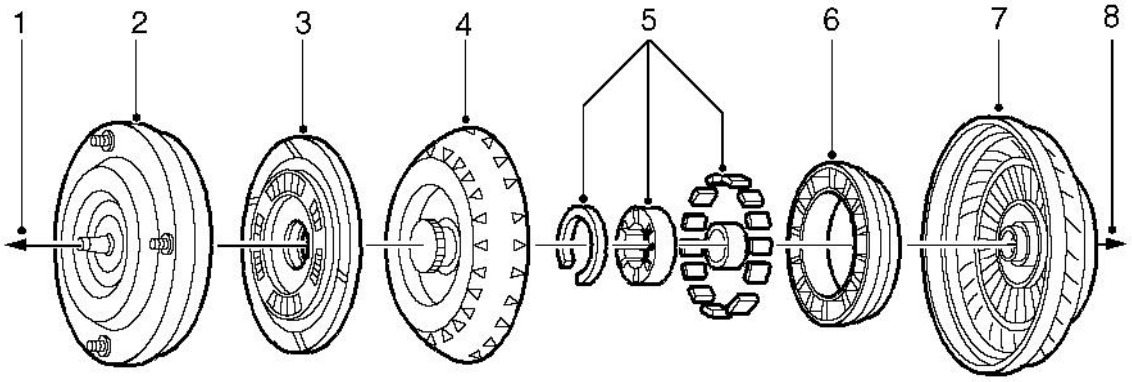


M44 1621

1 Reverse clutch
2 Front planetary gear
3 Rear planetary gear
4 Low one-way clutch
5 Low reverse brake
6 Input shaft
7 Output gear
8 Idler gear
9 Torque converter
10 Reduction planetary gear
11 Reduction one-way clutch
12 Reduction brake

On reverse gear selection, the reverse clutch, the low and reverse brake, and the reduction brake are engaged. Power flows from the input shaft to the reverse clutch and the front sun gear. The low and reverse brake is engaged, locking the front planetary carrier in position. When the front sun gear rotates clockwise, the front planetary carrier remains locked. The front pinion gears rotate anti-clockwise, forcing the internal gear and output gear to rotate anti-clockwise. The output gear rotation is transmitted to the reduction internal gear by the idler gear. The reduction brake locks the reduction sun gear, the reduction planetary carrier rotates in the reverse direction to the forward ranges and transmits drive to the road wheels through the final drive.

Torque Converter



M44 1622

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

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 most efficient angle.

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.

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.

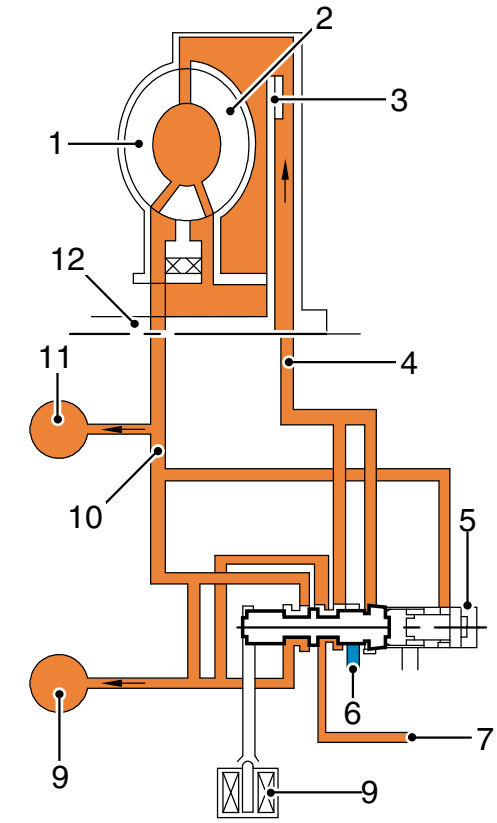
In addition to the lock and unlock conditions, the lock-up control can also initiate smooth lock-up, coast lock-up and lock-up prohibition control.

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

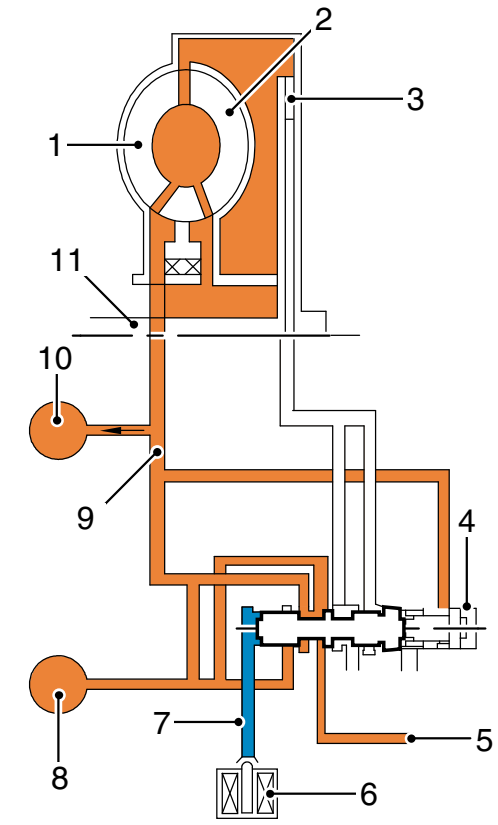


M44 1623

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

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.

Lock-Up Condition



M44 1624

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

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.

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.

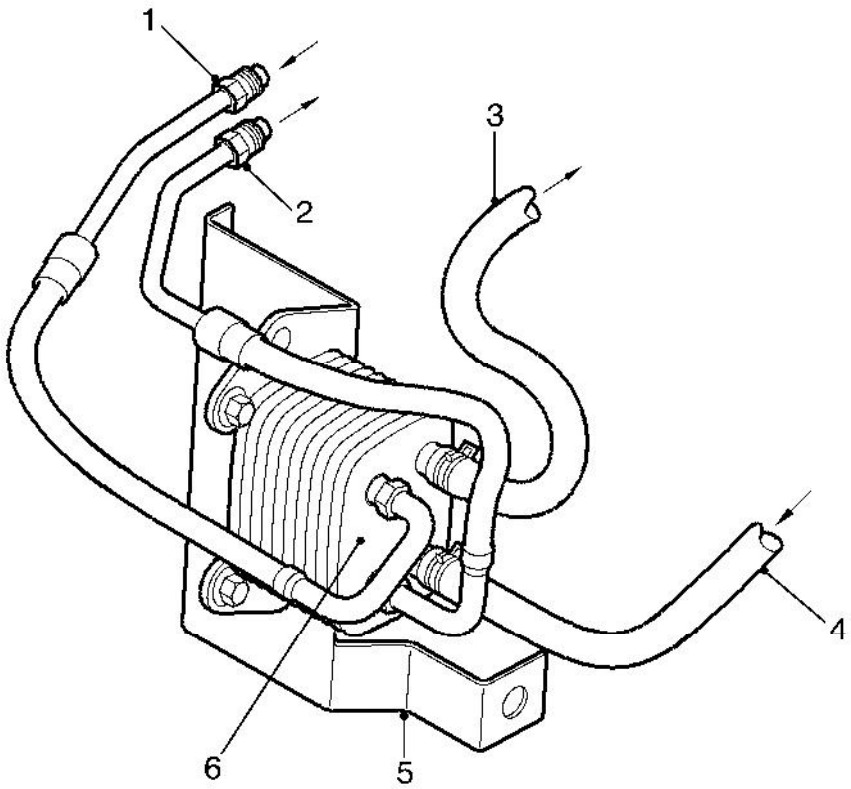
As the solenoid is operated, the pilot pressure is gradually applied to the control valve. This moves the valve, partially exposing the release pressure to a drain port.

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. On KV6 and Td4 cold climate models, a water cooled fluid cooler is located at the front of the gearbox. On Td4 hot climate models an air blast cooler, which replaces the water cooled cooler is located in the front LH wheel arch.

Fluid Cooler KV6



Cooler from all except NAS and Gulf States models shown; cooler for NAS and Gulf States models similar

1 Gearbox fluid feed pipe
2 Gearbox fluid return pipe
3 Engine coolant feed hose
4 Engine coolant return hose
5 Mounting bracket
6 Fluid cooler

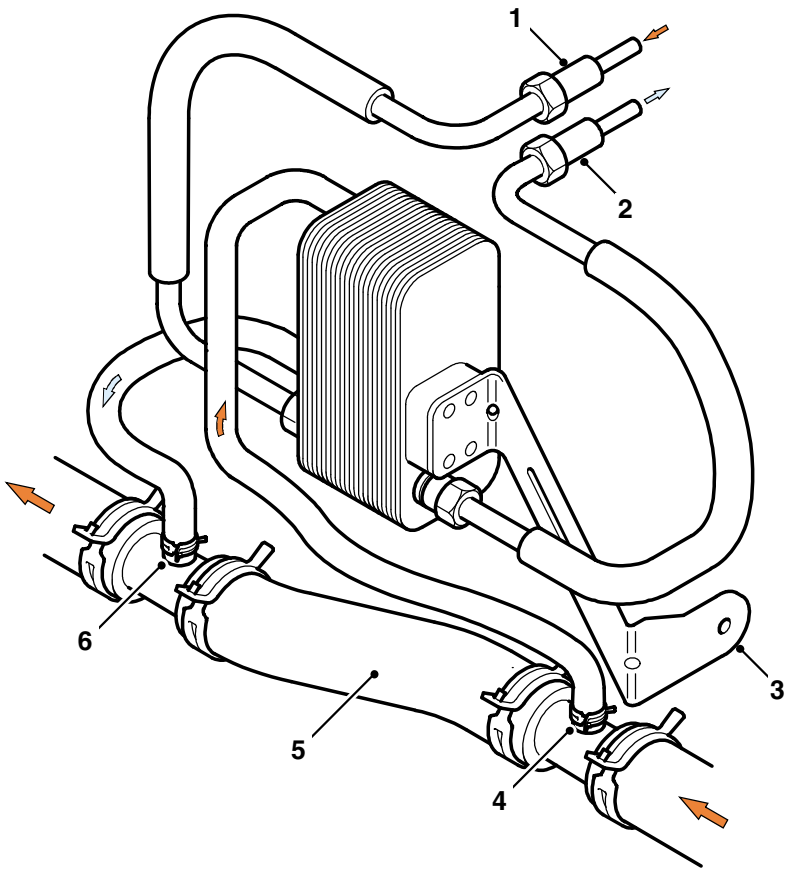
The fluid cooler is located on a bracket at the front of the gearbox. The cooler comprises cores which allow fluid to flow across from one side of the cooler to the other. Each core is surrounded by a water jacket which allows engine coolant to flow around the cooler.

The cooler is connected to the gearbox by metal pipes and flexible hoses, and to the engine cooling system by 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 (on all except NAS and Gulf States models), or the cylinder block (on NAS and Gulf States models), to the lower coolant connection on the fluid cooler. The coolant exits the cooler via the upper connection and flows to the thermostat housing.

Fluid Cooler Td4 (Cold Climates)



M44 1675

1 Gearbox fluid feed pipe
2 Gearbox fluid return pipe
3 Mounting bracket
4 Engine coolant feed hose
5 Radiator bottom hose
6 Engine coolant return hose

The fluid cooler is located on a bracket at the front of the gearbox and is similar in design to the KV6 fluid cooler. The Td4 cooler has a larger capacity than the KV6 cooler for additional cooling required with the diesel engine and is mounted on a different design of bracket.

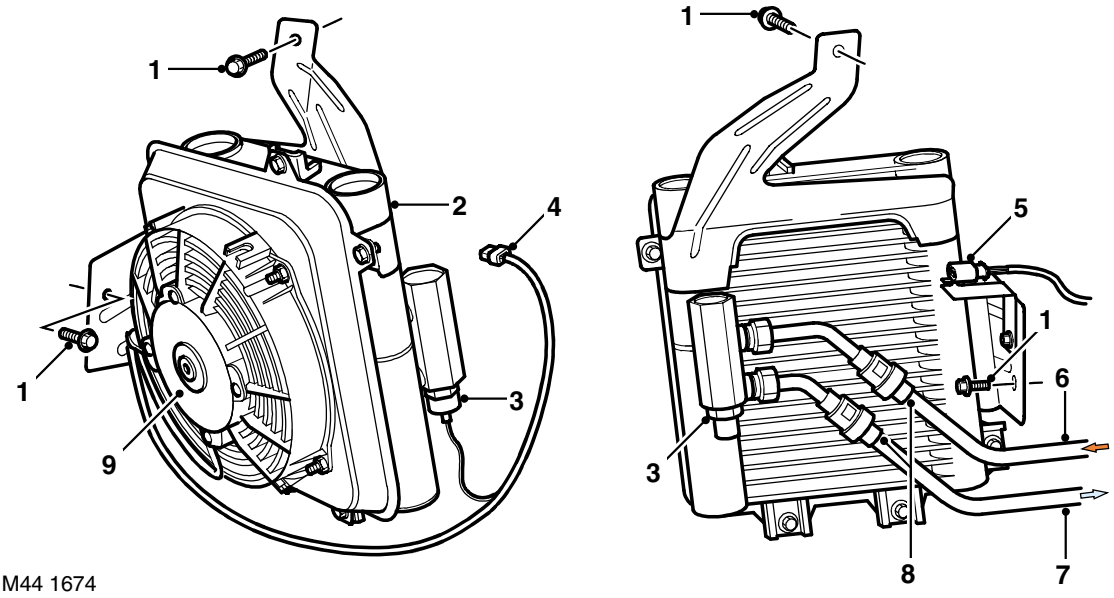
The cooler comprises cores which allow fluid to flow across from one side of the cooler to the other. Each core is surrounded by a water jacket which allows engine coolant to flow around the cooler.

The cooler receives its coolant supply from the radiator bottom hose. The radiator bottom hose has two smaller hoses connected to it which in turn are connected to the cooler. Between the two smaller hoses, in the radiator bottom hose, is a spring loaded valve. The valve opens and closes with changes in coolant pressure, diverting coolant from the bottom hose, through the cooler via the upper hose connection. The coolant exits the cooler through the lower connection and flows back into the bottom hose, downstream of the spring loaded valve.

The cooler is connected to the gearbox by metal pipes and flexible hoses. The gearbox fluid flows from the gearbox to the RH 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 LH 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.

Air Blast Fluid Cooler Td4 (hot climates)



M44 1674

1 Mounting bolt (3 off)
2 Air blast cooler
3 Temperature sensor
4 Sensor and fan connector
5 Harness connector
6 Gearbox fluid feed pipe
7 Gearbox fluid return pipe
8 Quick release connections
9 Electric fan

The air blast cooler is located on the front LH wheel arch in place of the Fuel Burning Heater (FBH) and is fitted to models for climates of 50°C (122°F).

The air blast cooler is a cross flow type cooler with end tanks at either side. A boss on the outer tank houses a temperature sensor which controls the operation of an electric cooling fan attached to the forward face of the cooler. The boss also provides for the gearbox fluid feed and return connections.

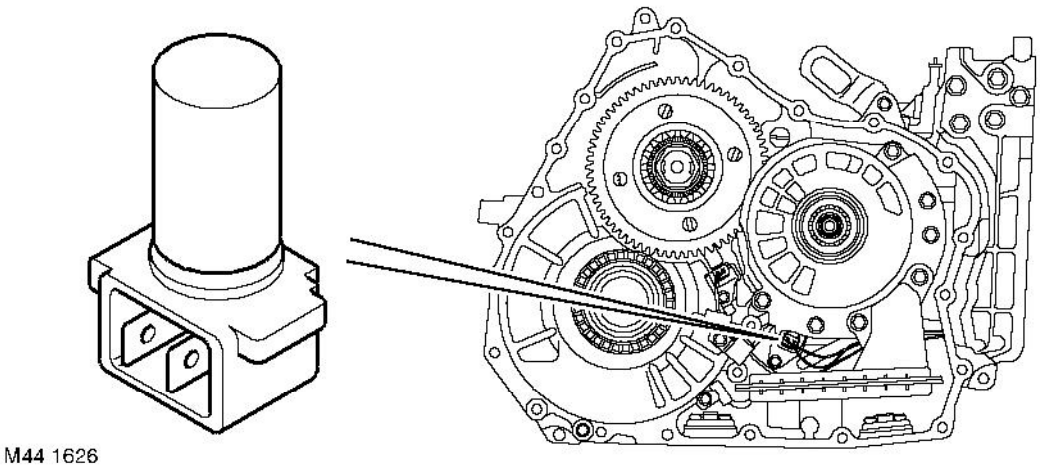
The front bumper on these models is modified to allow for the additional air flow required to pass through the cooler matrix. An aperture in the front LH corner of the bumper allows intake air to flow to the cooler. The air flow is directed by a duct at the rear of the bumper into the cooler matrix. The LH wheel arch liner on these models has louvres to aid the air flow through the matrix.

The electric fan is connected to the temperature sensor which in turn is connected to the harness multiplug used for the FBH in other markets. The power supply is permanent allowing the fan to operate after the ignition is switched off. The sensor activates the fan when gearbox fluid temperature in the cooler reaches approximately 100°C (212°F).

The air blast cooler is connected to the gearbox with metal pipes and flexible hoses. Two quick release couplings are provided to ease cooler removal. The cooler and associated pipes require an additional 0.7 litre of automatic transmission fluid.

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



M44 1626

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 5 or 12 volts
- Short circuit to earth.

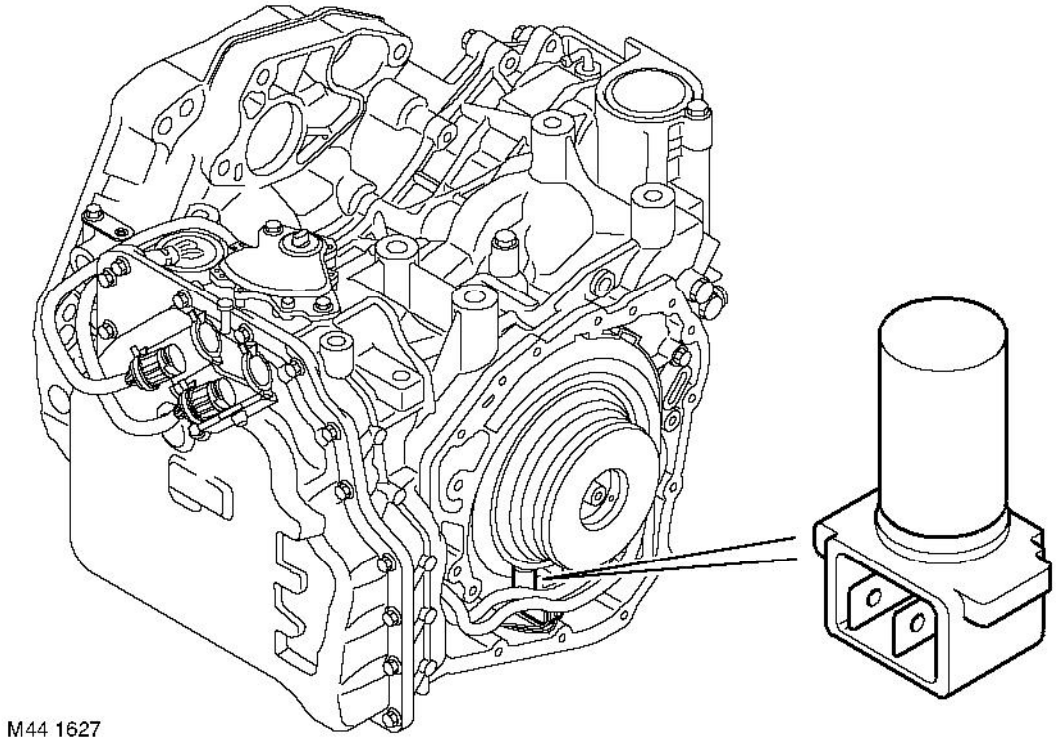
The EAT ECU will detect sensor failure if the vehicle speed exceeds 25 mph (40 km/h) and the sensor output is equivalent to less than 600 rev/min for two seconds.

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/T4 or any Keyword 2000 diagnostic tool.

Turbine Speed Sensor



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.

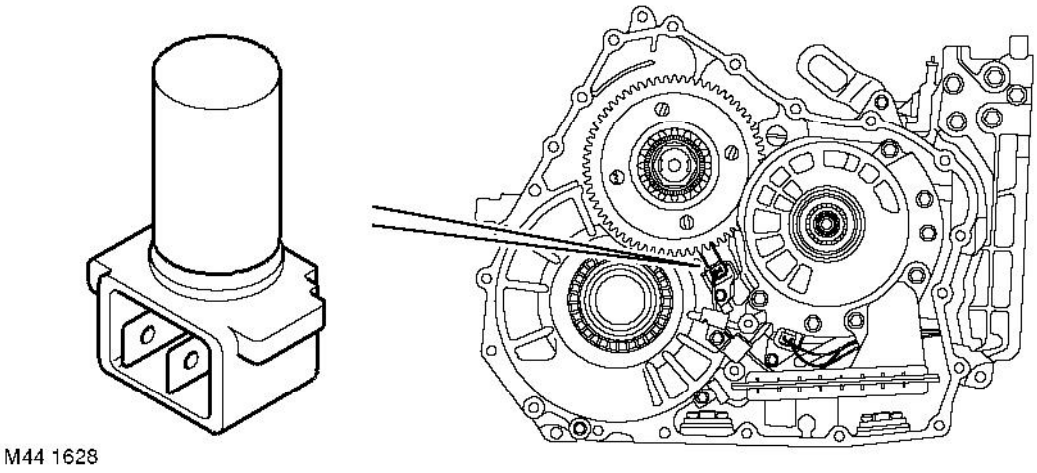
The EAT ECU will detect sensor failure if the vehicle speed exceeds 25 mph (40 km/h) and the engine speed is above 1300 rev/min, but the turbine speed is below 600 rev/min for two seconds.

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/T4 or any Keyword 2000 diagnostic tool.

Vehicle Speed Sensor



M44 1628

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.

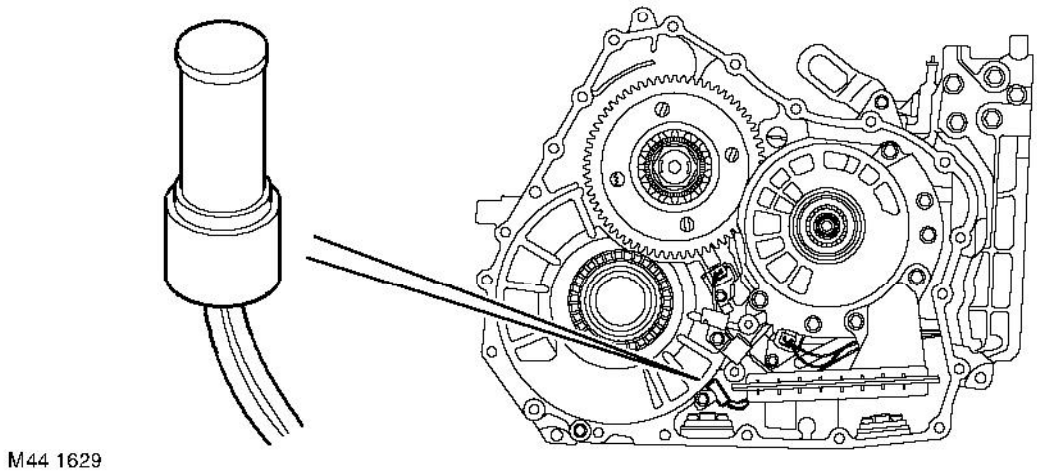
In the event of a vehicle speed sensor signal failure any of the following symptoms may be observed:

- 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



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 kΩ
-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

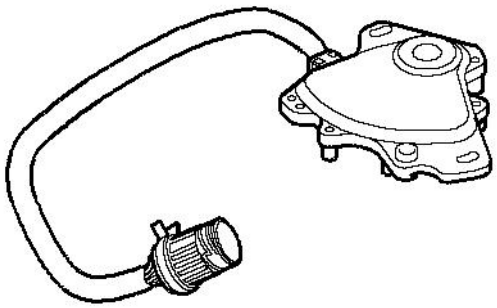
The fluid temperature sensor can fail in the following ways:

- 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



M44 1630

The selector and inhibitor switch is located on the selector shaft on top of the gearbox and connected to the main harness by a 10 pin connector (C0244).

While the ignition is on, the selector and inhibitor switch receives a battery voltage power feed from the main relay. In some markets, in order to illuminate the LED module whenever the key is in the ignition switch, the selector and inhibitor switch also receives a battery voltage power feed from an illumination relay installed behind the centre console.

Where fitted, operation of the illumination relay is controlled by the passive coil on the ignition switch. When the key is installed in the ignition switch the illumination relay energises to connect the power feed to the selector and inhibitor switch. When the main relay is energised by the ECM, the illumination relay de-energises and the power feed to the selector and inhibitor switch is taken from the main relay.

The EAT ECU and the LED module are provided with a voltage output from the selector and inhibitor switch that corresponds with the gear position the driver has selected. 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 and the LED module at any one time. The EAT ECU monitors the switch outputs 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:

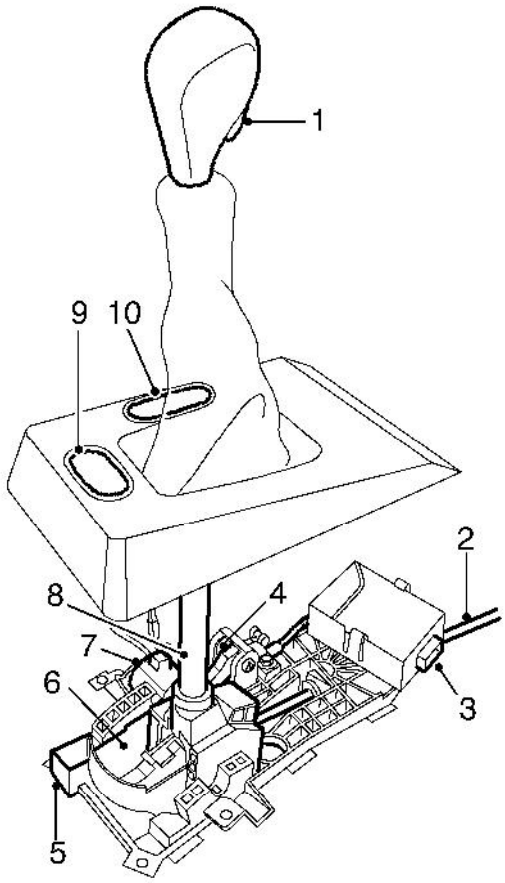
- Upshift to 5th gear inoperative
- Torque converter lock-up inoperative
- Torque reduction request from the EAT ECU to the ECM inoperative
- Cranking disabled if fault is on the two inhibitor switch contacts.

Gear Selector Lever 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.



M44 1799

1 Park/Reverse release button
2 Selector cable
3 Mirror fold ECU or ICE remote control interface unit (if fitted - reference only)
4 Key interlock mechanism (selected markets only)
5 Sport/manual switch connector
6 Sport/manual switch
7 Shift interlock solenoid
8 Selector lever
9 HDC switch
10 LED Module

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.

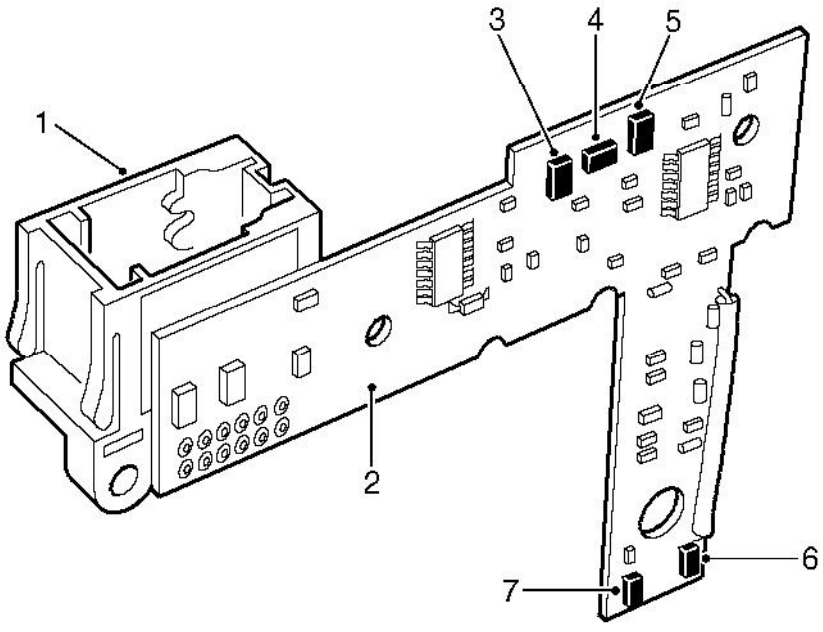
The selector lever position is displayed to the driver on the LED module in the centre console and in the instrument pack and corresponds with the position of the selector lever. The LED module illumination and instrument pack display is determined by the selector and inhibitor switch assembly on the 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, when the ignition switch is in position II, prevents the lever being moved from Park unless the foot brake is applied.

In some markets, the gear selector lever also incorporates a key interlock mechanism, operated by the selector lever and a Bowden cable connected to the ignition key barrel. The mechanism prevents the ignition key being removed from the barrel unless the selector lever is in the Park position. The mechanism also prevents the selector lever moving from the Park position until the ignition switch has turned from position 0 to position I or above.

☞ **STEERING, DESCRIPTION AND OPERATION, Description.**

Sport/Manual Switch



M44 1637

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. When the ignition switch is in position II, with the selector lever in the Park position, the EAT ECU supplies a power feed to the shift interlock solenoid. The shift interlock solenoid energises and extends a pin into the selector lever, locking the lever in Park.

While the selector lever is in Park, when the EAT ECU senses the brake pedal being pressed, it de-energises the shift interlock solenoid and the solenoid pin retracts, allowing the selector lever to be moved. When the selector lever is in any position other than Park, the shift interlock solenoid remains de-energised after the brake pedal is released, and the lever is free to be moved through the remainder of the range.

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 gear lever position 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.

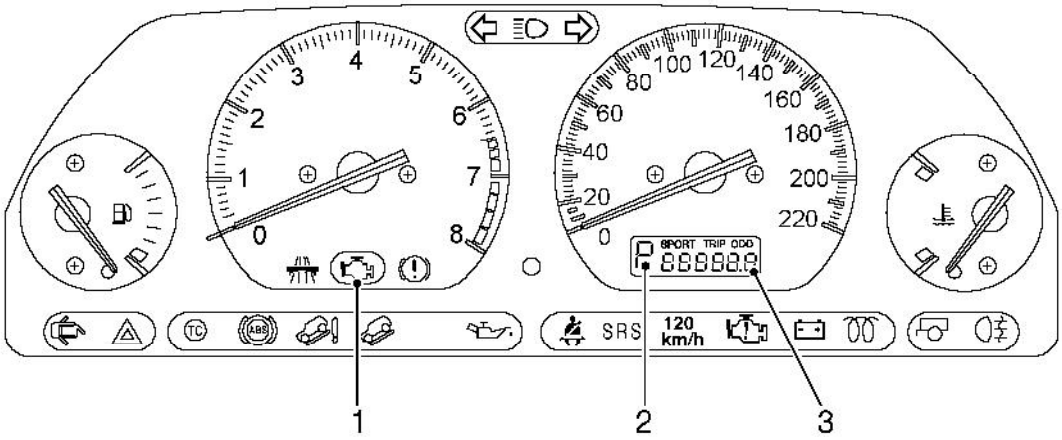
The brake switch can fail in the following ways:

- 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 the 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

1 MIL (SERVICE ENGINE SOON on NAS models)
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 an amber warning lamp located in the instrument pack. On all except NAS models, the warning lamp shows an engine silhouette. On NAS models the warning lamp shows a SERVICE ENGINE SOON legend. 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)

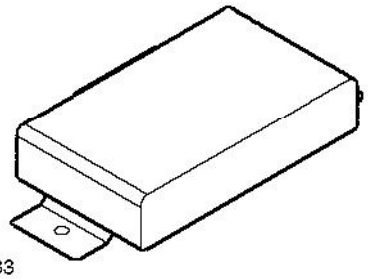
The LCD is located in a central position in the instrument pack. In addition to displaying the odometer and trip meter, the LCD also displays the current gearbox status. The following table shows the characters displayed and their definition.

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 (EAT) ECU


M44 1633

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/T4. 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 driveability and performance.

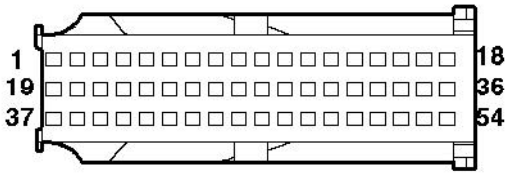
The inputs from the sensors constantly updates the EAT ECU with the current operating condition of both the gearbox and the engine. The ECU compares this current information with mapped information stored within its memory. The ECU will make any required adjustment to the operation of the gearbox through 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

The following table shows the harness connector face view and pin numbers and input/output information.

Pin No.	Description	Input/Output
1	Diagnostic ISO 9141 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 - Low 2	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 High 2	Input/Output
35	Not used	-
36	12V battery voltage from main relay	Input
37	Selector shift down (-) sensor	Input

Pin No.	Description	Input/Output
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
49	Cruise control engaged signal	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

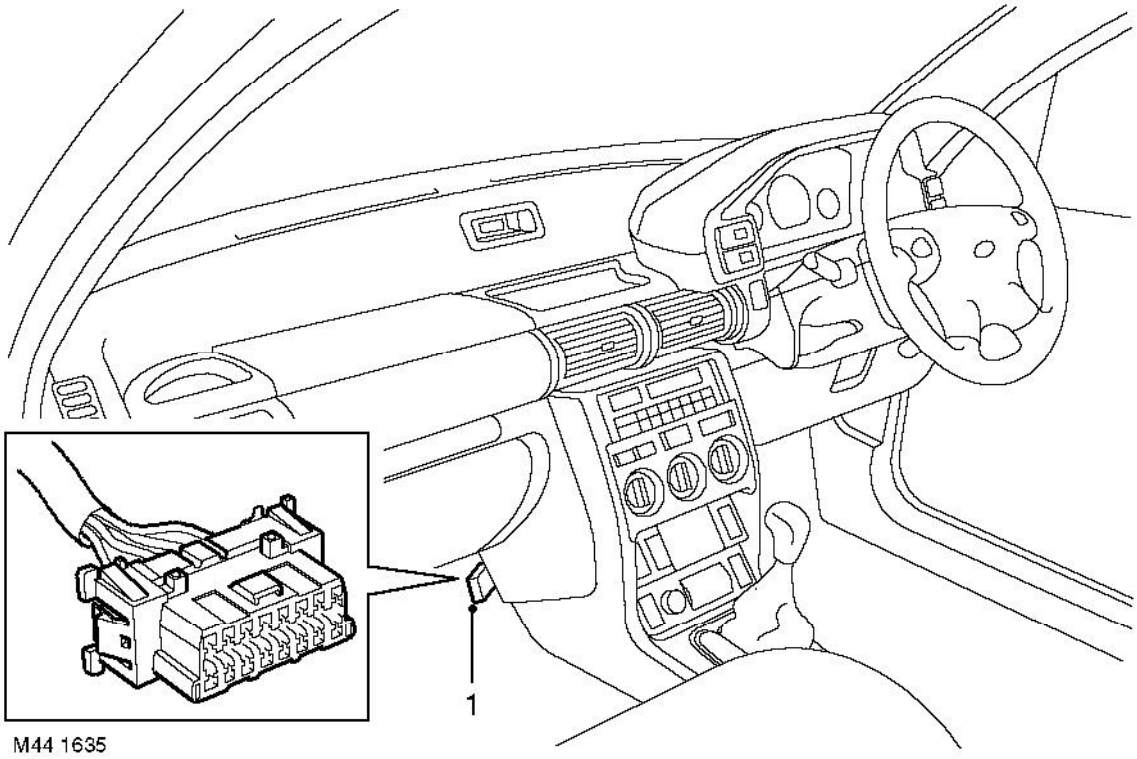
The main relay is located in the engine compartment fusebox and supplies battery voltage to the EAT ECU, in addition to other vehicle components. The main relay is energised by the ECM when the ignition is switched on.

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/T4. The diagnostic socket is located behind the centre console, in the passenger footwell.



1 Diagnostic socket

The diagnostic socket is connected to the EAT ECU on an ISO 9141 K Line. The system uses a 'P' code diagnostic strategy and can record faults relating to gearbox operation. The codes can be retrieved using TestBook/T4 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
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

P Code	Component	Description
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

Controller Area Network (CAN) Bus

The CAN bus is a high speed broadcast network between the ECM, instrument pack, ABS ECU and the EAT ECU allowing fast exchange of data between the ECU's every few microseconds.

The bus comprises two wires which are identified as CAN low (L) and CAN high (H). The wires are twisted together to minimise the electromagnetic interference (noise) produced by the CAN messages.

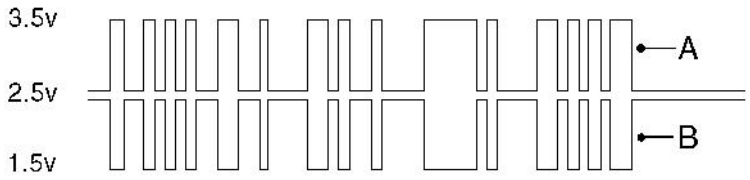
To prevent message errors from electrical reflections, 120Ω resistors are incorporated into the CAN wire terminals of the ECM, instrument pack, ABS ECU and the EAT ECU.

CAN messages consist of a signal which is simultaneously transmitted, in opposite phase, on both wires. CAN L switches between 2.5 and 1.5 volts, while CAN H switches between 2.5 and 3.5 volts. This causes a potential difference between the two lines to switch between 0 volt (logic 1) and 2 volts (logic 0) to produce the digital signal message.

In the event of a CAN bus failure any of the following symptoms may be observed:

- Transmission defaults to 4th gear
- Torque converter lock-up control is disabled
- Transmission of torque reduction message to the ECM is inhibited.

CAN Bus Switching



M44 1636

EAT ECU CAN Messages

The following table lists CAN message inputs and outputs from and to the EAT ECU.

Inputs	Outputs
Actual engine torque	Cooling request
Engine coolant temperature	Current/Target gear
Engine friction	Gear selector lever position
Engine speed	Gear shift in progress
Engine speed signal error	Gearbox fault status
Engine torque error	Torque reduction request
Ignition switch status	Gearbox MIL Status
Actual engine torque	Gear shift mode
Estimated engine torque	
Throttle angle (driver demand)	
Torque reduction status	
Engine MIL status	
Hill descent activity status	
Virtual throttle position (diesel only)	

CAN Inputs

- *Actual engine torque.* This message from the ECM indicates the actual engine torque produced at any one time. The EAT ECU uses this message to control gear shift scheduling.
- *Engine coolant temperature.* This message from the ECM is used by the EAT ECU for OBD diagnostic functions and to detect when the engine has completed a 'warm up' cycle.
- *Engine friction.* This message from the ECM is the current frictional torque losses within the engine and is expressed as a percentage of maximum engine torque. The EAT ECU uses this message to control gear shift scheduling.
- *Engine speed.* This message from the ECM is used by the EAT ECU to calculate gearbox oil pressure to assist control of gear shift scheduling.
- *Engine speed signal error.* This message from the ECM informs the EAT ECU if there is a fault with the engine speed calculation. If necessary, the EAT ECU then adjusts gearbox operation to prevent possibility of mechanical damage.
- *Engine torque error.* This message from the ECM informs the EAT ECU that torque values received are incorrect and there is an ECM torque measurement error.
- *Estimated engine torque* This message from the ECM informs the EAT ECU of the level of torque that the engine is producing. The EAT ECU uses this message to control gearshift scheduling.
- *Ignition switch status.* This message from the ECM is produced when the ECM energises the main relay. The EAT ECU uses this message to initiate the power-down routine at ignition off.
- *Actual engine torque.* This message from the ECM is the theoretical engine torque for current throttle setting and engine operating conditions. This is the same as the actual engine torque unless torque reduction in progress and is expressed as a percentage of maximum engine torque. The EAT ECU uses this message to control gear shift scheduling.
- *Throttle angle.* This message from the ECM informs the EAT ECU of the throttle angle (driver demand). The EAT ECU uses this message to control gear shift scheduling.

- *Torque reduction status.* This message from the ECM informs the EAT ECU of the success of a torque reduction request.
- *Engine MIL status.* This message from the ECM indicates to the EAT ECU that the MIL has been illuminated by the ECM. The EAT ECU will disable OBD fault monitoring.
- *Hill descent activity status.* This message from the ABS ECU informs the EAT ECU that HDC has been requested. Providing the selector lever is in position 1 or R, the EAT ECU enters HDC mode and assists the ABS with engine braking.
- *Virtual throttle position (diesel only).* This message from the ECM informs the EAT ECU of a virtual throttle position when cruise control is enabled and operative. The message is compiled from a combination of main throttle and secondary throttle inputs.

CAN Outputs

- *Cooling request.* Request for additional cooling of the transmission fluid. The ECM switches on, or increases the speed of the cooling and, if fitted, condenser fans.
- *Current/Target gear.* Informs the ECM what gear is currently engaged or, if a gear shift is in progress, the gear to which the gearbox is shifting. Used by the ECM for engine load change prediction.
- *Gear selector lever position.* The EAT ECU transmits a signal to the ECM of the gear selector lever position selected by the driver. The ECM outputs a CAN message to the instrument pack to display the selection in the LCD
- *Gear shift in progress.* Informs the ECM when a gear shift is in progress. Used at idle speed to compensate for engine load changes during the gear shift.
- *Gearbox fault status.* The EAT ECU uses this signal to display the status of the EAT ECU. If a gearbox fault occurs, the EAT ECU will generate this message to alternately display 'F' and '4' in the instrument pack LCD and initiate the default strategy for the gearbox.
- *Torque reduction request.* Requests the ECM to reduce engine torque for a gear shift (equivalent to lifting off the throttle in manual gearbox models). Amount of torque reduction required expressed as a percentage of maximum engine torque.
- *Gearbox MIL status.* The EAT ECU transmits a signal to the ECM that there is a gearbox fault which will increase emissions above an acceptable level. The ECM outputs a message to the instrument pack which illuminates the MIL.
- *Gear shift mode.* This signal is used to display the currently selected gearshift mode, drive, sport or manual, in the instrument pack LCD. This signal is originated from the EAT ECU.

Operation

General
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.

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 then 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 back 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 to assist the 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 (non NAS KV6 models) or interface unit (Td4 and NAS KV6 models). In cruise mode the EAT ECU uses a dedicated gearshift map to control the gearbox and assist in maintaining the set 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 driveability 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/T4 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.

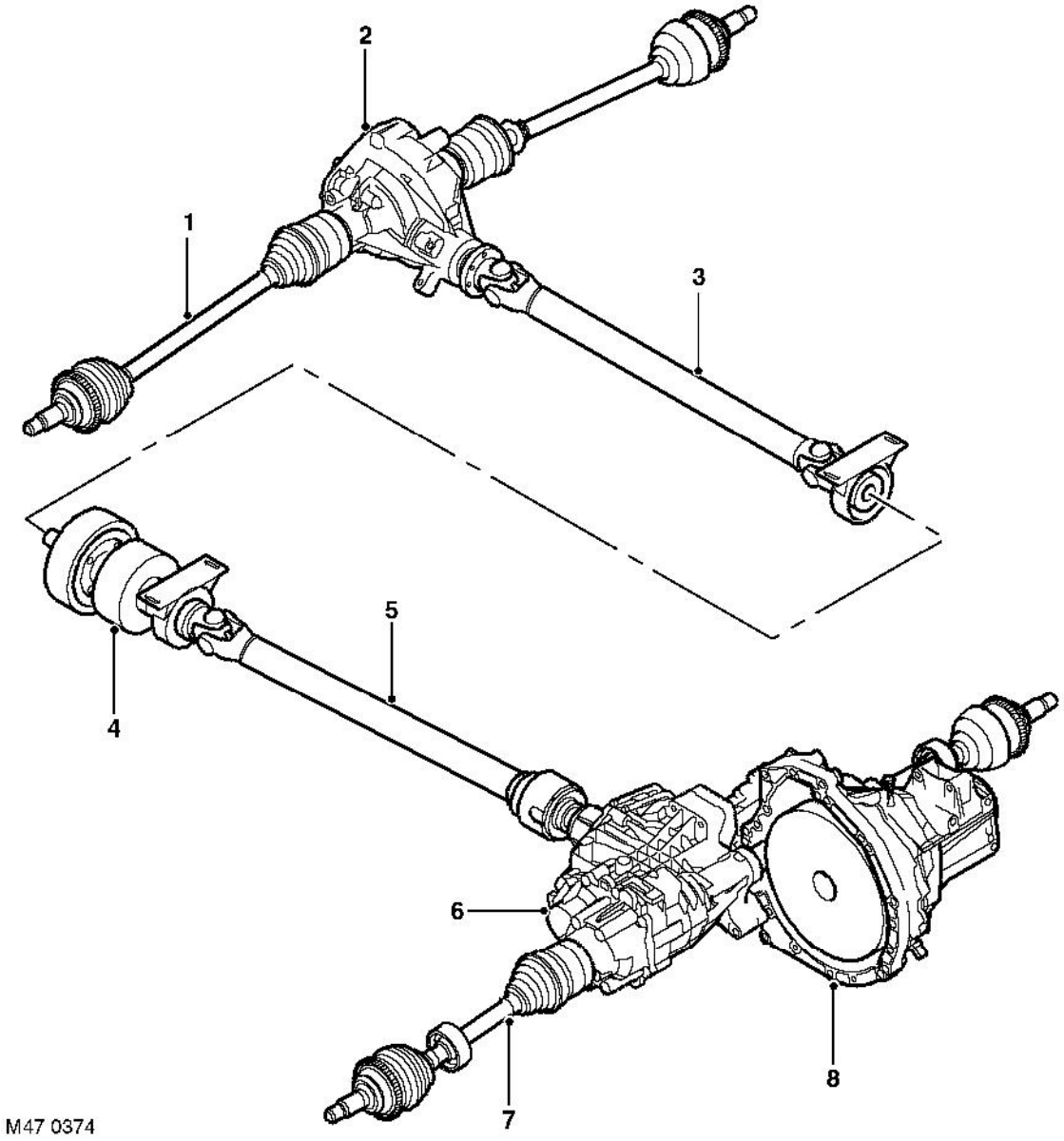
If the messages are not received from the ECM, the EAT ECU will implement a back-up strategy to protect the gearbox from damage, whilst allowing the vehicle to be driven.

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:

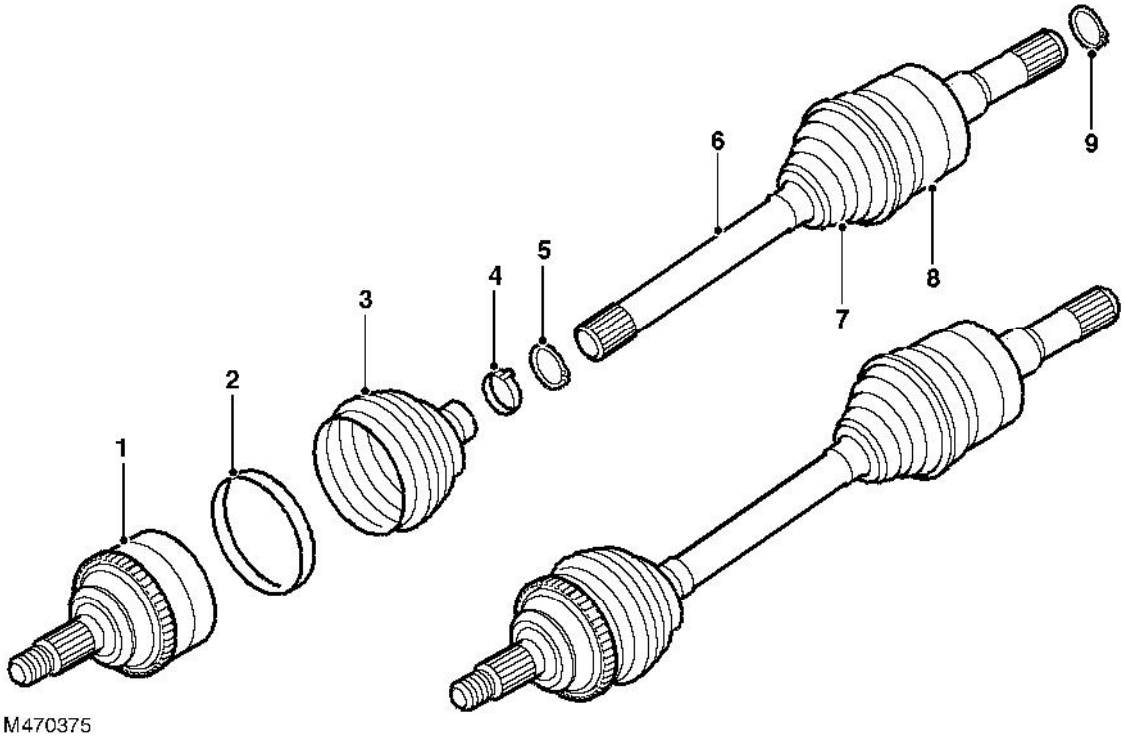
- Harsh gear changes
- No kickdown
- Torque reduction request inhibited.

Drive Shaft and Propeller Shaft Component Layout



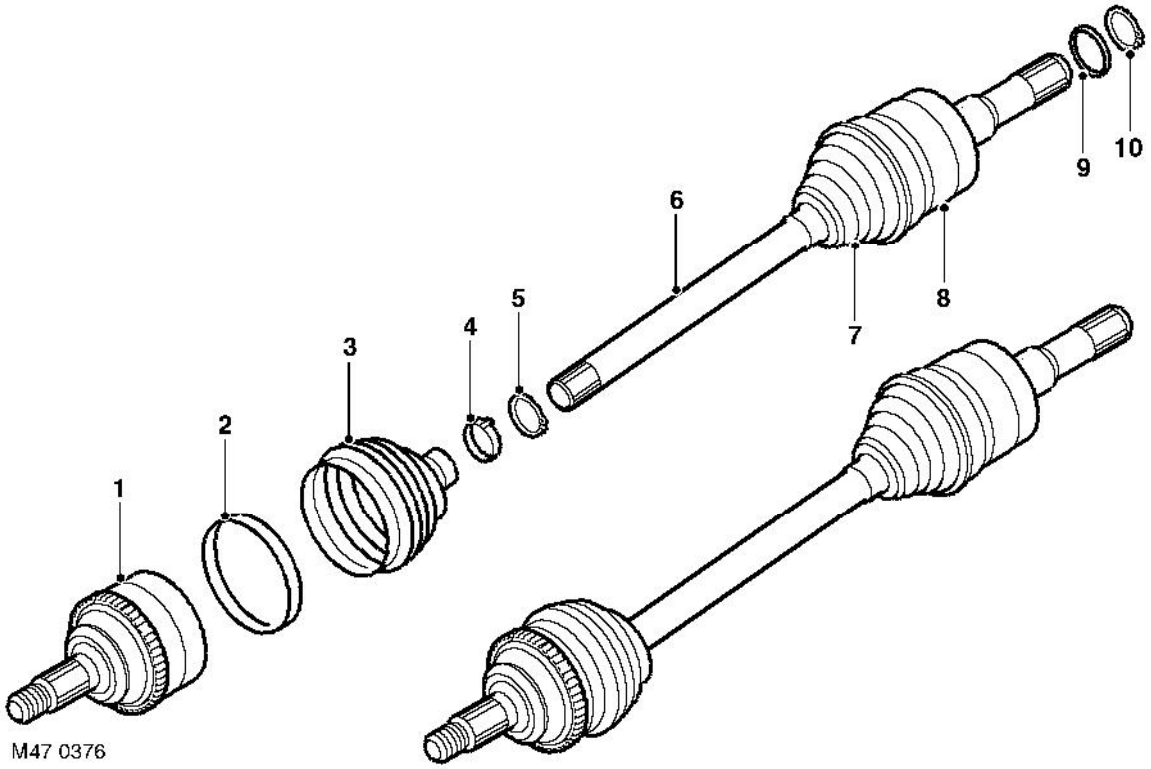
1 Rear drive shaft
2 Final drive unit
3 Rear propeller shaft
4 Vicous Coupling Unit (VCU)
5 Front propeller shaft
6 Intermediate reduction drive (IRD)
7 Front drive shaft
8 Gearbox

Front Drive Shaft Components



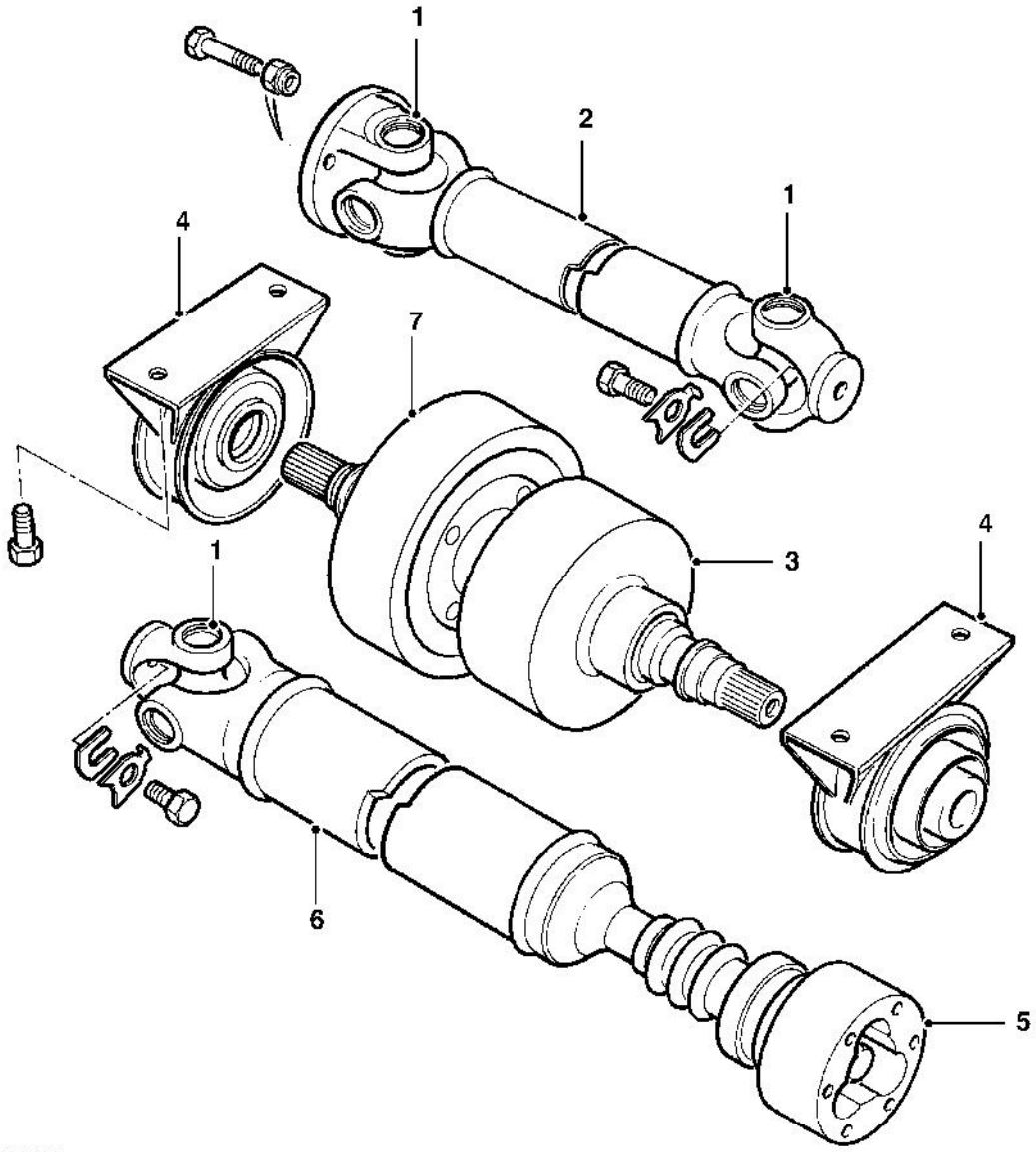
1 Outer joint
2 Clamp
3 Gaiter
4 Clamp
5 Circlip
6 Shaft
7 Gaiter
8 Inner joint
9 Circlip

Rear Drive Shaft Components



1 Outer joint
2 Clamp
3 Gaiter
4 Clamp
5 Circlip
6 Shaft
7 Gaiter
8 Inner joint
9 Flinger - oil seal
10 Circlip

Propeller Shaft and VCU Components



M47 0377A

1 Universal joint
2 Rear propeller shaft
3 VCU
4 Propeller shaft bearing
5 Coupling
6 Front propeller shaft
7 Torsional damper (K1.8 models only)

Description

Drive/Propeller Shafts
Two drive shafts transmit drive from the intermediate reduction drive (IRD) to the front wheels, and to two further drive shafts transmit drive from the final drive (differential) unit to the rear wheels.

Two propeller shafts and a viscous coupling unit (VCU) transmit drive from the IRD to the final drive unit.

Drive Shafts
All four drive shafts are of similar construction, the main difference being in the lengths of the front and rear drive shafts which differ between engine fitments.

Each drive shaft comprises a solid shaft with inner and outer constant velocity joints. The inner joint is of the tripode type with spherical bushing to reduce sliding resistance; the shaft and inner joint are one assembly. The outer joint is of the ball and socket type, with a splined connection between the joint and the shaft. The joints are packed with grease and protected by gaiters.

Front Propeller Shaft
The front propeller shaft consists of a thin walled tube with a coupling welded to the front end and a conventional universal joint welded to the rear end. The coupling bolts to the output flange of the IRD. The universal joint is splined to the input shaft of the VCU and secured by a bolt which is locked by a tabwasher and a 'U' washer.

The coupling reduces vibration and accommodates both angular movement (10 degrees maximum) and axial movement (50 mm maximum) between the propeller shaft and the IRD.

The universal joint incorporates serviceable, sealed needle bearings.

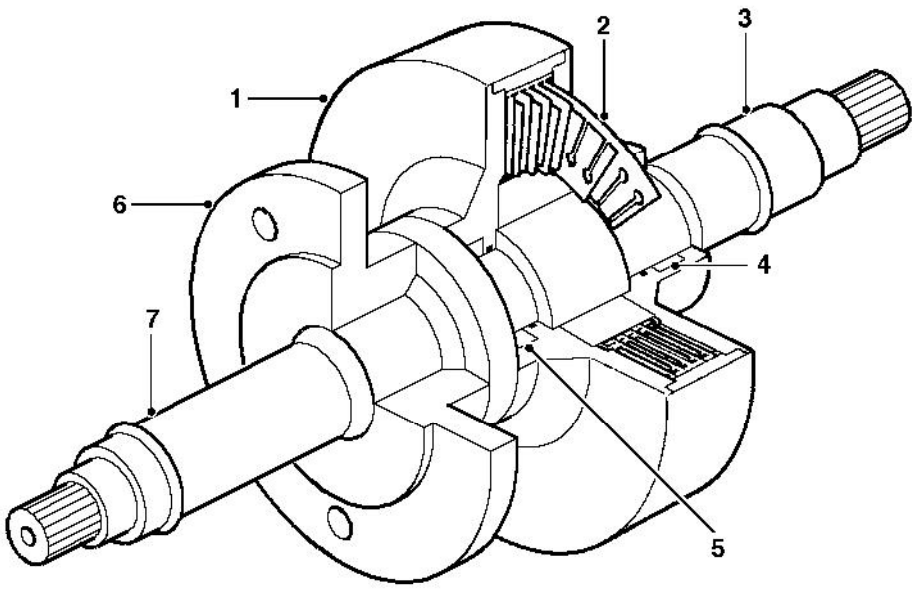
VCU
The VCU automatically controls the transfer of drive to the rear wheels by limiting the speed differential between the front and rear propeller shafts. The unit is supported in two propeller shaft bearings attached to the floor cross member.

The VCU comprises a short cylinder which contains an input shaft supported in a roller bearing race at the front and a ball bearing race at the rear. Within the cylinder, slotted discs are alternately attached to the outer surface of the input shaft and the inner surface of the cylinder. An output shaft is welded onto the rear of the cylinder. The input shaft is attached to the front propeller shaft and the output shaft is attached to the rear propeller shaft.

On models with 1.8 K Series engines, a torsional damper is bolted to a flange on the output shaft.

The cylinder is a sealed unit filled with a silicon jelly. The viscosity of the silicon jelly increases when subjected to shear. When there is a speed differential between the front and rear propeller shafts, adjacent slotted discs in the VCU rotate in relation to each other. The shearing action of the rotating slotted discs increases the viscosity and resistance to rotation of the silicon jelly.

Section Through VCU



M47 0378

1 Cylinder
2 Slotted discs
3 Input shaft
4 Roller bearing
5 Ball bearing
6 Torsional damper flange (K1.8 models only)
7 Output shaft

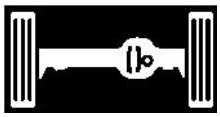
The rear wheels are 0.8% under driven, so in most conditions the vehicle is effectively front wheel drive, with the rear wheels turning the rear propeller shaft slightly faster than the IRD drives the front propeller shaft. Since the speed differential is low, the increase in viscosity of the silicon jelly is marginal and there is little resistance to relative rotation of the slotted discs.

When there is a significant speed differential between the front and rear propeller shafts , e.g. the front wheels lose traction or traversing rough terrain, the viscosity and resistance to rotation of the silicon jelly increases to a level that slows or stops relative rotation of the slotted discs. With the front and rear propeller shafts locked together, drive is thus transferred from the IRD to the rear wheels.

Torsional Damper (1.8 K Series Models Only)
The torsional damper reduces vibration from the propeller shafts. The damper consists of a rubber membrane bonded between an outer ring and an inner hub. Three bolts secure the inner hub to the output shaft of the VCU.

Propeller Shaft Bearings
The two propeller shaft bearings are identical, and each consist of a roller bearing race mounted into a centre bearing housing. The bearing is sealed-for-life and is a press fit on the input/output shaft of the VCU. Bearing covers and flingers prevent the ingress of moisture.

Rear Propeller Shaft
The rear propeller shaft consists of a thin walled tube with a conventional universal joint welded to each end. The rear universal joint is bolted to the input flange of the final drive unit. The front universal joint is splined to the output shaft of the viscous coupling unit and secured by a bolt which is locked by a tabwasher and a 'U' washer. Both universal joints incorporate serviceable, sealed needle bearings.



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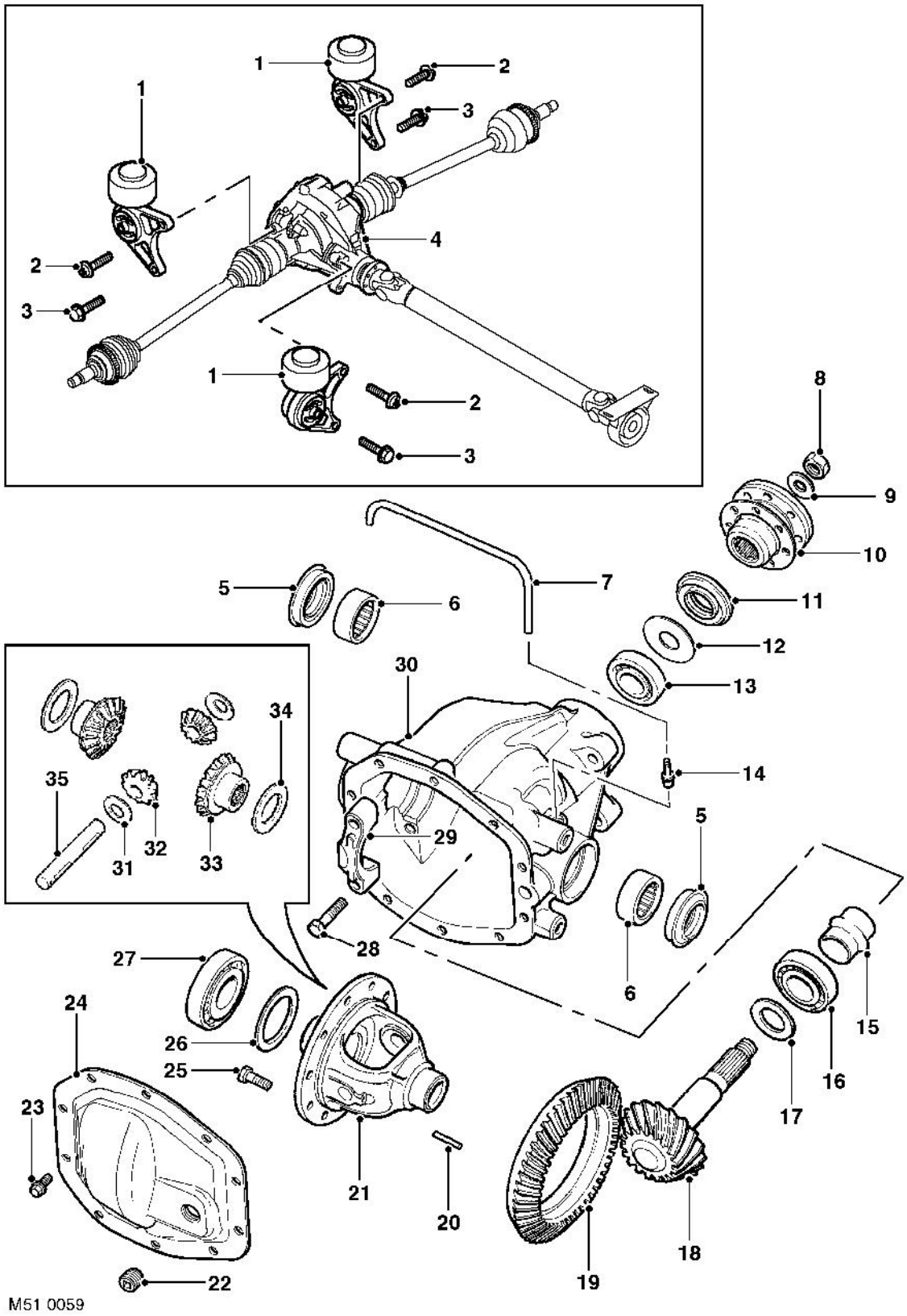
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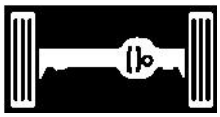
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Rear Differential





1 Bushed mounting (3 off)
2 Flanged screw (3 off)
3 Flanged bolt (3 off)
4 Differential assembly
5 Oil seal (2 off)
6 Needle roller bearing (2 off)
7 Breather tube
8 Pinion nut
9 Washer
10 Flange
11 Mudshield
12 Oil slinger
13 Taper roller bearing
14 Vent valve
15 Collapsible spacer
16 Pinion bearing
17 Shim kit
18 Pinion shaft and gear
19 Crown wheel
20 Roll pin
21 Differential case
22 Plug - Filler/Level
23 Bolt (10 off)
24 Cover
25 Bolt (10 off)
26 Shim (2 off)
27 Bearing (2 off)
28 Bolt (4 off)
29 Bearing cap (2 off)
30 Pinion housing
31 Belleville washer (2 off)
32 Planet gear (2 off)
33 Sun wheel (2 off)
34 Clutch pack (2 off)
35 Cross pin

Description

Rear Differential

The rear differential assembly serves to convert the "angle of drive" through 90° and distribute drive, in the desired proportions, to both rear wheels. The type of rear differential fitted is an integral carrier housing hypoid-gear in which the centre line of the drive pinion is mounted below the centre line of the ring gear. To minimise weight, the differential housing is manufactured in aluminium alloy. The assembly is secured to the rear subframe by three rubber bushed mountings.

The differential housing incorporates the drive pinion gear shaft, which is supported by two opposed taper roller bearings fitted to the pinion and cups assembled into the carrier housing. The pinion bearing pre-load is controlled by a collapsible spacer and the torque of the pinion nut. The pinion position is controlled by a selective shim located between the inner pinion bearing cone and the pinion gear head.

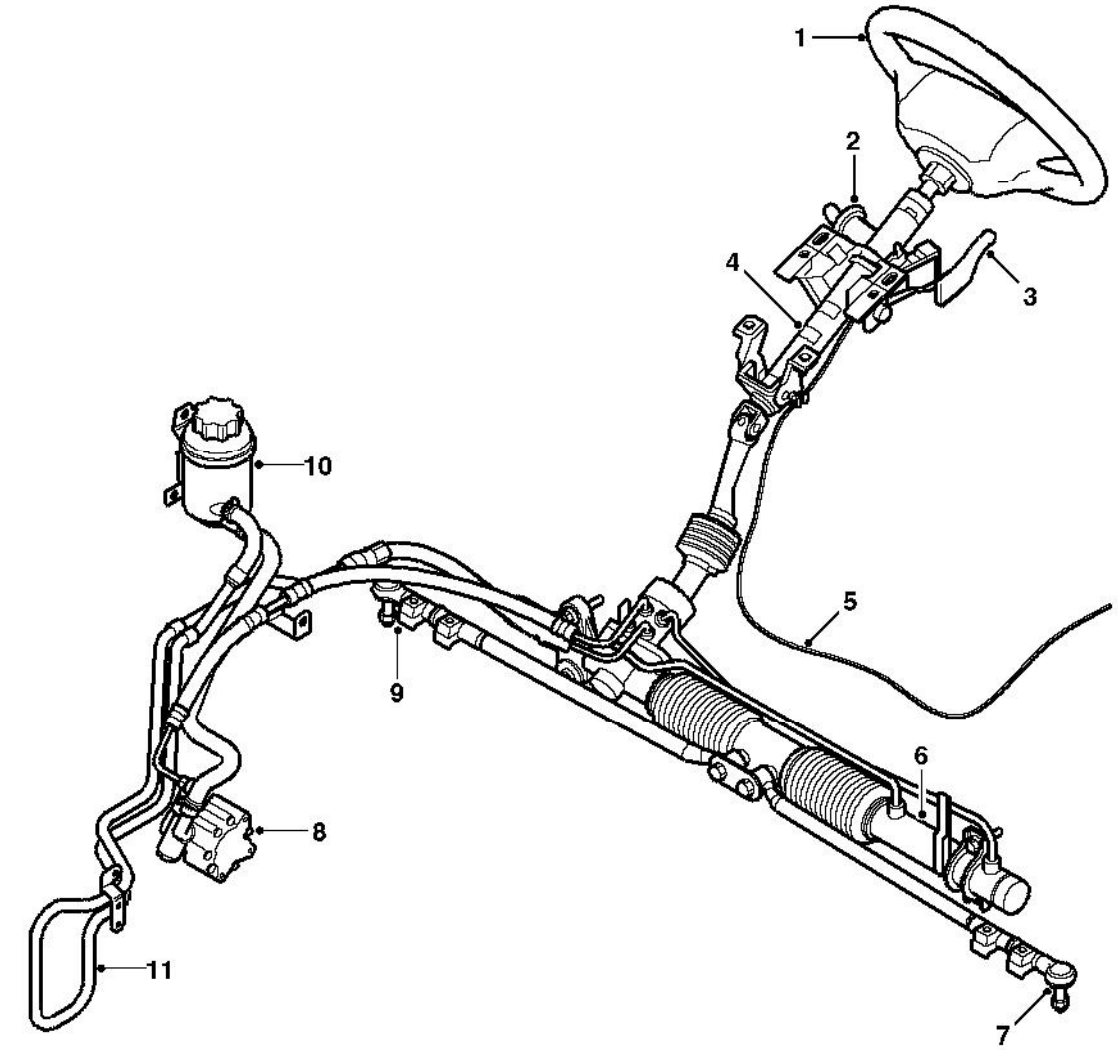
The differential assembly is supported by two opposed taper roller bearings. The bearing cups are secured in the housing by removable bearing caps. Shims are located between the differential bearing cones and differential case for controlling differential bearing pre-load and ring gear to pinion gear backlash.

The differential casing rear cover is manufactured from pressed steel and is sealed to the casing with RTV silicone sealant. The cover also incorporates the oil filler plug. A breather is located in the top of the differential casing to prevent pressurisation of the casing.

The pinion oil seal, which is fitted in the differential casing, is referred to as a "labyrinth" type seal and is especially designed to prevent contaminant ingress. The oil seal works in conjunction with a pressed steel shield, referred to as a "flinger" which is pressed on to the pinion drive flange. The two drive shafts are also sealed by "labyrinth" type oil seals fitted in the differential housing.

The differential oil level should be maintained to the bottom of the filler plug. No oil changes are specified.

Steering Components - Td4

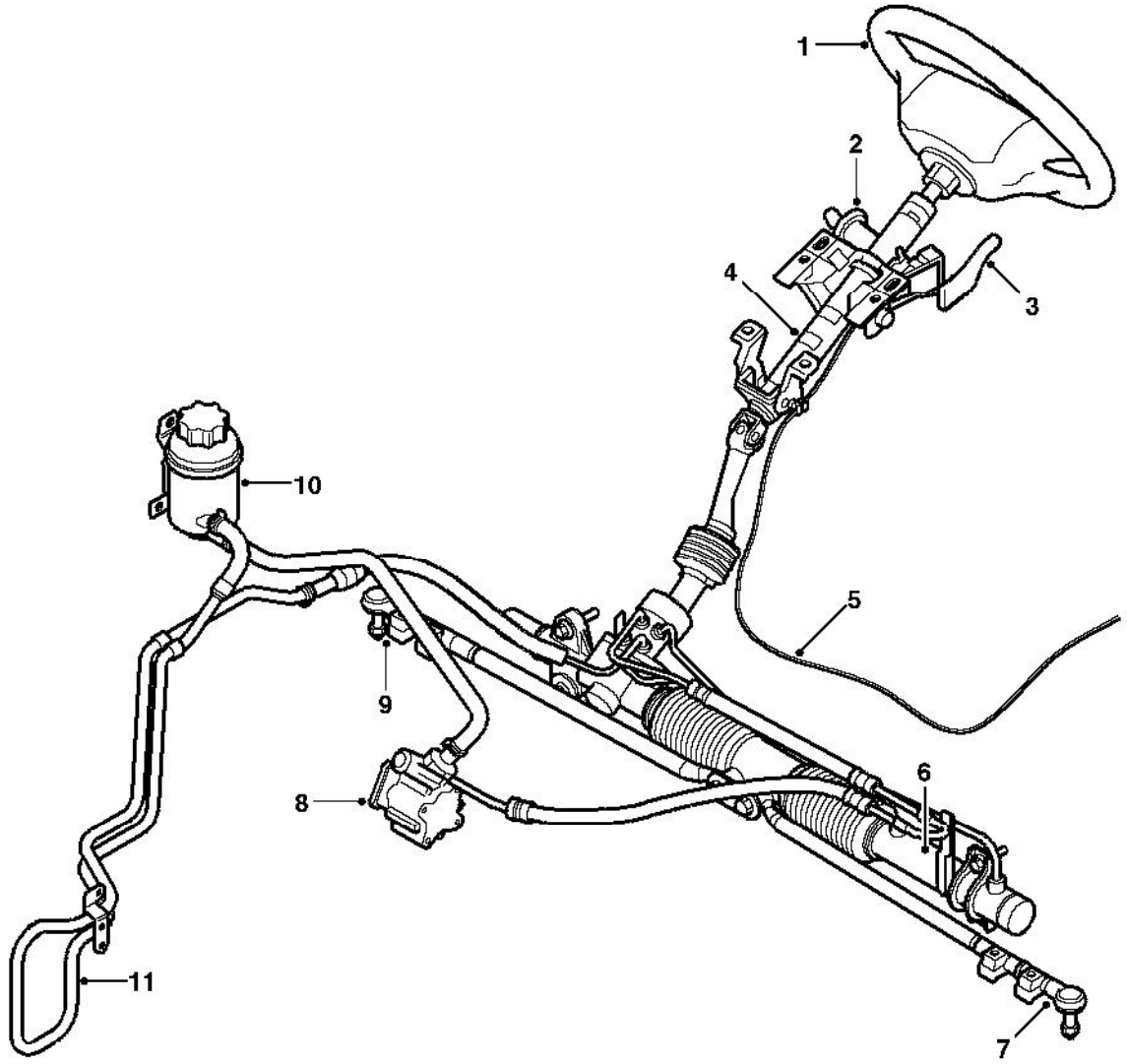


M57 1001

RHD shown, LHD similar

1 Steering wheel
2 Ignition switch/column lock assembly
3 Column adjuster
4 Telescopic column
5 Key interlock cable (if fitted)
6 Steering rack
7 LH track rod end
8 PAS pump
9 RH track rod end
10 Reservoir
11 Fluid cooler

Steering Components - K1.8

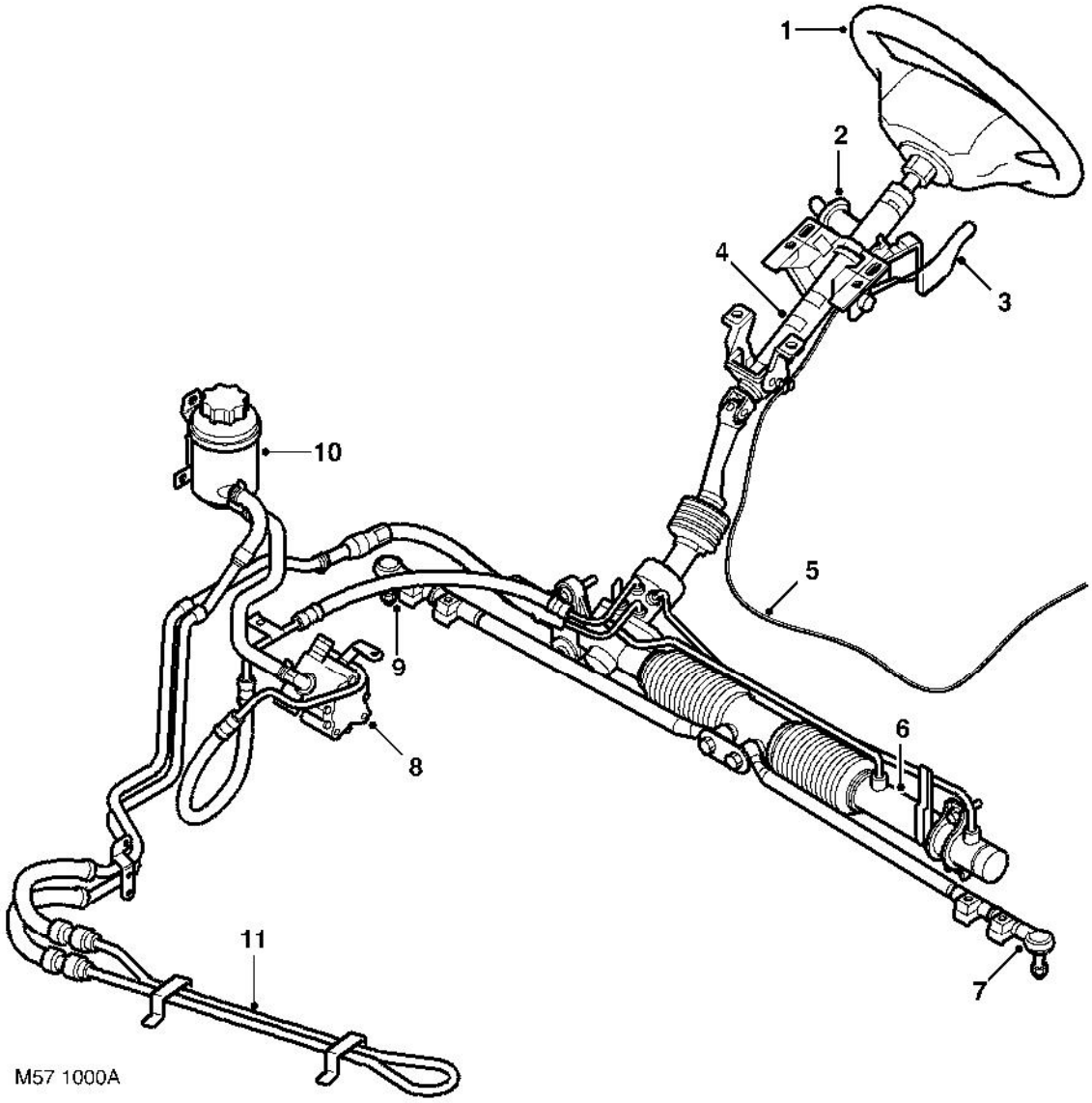


M57 0999

RHD shown, LHD similar

1 Steering wheel
2 Ignition switch/column lock assembly
3 Column adjuster
4 Telescopic column
5 Key interlock cable (if fitted)
6 Steering rack
7 LH track rod end
8 PAS pump
9 RH track rod end
10 Reservoir
11 Fluid cooler

Steering Components - KV6



RHD shown, LHD similar

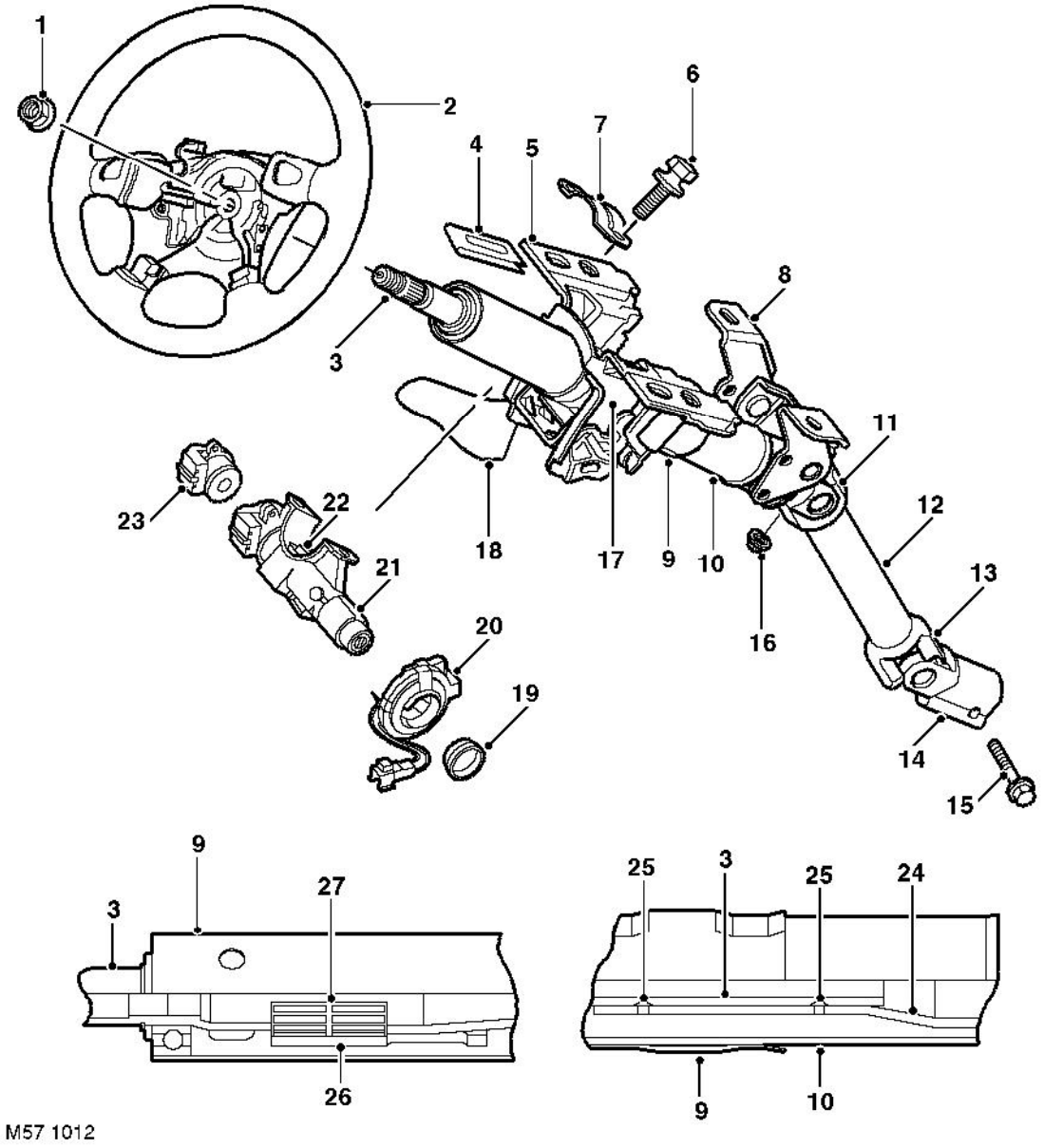
1 Steering wheel
2 Ignition switch/column lock assembly
3 Column adjuster
4 Telescopic column
5 Key interlock cable (if fitted)
6 Steering rack
7 LH track rod end
8 PAS pump
9 RH track rod end
10 Reservoir
11 Fluid cooler

Description

General

The major steering components comprise a shock absorbing telescopic steering column, a Power Assisted Steering (PAS) rack, a PAS pump, a fluid reservoir, a fluid cooler and fluid pipes and hoses.

Steering Column



1 Locknut
2 Steering wheel
3 Upper shaft
4 'U' Clip (2 off)
5 'Curling' plate (2 off)
6 Shear bolt (2 off)
7 Clamp plate
8 Lower mounting
9 Upper column tube
10 Lower column tube
11 Universal joint
12 Intermediate shaft
13 Universal joint
14 Adaptor
15 Clamp bolt
16 Locknut – mounting (2 off)
17 Upper mounting
18 Column adjuster
19 Light ring – ignition switch
20 Transponder coil
21 Steering column lock assembly
22 Lock bolt
23 Ignition switch
24 Lower shaft
25 Injection moulded shear pins
26 Lock collar
27 Wave form interference ring

The steering column design incorporates an energy absorbing mechanism to reduce driver impact loads in the event of a collision. The column is mounted on four captive studs which are located in an extension to the bulkhead. The two lower mountings are fixed and cannot move when loads are applied to them. The upper mounting is designed to disengage or deform when a load is applied, allowing the column to collapse in the event of an accident. The steering column is adjustable to allow the steering wheel to be moved vertically up or down to the desired position. The steering column is not serviceable and must be replaced as a complete assembly if necessary.

The upper column tube is telescopic and can slide over the lower column tube. The upper column tube provides for the location of the steering lock and ignition switch and also the steering switch gear and a rotary coupler. The rotary coupler provides the electrical connection for the steering wheel mounted airbag and the switches for the horn and, where fitted, In-Car Entertainment (ICE) and cruise control.

The central shaft comprises of two parts and is located in bearings in the upper and lower column tubes. The upper shaft is located inside the lower shaft. Mating cross holes in each shaft are connected by nylon injection moulded shear pins.

The upper shaft is splined to accept the steering wheel. The lower shaft is connected by a universal joint to the intermediate shaft. A second universal joint on the opposite end of the intermediate shaft is attached to a split adaptor. The adaptor is splined and mates with the splined input shaft from the steering rack.

The upper mounting bracket has two open slots with a PTFE coated, metal 'U' clip over each slot. Two soft metal 'curling' plates are riveted to the mounting bracket and cover the slots.

The mounting studs pass through the 'U' clips and the curling plates. The lock nuts that retain the upper mountings to the bulkhead extension are tightened to between 12 and 15 Nm. This torque figure controls the breakout load required to move the upper mounting brackets from the studs in the bulkhead extension and is critical to the crash performance of the column.

Energy absorption is achieved by the following mechanism: When an axial load is applied to the steering column, the mounting bracket deforms or slides out of the 'U' clips and the curling plates deform. The 'U' clips remain captive on the studs When the column mounting moves, the upper column tube slides on the lower column tube and allows approximately 63 mm (2.5 in.) maximum of axial movement. The nylon shear pins holding the upper and lower shafts together shear, allowing the central shaft to telescope the same amount as the column tubes.

In the event of a collision where the steering rack itself moves, the two universal joints in the column allow the intermediate shaft to articulate, minimizing movement of the column towards the driver. If movement continues after articulation of the intermediate shaft, the nylon shear pins retaining the two halves of the central shaft shear causing the shafts to 'telescope' together reducing further column intrusion.

The steering wheel comprises a cast centre and wire frame onto which the soft polyurethane foam is moulded. A horn switch is located at each side of the wheel. On models with a high specification ICE system and/or cruise control, additional switches are located on the steering wheel for control of one or both features. All switches are connected by wires to the rotary coupler connector.

Protection for the drivers face and upper torso is provided by an SRS airbag located in the centre of the steering wheel under a plastic cover.

☞ **RESTRAINT SYSTEMS, DESCRIPTION AND OPERATION, Description.**

The column adjuster is located on the left hand side of the steering column and allows the steering column and wheel to be tilted up or down over a range of approximately 3.5° or 30 mm (1.2 in) of vertical movement of the steering wheel. The column adjuster comprises a bolt which passes through each side of the column upper mounting bracket. The column adjustment lever is attached to a two-start left hand threaded nut which screws onto the bolt.

When the lever is lowered the nut is slackened and allows the column to be moved up or down to the desired position. Lifting the lever upwards tightens the nut, clamping the mounting bracket to the column, retaining the steering column in the selected position. The nut tightening torque is 10.5 Nm (7.7 lbf.ft) which gives the correct 'feel' to the lever operation.

The steering lock houses the ignition switch, ignition illumination light ring, key lock barrel and the security system transponder coil.

The steering lock is attached to the upper column with a clamp plate and two shear bolts. The bolts are tightened to a torque which shears off the heads of the bolts preventing easy removal of the steering lock.

The steering lock operates by a bolt, which emerges when the ignition key is turned to position 0 and the ignition key removed. The bolt engages in a lock collar located on the upper shaft in the upper column tube. The lock collar is attached to the upper shaft by a 'wave form' interference ring, which allows the lock collar to slip on the upper shaft if a torque of 200 Nm (147.5 lbf.ft) or higher is applied. This prevents the bolt being sheared, by someone forcibly turning the steering wheel while the steering lock is engaged, yet still effectively locks the steering. The steering lock is also designed to be resistant to slide hammer and shock retraction.

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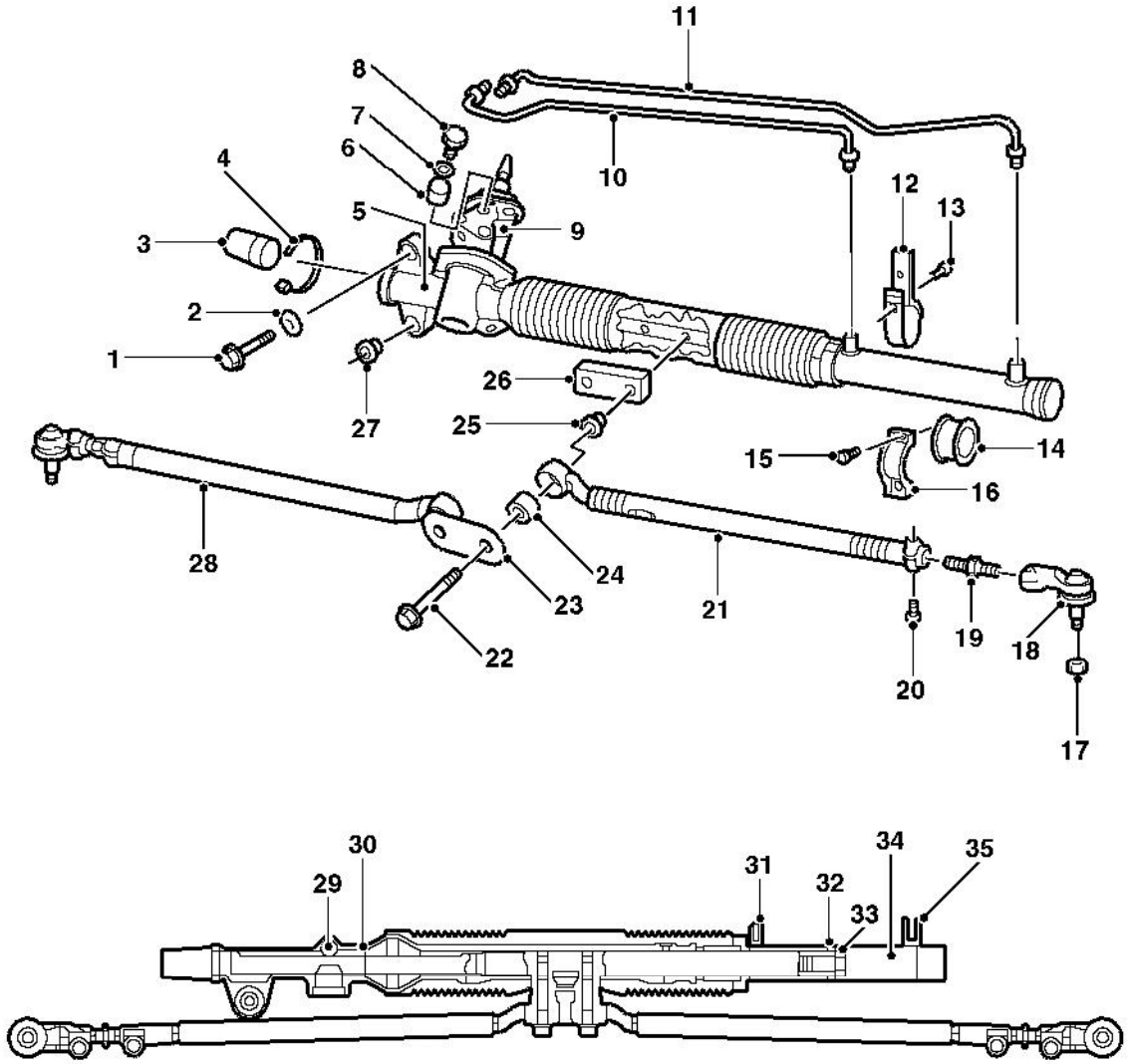
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Steering Rack



M57 1013

RHD shown, LHD similar

1 Flanged bolt (2 off)
2 Washer (lower bolt only)
3 Dust cover
4 Tie
5 Steering rack casting
6 Non return valve
7 Seal
8 Adaptor
9 Valve unit
10 Feed pipe (6 mm diameter)
11 Feed pipe (10 mm diameter)
12 Pipe support bracket
13 Bolt
14 Rack mounting cushion
15 Bolt (2 off)
16 Rack mounting bracket
17 Nut (2 off)
18 Track rod end (2 off)
19 Turnbuckle (2 off)
20 Bolt (4 off)
21 Track rod LH
22 Track rod bolt (2 off)
23 Support plate
24 Inner track rod bush (2 off)
25 Spacer (2 off)
26 Slider and bush assembly
27 Mounting bush (2 off)
28 Track rod RH
29 Steering pinion
30 Steering rack
31 Cylinder annulus port
32 Piston seal
33 Piston bolt
34 Cylinder
35 Cylinder full area port

The steering rack is unique in having the track rods mounted at a central location on the rack. The track rods are very long and combined with the optimized steering geometry provide low levels of 'bump steer'.

The steering rack is mounted in the engine compartment on the lower part of the bulkhead. The rack is retained with two bolts through cast lugs near the valve unit and two bolts which secure a clamp over the opposite end of the rack. The lower bolt through the cast lug is fitted with a large washer. The steering rack is handed for left and right hand drive vehicles.

The rack requires 3.2 turns from lock to lock and the rack and pinion has an overall ratio of 19.6 : 1.

A valve unit is fitted to one end of the steering rack and connects, via a splined input shaft, to the adaptor of the steering column. The valve unit has four hydraulic connections; a pressure feed from the PAS pump, a return line to the reservoir and two pressure lines to the annulus and full area of the hydraulic cylinder.

An input shaft, installed through the valve unit, is connected to a pinion gear which drives on a rack which, in turn is connected to the piston rod in the hydraulic cylinder.

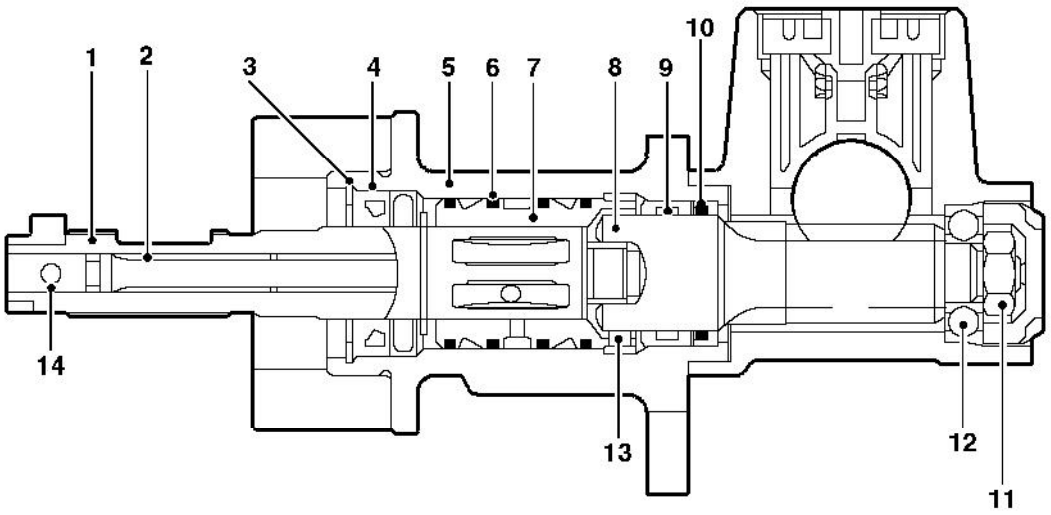
At a central position on the rack are two threaded holes which allow for the attachment of the track rods. Rubber bellows cover the movement area of the rack.

Two hydraulic ports, one at each end of the hydraulic cylinder of the rack, are connected by metal pipes to the valve unit. The ports supply hydraulic pressure to the annulus and full area of the cylinder. The annulus end of the cylinder is supplied with PAS pump outlet pressure and the full area end of the cylinder is supplied with pressure regulated by the valve unit. The cylinder end of the piston rod is fitted with a piston which houses a piston seal.

The track rods are fitted with rubber bushes which are hard enough to give positive feel to the steering but at the same time reduce unwanted feedback through the track rod. Each track rod is fitted with a track rod end. The track rod end is a ball joint which locates on an extended bracket on the suspension strut and secured with a lock nut. A turnbuckle is screwed into the track rod and the track rod end and allows for the adjustment of the steering alignment.

The track rods are located on a bushed slider which locates on the rack. Two spacers are located between the slider and the track rods. Two flanged bolts secure the track rods to the rack.

Valve Unit



M57 1014

1 Input shaft
2 Torsion bar
3 Circlip
4 Oil seal
5 Valve housing
6 PTFE ring (4 off)
7 Outer sleeve
8 Pinion shaft
9 Bearing
10 Oil seal
11 Nut
12 Bearing
13 Pin - pinion shaft to outer sleeve
14 Pin - input shaft to torsion bar

The valve unit is an integral part of the steering rack. The principal function of the valve unit is to provide maximum power assistance (i.e. when parking) with minimum effort required to turn the steering wheel.

The cast outer casing of the valve unit has four ports which provide the connections for pressure feed from the PAS pump, return to the fluid reservoir and pressure feeds from the valve unit to the annulus area and the full area of the cylinder. A non return valve and seal is fitted in the pressure feed port from the PAS pump.

The valve unit comprises an outer sleeve, input shaft, torsion bar and a pinion shaft. The valve unit is coaxial with the pinion shaft which is connected to the steering column via the input shaft. The valve unit components are located in a housing which is attached to a mating casting on the steering rack main body and secured with screws.

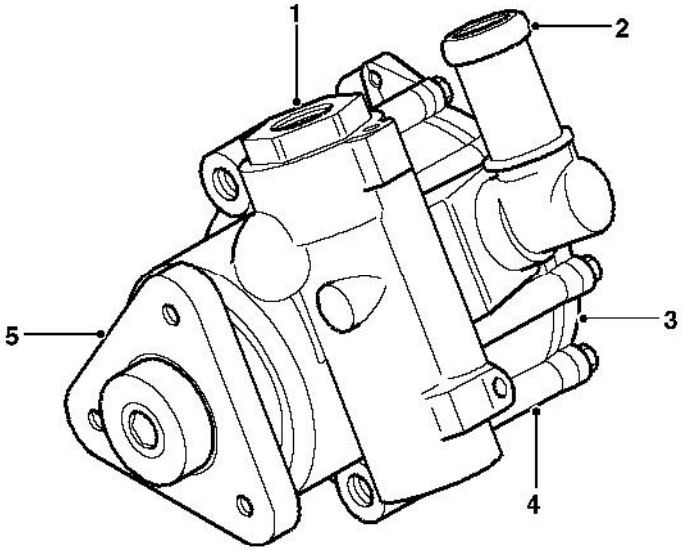
The outer sleeve is located in the main bore of the valve unit. Three annular grooves are machined on its outer diameter. PTFE rings are located between the grooves and seal against the bore of the valve unit. Holes are drilled radially in each annular groove through the wall of the sleeve. The bore of the outer sleeve is machined to accept the input shaft. Six equally spaced slots are machined in the bore of the sleeve. The ends of the slots are closed and do not continue to the ends of the outer sleeve. The radial holes in the outer sleeve are drilled into each slot.

The input shaft is splined at its outer end. The inner end of the input shaft forms a dog-tooth which mates with a slot in the pinion shaft. The fit of the dog-tooth in the slot allows a small amount of relative rotation between the input shaft and the pinion shaft before the dog-tooth contacts the wall of the slot. This ensures that, if the power assistance fails, the steering can be operated manually without over stressing the torsion bar. The central portion of the input shaft has equally spaced longitudinal slots machined in its circumference. The slots are arranged alternately around the input shaft.

The torsion bar is fitted inside the input shaft and is an interference fit in the pinion. The torsion bar is connected to the input shaft by a drive pin, fitted after hydraulic balancing. The central diameter of the torsion bar is machined to a smaller diameter than at each end. The smaller diameter allows the torsion bar to twist in response to torque applied from the steering wheel in relation to the grip of the tyres on the road surface.

The pinion shaft has machined teeth on its central diameter which mate with the teeth on the steering rack. A slot machined in the upper end of the pinion shaft mates with the dog-tooth on the input shaft. The pinion shaft locates in a cast housing which is part of the steering rack and rotates on ball and roller bearings.

Power Assisted Steering (PAS) Pump



M57 1027

Td4 pump shown, K1.8 and KV6 pumps similar

1 Outlet connection
2 Inlet connection
3 Cover
4 Body
5 Drive flange

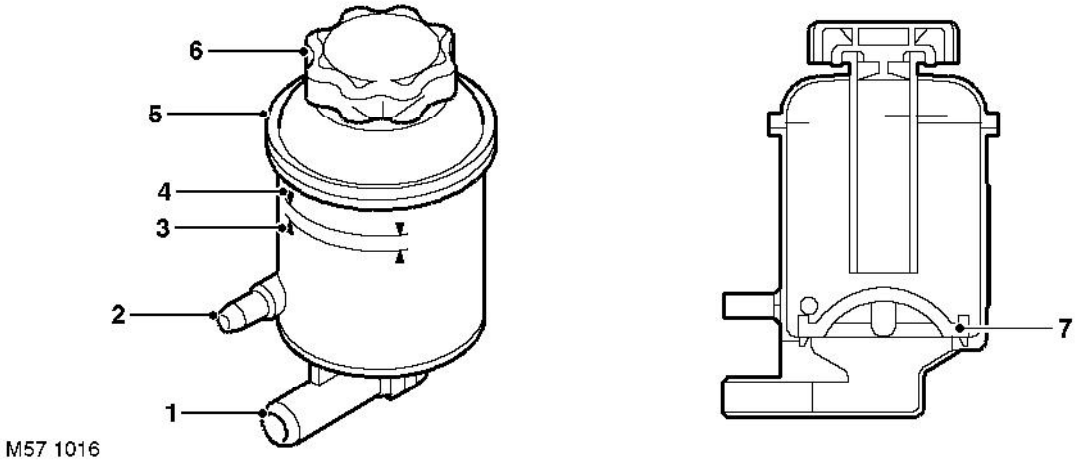
The vane type PAS pump supplies hydraulic pressure to the steering rack valve unit. The PAS pump is driven by a Poly Vee belt from the crankshaft pulley. A self adjusting tensioner is fitted to maintain the correct belt tension.

The PAS pump comprises a body and cover which house the internal components of the pump. A pressure relief valve assembly is installed in the body. The relief valve also incorporates a flow control valve. The pressure relief valve limits the maximum pressure to between 90 and 100 bar (1305 and 1450 lbf/in^2) on K1.8 models or 120 and 127 bar (1740 and 1842 lbf/in^2) on KV6 and Td4 models. The flow control valve limits the maximum flow to between 5.0 and 6.0 l/min (1.32 and 1.58 US gal/min).

A shaft runs longitudinally through the pump. One end of the shaft has a drive flange which accepts the drive pulley. The opposite end is closed by the cover. The shaft runs in bearings located in the body. Oil seals at each end of the shaft prevent the leakage of hydraulic fluid.

An oval cam ring is located in the body. Ten roller vanes are housed in a carrier and rotate within the cam ring. The carrier is mounted in the centre of the shaft and receives positive drive from the shaft via a drive pin. The carrier is seated against an end plate which is located in the cover. The front of the carrier is covered by a port plate which is located against a seal plate in the body. The port plate controls the fluid flow into and out of the roller vanes during their cycle.

Fluid Reservoir



1 Supply connection
2 Return connection
3 Lower fluid level mark
4 Upper fluid level mark
5 Reservoir body
6 Cap
7 Filter assembly

The fluid reservoir is mounted in the right hand side of the engine compartment on a bracket attached to the inner wing.

The reservoir comprises a body, a cap and a filter assembly. The reservoir has a capacity to the upper level mark of 335 cc.

An 'O' ring seal in the cap prevents leakage. The cap is pushed onto the latch and turned through 90° to lock. A breather hole is incorporated in the cap to allow changes in fluid level during operation.

A filter assembly is fitted into the bottom of the reservoir. The filter is made from fine nylon mesh which is moulded into the frame of the filter. The filter removes particulate matter from the fluid before it is drawn into the supply connection and is non-serviceable.

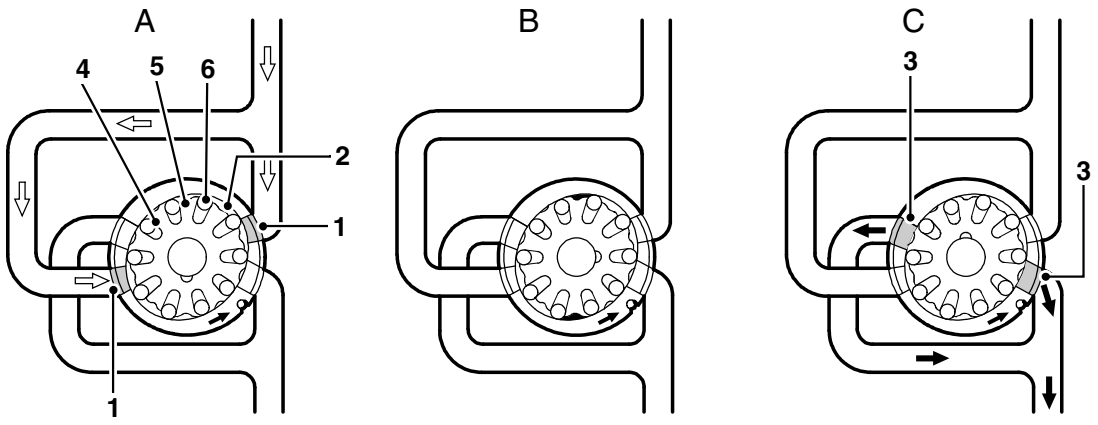
The primary function of the fluid reservoir is to hold a surplus of hydraulic fluid in the system to allow for expansion and contraction of the fluid due to temperature variations. The fluid level ensures that the supply connection is covered with fluid at all operational attitudes. Any air that may be present in the hydraulic system will be exhausted from the fluid at the reservoir.

High Pressure Hose

The high pressure hose connecting the PAS pump to the valve unit incorporates an attenuator. The attenuator comprises a bullet shaped valve which is located between two spiral wound springs. The valve operates as a restrictor to damp pressure pulses from the PAS pump, reducing noise and strain on downstream components. The attenuator is integral with the hose and cannot be serviced separately.

Operation

PAS Pump Operation



M57 1017

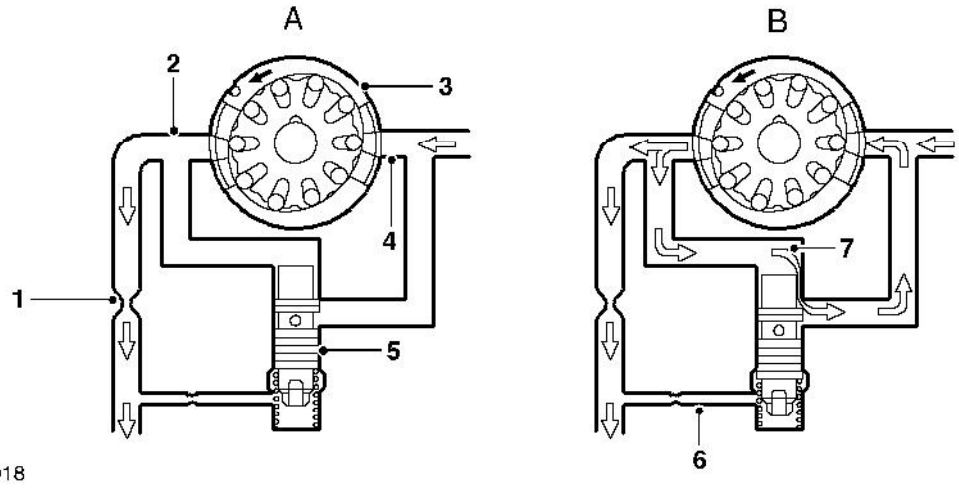
1 Inlet port
2 Roller vane chamber
3 Discharge port
4 Cam
5 Carrier
6 Roller vanes

As the pump rotates, centrifugal force causes the roller vanes to move outwards in the slots in the carrier and contact the cam ring. As the carrier rotates, the cam ring form causes the space between the rollers to increase. The increasing volume between the roller vanes causes a depression which draws fluid into the space between the rollers.

As the carrier continues to rotate, the inlet port is closed to the roller vanes which have drawn the fluid, trapping the fluid between the rollers. As the carrier rotates further, the cam form causes the space between the roller vanes to decrease, pressurizing the fluid between the rollers.

On further rotation of the carrier the roller vanes reach the discharge port and fluid is displaced under pressure from between the roller vanes into the discharge port. The space between each pair of rollers is subjected to this cycle twice for every revolution of the pump.

Pump Flow Control Valve Operation



1 Metering orifice
2 Discharge port
3 Pump
4 Inlet port
5 Flow control valve
6 Relief valve passage
7 Recirculation passage

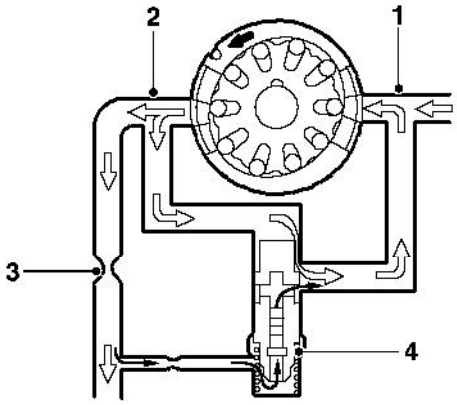
The pump is a positive displacement type pump and potential output from the pump increases proportionally with engine speed. The flow control valve maintains a constant predetermined flow to the control unit regardless of engine speed. The flow control valve controls the flow of fluid and increases or decreases the flow discharged from the pump to compensate for engine speed variations.

With the engine at idle the discharge flow from the pump is low and the full flow from the pump is delivered to the valve unit. As engine speed increases, the flow delivered by the pump increases proportionally. A pressure difference is created between each side of the metering orifice as the engine speed increases, the higher pressure being felt at the pump side of the metering orifice. This higher pressure is also felt at the top of the flow control valve via the recirculation passage. The lower pressure on the discharge side of the metering orifice is felt at the bottom of the flow control valve via the relief valve passage.

When the pressure at the top of the flow control valve exceeds the rating of the flow control valve spring, the valve begins to open against the spring pressure and the lower pressure at the discharge side of the metering orifice. Fluid is allowed to flow through the recirculation passage and recirculate through the pump.

As engine speed increases, the flow control valve is pushed down further, increasing the flow through the recirculation passage.

Pump Pressure Relief Valve Operation



M57 1019

1 Inlet port
2 Discharge port
3 Metering orifice
4 Pressure relief valve

The pressure relief valve is located in the centre of the flow control valve. If the pressure on the discharge side of the metering orifice reaches a predetermined level, a spring loaded ball in the centre of the valve will lift from its seat and allow pressurized fluid to recirculate within the pump.

The pressure relief valve will operate if the discharge from the pump is restricted, steering held at full lock. If the discharge from the pump is completely blocked, all fluid discharged will be recirculated through the pump. As no fresh fluid is drawn into the pump from the reservoir, the fluid temperature inside the pump will increase quickly. Consequentially, periods of operation of full lock should be kept to a minimum to avoid overheating the pump and the fluid within it.

Steering Rack Operation
Rotary movement of the steering wheel is transferred via the steering column to the input shaft of the valve unit on the steering rack. The rotary movement of the input shaft is converted into linear movement of the steering rack through the rack and pinion. With the engine running and the PAS pump operating, pressurised fluid is available to the steering rack for power assistance.

Neutral Position
With no movement of the steering wheel being applied, the slots in the outer sleeve and the input shaft are so aligned that the fluid flows across the valve unit with minimal restriction. Some pressure is applied to the full area port and the annulus port which in turn is felt at either side of the piston in the hydraulic cylinder. With the forces approximately equal on each side of the cylinder, the steering remains in the neutral position. Fluid delivered from the PAS pump is returned from the valve unit via the fluid cooler back to the reservoir. With minimal restriction across the valve unit and through the return hose, the pressure applied to each side of the piston is very low.

Right Steering (RHD Models; Left Steering on LHD Models)
Clockwise (on RHD, anti-clockwise on LHD) rotation of the steering wheel rotates the input shaft and the torsion bar in the same direction. The slots in the input shaft move out of their neutral alignment with the slots in the outer sleeve, as the torsion bar twists, and restricts the flow back to the reservoir. This restriction causes the supply pressure from the PAS pump to increase. The increased PAS pump pressure is directed to the annulus side of the hydraulic cylinder. Due to the relative displacement of the slots, the full area side of the cylinder is opened to return, producing a pressure difference across the piston. This results in a linear output force along the rack which provides the power assistance to turn the road wheels in the appropriate direction.

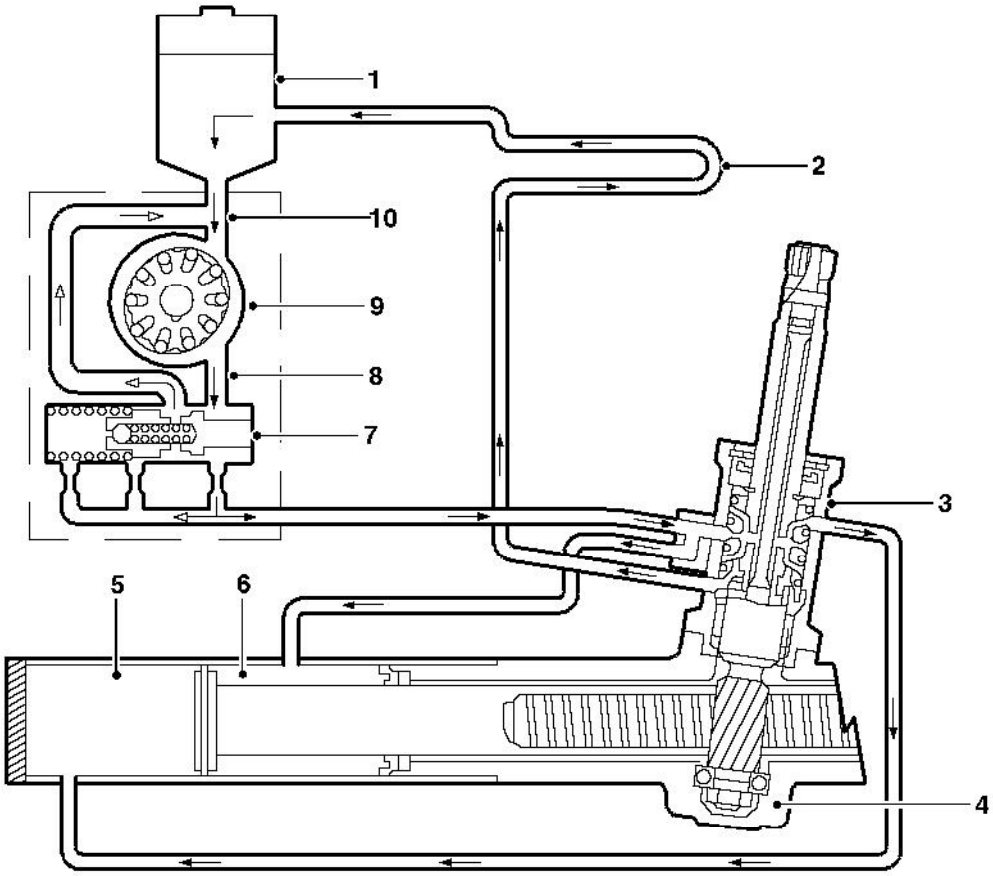
Left Steering (RHD Models; Right Steering on LHD Models)
Anti-clockwise (on RHD, clockwise on LHD) rotation of the steering wheel rotates the input shaft and the torsion bar in the same direction. The slots in the input shaft move out of their neutral alignment with the slots in the outer sleeve, as the torsion bar twists, and restricts the flow back to the reservoir. This restriction causes the supply pressure from the PAS pump to increase. The increased PAS pump pressure is directed to the annulus side of the hydraulic cylinder. Due to the relative displacement of the slots the increased PAS pump pressure is also applied to the full area side of the cylinder. The difference in effective areas on each side of the piston produces a linear output force along the rack which provides the power assistance to turn the road wheels in the appropriate direction.

Progressive Assistance
Progressive power assistance is dependent on the amount of road wheel resistance opposing the turning of the front wheels. When the steering wheel is turned to the left or right, the rotary movement is transferred through the steering column to the input shaft which rotates the same amount as the steering wheel. The rotary movement is also transferred from the input shaft to the torsion bar. If the road wheel resistance is high, e.g. when parking, the torsion bar will twist. The twisting of the torsion bar means that the rotary movement of the pinion and the outer sleeve is less than that of the input shaft.

The twisting of the torsion bar moves the slots in the input shaft and the torsion bar out of alignment. The greater the resistance of the road wheels to the steering rotary movement, the greater the misalignment of the slots in the input shaft and outer sleeve. As the misalignment becomes greater, the restriction in the return flow of fluid to the reservoir increases and therefore the fluid pressure applied to the hydraulic cylinder also increases. As the fluid pressure increases, so does the amount of assistance provided.

When the road wheel resistance reduces or less effort is applied to the steering wheel, the reduced torque applied to the input shaft allows the torsion bar to unwind. This reduces the misalignment between the slots in the input shaft and the outer sleeve, reducing the fluid pressure applied to the hydraulic cylinder and therefore the amount of assistance provided.

Hydraulic Circuit Operation



M57 1020

1 Reservoir
2 Fluid cooler
3 Valve unit
4 Steering rack and pinion gear
5 Full area pressure chamber
6 Annulus pressure chamber
7 Flow control/relief valve
8 Discharge port
9 PAS pump
10 Low pressure suction line

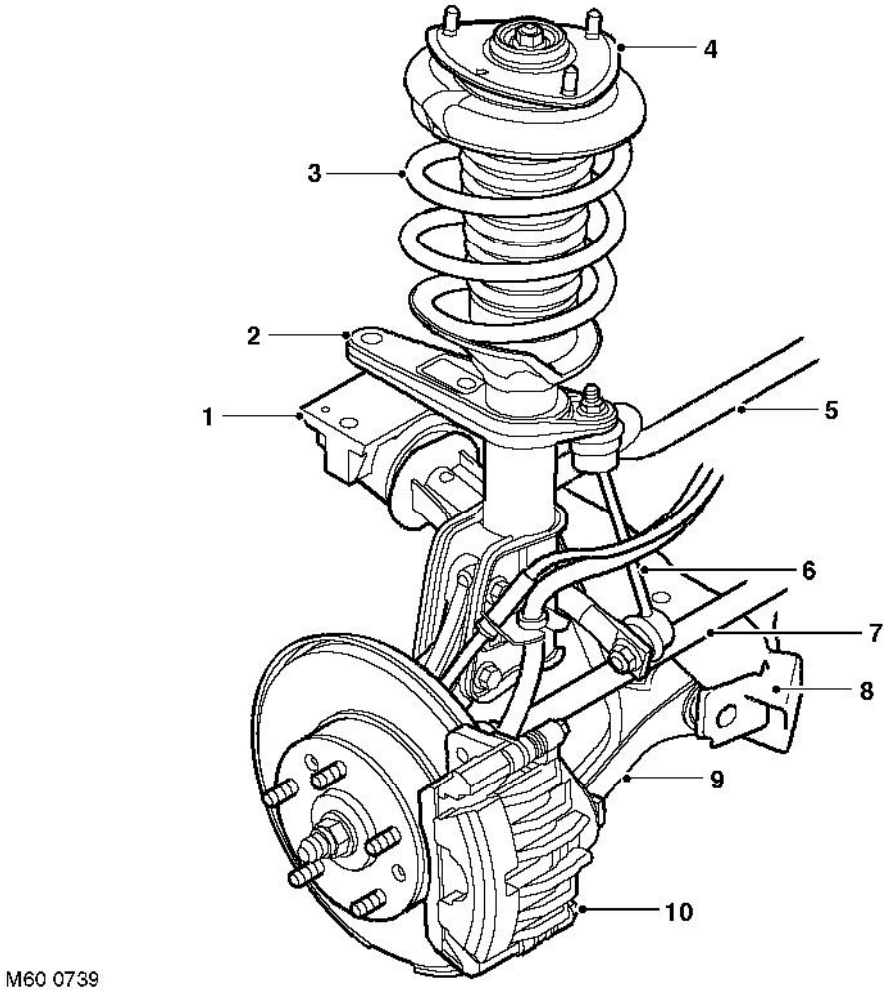
When the engine is started, the PAS pump draws fluid from the reservoir down the low pressure suction line. The fluid passes through the PAS pump and emerges as pressurised fluid at the discharge port. The attenuated high pressure hose transports the pressurised fluid to the steering gear valve unit.

If no steering effort is applied, there is minimal restriction within the system and the supply pressure from the pump is low. Minimal pressure is applied, via the valve unit, to each side of the piston in the hydraulic cylinder and the full flow from the PAS pump returns to the reservoir via the fluid cooler.

If steering effort is applied in either direction, the return flow of fluid to the reservoir is restricted, causing the supply pressure from the PAS pump to increase. The pressurised fluid is directed to the hydraulic cylinder, via the valve unit, providing power assistance to reduce the steering effort required. The fluid displaced by the movement of the piston in the cylinder is returned through the valve unit to the reservoir via the fluid cooler.

The fluid cooler reduces the fluid temperature which prolongs the life of the hoses and seals in the system.

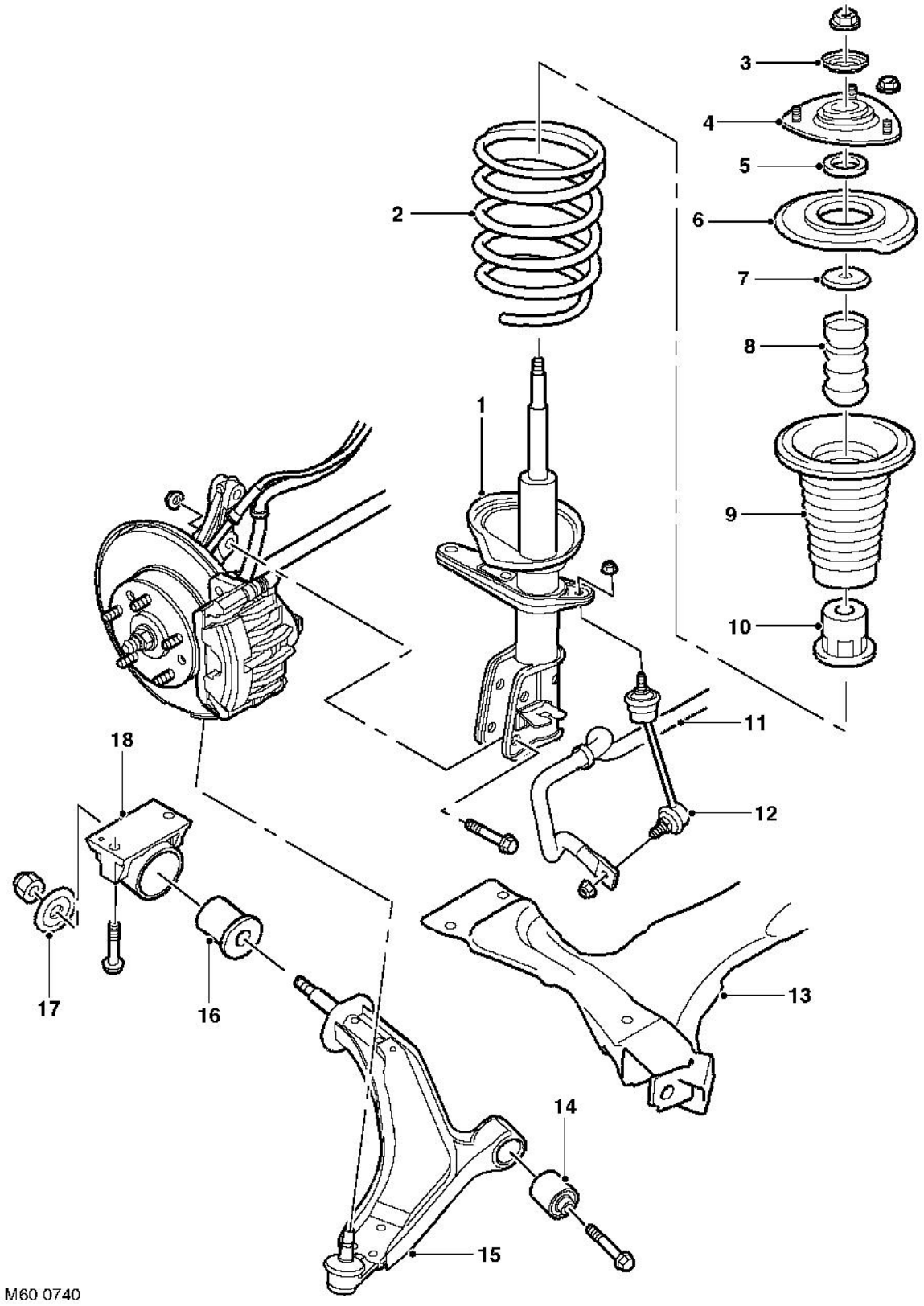
Front Suspension Component Location



RH Front suspension shown, LH is mirror image

1 Bush and housing assembly
2 Damper
3 Road spring
4 Top mount
5 Anti-roll bar
6 Anti-roll bar link
7 Drive shaft
8 Front subframe
9 Lower arm
10 Brake caliper and hub assembly

Front Suspension Component Detail



RH Front suspension shown, LH is mirror image

1 Damper
2 Road spring
3 Rebound washer
4 Top mount
5 Bearing
6 Spring seat
7 Bump washer
8 Spring aid
9 Dust cover
10 Bump cup
11 Anti-roll bar
12 Anti-roll bar link
13 Subframe
14 Bush
15 Lower arm
16 Bush
17 Snubber washer
18 Rear bush housing

Description

General
The front suspension comprises two MacPherson strut dampers with coil springs, two lower suspension arms and an anti-roll bar. A front subframe is bolted to the body and provides mounting points for the lower suspension arms. Each damper has a steering arm which provides for the attachment of the track rods from the power steering rack.

The suspension is designed to allow longitudinal movement of the wheel, which allows the wheel to move rearwards and upwards in response to surface undulations. The longitudinal movement allows the springs and dampers time to react to surface changes which improves ride quality.

MacPherson Struts
The left and right hand dampers are handed but otherwise similar in construction. The front dampers are similar to the rear dampers but have slightly different damping characteristics. The damping characteristics of the front dampers also differs between model variants. The spring rates also differ between the front and rear suspension and model variants.

The damper has a forged steering arm which provides for the attachment of the track rod via a ball joint and the anti-roll bar link. The damper body is fabricated from thick walled tubing and has welded brackets for attachment of the swivel hub. A smaller welded bracket provides for the attachment of the brake hose to the caliper and the ABS sensor cable.

Each damper is fitted with a coil spring. The coil spring locates in a fabricated seat and is retained in a partially compressed condition on the damper by a spring seat, top mount and nut. The top mount is fitted with three studs which locate in mating holes in the inner wing turret. The top mount is fitted with a bearing which allows the damper rod to rotate when the steering is turned.

On vehicles fitted with air conditioning, the front springs are approximately 5 mm longer. This maintains the correct ride height with respect to the additional weight of the air conditioning equipment.

A spring aid and a bump cup are fitted to the damper to prevent shock loads when the damper is fully compressed. A dust cover prevents the ingress of dirt and water to maintain the integrity of the chromium plated damper rod.

The damper functions by restricting the flow of hydraulic fluid through internal galleries within the damper. A chromium plated damper rod moves axially within the damper. As the rod moves, its movement is limited by the flow of fluid through the galleries thus providing damping of undulations in the terrain. The damper rod is sealed at its exit point from the damper body to maintain fluid within the unit and to prevent the ingress of dirt and moisture. The seal also acts as a wiper to keep the rod outer diameter clean.

Anti Roll Bar
The anti-roll bar is mounted to the upper face of the front subframe in two places. Rubber bushes fitted to the anti-roll bar are held in position by two clamps retained with bolts. The outer ends of the anti-roll bar are each connected to a link, which in turn is attached to the damper.

The links have a ball joint at each end. The link transmits suspension movements directly to the anti-roll bar. The design of the links reduces the steer effects commonly found in this type of suspension.

Lower Suspension Arms
The lower suspension arms are fabricated from steel and each arm is handed. The arms are attached at two pivot points. The forward end of the arm contains a bush and is attached to lugs on the front subframe with a bolt. A spigot on the rear mounting of the arm engages with a bush and housing assembly and is retained with a snubber washer and a nut. A ball joint is located on the outer part of the arm and is connected to the swivel hub and secured with a nut.

The two pivot bushes have a significant role in vehicle handling. The bushes control the longitudinal movement of the wheel due to braking, acceleration or surface undulations.

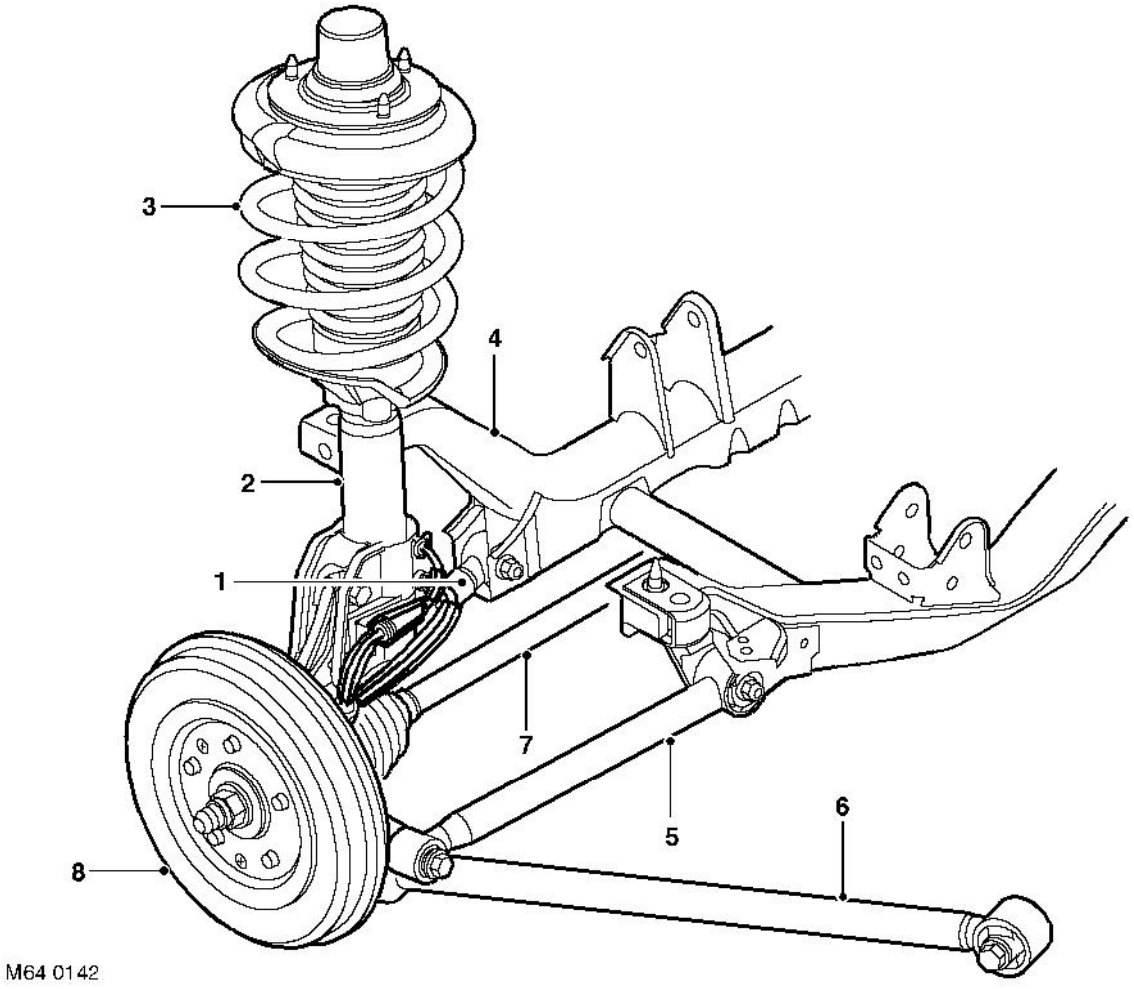
Front Bush
The front bush is located at a specified angle to the axis of rotation of the lower suspension arm. The front bush is deflected radially and axially as the wheel moves rearwards. The angle of the bush ensures that the wheel moves directly rearward reducing the effects of longitudinal steer to a minimum.



Rear Bush

The rear bush is mounted on the axis of rotation of the lower suspension arm. In the radial direction the bush is relatively soft in its construction. In the axial direction, the bush is very soft for the first 2 mm of movement. Snubbing areas to the front and rear of the bush provides a progressive increase in the hardness of the bush as the deflection of the wheel increases. The rear bush controls the amount that the wheel can move forward or rearward.

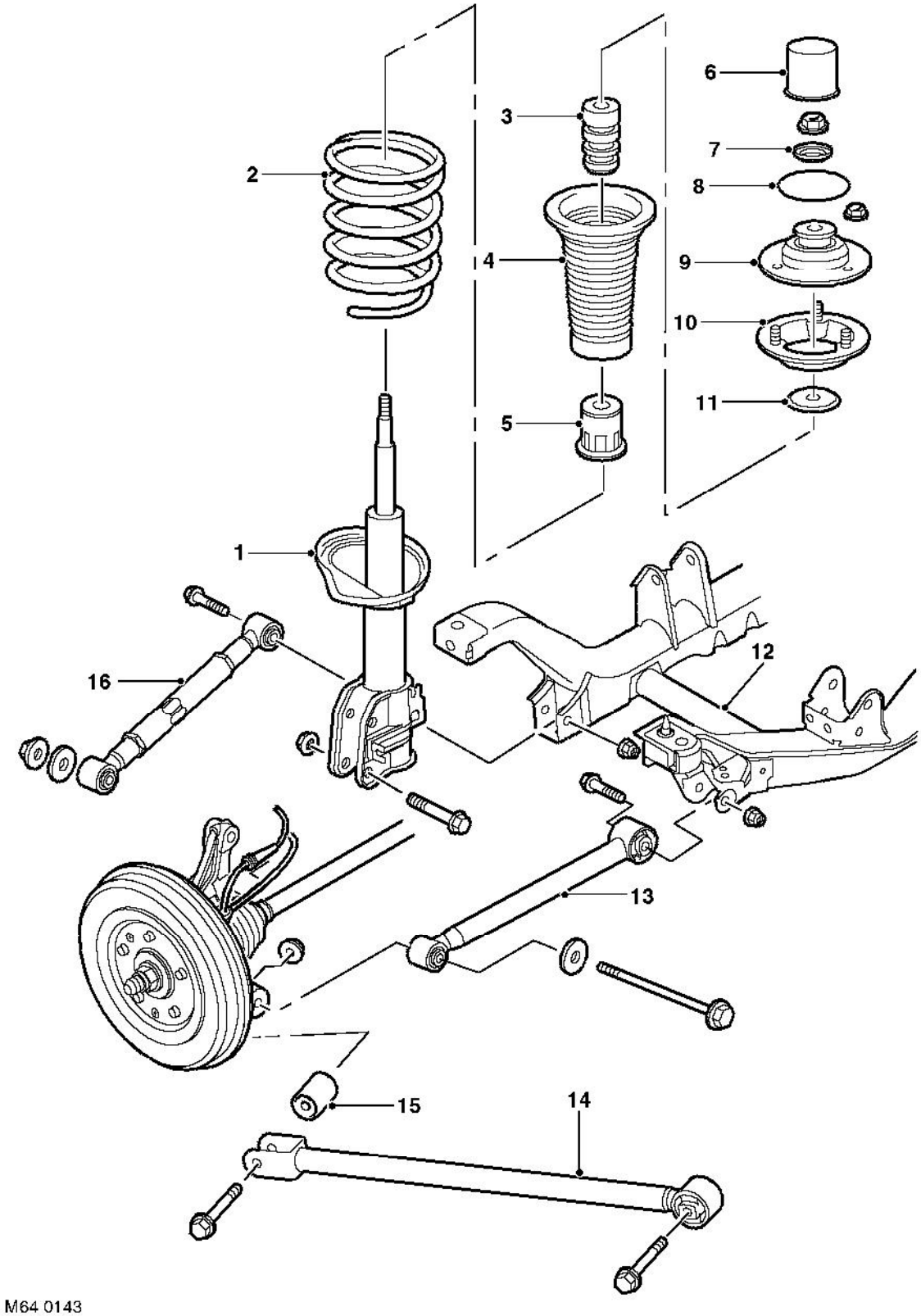
Rear Suspension Component Location



RH Rear suspension shown, LH is mirror image

1 Adjustable transverse link
2 Damper
3 Road spring
4 Rear subframe
5 Fixed transverse link
6 Trailing link
7 Drive shaft
8 Brake and hub assembly

Rear Suspension Component Detail



RH Rear suspension shown, LH is mirror image



1 Damper
2 Road spring
3 Spring aid
4 Dust cover
5 Bump cup
6 Cover
7 Rebound washer
8 Seal
9 Top mount
10 Spring seat
11 Bump plate
12 Rear subframe
13 Fixed transverse link
14 Trailing link
15 Bush
16 Adjustable transverse link

Description

General
The rear suspension comprises two MacPherson strut dampers with coil springs and two sets of three links (known as "trapezoidal links"). A rear subframe is bolted to the body and provides the mounting points for the fixed and adjustable links. The third link is known as the trailing link and is attached from the hub carrier to the body.

The suspension is designed to allow longitudinal movement of the wheel, which allows the wheel to move rearwards and upwards in response to surface undulations. The longitudinal movement allows the springs and dampers time to react to surface changes and improves ride quality.

MacPherson Struts
The left and right hand dampers are handed but otherwise similar in construction. The rear dampers are similar to the front dampers but have slightly different damping characteristics.

The damper body is fabricated from thick walled tubing and has welded brackets for attachment of the hub carrier. Two smaller welded brackets provide for the attachment of the brake hose to the brake pipe and the ABS sensor cable.

Each damper is fitted with a coil spring. The coil spring locates in a fabricated seat and is retained in a compressed condition on the damper by a top mount and nut. The top mount is fitted with three studs which locate in mating holes in the inner wing turret and retained with three self locking nuts. A bump plate is fitted which accommodates a spring aid. The bump plate is sealed against the inner wing turret to prevent the ingress of moisture into the interior load space.

The spring rates differ between the front and rear suspension.

A spring aid and a bump cup are fitted to the damper to prevent shock loads when the damper is fully compressed. A dust cover prevents the ingress of dirt and water to maintain the integrity of the chromium plated damper rod.

The damper functions by restricting the flow of a hydraulic fluid through internal galleries within the damper. A chromium plated damper rod moves laterally within the damper. As the rod moves, its movement is limited by the flow of fluid through the galleries thus providing damping of undulations in the terrain. The damper rod is sealed at its exit point from the damper body to maintain fluid within the unit and to prevent the ingress of dirt and moisture. The seal also acts as a wiper to keep the rod outer diameter clean.

Trapezoidal Links
Three links make up the trapezoidal linkage. The fixed transverse link is fabricated and is not adjustable. The adjustable transverse link comprises a tube, threaded at each end. A threaded fitting is screwed into each end of the tube and locked with lock nuts to a prescribed distance between centres. Each fitting has a pressed bush installed. The trailing link is fabricated and is not adjustable.

The fixed transverse link is bushed at each end and is located in the forward mounting of the rear subframe and the forward attachment on the hub. The adjustable transverse link is also bushed at each end and is located in the rearward mounting of the rear subframe and the rearward attachment on the hub. The fixed transverse link and the adjustable transverse link are attached to the rear subframe with individual bolts and nuts and are attached to the hub with a single bolt and nut with a washer at each end.

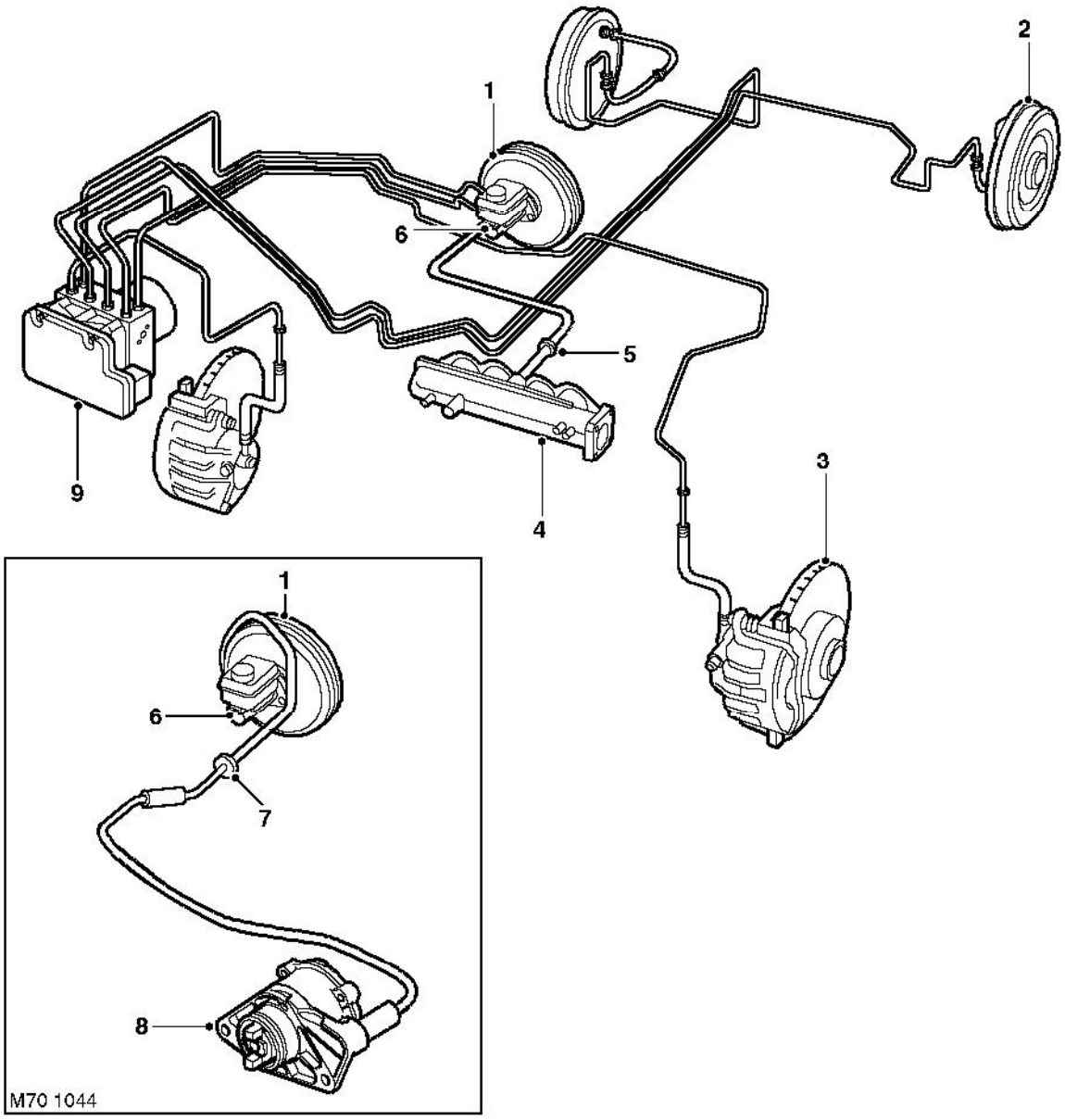
The trailing link is bushed at one end. The bushed end is located in a separate bracket which is bolted to the body. The link is secured with a bolt which screws through the bracket into a captive nut in the body rail. The opposite end is forked and locates over a bushed lug on the hub and secured with a bolt and nut.

The fixed transverse links, the adjustable transverse links and the trailing link have a significant role in the vehicle handling. The bushes in each link control the longitudinal movement of the wheel due to braking, acceleration or surface undulations.



The adjustable transverse link allows for the toe-in of the wheel to be adjusted if necessary. The fixed transverse link is slightly shorter than the adjustable link which promotes a small amount of toe-in during cornering. This also minimizes the effects of bump steer. The bush attaching the fixed transverse link to the rear subframe has a very soft initial movement rate which becomes progressively harder as the rate of deflection increases. The three remaining bushes in the fixed transverse and the adjustable transvserse links are of hard construction which give precise handling and minimizes transient steer effects. The soft bush allows for small amounts of toe-in during cornering.

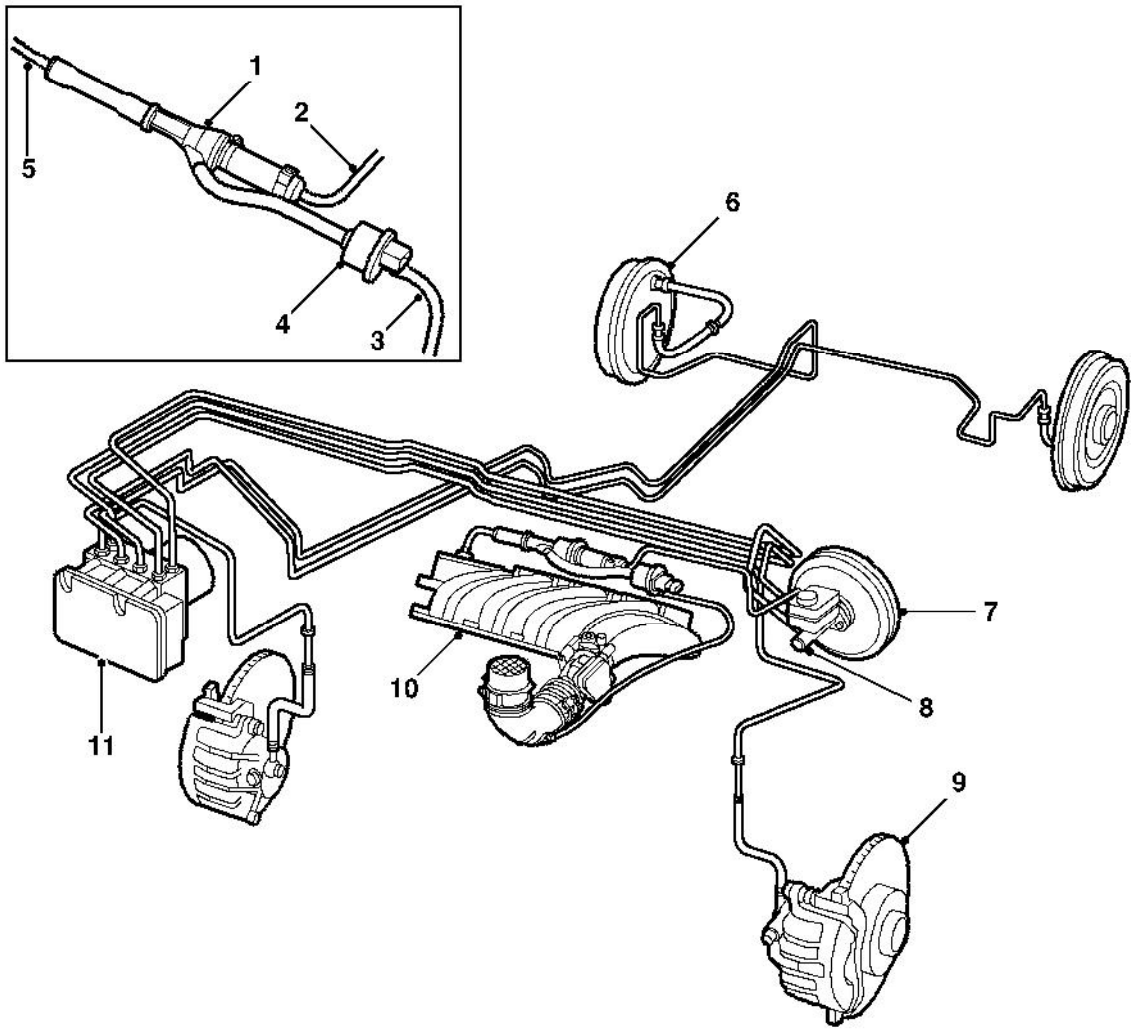
Brake System Layout (K1.8 and Td4)



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

Brake System Layout (KV6)



M70 1112

LHD shown, RHD similar

1 Vacuum enhancer venturi valve
2 Vacuum pipe from brake servo
3 Air feed pipe from intake duct
4 Vacuum enhancer solenoid valve
5 Vacuum pipe from inlet manifold
6 Rear brake
7 Brake servo assembly
8 Master cylinder assembly
9 Front brake
10 Engine inlet manifold
11 ABS modulator/ECU

Description

General
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.

Slip Control System
Freelander incorporates an electronic slip control system. Up to 2001 MY, this consists of a TEVES Mk 20 ABS modulator and passive ABS sensors. From 2002 MY onwards, a TEVES Mk 25 ABS modulator and active ABS sensors are installed. Both systems incorporate the same features, as follows:

- Anti-lock braking system
- Hill descent control
- Electronic traction control
- Electrical brake-force distribution
- CAN communication link

Both systems communicate via CAN with the Engine Control Module (ECM), the instrument pack and, on automatic derivatives, with the Electronic Automatic Transmission (EAT) ECU. The systems comprise the following components:

- Electronic control unit
- Modulator
- ABS sensors
- Mechanical brake switch
- Brake fluid level switch
- HDC relay and switch
- 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 software driver which will result in the illumination and disabling 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
  - Failure of two ABS sensors
  - Main driver failure
  - Redundancy error
  - Over voltage

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:

- Ignition voltage supplied to the ABS ECU < 8 volts
- Failure of one or more of the ABS sensors
- Pump motor failure

If there is a CAN error message from the ECM or the EAT ECU, or if there is a brake pedal switch fault, the ABS ECU disables the ETC and HDC functions and illuminates the related warning lamps.

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 outlet 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

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 of the inlet valves and will generate relevant fault codes which can be accessed via TestBook/T4.

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 ABS ECU can detect electrical failure of each of the outlet valves and will generate relevant fault codes which can be accessed via TestBook/T4.

ABS Sensors
Up to 2002 MY

An ABS 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 reluctor 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.

The exciter rings for the ABS sensors are fitted to the outer diameter of the constant velocity joint on each drive shaft, and shielded by the hub centre boss.

From 2002 MY

An active ABS sensor is installed in each of the four wheel hub carriers to provide the ABS ECU with a speed signal from each road wheel. Each of the ABS sensors is positioned in close proximity to the inboard seal of the related wheel bearing and secured with a bolt. The seals, which rotate with the wheels, each contain a magnetic element incorporating 48 pole pairs.

The ABS sensors operate 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 ABS ECU. When the wheels rotate, the pole pairs in the seals induce voltage fluctuations in the ABS sensors that are converted into square wave signals and output to the ABS ECU. The frequency of the signal is proportional to wheel speed.

Since the sensors are active devices, an output is available when the road wheels are not turning, which enables the ABS ECU to check the sensor while the vehicle is stationary.

All ABS Sensors

Failures or malfunctions relating to the ABS sensors and connections are detected by the ABS ECU. In the event of failure of two or more of the ABS 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 brake 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 a double contact switch where the Brake Lamp Switch (BLS) contacts are open and the Brake Test Switch (BTS) contacts are closed when the brake pedal is at rest. When the pedal is depressed, the BLS contacts close and BTS contacts open, supplying 12 volts to the brake/stop lamps and indicating to the ABS ECU that the pedal has been operated. When the pedal is depressed there is a time when both the BLS and the BTS contacts are closed, which allows the ABS ECU to perform a plausibility check on the switch. The switch used is a carry over from the Range Rover.

A Hall effect brake pedal position sensor is installed adjacent to the mechanical brake switch. This is not used by the brake system but by other system ECU's which are not compatible with the outputs from a mechanical switch.

Brake Fluid Level Switch

The Brake Fluid Level Switch (BFLS) is a Reed switch located in the brake fluid reservoir. The BFLS is connected to the ABS ECU and to earth. The BFLS is closed when the brake fluid level is above the minimum limit. If the brake fluid level decreases below the minimum limit, the BFLS opens and the ABS ECU sends a CAN message to the instrument pack to activate the brake warning lamp.

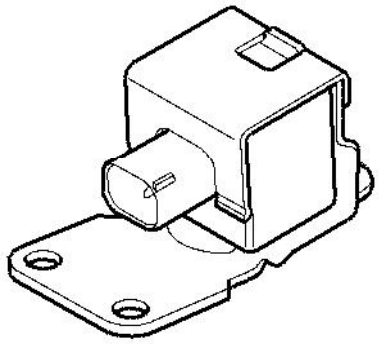
Hill Descent Control Relay and Switch

The HDC relay is located inside the engine compartment fusebox. The HDC switch is a latching switch mounted on the gear lever surround of automatic vehicles and the gear lever for manual vehicles.

Accelerometer

The accelerometer (sometimes known as the "G" sensor) is mounted near the centre-line of the vehicle alongside the handbrake lever. It provides information to the ABS ECU regarding vehicle longitudinal acceleration.

The ABS ECU uses the input from the accelerometer to corroborate the inputs from the ABS sensors, e.g. if all four wheels are spinning, the input from the accelerometer enables the ABS ECU to determine the true speed of the vehicle.



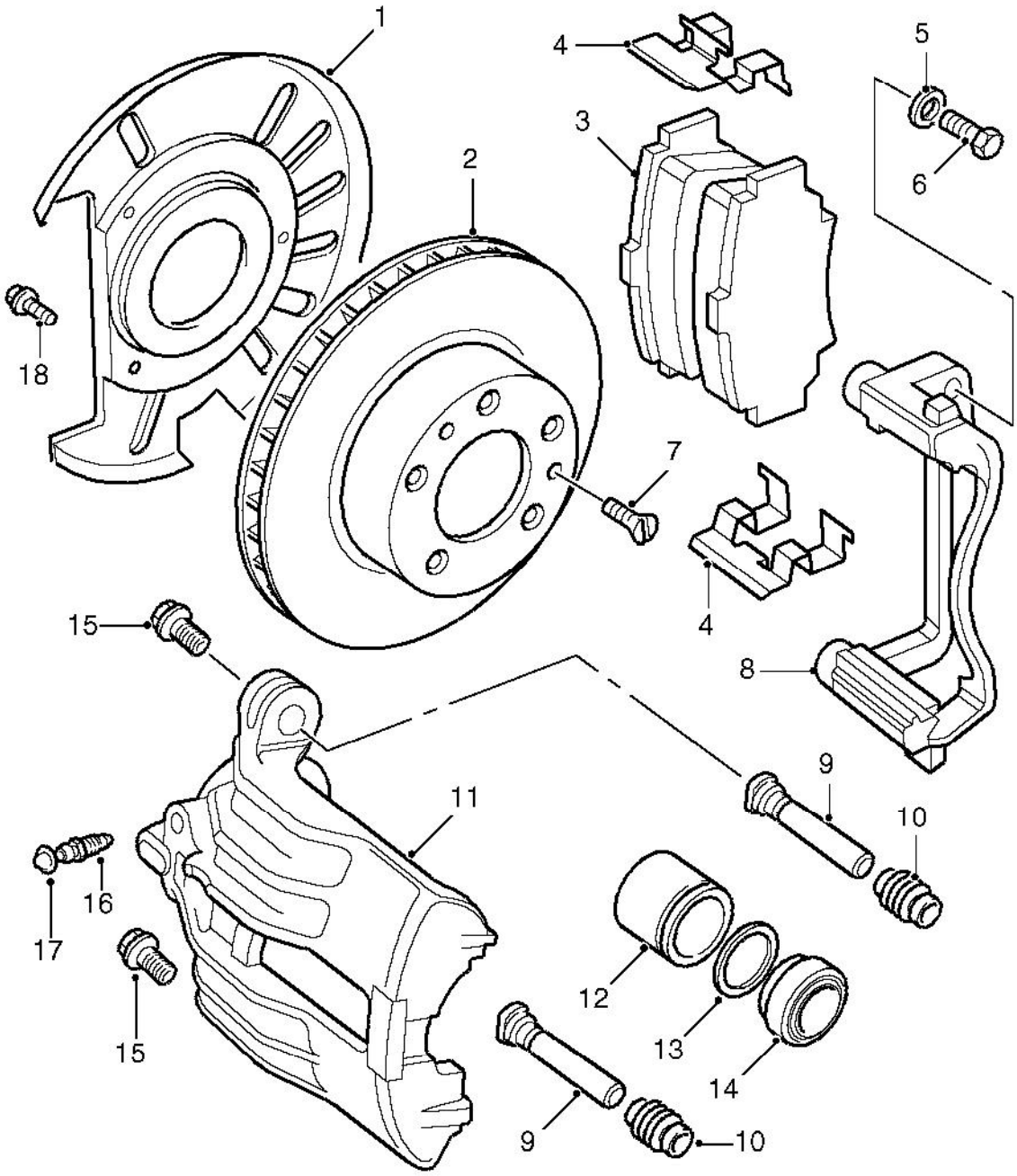
M70 1164

Front Brakes

The front brakes each comprise a hub mounted, single piston caliper assembly and a vented disc. The inboard side of the disc is protected by a mudshield.

When hydraulic pressure is supplied to the caliper, the piston extends and forces the inner pad against the disc. The caliper body reacts and slides on the guide pins to bring the outer pad into contact with the disc.

Front Brake Components



M70 1045

1 Mudshield
2 Brake disc-vented
3 Brake pads
4 Pad retainer
5 Washer
6 Caliper fixing bolt
7 Brake disc fixing screw
8 Caliper carrier
9 Guide pin
10 Guide pin dust cover
11 Caliper body
12 Piston
13 Piston seal
14 Piston dust cover
15 Guide pin bolt
16 Bleed screw
17 Bleed screw cap
18 Mudshield fixing bolt

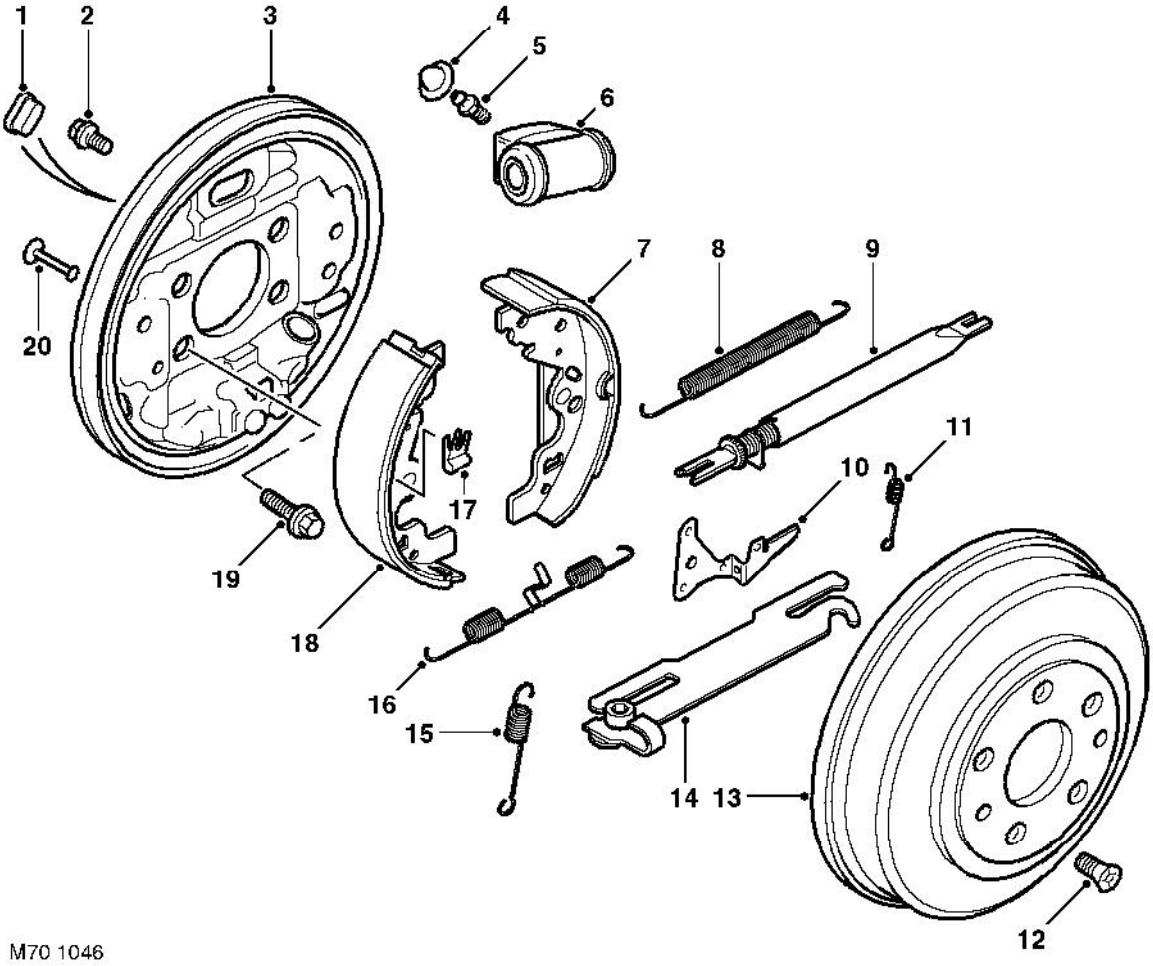
Rear Brakes

The rear brakes each comprise a hub mounted backplate and drum containing leading and trailing brake shoes when operated by the foot brake. An adjuster rod is incorporated to automatically adjust the brake shoes to compensate for wear of the brake linings. Adjustment occurs during operation of the foot brake.

When hydraulic pressure is supplied to the wheel cylinder, the cylinder extends and forces the brake shoes against the drum.

When a force is supplied to the shoes via the hand brake lever and cables, both brake shoes become leading.

Rear Brake Components



1 Blanking plug
2 Wheel cylinder fixing bolt
3 Backplate
4 Bleed screw cap
5 Bleed screw
6 Wheel cylinder
7 Leading brake shoe
8 Upper shoe return spring
9 Adjuster rod
10 Adjuster lever
11 Anti rattle spring
12 Drum fixing screw
13 Brake drum
14 Hand brake strut
15 Adjuster lever spring
16 Lower shoe return spring
17 Shoe retaining pin spring clip
18 Trailing brake shoe
19 Backplate fixing bolt
20 Shoe retaining pin

Hydraulic System
The hydraulic unit of the modulator consists of a pump, 12 solenoid operated valves and accumulator and damper chambers. Each brake unit has its own inlet and outlet valves.

The hydraulic system operates the brakes in response to brake pedal movement.

For normal brake operation, brake pedal movement is assisted by the brake servo assembly and transmitted to the master cylinder assembly. The master cylinder assembly converts brake pedal movement to hydraulic pressure. Primary and secondary brake pipe circuits supply the hydraulic pressure to the brakes: the primary circuit supplies the front left and rear right brakes; the secondary circuit supplies the front right and rear left brakes.

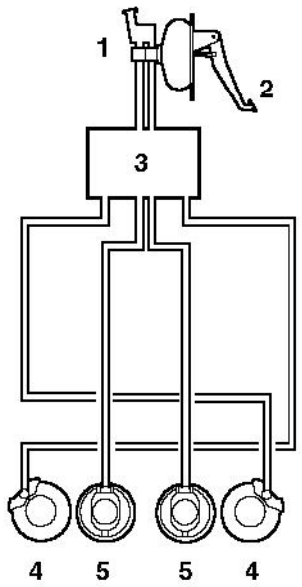
A red, brake warning lamp in the instrument pack illuminates if the fluid level in the hydraulic system falls to an unsafe level. The brake fluid level is checked via a level switch in the brake fluid reservoir.

On right hand drive vehicles the brake fluid reservoir is remotely located on a bracket on the bulkhead. Left hand drive vehicles have the brake fluid reserver in the usual position on top of the master cylinder.

Vacuum for the brake servo assembly is obtained from the engine inlet manifold (petrol models) or a vacuum pump (diesel models) through a vacuum line and non return valve.

To reduce operating noise, sleeving is installed on some of the brake pipes in the engine compartment and the pipes are located in sprung pipe clips.

ABS Hydraulic System Schematic



M70 1047

1 Servo/Master cylinder assembly
2 Brake pedal
3 ABS modulator
4 Front brake
5 Rear brake

Brake Servo Assembly
The brake servo assembly provides power assistance to reduce the pedal load when braking.

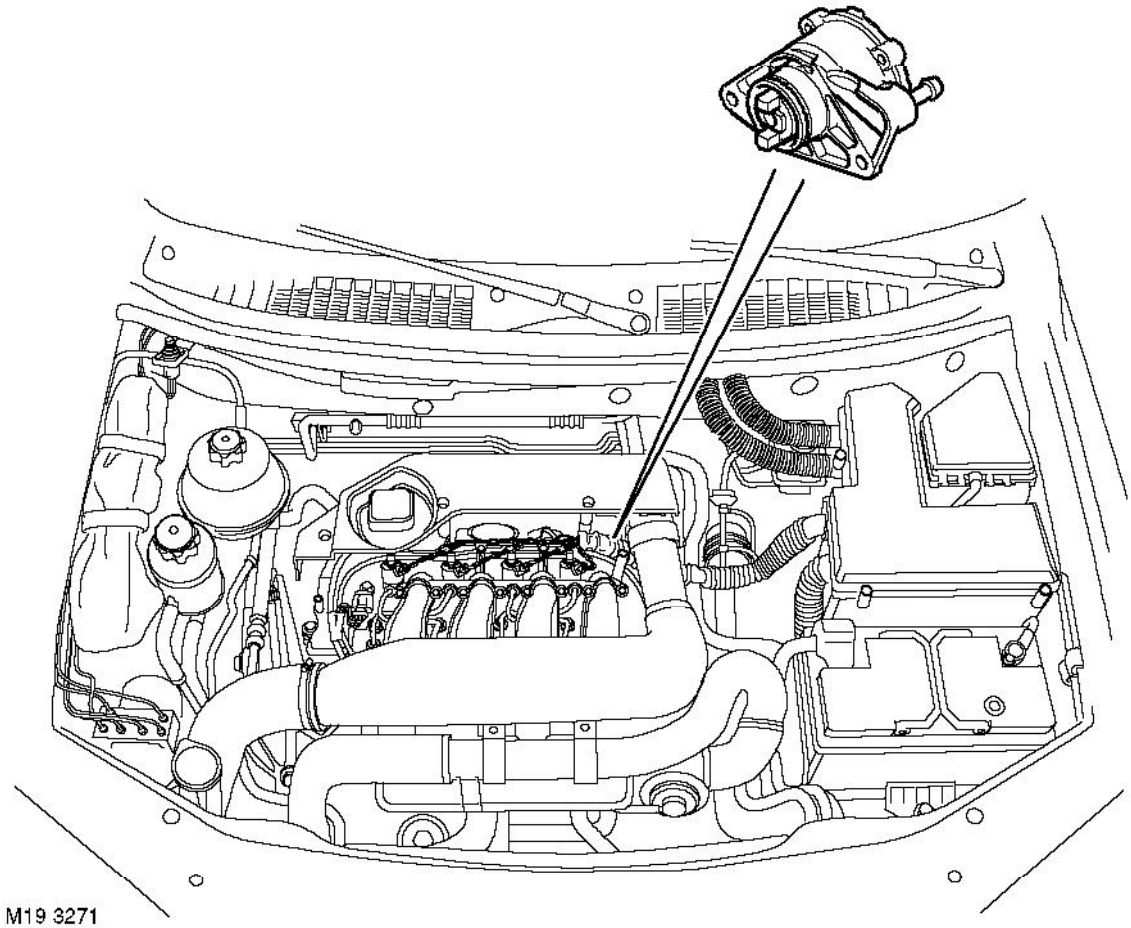
The assembly is attached to the front of the pedal box and comprises a circular housing containing a diaphragm, push rods, valve and filter. A push rod at the rear of the housing is connected to the brake pedal. The vacuum line is connected to a port in the front face of the housing.

With the brake pedal released and the engine running, vacuum pressure is present on both sides of the diaphragm. When the brake pedal is pressed, the rear push rod moves forward and opens the valve to allow atmospheric pressure through the filter into the pedal side of the diaphragm. The pressure differential acting on the diaphragm increases the pressure being applied by the brake pedal, which is transmitted to the master cylinder via the forward push rod.

If the servo fails, the hydraulic system will still function but will require greater pedal effort due to the lack of vacuum assistance.

Vacuum Pump (Diesel Models Only)
As the diesel engine air inlet system does not produce sufficient depression to operate the brake servo assembly, an engine driven vacuum pump is installed. The vacuum pump is attached to the LH end of the camshaft cover and driven at half engine speed by the exhaust camshaft. The pump is a rotary vane type, lubricated and cooled by engine oil supplied through a jet in the end of the exhaust camshaft. Air extracted from the brake servo is vented into the camshaft cover with returning lubricating oil.

Vacuum Pump Location



1 Alternator
2 Vacuum pump
3 Brake servo assembly vacuum connection
4 Oil feed pipe
5 Oil drain pipe

Vacuum Enhancer System (KV6 Only)
The vacuum enhancer system increases the relatively low vacuum available from the inlet manifold to increase braking assistance. The system consists of a venturi valve, a solenoid valve and associated pipes.

The venturi valve is installed in the vacuum pipe between the brake servo and the inlet manifold. An air feed pipe, from the intake duct upstream of the throttle body via the solenoid valve, is also connected to the venturi valve. Internal ducts in the venturi valve connect the brake servo and air feed ports to the inlet manifold port. The duct connecting the air feed port to the inlet manifold port incorporates the venturi. A check valve, integrated into the brake servo port, prevents the reverse flow of air and fuel vapour to the brake servo.

The solenoid valve controls the air feed to the venturi valve. Operation of the solenoid valve is controlled by the ECM.

To improve engine idle speed refinement, when the gearbox lever is in Park or Neutral, the solenoid valve is closed and the brake servo senses the vacuum in the inlet manifold via the venturi valve. When the gearbox lever is selected to positions other than Park or Neutral, the ECM energises the solenoid valve and air from the upstream side of the throttle body is fed to the venturi valve. The air flows through the venturi valve into the inlet manifold. As the air flows through the venturi in the venturi valve, it increases in velocity and decreases in pressure, resulting in an increase in the vacuum sensed by the brake servo. Depending on ambient conditions and engine speed, the vacuum enhancer system increases inlet manifold vacuum by a maximum of approximately 40%.

Master Cylinder Assembly

The master cylinder assembly produces hydraulic pressure to operate the brakes when the brake pedal is pressed. The assembly is attached to the front of the brake servo assembly, and comprises a cylinder containing two pistons in tandem. The rear piston produces pressure for the primary circuit and the front piston produces pressure for the secondary circuit.

The brake fluid reservoir is located either on top of the master cylinder assembly (LH drive vehicles) or above the master cylinder on a bracket on the bulkhead (RH drive vehicles). The reservoir is internally divided to provide an independent supply of fluid to each brake circuit, and so prevent a single fluid leak from disabling both primary and secondary brake circuits.

Should a failure occur in one circuit, the remaining circuit will still operate effectively, although brake pedal travel and vehicle braking distances will increase. If the fluid level in the reservoir is too low, the brake fluid level switch in the reservoir filler cap breaks a contact to the ABS ECU, which sends a CAN message to illuminate the brake warning lamp in the instrument pack.

ABS Master Cylinder

When the brake pedal is pressed, the front push rod in the brake servo assembly pushes the primary piston along the cylinder bore. This produces pressure in the primary pressure chamber which, in conjunction with the primary spring, overcomes the secondary spring and simultaneously moves the secondary piston along the cylinder bore. The initial movement of the pistons, away from the piston stops, closes the primary and secondary centre valves. Further movement of the pistons then pressurizes the fluid in the primary and secondary pressure chambers, and thus the brake circuits. The fluid in the chambers, behind the pistons, is unaffected by movement of the pistons and can flow unrestricted through the feed holes between the chambers and the reservoir.

When the brake pedal is released, the primary and secondary springs push the pistons back down the bore of the cylinder. As the pistons contact the piston stops, the primary and secondary centre valves open, which allows fluid to circulate unrestricted between the two hydraulic circuits and the reservoir, through the centre valves, the chambers behind the pistons and the feed holes.

ABS

The ABS is a full time, four channel system that gives individual speed control of all four wheels to provide the vehicle with anti-lock braking (ABS), Electronic Traction Control (ETC.) Hill Descent Control (HDC) and Electronic Brake force Distribution (EBD) functions.

ABS Modulator

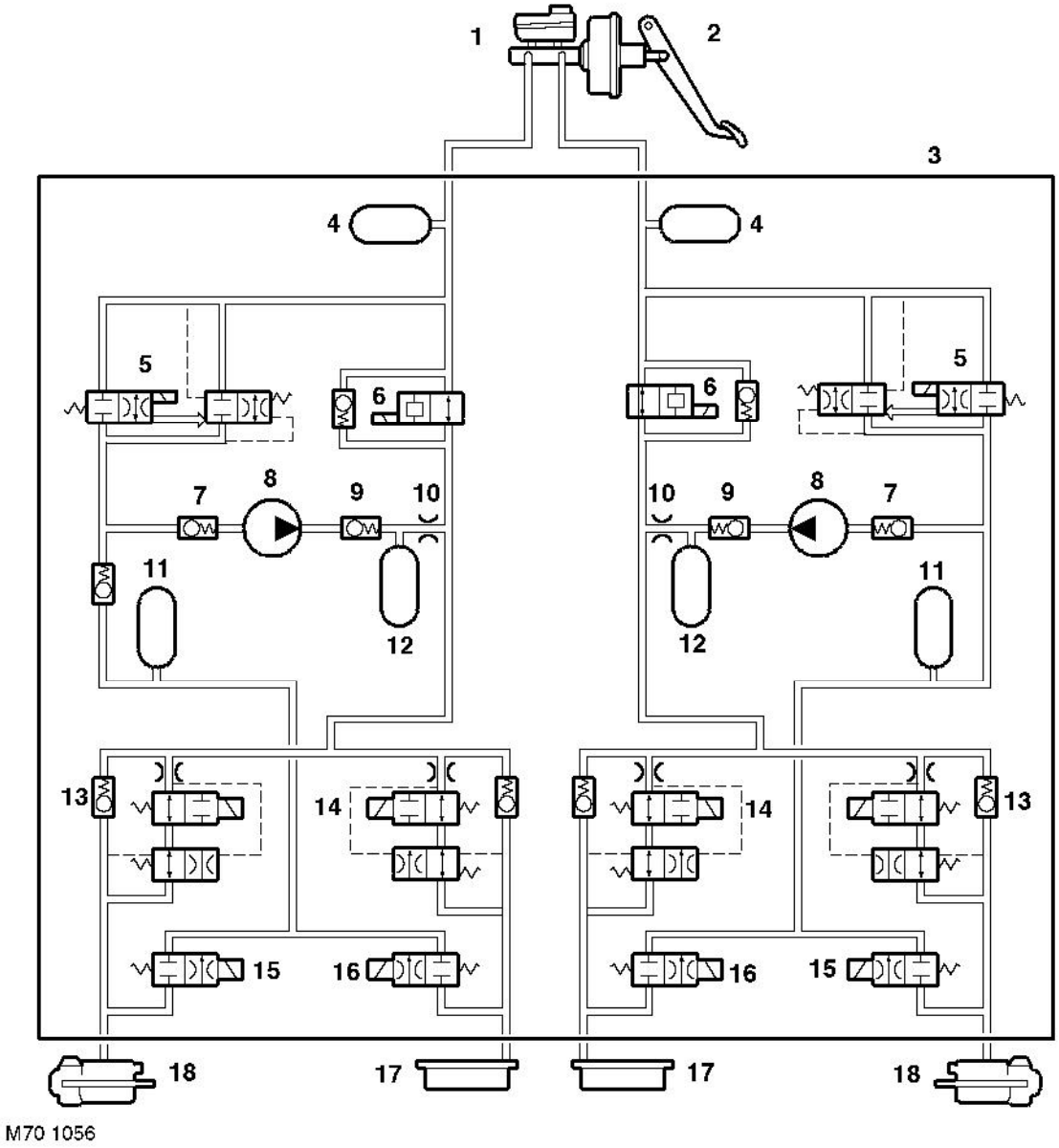
The ABS modulator controls the supply of hydraulic pressure to the brakes in response to inputs from the ABS ECU. The modulator is attached by three mounting bushes to a bracket on the RH inner wing, and connected to the primary and secondary hydraulic circuits downstream of the master cylinder assembly. A multi-pin connector links the ABS modulator to the vehicle wiring.

Internal passages in the ABS modulator, separated into primary and secondary circuits, connect to the various components that control the supply of hydraulic pressure to the brakes. Separation valves and check valves control the flow through the internal circuits. Damper chambers and restrictors are included in each circuit to refine system operation. Inlet and outlet solenoid valves control the flow to the individual brakes. An accumulator is connected to each circuit to absorb flow surges. A common return pump is connected to both circuits to provide a pressure source and return fluid to the reservoir.

The ABS modulator has three operating modes:

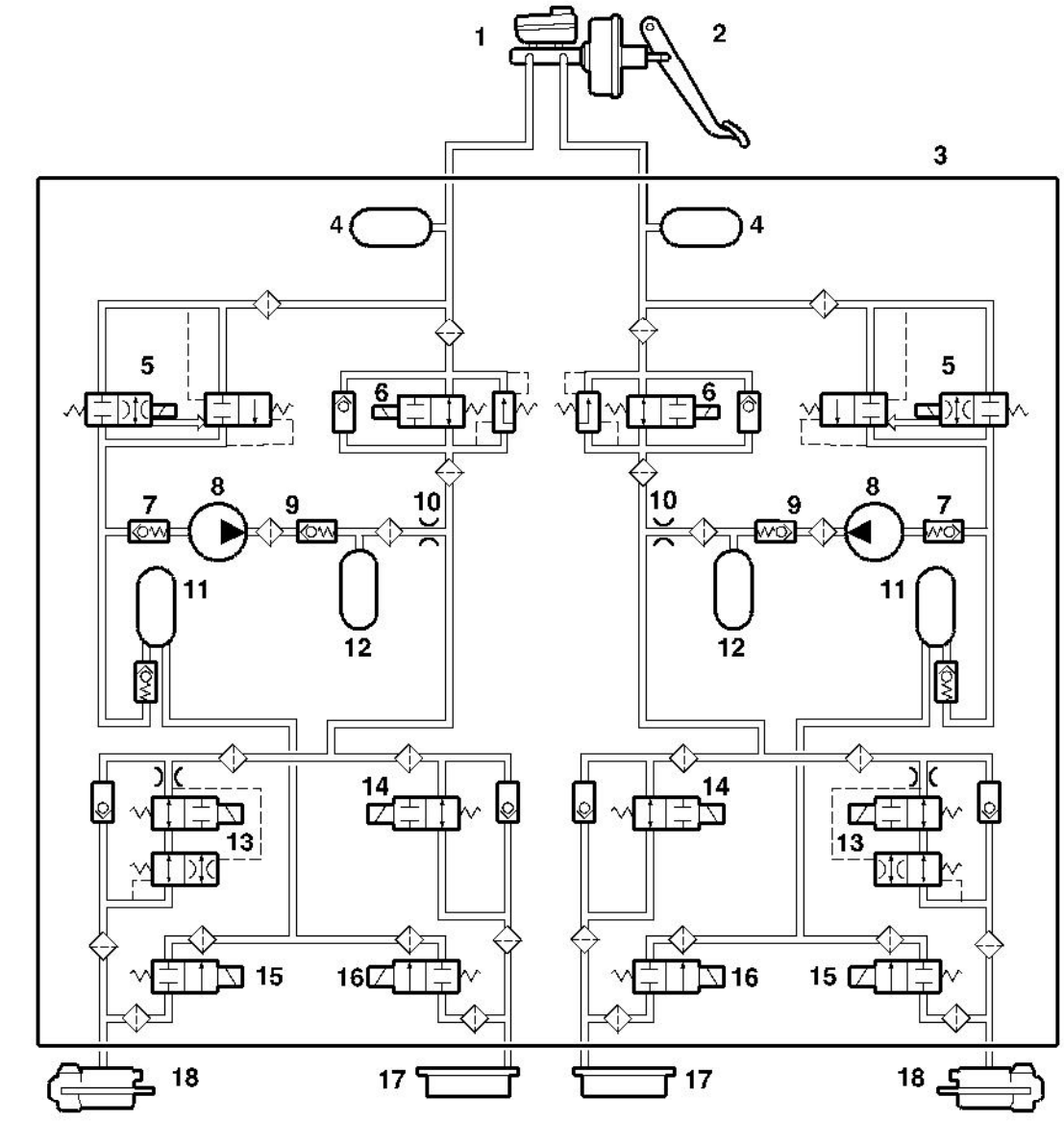
- Normal braking mode: When the brake pedal is pressed, pressurized fluid from the master cylinder assembly flows through the open separation valves and inlet valves to operate the brakes.
- ABS braking mode: When in the normal braking mode, if the ABS ECU detects that a wheel is about to lock, it energizes the inlet and outlet solenoid valves of the related brake and starts the return pump. The inlet solenoid valve closes to isolate the brake from pressurized fluid; the outlet solenoid valve opens to release pressure from the brake into the return pump circuit. The brake releases and the wheel begins to accelerate. The ABS ECU then operates the inlet and outlet valves to control the supply of hydraulic pressure to the brake and apply the maximum braking effort (for the available traction) without locking the wheel.
- Active braking mode: When ETC or HDC are enabled, and the ABS ECU determines that active braking is required, it starts the return pump. Hydraulic fluid, drawn from the reservoirs through the master cylinder, is pressurized by the return pump. The ABS ECU then operates the inlet and outlet solenoid valves to control the supply of hydraulic pressure to the individual brakes and slow the wheel(s).

ABS Modulator Schematic (Up To 2002 MY)



1 Master cylinder
2 Brake pedal
3 ABS modulator
4 Pulsation damper
5 Solenoid valve
6 Separation valve
7 One way check valve
8 ABS pump
9 Check valve
10 Restrictor valve
11 Low pressure accumulator
12 Damper chamber
13 Check valve
14 Inlet valve
15 Outlet valve
16 Outlet valve
17 Rear brake
18 Front brake

ABS Modulator Schematic (From 2002 MY)



M70 1117

1 Master cylinder
2 Brake pedal
3 ABS modulator
4 Pulsation damper
5 Shuttle valve
6 Separation valve (with integrated pressure relief valve)
7 Check valve
8 Return pump
9 Check valve
10 Restrictor
11 Low pressure accumulator
12 Damper chamber
13 Front brake inlet valve
14 Rear brake inlet valve
15 Front brake outlet valve
16 Rear brake outlet valve
17 Rear brake
18 Front brake

ABS ECU

The ABS ECU controls the operation of the ABS modulator to provide the ABS, ETC and HDC functions. It also operates warning lamps in the instrument pack to provide the driver with status information on each function. The ABS ECU is attached to the ABS modulator. Incorporated into the ABS ECU are integrated circuits and software for system control and diagnostics. An electrical connector interfaces the unit with the vehicle wiring.

The warning lamps consist of:

- An amber ABS graphic.
- An amber ETC graphic.
- Two inclined vehicle graphics for HDC, one amber (fault), which includes an exclamation mark, and one green (information).

The warning lamps are Light Emitting Diodes (LED) installed on the printed circuit board of the instrument pack and cannot be replaced separately.

When the ignition is switched on, the ABS ECU performs a 'bulb' check of the warning lamps as part of the power up procedure. If a warning lamp remains illuminated after the bulb check, a fault has been detected and repair action is required. On a serviceable system:

- The ETC and HDC warning lamps are extinguished after 2 to 3 seconds.
- Up to 2002 MY, the ABS warning lamp is extinguished briefly, after 1.3 to 2 seconds, then remains illuminated until vehicle speed exceeds 4.4 mph (7 km/h).
- From 2002 MY, the ABS warning lamp is extinguished briefly, after 1.3 to 2 seconds, is illuminated again for a further 0.5 second and then extinguished.

The ABS ECU continually calculates vehicle speed using the inputs from all four ABS sensors. Vehicle speed is used as a reference against which individual wheel speeds are monitored for unacceptable acceleration or deceleration. Vehicle speed is also output to the instrument pack for the speedometer.

Operation

ABS

The purpose of ABS is to prevent vehicle wheels locking during brake application, thus maintaining vehicle steerability and stability. This allows the vehicle to be steered while the brakes are applied, even under emergency conditions, and to avoid obstacles where there is sufficient space to redirect the vehicle.

WARNING: ABS is an aid to retaining steering control and stability while braking:

- ***ABS cannot defy the natural laws of physics acting on the vehicle.***
- ***ABS will not prevent accidents resulting from excessive cornering speeds, following another vehicle too closely, aquaplaning, etc.***
- ***The additional control provided by ABS must never be exploited in a dangerous or reckless manner which could jeopardise the safety of driver or other road users.***
- ***The fitting of ABS does not imply that the vehicle will always stop in a shorter distance.***

NOTE: During normal braking the feel of the brake pedal on vehicles equipped with ABS will be the same as that on non ABS vehicles. During anti-lock braking operation the driver will experience feedback in the form of a pulsating brake pedal and solenoid/pump motor noise from the ABS modulator.

The anti-lock braking function is automatically enabled whenever the ABS modulator is in the normal braking mode.

While the anti-lock braking function is enabled, if the ABS ECU detects a wheel decelerating faster than the average, indicating it is about to lock, it operates the ABS modulator in the ABS braking mode for the affected wheel.

ABS ECU Connector Pin Details (Up To 2002 MY)

Pin No.	Description	Input/Output
1	System earth	–
2	Front LH ABS sensor	Input
3	Front LH ABS sensor	Input
4	Not used	–
5	Rear RH ABS sensor	Input
6	Rear RH ABS sensor	Input
7	Not used	–
8	ISO 9141 K line	Input/Output
9	Accelerometer supply	Output
10	Accelerometer earth	–
11	Brake switch (BTS contacts)	Input
12	Ignition power supply	Input
13 and 14	Not used	–
15	Battery power supply	Input
16	CAN bus 1 low (connection with instrument pack)	Input/Output
17	CAN bus 1 high (connection with instrument pack)	Input/Output
18	Brake switch (BLS contacts)	Input
19	Road speed signal	Output
20	Not used	–
21	Accelerometer signal	Input
22 to 27	Not used	–
28	Hill descent switch	Input
29	System earth	–
30	Front RH ABS sensor	Input
31	Front RH ABS sensor	Input
32	Not used	–
33	Rear LH ABS sensor	Input
34	Rear LH ABS sensor	Input
35	Not used	–
36	CAN bus 2 low (connection with ECM/EAT ECU)	Input/Output
37	CAN bus 2 high (connection with ECM/EAT ECU)	Input/Output
38 and 39	Not used	–
40	HDC relay coil	Output
41	Brake fluid level switch	Input
42	Not used	–
43	Battery power supply	Input



ABS ECU Connector Pin Details (From 2002 MY)

Pin No.	Description	Input/Output
1	Battery power supply (for return pump)	Input
2	Diagnostic ISO 9141 K line	Input/Output
3	Not used	–
4	Ignition power supply	Input
5	Not used	–
6	HDC switch	Input
7 and 8	Not used	–
9	Brake fluid level switch	Input
10	Not used	–
11	CAN bus 1 high (connection with instrument pack)	Input/Output
12	Not used	–
13	CAN bus 2 low (connection with ECM/EAT ECU)	Input/Output
14	Not used	–
15	CAN bus 1 low (connection with instrument pack)	Input/Output
16	System earth	–
17 to 23	Not used	–
24	Accelerometer earth	–
25	Not used	–
26	Accelerometer supply	Output
27 to 31	Not used	–
32	Battery power supply (for solenoid valves)	Input
33	Front RH ABS sensor earth	–
34	Front RH ABS sensor signal	Input
35	HDC relay coil	Output
36	Rear LH ABS sensor signal	Input
37	Rear LH ABS sensor earth	–
38	Brake switch (BLS contacts)	Input
39	Road speed signal	Output
40	Accelerometer signal	Input
41	Brake switch (BTS contacts)	Input
42	Rear RH ABS sensor earth	–
43	Rear RH ABS sensor signal	Input
44	CAN bus 2 high (connection with ECM/EAT ECU)	Input/Output
45	Front LH ABS sensor signal	Input
46	Front LH ABS sensor earth	–
47	System earth	–

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. Traction control will not function with speeds above 50 km/h.

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, for as long as ignition voltage is supplied to the ABS ECU
- During diagnostics

To allow the vehicle to be tested on two wheel rolling roads there is a feature which allows the ETC function to be disabled. To disable ETC, the brake pedal has to be operated 10 times within 10 seconds of turning the ignition on. When traction control is disabled, the ETC warning lamp 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 ABS sensor or accelerometer faults will be registered during this period.

The ETC function can be re-enabled at the start of a subsequent ignition cycle by again operating the brake pedal 10 times within 10 seconds of turning the ignition on. Alternatively, the ABS ECU will automatically re-enable the ETC function when it receives a 4.4 mph (7 km/h) speed signal from all four ABS sensors.

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 (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 HDC information warning lamp is illuminated continuously to indicate HDC is available. If conditions are not met to enable HDC operation, after the switch is operated, the warning lamp flashes. When going downhill and HDC is selected the vehicle will maintain a target speed by applying the brakes. The target speed will be relative to the throttle pedal position. 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.

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.

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.

Fault	Status of Warning Lamps				Default Strategy
	ABS	ETC	HDC Fault	HDC Information	
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 fault	On	On	On	Off	ABS: Disabled. ETC: Disabled. HDC: Disabled.
HDC 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:

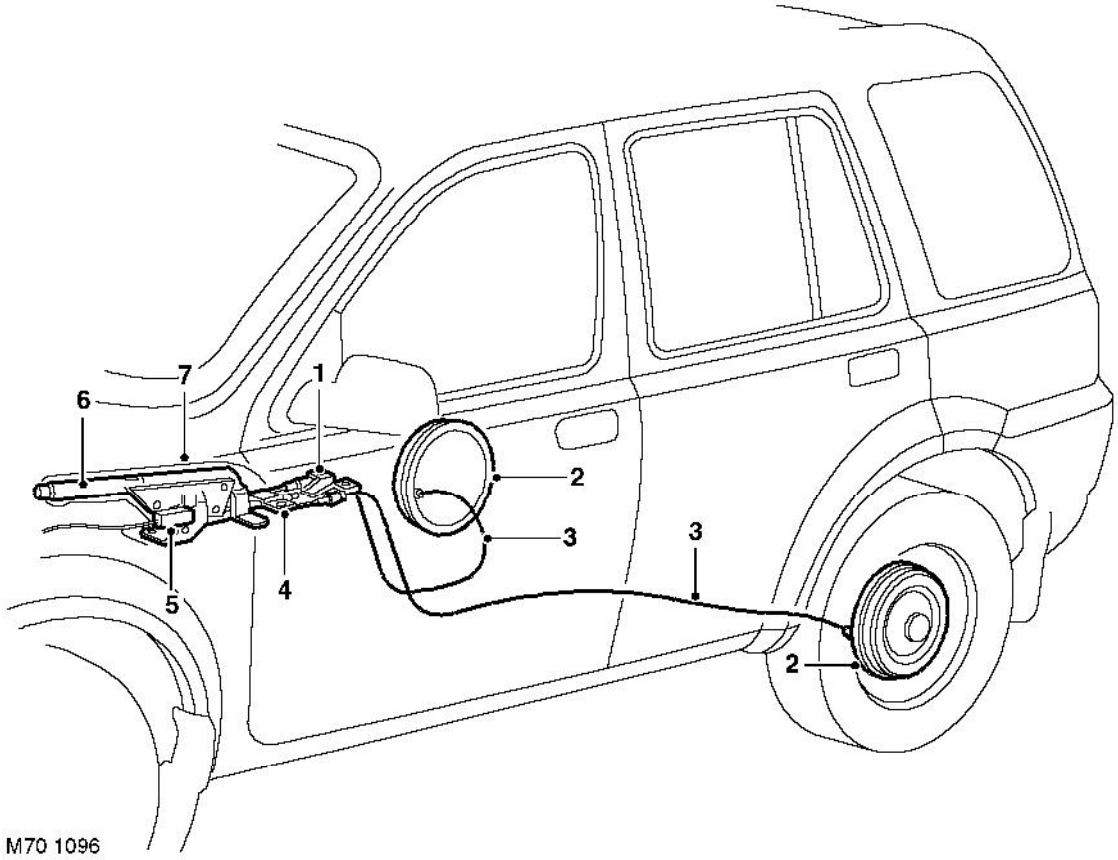
Component	Resistance, Ohms
HDC relay coil	73 to 89
ABS sensor (up to 2002 MY)	950 to 1100
ABS sensor (from 2002 MY)	1 maximum
Inlet solenoid valve	5.9 to 7.3
Outlet solenoid valve	3.0 to 3.6

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 Lamps

Operating Condition					
	Brake/ EBD (Red)	**ABS (Amber)**	**ETC (Amber)**	**HDC Fault (Amber)**	**HDC Information (Green)**
Bulb check (ABS warning lamp only flashes off if there are no faults stored in the ABS ECU):					
Up To 2002 MY	On for 1.7 seconds	On for 1.7 seconds, off for 0.5 second, on until vehicle speed >7 km/h then off	On for 1.7 seconds	On for 1.7 seconds	On for 1.7 seconds
From 2002 MY	On for 2.7 seconds	On for 1.7 seconds, off for 0.5 second, on for 0.5 second then off	On for 2.7 seconds	On for 2.7 seconds	On for 2.7 seconds
Normal operation (no faults detected)	Off	Off (after lamp check)	Off	Off	Off
Hand brake on	On	Off	Off	Off	Off
Low brake fluid	On	Off	Off	Off	Off
ABS failure	Off	On	On	On	Off
ETC failure	Off	Off	On	On	Off
ABS and EBD failure	On	On	On	On	Off
ABS ECU not connected	On	On	On	On	Off
Diagnostic mode	On	On	On	On	On
ETC disabled mode	Off	Off	On	On	Off
HDC selected, conditions not met for HDC operation	Off	Off	Off	Off	Flashes at 2Hz
HDC selected, HDC is available and vehicle ready for descent	Off	Off	Off	Off	On
HDC failure	Off	Off	Off	On	Off
Brakes overheated	Off	Off	Flashes at 2Hz	Flashes at 2Hz (if HDC selected)	-

Handbrake Component Layout



1 Cable/Console bracket
2 Rear brake
3 Rear brake cable
4 Cable equaliser
5 Warning switch
6 Handbrake lever
7 Gaiter

Description

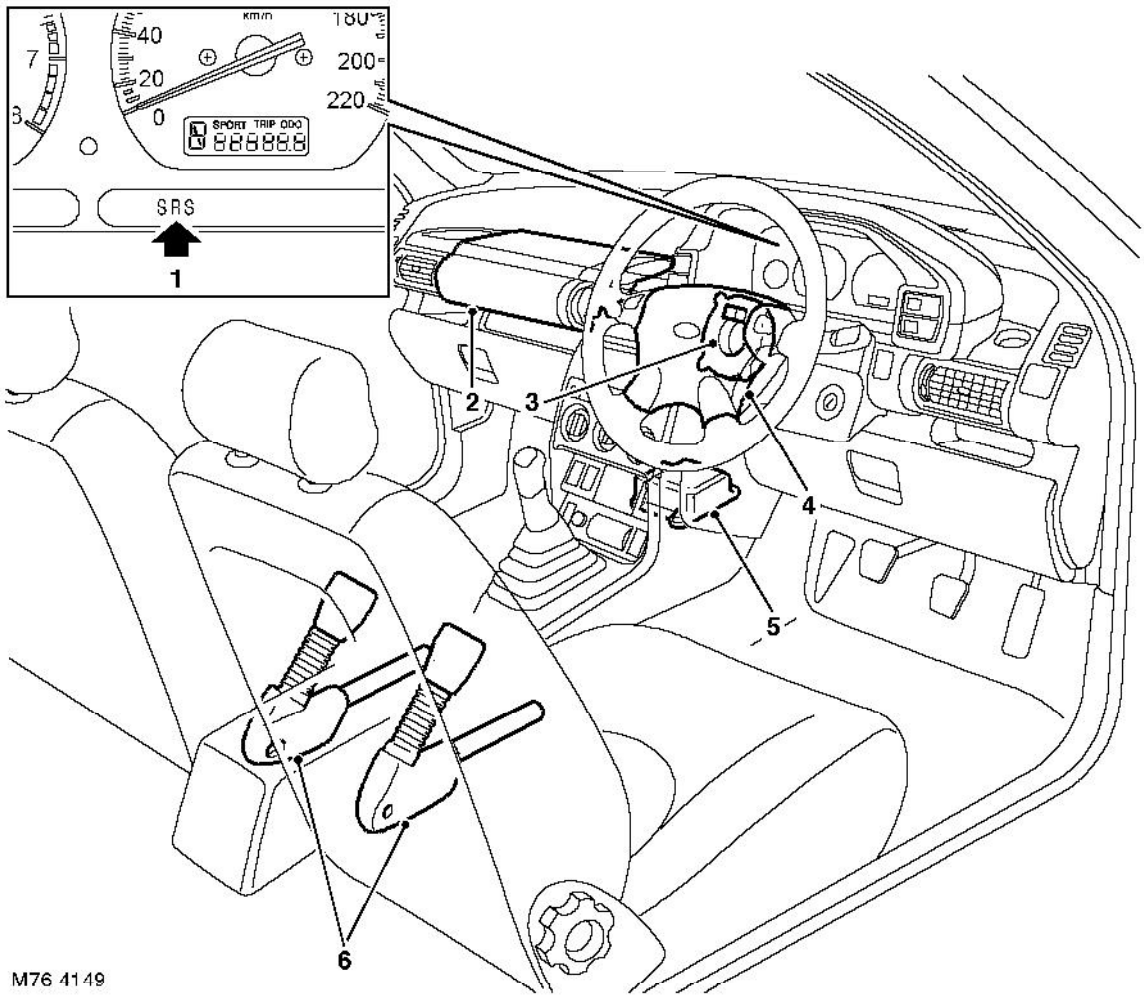
The handbrake operates on both rear brakes via two handbrake cables, a cable equaliser and an intermediate rod on the handbrake lever.

As the handbrake lever is applied, movement is transmitted by the intermediate rod and the cable equaliser to the two handbrake cables. Each handbrake cable pulls on a lever on the trailing brake shoe. The lever pivots against the brake's adjuster rod, which forces the brake shoes apart and brings the brake linings into contact with the drum.

The cables are adjusted by the handbrake adjust nut that locates the cable equaliser on the intermediate rod.

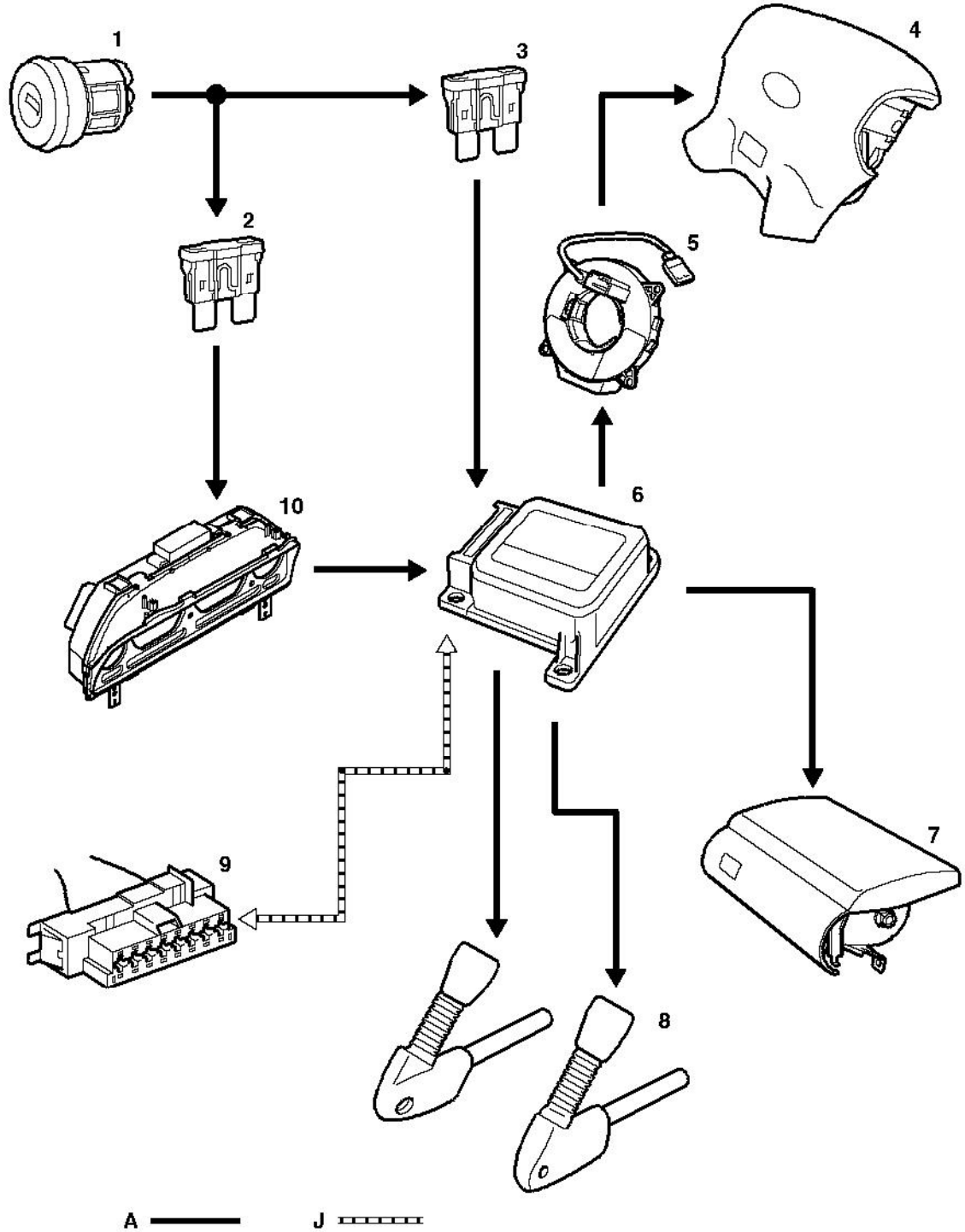
A warning switch, on the base of the handbrake lever, operates the brake warning lamp in the instrument pack. When the handbrake is applied and the ignition is on, the warning switch connects an earth to the instrument pack and illuminates the brake warning lamp. In some markets, the central control unit performs a bulb check of the brake warning lamp each time the ignition is switched on.

SRS Component Layout



1 SRS warning lamp
2 Passenger's airbag module
3 Rotary coupler
4 Driver's airbag module
5 Airbag DCU (pre 2002 MY version shown)
6 Seat belt pretensioners

SRS Control Diagram



M76 4150

A = Hardwired connections; J = Diagnostic ISO 9141 K line bus

1 Ignition switch
2 Fuse 8, passenger compartment fusebox
3 Fuse 36, passenger compartment fusebox
4 Driver's airbag module
5 Rotary coupler
6 Airbag DCU (pre 2002 MY version shown)
7 Passenger's airbag module
8 Seat belt pretensioners
9 Diagnostic socket
10 Instrument pack

Description

General

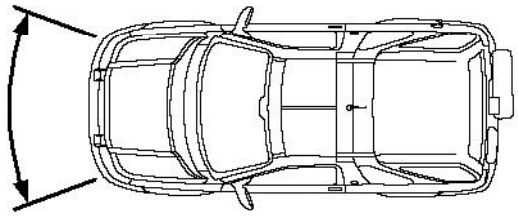
The Supplementary Restraint System (SRS) provides additional protection for front seat occupants during a frontal collision above a preset severity. The SRS is an electronically controlled, single point sensing system. The system comprises:

- An airbag Diagnostic Control Unit (DCU).
- A driver's airbag module.
- A front passenger's airbag module.

NOTE: In some markets an optional stowage bin is installed in place of the front passenger's airbag module.

- Two front seat belt pretensioners.
- A warning lamp.

Impact Zone for SRS Activation (Approximate)

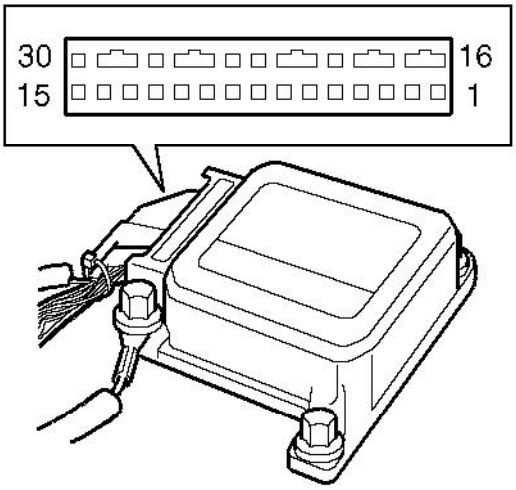


M76 4151

Interconnecting wiring for the system is integrated into the vehicle harnesses. A rotary coupler connects the vehicle harness to the driver's airbag module. An ISO 9141 K line (bi-directional) serial communication link connects the airbag DCU to the vehicle's diagnostic socket.

The system is operational only while the ignition is on. With the ignition on, any frontal collision is detected by the airbag DCU. If the impact is above the preset severity, the DCU sends out simultaneous fire signals to the airbag modules and the seat belt pretensioners. The airbag modules then deploy protective airbags in front of the driver and front seat passenger, and the seat belt pretensioners retract to tighten the front seat belts. Collision detection to full deployment of the airbags and pretensioners takes approximately 45 milliseconds.

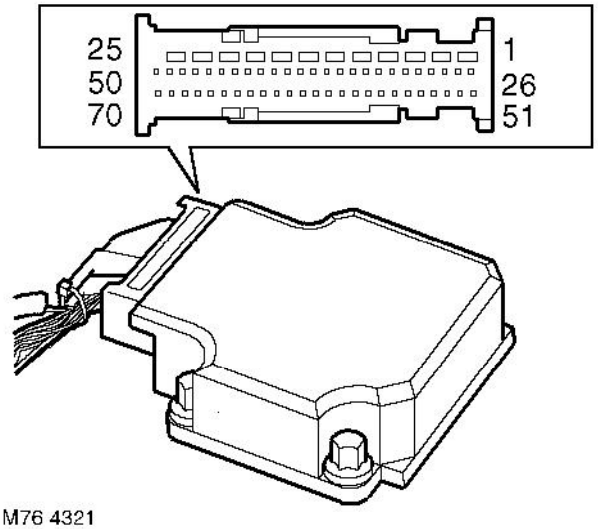
Airbag DCU (Up To 2002 MY)



M76 4152

The airbag DCU controls the operation of the system and also contains the collision detection sensors. The airbag DCU is attached to a bracket on the transmission tunnel, directly below the heater. On pre 2002 MY vehicles, a vehicle earth connects to one of the fixings. A multi-pin connector provides the airbag DCU connection with the vehicle harness.

Airbag DCU (From 2002 MY)



M76 4321

Incorporated into the airbag DCU is a mechanical safing sensor, an electronic single point sensor and integrated circuits for control and diagnostics. The mechanical safing sensor is a normally open switch that closes at the preset deceleration limit. The single point sensor is an accelerometer that produces an output proportional to the vehicle's deceleration.

Power Back-up

The airbag DCU incorporates capacitors to ensure the system will function if the external power supply is disconnected during a collision:

- Up to 2002 MY, the DCU incorporates a hardware capacitor, that provides power for 200 milliseconds to enable system operation and collision recording, and individual capacitors that provide power for 150 milliseconds for each fire signal output.
- From 2002 MY, the DCU incorporates individual capacitors that provide power for 150 milliseconds for each airbag fire signal output.

The capacitors are kept charged while the ignition is on by a dc-dc voltage converter incorporated into the airbag DCU. It can take up to 10 minutes from the ignition being switched off for the energy stored in the capacitors to fully dissipate and make the system inert.

Airbag DCU Connector Pin Details (Up To 2002 MY)

Pin No.	Description	Input/Output
1	RH pretensioner (+ve)	Output
2	RH pretensioner (-ve)	Output
3	LH pretensioner (+ve)	Output
4	LH pretensioner (-ve)	Output
5	Power supply	Input
6	Vehicle earth	–
7	SRS warning lamp	Output
8	Not used	–
9	ISO 9141 K line	Input/Output
10	Driver airbag module (+ve)	Output
11	Driver's airbag module (-ve)	Output
12	Not used	-
13	Passenger's airbag (+ve)	Output
14	Passenger's airbag (-ve)	Output
15 to 30	Not used	-

Airbag DCU Connector Pin Details (From 2002 MY)

Pin No.	Description	Input/Output
1 to 25	Not used	–
26	Ignition power supply	Input
27	SRS warning lamp	Output
28	Vehicle earth	–
29	Driver airbag module (–ve)	Output
30	Driver airbag module (+ve)	Output
31	Passenger's airbag (+ve)	Output
32	Passenger's airbag (–ve)	Output
33	LH pretensioner (–ve)	Output
34	LH pretensioner (+ve)	Output
35	RH pretensioner (–ve)	Output
36	RH pretensioner (+ve)	Output
37 to 53	Not used	–
54	ISO 9141 K line	Input/Output
55 to 75	Not used	–

Airbag Modules

During a frontal collision each airbag module deploys a gas filled bag to form a protective cushion between the front seat occupant and the steering wheel or fascia/windshield. The driver's airbag module is attached to the centre of the steering wheel. The passenger's airbag module is installed in the fascia, above the glovebox.

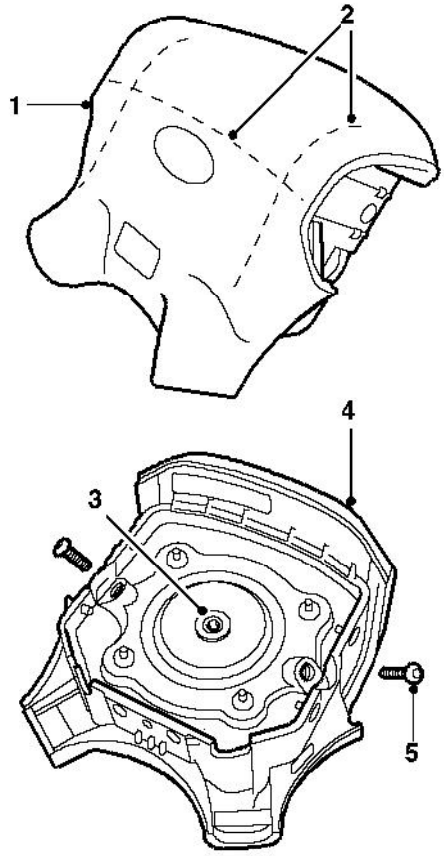
Each airbag module has a gas generator attached to a folded airbag installed in a housing. The driver's airbag has an inflated volume of 60 litres (2.12 ft^3); the passenger's airbag has an inflated volume of 150 litres (5.30 ft^3). The gas generator of the driver's airbag module is filled with a nitrocellulose based material; the gas generator of the passenger's airbag module is filled with a sodium azide based material.

The outlet of the gas generators incorporates a filter screen to prevent solid combustion by-products entering the airbag during deployment. An igniter (squib) in each generator provides an ignition source when triggered by a fire signal from the airbag DCU. A 2 pin connector provides the interface between the igniter and the vehicle wiring.

On the driver's airbag module, the housing is closed by a cover that forms the steering wheel centre pad; split lines are formed in the inner surface of the cover to direct the airbag through the required exit point during deployment. On the passenger's airbag module, the housing is closed by a trim panel profiled to match the fascia; a tethered deployment door forms an integral part of the trim panel.

Both airbag modules operate in the same way. On receipt of a fire signal from the airbag DCU, the igniter ignites the material in the gas generator. The burning material rapidly produces a large amount of nitrogen gas which passes through the filter screen into the airbag, forcing the airbag to unfold. On the driver's airbag module, the unfolding airbag ruptures the cover along the split lines; on the passenger's airbag module, the unfolding airbag breaks the deployment door fixings to the module housing and trim panel, and the deployment door lifts off the fascia (but remains tethered to the module housing). Once free of the housing the airbag inflates to its full extent. Vents in the airbag prevent excess pressure bursting the bag and, as soon as the material in the gas generator is exhausted, allows the airbag to instantly deflate.

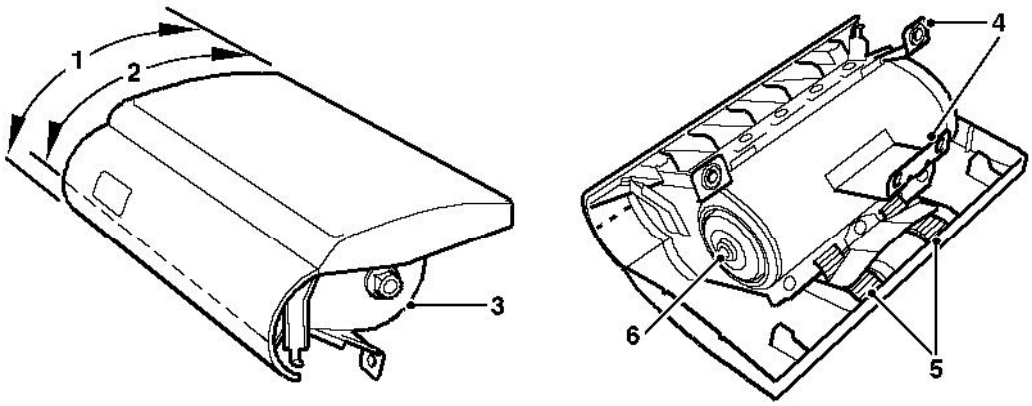
Driver's Airbag Module Components



M76 4153

1 Cover
2 Split lines
3 Electrical connector
4 Housing
5 Fixing

Passenger's Airbag Module Components



M76 4154

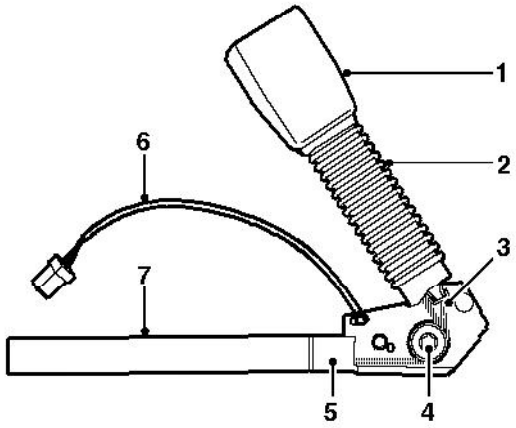
1 Trim panel
2 Deployment door section
3 Housing
4 Fixing bracket
5 Tethers
6 Electrical connector

Seat Belt Pretensioners
During a frontal collision the seat belt pretensioners tighten the front seat belts to ensure the occupants are securely held in their seats. A pretensioner is integrated into the buckle assembly of each front seat belt.

The two pretensioners are handed, but otherwise identical. Each pretensioner has a tube containing propellant and a piston. The piston is attached to steel cables, the opposite ends of which are attached to the seat belt buckle. An igniter (squib) in the base of the tube provides an ignition source when triggered by a fire signal from the airbag DCU. A fly lead with a 2 pin connector links the igniter to the vehicle wiring.

On receipt of a fire signal from the airbag DCU, the igniter ignites the propellant. The burning propellant rapidly produces nitrogen gas that drives the piston along the tube, pulling on the cables and drawing the buckle towards the buckle assembly fixing point on the seat.

Seat Belt Pretensioner Components



M76 4155

1 Seat belt buckle
2 Gaiter
3 Steel cables
4 Fixing
5 Igniter
6 Fly lead
7 Piston tube

SRS Warning Lamp
The SRS warning lamp provides system status information for the driver. The lamp consists of a non serviceable LED behind a red SRS graphic, which is located below the speedometer in the instrument pack.

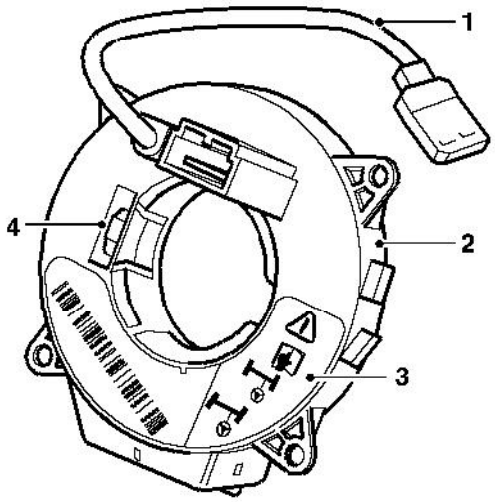
Rotary Coupler
The rotary coupler is installed on the steering column to provide the interface between the fixed wiring harness and the moveable driver's airbag module. In addition to the wiring for the driver's airbag module, the rotary coupler also provides the interface for the following switches which, depending on equipment level, can also be incorporated into the steering wheel:

- Horn switches.
- ICE system control switches.
- Cruise control system switches.

A rotating link harness is encapsulated into a plastic cassette comprising outer and inner housings with integral connectors. Screws attach the outer housing to the steering column switch assembly and the inner housing is keyed to the steering wheel by its connector. The inner housing can turn a maximum of five revolutions in relation to the outer housing. For maintenance purposes the inner housing incorporates a position indicator wheel; a white segment is visible on the wheel when the rotary coupler is centralised. To prevent breaking the rotating link harness, both the steering and the rotary coupler must be centralised when removing and installing the steering wheel.

A new rotary coupler has a blue locking tab which ensures the unit is locked at its factory centred position. The peg should remain intact until just before steering wheel fitment.

Rotary Coupler Components



M76 4156

1 Fly lead (to airbag module)
2 Outer housing
3 Inner housing
4 Position indicator wheel

Operation

General
When the ignition is switched on, the airbag DCU performs a bulb check of the SRS warning lamp as part of the power up procedure. The lamp should be extinguished after approximately 5 seconds, indicating that the system is fully operational. If the lamp remains illuminated, a fault has been detected and repair action is required.

While the ignition is on, data from the single point sensor is continuously monitored by the airbag DCU. If the data from the single point sensor indicates vehicle deceleration is at or above the preset limit, and the mechanical safing sensor is closed, the DCU interprets this as a collision that requires deployment of the airbags and retraction of the seat belt pretensioners. It then activates transistors to send fire signals to the airbag modules and the seat belt pretensioners. On pre 2002 MY vehicles, the airbag DCU simultaneously records in memory the following information:

- The error code of the last permanent fault (if any) detected before the collision.
- Internal program information about the collision as seen by the airbag DCU.
- The diagnostic status of the airbag and seat belt pretensioner circuits before deployment.
- The voltage of each power backup capacitor before deployment.
- Information on the airbag DCU internal program status.

NOTE: If external power is lost during the collision, recording of the last three above items only occurs if there is sufficient power in the backup capacitors after outputting the fire signals.

After deployment, the airbag DCU enters a crash locked mode and illuminates the SRS warning lamp. In the crash locked mode the airbag DCU is permanently disabled and must be replaced during subsequent repair action. Crash locked mode cannot be cleared using TestBook/T4.

Diagnostics
While the ignition is on the diagnostic function of the airbag DCU monitors the SRS for faults. If a fault is detected, the airbag DCU stores a related fault code in memory and switches the earth output to illuminate the SRS warning lamp. With a supply voltage range fault, the warning lamp is illuminated only for the duration of the fault. With all other faults, including intermittent faults, the warning lamp is illuminated for the remainder of the drive cycle. At the next ignition on, if the fault is still present the warning lamp remains illuminated after the lamp check; if the fault does not recur, the warning lamp extinguishes but the fault code remains stored in memory. On pre 2002 MY vehicles, an intermittent fault will be cleared from memory if 40 drive cycles are completed without its recurrence.

After detecting a fault, the system may retain some operational capability. If a fault is detected in an airbag or pretensioner circuit, the circuit may be disabled, depending on the fault; the other airbag and pretensioner circuits remain operational and their related components will still be deployed in a collision. If an internal or power supply fault is detected, the complete system will be disabled. If a fault exists in the SRS warning lamp circuit, the lamp will not illuminate during the lamp check at ignition on, but, provided there are no other faults, the system will otherwise be fully operational.

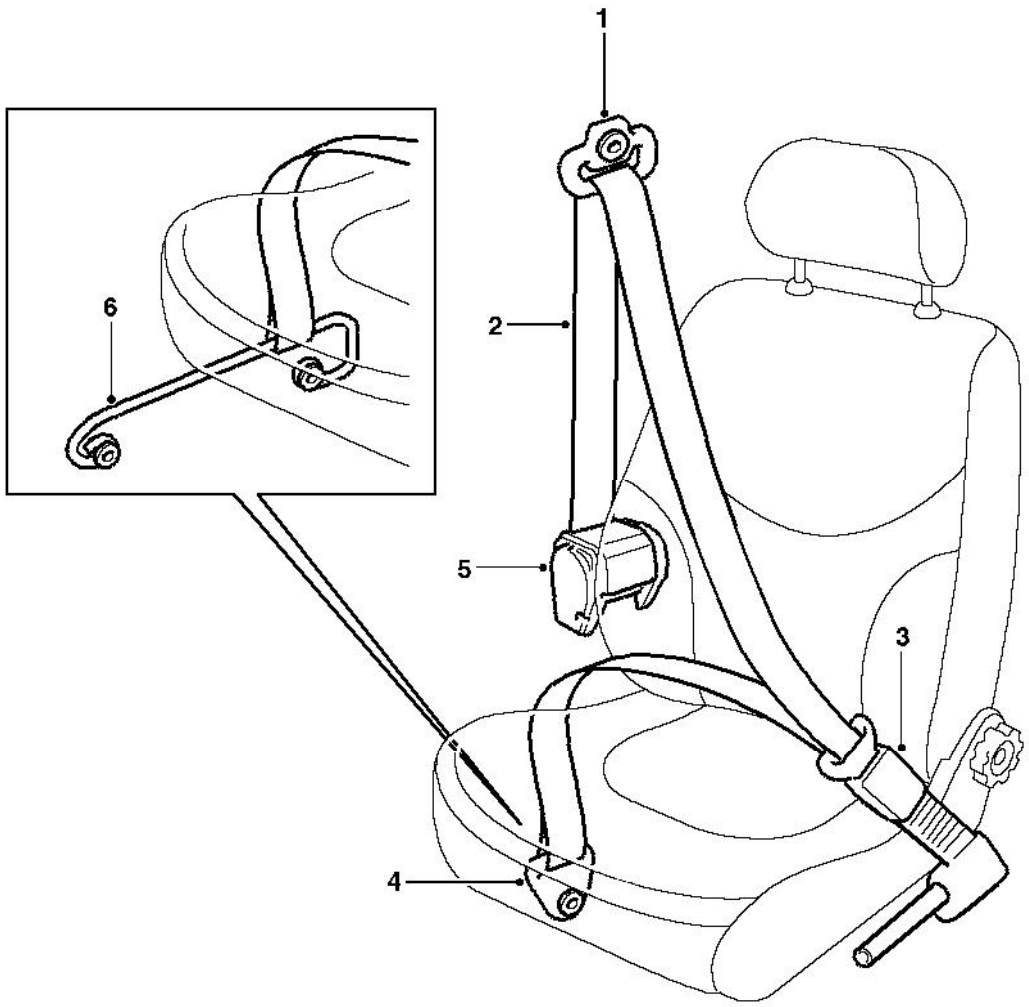
Fault code retrieval and fault diagnosis of the SRS can only be done using TestBook/T4. Additional SRS information that can be read using TestBook/T4 is the:

- Airbag DCU bar code.
- Evolution number of the hardware and software, and the algorithm level.
- Status of the crash locked mode.
- Vehicle Identification Number (VIN) data.

Diagnostic checks performed by the airbag DCU include:

- Monitoring of the airbag and pretensioner circuits for open/short circuits.
- Internal errors.
- Supply voltage (limits are: 8.6 to 19.0 V at power up, 6.0 to 19.0 V during drive cycle up to 2002 MY; 10.0 to 16.5 during normal operation from 2002 MY onwards).

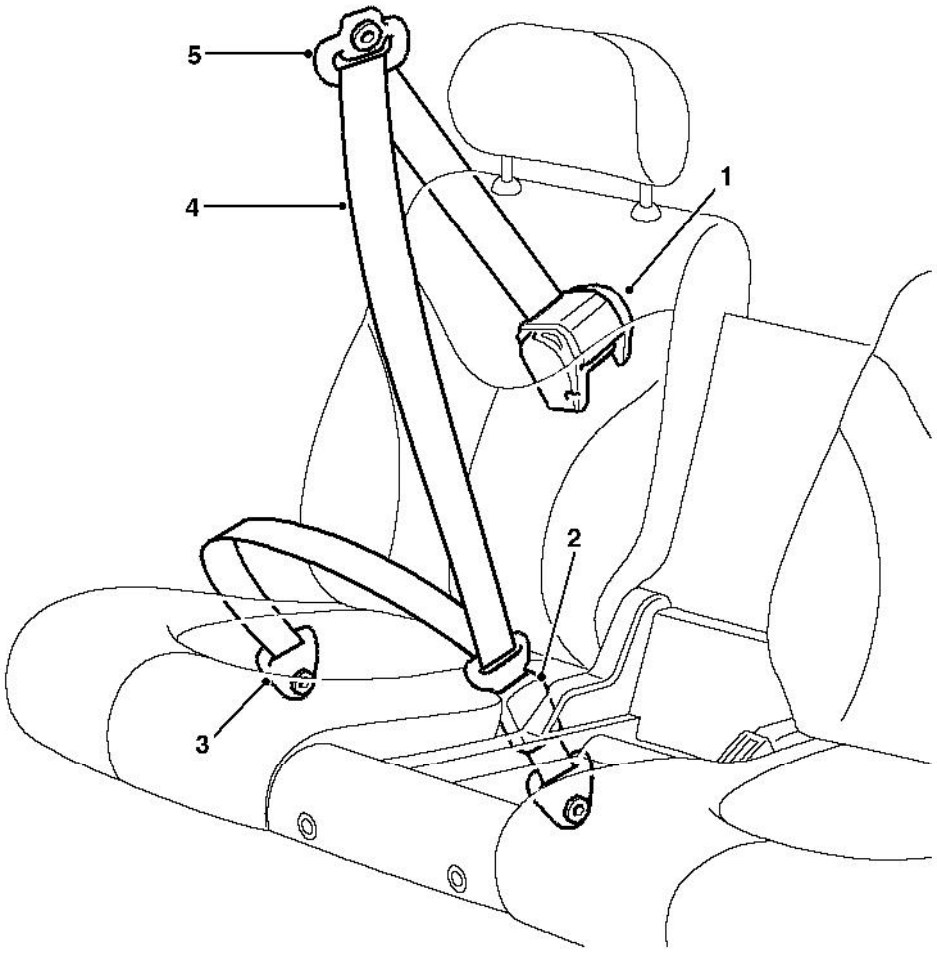
Front Seat Belt Components



M76 4157

1 Upper mounting
2 Webbing
3 Buckle
4 Webbing anchor point (5 door models)
5 Inertia reel
6 Webbing anchor point (3 door models)

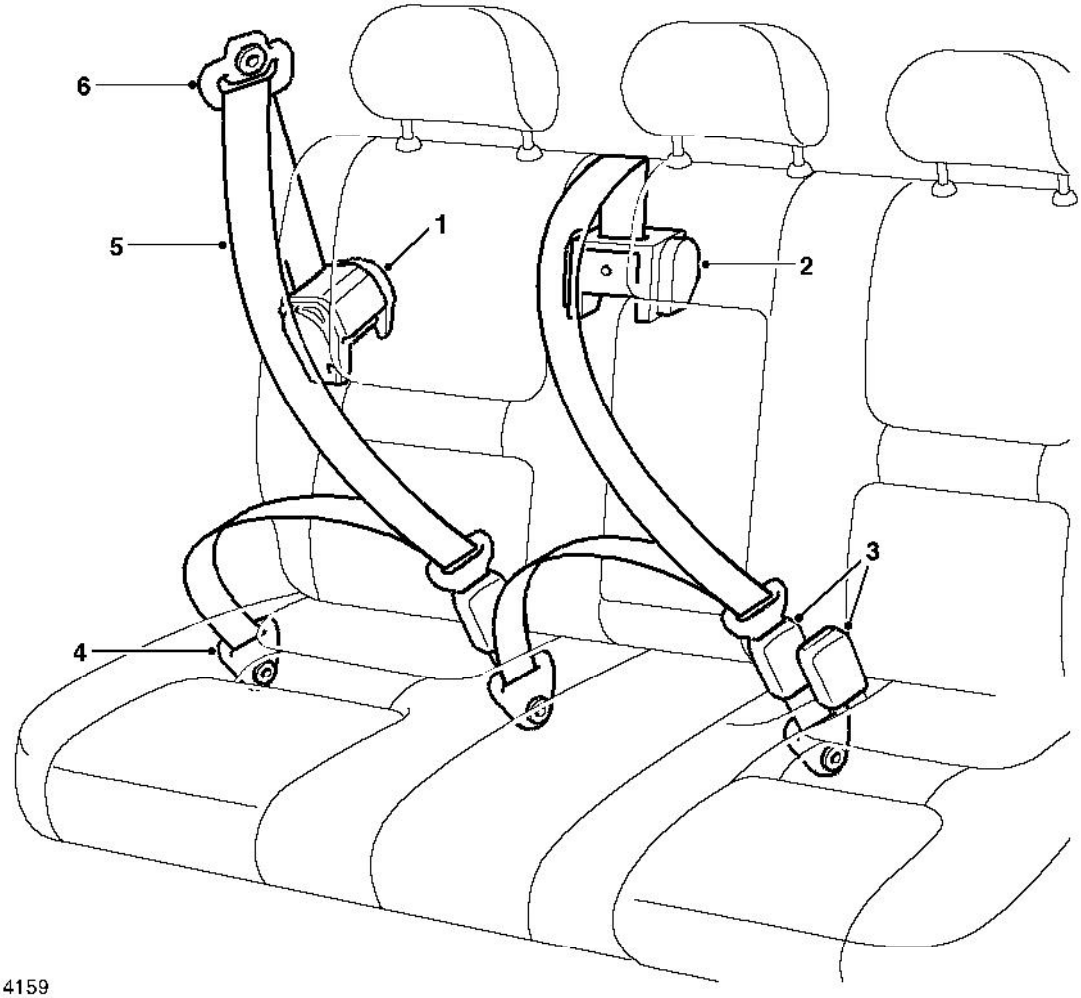
Rear Seat Belt Components - Three Door Models



M76 4158

1 Inertia reel
2 Buckle
3 Webbing anchor point
4 Webbing
5 Upper mounting

Rear Seat Belt Components - Five Door Models



1 Outboard inertia reel
2 Centre inertia reel
3 Buckles
4 Webbing anchor point
5 Webbing
6 Upper mounting

Description

General
Seat belts are provided as the primary restraint for all occupants. An inertia reel, three point seat belt is installed at each seat position. A load limiter feature is incorporated into the inertia reels on NAS vehicles and is available as an option in all other markets.

On NAS vehicles, the inertia reel of the driver's seat belt is the Emergency Locking Retractor (ELR) type and the inertia reel for all of the passenger seat belts are the Automatic Locking Retractor (ALR) type. In all other markets ELR inertia reels are fitted at all seat positions.

Both types of inertia reel incorporate a liftshaft locking system with webbing sensor and car sensor activating mechanisms. The webbing sensor activates the locking system if the webbing is subjected to a sharp pull. The car sensor activates the locking system if the vehicle is subjected to sudden deceleration or a severe tilt angle.

Front Seat Belts
The inertia reel of each front seat belt is attached to the related B/C post, behind the finishers. The webbing runs from the inertia reel, through an upper mounting attached to a height adjuster on the B/C post, to an anchor point either at the base of the B/C post (five door models), or on a bar attached to the inner sill (three door models).

The buckle assembly for each belt, consisting of a buckle attached to a flexible stalk and an integrated pretensioner, is secured to the inboard side of the related front seat frame.

Rear Seat Belts
Inertia reel seat belts are installed for all of the rear seats.

Three Door Models
The inertia reel of each rear seat belt is attached to a bracket on top of the related rear suspension turret, behind the loadspace rear quarter trim. The webbing runs from the inertia reel, through an upper mounting on the D post, to an anchor point in the rear wheel arch.

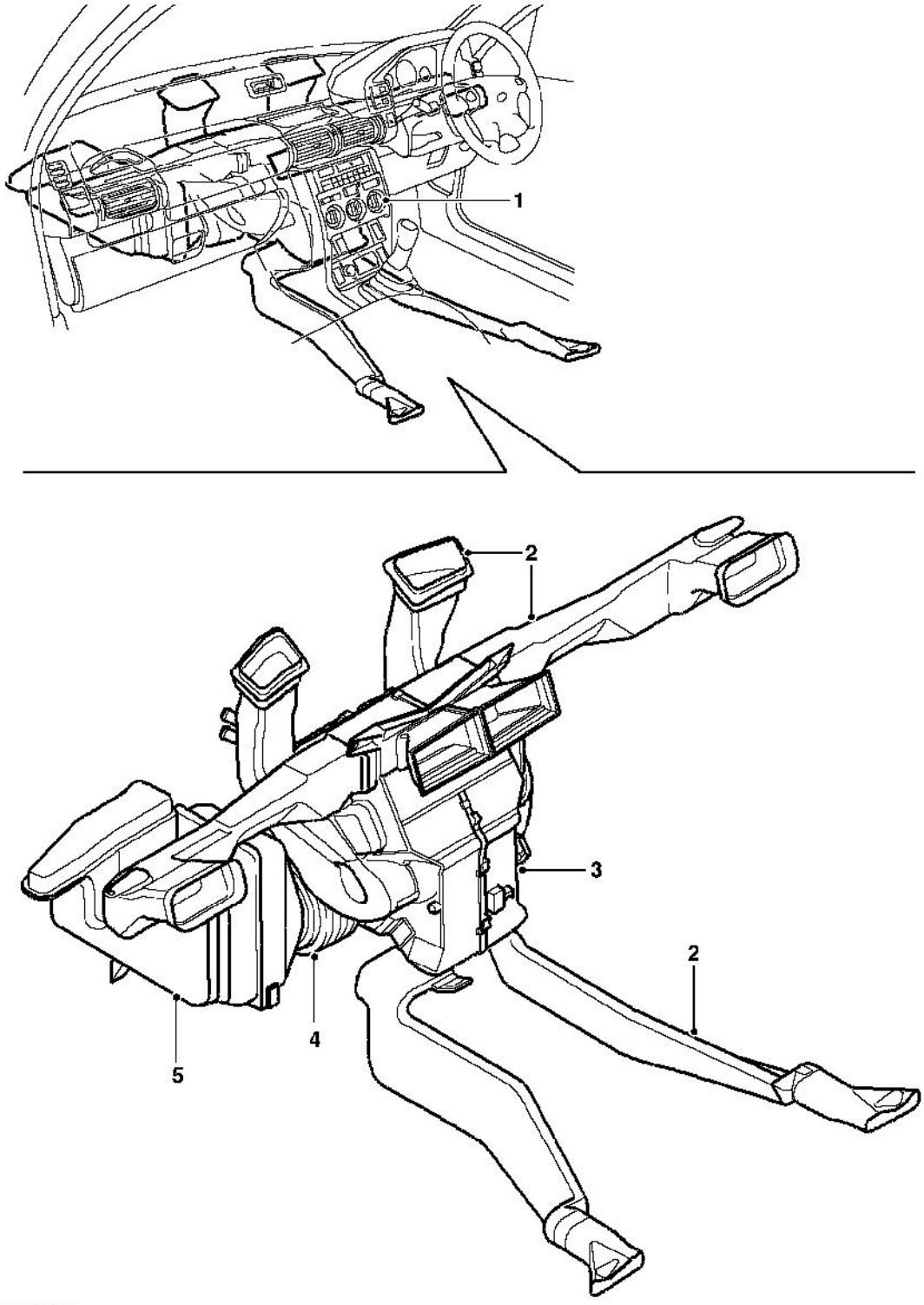
The buckle for each belt is directly attached to the inboard side of the related rear seat frame.

Five Door Models
The inertia reel of each outboard rear seat belt is attached to the related D post, behind the D/E post finisher. The webbing runs from the inertia reel, through an upper mounting on the D post, to an anchor point in the rear wheel arch.

The inertia reel for the centre rear seat belt is installed in a recess in the back of the rear seat. The webbing runs from the inertia reel, over the top of the seat, to an anchor point in the lower frame of the right rear seat.

The buckle assembly for each belt, consisting of a buckle attached to a length of webbing, is fixed to the lower frames of the rear seats. The buckle assembly for the right seat belt shares an anchor point with the webbing of the centre seat belt.

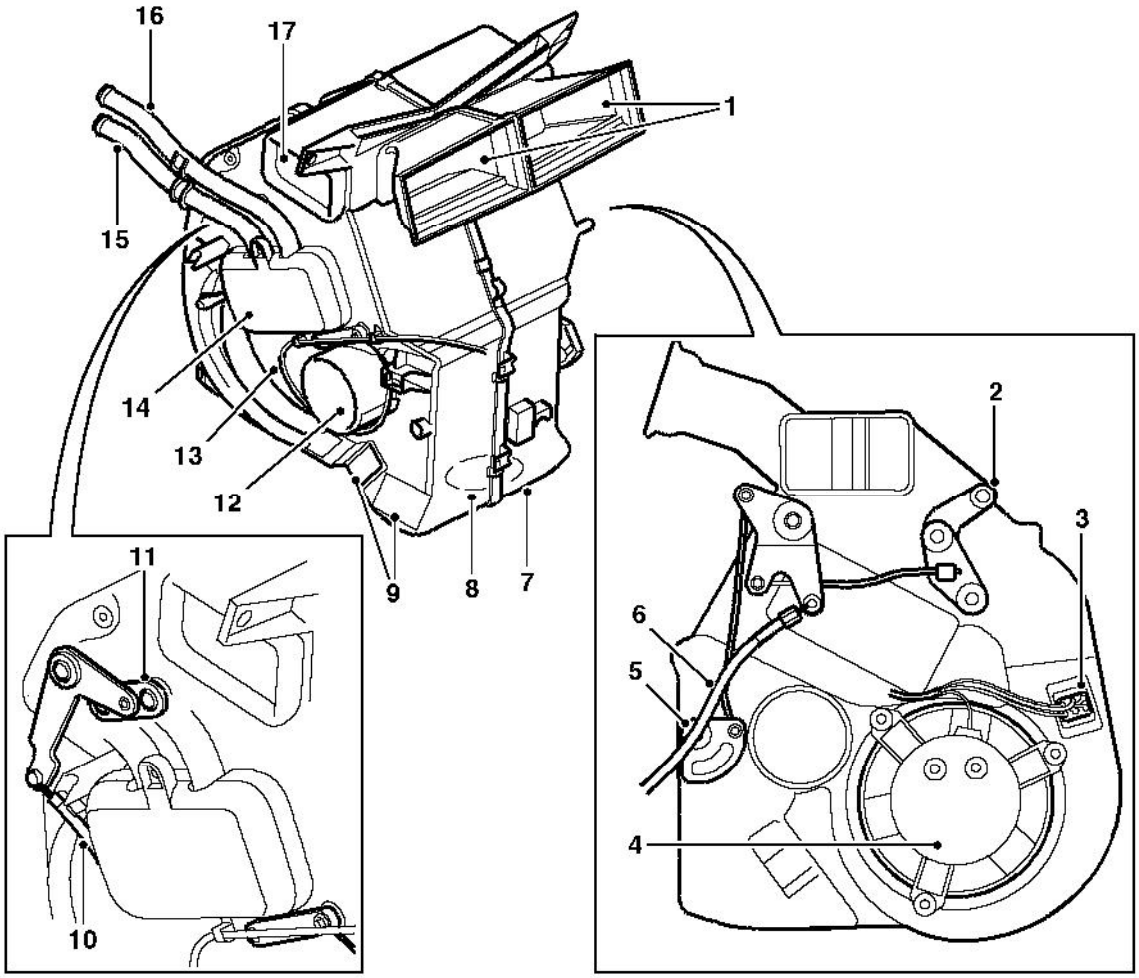
Heating and Ventilation System Component Layout



RHD shown, LHD similar

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

Heater Assembly Components

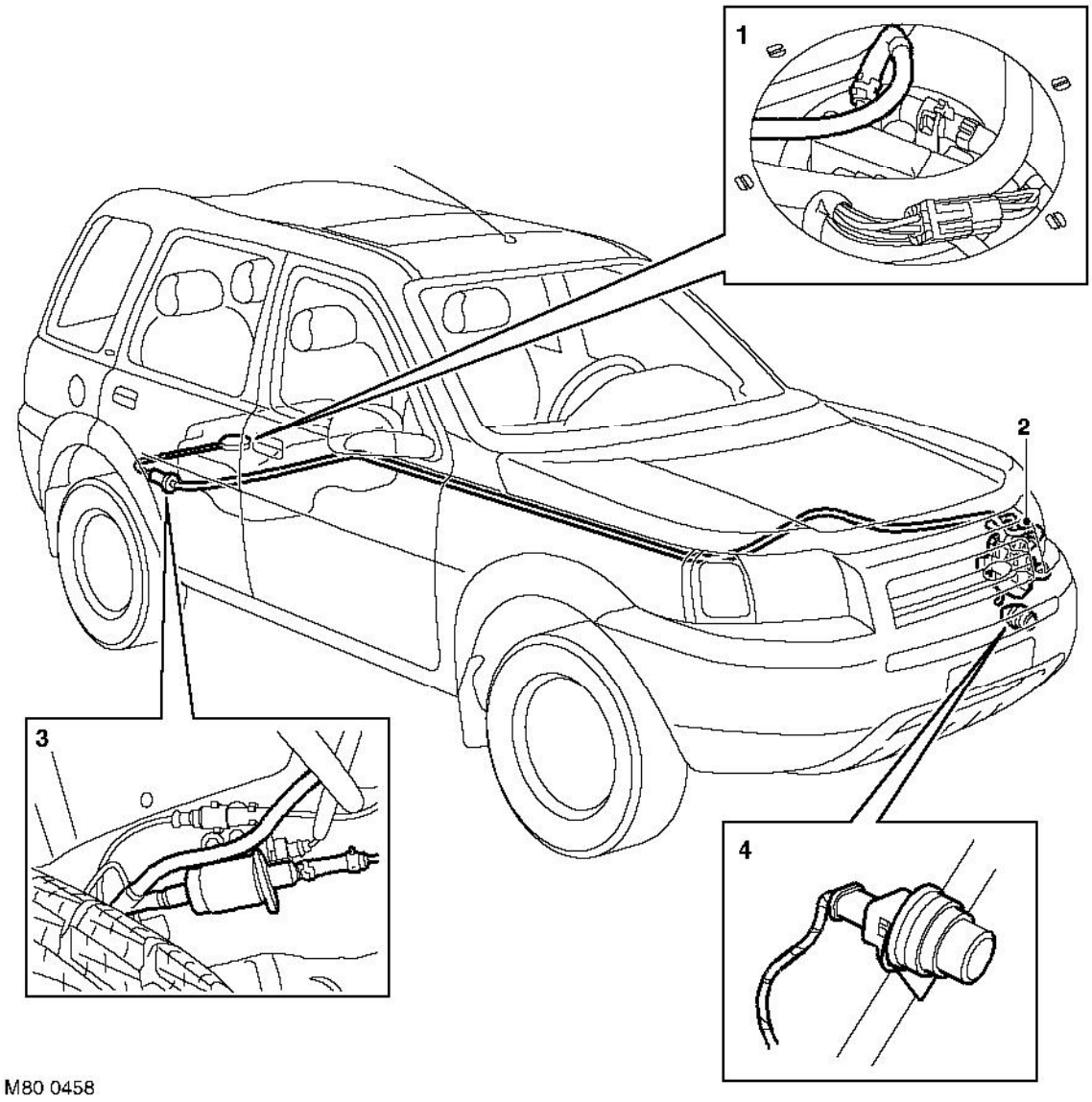


M80 0457

RHD shown, LHD similar

1 Centre face level air outlets
2 Fresh air flap lever
3 Resistor pack
4 Blower motor and impeller fan
5 Main distribution flap lever
6 Distribution control cable
7 Casing
8 Rear footwells air outlet
9 Front footwell air outlets
10 Blend flap control cable
11 Blend flap lever
12 Windscreen and side window air outlet
13 Heater matrix 'close off' flap and control cable
14 Heater matrix cover
15 Engine coolant feed
16 Engine coolant return
17 Outer face level air outlet

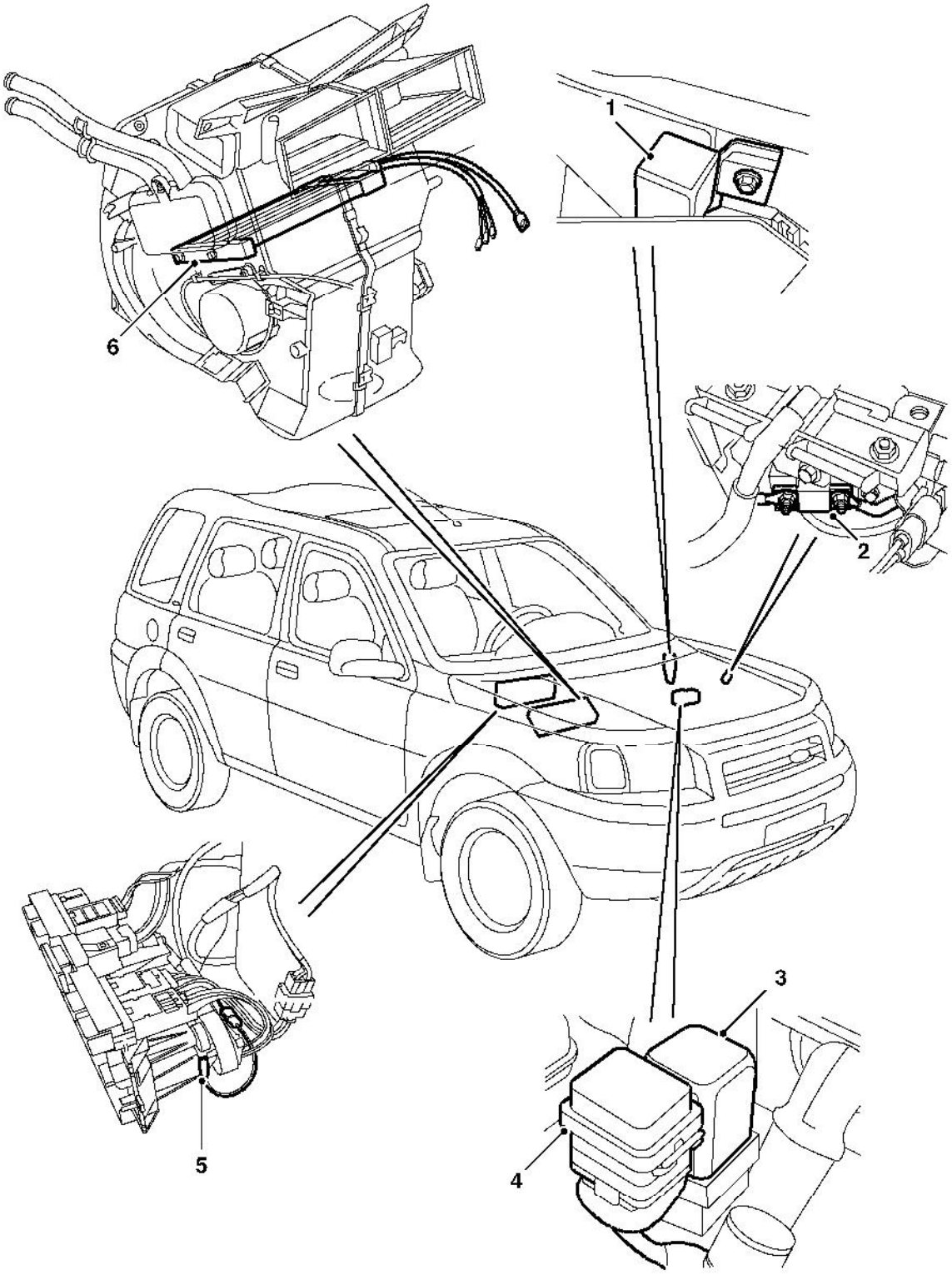
Fuel Burning Heater Component Layout



LH drive shown, RH drive similar

1 Fuel Burning Heater fuel line connection
2 Fuel Burning Heater unit
3 Fuel Burning Heater pump
4 Air temperature sensor

PTC Heater System Component Layout



M80 0535

1 Power relay
2 In–line fuse
3 Control relay
4 Fuse holder
5 Microswitch
6 PTC heater

Description

General

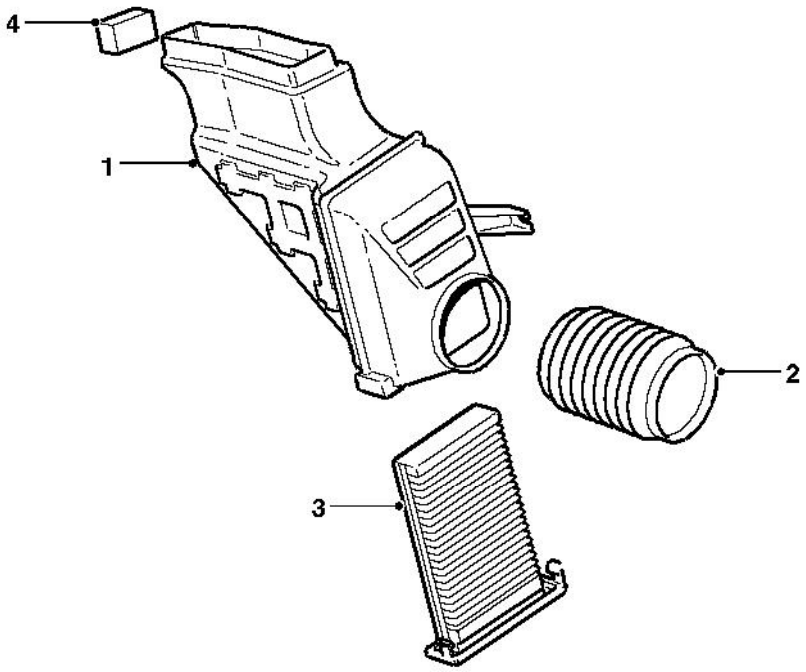
The heating and ventilation system controls the temperature and distribution of air supplied to the vehicle interior. Air is drawn into a heater assembly through a connector hose and an air inlet duct or, on vehicles with air conditioning, the cooling unit.

☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**

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.

Up to 2002 MY, diesel models in colder climate markets incorporate a Fuel Burning Heater (FBH) in the engine coolant supply to the heater assembly. From 2002 MY, only diesel models in the coldest of those markets retain the FBH; diesel models in the remainder of those markets incorporate an electric Positive Temperature Coefficient (PTC) heater, inside the heater assembly, instead of the FBH.

Air Inlet Duct



M80 0460

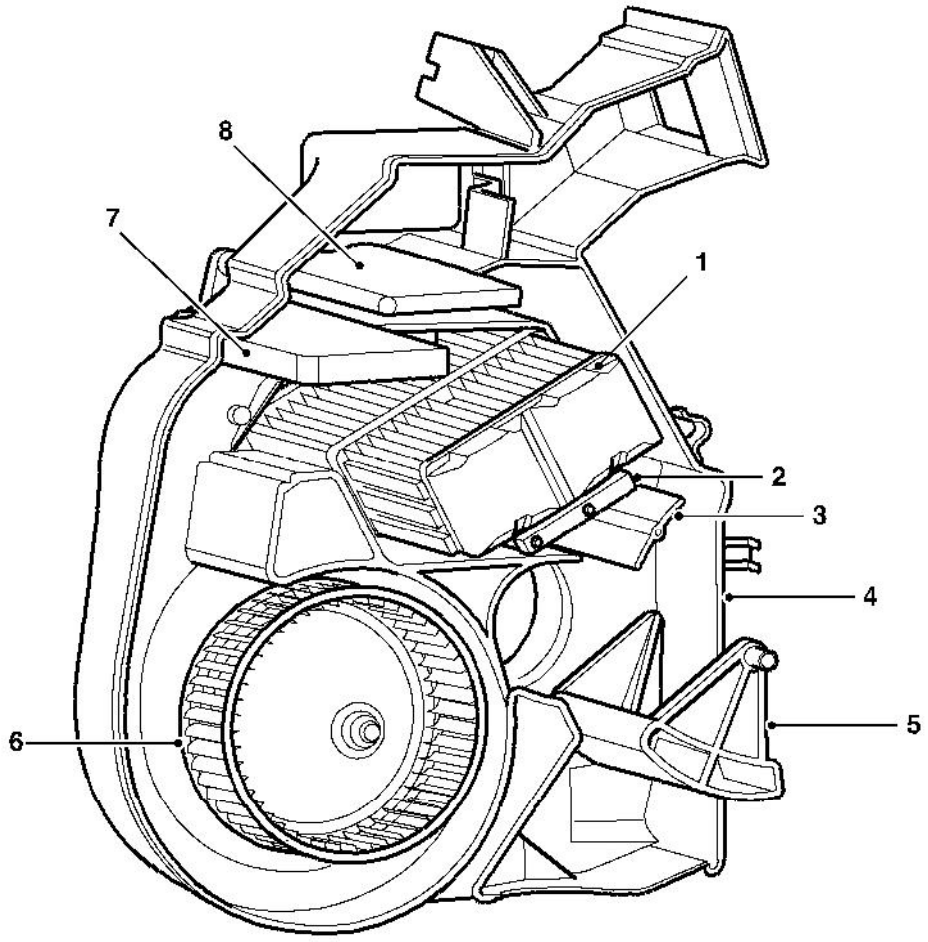
RHD (non aircon) shown, LHD (non aircon) similar

1 Air inlet duct
2 Connector hose
3 Pollen filter
4 Foam block

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 two scrivets.

Heater Assembly

Interior View of Heater Assembly



M80 0461A

RHD shown, LHD similar

1 Heater matrix
2 PTC heater (where fitted)
3 Heater matrix 'close off' flap
4 Casing
5 Distribution main flap
6 Blower fan
7 Blend flap
8 Distribution fresh air flap

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. The casing on some diesel models also contains a PTC heater. 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.

Blower
The blower controls the volume of air being supplied to the distribution outlets. The blower is installed in the driver's side of the casing and consists of an open hub, centrifugal fan powered by an electric motor. The open end of the fan surrounds the air inlet, which is on the passenger's side of the casing. The blower switch and the resistor pack control the operation of the blower, which can be selected to run at one of four speeds.

Resistor Pack
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.

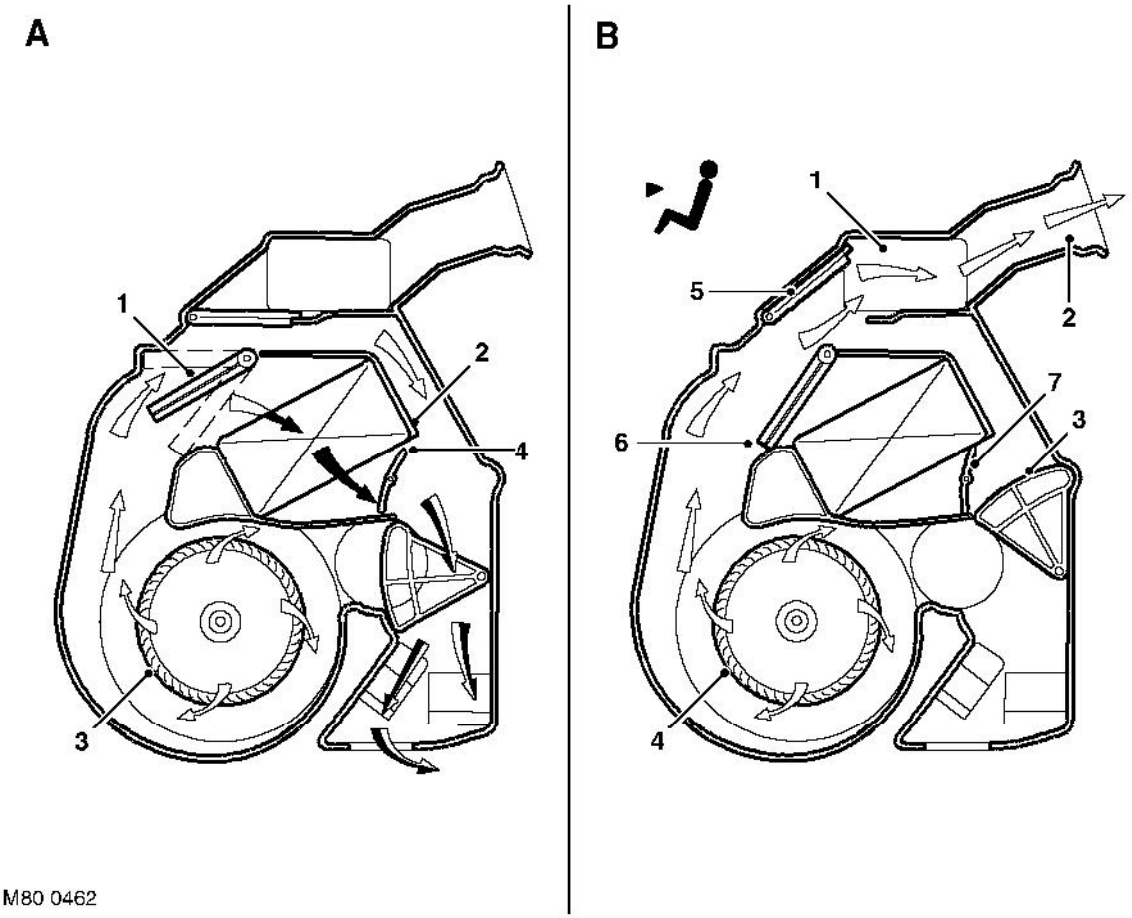
Heater Matrix
The heater matrix provides the heat source to warm the air being supplied to the distribution outlets. It is installed in the LH side of the casing behind a protective cover. The matrix is a copper and brass, two pass, fin and tube heat exchanger. Engine coolant is supplied to the matrix 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 some models, the coolant flow is assisted by an electric pump when the FBH system is operating.

Control Flaps
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, and an extra flap closes the air path from the off side of the heater matrix to the blend chamber 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.

Blend Flap: The blend flap regulates the flow of air through the heater matrix to control the temperature of the air leaving the heater assembly. It consists of a hinged flap between the cold air bypass and the heater matrix. The flap hinge is connected to a lever mechanism on the LH side of the casing. A control cable is installed between the lever mechanism and the temperature knob on the control panel to operate the flap. Turning the temperature knob turns the flap and varies the proportions of air going through the cold air bypass and the heater matrix. The proportions vary, between full bypass no heat and no bypass full heat, to correspond with the selection on the temperature knob. When the flow is split between the cold air bypass and the heater matrix, the two flows are mixed downstream of the heater matrix to produce an even air temperature at the individual outlets.

A flap on the air outflow side of the heater matrix is used to close off the path of cold air flowing around the bypass route from picking up heat from the matrix in the blend chamber and so prevent an increase in air temperature when the airflow is diverted to the foot or defrost outlets. The flap hinge is connected to a lever mechanism on the LH side of the casing. A control cable is installed between the lever mechanism and the temperature knob on the control panel to operate the flap. Turning the temperature knob turns the flap. When unheated air is required and the temperature control is at its minimum setting, the 'close-off' flap is completely shut to prevent thermal pick-up. As the temperature control knob is turned up to select a higher ambient temperature, the 'close-off' flap is opened to allow the passage of air flow through the heater matrix to the blend chamber.

Distribution Flaps: A main flap and a fresh air flap control the flow of air to the distribution outlets in the casing. The main flap is a rotating segment that controls the flow to the windscreen/side window and footwell outlets. The fresh air flap is a hinged door that controls the flow to the face level outlets. The hinge of each flap is connected to a common lever mechanism on the RH side of the casing. A control cable is installed between the mechanism and the distribution knob on the control panel to operate the flaps together. Turning the distribution knob turns the flaps to direct air through the corresponding outlets in the casing.

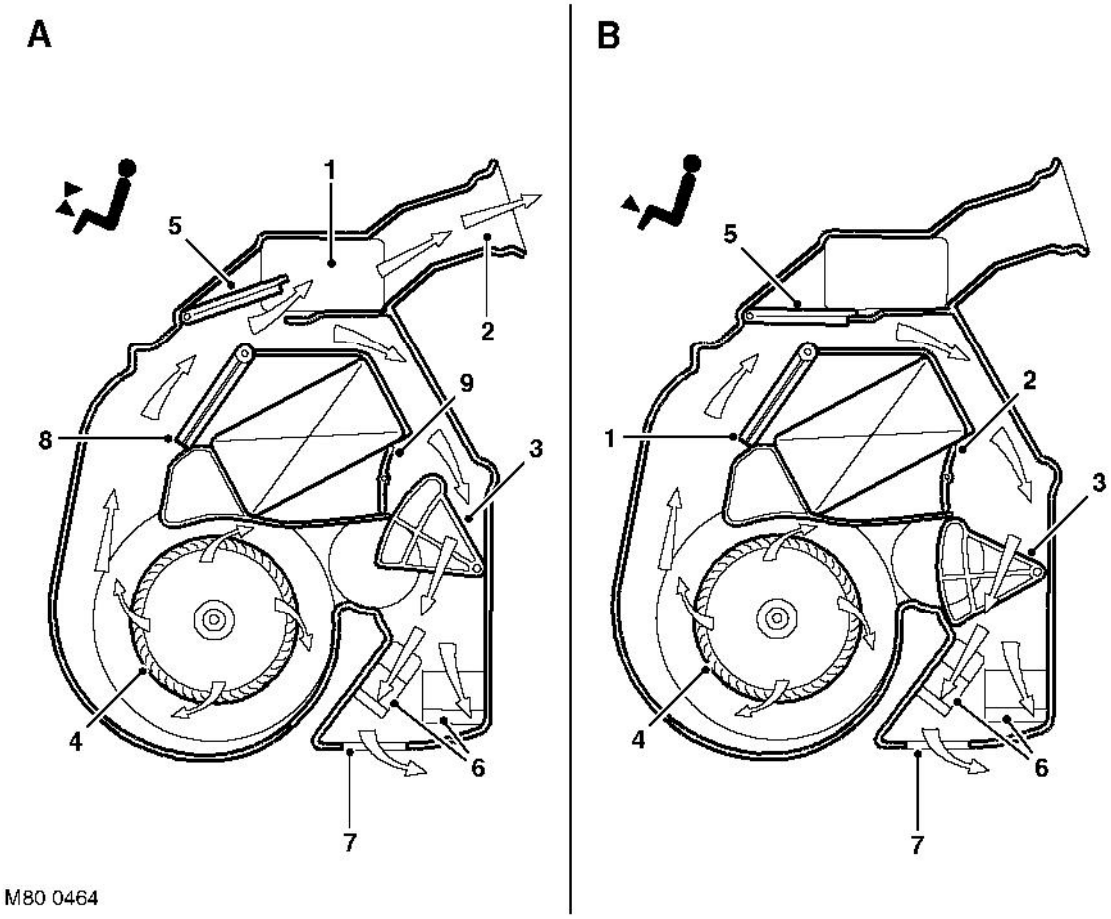


a Temperature Control

- **1** Temperature control flap (partially open)
- **2** Heater Matrix
- **3** Blower
- **4** Heater Matrix 'close off' flap (partially open)

b Face Level Distribution Control

- **1** Outer face level air outlet
- **2** Centre face level air outlet
- **3** Distribution main flap
- **4** Blower
- **5** Distribution fresh air flap
- **6** Temperature control flap
- **7** Heater matrix 'close-off' flap

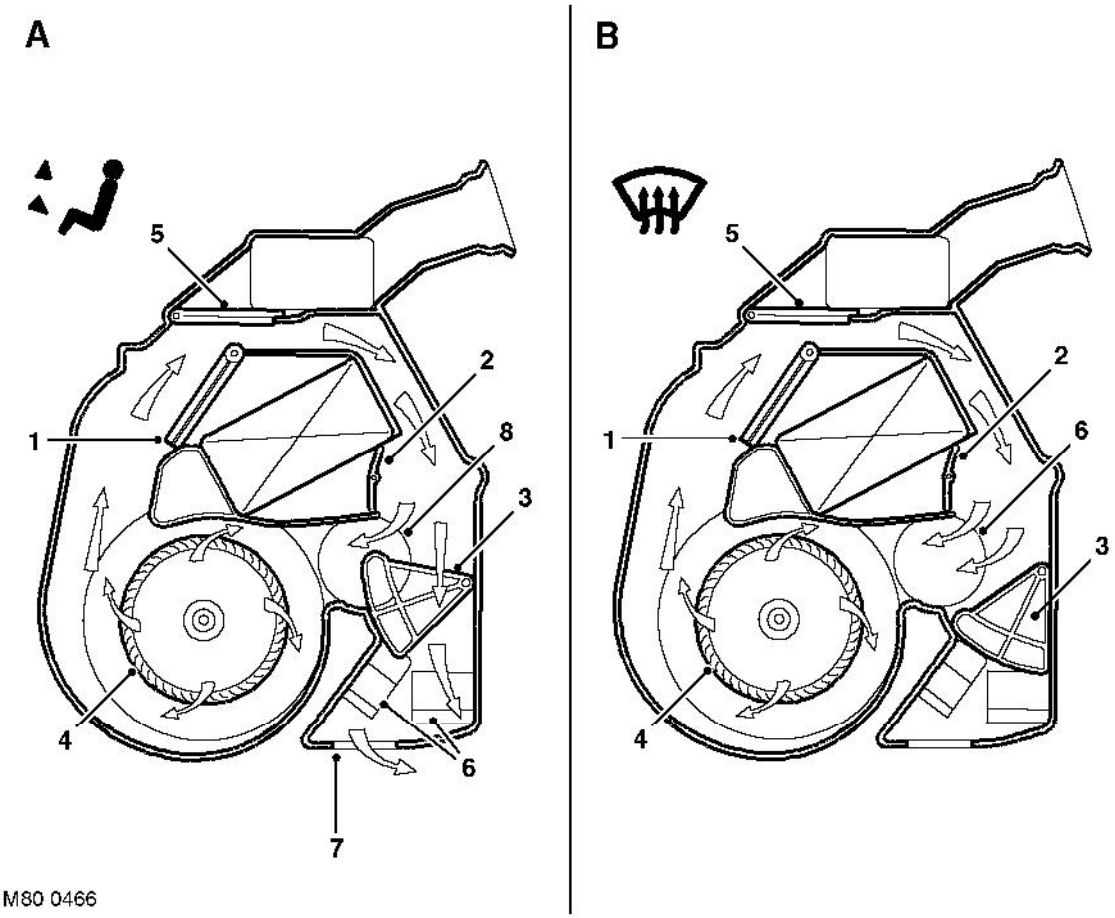


a Face Level and Footwells Distribution Control

1 Outer face level air outlet
2 Centre face level air outlet
3 Distribution main flap
4 Blower
5 Distribution fresh air flap
6 Front footwell air outlets
7 Rear footwells air outlet
8 Temperature control flap
9 Heater matrix 'close-off' flap

b Footwells Distribution Control

1 Temperature control flap
2 Heater matrix 'close-off' flap
3 Distribution main flap
4 Blower
5 Distribution fresh air flap
6 Front footwell air outlets
7 Rear footwells air outlet



a Footwells and Windscreen/Side Window Demist Distribution Control

1 Temperature control flap
2 Heater matrix 'close-off' flap
3 Distribution main flap
4 Blower
5 Distribution fresh air flap
6 Front footwell air outlets
7 Rear footwells air outlet
8 Windscreen and side window air outlet

b Windscreen/Side Window Demist Distribution Control

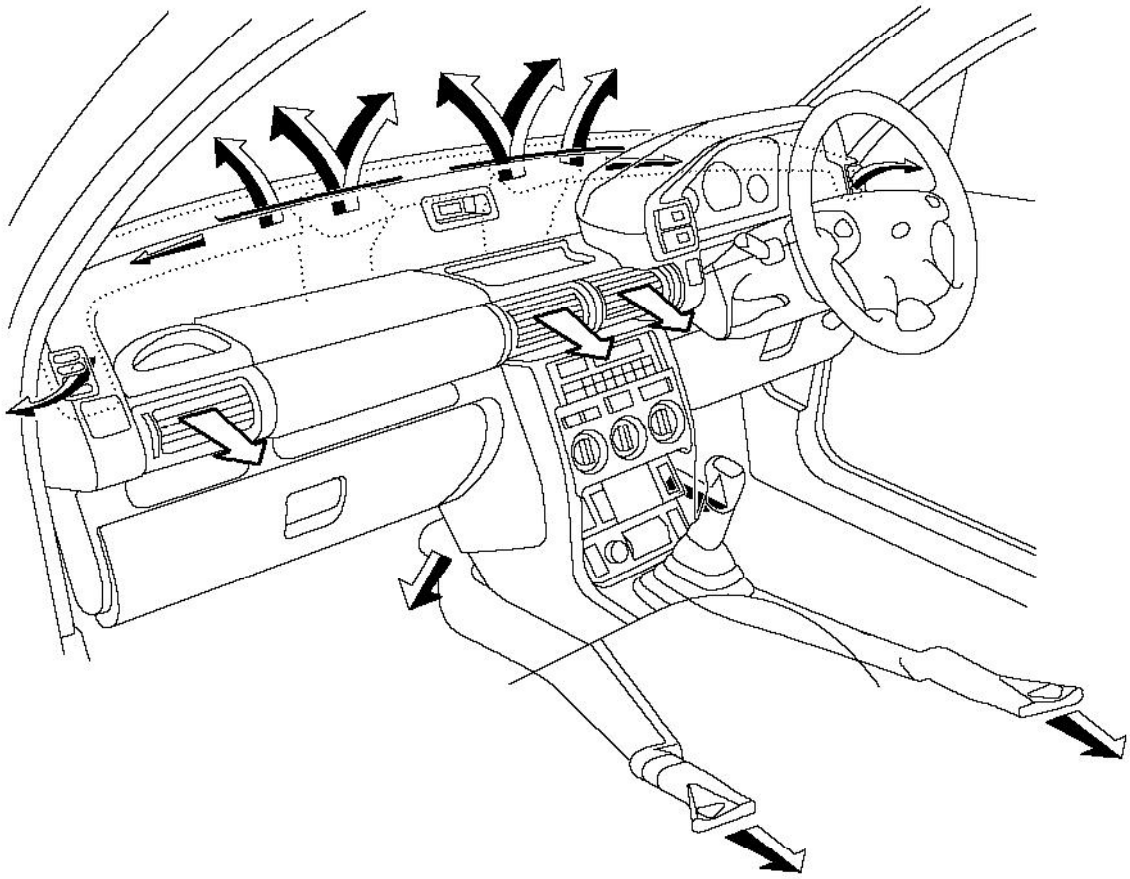
1 Temperature control flap
2 Heater matrix 'close-off' flap
3 Distribution main flap
4 Blower
5 Distribution fresh air flap
6 Windscreen and side window air outlet

Distribution

Air from the heater assembly is distributed around the vehicle interior through fascia and floor level outlets. Fascia outlets consist of fixed vents for the windscreen and side windows, and adjustable vent assemblies for face level air. Floor level outlets consist of fixed vents for the front and rear footwells.

The front footwell vents are integrated into the heater assembly. Two central vent assemblies for face level air are connected directly onto the related outlets of the heater assembly. Air for the rear footwell, outer face level vent assemblies and windscreen/side windows is distributed through ducts.

Fascia Outlets



M80 0468

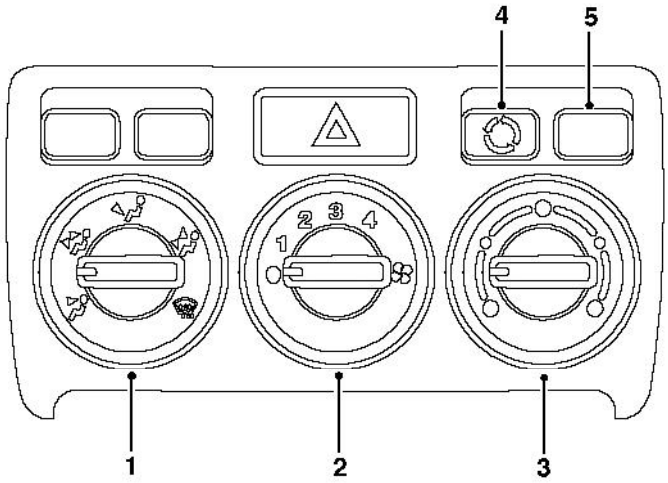
Ducts

The rear footwell ducts extend along each side of the transmission tunnel and vent into the rear footwells from below the front seats. The outer face level ducts attach to the underside of the fascia and connect to the vent assembly at each end of the fascia. The windscreen/side window ducts connect to a duct integrated into the top of the fascia.

Vent Assemblies

The vent assemblies allow occupants to control the flow and direction of face level air. Each vent assembly incorporates a thumbwheel to regulate flow and moveable vanes to control direction.

Heating and Ventilation Controls



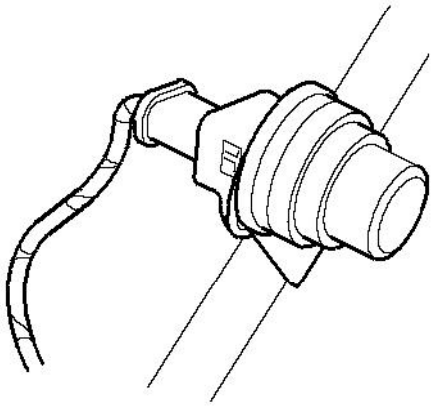
1 Distribution control knob
2 Blower fan speed control knob
3 Temperature control knob
4 Fresh/recirculated air selection switch
5 Air conditioning selection switch (where fitted)

Rotary knobs are installed on the centre console to control air distribution, blower speed and air temperature. The air distribution and temperature knobs operate cables connected to the control flaps in the heater assembly. The blower speed knob operates a rotary switch in the blower's electrical circuit. Graphics on the control panel indicate the function and operating positions of the controls.

Fuel Burning Heater (FBH) System (Where Fitted)
The FBH system is an auxiliary heating system that compensates for the relatively low coolant temperatures inherent in the diesel engine. At low ambient temperatures, the FBH system heats the coolant supply to the heater assembly, and maintains it within the temperature range required for good in-car heating performance. Operation is fully automatic, with no intervention required by the driver.

The system consists of an ambient air temperature sensor, a FBH fuel pump and a FBH unit. Fuel for the FBH system is taken from the vehicle fuel tank, through a line attached to the fuel tank's fuel pump, and supplied via the FBH fuel pump to the FBH unit. The connection on the fuel tank's fuel pump incorporates a tube which extends down into the tank. In the FBH unit, the fuel delivered by the FBH fuel pump is burned and the resultant heat output is used to heat the coolant. An ECU integrated into the FBH unit controls the operation of the system at one of two heat output levels, 5 kW at full load (i.e. maximum output) and 2.5 kW at part load.

Ambient Air Temperature Sensor



M80 0470

The ambient air temperature sensor controls a power supply, from the alternator via the Engine Control Module (ECM) to the FBH unit. The sensor is installed on a bracket attached to the body behind the RH side of the front bumper valance. The sensor contains a switch that is closed at temperatures below 5 °C (41 °F) and open at temperatures of 5 °C (41 °F) and above.

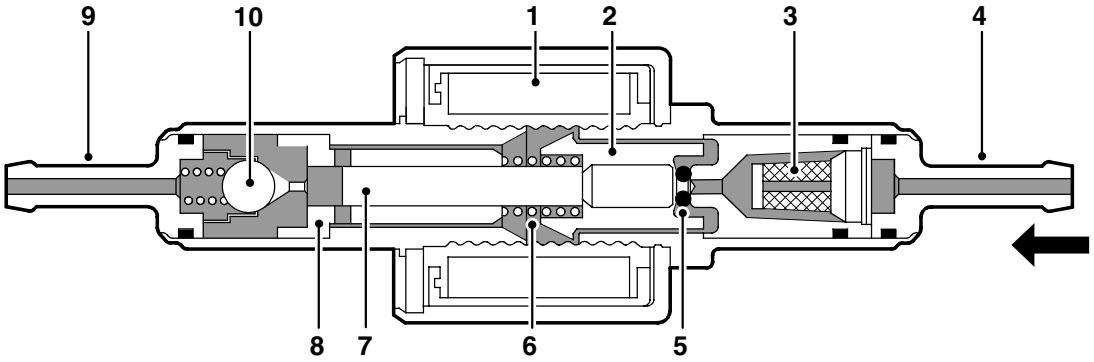
FBH Fuel Pump

The FBH fuel pump regulates the fuel supply to the FBH unit. The FBH fuel pump is installed in a rubber mounting in a bracket attached inside the rear RH wheelarch. The pump is a self priming, solenoid operated plunger pump, with a fixed displacement of 0.063 cm^3/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)

Sectioned View of FBH Fuel Pump



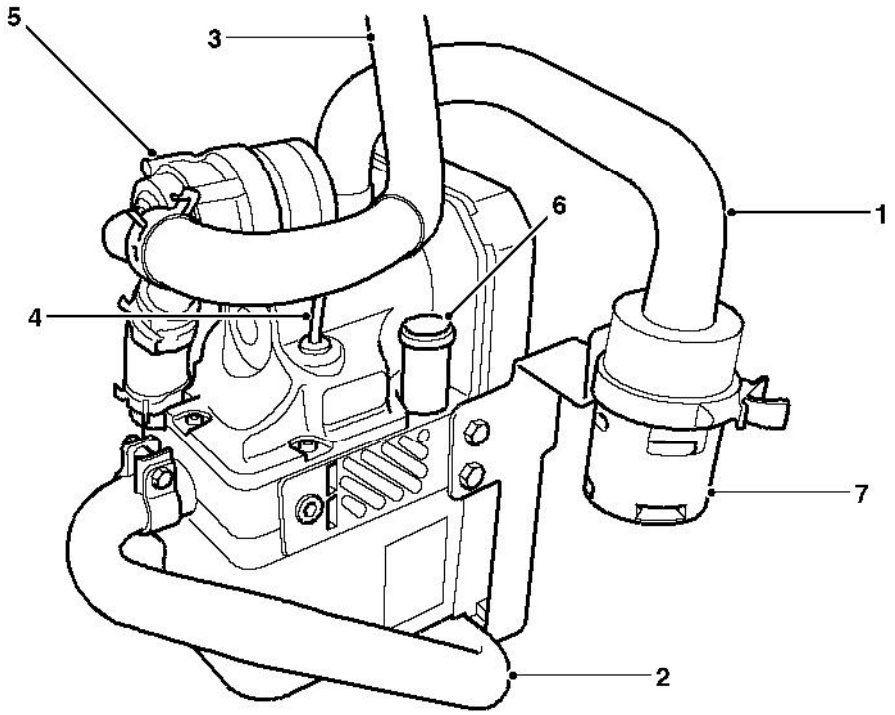
M80 0471

1 Solenoid coil
2 Plunger
3 Filter insert
4 Fuel line connector
5 'O' ring seal
6 Spring
7 Piston
8 Bush
9 Fuel line connector
10 Non return valve

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; fuel is then drawn in 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 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.

FBH Unit

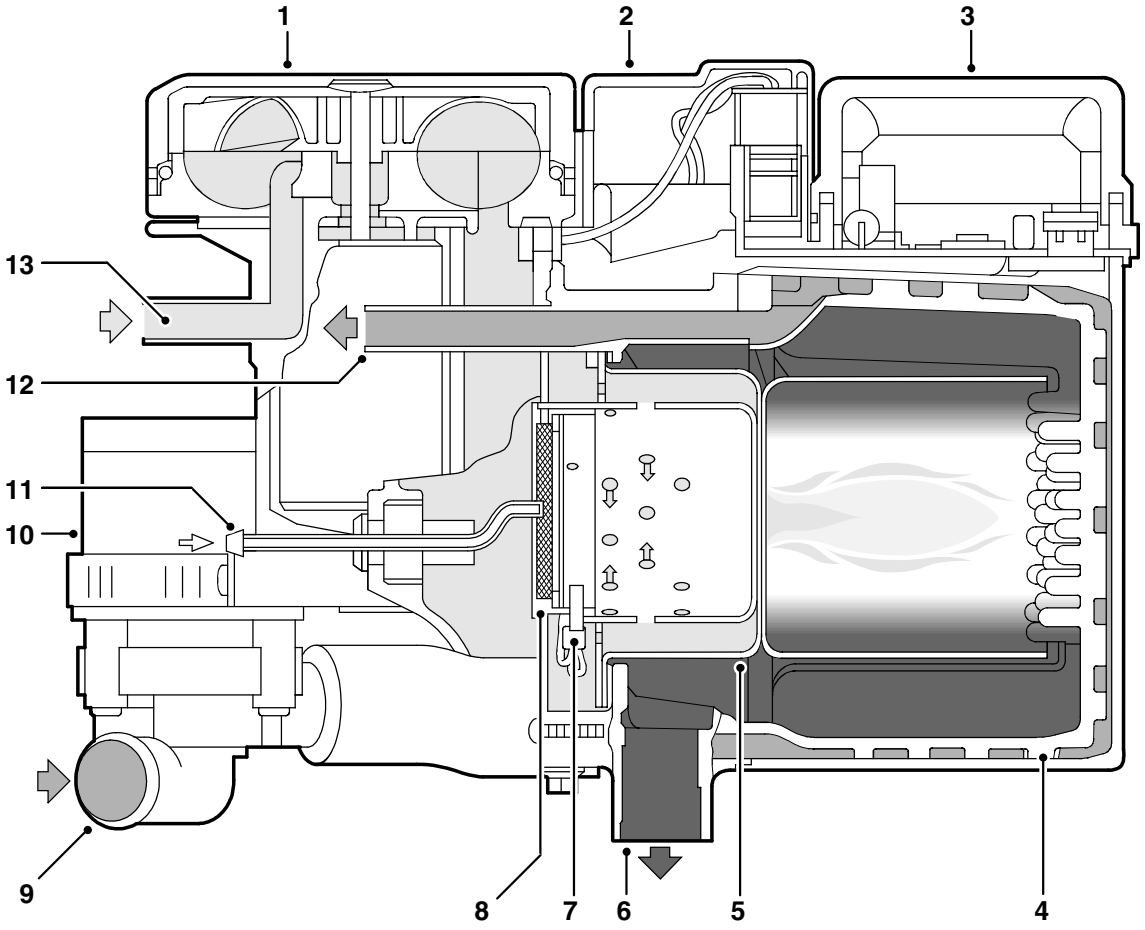


M80 0459

1 Air inlet hose
2 Exhaust pipe
3 Coolant inlet hose
4 Fuel supply line
5 Circulation pump
6 Coolant outlet hose
7 Air inlet filter

The FBH unit is installed behind the front bumper, in front of the LH wheelarch. It is connected in series with the coolant supply to the heater assembly. Two electrical connectors on the FBH unit connect it to the vehicle wiring. Spring clamps secure the fuel supply line to a spigot on the FBH unit.

Sectioned View of FBH Unit



M80 0472

1 Combustion air fan
2 Burner housing
3 ECU
4 Heat exchanger
5 Burner insert
6 Exhaust
7 Glow plug/flame sensor
8 Evaporator
9 Coolant inlet
10 Circulation pump
11 Fuel inlet
12 Coolant outlet
13 Air inlet

The FBH unit consists of:

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

Circulation Pump

The circulation pump is installed at the coolant inlet to the FBH unit to assist the coolant flow through the FBH unit and the heater assembly. 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 and to purge and cool the FBH unit. A canister type filter is included in the air inlet supply line to prevent particulates entering and contaminating the FBH unit.

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 through a pipe below the FBH unit.

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; as the coolant temperature decreases, the coolant will be approximately 2 °C (3.6 °F) cooler than the temperature detected by the sensor.

PTC Heater System (Where Fitted)
The PTC heater system, like the FBH, is an auxiliary heating system that compensates for the relatively low coolant temperatures inherent in the diesel engine. When the heater blower is selected on (any speed) and the temperature control is selected to the 1 o'clock position or above, i.e. warm to hot, the PTC heater automatically comes on to boost the temperature of the air flowing through the heater assembly. The system consists of:

- The PTC heater.
- A heater switch.
- Two relays.
- A link harness and fuses.

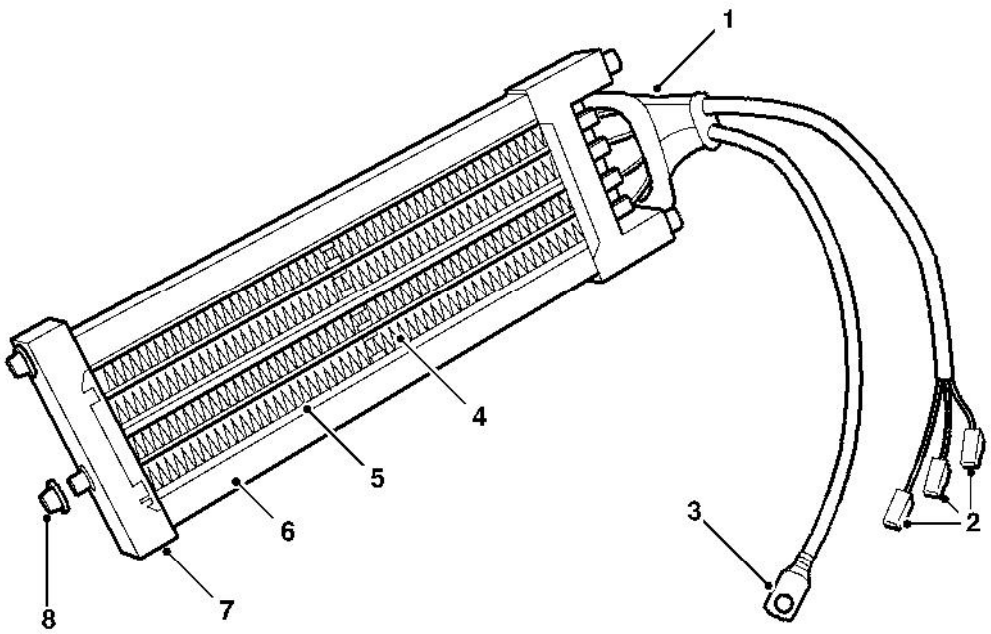
PTC Heater
The PTC heater is installed in the heater assembly on the downstream side of the coolant heater matrix. The PTC heater is an electrical heating element consisting of alternating layers of radiator fins and thermistor elements installed in a frame and secured with spring clips. Plastic end covers on the frame each incorporate two lugs for locating the PTC heater in the heater assembly casing. Silicone caps are installed on the lugs to prevent rattling. Three power supply leads and a common earth lead are connected to the thermistor element layers. A grommet protects the leads where they pass through the heater assembly casing.

The thermistor elements are made of a ceramic based compound which is treated with a semiconductor material to make it conductive. At low temperatures the thermistor elements offer low electrical resistance, but once a predetermined temperature is exceeded their resistance rapidly increases with increasing temperature. This characteristic provides a fast warm-up (less than 10 seconds) of the thermistor elements when they are supplied with electrical power, followed by a temperature regulating effect where the current consumption is matched to the heat output.

When the PTC heater is supplied with electrical power, the thermistor elements heat up to the predetermined temperature. The radiator fins absorb heat from the thermistor elements and transfer it to the air stream.

The PTC heater is rated at 900 W at a nominal operating voltage of 13.5 V, ambient air temperature of 0 °C (32 °F) and air flow of 5 kg/minute (11 lb/minute). The initial current draw is in the region of 55 to 75 A, depending on the ambient air temperature and the temperature of the PTC heater. The theoretical surface temperature of the PTC heater, without any airflow, is 165 °C (329 °F) maximum.

PTC Heater Components



M80 0536

1 Grommet
2 Electrical connectors
3 Earth eyelet
4 Radiator fins
5 Thermistor element
6 Frame
7 End cover
8 Silicone cap

Heater Switch

The heater switch controls when the PTC operates. The switch is installed on the rear of the heater control panel and is operated by the spindle of the temperature control knob.

When the temperature control knob is selected in the cold to warm range, i.e. less than approximately 1 o'clock, the heater switch is open and the PTC heater is off. When the temperature control knob is selected in the warm to hot range, i.e. approximately 1 o'clock and above, the heater switch is closed and the PTC heater is on.

Relays

A power relay and a control relay control the switching of power to the PTC heater. The power relay is installed on the engine bulkhead behind the engine compartment fusebox and is operated by the control relay. The control relay is installed at the side of the E-box and is operated by the heater switch.

Link Harness and Fuses

The link harness interconnects the PTC heater system components and connects the system to the main harness. The harness is routed from the RH side of the heater assembly, through the engine bulkhead into the plenum, then along the plenum and into the rear right corner of the engine compartment. Grommets protect the link harness where it passes through the engine bulkhead and the front wall of the plenum.

An 80 A in-line fuse is incorporated into the link harness to protect the power feed from the battery to the power relay. Three 30 A fuses, in a fuse holder alongside the control relay, protect the individual power feeds from the power relay to the PTC heater.

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.

Fuel Burning Heater (FBH) System (Where Fitted)
The FBH system only operates while the engine is running and the ambient temperature is less than 5 °C (41 °F). With the engine running and the ambient temperature below 5 °C (41 °F), the air temperature sensor connects the alternator power supply to the ECU in the FBH unit. On receipt of the alternator power supply, the ECU starts the circulation pump and, depending on the input from the temperature sensor in the heat exchanger, enters either a standby or active mode of operation. If the heat exchanger casing temperature is 65 °C (149 °F) or above, the ECU enters a standby mode of operation. If the heat exchanger casing temperature is below 65 °C (149 °F), the ECU enters an active mode of operation. In the standby mode, the ECU monitors the heat exchanger casing temperature and enters the active mode if it drops below 65 °C (149 °F). In the active mode, the ECU initiates a start sequence and then operates the system at full or part load combustion to provide the required heat input to the coolant.

Start Sequence
At the beginning of the start sequence the ECU energises the glow plug function of the glow plug/flame sensor, to preheat the combustion chamber and start the combustion air fan at slow speed. After approximately 30 seconds, the ECU energises the FBH fuel pump at the starting sequence speed. The fuel delivered by the FBH fuel pump evaporates in the combustion chamber, mixes with air from the combustion air fan and is ignited by the glow plug/flame sensor. The ECU then progressively increases the speed of the FBH fuel pump and the combustion air fan to either part or full load speed, as required by the system. Once full or part load speed is achieved, the ECU switches the glow plug/flame sensor from the glow plug function to the flame sensing function to monitor combustion. From the beginning of the start sequence to stable combustion takes approximately 90 seconds for a start to part load combustion and 150 seconds for a start to full load combustion.

Coolant Temperature Control

When the ECU first enters the active mode, it initiates a start to full load combustion. Full load combustion continues until the heat exchanger casing temperature reaches 60 °C (140 °F), at this point the ECU decreases the speed of the FBH fuel pump and the combustion air fan to half speed, to produce part load combustion. The ECU maintains part load combustion while the heat exchanger casing temperature remains between 54 and 65 °C (129 °C and 149 °F). If the heat exchanger casing temperature decreases to 54 °C (129 °F), the ECU switches the system to full load combustion again. If the heat exchanger casing temperature increases to 65 °C (149 °F), the ECU enters a control idle phase of operation.

On entering the control idle phase, the ECU immediately switches the FBH fuel pump off, to stop combustion, and starts a timer for the combustion air fan. After a 2 minute cool down period, the ECU switches the combustion air fan off and then remains in the control idle phase while the heat exchanger casing temperature remains above 59 °C (138 °F). If the heat exchanger casing temperature decreases to 59 °C (138 °F), within 15 minutes of the ECU entering the control idle phase, the ECU initiates a start to part load combustion. If more than 15 minutes elapse before the heat exchanger casing temperature decreases to 59 °C (138 °F), the ECU initiates a start to full load combustion.

In order to limit the build up of carbon deposits on the glow plug/flame sensor, the ECU also enters the control idle phase if the continuous part and/or full load combustion time exceeds 72 minutes. After the cool down period, if the heat exchanger casing is still in the temperature range that requires additional heat, the ECU initiates an immediate restart to part or full load combustion as appropriate.

Shutdown

The FBH system is de-activated when the alternator power supply to the FBH unit is disconnected, either by the engine stopping or, if the ambient temperature increases to 5 °C (41 °F) or above, by the contacts in the air temperature sensor opening. If the system is active when the alternator power supply is disconnected, the ECU de-energises the FBH fuel pump to stop combustion, but continues operation of the combustion air fan and the circulation pump to cool down the FBH unit. The cool down time depends on the combustion load at the time the alternator power input is disconnected.

Cool Down Times

Combustion Load	Cool Down Time, Seconds
Part	100
Full	175

Diagnostics

The ECU in the FBH unit monitors the system for faults. Any faults detected are stored in volatile memory in the ECU, which can be interrogated by Testbook/T4. A maximum of three faults and associated freeze frame data can be stored at any one time. If a further fault is detected, the oldest fault is overwritten by the new fault.

The ECU also incorporates an error lockout mode of operation that inhibits system operation to prevent serious faults from causing further damage to the system. In the error lockout mode, the ECU immediately stops the FBH fuel pump, and stops the combustion air fan and circulation pump after a cool down time of approximately 2 minutes. Error lockout occurs for start sequence failures and/or combustion flameouts, heat exchanger casing overheat and out of limit input voltage. The error lockout mode can be cleared using Testbook/T4, or by disconnecting the battery power supply for a minimum of 10 seconds.

Start Failure/Flameout: If a start sequence fails to establish combustion, or a flameout occurs after combustion is established, the ECU immediately initiates another start sequence. The start failure or flameout is also recorded by an event timer in the ECU. The event timer is increased by one after each start failure or flameout, and decreased by one if a subsequent start is successful. If the event timer increases to three (over any number of drive cycles), the ECU enters the error lockout mode.

Heat Exchanger Casing Overheat: To protect the system from excessive temperatures, the ECU enters the error lockout mode if the heat exchanger casing temperature exceeds 105 °C (221 °F).

Out of Limit Voltage: The ECU enters the error lockout mode if the battery or alternator power input is less than 10.5 ± 0.3V for more than 20 seconds, or more than 15.5 ± 0.5V for more than 6 seconds.

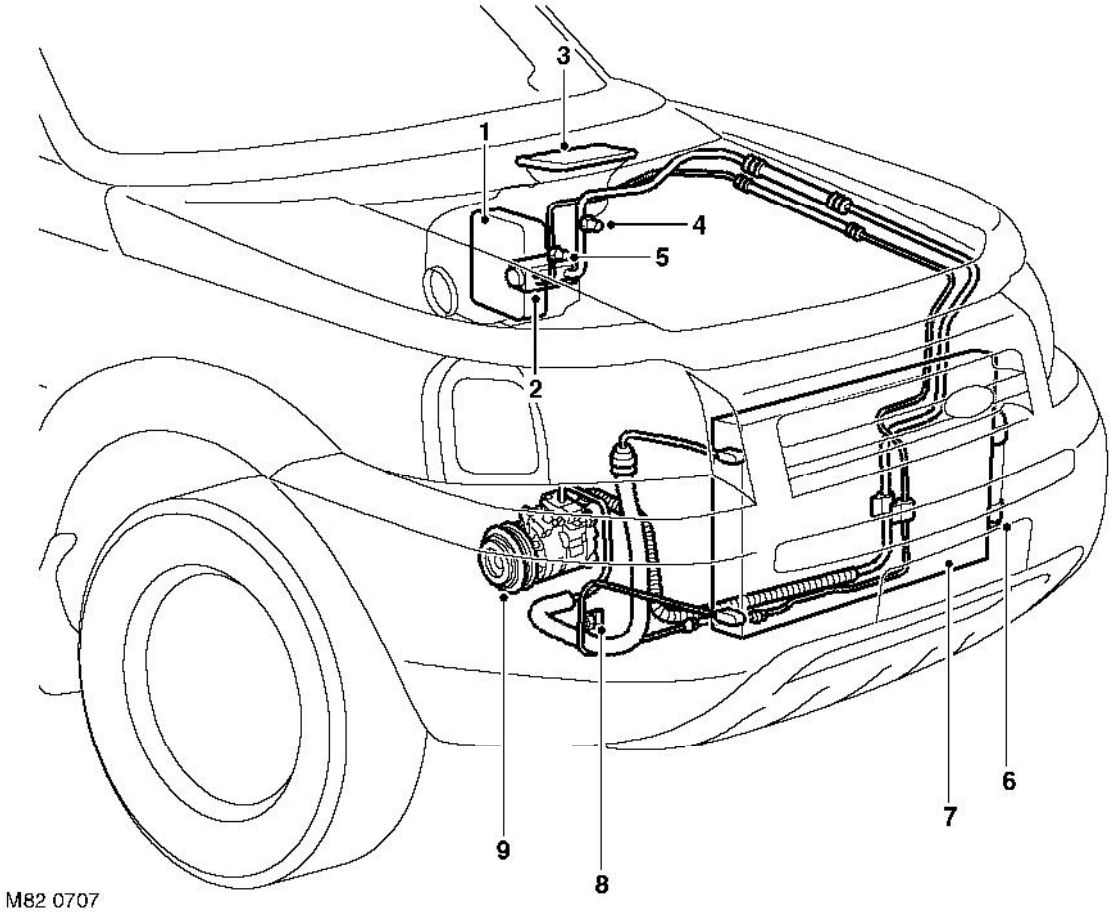
PTC Heater (Where Fitted)
The PTC heater operates while the engine is running and, for a limited period, if the ignition is switched on without starting the engine.

When the ignition switch is turned to position II, the ECM energises the fuel pump relay, which, in addition to connecting power supplies to the fuel pumps, connects a power supply to the coil of the power relay in the PTC heater system. The ECM keeps the fuel pump relay energised while the engine is running. If the engine is not started within approximately 60 seconds of turning on the ignition, the ECM de-energises the fuel pump relay.

The earth side of the power relay coil is connected to earth via the contacts of the control relay. The coil of the control relay is connected in series to the heater switch, blower switch and ignition switch. While the ignition switch is in position II, if the blower is selected on and the temperature control is turned clockwise to a position past 1 o'clock, a power supply is connected to the coil of the control relay. The control relay energises and connects the coil of the power relay to earth, which then energises and connects power to the PTC heater.

On manual gearbox models, when the control relay is energised a power feed is connected to the ECM. When the ECM senses the power feed, if the engine coolant temperature is below 85 °C (185 °F) it increases engine idle speed by 50 rev/min, to improve idle speed refinement while the additional load is imposed on the alternator by the PTC heater.

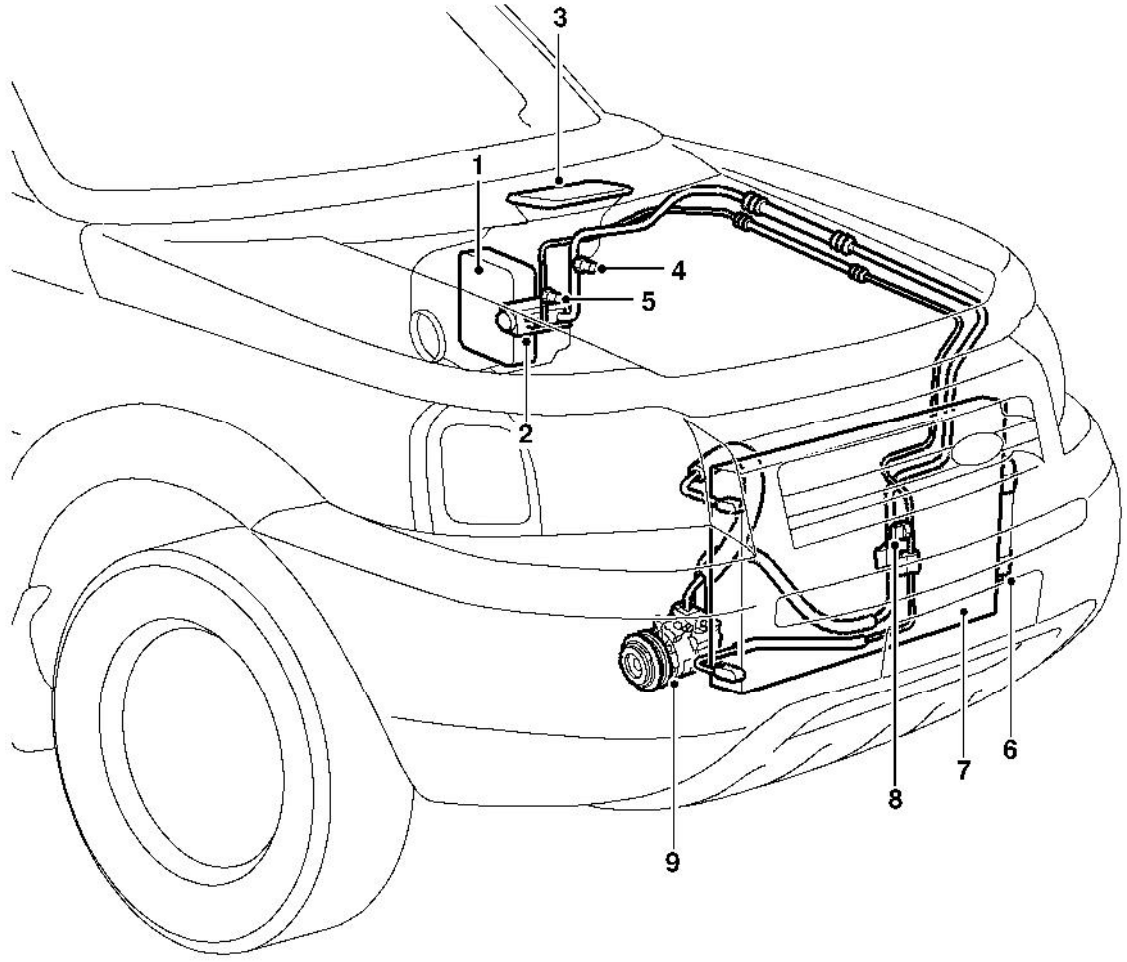
A/C Refrigerant System Component Layout – KV6 Series Engines



RHD shown, LHD similar

1 Evaporator
2 Thermostatic expansion valve
3 Air inlet unit
4 Low pressure servicing connection
5 High pressure servicing connection
6 Modulator
7 Condenser
8 Refrigerant pressure sensor
9 Compressor

A/C Refrigerant System Component Layout – K1.8 Series Engines

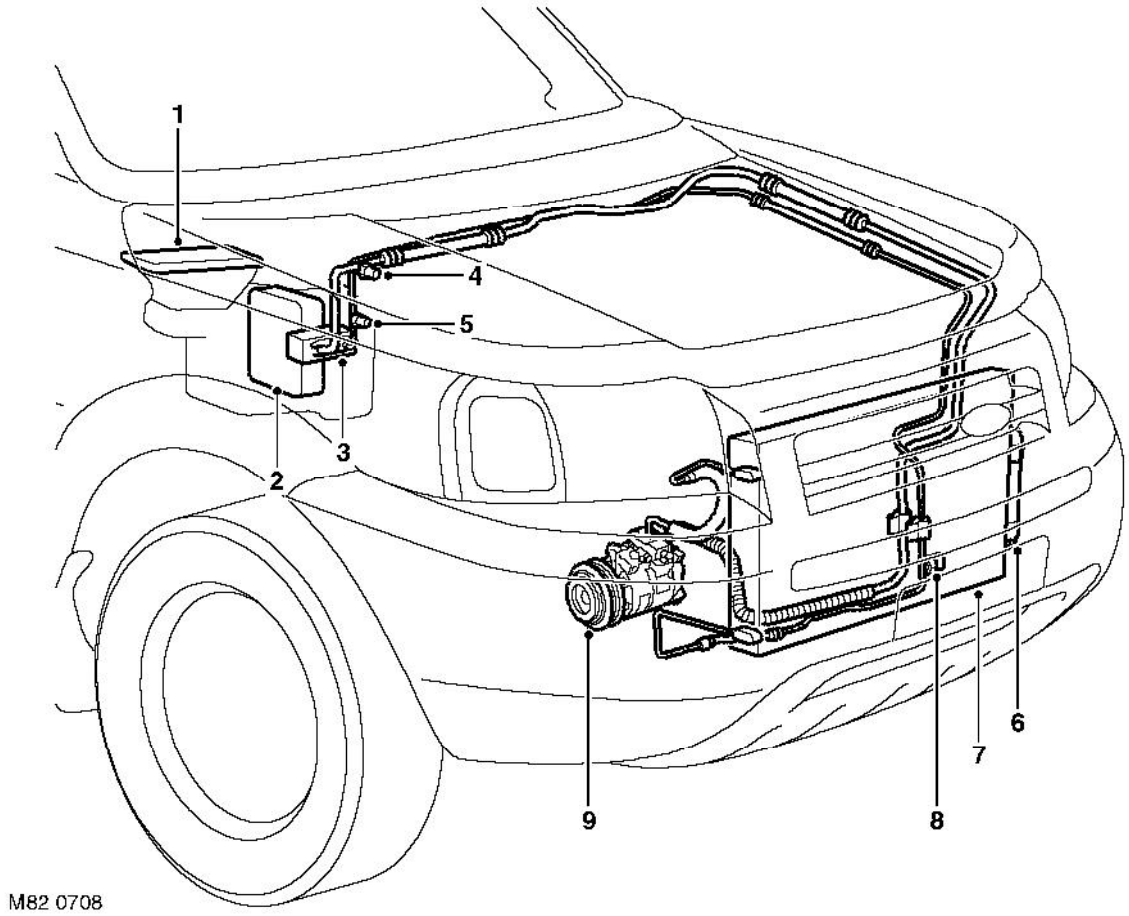


M82 0729

RHD shown, LHD similar

1 Evaporator
2 Thermostatic expansion valve
3 Air inlet duct
4 Low pressure servicing connection
5 High pressure servicing connection
6 Modulator
7 Condenser
8 Refrigerant pressure sensor
9 Compressor

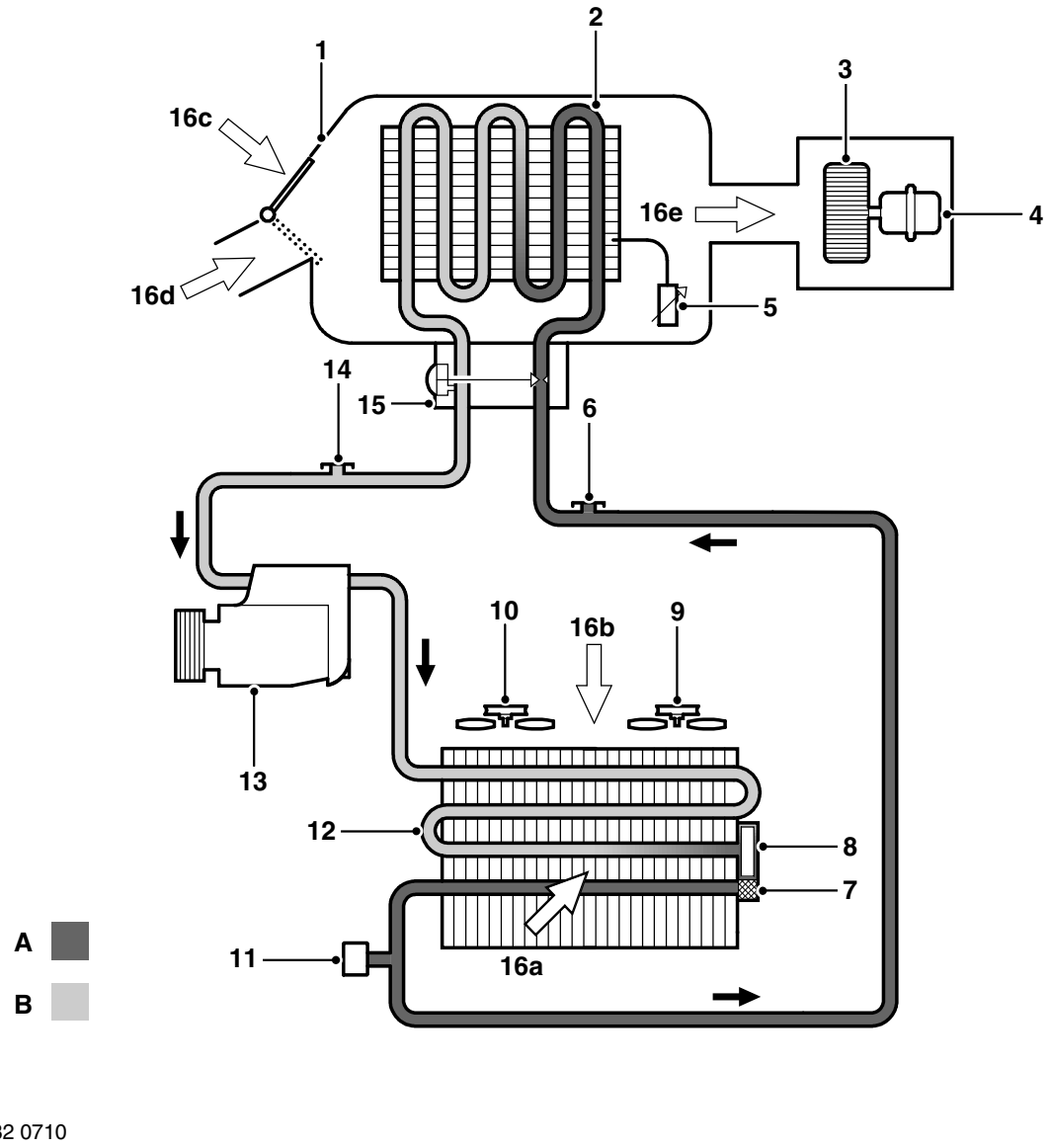
A/C Refrigerant System Component Layout – Td4 Series Engines



LHD shown, RHD similar

1 Air inlet unit
2 Evaporator
3 Thermostatic expansion valve
4 Low pressure servicing connection
5 High pressure servicing connection
6 Modulator
7 Condenser
8 Refrigerant pressure sensor
9 Compressor

A/C System Schematic Layout

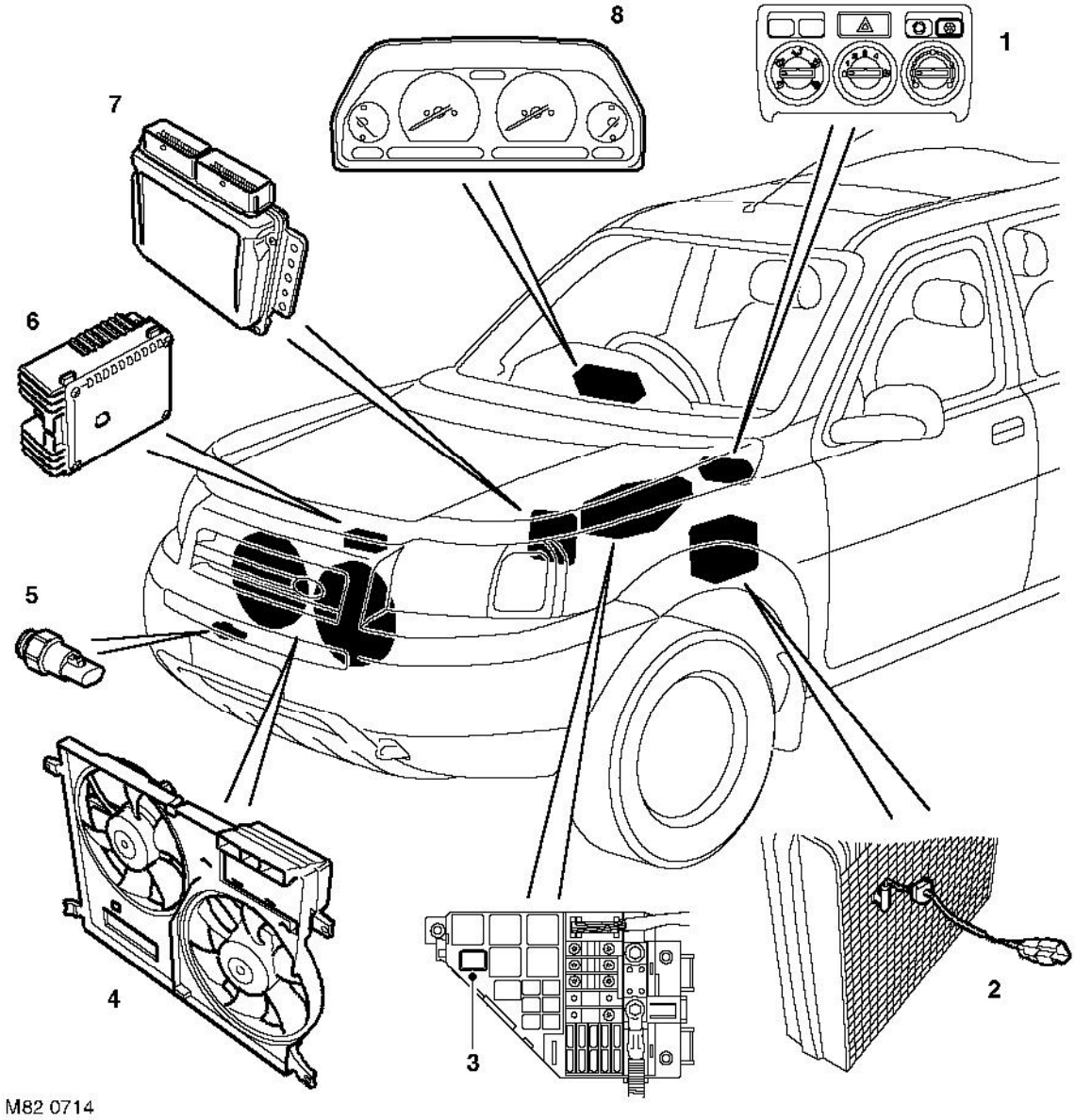


M82 0710

A = Refrigerant liquid; B = Refrigerant vapour

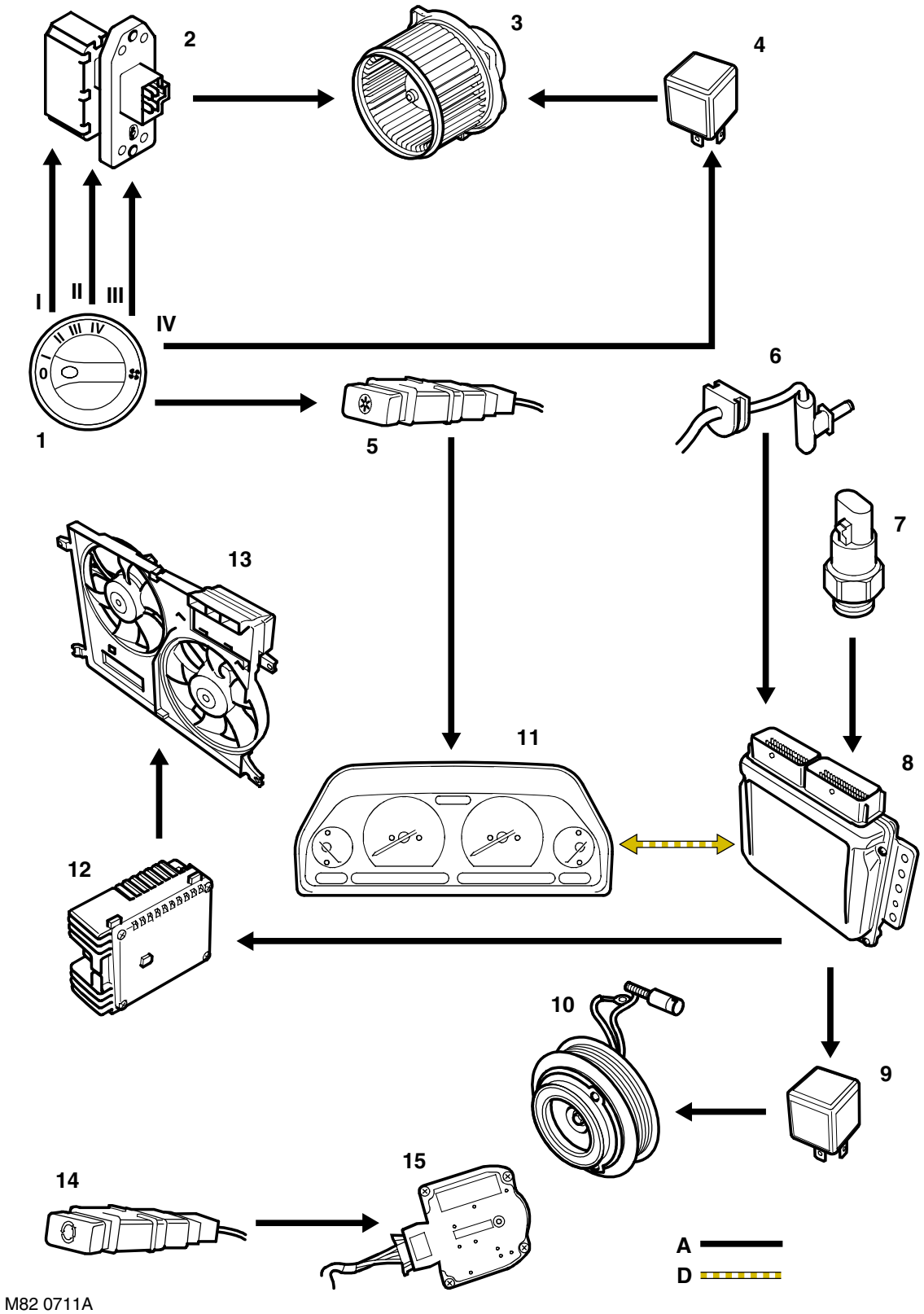
1 Cooling unit
2 Evaporator
3 Blower
4 Heater assembly
5 Evaporator temperature sensor
6 High pressure servicing connection
7 Filter (in modulator)
8 Desiccant (in modulator)
9 Cooling/condenser fan 1
10 Cooling/condenser fan 2
11 Refrigerant pressure sensor
12 Condenser
13 Compressor
14 Low pressure servicing connection
15 Thermostatic expansion valve
16 Air flows:
- **a** Ambient air flow through condenser
- **b** Cooling fan forced air flow through condenser
- **c** Recirculated air flow
- **d** Ambient air flow through evaporator
- **e** Cooled air flow to vehicle interior (via heater assembly)

A/C Control Component Layout



1 Control panel
2 Evaporator temperature sensor
3 Compressor control relay
4 Cooling/condenser fans
5 Refrigerant pressure sensor
6 Cooling/condenser fan controller
7 Engine Control Module (ECM)
8 Instrument pack

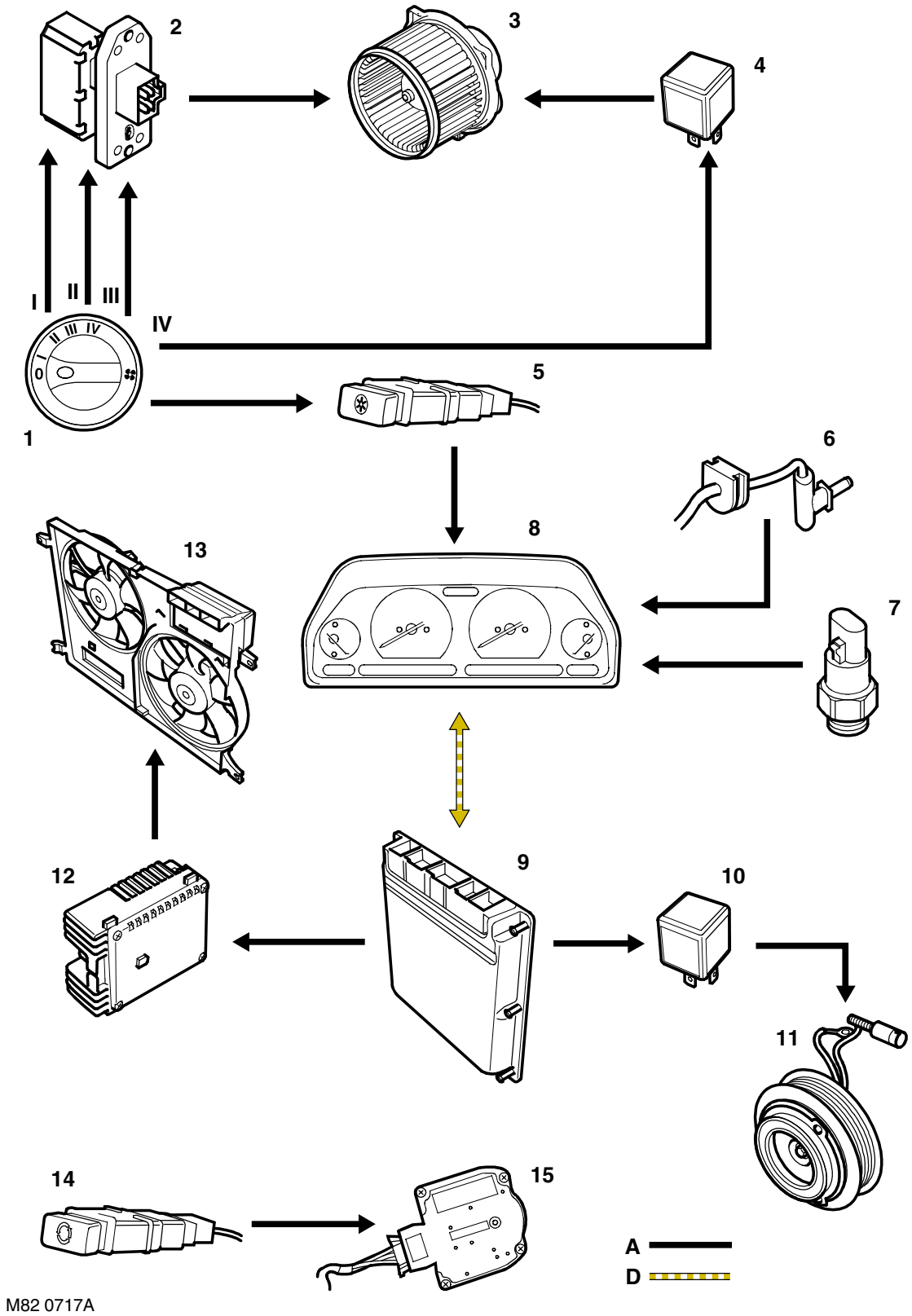
A/C System Control Schematic – K1.8 and Non NAS KV6



A = Hardwired; D = CAN Bus

1. Blower switch
2. Resistor pack
3. Blower motor
4. Blower motor relay
5. Air conditioning switch
6. Evaporator temperature sensor
7. Refrigerant pressure sensor
8. Engine Control Module (ECM)
9. A/C compressor clutch relay
10. Compressor clutch
11. Instrument pack
12. Cooling/condenser fan controller
13. Cooling/condenser fans
14. Fresh/recirculated air switch
15. Recirculated air motor

A/C System Control Schematic – Td4 and NAS KV6



A = Hardwired; D = CAN Bus

1. Blower switch
2. Resistor pack
3. Blower motor
4. Blower motor relay
5. Air conditioning switch
6. Evaporator temperature sensor
7. Refrigerant pressure sensor
8. Instrument pack
9. Engine Control Module (ECM)
10. A/C compressor clutch relay
11. Compressor clutch
12. Cooling/condenser fan controller
13. Cooling/condenser fans
14. Fresh/recirculated air switch
15. Recirculated air motor

Description

General
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.

☞ **HEATING AND VENTILATION, DESCRIPTION AND OPERATION, Description.**

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:

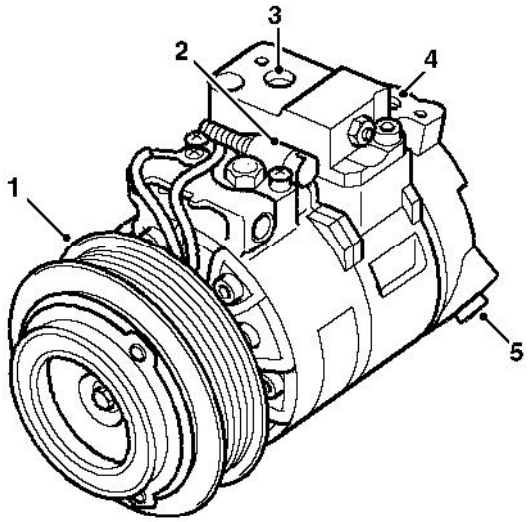
- Compressor (variable load)
- Condenser (with modulator)
- Thermostatic expansion valve
- Evaporator

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.

Compressor



M82 0712

1 Pulley
2 Clutch connector
3 Inlet connection
4 Outlet connection
5 Control valve vent

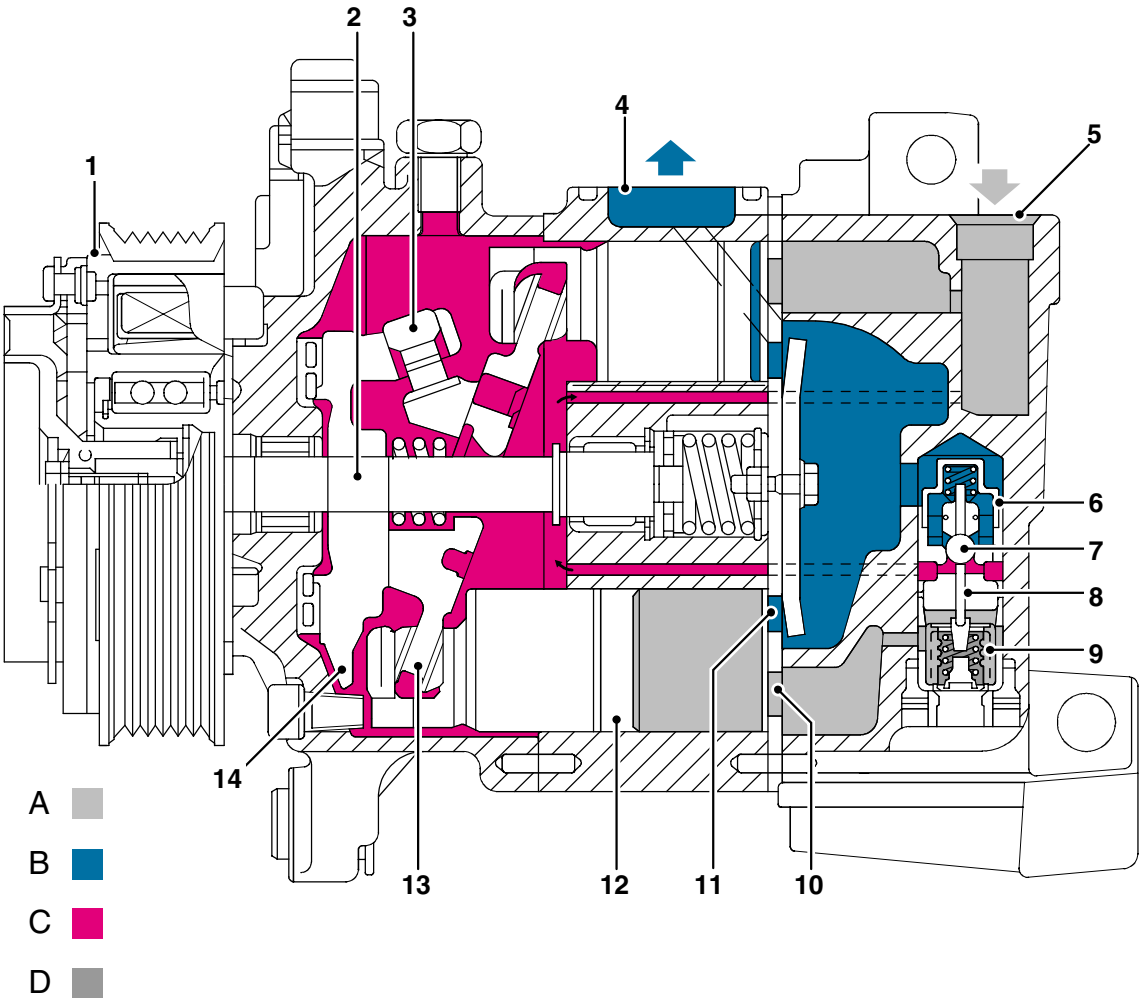
A variable displacement compressor is driven from the crankshaft via the ancillary drive belt. An electro-mechanical clutch is used to engage and disengage the drive between the drive belt pulley and the compressor. Operation of the compressor clutch is controlled by the Engine Control Module (ECM).

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 swash plate unit with variable displacement. Operation of an electrically actuated clutch is controlled by the Engine Control Module(ECM).

Sectioned View of Compressor



A = Inlet pressure; B = Outlet pressure; C = Servo pressure; D = Ambient air pressure

1 Clutch and pulley assembly
2 Shaft
3 Guide pin
4 Outlet port
5 Inlet port
6 Control valve assembly
7 Ball valve
8 Push rod
9 Diaphragm
10 Suction valve
11 Discharge valve
12 Piston
13 Swash plate
14 Lug plate

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 swash plate is installed on the shaft and connected to the lug plate by two guide pins. The swash plate is a sliding fit on the shaft and biased away from the lug plate by a spring. The outer circumference of the swash 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 swash 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 swash 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 swash plate holds the swash 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 swash plate turn with the shaft, and the movement of the angled swash 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.

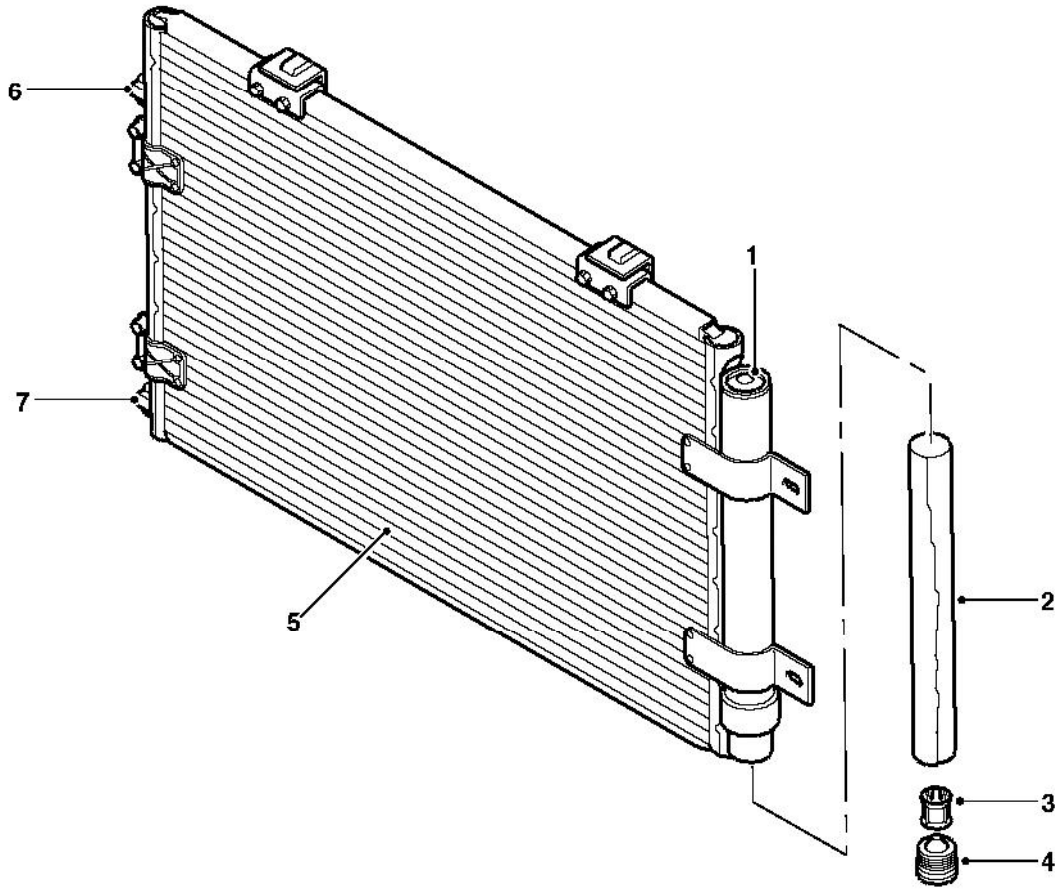
The flow rate through the compressor is determined by the length of the piston stroke, which is controlled by the tilt angle of the swash plate. The tilt angle of the swash plate is set by the servo pressure and compressor inlet pressure acting on the pistons during their induction stroke. A relative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

The control valve regulates the servo pressure in the swash 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 $lbf.in^2$).

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 swash plate chamber, which maintains the swash 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 swash plate chamber pressure, together with the increase in inlet pressure, causes pistons on their induction stroke to move the swash 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 swash plate chamber pressure, which in turn reduces the tilt angle of the swash 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).

Condenser and Modulator



M82 0715

1 Modulator
2 Desiccant
3 Filter
4 Plug
5 Heat exchanger
6 Outlet connection
7 Inlet connection

The condenser transfers heat from the refrigerant to the surrounding air to convert the vapour from the compressor into a liquid. A modulator mounted on the side of the condenser performs the same basic function as a conventional receiver/drier, in that it incorporates a filter and a desiccant to remove moisture and solid impurities from the refrigerant. The modulator also functions as a reservoir for liquid refrigerant, to accommodate changes of heat load at the evaporator.

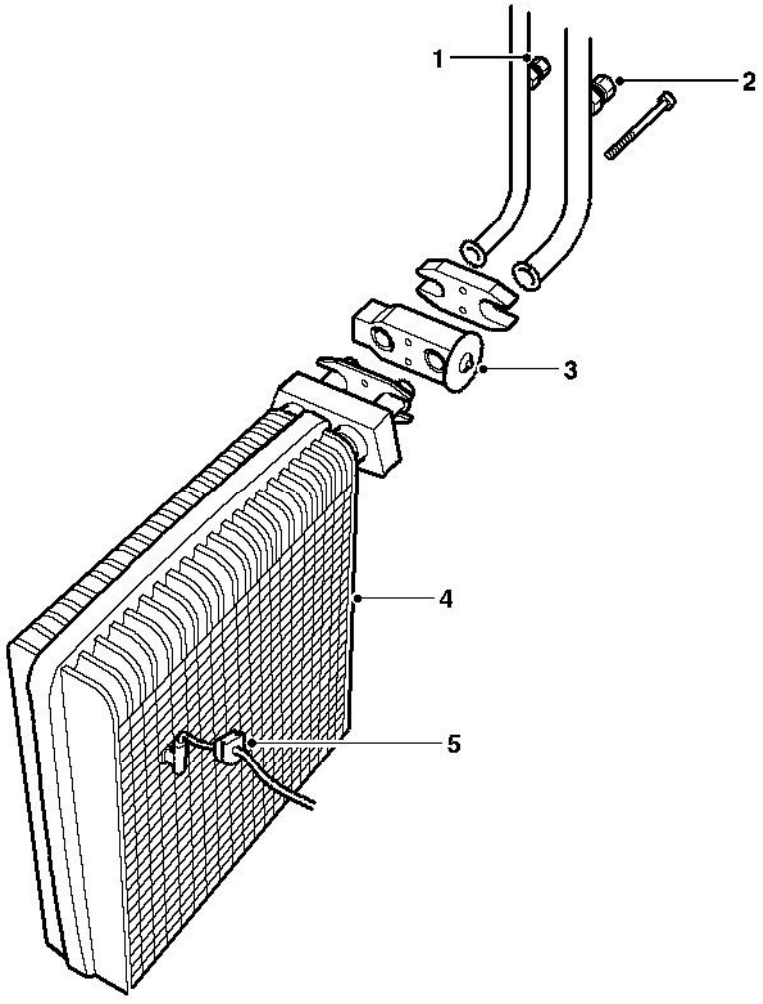
The condenser is installed immediately in front of the radiator. Side mounting brackets on the condenser end tanks locate to mounting points on the front of the radiator using bolts. The modulator on the LH end of the condenser is mounted in a dedicated bracket. Exact mounting position of the condenser unit is dependent on the engine variant for the particular vehicle.

The unit is classified as a sub-cooling condenser and consists of a fin and tube heat exchanger installed between two end tanks. Divisions in the end tanks separate the heat exchanger into a three pass upper (condenser) section and a single pass lower (sub-cooler) section, which are interconnected by the modulator on the LH end of the tank. The modulator is separately serviceable unit from the condenser, and it contains a serviceable desiccant pack and filter retained by a threaded plug.

Ambient air passing through the heat exchanger due to the ram air effect is supplemented by the two cooling fans, which combine to cool the refrigerant in the condenser sufficiently in order to form a high pressure slightly sub-cooled liquid.

The sub-cooled liquid is then passed to the modulator (which performs the same basic function as a standard receiver/drier) which is of a canister type construction located at the LH side of the condenser. In the modulator, most of the remaining gas in the refrigerant separates off and the refrigerant passes through the desiccant and filter, to remove moisture and solid impurities before the refrigerant enters the sub-cooled section of the condenser. The refrigerant is cooled even further as it passes through the sub-cooler section of the condenser, resulting in the refrigerant at the outlet to the condenser being almost 100% liquid.

Thermostatic Expansion Valve (TXV)



M82 0716

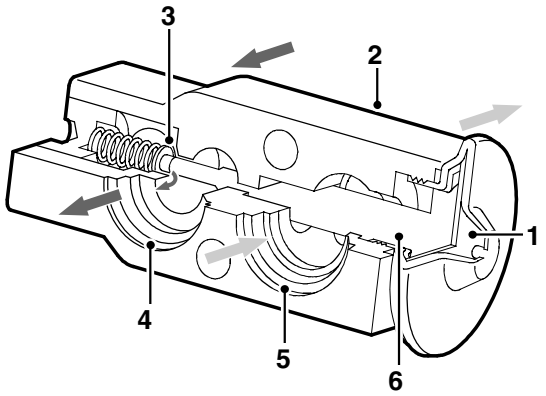
1 High pressure (evaporator inlet) servicing connection
2 Low pressure (evaporator outlet) servicing connection
3 Thermostatic expansion valve (TXV)
4 Evaporator matrix
5 Evaporator temperature sensor

The sub-cooled liquid refrigerant passes from the outlet of the condenser through a pipe to a thermostatic expansion valve (TXV) situated at the engine compartment bulkhead. The TXV connects to the evaporator unit mounted inside the air inlet and blower motor casing in the vehicle cabin.

The thermostatic expansion valve meters the flow of refrigerant into the evaporator, to match the refrigerant flow with the heat load of the air passing through the evaporator matrix.

The thermostatic expansion valve (block valve) incorporates a restrictor which converts the liquid refrigerant into a low temperature, low pressure liquid vapour mixture (fine spray). The valve has an internally located temperature sensing bulb for precise control of superheat. If high temperatures are sensed, the valve opens wider and vice versa.

The thermostatic expansion valve is attached to the inlet and outlet ports of the evaporator, in the cooling unit behind the passenger's side of the fascia. The valve is the parallel charge type, consisting of an aluminium housing containing inlet and outlet passages. A ball and spring metering valve is installed in the inlet passage and a temperature sensor is installed in the outlet passage. The temperature sensor consists of a push rod connected to a diaphragm. The bottom end of the push rod acts on the ball of the metering valve. Pressure on top of the diaphragm is controlled by evaporator outlet temperature conducted through the push rod. The bottom of the diaphragm senses evaporator outlet pressure via internal passages.



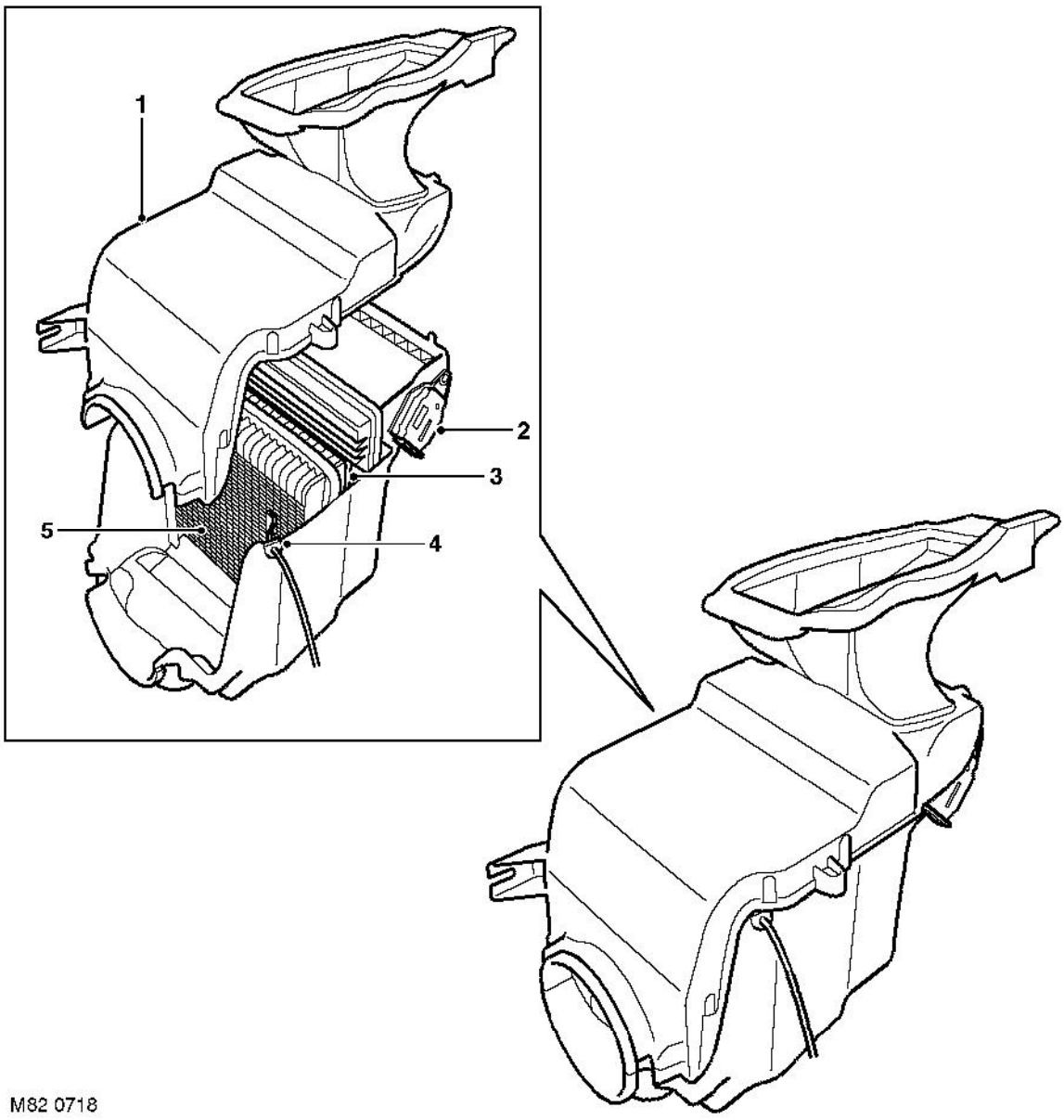
M82 0720

1 Diaphragm
2 Housing
3 Metering valve
4 Inlet passage to evaporator
5 Outlet passage from evaporator
6 Temperature sensitive tube

Liquid refrigerant flows through the metering valve into the evaporator. The restriction across the metering valve reduces the pressure and temperature of the refrigerant. The restriction also changes the solid stream of refrigerant into a fine spray, to improve the evaporation process. As the refrigerant passes through the evaporator, it absorbs heat from the air flowing through the evaporator matrix. The increase in temperature causes the refrigerant to vapourise and increase in pressure.

The temperature and pressure of the refrigerant leaving the evaporator act on the diaphragm and temperature sensitive tube, which move to regulate the metering valve opening and so control the volume of refrigerant flowing through the evaporator. The warmer the air flowing through the evaporator matrix, the more heat available to evaporate refrigerant and thus the greater the volume of refrigerant allowed through the metering valve.

Cooling Unit and Evaporator



1 Evaporator casing
2 Fresh/recirculated air flap motor
3 Pollen filter
4 Evaporator temperature sensor
5 Evaporator matrix

The cooling unit directs the flow of air, from the plenum or the vehicle interior, through the evaporator to the heater assembly.

The cooling unit is installed in place of the air inlet duct used for non air-conditioned vehicles, and contains the evaporator, inlet and outlet pipes connecting to the thermostatic expansion valve through the bulkhead and the evaporator temperature sensor. It also incorporates the water condensate drain and the fresh and recirculated air inlets.

A control flap, operated by a recirculated air motor, opens and closes the fresh and recirculated air inlets. On the downstream side of the evaporator, the casing is lined with polystyrene insulation.

The fin and plate, brazed aluminium evaporator is installed in the cooling unit behind the passenger's side of the fascia, to absorb heat from the exterior or recirculated inlet air. Low pressure, low temperature refrigerant changes from liquid to vapour in the evaporator, absorbing large quantities of heat as it changes state.

Most of the moisture in the air passing through the evaporator condenses into water, which is drained away from the air inlet casing via a drain tube routed to beneath the vehicle.

Refrigerant Lines

To maintain similar flow velocities around the system, the diameter of the refrigerant lines varies to suit the two pressure/temperature regimes. The larger diameters are installed in the low pressure/temperature regime and the smaller diameters are installed in the high pressure/temperature regime. Low and high pressure charging connections are incorporated into the refrigerant lines for system servicing.

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.

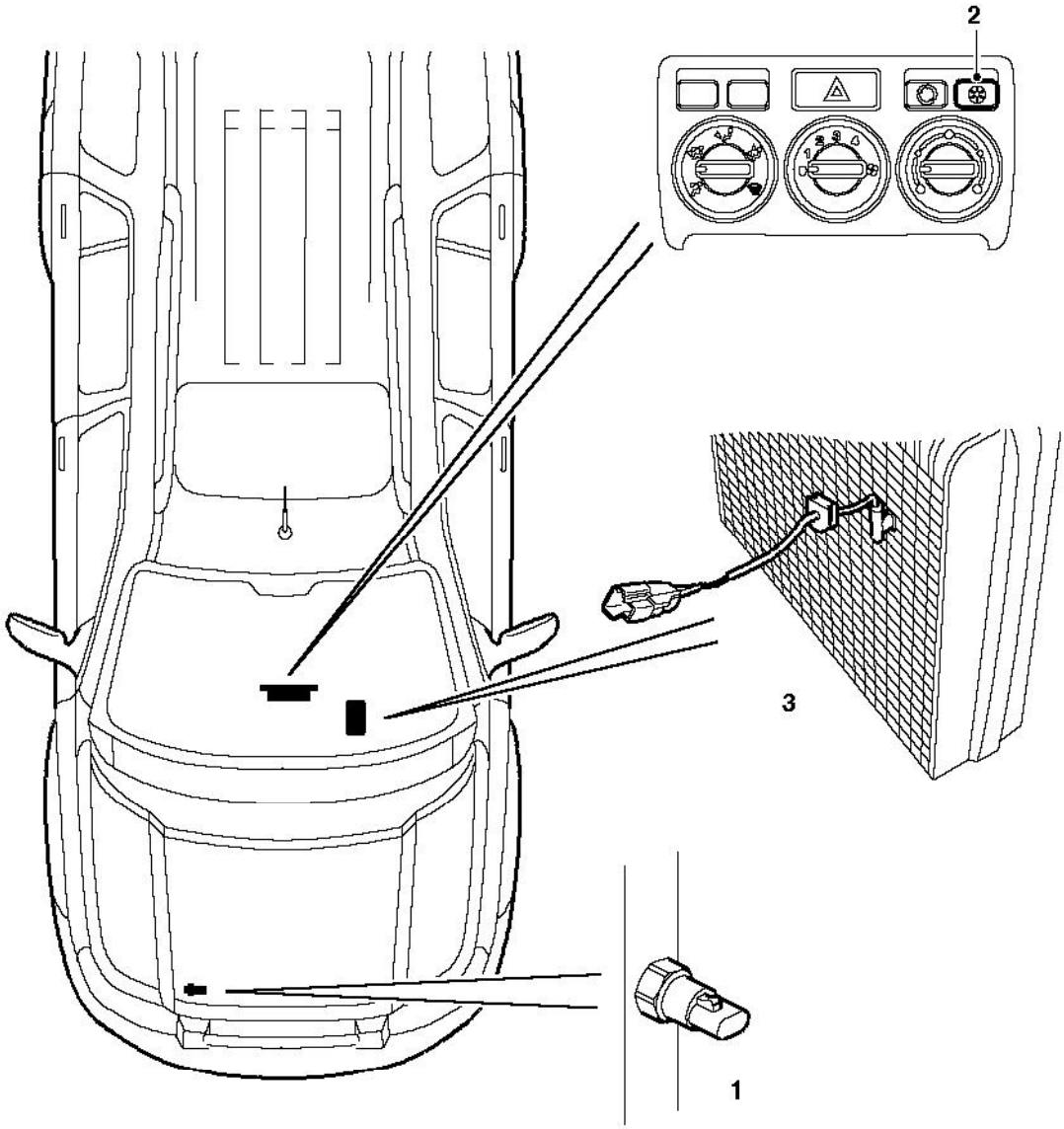
When air conditioning is not selected, air is supplied by ram effect or blower operation to the areas selected by the air distribution control. The air mix flap on the heater assembly blend unit controls the temperature of the air being delivered. No cooled air is available.

☞ **HEATING AND VENTILATION, DESCRIPTION AND OPERATION, Description.**

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.

Evaporator Temperature Sensor



1 Refrigerant pressure sensor
2 Air conditioning switch
3 Evaporator temperature sensor

The evaporator temperature sensor is a Negative Temperature Coefficient (NTC) encapsulated thermistor installed in the air outlet side of the evaporator. On K1.8 and non NAS KV6 models, the evaporator temperature sensor signal is fed directly to the ECM. On Td4 and NAS KV6 models, the evaporator temperature sensor is connected to the instrument pack, and the signal is relayed to the ECM from the instrument pack via the CAN Bus.

The temperature signal is used to 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.

☞ **ENGINE MANAGEMENT SYSTEM - MEMS, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**

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 K1.8 and non NAS KV6 models, the refrigerant pressure sensor signal is fed directly to the ECM. On Td4 and NAS KV6 models, the refrigerant 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.

Control Switches

The control switches consist of two latching push switches installed in the centre console, an air conditioning switch and a fresh/recirculated air switch. Each switch contains an amber indicator lamp which illuminates when air conditioning or recirculated air is selected, as applicable.

The A/C switch is supplied with a positive feed through the blower motor switch when one of the four blower speeds is selected. When the A/C switch is selected, a signal is supplied to the instrument pack through a hard wire connection. The instrument pack interprets the A/C request signal and transfers the request to the ECM via the CAN bus.

☞ **INSTRUMENTS, DESCRIPTION AND OPERATION, Description.**

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.

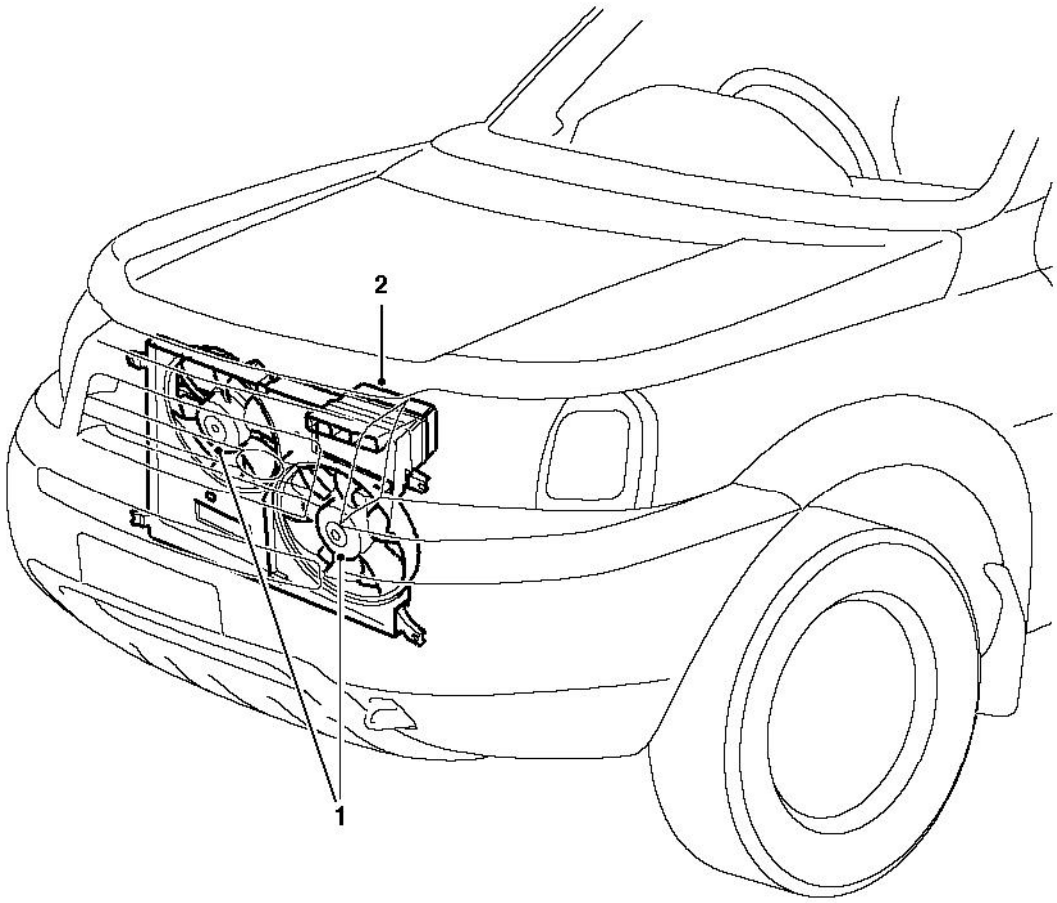
Compressor

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.in) 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/in^2), e.g. due to a blockage. Compressor engagement is re-enabled when the pressure decreases to 23 bar (334 lbf.in^2).
- The lower pressure limit is 1.6 bar (23.2 lbf/in^2), e.g. due to a leak. Compressor engagement is re-enabled when the pressure increases to 2.0 bar (29.0 lbf/in^2).

Cooling and Condenser Fans



M82 0719

1 Cooling and condenser fans

2 Cooling/condenser fan controller

The cooling fans operate automatically whenever the air conditioning system is switched on, provided the system pressure is correct. The motors of the two fans are variable speed and are switched together in parallel.

The ECM controls the operation of the variable speed cooling fans via a cooling fan controller installed on the back of the cooling fan assembly. The control signal from the ECM to the fan controller is a pulse width modulated (PWM) signal. The output from the ECM runs from 10% to 90%, corresponding to 0% to 100% fan current output from the interface. PWM signals below 10% or greater than 90% correspond to open and closed loop circuit failures, which can be diagnosed using TestBook/T4. The cooling fan controller receives the PWM signal and regulates the power feeds to the cooling fans accordingly to produce the required fan speed.

When air conditioning is selected, the cooling fans initially operate at minimum speed. If the pressure increases to 16 bar (232 lbf/in^2), the speed of the fans progressively increase up to a maximum speed at 27 bar (392 lbf/in^2). When the fans are at maximum speed, if the refrigerant pressure decreases, the speed of the fans progressively decrease down to a minimum speed at 15 bar (218 lbf/in^2). Operation of the cooling fans is also affected by coolant temperature.

☞ **ENGINE MANAGEMENT SYSTEM - MEMS, DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**

Operation

General
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.

Air Conditioning
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.

On K1.8 and non NAS KV6 models, the ECM is also in receipt of signals from the refrigerant pressure sensor and the evaporator temperature sensor, which it uses to determine the engine load, cooling fan speed and compressor clutch control. On Td4 and NAS KV6 models, the signals from the refrigerant pressure sensor and the evaporator temperature sensor are supplied to the instrument pack, which calculates the additional engine load and the cooling fan speed and transmits them to the instrument pack on the CAN Bus.

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.

Blower Control
The blower can be operated at any one of four speeds by rotating the blower switch to the required position. When the blower is switched off the air conditioning system will not operate.

The fresh air/recirculation flap has two positions and is operated by pressing the button in the centre console. In the recirculation position, air is drawn into the heater from the vehicle by closing the exterior air inlet and opening the interior inlet. In the fresh air position, air is drawn into the heater from outside the vehicle by opening the exterior air inlet and closing the interior inlet.

Heater Distribution and Blend Unit Control
Blower unit air flow, having passed through the evaporator passes into the heater blend unit to be heated, if required. It is then directed into the vehicle interior in accordance with the flap positions, which are designated by the air distribution control on the fascia panel. A heater flap controls the amount of air flowing through the heater matrix, this flap is moved in response to temperature selection using the knob on the control panel.

The distribution control moves the flaps which control the direction of the air flow into the interior of the vehicle.

Compressor and Cooling Fan Operating Conditions

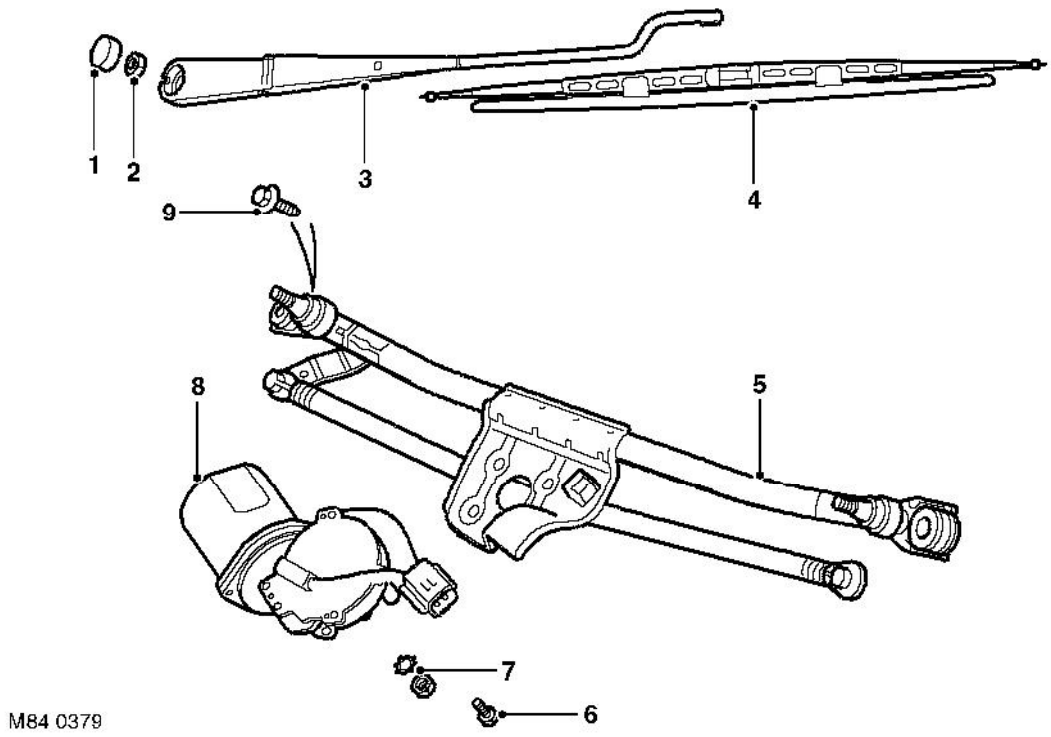
The Engine Control Module (ECM) controls the compressor and cooling fan operation in response to signals received from the refrigerant pressure sensor, evaporator temperature sensor and engine coolant temperature sensor, either directly or on the CAN Bus from the instrument pack. The refrigerant pressure can be low, medium or high, the system operating characteristics applicable for each condition is shown in the following table:

A/C Compressor On/ Off	Refrigerant Pressure Sensor Operating Range	Action
Off	MED range	Air Con MED limit reached, cooling fans switched to High speed.
Off	NORMAL range	Normal Condition, Low fan speed - no additional action
Off	HIGH range	COMPRESSOR NOT ALLOWED TO BE TURNED ON, cooling fans at high speed
Off	LOW range	COMPRESSOR NOT ALLOWED TO BE TURNED ON*
On	MED range	Air Con MED limit reached, cooling fans to High speed
On	NORMAL range	Standard condition, low fan speed - no additional action
On	HIGH range	AIR CON COMPRESSOR MUST BE DISENGAGED IMMEDIATELY, cooling fans set to High speed.
On	LOW range	AIR CON COMPRESSOR MUST BE DISENGAGED IMMEDIATELY*

* With pressure below the low pressure limit, the cooling fans will always be off unless air conditioning is running whilst evaporator temperature drops below minimum. If evaporator temperature drops below minimum, the cooling fans are required to prevent cabin temperature cycling.

The engine management system also drives fan speed based on engine temperature. A faster cooling fan request from either the engine cooling control or the A/C system will override another slow cooling fan speed request.

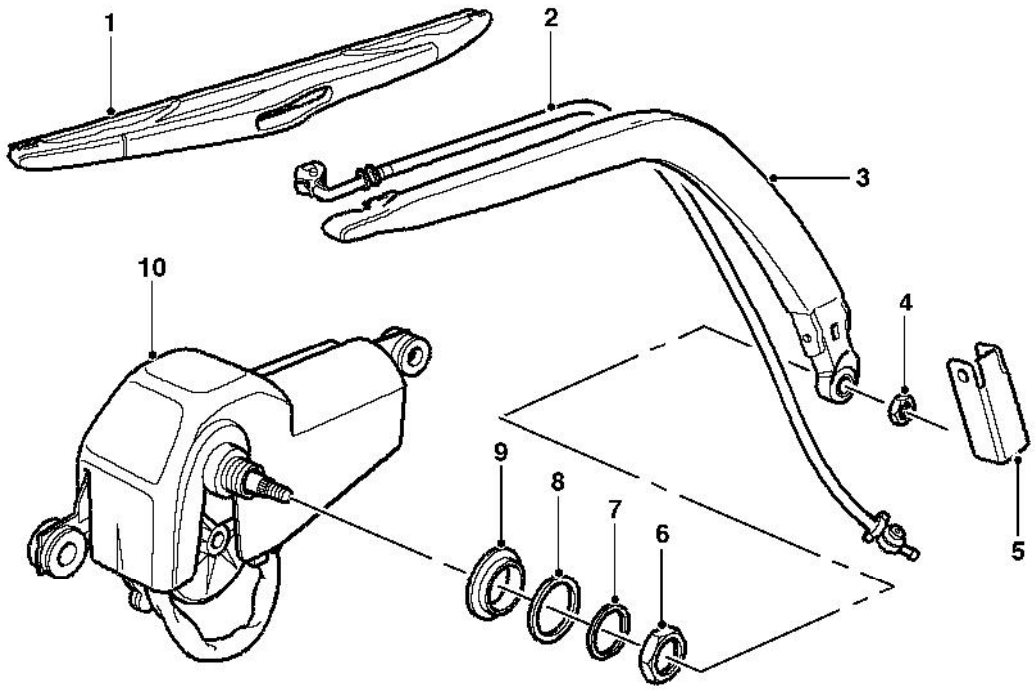
Windscreen Wiper Components



RHD shown, LHD mirror image

1 Cap, 2 off
2 Nut, 2 off
3 Wiper arm, 2 off
4 Wiper blade, 2 off
5 Wiper link assembly
6 Motor mounting bolt, 3 off
7 Nut and washer
8 Wiper motor
9 Mounting bolt, 3 off

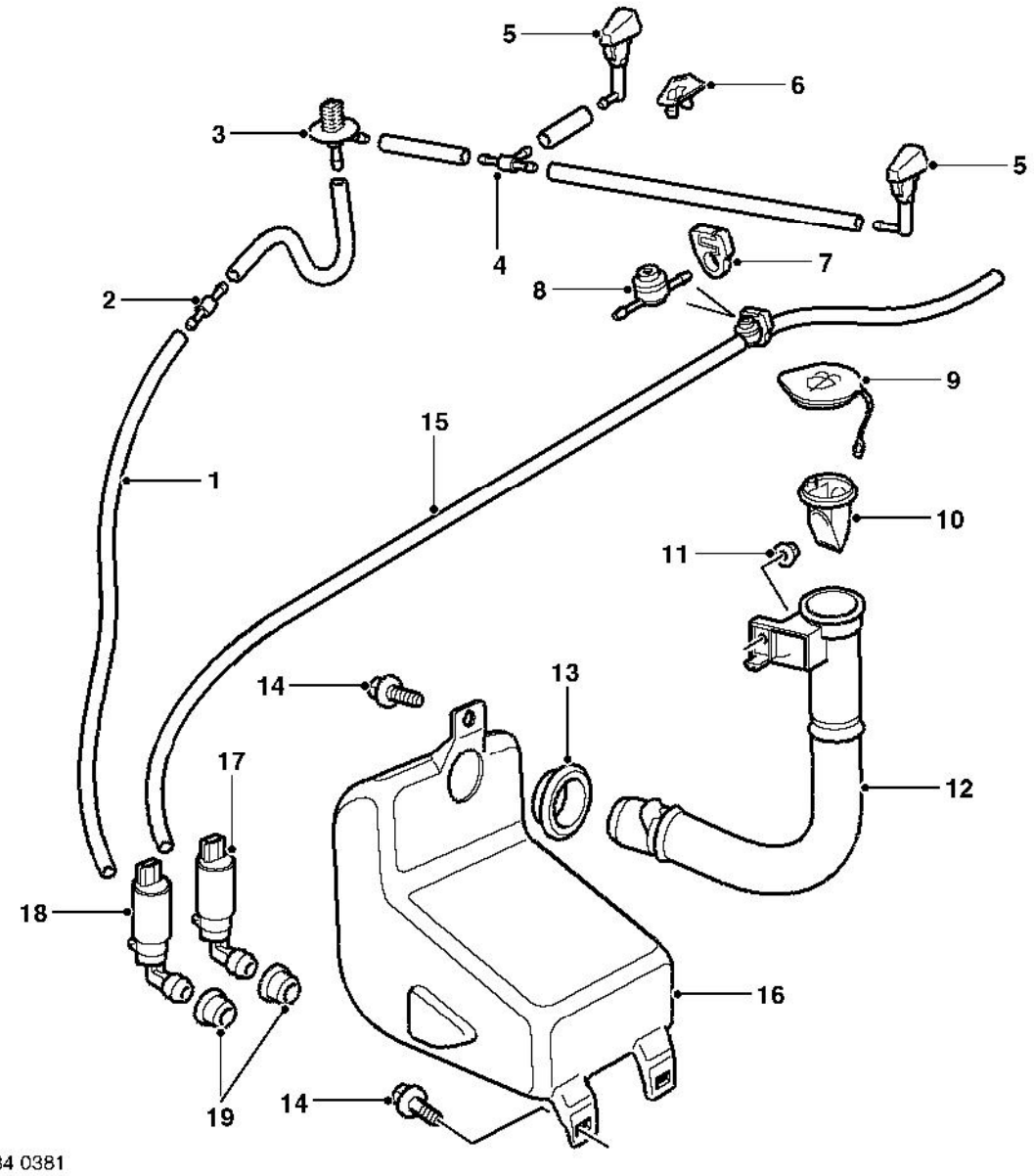
Rear Screen Wiper Components



M84 0380

1 Wiper blade
2 Washer jet and hose
3 Wiper arm
4 Nut
5 Cover
6 Nut
7 Washer
8 Rubber washer
9 Rubber spacer
10 Wiper motor

Washer Components



M84 0381

1 Windscreen washer hose
2 Non return valve
3 Connector elbow
4 Connector 'T' piece
5 Washer jet, 2 off
6 Washer jet holder, 2 off
7 Hose clip
8 Non return valve
9 Filler cap
10 Filler filter
11 Mounting nut
12 Filler neck tube
13 Filler neck seal
14 Mounting bolt, 3 off
15 Rear screen washer hose
16 Washer reservoir
17 Rear screen washer pump
18 Windscreen washer pump
19 Grommet, 2 off

Description

Windscreen Wipers
Two front windscreen wipers are operated by a single electric motor. The motor and a link assembly are located below the plenum grill at the base of the windscreen.

The link assembly is handed for left and right hand drive vehicles. All other wiper components remain common to both versions. The component descriptions and operation are the same for both left and right hand drive.

The parallel coupled link assembly comprises a curved galvanized tube which has a cast wheel box pushed into each end of the tube and crimped for retention. A galvanized link arm is attached to a lever at the base of each wheel box.

Each link is attached by a spherical bearing which is permanently attached to the lever and the link. The opposite end of each link also has a spherical bearing, which are both attached to a spigot which in turn is attached to a lever. The lever has a splined bore and mates with a splined shaft from the motor. A spring washer and nut secure the lever to the shaft.

Each wheel box comprises a cast housing, through which a splined shaft is located on bearings. The outer end of each shaft has splines which provide positive location for the wiper arms. The link assembly is a sealed unit and is not serviceable. The motor is attached to the link assembly with three bolts. The motor can operate at two speeds for fast and slow wiper operation. The motor is a DC motor with permanent magnets. The central shaft of the motor is fitted with a worm drive which in turn rotates a gear connected to the splined drive shaft.

A wiper arm is located on the splined shaft of each wheel box and secured with a nut. The wiper arm attachment to the splined shaft has a pivot to which the remainder of the arm is attached. The two parts of the arm are connected by a spring which controls the pressure of the blade on the screen to a predetermined amount.

Each wiper blade is attached to its wiper arm with a clip that allows the blade to pivot. Each wiper blade comprises a number of levers and yokes to which the rubber wiper is fitted. The levers and yokes ensure that the pressure applied by the arm spring is distributed evenly along the full length of the blade. The rubber wiper is held in the yokes by a pair of stainless steel strips, which also distribute the spring pressure evenly. The driver's side wiper blade is fitted with an aerofoil, which presses the wiper blade onto the windscreen at high speed. This prevents the wiper blade from lifting off the screen and maintains the wiping performance.

Rear Screen Wiper
The rear screen wiper is attached to a splined shaft which is driven by an electric motor via an eccentric drive mechanism.

The motor is a single speed dc motor with permanent magnets. The motor shaft is fitted with a worm drive which rotates a gear wheel. The gear wheel has an offset spigot to which an eccentric cam is fitted which can rotate through 180° in each direction. A coil spring is located around the cam and operates as a simple friction clutch to enable the cam to be rotated when the motor is driven in reverse. A connecting link is attached to the cam and drives two gears located in a link. The connecting link converts the rotary motion of the gear wheel into linear movement of the link. The linear movement is converted back into rotary movement of the splined shaft which moves the wiper arm in an arc in two directions across the rear screen.

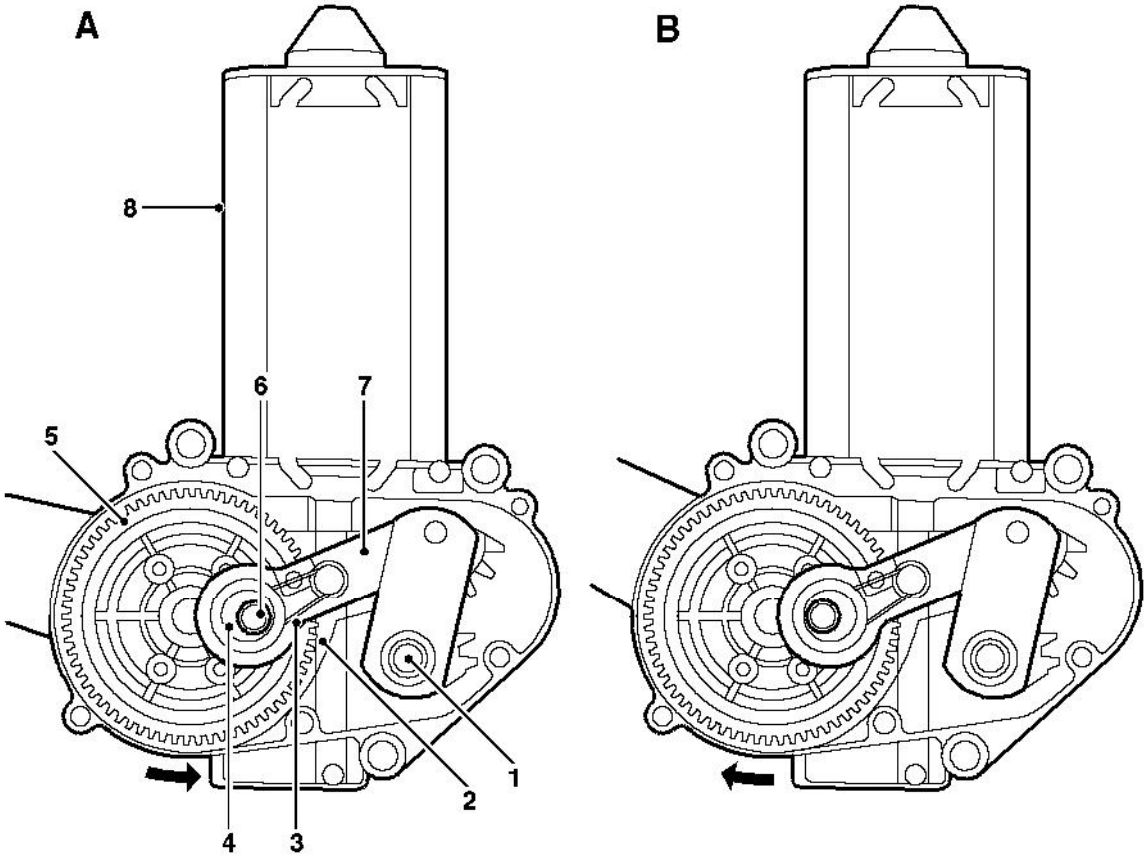
The wiper motor has the ability to park the wiper arm off the rear screen when the wiper is selected off. When the motor is operating to wipe the rear screen, the motor shaft is rotating in a clockwise direction. When the rear screen wiper is selected off, the Central Control Unit (CCU) allows the wiper arm to reach the vertical position on the screen. A microswitch, actuated by a slip ring on the underside of the gear wheel, signals that the wiper arm has reached this position. The CCU then reverses the polarity of the supply to the motor which causes the motor shaft to rotate in an anti-clockwise direction.

When the motor changes direction, the eccentric cam is rotated through 180° which effectively lengthens the linear movement of the connecting link. This causes the wiper arm to sweep across the screen to its park position. The longer linear movement of the connecting link, causes the wiper arm to rotate further than during normal wiping, parking the wiper arm and blade off screen. A second slip ring operated microswitch, on the underside of the gear wheel, signals the CCU that the wiper arm has reached the off screen position and the CCU removes the supply to the rear screen wiper motor.

The wiper arm is located on the splined shaft from the motor and secured with a nut. The wiper arm attachment to the splined shaft has a pivot to which the remainder of the arm is attached. The two parts of the arm are connected by a spring which controls the pressure of the blade on the screen to a predetermined amount.

The wiper blade is pushed onto the wiper arm which has a clip-on feature that allows the blade to pivot. The wiper blade comprises a lever, two yokes and a plastic strip. The rubber wiper is fitted to the plastic strip and held in the yokes. The lever, yokes and plastic strip ensure that pressure applied by the arm spring is distributed evenly along the length of the blade.

Rear Screen Wiper Operating Principle



A = Motor operating (forward operation - wiper at bottom of screen)
B = Park position (reverse operation - off-screen parked)

1 Splined shaft
2 Motor worm drive
3 Coil spring
4 Cam
5 Gear wheel
6 Spigot
7 Link
8 Motor

Windscreen Washers

The windscreen washers consist of two washer jets located on the top surface of the bonnet. Each washer jet contains two adjustable outlets which can be moved to obtain the correct coverage of the windscreen. The two washer jets are connected in series to a flexible pipe which is routed in the electrical harness to a washer reservoir. The reservoir is located inside the RH front wheel arch behind the wheel arch liner. A non-return valve is located in the feed pipe to the windscreen washer jets to prevent washer fluid siphoning back to the reservoir.

The reservoir is moulded from plastic and has a capacity of approximately 4.0 litres (1.0 US gallon). The reservoir has two ports which allow for the attachment of two washer pumps. The flexible pipe from the windscreen washer jets is connected to the forward of the two electric washer pumps. The reservoir has a filler tube which protrudes into the engine compartment. The tube is sealed by a removable cap. A filter is located in the neck of the filler tube and prevents the ingress of particulate matter when replenishing the reservoir. The filter can be removed for cleaning.

Rear Screen Washer

The rear washer uses the same reservoir as the windscreen washers. A second electric washer pump is fitted to the reservoir and supplies washer fluid, via a pipe located in the wiring harness, to a single washer jet which is fitted in the rear wiper arm. The washer jet has four outlets which direct washer fluid to each side of the wiper blade. A non-return valve is located in the feed pipe to the rear screen washer jet to prevent washer fluid siphoning back to the reservoir.

Operation

General
The wipers and washers operate only while the ignition switch is in position II. Operation of the rear screen wiper and washer is prevented or discontinued if the tail door opens, the tail door window is lowered or, on 3 door models, the roof is opened (soft back) or removed (hard back).

Windscreen Wipers
The wash/wipe stalk, located on the RH side of the steering column, and the CCU control the operation of the wipers. Intermittent wipe, slow speed and fast speed are selected using a rotary wiper control switch on the stalk. A flick wipe function can be selected using the stalk. The CCU is responsible for the operation of the intermittent wipe facility and the park facility when the wipers are turned off.

Intermittent Wipe
When intermittent wipe is selected, the wipers operate at slow speed with a delay between wipes. A five position rotary potentiometer, inboard of the wiper control switch, varies the time delay of the intermittent wipe function. The CCU monitors the resistance through the rotary potentiometer and adjusts the time delay to suit the position selected.

The following table details the resistance at each rotary potentiometer position and the corresponding time delays:

Switch Position	Switch Resistance, Ω	Delay, Seconds
1	0	3 ± 1
2	1600 ± 80	5 ± 1
3	3200 ± 160	8 ± 2
4	4800 ± 240	12 ± 2
5	6400 ± 320	17 ± 3
Default	Open circuit	8 ± 2

Slow and Fast Speeds
Slow and fast speed operation is achieved by three brushes in the motor. One brush is the common earth. The slow speed is initiated by a brush positioned 180° to the common brush. The fast speed is initiated by a brush positioned at approximately 45° to the common brush. The fast speed operates by the brushes transferring direct current to a smaller portion of the armature coils, which causes the armature to rotate faster, but with a lower torque than the slow speed.

Flick Wipe
The wipers perform a single wipe at fast speed if the wash/wipe stalk is momentarily moved down. If the stalk is held down the wipers operate at fast speed until the stalk is released.

Rear Screen Wiper
The rear screen wiper is controlled from a latching push switch, located on the RH side of the instrument pack cowl, and the CCU. The wiper operates only while the tail door window is closed and, on 3 door models, the roof is closed (soft back) or on (hard back).

The CCU operates the wiper motor via a dual, forward/reverse relay installed above the RH rear suspension turret. The forward relay is energised when the wiper is operating in intermittent and continuous modes. The reverse relay is energised to reverse the rotational direction of the motor to activate the off-screen park function.

Intermittent
When the rear window wiper switch is selected on, the CCU initially operates the wiper continuously for approximately 6 seconds (3 or 4 wipes) and then changes to intermittent operation with a fixed delay of five seconds between wipes.

Continuous
When reverse gear is engaged while the rear screen wiper is on, the CCU changes the wiper to continuous operation until reverse gear is disengaged, then reverts to intermittent operation again. If reverse gear is engaged while the rear screen wiper is off, but the windscreen wipers are on, the CCU also operates the rear screen wiper continuously, until reverse gear is disengaged or the windscreen wipers are selected off.

Off-screen Park
When the rear screen wiper is selected off, the CCU waits for the next signal from the wiper vertical microswitch in the wiper motor, then de-energises the forward relay and energises the reverse relay. The reverse relay operates the motor in the opposite direction, which lengthens the stroke of the wiper arm. When the wiper arm reaches the off-screen position, the CCU receives a signal from the off-screen park microswitch in the wiper motor and de-energises the reverse relay to stop the wiper.

Off-screen Park Monitoring
In order to monitor the off-screen park function, the CCU invokes a 10 second timer each time intermittent or continuous operation of the rear screen wiper is deselected (by either the control switch on the instrument pack cowl or the CCU). If, within the 10 seconds, a signal is received from both the vertical and the off-screen park microswitches in the wiper motor, the CCU determines that the system is serviceable and continues operation as normal. If, within the 10 seconds, a signal is not received from both microswitches, the CCU determines there is a fault with one of the microswitches or the motor circuit and de-energises the forward and reverse wiper relays to prevent further operation. Since a faulty wiper could stop at any position on the tail door window, to prevent damage to the wiper or window after a fault is detected, the CCU also inhibits operation of the tail door window, with the following exceptions:

- Clear of seal/seal engagement window movement when the tail door is opened/closed.
- Automatic window retraction when the roof is removed/opened.
- Window calibration using the vehicle key in the tail door lock.

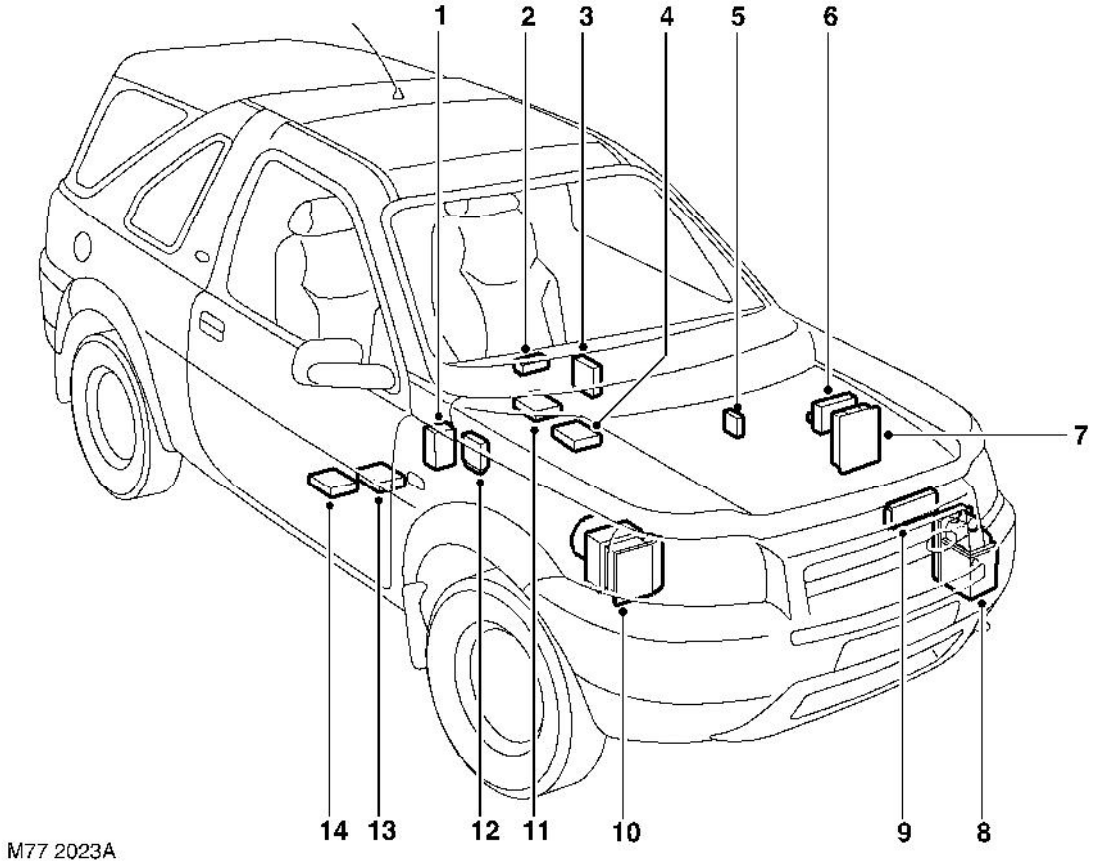
When the fault has been corrected, tail door window operation returns to normal after the CCU has detected the two microswitch inputs from the rear screen wiper motor again.

Windscreen Washers
The windscreen washers are operated by pulling on the wash/wipe stalk located on the RH side of the steering column. Operation of the windscreen washers can also operate the windscreen wipers in a programmed wash/wipe mode.

When the wash/wipe stalk is pulled, the washers operate immediately and stop immediately the stalk is released. When the stalk is held on for more than 0.6 second, the CCU enters the programmed wash/wipe mode and, if the windscreen wipers are selected to intermittent operation or off, operates them at slow speed. If the windscreen wipers are already selected to slow or fast speed, they remain at the selected speed. When the stalk is released with the CCU in the wash/wipe mode, if the windscreen wipers are selected to intermittent operation or off, the wipers operate at slow speed for a further 2 seconds (3 or 4 wipes) and then revert to intermittent operation or park, as applicable.

Rear Screen Washer
The rear washer is controlled by a non-latching push switch, located on the RH side of the instrument pack cowl, and the CCU. Pressing the rear washer switch operates the washer until the switch is released. When the washer switch is pressed, the CCU also operates the rear screen wiper in a programmed wash/wipe mode. While the switch is pressed, the CCU operates the wiper continuously. When the switch is released the CCU operates the wiper continuously for a further six seconds (3 or 4 wipes) and then parks the wiper or reverts to the previous operating mode.

Control Unit Locations



RHD shown, LHD similar

1 CCU
2 RF receiver
3 Immobilisation ECU
4 SRS DCU
5 EAT ECU (automatic gearbox models only)
6 Folding door mirror ECU, from 2002 MY (where fitted)
7 ECM
8 Fuel burning heater ECU (some Td4 models)
9 Cooling fan ECU (all except K1.8 non A/C)
10 ABS modulator
11 Folding door mirror ECU, up to 2002 MY (where fitted)
12 Window lift ECU
13 Cruise control interface ECU (where fitted)
14 Cruise control ECU (where fitted)

Description

Central Control Unit (CCU)
The CCU is plugged into the back of the passenger compartment fusebox below the fascia. Two connectors provide the interface between the CCU and the passenger compartment fusebox and three connectors provide the interface between the main harness and the CCU. The CCU is responsible for controlling the following functions:

- Transit mode.
- Anti theft alarm.
- Windscreen wipers.
- Courtesy lamp delay.
- Door open warning lamp.
- Key in alarm.
- Rear fog guard lamps.
- Lights on alarm.
- Seat belt warning.
- Handbrake warning.
- Rear screen wiper.
- Tail door window.
- Heated rear window.
- Heated windscreen.
- Tail door latch.
- Window lift.
- Seat heating.
- Daytime running lamps.

Some of the features controlled by the CCU are market selectable and may not be operative or available in specific markets. TestBook can be used to configure the CCU to enable/disable market selectable features, tailor anti theft alarm features to customer requirements and can also interrogate the CCU for stored fault codes and alarm triggers. TestBook is connected to the CCU via the diagnostic socket which is located in the passenger footwell.

Transit Mode
The transit mode feature is to minimise battery usage when the vehicle is being stored or transported prior to sale. When the CCU is programmed in the transit mode, the following functions are disabled:

- RF receiver.
- Tail door actuator.
- Tail door window.
- Central Door Locking (CDL).
- Interior lamps.

If the ignition is switched to position II, the CCU buzzer will sound an alarm to warn that the vehicle is in transit mode. The dealer can remove the transit mode feature and programme the CCU to the applicable market specification at the Pre Delivery Inspection (PDI) using TestBook/T4.

Anti Theft Alarm System
The CCU controls the Central Door Locking (CDL) and the alarm system for the vehicle. These are integrated into the vehicle security system, which also includes engine immobilisation.

☞ **SECURITY, DESCRIPTION AND OPERATION, Description.**

Windscreen Wipers
The CCU controls the intermittent wipe and programmed wash/wipe of the windscreen wipers.

☞ **WIPERS AND WASHERS, DESCRIPTION AND OPERATION, Description.**

Courtesy Lamp Delay
The CCU controls the delay function of the interior courtesy lamp. The courtesy lamp can also be switched on using a manual switch on the lamp unit.



Door Open Warning Lamp
The CCU illuminates a warning lamp on the instrument pack if the driver's door, passenger door(s), tail door or bonnet is open while the ignition is on.

Key In Alarm
The CCU will sound a continuous warning on the integral sounder when the driver's door is open while the key is in the ignition switch at position 0 or I. This is to prevent the driver inadvertently leaving the vehicle with the key in the ignition switch.

Rear Fog Guard Lamps
The CCU controls the operation of the rear fog guard lamps via a rear fog guard lamp relay. The guard lamps operate only if the headlamps are on and the ignition switch is in position II. When the headlamps or the ignition are switched off the CCU automatically switches off the guard lamps.

Lights On Alarm
The CCU will sound a continuous warning on the integral sounder when the driver's door is open while the side lamps or headlamps are on and the ignition is off. This is to prevent the driver inadvertently leaving the vehicle with the side lamps or headlamps on.

Seat Belt Warning
When the ignition is switched on the CCU performs a bulb check of the seat belt warning lamp in the instrument pack for approximately 5 seconds, or until the ignition is switched off or the engine cranks. To prevent a driver inadvertently driving without fastening their seat belt, if the driver's seat belt is unfastened when the ignition is switched on the CCU sounds a warning on the integral sounder for approximately 5 seconds and keeps the seat belt warning lamp illuminated after the bulb check.

Handbrake Warning
A warning lamp to warn the driver that the handbrake is on is located in the instrument pack. The warning lamp illuminates when the ignition is on and the handbrake is applied. In some markets the CCU performs a bulb check of the warning lamp for approximately 5 seconds at the beginning of each ignition cycle.

Rear Screen Wiper
The CCU controls the rear screen wiper via a forward and a reverse relay. The wiper will not operate if the tail door window is lowered or not calibrated or, on 3 door models, if the roof is open (soft back) or removed (hard back).
☞ **WIPERS AND WASHERS, DESCRIPTION AND OPERATION, Description.**

Tail Door Window
The CCU controls the lowering and raising of the tail door window, which can be opened using a console switch or the remote handset. On 3 door models, opening/removal of the roof will automatically lower the window. The window can be raised using the console switch or the vehicle key in the tail door key barrel. When the tail door is opened, the tail door window lowers to a 'clear of seal' position. When the door is closed the window automatically rises to its fully up position.
☞ **WINDOWS, DESCRIPTION AND OPERATION, Description.**

Heated Rear Window (HRW)
The CCU controls the operation of the HRW. When the HRW switch, located on the centre of the fascia, is pressed and released a signal is sent to the CCU. With the ignition on, the oil pressure sense present (i.e. the engine running), the tail window not lower than the 'clear of seal' position and, on 3 door models the roof closed/on, the CCU will grant the HRW on. The CCU will energise the HRW relay for approximately 15 minutes after which the CCU will de-energise the HRW relay. A warning lamp in the HRW switch shows when the HRW is operating.

If the switch is pressed before the timed 15 minute period, the CCU will immediately switch off the HRW. Removal of any of the input signals to the CCU will also stop HRW operation. The HRW switch will require re-selection to operate again.

Heated Windscreen

Operation of the heated windscreen is controlled by the CCU and a non latching switch on the centre console. The switch contains a LED which illuminates while the heated windscreen is on. Power for the heater elements is supplied by a relay, on the inboard side of the E-box, controlled by the CCU. Two fuses next to the relay provide electrical protection for the heater elements.

When the heated windscreen switch is pressed, the CCU energises the heated windscreen relay, provided the engine is running, to connect a battery power feed to each of the heater elements. The feed to the RH heater element also provides the power feed to illuminate the LED in the heated windscreen switch.

The CCU de-energises the heated windscreen relay after approximately 5 minutes, when the switch is pressed again, or if the engine stops.

Tail Door Latch

The tail door latch is operated by a tail door lock motor controlled by the CCU. When the CCU receives an open request from the tail door handle switch, it energises the tail door lock motor for 440 ± 40 milliseconds provided the vehicle is in the following configuration:

- The door locking system is in the unlocked state.
- The alarm system is disarmed.
- Road speed is less than 3 ± 1 mph (5 ± 1.5 km/h).

The position of the ignition switch has no effect on the operation of the tail door lock motor.

Window Lift

Power for side door window operation is supplied from the window lift relay and, on 5 door models, the auxiliary relay, both located in the passenger compartment fusebox. The CCU controls the relays, which are energised while the ignition switch is in position II and for approximately 40 seconds after the ignition is turned off.

☞ **WINDOWS, DESCRIPTION AND OPERATION, Description.**

Seat Heating

Power for the seat heaters is supplied from the auxiliary relay in the passenger compartment fusebox. The CCU controls the auxiliary relay, which is energised while the ignition switch is in position II and for approximately 40 seconds after the ignition is turned off.

Daytime Running Lamps

The daylight running feature is controlled by the CCU via two daylight running relays located inboard of the passenger compartment fusebox. The CCU switches the relays, to illuminate the dipped beams, side lamps, tail lamps, rear number plate lamp and side marker lamps, when the following conditions are met:

- The engine is running.
- Gearbox selector lever not in Park.
- Headlamps not selected on.

The CCU and the daylight running relays are also used to operate the head/side lamps when they are selected on using the lighting switch on the LH column stalk. The lamps then operate as on non daylight running vehicles, and remain on when the gearbox is in Park and when the engine is switched off.

Self Test Mode

The CCU can be put into a self test mode to enable the inputs and outputs to be tested for correct functionality without the need for TestBook/T4. To put the CCU into the self test mode the vehicle must be unlocked and disarmed, then the ignition turned on and the following sequence completed within 4 seconds:

- Hold the rear fog guard lamp switch on.
- Turn the ignition off.
- Turn the ignition on.
- Release the rear fog guard lamp switch.

On successful entry to the self test mode the CCU simultaneously operates the sounder and illuminates the courtesy lamps for 0.8 second.

When testing an input, e.g. a door open switch, on successful receipt of the input the CCU also simultaneously operates the sounder and illuminates the courtesy lamps for 0.8 second.



Outputs are tested in sequence using the CDL lock switch to progress through the outputs. A CDL unlock request repeats the last test. Outputs are either operated continuously until the CDL lock switch is released, or operated with a pulse.

Self Test Outputs Sequence

Output	Test Type
Rear fog lamps	Continuous
Lock	Pulsed for 0.76 second
Superlock	Pulsed for 0.76 second
Unlock	Pulsed for 0.76 second
Front wiper	Continuous, then self parks
Alarm LED	Continuous
Volumetrics	Continuous
Horn	Pulsed for 0.8 second
Heated windscreen	Pulsed for 0.8 second
Heated rear window	Pulsed for 0.8 second
Tail window down	Pulsed, drives fully down
Tail door actuator	Pulsed for 0.44 second
Tail window up	Pulsed, drives fully up
Rear wiper	Continuous
Hazard lamps	Continuous
Door open warning	Continuous
Seat belt warning lamp	Continuous
Handbrake/Brake warning lamp	Continuous
Daytime running lamps	Continuous

Self test mode is cancelled when the ignition is turned off, if oil pressure is sensed (i.e. engine running) or if the vehicle speed exceeds 0.6 mph (1 km/h).

Radio Frequency (RF) Receiver

The RF receiver is part of the security system and relays data from the remote transmitter (plip) to the CCU. The RF receiver is located on top of the instrument pack, between the housing and the face plate.

☞ **SECURITY, DESCRIPTION AND OPERATION, Description.**

Immobilisation ECU

The immobilisation ECU controls operation of the starter motor to provide the engine immobilisation function of the security system. The immobilisation ECU is secured to the rear of the fascia near the vehicle centre-line.

☞ **SECURITY, DESCRIPTION AND OPERATION, Description.**

Supplementary Restraint System (SRS) Diagnostic Control Unit (DCU)

The SRS DCU controls the operation of the vehicle's airbags and seat belt pretensioners. The SRS DCU is attached to the transmission tunnel below the heater assembly.

☞ **RESTRAINT SYSTEMS, DESCRIPTION AND OPERATION, Description.**

Electronic Automatic Transmission (EAT) ECU (Automatic Gearbox Models Only)

On automatic gearbox models, the EAT ECU controls gear changing and torque converter lockup. The EAT ECU is installed in the Environmental (E) box in the engine compartment.

☞ **AUTOMATIC GEARBOX - JATCO, DESCRIPTION AND OPERATION, Description.**

Engine Control Module (ECM)
The ECM controls all aspects of engine operation and interfaces with the security system during engine starting. The ECM is installed in the E-box in the engine compartment.

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - MEMS, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**

Fuel Burning Heater (Some Td4 Models)
On Td4 models, the fuel burning heater incorporates an ECU that automatically controls the operation of the fuel burning heater. The ECU is integrated into the top of the fuel burning heater, which is installed at the front of the left front wheel arch behind the wheel arch liner.

☞ **HEATING AND VENTILATION, DESCRIPTION AND OPERATION, Description.**

Cooling Fan ECU (All Except K1.8 Without A/C)
The cooling fan ECU controls the speed of the two cooling fans. The cooling fan ECU is installed in the rear upper left corner of the cooling fan housing.

☞ **COOLING SYSTEM - Td4, DESCRIPTION AND OPERATION, Description.**
☞ **COOLING SYSTEM - K SERIES 1.8, DESCRIPTION AND OPERATION, Description.**
☞ **COOLING SYSTEM - K SERIES KV6, DESCRIPTION AND OPERATION, Description.**

Anti-lock Braking System (ABS) Modulator
The brake system incorporates an ABS ECU that controls the operation of the hydraulic modulator to provide the ABS, electronic brake force distribution, traction control and hill descent control functions. The ABS ECU is attached to the hydraulic modulator, which is installed in the front right corner of the engine compartment.

☞ **BRAKES, DESCRIPTION AND OPERATION, Description.**

Folding Door Mirror ECU (Some Markets)
In some markets folding door mirrors are installed and these are controlled by the folding door mirror ECU. The folding door mirror ECU is installed:

- Up to 2002 MY, on the transmission tunnel, below the centre console.
- From 2002 MY, on the front passenger side 'A' post.

Window Lift ECU
The window lift ECU is installed to provide one shot opening of the driver's door window. The window lift ECU is installed on the driver's side A post, level with the lower edge of the fascia.

☞ **WINDOWS, DESCRIPTION AND OPERATION, Description.**

Cruise Control Interface ECU (Some KV6 and Td4 Models)
Where fitted, the cruise control interface ECU provides the interface between the cruise control operating system and the cruise control switches on the steering wheel. The interface ECU is installed under the RH front seat.

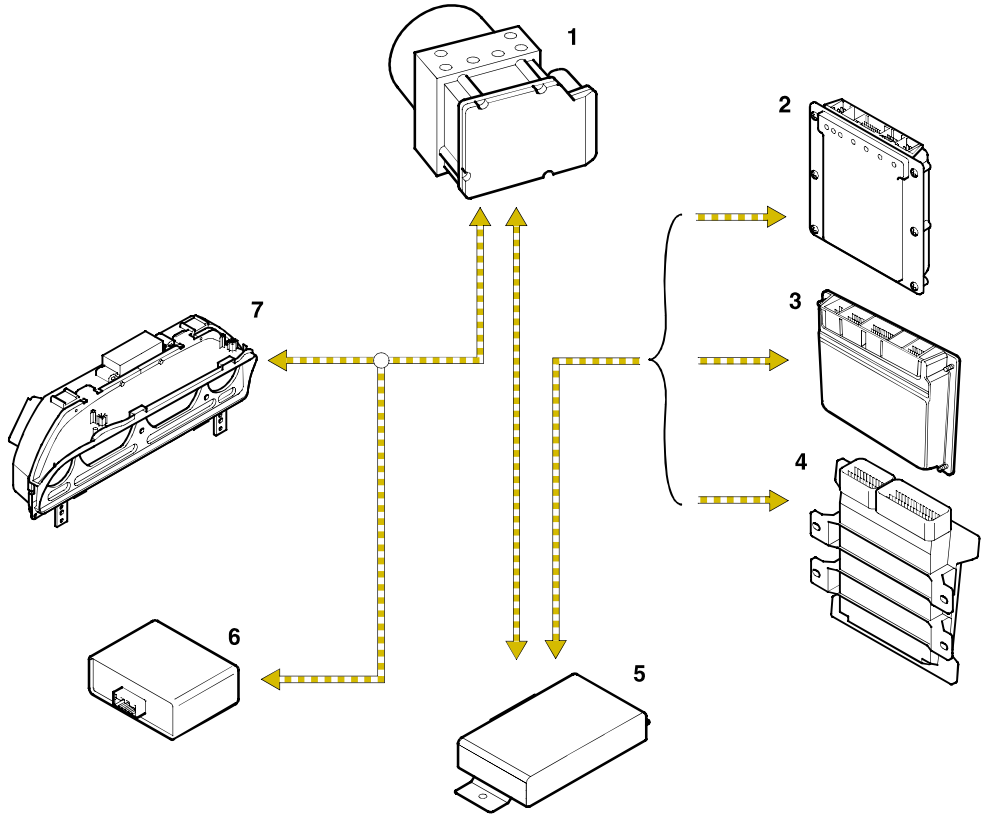
☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Cruise Control Description.**

Cruise Control ECU (Some KV6 Models)
Where fitted, the cruise control ECU controls the vacuum system that operates the throttle. The cruise control ECU is installed under the RH front seat next to the cruise control interface ECU.

☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**

CAN Bus Control Diagram

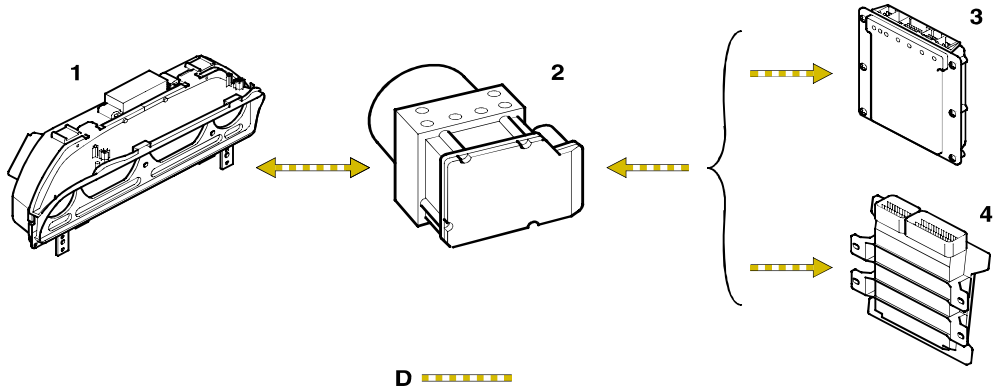
Automatic Gearbox Models



D = CAN bus

1 Antilock brake system ECU
2 Engine control module (Td4)
3 Engine control module (non NAS KV6)
4 Engine control module (NAS KV6)
5 Electronic automatic transmission ECU
6 Cruise control interface unit (Td4 and NAS KV6 only, where fitted)
7 Instrument pack

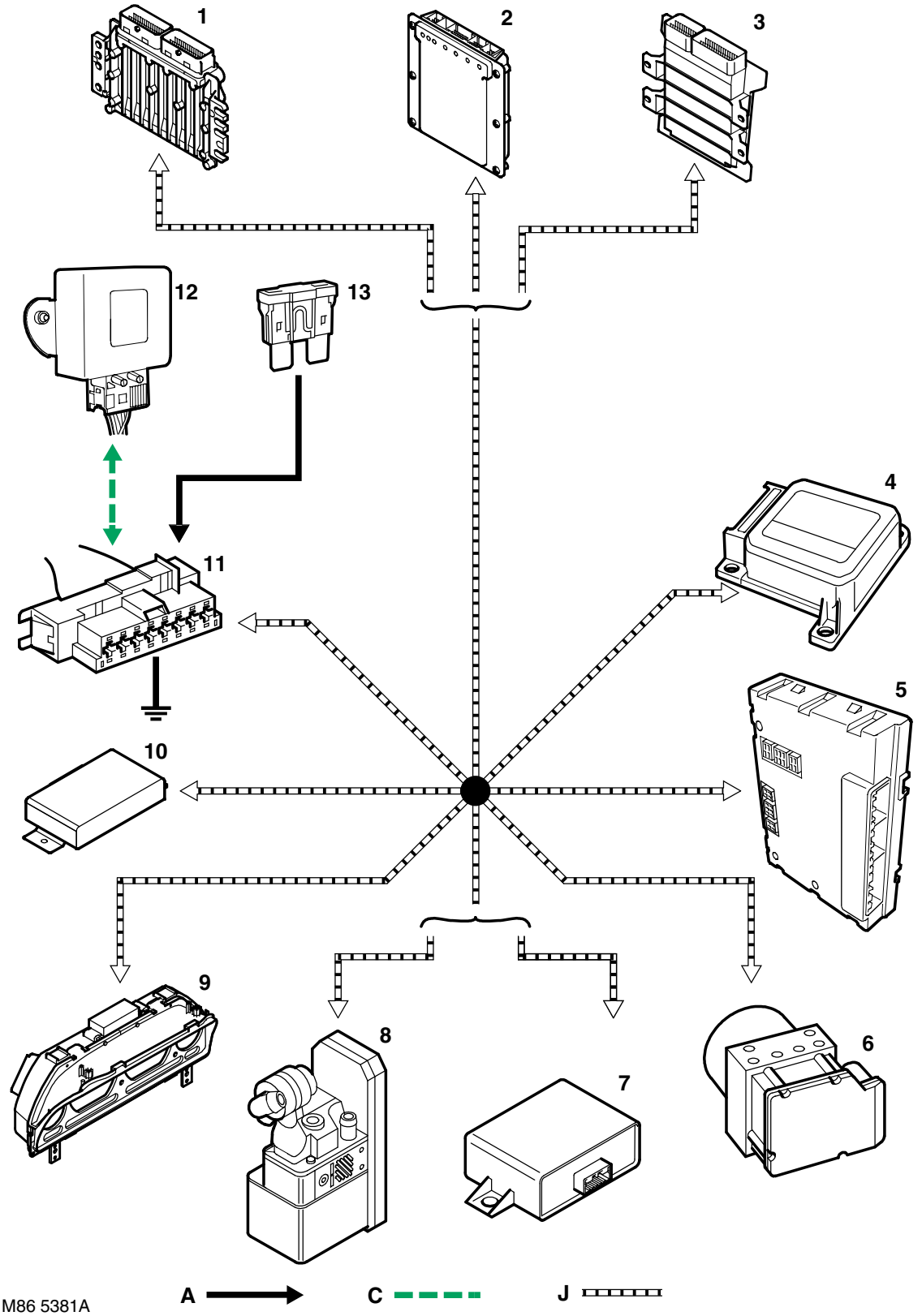
Manual Gearbox Models



D = CAN bus

1 Instrument pack
2 Antilock brake system ECU
3 Engine control module (Td4)
4 Engine control module (KV6)

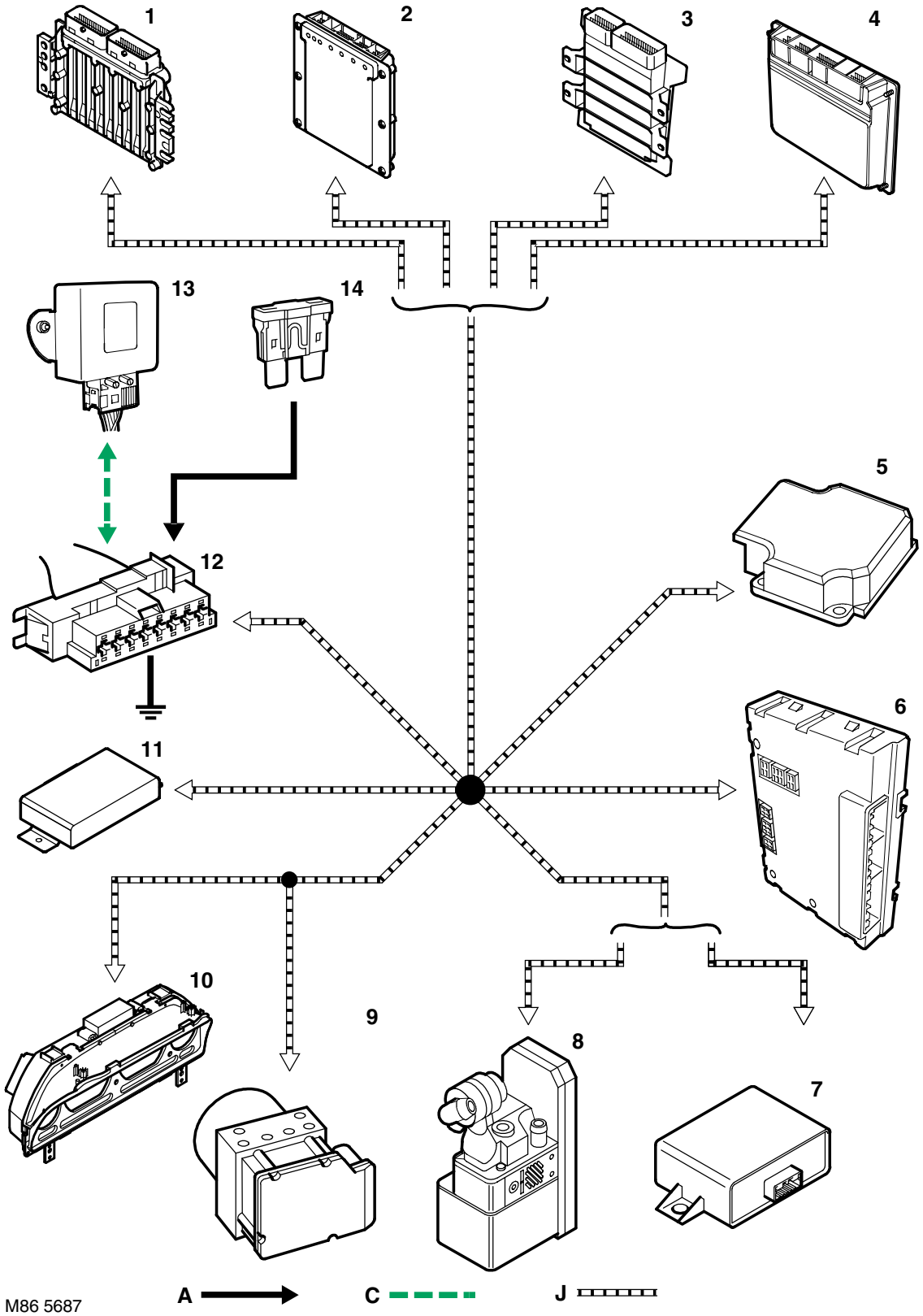
Diagnostic Buses (Up To 2002 Model Year)



A = Hardwired connection; C = Diagnostic DS2 bus; J = Diagnostic ISO 9141 K line bus

1 Engine control module (KV6)
2 Engine control module (Td4)
3 Engine control module (K1.8)
4 SRS diagnostic and control unit
5 Central control unit
6 ABS ECU
7 Cruise control ECU (KV6, where fitted)
8 Fuel burning heater (where fitted)
9 Instrument pack
10 EAT ECU (where fitted)
11 Diagnostic socket
12 Immobilisation ECU
13 Fuse 14 battery power supply, passenger compartment fusebox

Diagnostic Buses (From 2002 Model Year)



A = Hardwired connection; C = Diagnostic DS2 bus; J = Diagnostic ISO 9141 K line bus



1 Engine control module (KV6, all except NAS)
2 Engine control module (Td4)
3 Engine control module (K1.8)
4 Engine control module (NAS)
5 SRS diagnostic and control unit
6 Central control unit
7 Cruise control ECU (non NAS KV6, where fitted)
8 Fuel burning heater (where fitted)
9 Instrument pack
10 EAT ECU (where fitted)
11 Diagnostic socket
12 ABS ECU
13 Immobilisation ECU
14 Fuse 14 battery power supply, passenger compartment fusebox

Description

General

A number of different types of data bus can be incorporated into vehicle wiring harnesses for the transmission of commands and information between ECU's. Some of the buses are installed as a network connecting several ECU's together and some are installed as dedicated links between pairs of ECU's. The bus configuration installed on a particular vehicle depends on the model and equipment level.

Freelander incorporates the following data bus systems:

- Controller Area Network (CAN) bus. A network connected between the instrument pack, the ABS and powertrain related ECU's
- Diagnostic DS2 bus
- ISO 9141 K line

Serial interface circuits in the ECU's transmit and receive commands and information on the buses as digital messages. ECU's connected to the same bus use a common protocol (format) and baud rate (transmission speed) for the messages they transmit. The protocol and baud rate vary from bus to bus.

Not all system ECU's are connected to the CAN bus system but they may require information that is being transmitted on the CAN bus system. The instrument pack acts as a gateway translating CAN bus signals into a format compatible with non CAN ECU's. Some signals are also converted from their existing state into the CAN format and transmitted on the CAN bus system for use by CAN based ECU's, for example the air conditioning pressure sensor reading is converted by the instrument pack and sent via CAN to the respective engine management system.

A twisted pair of wires are used for the CAN bus and single wires are used for the diagnostic buses. Bus wires can be repaired using the recommended connectors and the recommended procedure. The unwound length of CAN bus wires must not exceed 40 mm (1.6 in). If a fault is suspected on the CAN bus system it must be diagnosed and rectified using TestBook/T4.

Data Bus Types

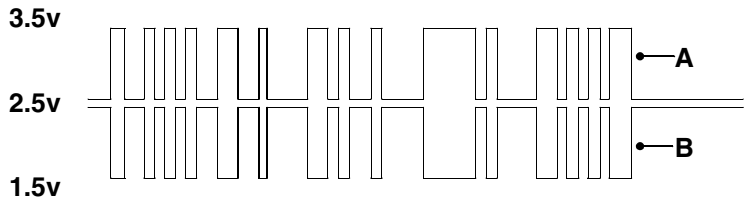
Bus	Baud Rate (kbits/s)	Protocol
CAN	500	ISO 11898
ISO 9141 K line	10.4	ISO keyword 2000
Diagnostic DS2	9.6	BMW corporate for diagnostics

CAN Bus

The CAN bus is a high speed broadcast network where the ECU's automatically transmit information on the bus every few microseconds. The two wires of the bus are identified as CAN Low (L) and CAN High (H), and are twisted together to minimise the electromagnetic interference (noise) produced by the CAN messages. To prevent message errors from electrical reflections, 120 ohm resistors are incorporated into the CAN wire terminals of the instrument pack and the Engine Control Module (ECM).

Messages consist of a signal which is simultaneously transmitted, in opposite phase, on both wires. CAN L switches between 2.5 and 1.5 volts while CAN H switches between 2.5 and 3.5 volts, which causes the potential difference between the two lines to switch between 0 volt (logic 1) and 2 volts (logic 0) to produce the digital signal message.

CAN Bus Switching



M86 5036

A = CAN H; B = CAN L



CAN Message Transmission

Messages transmitted via the CAN system are made up of eight data bytes and transmitted using a baud rate of 5,000 kbits per second. The twisted pair of wires used are coloured yellow and black (CAN_H) and yellow and brown (CAN_L).

The following table lists the signals transmitted via the CAN system illustrating the system originating the message and the message recipient:

CAN Message Transmission

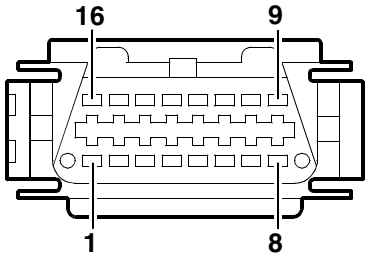
Message	Source	Destination
Brake pedal application status	ABS ECU	EAT ECU
Electronic brake distribution	ABS ECU	Instrument pack
ABS lamp status	ABS ECU	Instrument pack
Traction control lamp status	ABS ECU	Instrument pack
Brake intervention status	ABS ECU	EAT ECU
Vehicle speed error status	ABS ECU	ECM
Vehicle speed	ABS ECU	ECM, Instrument pack
Road surface status (roughness)	ABS ECU	ECM (petrol only)
Hill Descent Control (HDC) activity status	ABS ECU	EAT ECU, ECM (not Td4) instrument pack
Hill Descent Control (HDC) fault status	ABS ECU	EAT ECU, ECM (not Td4), instrument pack
Ignition switch status	ECM	ABS ECU, EAT ECU
Engine speed error status	ECM	ABS ECU, EAT ECU
Torque reduction status	ECM	EAT ECU
Torque measurement error status	ECM (not Td4)	ABS ECU, EAT ECU
Actual engine torque	ECM	ABS ECU, EAT ECU
Engine speed	ECM	ABS ECU, EAT ECU, instrument pack
Maximum engine torque	ECM	ABS ECU, EAT ECU
Friction torque loss	ECM	ABS ECU, EAT ECU
Multiplexed information (CAN specification version, engine type identifier, scaling factor for torque values)	ECM	ABS ECU, EAT ECU, instrument pack
Coolant temperature	ECM	EAT ECU, instrument pack
Driver demand/throttle angle	ECM	ABS ECU, EAT ECU
Cruise active	ECM (Td4 and NAS KV6 only)	Cruise control interface unit, EAT ECU, instrument pack
Glowplug lamp status	ECM (Td4 only)	Instrument pack
Engine MIL status	ECM	EAT ECU, instrument pack
Cruise control master switch status	ECM (Td4 only)	Cruise control interface unit, instrument pack
Engine status (non emissions related faults)	ECM	Instrument pack
Fuel consumption	ECM	Instrument pack
Modified throttle angle	ECM (Td4 only)	ABS ECU
Throttle pedal switch status	ECM	ABS ECU
Throttle pedal fault	ECM	ABS ECU
Target gear (actual gear unless changing, then target gear)	EAT ECU	ABS ECU, ECM, instrument pack
Shift in progress	EAT ECU	ABS ECU, ECM
Gearbox MIL status	EAT ECU	ECM (KV6)
Selector lever position	EAT ECU	ABS ECU, ECM, instrument pack
Gear shift mode	EAT ECU	Instrument pack

Message	Source	Destination
Torque level required	EAT ECU	ECM
Transmission fault status	EAT ECU	Instrument pack
Gearbox cooling request	EAT ECU	ECM
Fuel level	Instrument pack	ECM (not diesel)
A/C request	Instrument pack	ECM
A/C switch status	Instrument pack	ECM
A/C compressor load	Instrument pack	ECM (Td4 and NAS KV6 only)
Engine cooling fan speed	Instrument pack	ECM (Td4 and NAS KV6 only)
Vehicle reference speed	Instrument pack	EAT ECU, ECM (not Td4)
Gear selected (manual gearbox)	Instrument pack	ABS ECU

Diagnostic Buses

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.

Diagnostic Socket (C0040)



M86 5037

Diagnostic Socket (C0040)

Pin No.	Description	Input/output
1 to 3	Not used	–
4	Chassis earth	Output
5 and 6	Not used	–
7	ISO 9141 K line	Input/Output
8 to 12	Not used	–
13	DS2 bus	Input/Output
14 and 15	Not used	–
16	Battery power supply	Input

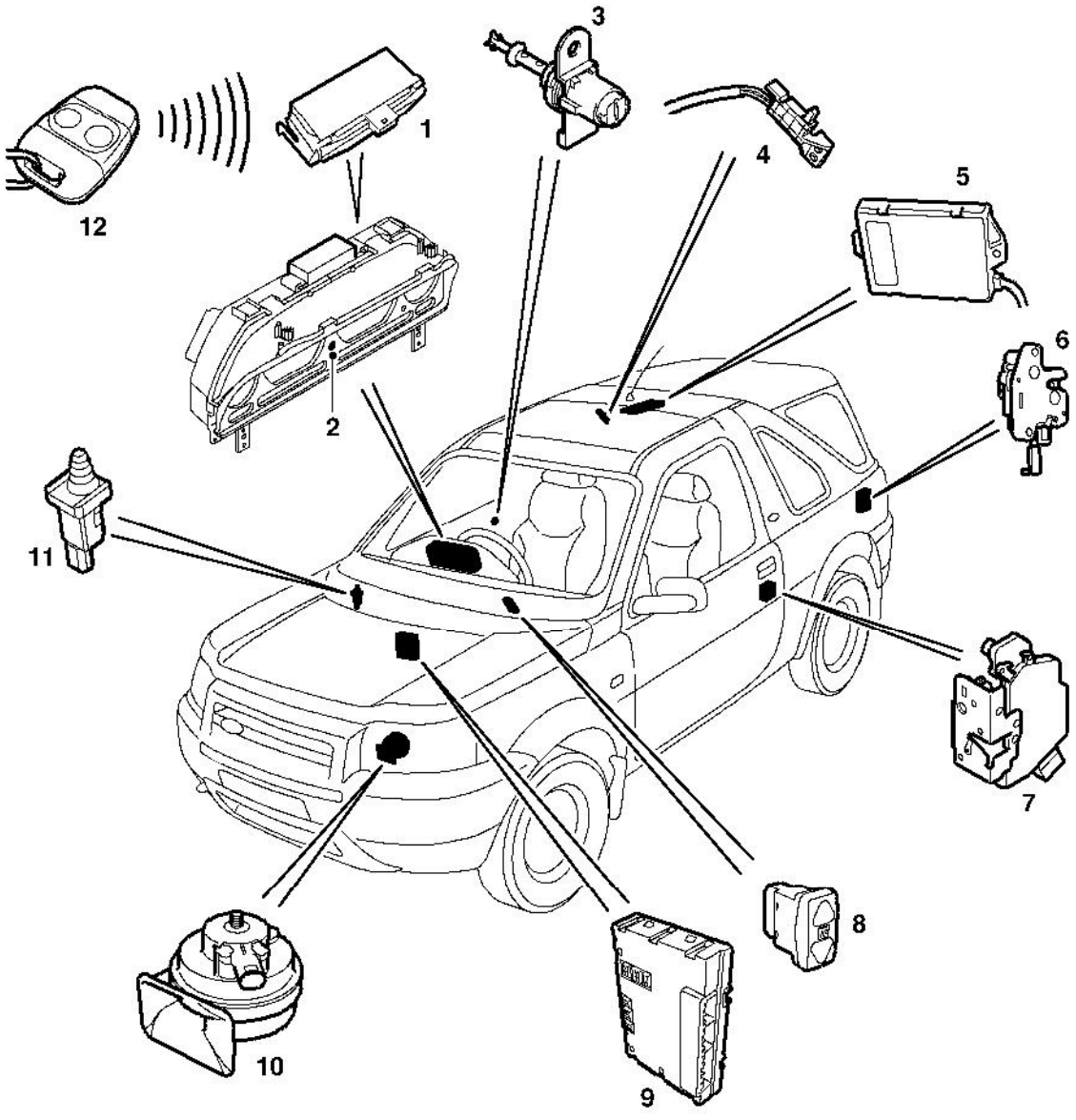
ISO 9141 K Line

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/T4 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 immobilisation ECU. The protocol used means that only TestBook/ T4 can communicate with the immobilisation system.

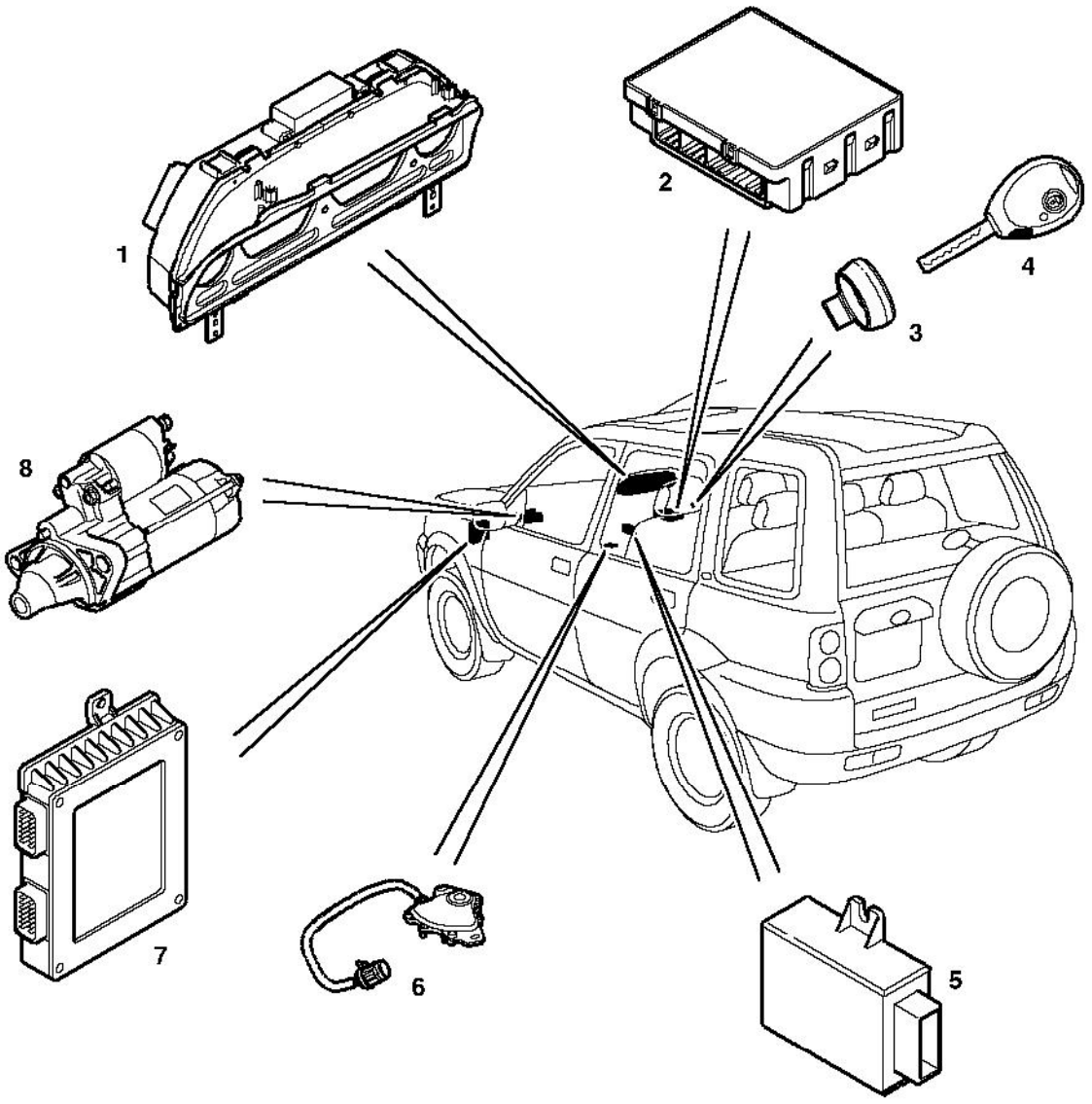
Locking and Alarm System Component Layout



M86 5313B

1 RF receiver
2 Alarm LED
3 Driver's door key barrel switch
4 Roof switch (3 door only)
5 Volumetric sensor
6 Tail door latch
7 Door latch
8 CDL switch
9 CCU
10 Horn
11 Bonnet switch
12 Remote handset

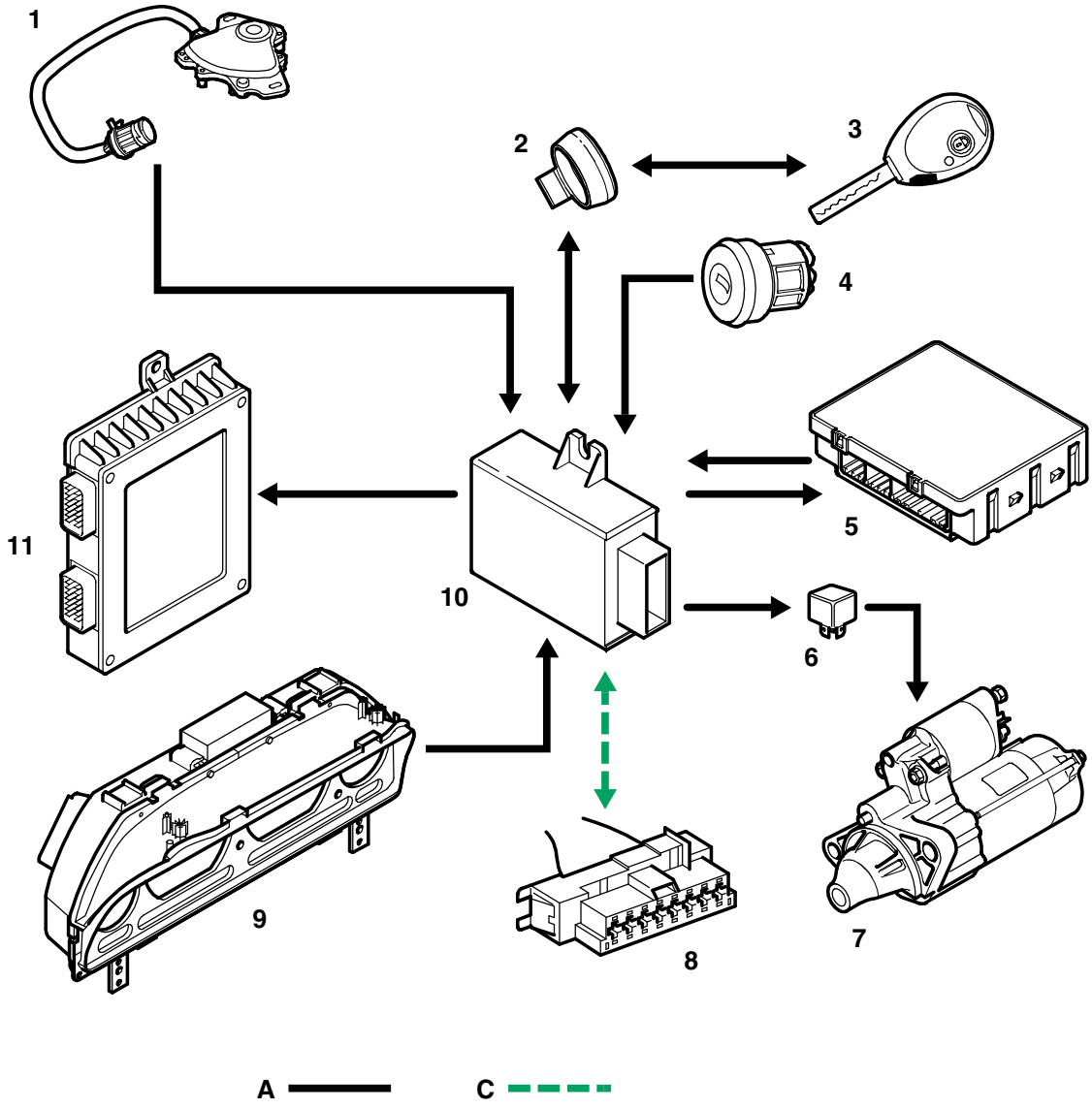
Immobilisation System Component Layout



M86 5275A

1 Instrument pack
2 Central control unit
3 Transponder coil (ring antenna)
4 Key transponder
5 Immobilisation ECU
6 Automatic transmission position switch
7 Engine Control Module (ECM)
8 Starter motor

Immobilisation System Control Diagram

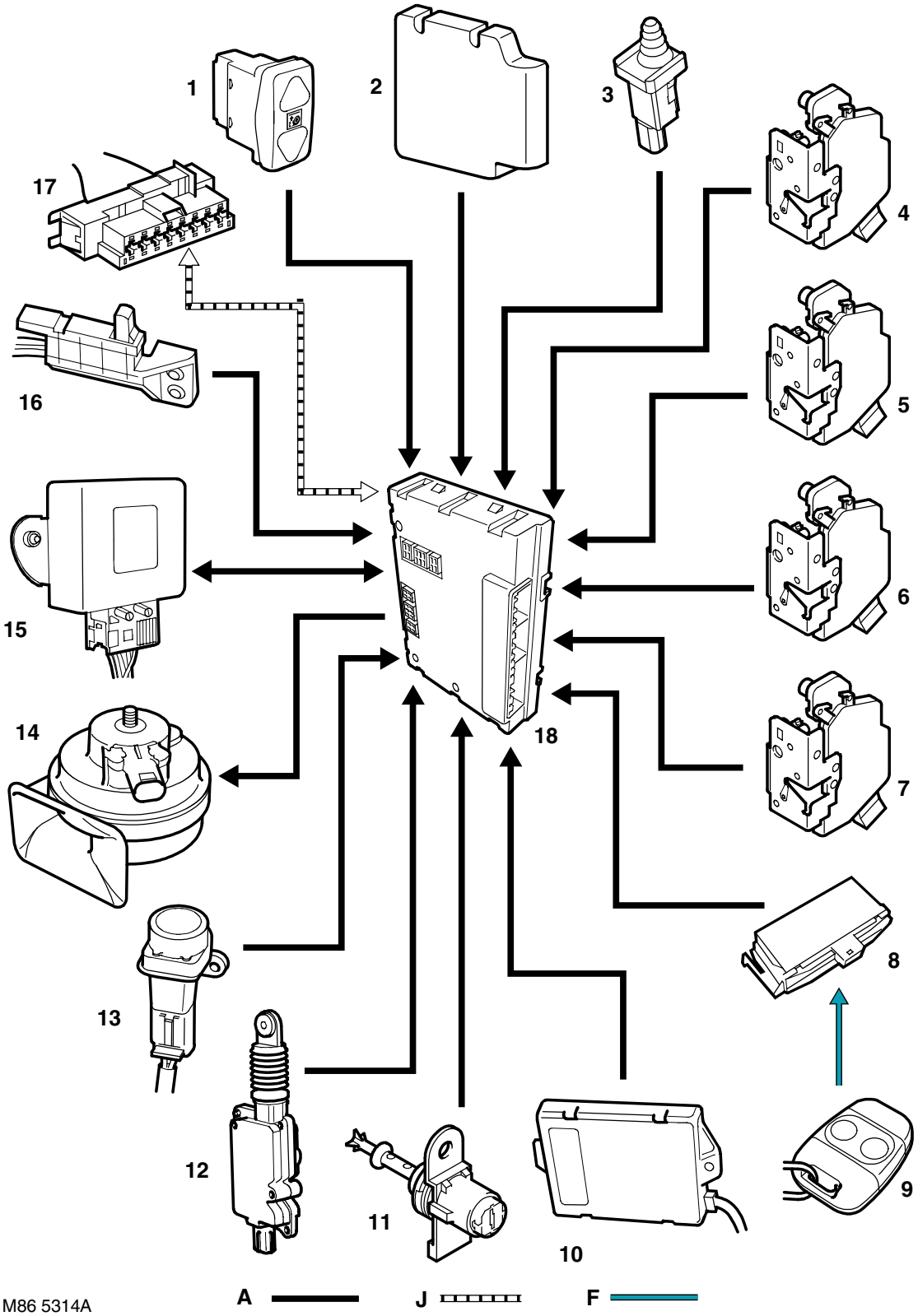


M86 5274A

A = Hardwired connection; C = Diagnostic DS2 bus

1 Automatic transmission position switch
2 Transponder coil (ring antenna)
3 Key transponder
4 Ignition switch
5 Central control unit
6 Starter relay
7 Starter motor
8 Diagnostic socket
9 Instrument pack
10 Immobilisation ECU
11 Engine control module

Locking and Alarm System Control Diagram



A = Hardwired connection; F = RF transmission; J = Diagnostic ISO 9141 K line bus

1 CDL switch
2 ABS ECU
3 Bonnet switch
4 Driver's door actuator and switch
5 Front passenger door actuator and switch
6 Left hand rear door actuator and switch
7 Right hand rear door actuator and switch
8 RF receiver
9 Remote handset
10 Volumetric sensor
11 Driver's door key barrel switch
12 Tail door switch and actuator
13 Inertia switch
14 Horn or BBUS
15 Immobilisation ECU
16 Roof switch (3 door only)
17 Diagnostic socket
18 Central control unit

Description

General
This description covers all aspects of the vehicle locking and alarm system and the immobilisation system.

The vehicle locking and alarm system is controlled by the central control unit (27VT) located on the back of the passenger compartment fusebox below the fascia.

The immobilisation system (EWS-3D) is essentially a stand alone system with its own controlling ECU located centrally behind the fascia.

Locking and Alarm System
The locking and alarm system comprises:
- Central door locking master switch
- Door switches
- Roof switch (3 door only)
- Remote handset (RF transmitter)
- RF receiver
- Driver's door key barrel
- Door lock actuators
- Tail door switch
- Tail door release actuator
- Bonnet switch
- Inertia switch
- Horn or BBUS
- Alarm LED
- Immobilisation ECU
- ABS ECU Speed input
- Volumetric sensor

Central Locking
The vehicle can be locked and unlocked by three methods; CDL switch, vehicle key or remote handset.

CDL Switch
The CDL switch is located in the centre console. The CDL switch allows the occupants to CDL lock the vehicle from inside without arming the alarm. The CDL switch is inoperative if the inertia switch is tripped. The CDL locked state can be removed by operation of the CDL switch, remote handset or by a key unlock operation in the driver's door key barrel.

If the inertia switch is tripped while the doors are CDL locked and the ignition is on, all doors will automatically unlock.

Key Locking
The vehicle can be CDL locked using the vehicle key in the driver's door key barrel. Turning the top of the key to the rear of the vehicle will CDL lock all doors. Turning the key a second time, within one second of the first turn, will superlock all doors.

Key Unlocking
Single point entry is a programmable feature and its selection affects how the vehicle responds to key unlock requests:
- Turning the top of the key once towards the front of a vehicle which is in a CDL state, with the alarm disarmed, will unlock all the doors irrespective of their existing lock status
- Turning the top of the key once towards the front of a vehicle in a superlocked state without SPE selected and the alarm armed, will unlock all the doors irrespective of their existing lock status
- Turning the top of the key once towards the front of a vehicle in a superlocked state with SPE selected and the alarm armed, will unlock the driver's door. The remaining doors will unlock to the CDL state and can be unlocked with a further key unlock operation



Remote Locking
On vehicles with superlocking selected the vehicle can be superlocked by pressing the lock button on the remote handset once. On vehicles with superlocking not selected (market option) the vehicle can be CDL locked by pressing the lock button on the remote handset once.

Remote Unlocking
With the vehicle CDL locked, pressing the unlock button on the remote handset once will unlock all doors.

If the vehicle is superlocked, pressing the unlock button once on the remote handset will only unlock the drivers door for SPE. The remaining door(s) will unlock to the CDL state. If the button is pressed a second time, the remaining door(s) will unlock.

NOTE: If the vehicle is superlocked and SPE has not been selected in the CCU, pressing the unlock button once on the remote handset will unlock all the doors.

Central Locking Notes
Locking or unlocking using the vehicle key or remote handset is prevented if the CCU senses that the ignition is 'on'. Using the key to lock the vehicle via the driver's key lock with the ignition 'on' will mechanically lock the driver's door.

Superlocking is prevented if the CCU senses that one or more doors are open. In this instance CCU will attempt to CDL lock all doors.

Inertia Switch
The inertia switch is located on the bulkhead in the engine compartment. The switch is mounted vertically and has a reset button on its top surface, covered by a rubber boot.

If the inertia switch is tripped, with the ignition 'on' and the alarm disarmed, all the doors will be unlocked regardless of their locked state at that time. Further locking is disabled unless:

1. the ignition is switched off and the driver's door is opened and closed
2. the driver's door is opened and closed and the inertia switch is manually reset

The inertia switch can be reset by depressing the button on the top of the switch.

Tail Door
The CCU also controls the tail door release. The tail door can only be opened if the vehicle is unlocked, the alarm is not armed and the vehicle is travelling at not more than 3 mph (5 km/h).

Slam Locking
The driver's door is designed to prevent slam locking. The remaining door(s) can be slam locked.

Latch Motor Protection
To protect the door lock latches from damage, the CCU will only allow eight changes of state of the locks in any sixteen second period or less. If eight changes of state occurs within the sixteen second period, the CCU will prevent further operation of the latch motors for a further sixteen second period. The CCU will always prevent further operation only when the latch motors are in an unlocked condition. If SPE is operational, the CCU will override the SPE function and all doors will unlock if eight operations is exceeded in the sixteen second period.

The alarm system will continue to operate during the latch motor protection period.

Alarm System
The alarm system can be armed and disarmed using the vehicle key or the remote handset. The alarm system monitors the driver's door, passenger door(s), tail door, bonnet and roof (3 door models only) using perimetric sensing. It also monitors movement within the passenger compartment using volumetric sensing.

In certain countries, the alarm system is programmed not to arm under any circumstances.

NOTE: Hazard warning light confirmation of alarm arm or disarm is market programmable and therefore may not be operative on certain market variants.

Perimetric Sensing
Perimetric sensing is invoked by the CCU to monitor entry to the vehicle after the alarm has been set. The panel open switches on the driver's door, passenger door(s), tail door, bonnet and roof (3 door only) are all monitored by the CCU.

If a panel is opened after the alarm has been set, the alarm will be triggered. The horn or BBUS will sound and the hazard warning lights will operate. On 3 door models, if the roof is off when the alarm is armed, further operation of the roof off switch will not trigger the alarm.

Volumetric Sensing
The volumetric sensor is located in a central position on the roof panel, behind the headlining. The volumetric sensor is a microwave sensor which monitors movement inside the vehicle to detect any possible intrusion. The vehicle can be armed with the volumetric sensor disabled to avoid accidental triggering of the alarm if a pet is in the vehicle for instance. The volumetric sensor is also inoperative if the CCU senses that a panel has been left open, with the exception of the bonnet.

A fifteen second delay is initiated after arming of the alarm before signals from the volumetric sensor are interpreted as an intrusion. This precaution is included in the CCU software to avoid accidental or nuisance triggering of the alarm.

If the alarm has been triggered, the CCU will ignore further volumetric sensor signals for the duration of the alarm sounding. The CCU will delay volumetric sensing for a further 15 seconds after the alarm has stopped sounding, unless ten triggers have been sensed by the volumetric sensor since the alarm was last armed.

The volumetric gain setting is controlled by the VIN stored in the CCU. The VIN informs the CCU of the vehicle body and roof type to avoid under or over sensitivity.

If battery supply voltage falls to below 9 Volts, the CCU will ignore inputs from the volumetric sensor.

Alarm - Key Operation
Arming and disarming using the vehicle key in the driver's door key barrel will be ignored if the CCU senses that the ignition is 'on'. In certain markets the alarm system is programmed not to arm under any circumstances, in these cases key operation will only operate the door locking facility as described in Key Locking/Unlocking.

NOTE: Using the vehicle key in the driver door key barrel will not enable volumetric sensing.

Key Arm
The vehicle alarm can be fully armed by turning the top of the key to the rear of the vehicle once with all panels closed. The Vehicle will be CDL locked, the hazard warning lights will flash three times. The alarm LED will fast flash for ten seconds and then change to slow flash. Perimetric sensing will be activated.

The vehicle alarm can also be fully armed by turning the top of the key to the rear of the vehicle a second time, within one second of the first turn, with all the panels closed. The vehicle will be superlocked, the hazard warning lights will flash three times. The alarm LED will fast flash for ten seconds and then change to slow flash. Perimetric sensing will be activated.

Key Disarm
The vehicle can be disarmed by turning the top of the key towards the front of the vehicle. The vehicle will unlock all the doors, if the vehicle is being unlocked from the superlock state with SPE active, the driver's door will unlock, the remaining doors will enter the CDL state. Also the hazards will flash once and the alarm LED will extinguish.

Alarm Remote Handset Operation
In certain markets, the alarm system is programmed not to arm under any circumstances. In these cases the remote handset will only operate the door locking facility as described in remote handset lock/unlock.

Remote Handset Arm
The vehicle alarm can be fully armed by pressing the lock button on the remote handset once with all panels closed. The Vehicle will be superlocked, the hazard warning lights will flash three times. The alarm LED will fast flash for ten seconds and then change to slow flash. Perimetric and volumetric sensing will be activated.

Remote Handset Disarm
The vehicle can be fully disarmed by pressing the unlock button once on the remote handset. The hazard warning lights will flash once and the alarm LED will go off. Perimetric and volumetric sensing will be disabled.



Partial Arming
If one or more of the panels is left open, the CCU will attempt to partially arm as much of the vehicle as possible. If a failure of a panel open switch or wiring occurs, the CCU will partially arm the alarm in the same manner as if a panel is left open.

When the alarm is armed with one or more panels open, the CCU will sound a mislock warning from the horn or BBUS to tell the driver that a panel is open.

The mis-lock warning sound is market selectable and therefore may not be operative in specific markets. When the CCU enters a partially armed state, there is no hazard warning flasher operation, the alarm LED will be extinguished for 10 seconds and will then slow flash.

The CCU will partially alarm the vehicle according the priority of the panel left open. The panel priority is driver's door, passenger door(s), tail door and bonnet with the driver's door being the highest priority and the bonnet being the lowest.

Drivers Door
If the driver's door is open and a lock request is made, the CCU will CDL lock the closed doors, give a mislock sound, suspend superlocking and volumetric sensing and monitor the panel(s) left open. With the driver's door open CDL centre console switch lock requests are ignored.

Vehicle state changes:
- If the driver's door is open and a lower priority panel closes, the CCU will give a mis-lock sound and remain in the driver's door partial arm condition
- If the driver's door closes, the CCU will sound a mis-lock warning and remain in the driver's door partial arm condition. If the driver's door is opened, the alarm will be triggered
- If the driver's door closes and one or more lower priority panels are open and a lock request is made, the CCU will CDL lock the closed door(s) and enter the partial arm state of the panel open with the next highest priority
- If the driver's door closes and all other panels are closed and a lock request is made, the CCU will lock the doors and arm the alarm

Passenger Door(s)
If one or more of the passenger doors are open and the driver's door is closed and a lock request is made, the CCU will CDL lock the closed door(s), suspend superlocking and volumetric sensing and monitor the panel(s) left open.

Vehicle state changes:
- If one or more passenger door(s) are open and a lower priority panel closes, the CCU will sound a mis-lock warning and remain in the passenger door partial arm condition
- If the passenger door(s) close(s) and one or more lower priority panels remain open, the CCU will sound a mis-lock warning and enter the partial arm condition of the panel with the next highest priority
- If the passenger door(s) close(s) and all other panels are closed, the CCU will arm the alarm door sense switches for the closed door(s)

Tail Door
If the tail door is open and all higher priority panels are closed and a lock request is made, the CCU will allow superlocking of the passenger and driver's doors, suspend volumetric sensing and monitor the panel(s) left open.

Vehicle state changes:
- If the tail door is open and the bonnet closes, the CCU will sound a mis-lock warning and remain in the tail door partial arm condition
- If the tail door closes and the bonnet remains open, the CCU will suspend operation of the tail door open actuator until the next unlock request is made and enter the bonnet partial arm condition
- If the tail door closes and the bonnet and all other panels are closed, the CCU will lock the doors and arm the alarm

Bonnet
If the bonnet is open and all higher priority panels are closed and a lock request is made, the CCU will allow superlocking of the passenger and driver's doors and volumetric sensing and monitor the panel left open.

Vehicle state changes:
- If the bonnet closes and all other panels are closed, the CCU will enter the locked and armed condition

Mislock Warning
When the CCU enters a partial armed condition or the alarm is armed with the tail door window down, the CCU will sound a mis-lock warning. The mis-lock warning is market selectable. The mis-lock warning is sounded from either the vehicle horn for a period of 0.02 seconds or from the BBUS for a period of 0.1 seconds.

Alarm Activated
The audible and visual warning activated by the CCU when an alarm trigger is received by the CCU, is market selectable. The audible warnings can be a constant tone from the horn for a period of 30 seconds or an intermittent tone from the horn for 30 seconds, with the horn sounding for 0.5 seconds and off for 0.5 seconds. The visual warning is flashing of the hazard warning lights for 30 seconds.

When a BBUS is fitted, all alarm and miss-lock warnings will be sounded via the BBUS.

Alarm Reset
When the alarm has been activated, it can be silenced, with the ignition 'off', by either disarming or repeat arming using the vehicle key or the remote handset.

Battery Backed Up Sounder
The BBUS is market programmable and when fitted will provide security warnings: alarm sounder and mislock.

In the event of a tamper detection i.e. power loss to the BBUS, the sounder can only be silenced with reconnection of power to the BBUS and a disarm request followed by an arm request.

In the alarm armed condition the BBUS will sound if it detects a power supply/battery disconnection. If the alarm is not armed the BBUS can be disconnected without the device sounding. Therefore, to prevent the BBUS sounding inadvertently, before any work on the vehicle which requires battery disconnection is carried out, ensure the alarm is not armed.

It is recommended that the BBUS is changed after three years due to limits of battery life.

Remote Handset (RF Transmitter)
Two remote handsets are supplied with each vehicle. Two buttons on the handset control the locking and unlocking and alarm arm and disarm functions remotely. The remote handset transmits a coded signal which is recognized by the RF receiver. If the handset battery is removed or changed, or the vehicle battery is disconnected, the synchronization of the handset and the RF receiver will be lost.

Remote Handset Re-synchronization
Re-synchronization can be achieved using the handset by operating either handset button five times in quick succession with the ignition off.

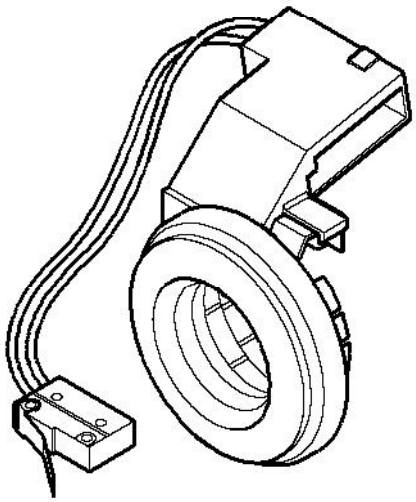
Remote Handset Battery Low Warning
If the remote handset battery voltage becomes low, when the handset transmits a signal to the CCU, it also transmits a low battery signal when the driver's door is opened. The CCU buzzer sounds a 10 second warning and the alarm LED flashes for 10 seconds to signify to the driver that the handset battery requires replacement. When the battery is replaced, the remote handset will require re-synchronization with the CCU.

Immobilisation System
The immobilisation system (EWS-3D) comprises:
- Immobilisation ECU
- Ignition switch transponder coil (Ring antenna)
- Key transponder
- Ignition switch
- Instrument pack
- Engine Control Module (ECM)
- Central Control Unit (CCU)
- Park/neutral switch
- Starter motor

Immobilisation System - General

The function of the immobilisation system is to prevent unauthorised starting of the vehicle. The ECU operates in a secure interface which cannot be by-passed or copied. Re-mobilisation is achieved through a transponder in the vehicle key which is energised by a transponder coil surrounding the ignition switch when the ignition is turned to 'AUX' position I. When energised the transponder data is read by the immobilisation ECU which will confirm the validity of the start request.

Ignition Switch Transponder Coil



M86 5306

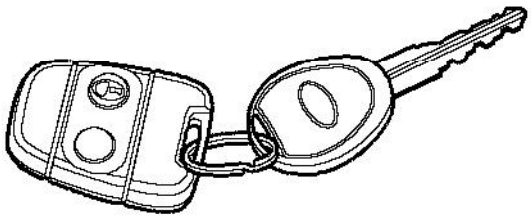
The transponder coil is located in a black plastic housing which is located around the ignition key barrel. The coil is connected by two wires to the immobilisation ECU.

The transponder coil passes electrical energy and data at a frequency of 125 kHz to a transponder in the vehicle key, up to a range of 20 mm (0.78 in) from the coil.

Key Transponder

Each vehicle is supplied with two vehicle keys and two separate RF transmitters. The RF transmitters are used to lock and arm the vehicle, and for the tail door window drop function. The key head contains the transponder used by the immobilisation system.

Key and Remote Handset



M86 5308

Each keyblade has an external waveform. The waveform is coded and recorded in a BMW Group database, therefore replacement keys are only available from franchised dealers/suppliers.

The transponder contains a 128 byte EEPROM which is programmed with vehicle identification data which is checked by the immobilisation ECU before re-mobilisation is activated. The information programmed into the EEPROM cannot be overwritten.

Immobilisation ECU

The immobilisation ECU is the central component in the immobilisation system and is located behind the fascia in a central position.

The EWS-3D ECU communicates with the CCU and is connected to the diagnostic socket enabling diagnostic procedures to be carried out.

There is no audible or visual indication to the driver of the condition of the immobilisation system.

The immobilisation ECU receives information from related systems on the vehicle and passes a coded signal to the ECM to allow starting if all starting parameters have been met. The information is decoded by the ECM which will allow the engine run if the information is correct. The information is on a rolling code system and both the ECU and the ECM will require synchronisation if either component is renewed.

Depending on engine fitment, three different ECM's can be used on the vehicle. Each ECM communicates with the immobilisation ECU using the same protocol .

The immobilisation ECU also protects the starter motor from inadvertent operation. The ECU receives an engine speed signal from the ECM via the instrument pack. When the engine speed exceeds a predetermined value, the ECU prevents operation of the starter motor via an integral starter disable relay.

Immobilisation ECU and 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 BMW Group dealers only. Keys can be disabled to prevent use of an unauthorised key using TestBook (immobilisation diagnostic).



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

Key and ECU Ordering Procedure – Japanese Market Only

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 Japanese parts organisation
5. The Japanese parts organisation will send the order to BMW Japan
6. BMW Japan will validate the VIN via a direct link to the BMW database. If the VIN is incorrect, BMW Japan will contact the Japanese parts organisation who, in turn, will inform the dealer to revalidate the VIN
7. When the VIN is validated, BMW Japan will confirm from the database that immobilisation codes remain available
8. If no codes are available, the order is returned the Japanese parts organisation who inform the dealer that all available codes have been used and that a new immobilisation ECU and key set is required. The dealer will advise the customer that a new immobilisation ECU and key set is required. If the customer agrees, then the ordering procedure is repeated from step 3
9. BMW Japan 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
10. BMW Japan will pass the completed order form to their key cutting centre who use the bar code to produce the new keys or new immobilisation ECU and key sets
11. BMW Japan will despatch the part(s) to the Japanese parts organisation to meet overnight delivery schedules
12. On receipt, the Japanese parts organisation will despatch the part(s) to the dealer using VOR or overnight delivery services

Replacement Key CCU Programming

A replacement key will arrive ready for use. The EWS-3D will recognise the first use of the key and will initiate the random rolling code from then on.

Remote handset replacements will require synchronising. This is achieved using TestBook (security diagnostics) to enter two bar code serial numbers, supplied on a label with the handset, into one of four code positions in the CCU. TestBook can also be used to enable or disable keys, if a key is lost for example.

Operation

Immobilisation System
The immobilisation system prevents unauthorised starting of the vehicle. The immobilisation ECU is a secure interface between the ECM which cannot be copied or by-passed.

Immobilisation ECU
The ECU ensures that the vehicle is in a safe condition to start the engine. On vehicles with automatic gearbox, the ECU prevents starter operation if the gearbox is not in park or neutral. A feed from the automatic transmission solenoid (C0024) is connected to pin 3 on the immobilisation ECU. The feed is only present when the selector lever is in either park/neutral. If the selector lever is moved to any other position the feed to the immobilisation ECU is removed and engine cranking will be disabled.

When the ignition is switched 'off' and the key removed from the switch, the immobilisation ECU becomes active and prevents unauthorised starter operation. Re-mobilisation is achieved by insertion of the vehicle key into the ignition switch and the switch turned to 'AUX' position I.

Ignition Switch Transponder Coil and Key Transponder
The coil is supplied with a modulated electric current from the immobilisation ECU. When the key transponder is within 2 cm (0.78 in) from the coil, with the ignition switch in the 'AUX' position, an energy transfer from the coil to the transponder takes place, similar to the transformer principle, at a frequency of 125 kHz. The ECU de-modulates and decodes the received data and compares this with identification code data from the ECM. If the data is correct the ECU allows starter operation.

When the key is inserted in the ignition switch, the key transponder transmits three separate pieces of information to the ECU via the transponder coil:

- A unique key identification number which is passed to the ECU
- A unique key password used by the ECU to communicate with the transponder
- Confirmation that the rolling code from the transponder is correct to the rolling code stored by the ECU

Programming
The immobilisation ECU is programmed with vehicle specific data during manufacture. The key transponders are supplied with the specific vehicle preprogrammed with the mechanical code for that vehicle's lockset. The mechanical code is read at the factory before the keys are programmed and the information is stored in a central database. The data is required to cut spare or replacement keys.

The ECU is programmed during manufacture with data to support up to ten keys. The programmed information is recorded against the VIN for that vehicle and stored in a central database.

Replacement or spare keys will be ordered and delivered to the dealer already programmed with the correct information specific to the particular vehicle and ready for use.

If a replacement immobilisation ECU is required it will be ordered and delivered to the dealer programmed with the original information stored during manufacture. The ECM will not require reprogramming because the replacement ECU will have the same identification code as before. The ECM and the EWS-3D immobilisation ECU will however need have their rolling code synchronised using TestBook.

If the ECM is replaced, the ECM will have to learn the identification code. This is achieved using TestBook. When the immobilisation ECU receives the correct diagnostic message it will transmit the identification code on a continual basis until the ignition is switched off. Simultaneously, the ECM is also receives a diagnostic command to learn the new code.

Starter Motor Protection
The immobilisation system 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 wired in series with the main starter motor solenoid and therefore when disabled it cuts off the power supply to the starter motor. This prevents damage to the starter motor being caused by a sticking ignition switch. The engine speed is derived from the instrument pack which converts the speed from a CAN bus signal into a pulsed signal compatible with the EWS-3D ECU.

Diagnostics
A diagnostic socket allows the exchange of information between the CCU and the immobilisation ECU and TestBook. The diagnostic socket is located in the driver's footwell and is constructed to ISO standard. A dedicated diagnostic bus is connected between the socket and the instrument pack and allows the retrieval of diagnostic information and programming of certain functions to be performed using TestBook.

The CCU and the immobilisation ECU monitor all inputs and outputs and if a fault is detected a code for that fault is stored in a fault log.

The CCU has two fault logs for internal and external faults. The CCU is capable of detecting short or open circuits. The CCU will disable certain functions when faults are detected and reinstate functions when faults are corrected and the function is again requested.

The immobilisation ECU also stores fault codes. The diagnostic interface is also used for matching a replacement ECM to the existing immobilisation ECU.



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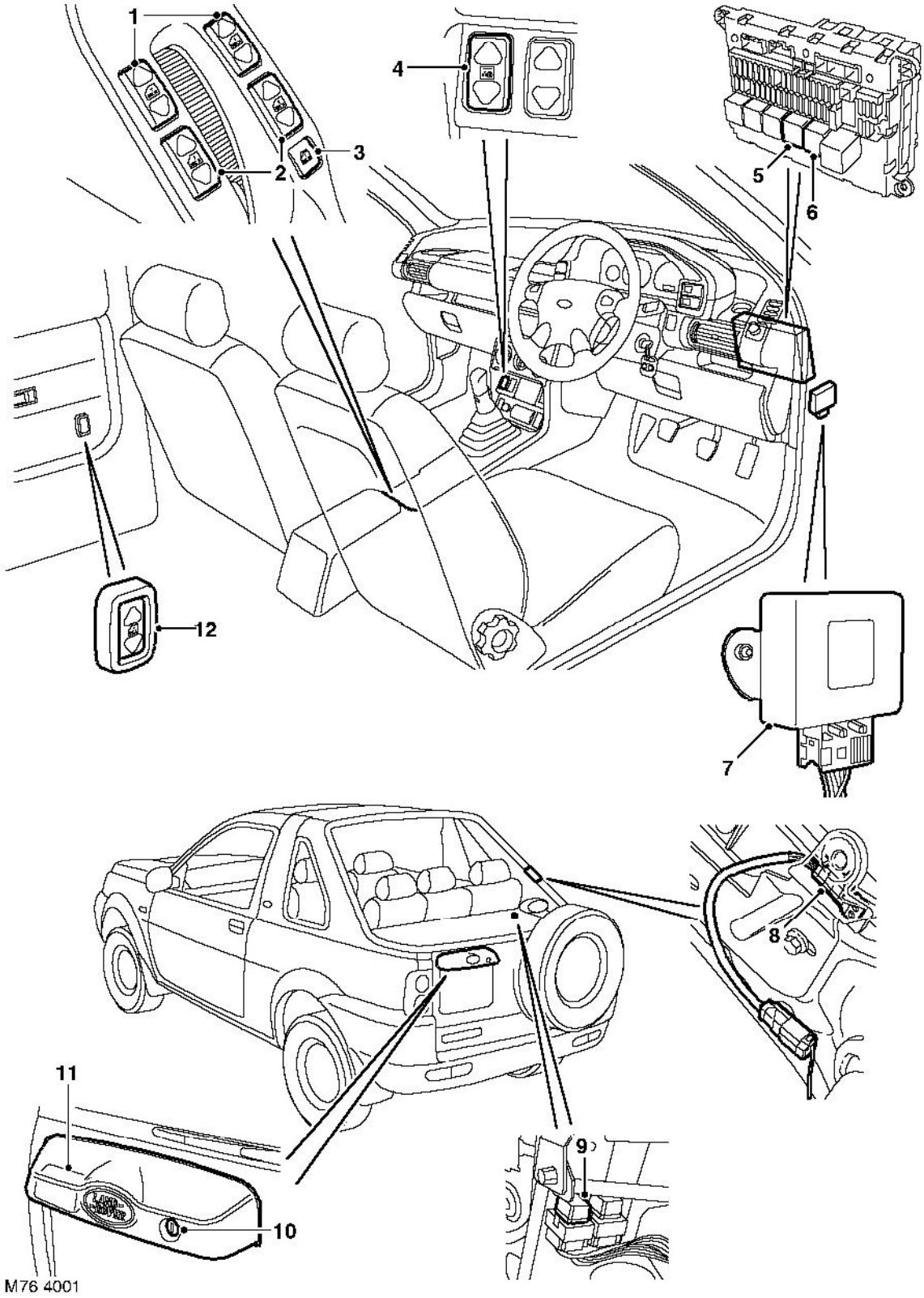
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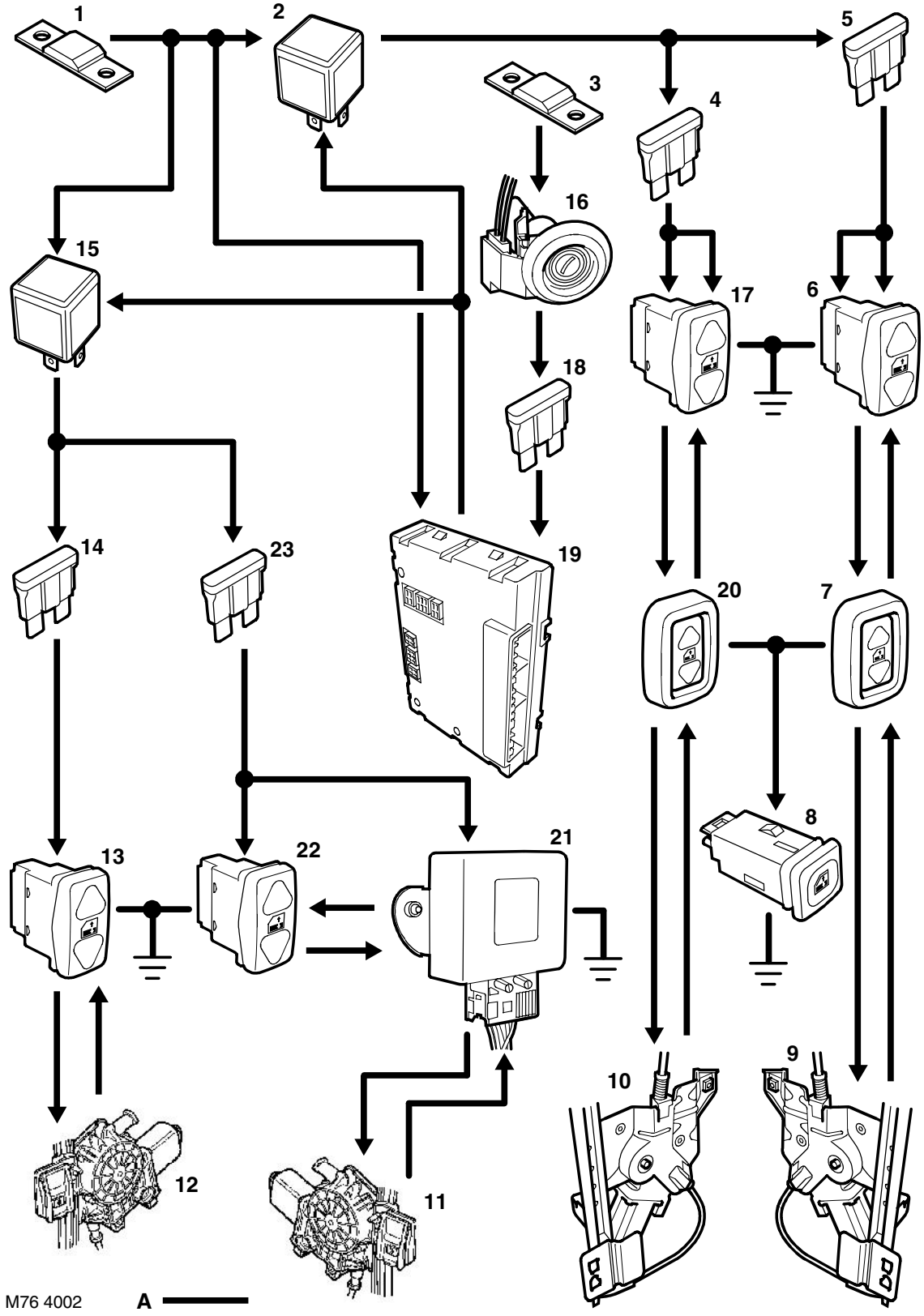
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Window Component Layout



1 Front side door window switches
2 Rear side door window switches (5 door only)
3 Isolator switch (5 door only)
4 Tail door window switch
5 Sunroof relay (5 door only)
6 Window lift relay
7 Window lift ECU
8 Roof sensing switch (3 door only)
9 Tail door window relay
10 Tail door lock
11 Tail door handle
12 Rear side door window switch (5 door only)

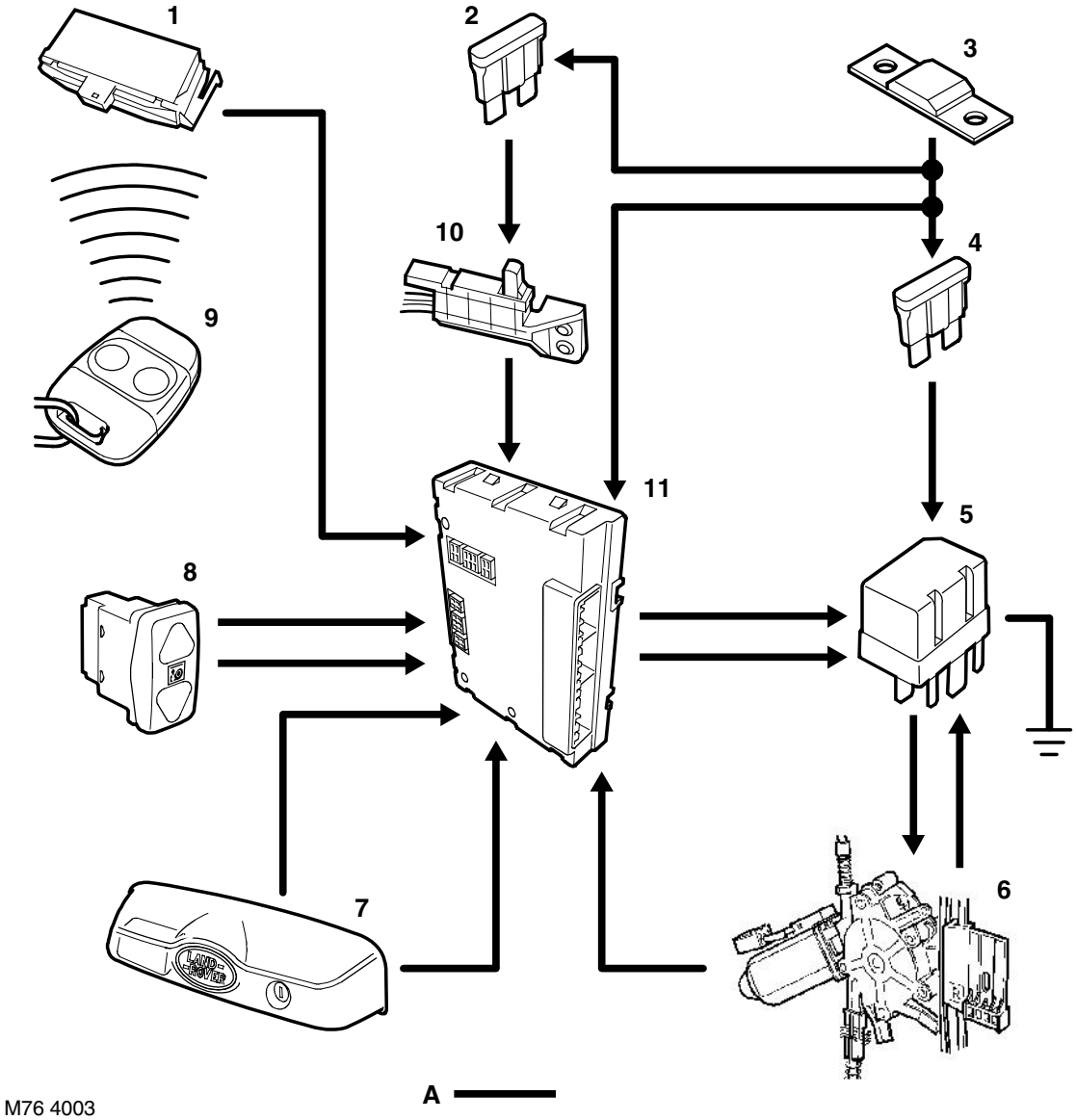
Side Door Window Control Diagram



A = Hardwired connections

1 Fusible link 4, engine compartment fusebox
2 Sunroof relay
3 Fusible link 3, engine compartment fusebox
4 Fuse 26, passenger compartment fusebox
5 Fuse 27, passenger compartment fusebox
6 Centre console RH rear window switch (5 door only)
7 Door trim RH rear window switch (5 door only)
8 Isolator switch (5 door only)
9 RH rear window motor (5 door only)
10 LH rear window motor (5 door only)
11 Driver's window motor
12 Front passenger's window motor
13 Front passenger's window switch
14 Fuse 34, passenger compartment fusebox
15 Window lift relay
16 Ignition switch
17 Centre console LH rear window switch (5 door only)
18 Fuse 8, passenger compartment fusebox
19 CCU
20 Door trim LH rear window switch (5 door only)
21 Window lift ECU
22 Driver's window switch
23 Fuse 33, passenger compartment fusebox

Tail Door Window Control Diagram



M76 4003

1 RF receiver
2 Fuse 14, passenger compartment fusebox
3 Fusible link 4, engine compartment fusebox
4 Fuse 31, passenger compartment fusebox
5 Tail door window lift relay
6 Tail door window motor
7 Tail door handle and lock
8 Tail door window switch
9 Remote transmitter (plip)
10 Roof sensing switch (3 door models only)
11 CCU

Description

General
All models feature electrically operated windows on the side doors and the tail door.

The side door windows are controlled by a window lift ECU and individual rocker switches located in the centre console and, on 5 door models, in the rear door trim casings. 5 door models also incorporate an isolator switch, in the centre console, for the rear side door windows.

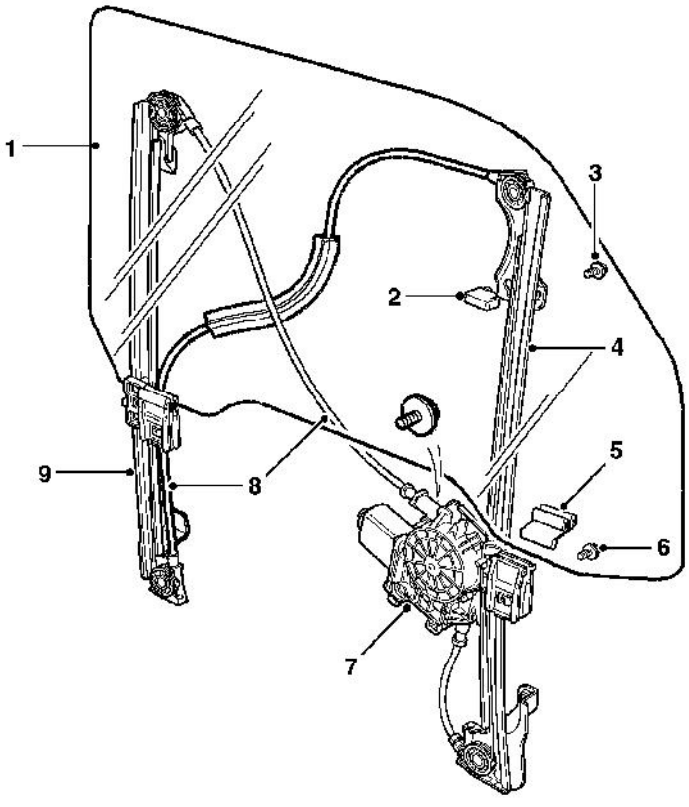
The tail door window is controlled by the Central Control Unit (CCU), a rocker switch on the fascia, the remote handset and the tail door handle and lock. The CCU also uses inputs from the rear screen wiper system and, on 3 door models, a roof switch, to inhibit window operation while the rear screen wiper is operating or the roof is open (soft back) or removed (hard back).

Front Door Windows
The front window regulator and motor is supplied as an assembly and is handed. Each assembly comprises a front and rear runner, a continuous cable and a motor.

The runners are secured in the door frame with four screws. The door glass is located in two carriers which are located in tracks in the runners. The glass is retained in friction pads in each carrier and secured with clamp screws.

Each carrier is attached to the cable which, in turn, is attached to a drum driven by the motor. When the motor is operated the drum pulls the cable in the required direction to raise or lower the glass.

Front Door Window Regulator



M76 4004

LH regulator shown, RH similar

1 Window glass
2 Glass stop damper
3 Mounting screw (4 off)
4 Forward runner
5 Friction pad
6 Glass clamp screw
7 Motor assembly
8 Cable
9 Rear runner

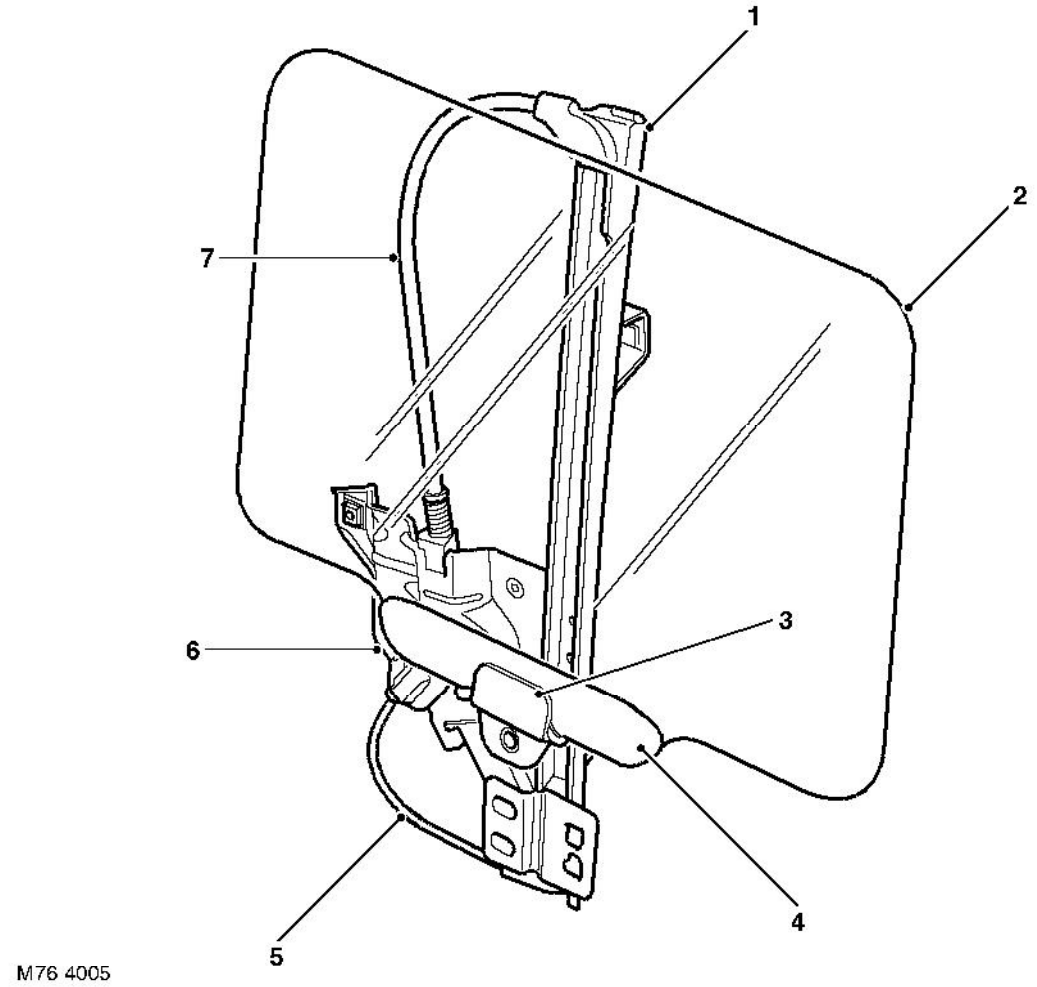
Rear Door Windows

The rear window regulator and motor is supplied as an assembly and is handed. Each assembly comprises a runner, a continuous cable and a motor.

The runner is secured in the door frame with four bolts. The door glass is located in a carrier located in a track in the runner. The glass is retained in friction pads in the carrier and secured with a clamp screw.

The carrier is attached to the cable which, in turn, is attached to a drum driven by the motor. When the motor is operated, the drum pulls the cable in the required direction to raise or lower the glass.

Rear Door Window Regulator



RH regulator shown, LH similar

1 Runner
2 Window glass
3 Friction pad
4 Carrier
5 Cable
6 Motor and regulator
7 Cable

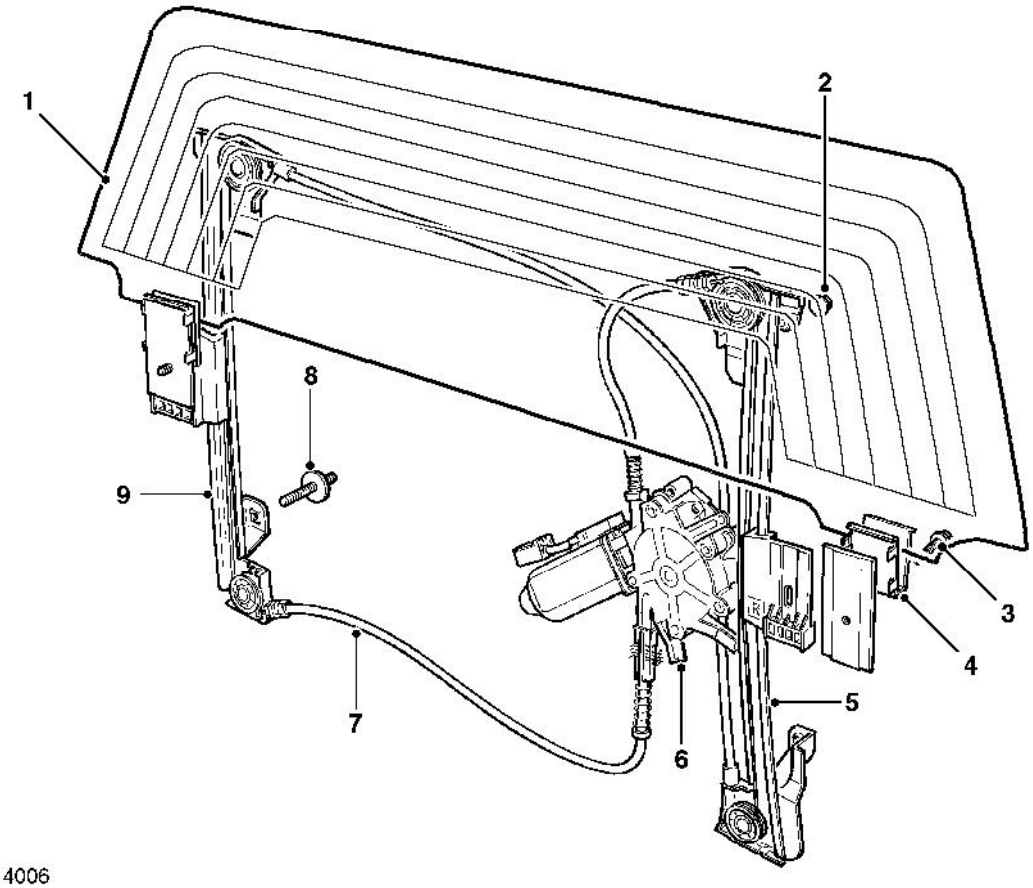
Tail Door Window

The tail door window regulator comprises left and right hand runners, a continuous cable and a motor. The runners are secured in the tail door frame with four screws. The glass is located in two carriers which are located in tracks in the runners. The glass is retained in friction pads in each carrier and secured with clamp screws.

Each carrier is attached to the cable which, in turn, is attached to a drum driven by the motor. When the motor is operated, the drum pulls the cable in the required direction to raise or lower the glass.

The motor incorporates a movement sensor that supplies a position feedback signal to the CCU.

Tail Door Window Regulator



M76 4006

1 Tail door glass
2 Nut (3 off)
3 Clamp screw (2 off)
4 Friction pad (2 off)
5 RH runner
6 Motor
7 Cable
8 Mounting screw (4 off)
9 LH runner

Window Lift ECU

The window lift ECU provides 'one shot' opening of the driver's door window. Instead of the window switch being connected direct to the window motor, as on the other side door(s), the driver's door window switch is connected to the window motor via the window lift ECU. The window lift ECU is installed on the driver's side A post, level with the lower edge of the fascia.

Operation

Side Door Windows
Power for side door window operation is supplied from the window lift relay and, on 5 door models, the sunroof relay, both located in the passenger compartment fusebox. The CCU controls the relays, which are energised while the ignition switch is in position II and for 40 seconds after the ignition is turned off.

When an up or down selection is made on one of the side door window switches, the switch simultaneously connects a power supply and an earth to the related door window motor to drive the window in the required direction. When the opposite selection is made, the switch changes the polarity of the connections to drive the window in the opposite direction. The window stops moving immediately the switch is released, except when a momentary down selection is made on the driver's door switch.

The driver's door window switch is connected to the window motor via the window lift ECU. When the window lift ECU senses a momentary (0.2 second or less) down selection on the driver's door switch, it connects the driver's door window motor to a power supply direct from the window lift relay and to an ECU earth. The window lift ECU maintains these connections until the door window motor stalls, after driving the window fully down, or an up selection is made on the window switch.

On 5 door models, each rear window switch on the centre console is connected to the window motor via the related rear door mounted window switch. When the isolator switch is pressed, the earth path for the two rear door mounted window switches is disconnected. With the isolator switch pressed, only the rear window switches in the centre console will operate the rear door window motors.

Tail Door Window
The CCU controls the tail door window via the tail door window relay located above the RH rear suspension turret. The tail door window relay is a dual relay that incorporates separate 'up' and 'down' contacts. When the CCU wants to operate the window, it switches the appropriate contacts in the tail door window relay to connect a power supply and an earth to drive the window motor in the required direction. The contacts change the polarity of the motor to change the direction of drive.

The tail door window can be lowered using the console switch or the remote handset. On 3 door models, opening/ removal of the roof will automatically lower the window. The window can be raised using the console switch or the vehicle key in the tail door key barrel. When the tail door is opened, the tail door window lowers to a 'clear of seal' position and, when the door is closed, the window automatically rises to its fully up position in the window seal.

Tail Door Window Lower
The rear screen wiper must be parked off-screen before the CCU will allow the tail door window to lower. If the rear screen wiper is operating when a window down request is made, the CCU will automatically park the wiper off-screen before lowering the window. If the Heated Rear Window (HRW) is operating, the CCU will turn off the HRW when the window is lowered.

Remote Handset Lower: With the ignition off and the tail door closed, if the unlock button on the remote handset is pressed for a minimum of 1 second the CCU will unlock the doors and energise the tail door window down relay to fully lower the window.

Console Switch Lower - Inch Down: With the ignition on, pressing the console switch in the down position will signal the CCU to lower the tail door window for as long as the switch is held. The window will stop at the chosen position when the switch is released. When the window is almost fully down, the CCU will continue to lower the window irrespective of whether the switch is pressed or not.

Console Switch Lower - One Shot: With the ignition on, pressing the console switch in the down position, for approximately 0.2 second or less, will signal the CCU to lower the tail door window until it is fully down or an up request is received. This feature is market programmable.

Roof Removal (3 Door Models Only): Opening/ removal of the roof will trip the roof off switch. This signals the CCU which, if the alarm is not armed, automatically lowers the tail door window even if the tail door is open. If the roof is opened/ removed while the alarm is armed, the roof off switch triggers the alarm and the CCU will not lower the tail door window.



Tail Door Window Raise

If the rear screen wiper is selected on when the tail door window is raised, the CCU will start/ resume operation of the wiper once the window is closed.

Tail Door Key Barrel Raise: With the tail door closed and, on 3 door models the roof closed/on, turning and holding the key in the tail door key barrel will signal the CCU to raise the tail door window. The key must be held until the window is fully raised (stalled position). If the key is released before the window is fully raised, the raise signal is removed from the CCU and the window will be fully lowered.

Console Switch Raise: With the ignition on, the tail door closed and, on 3 door models the roof closed/on, pressing the console switch in the up position will signal the CCU to raise the tail door window. The switch must be pressed until the window is fully raised (stalled position). If the switch is released before the window is fully raised, the raise signal is removed from the CCU and the window will be fully lowered.

Motor Timeout

To protect the tail door window motor from damage, the motor outputs have a fail-safe inhibit relative to the window height. This prevents the motor from being overdriven. If the fail-safe limit is reached, the CCU will energise the tail window down relay, to fully lower the window, and change the window position setting to uncalibrated. The calibration procedure will need to be performed to restore normal tail door window operation.

Tail Door Window Open Warning

If the tail door window is calibrated and open and, on 3 door models the roof is closed/on, and a lock request is made from the remote handset or the driver's door key barrel, the CCU will sound an audible miss-lock warning to advise that the window is open. The window can be closed using either the console switch or the tail door key barrel.

Calibration

When the CCU is changed from transit mode to a valid market mode, and after the vehicle battery has been disconnected, the tail door window must be calibrated to provide the CCU with a window position datum. When the CCU mode is changed to a valid market, or the battery reconnected, the CCU automatically begins the calibration process by energising the down contacts in the tail window lift relay until the window motor stalls, to ensure the window is fully down. The calibration procedure is completed as follows:

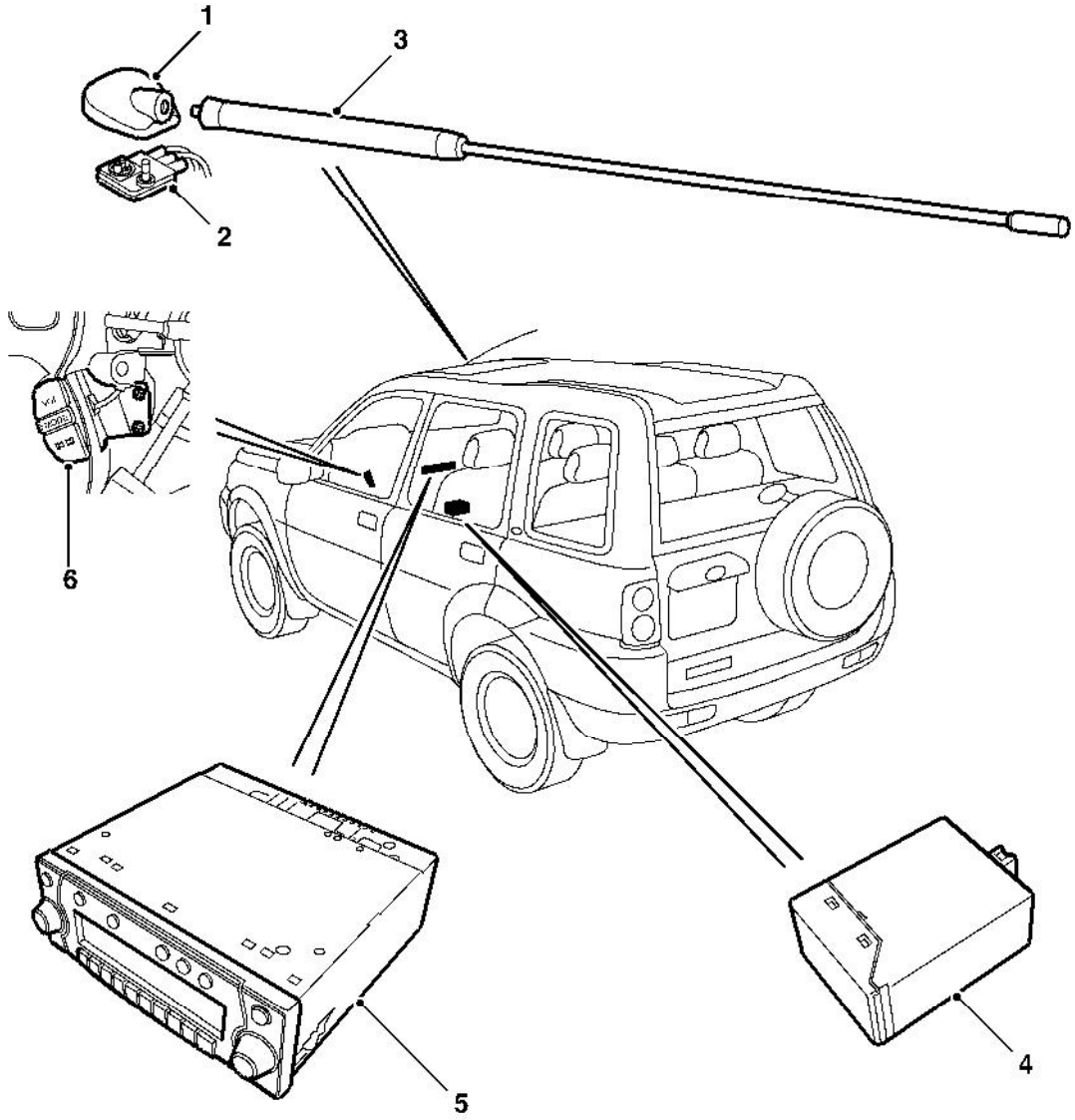
1. Ensure the tail door is closed, the vehicle unlocked and the alarm disarmed.
2. On 3 door models, ensure the roof is on (hard back) or lowered and secured (soft back).
3. With the ignition on, use the console switch, or the vehicle key in the tail door lock, to raise the window until the motor stalls with the window fully closed.
4. Switch off the ignition.

If the calibration procedure is unsuccessful, the CCU will sound a warning for approximately 0.8 second and fully lower the window.

Tail door window calibration can fail for the following reasons:

- Window stops before minimum travel is achieved.
- Window does not achieve a stall.
- Window request removed before stall is achieved.
- Tail door opened while driving window up.

Navigation System Component Location



M86 5659

1 GPS antenna
2 Diplexer unit
3 FM antenna
4 Remote control interface unit
5 Navigation computer
6 Steering wheel switches

Description

General
The navigation system provides audio and visual route guidance to help the driver reach a selected destination. The system is an optional fit consisting of a Traffic Pro navigation computer and antenna, manufactured by Harman/ Becker Automotive Systems, which are fitted in place of the In Car Entertainment (ICE) head unit and antenna. Compact Disc (CD) and radio functions are incorporated into the navigation computer.

The navigation system allows the driver to choose between the shortest and fastest routes between the vehicle's current position and a selected destination, and to select a stopover point in the journey and a route that avoids motorways, ferries and toll roads. Directions to Points Of Interest (POI) e.g. airports, hospitals, petrol stations etc, either local, national or in another country, can also be selected. A traffic jam function enables the driver to request diversion instructions, around an obstructed part of the selected route, during the journey. A Traffic Management Control (TMC) function, currently only available in some European countries, monitors traffic broadcasts and automatically selects an alternative route during the journey if the original route is effected by a traffic jam, accident or road works etc.

The position of the vehicle is determined by the navigation computer using a combination of vehicle sensor inputs and radio signals from the 24 Global Positioning System (GPS) satellites orbiting the earth. The position of the vehicle is then plotted on a digitised map, loaded into the navigation computer from a CD-ROM, to determine the journey route and provide the route guidance.

The GPS satellite signals are used for initial determination of the vehicle's position and periodic position updates. The vehicle sensor inputs are used to monitor the vehicle's direction of travel and distance travelled between position updates from the GPS satellite signals. The vehicle sensor inputs consist of:

- A vehicle speed signal from the ABS ECU, to monitor the distance travelled and for automatic volume control.
- A reverse gear signal from the selector and inhibitor switch of the automatic gearbox, or reverse gear switch of the manual gearbox, to enable the navigation computer to differentiate between forward and rearward movement of the vehicle.
- A gyro in the navigation computer, to monitor changes of direction, i.e. steering inputs.

The signal from each GPS satellite contains information about satellite position, almanac data and time (almanac data is the current status of the satellite). Signals from between five and 11 of the GPS satellites can be received at a given point on the earth's surface at any one time. The number and quality of separate GPS satellite signals received also varies with vehicle location. In hilly or tree lined areas, built up areas with tall buildings, multi-storey car parks, garages, tunnels, bridges and during heavy rain/thunderstorms, signal reception of some or all of the GPS satellites will be poor or non existent.

A minimum of three separate GPS satellite signals are required for the navigation computer to calculate a three dimensional (3D) positional fix. When only two signals are being received, the navigation computer will calculate a less accurate two dimensional (2D) positional fix. The more widely dispersed that the GPS satellites are, the more accurate the positional fix. The navigation computer can store information from a maximum of 12 GPS satellites at any one time. When more than three signals are stored, the navigation computer selects the three most widely dispersed signals for the position calculation.

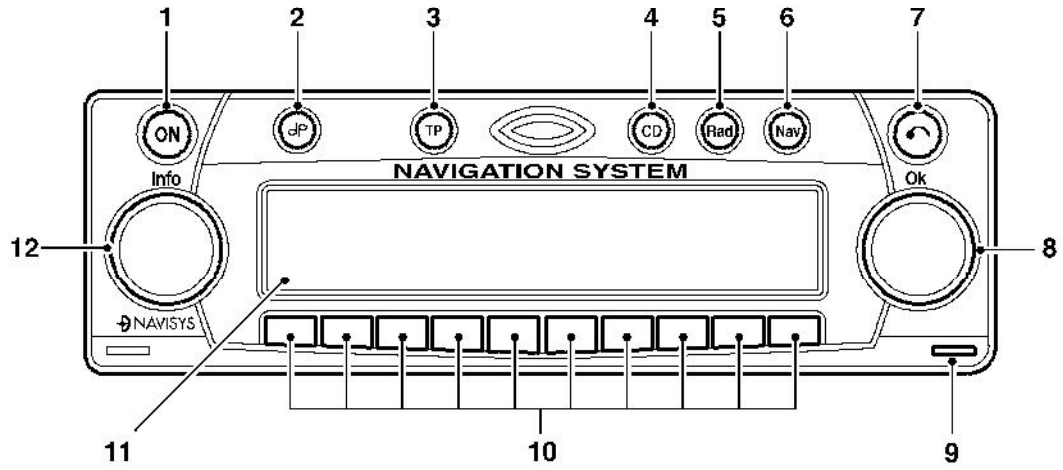
Antenna Assembly
The antenna assembly consists of a GPS antenna, installed at the front of the roof centreline, and an FM radio antenna which screws into the GPS antenna. A diplexer unit on the underside of the GPS antenna amplifies the radio signals received from the GPS satellites and radio stations and transmits them through separate co-axial cables to the navigation computer for processing.

Navigation Computer
The navigation computer is installed in the DIN radio slot in the fascia. A spring loaded catch on each side of the navigation computer secures it in position. Slide tools, installed in slots at the bottom front corners of the navigation computer, are required to unlock the catches during removal.

The navigation computer contains all the hardware and software required for control of the navigation, radio and CD systems, including the GPS receiver and a solid state piezo gyro for the navigation system. The piezo gyro measures the motion of the vehicle around its vertical axis.

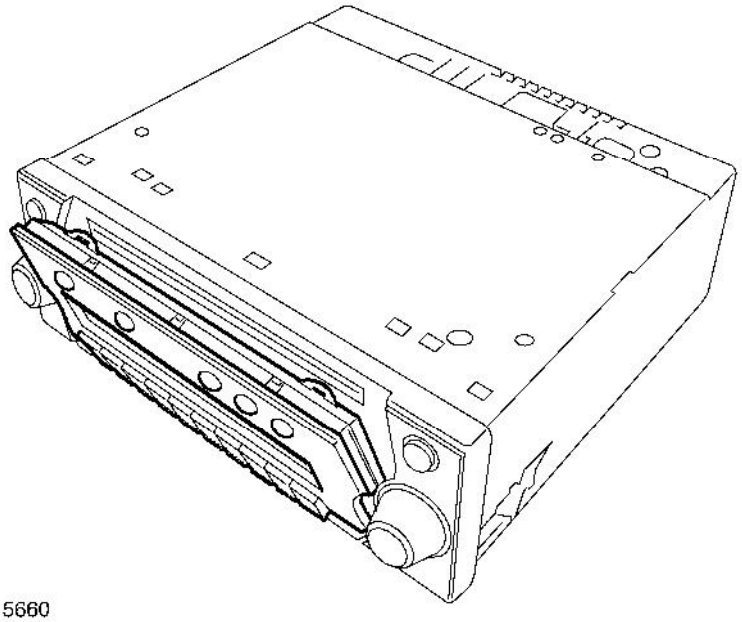
The controls for the navigation computer are all located on the front panel of the unit. The centre section of the front panel hinges to allow access to the CD player and, for security purposes, can be removed from the unit. The controls perform the following functions:

- On/Off (ON) button, for switching the unit on and off.
- Tone button, for activating the tone menu to adjust bass, treble, balance, fade and loudness functions.
- Traffic Programme (TP) button, for activating the traffic information programme menu (Europe only).
- Compact Disc (CD) mode button, for selecting CD operation.
- Radio (Rad) mode button, for selecting radio operation and tuning menus.
- Navigation (Nav) mode button, for entry and exit of the navigation menu and service mode.
- CD eject button, opens the removable panel and ejects the CD.
- RH rotary control, scrolls through menus when turned and enters a selection when pressed. Also mutes audio navigation instructions when pressed in navigation mode.
- Multifunction buttons, for entering the security code and menu selections.
- Liquid Crystal Display (LCD), green screen that displays navigation, radio and CD information.
- LH rotary control, adjusts volume when turned. When pressed, restores, repeats or interrupts audio navigation instructions or provides destination details.



M86 5652

1 On/Off button
2 Tone button
3 Traffic programme button (Europe only)
4 CD mode button
5 Radio mode button
6 Navigation mode button
7 CD eject button
8 RH rotary control
9 Release tool slot
10 Multifunction buttons
11 LCD
12 LH rotary control



M86 5660

Inputs and Outputs

In addition to the vehicle sensor and the antenna inputs, the navigation computer also receives the following:

- A permanent battery feed from the passenger compartment fusebox, to power the navigation function.
- An ignition switched battery feed from the passenger compartment fusebox, to power the navigation, radio and CD functions when the ignition switch is in positions I and II.
- An illumination power feed for switch illumination and LCD backlighting when the exterior lights are on.

Navigation computer outputs consist of those for the ICE system speakers and to the auxiliary CD autochanger, where fitted.

Security Code

The navigation computer is programmed with a five digit security code selected from numbers 1 to 7. If the battery or the navigation computer are disconnected, the code is requested on the LCD the first time the navigation computer is switched on after reconnection; this also occurs if a different removable panel is fitted.

The code is entered using the appropriate multifunction buttons. The navigation computer automatically starts to operate when the fifth digit of the correct code is entered. If an incorrect code is entered, CODE is displayed on the LCD to prompt another entry attempt. If an incorrect code is entered three times in succession, WAIT is displayed on the LCD and the unit is disabled for approximately 60 minutes. If the navigation computer is switched off, the remaining disabled time will resume when the power is restored.

Automatic Volume Control (AVC)

The AVC feature automatically increases and decreases the audio volume with increases and decreases of vehicle road speed. The AVC feature, also known as the GAL setting, uses the vehicle speed signal from the ABS ECU and can be turned off or adjusted to start at a different vehicle speed. The GAL setting is accessed through the User Menu and can be set to between 0 and +15, where 0 is off and +1 to +15 progressively increase the vehicle speed at which AVC starts to operate.



System Settings Menu

The system settings menu provides access to features that can be changed to suit market and personal preferences and to navigation system operating features. On European systems, the system settings menu also includes computer games and a currency converter. While the navigation computer is in the navigation mode, the system settings menu can be accessed by pressing the Nav button. Using the RH rotary control, the following features can be selected and adjusted:

- *TIME* – Allows the navigation system clock to be set to local time as opposed to the Greenwich Mean Time (GMT) transmitted from the GPS satellites. The local time setting is necessary for correct navigation on routes with time restrictions and for Estimated Time of Arrival (ETA) calculations. The time can only be adjusted in 30 minute steps.
- *SAVE POSITION* – Allows the current vehicle position to be saved and allocated a name in the navigation destination memory.
- *GAMES* – Provides access to a selection of computer games.
- *LANGUAGE* – Allows the navigation system language and voice (where applicable) to be changed.
- *ANIMATIONS* – Allows the LCD animations to be switched on and off.
- *MEASURING UNIT* – Allows the route guidance distances displayed on the LCD to be switched between metric and Imperial units.
- *ANNOUNCEMENT ETA* – Allows the route guidance ETA announcement to be switched on and off.
- *CALCULATE EURO* – Provides access to a currency converter.

User Menu

The user menu provides access to further features that can be changed to suit personal preferences. While the navigation computer is in navigation, radio or CD modes, the user menu can be accessed by pressing and holding the tone button for more than 2 seconds. The user menu is displayed over two screens, which can be toggled between using the ⇒ multifunction button. Using the appropriate multifunction button or the RH rotary control, the following settings can be selected and adjusted:

Screen 1

- *Gal* – Automatic volume control setting (see above).
- *Tel* – If a handsfree telephone system is connected to the navigation computer, allows either *mute* (telephone mute mode) or *audio signal* (telephone conversation via the ICE speakers) to be selected.
- *Lcd* – The LCD can be set to appear *negative, positive* or *automatic*. In *automatic*, the display will be positive or negative, depending on the setting of the exterior lamps.
- *Led* – A Light Emitting Diode (LED) in the display can be set to *off* or *blinking*. When set to *blinking*, the LED flashes when the navigation computer is switched off.
- *M/S* – Radio reception can be set to *Stereo, Mono* or *Auto*, to suppress interference and reflections and so optimise reception. *Stereo* is for exceptionally good reception conditions. *Mono* is for poor reception conditions. In *auto*, the normal setting, the navigation computer automatically switches between stereo and mono depending on reception conditions.

Screen 2

- *Nav* – Sets how audio navigation instructions are delivered. In *onl*, other audio sources are suppressed and only the navigation instruction is output to the speakers. In *mixed*, the volume of any other audio source is reduced and the volume of the navigation announcement is the same as the original audio source +/– 6 dB (adjustable). In *independ*, the audio source and navigation announcement can be set to independent volume levels.
- *Aux* – Used to switch auxiliary CD AF connections between *Aux mode on* and *Aux mode off*. If no CD autochanger is installed, an external cassette or CD player can be connected to the navigation computer and powered by switching on the auxiliary CD AF connections.
- *Cmp* – Allows a compass to be shown on the LCD when route guidance is not active.
- *BeV* – Used to adjust the signal tone volume. Signal tones sound to confirm storage confirmation etc. and can be set between 0 (quiet) and +5 (loud).

Service Menu

The service menu provides access to details of the navigation computer hardware and software, and can be accessed when the navigation computer is in radio mode, by simultaneously pressing the *NAV* button and the 10 multifunction buttons. The following items can then be scrolled through by pressing the *Nxt* (next) and *Prv* (previous) multifunction buttons, or turning the RH rotary control:

- *Model No.*
- *Serial No.*
- *Changer Reset*
- *GAL*
- *Radio Software*
- *Radio Bolo*
- *Navi Rom*
- *Navi Flash*
- *RTC Value*

When Changer Reset is displayed, the CD autochanger (where fitted) can be reset by pressing the appropriate multifunction button.

When the End multifunction button is pressed, the navigation computer quits the service menu and returns to radio mode.

Garage Menu

Garage menu enables the navigation system to be tested and calibrated, and also contains a route navigation demonstration. The garage menu is entered from the main navigation menu, as follows:

1. Press the Nav button to access the system settings.
2. Press and hold multifunction button 3, then press multifunction button 5 to display the garage menu.

The garage menu contains the following, which can be accessed using the RH rotary control:

- *CALIBRATION RIDE* – Used to calibrate the navigation computer, to enable route navigation.
- *GPS INFO*– Provides functional test of antenna by checking GPS reception. If functioning correctly, displays the number of satellites being received, the date, time (Greenwich Mean Time) and the type of positional fix currently possible.
- *CALIBRATION*– Allows vehicle specific calibration data to be entered, e.g. tyre size. Also allows current calibration to be deleted prior to re-calibrating.

NOTE: Only known calibration data should be entered. The navigation computer cannot make route calculations if incorrect data is entered.

- *SENSORS*– Allows wheel speed, reverse gear and gyro sensor inputs to be checked.
- *VERSION*– Displays navigation computer hardware and software details.
- *SPEECH TEST*– Performs a test of the navigation computer audio output.
- *MODULE TEST*– Performs a test routine on the internal components of the navigation computer.
- *DEMO* – Allows a route navigation demonstration to be run.

To quit the garage menu, press the Nav button.

Calibration

Calibration is required after initial installation or replacement of the navigation computer. It may also be necessary after repairs to system wiring and if route navigation becomes inaccurate or fails to operate. If the navigation computer contains an existing calibration, this must be deleted, using the garage menu, prior to running the new calibration routine. The sensor inputs should also be checked before running the calibration routine.

Sensor Check

1. Call up the SENSORS screen on the LCD:
   - If the navigation CD-ROM has not been installed before, press and hold multifunction button 1 then press multifunction button 10.
   - If the navigation CD-ROM has been installed before, use the garage menu as detailed above.
2. Drive the vehicle forwards a short distance at a speed greater than 2.5 mph (4 km/h) and ensure the road speed counter on the SENSORS screen starts to increment.
3. Select reverse gear and ensure the direction arrows on the SENSORS screen point rearwards.



4 Ensure the GPS data on the SENSORS screen is displayed and updated.

NOTE: The GPS data will randomly display a GPS MODULE FAILURE message. This is not a fault condition, and no action need be taken, provided the GPS data switches between the GPS MODULE FAILURE message and actual GPS data.

5 Exit the SENSORS screen:

- If the navigation CD-ROM has not been installed before, press and hold multifunction button 1 then press multifunction button 10.
- If the navigation CD-ROM has been installed before, press the Nav button.

Calibration Routine

1 Park the vehicle outside in an area clear of high buildings, trees etc.

NOTE: The more open the surrounding area is, the faster the system will acquire sufficient GPS satellite signals to begin calibration. To minimise the calibration time, the vehicle should not be moved again until the calibration ride.

NOTE: On NAS Freelanders, when the security system RF receiver is active it disrupts the GPS satellite signals. To allow the navigation system to operate, the RF receiver is deactivated when the ignition is on. During calibration, ensure the ignition remains on and that the vehicle is not parked next to a Freelander with an active RF receiver.

2 Turn the ignition switch to position II. If the navigation computer does not come on, press the navigation computer ON button.

3 If necessary, use the navigation computer multifunction buttons to enter the security code.

4 Call up the SENSORS screen on the LCD:

- If the navigation CD-ROM has not been installed before, press and hold multifunction button 1 then press multifunction button 10.
- If the navigation CD-ROM has been installed before, use the garage menu as detailed above.

5 Turn the LH rotary control to minimum volume.

6 Wait for 30 minutes. If necessary, the engine can be started.

NOTE: Land Rover recommend a minimum of 30 minutes be allowed to elapse in order to ensure that only a short distance need be driven to achieve calibration.

7 After the 30 minutes have elapsed, ensure the navigation computer LCD shows a GPS almanac figure of 27 or higher.

8 Start the vehicle engine and allow to idle.

9 Install the navigation CD-ROM.

10 Wait until the navigation computer LCD prompts for a language to be selected. Turn the RH rotary control to scroll through the options, highlight the required language and press the RH rotary control to select.

11 The navigation computer LCD will prompt for a voice to be selected. Turn the RH rotary control to scroll through the options, highlight the required voice and press the RH rotary control to select.

12 Wait until the navigation computer LCD advises "language has been loaded OK". Press the RH rotary control to confirm the language and voice selections.

13 The navigation computer LCD will default to the CALIBRATION RIDE screen and should show the CALIBRATION RIDE CAN START message. The GPS data and the road speed counter will also be shown.

14 Drive the vehicle over a road route approximating that shown below (it is not necessary to copy the route exactly). Calibration is complete when the navigation computer LCD switches to show DESTINATION & POI and the satellite graphic. If all the pre calibration ride conditions were complied with, calibration is typically achieved within 3 miles (5 km) and usually occurs when the vehicle returns to the start point. However, calibration may be achieved earlier in the journey and, if it is, there is no need to complete the remainder of the calibration route.

15 After calibration is achieved, return to the dealership, park the vehicle and stop the engine.

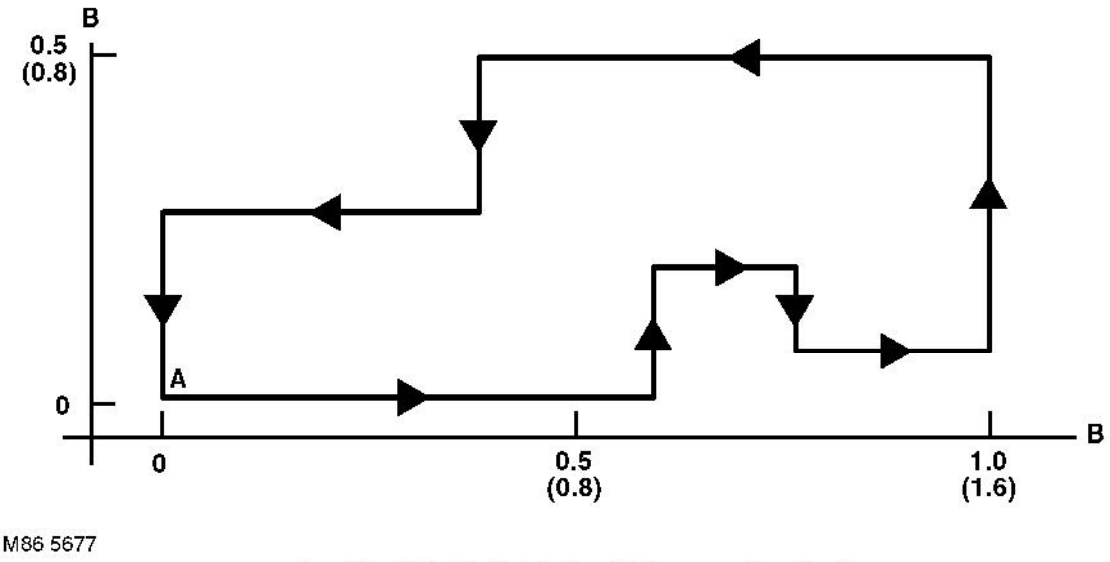
16 Turn the ignition switch to position I.

17 Use the system settings menu to set the navigation computer to local time and the required units of measure:
- **a** Press the Nav button.
- **b** Turn the RH rotary control to scroll through the displayed menu, highlight TIME and press the RH rotary control to select. Press the + or – multifunction button to adjust the time in 30 minute steps. Select the 24 hour clock and confirm by pressing the OK multifunction button.
- **c** If metric units of measure are required, go to step e. (the navigation computer defaults to metric units of measure).
- **d** If Imperial units of measure are required, turn the RH rotary control to scroll through the displayed menu, highlight MEASURING UNIT and press the RH rotary control to select. Turn the RH rotary control to highlight IMPERIAL and press the RH rotary control to select.
- **e** Press the Nav button to return to the destination menu.

18 Calibration is complete. The navigation system is ready for use.

NOTE: The accuracy of the system will automatically be fine tuned when a further journey is made, but this is not required as part of the calibration procedure.

NOTE: In European countries, the territory will have to be set the first time the navigation system is used, and the first time a destination in another country is selected. The first time the navigation system is used or a destination in another country is selected, a map is displayed with the default/current territory highlighted. To change the territory: Press the RH rotary control to display the territory list; turn the RH rotary control to scroll through the list and highlight the required territory; press the RH rotary control to confirm the selection.



A = Start/Finish Point; B = Distance, miles (km)

Reset

If the navigation system malfunctions, a system reset can be triggered by simultaneously pressing the TP button and multifunction button 1 or 3. The navigation CD will need to be installed after the system reset.

Steering Wheel Switches

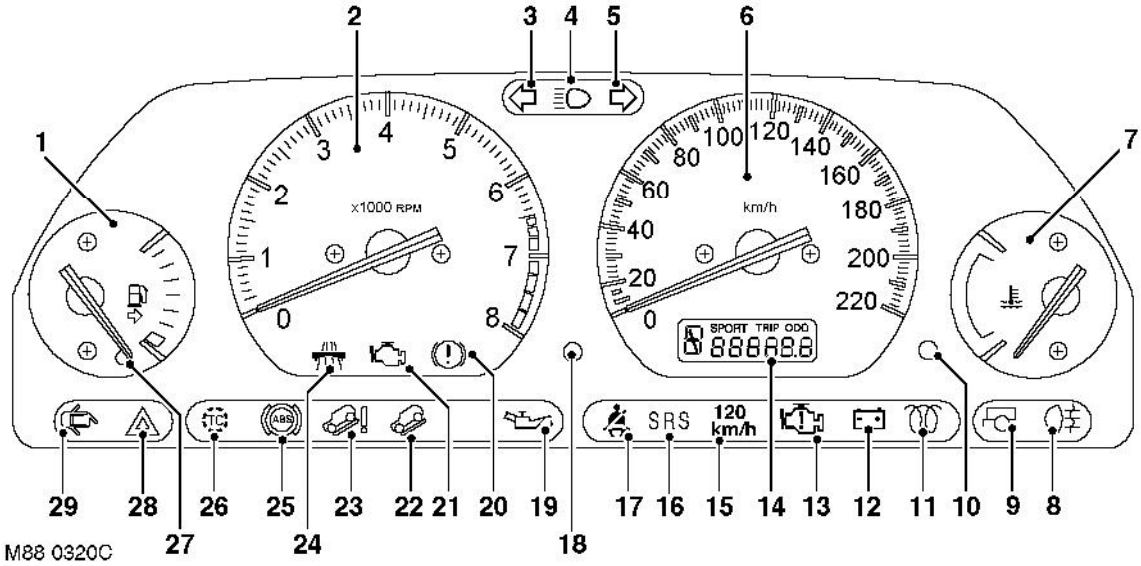
The steering wheel switches provide remote control operation for some of the navigation computer functions. The switches can be used to select between the radio/CD/navigation modes, to adjust the volume (in all modes) and to select search/preset up/down for radio and CD operation.

Remote Control Interface Unit

The remote control interface unit converts the analogue signals from the steering wheel switches into digital signals for use by the navigation computer. The remote control interface unit is installed in a plastic bracket immediately in front of the gear selector lever.

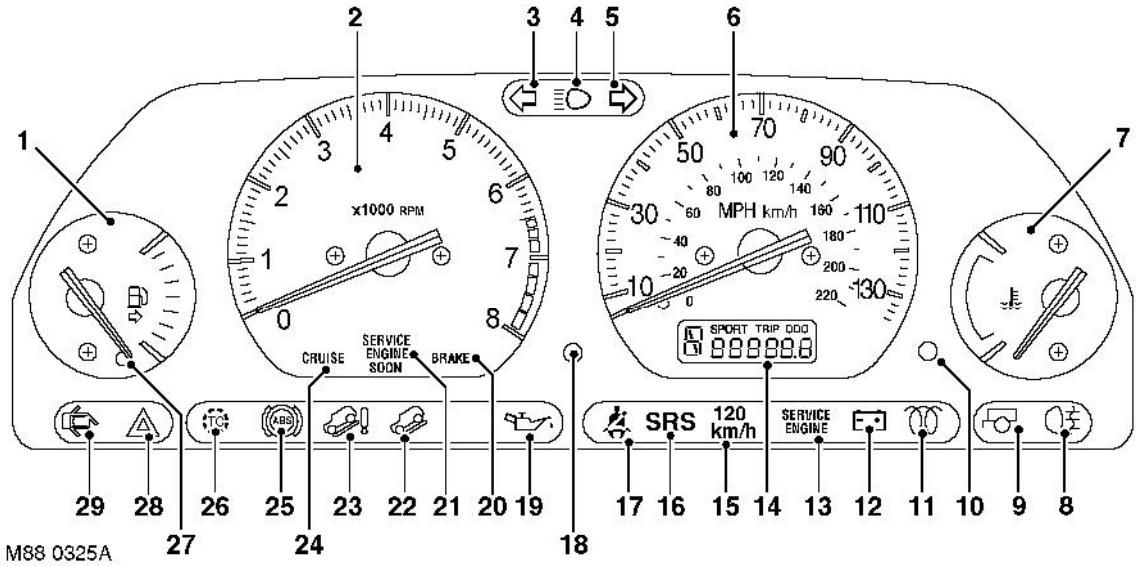
The radio remote switches form a resistance ladder between two wires with the resistance across wires dependent on which switch is pressed. The remote control interface unit monitors the two wires and converts their input into Instrument (I) bus protocol messages, which it outputs on a dedicated serial link to the navigation computer.

Instrument Pack Component Location - Front View (All Markets, Except NAS)



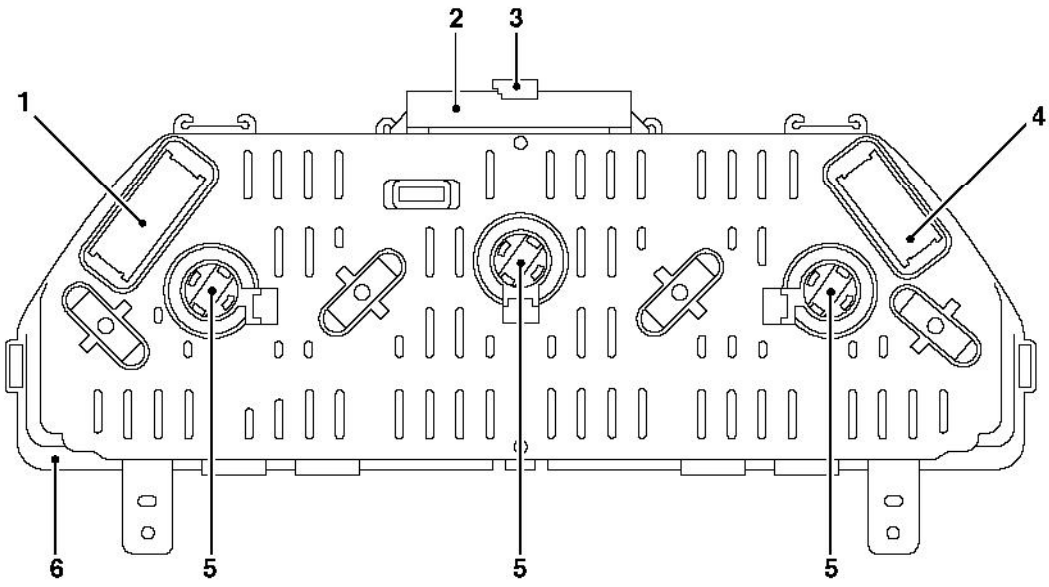
1 Fuel level gauge
2 Tachometer
3 LH direction indicator warning lamp
4 Headlamp main beam warning lamp
5 RH direction indicator warning lamp
6 Speedometer
7 Engine coolant temperature gauge
8 Rear fog lamp warning lamp
9 Trailer direction indicator/hazard failure warning lamp
10 Trip counter reset button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

Instrument Pack Component Location - Front View (NAS Only)



1 Fuel level gauge
2 Tachometer
3 LH direction indicator warning lamp
4 Headlamp main beam warning lamp
5 RH direction indicator warning lamp
6 Speedometer (USA version shown)
7 Engine coolant temperature gauge
8 Rear fog lamp warning lamp
9 Trailer direction indicator/hazard failure warning lamp
10 Trip counter reset button
11 Not used
12 Ignition/No charge warning lamp
13 Engine malfunction warning lamp (Service Engine)
14 Liquid Crystal Display (LCD)
15 Not used
16 Supplementary Restraint System (SRS) warning lamp
17 Not used
18 Alarm LED
19 Low oil pressure warning lamp
20 Handbrake and brake system warning lamp
21 Malfunction Indicator Lamp (MIL) (Service Engine Soon)
22 Hill Descent Control (HDC) active warning lamp
23 HDC failure warning lamp
24 Cruise control active warning lamp (if fitted)
25 Anti-lock Braking System (ABS) warning lamp
26 Traction Control (TC) active warning lamp
27 Low fuel level warning lamp
28 Hazard flasher warning lamp
29 Door open warning lamp

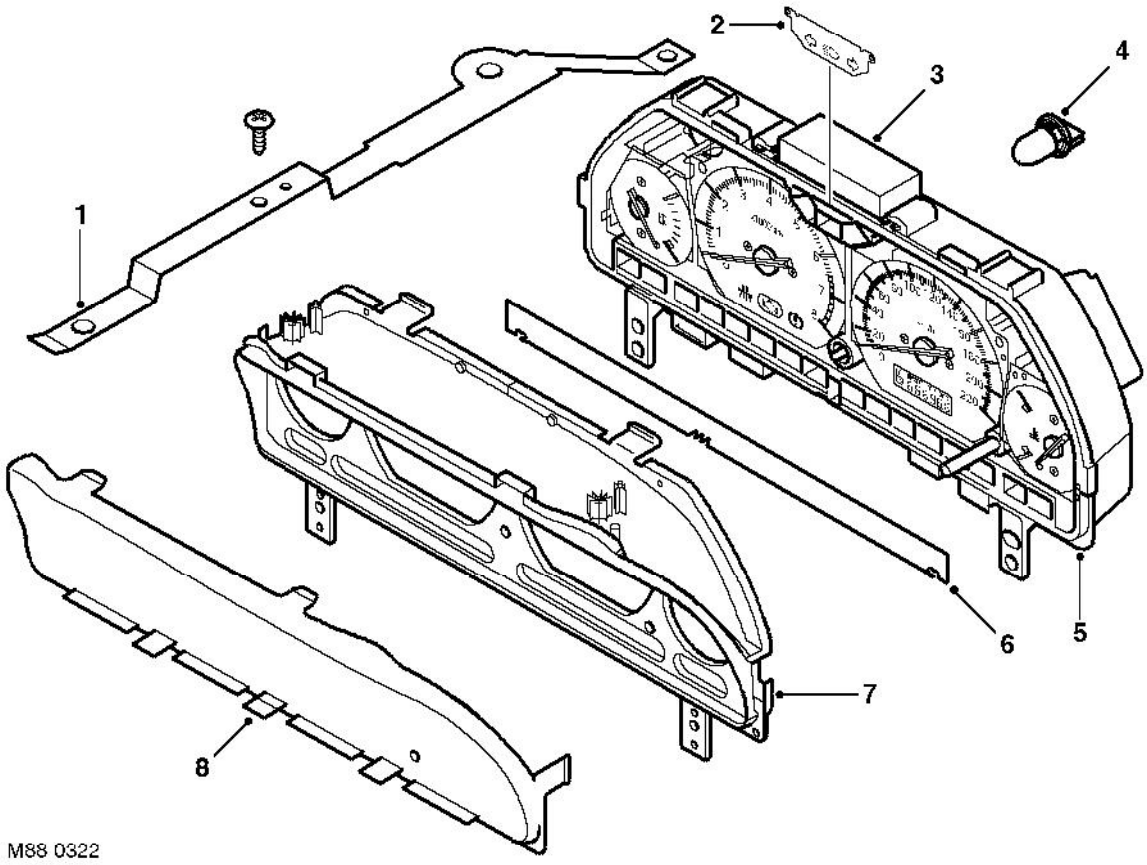
Instrument Pack Component Layout - Rear View



M88 0321

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

Instrument Pack Components - Exploded View



1 Support bracket (2 off)
2 Warning lamp filter
3 RF receiver (Ref. only)
4 Panel illumination bulb (3 off)
5 Instrument pack housing assembly
6 Warning lamp filter
7 Instrument pack face plate
8 Instrument lens

Description

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.

The instrument pack is a totally electronic controlled device receiving electrical signals from sender units and CAN messages from the Engine Control Module (ECM), ABS ECU and the Electronic Automatic Transmission (EAT) ECU and transposing them via a microprocessor 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.

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 contains a non-volatile EEPROM memory which records the vehicle identification number (VIN), engine type and odometer reading. The stored odometer value cannot be changed. The EEPROM is protected by a security code to prevent unauthorised access.

A flash memory stores software and hardware identifiers which are accessible via diagnostics.

The main function of the instrument pack is to provide information to the driver of the vehicle status. 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 (KV6 and Td4 JATCO automatic models 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
- Amber = 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 (Amber) - Diesel models only
- Seat belt (Red) - Selective markets only
- SRS (Red)
- Engine Malfunction Indicator Lamp (MIL) (Amber) - All markets except NAS
- Service Engine Soon (MIL) (Amber) – NAS only
- Anti-lock Braking System (ABS) (Amber)
- Door open (Red)
- Hazard warning (Red)
- Hill descent control information (Green)
- Hill descent control fault (Amber)
- Handbrake and brake system (Red)
- Low oil pressure (Red)
- Ignition/No charge (Red)
- Engine malfunction (Amber) - Diesel models only
- Service Engine (Engine malfunction) (Amber) - NAS only
- Overspeed (Red) - Selective markets only
- Cruise control (Amber) - KV6 and Td4 JATCO automatic models only
- Low fuel level (Amber)
- Trailer lamp failure warning lamp (Red)
- Electronic Traction Control (TC) fault (Amber)
- Rear fog guard lamp (Red)

Operating Modes

The instrument pack will function in seven modes:

- Shut down
- Normal
- Powered/Unpowered
- Diagnostic
- Crank
- Standby normal
- 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 (O). 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.

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 ISO 9141 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.

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.

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.

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 999999 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.

The odometer uses the same CAN messages as the speedometer to calculate the distance travelled. If the CAN message fails, the LCD will display the odometer distance and 'Error' alternately for one second each.

On vehicles with JATCO automatic gearbox, the LCD also displays gearbox status information as shown in the following table:

LCD Character	Description
P	Park
R	Reverse
N	Neutral
D	Drive
Sport	Sport mode
4	Automatic gearbox operation up to 4th ratio
2	Automatic gearbox operation up to 2nd ratio
1	Automatic gearbox operation in 1st gear ratio
1	Manual mode 1st ratio
2	Manual mode 2nd ratio
3	Manual mode 3rd ratio
4	Manual mode 4th ratio
5	Manual mode 5th ratio
F and 4 (Flashing alternately)	Gearbox fault has occurred. Gearbox remains in fourth gear.

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, 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. Refer to the applicable Engine Management System section for ECT location and description.

☞ **ENGINE MANAGEMENT SYSTEM - MEMS, DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**

☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**

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 backlighting 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 backlight illumination colour.

The lamps illuminate when the side lamps or headlamps are switched on. In selected markets the instrument panel, radio and switch illumination is also controlled by an instrument illumination dimmer control.

Warning Lamps

The following warning lamp descriptions cover all model and market variants. Therefore, some warning lamps may not be present on specific models.

Left and Right Hand Indicators
The LH and RH indicator warning lamps flash in time with the exterior direction indicators when they are operated. If either warning lamp flashes very rapidly, this indicates that one of the front or rear exterior indicator bulbs has failed.

When hazard warning lamps are operative, both direction indicator warning lamps flash simultaneously with the exterior indicators.

Headlamp Main Beam
The headlamp main beam warning lamp illuminates when the headlamps are switched to main beam or the headlamp flash is operated.

Glow Plug (Diesel Models Only)
The glow plug warning lamp illuminates when the ignition is switched to position II. The lamp illuminates on a timer from the ECM. The period for which the lamp is illuminated is dependent on engine coolant temperature and the engine should not be started until the lamp has extinguished.

Seat Belt (Selective Markets Only)
The lamp illuminates when the ignition is switched to position II. When the seat belt buckle is secured in the stalk, a switch in the stalk extinguishes the lamp.

SRS
The SRS lamp illuminates for approximately 5 seconds when the ignition is switched to position II for a bulb check. If the lamp remains illuminated or illuminates when the engine is running, the SRS has a fault which must be rectified as soon as possible.

Malfunction Indicator Lamp (MIL) (Service Engine Soon – NAS) – Petrol Engines Only
The MIL illuminates at all times when the ignition is in position II and the engine is not running. If the lamp remains illuminated or illuminates when the engine is running, a fault has occurred in the engine emission control system or an emission related automatic gearbox fault has occurred. Stop the vehicle and switch off the ignition for at least 30 seconds. If the lamp illuminates after the engine is restarted, rectification must be sought as soon as possible to avoid potential engine or gearbox damage and excessive exhaust emissions.

Anti-Lock Braking System (ABS)
The ABS lamp illuminates when the ignition is switched to position II and extinguishes after the engine is started. If the lamp illuminates at any other time, a fault has occurred in the ABS and should be rectified at the earliest opportunity.

Door Open
The lamp illuminates if any side door, the tail door or the bonnet is open and the ignition switch is in position II.

Hazard Warning
The lamp illuminates alternately with the direction indicators and direction indicator warning lamps when the hazard warning switch is operated.

Hill Descent Control Information
The lamp illuminates for approximately 2 seconds when the ignition is switched to position II for a bulb check. The lamp illuminates when the driver selects Hill Descent Control (HDC), to inform the driver that the system is enabled. If the lamp flashes, the system cannot enable HDC due to excessive speed or incorrect gear selection.

Hill Descent Control Fault
The lamp illuminates for approximately 2 seconds when the ignition is switched to position II for a bulb check. The lamp illuminates if a fault is detected within the HDC system, providing the driver with a visible warning. The lamp is illuminated for a short period when the ignition is switched to position II.

Handbrake and Brake System
In some markets, the lamp illuminates for approximately 2 seconds when the ignition is switched to position II for a bulb check. The lamp illuminates when the handbrake is applied. If the lamp illuminates when the handbrake is released, urgent attention is required to the braking system.



Low Oil Pressure
The low oil pressure lamp illuminates at all times when the ignition switch is in position II and the engine is not running. If the lamp remains on, flashes on and off or illuminates at any time when the engine is running, the engine must be stopped at the earliest opportunity or serious engine damage could occur.

Ignition/No Charge
The ignition/no charge lamp illuminates at all times when the ignition switch is in position II and the engine is not running. If the lamp remains illuminated or illuminates when the engine is running, a fault has occurred with the battery charging system and should be rectified at the earliest opportunity. On petrol models the lamp is controlled by an output direct from the alternator. On diesel models the lamp is controlled by the ECM.

Engine Malfunction (Diesel Models Only)
The engine malfunction lamp illuminates for approximately 2 seconds when the ignition is switched to position II for a bulb check. If the lamp remains illuminated or illuminates during driving, an engine management fault has occurred. If the lamp is permanently illuminated, the vehicle may still be driven but rectification of the fault should be sought at the earliest opportunity. If the lamp flashes, the fault must be rectified immediately.

Service Engine (NAS Only)
The service engine warning lamp illuminates for approximately 2 seconds when the ignition is switched to position II for a bulb check. If the lamp remains illuminated or illuminates during driving, an engine management fault has occurred. If the lamp is permanently illuminated, the vehicle may still be driven but rectification of the fault should be sought at the earliest opportunity. If the lamp flashes, the fault must be rectified immediately.

Overspeed Warning (Selected Markets Only)
The overspeed lamp is illuminated for approximately 2 seconds when the ignition is switched to position II for a bulb check. The lamp will only illuminate when the engine is running if the vehicle speed exceeds 120 km/h, and will extinguish when the speed drops below this value.

Cruise Control (If Fitted)
The cruise control lamp illuminates when the cruise control switch in the centre console is selected on and the cruise control is active. The lamp remains illuminated until the cruise control switch is selected off or cruise control is deactivated.

Low Fuel Level
The low fuel level lamp is located in the fuel gauge dial face. The lamp is illuminated for 2 seconds when the ignition is switched to position II for a bulb check. The lamp illuminates when the fuel level drops to approximately 10 litres (2.65 US gallons) on petrol models or 7 litres (1.85 US gallons) on diesel models.

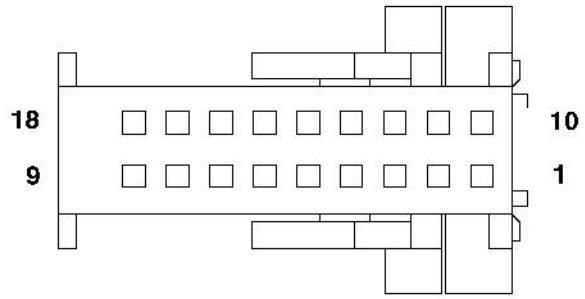
Trailer Lamp Failure
The trailer lamp failure warning lamp illuminates to show failure of one or more of the trailer indicator or tail lamps.

Rear Fog Lamp
The rear fog lamp warning lamp illuminates when the headlamps are switched on and the rear fog lamp switch is operated. The lamp is extinguished when the fog lamp switch is operated to turn off the fog lamps or the headlamps are switched off.

Electronic Traction Control (TC)
The TC warning lamp is illuminated for approximately 4 seconds when the ignition is switched to position II for a bulb check. When traction control is operating, the TC warning lamp will be illuminated for a minimum of 2 seconds or for as long as the traction control system is active. The TC warning lamp also illuminates when the ABS ECU detects a brake system fault which affects traction control. If a fault is detected the lamp will remain permanently illuminated. The vehicle may still be driven but rectification of the fault should be sought at the earliest opportunity.

Instrument Pack Connector Details
The following tables shows the harness connector face views, pin numbers and input/output information for connectors C0230 and C0233.

Connector C0233

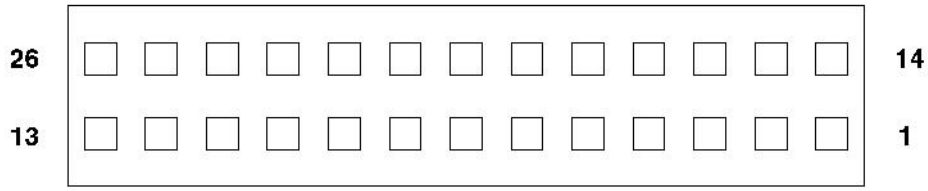


M88 0335

The following table shows pin inputs/outputs for connector C0233.

Pin No.	Description	Input/Output
1	Door open signal	Input
2	Hazard warning lamps active signal	Input
3	Not used	-
4	Brake warning signal	Input
5	Panel illumination –	Output
6	Panel illumination +	Input
7	Earth	Input
8	Ignition switch position II (ignition) signal	Input
9	Ignition switch position III (crank) signal	Input
10	Ignition charge signal	Input
11	SRS warning signal	Input
12	Oil pressure low signal	Input
13	Air Conditioning request signal	Input
14	Reverse switch signal	Input
15	Alarm active signal	Input
16	LH direction indicator active signal	Input
17	Main beam active signal	Input
18	RH direction indicator active signal	Input

Connector C0230



M88 0334

The following table shows pin inputs/outputs for connector C0230.

Pin No.	Description	Input/Output
1	Seat belt warning signal	Input
2	Not used	-
3	Not used	-
4	Engine speed signal	Input (PWM)
5	Cruise active signal	Input (digital)
6	Not used	-
7	1st gear input (manual gearbox only)	Input (digital)
8	A/C pressure sensor (power supply) (diesel and NAS KV6 only)	Output
9	A/C pressure sensor signal (System pressure) (diesel and NAS KV6 only)	Input (analogue)
10	A/C pressure sensor earth (diesel and NAS KV6 only)	Output
11	Diagnostic ISO 9141 K Bus (serial)	Input/Output
12	CAN + (serial)	Input/Output
13	CAN + (serial)	Input/Output
14	Rear fog lamp active signal	Input
15	Trailer lamp failure signal	Input
16	Not used	-
17	Not used	-
18	Not used	-
19	Not used	-
20	A/C evaporator temperature signal (diesel and NAS KV6 only)	Input (analogue)
21	Fuel level sender signal	Input (analogue)
22	Not used	-
23	Permanent battery supply (13.4 V nominal)	Input
24	Earth	Input
25	CAN – (serial)	Input/Output
26	CAN – (serial)	Input/Output

Diagnostics
A diagnostic socket allows the exchange of information between the instrument pack and TestBook or other diagnostic tool. The diagnostic socket is located behind the centre console, in the passenger footwell.

The diagnostic socket is connected to the instrument pack on an ISO 9141 K Line. When the diagnostic mode is accessed the LCD displays 'dIAg, which remains until the diagnostic mode is exited.

The instrument pack stores fault flags which can be retrieved using TestBook or any diagnostic tool using Keyword 2000 protocol.

Each fault stores two flags. The first flag (fault log) indicates that a fault has occurred with that function. This flag can only be removed using a diagnostic tool.

The second flag (active fault) indicates that there is currently a fault with that function. This flag is only active while the fault condition exists. Removal of the fault condition will clear the active fault flag.

Controller Area Network (CAN)
The CAN bus is a high speed broadcast network between the instrument pack, the ECM, the EAT ECU and the ABS ECU, allowing fast exchange of data between the components every few microseconds.

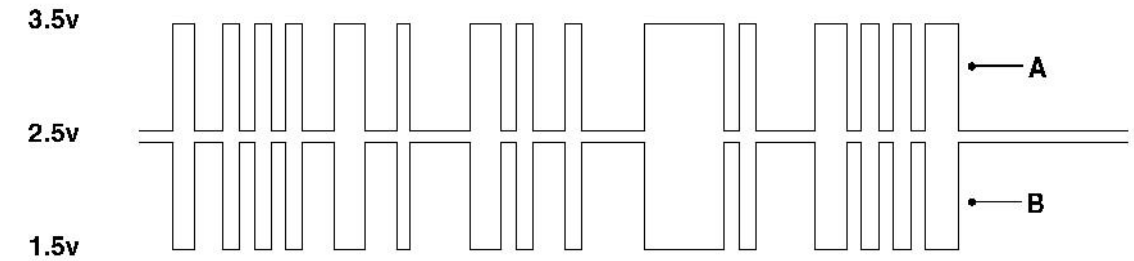
The bus comprises two wires which are identified as CAN Low (L) and CAN High (H). The wires are twisted together to minimise the electromagnetic interference (noise) produced from the CAN messages.

To prevent message errors from electrical reflections, 120Ω resistors are incorporated into the CAN wire terminals of the ECM, ABS ECU, EAT ECU and the instrument pack.

CAN messages consist of a signal which is simultaneously transmitted, in opposite phase, on both wires. CAN L switches between 2.5 and 1.5 volts, while CAN H switches between 2.5 and 3.5 volts. This causes a potential difference between the two lines to switch between 0 volt (logic 1) and 2 volts (logic 0) to produce the digital signal message.

In the event of CAN bus failure, any of the following symptoms may be observed:
- Tachometer, speedometer and temperature gauge will fail to operate
- CAN controlled warning lamps will be inoperative.

CAN Bus Switching



M88 0324

A = CAN High
B = CAN Low



Instrument Pack CAN Messages

The instrument pack acts as a CAN gateway to other CAN controlled functions on the vehicle. The following table lists signals which are routed through the gateway and translated to or from CAN as applicable. For further details about the origins of these messages refer to the relevant section.

☞ **BRAKES, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - EDC, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - MEMS, DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM - SIEMENS (ALL EXCEPT NAS), DESCRIPTION AND OPERATION, Description.**
☞ **ENGINE MANAGEMENT SYSTEM – SIEMENS (NAS), DESCRIPTION AND OPERATION, Description.**
☞ **AUTOMATIC GEARBOX - JATCO, DESCRIPTION AND OPERATION, Description.**

Signal	Source	Destination
Air conditioning on request	Air conditioning switch	ECM
Road speed	ABS ECU	ECM and EAT ECU (Petrol engines only) and instrument pack
Current gear (vehicles with manual gearbox only)	Gearbox switches	ABS ECU
Fuel level (Petrol engines only)	Fuel level sender	ECM and instrument pack
Engine speed (pulse train)	ECM	EWS3D immobilisation ECU and instrument pack
Evaporator temperature	Evaporator temperature sensor	ECM
Air conditioning pressure	Air conditioning pressure sensor	ECM
Electric cooling fan speed (diesel and NAS KV6 engines only)	Air conditioning pressure signal	ECM

CAN Inputs

The following CAN inputs are received by the instrument pack:

Inputs	
Electronic Brake Distribution (EBD)	Engine MIL status
ABS lamp status	Cruise main switch (diesel only)
Traction control lamp status	Engine status
Vehicle speed	Fuel consumption
HDC activity status	Target gear (Automatic gearbox only)
HDC fault status	Selector position (Automatic gearbox only)
Engine speed	Gear shift mode (Automatic gearbox only)
Engine coolant temperature	Gearbox fault status
Glow plug lamp status	

- *Electronic Brake Distribution (EBD):* This signal represents the electronic brake proportioning status. This signal is used to indicate a fault with either the brake proportioning system or low brake lamp fluid and illuminate the brake system warning lamp. The signal is originated from the ABS ECU.
- *ABS Lamp Status:* This signal is used to illuminate the ABS warning lamp when an ABS fault occurs. The ABS system will illuminate the lamp when the engine is not running and extinguish it when the engine starts. Further illumination indicates an ABS fault. The signal is originated from the ABS ECU.
- *Traction Control (TC) Lamp Status:* This signal is used to illuminate the TC warning lamp for a bulb check when the ignition is first switched on and also for when TC is active. The signal is also used to illuminate the TC warning lamp when the ABS ECU detects a fault in the brake system for traction control. The signals are originated from the ABS ECU.
- *Vehicle Speed:* This signal is used to operate the speedometer and the odometer and trip functions. The signal is originated from the ABS ECU.
- *HDC Activity Status:* This signal is used to illuminate the HDC active lamp. The signal informs the instrument pack if the HDC function is enabled or disabled. If the HDC function is disabled, the HDC lamp will flash to indicate that the incorrect gear is selected or the vehicle is travelling at excessive speed for HDC operation. The

signal is originated from the ABS ECU.

- *HDC Fault Status:* This signal is used to illuminate the HDC fault lamp. The signal is a combination of the HDC activity and fault messages and is only illuminated when the ABS system detects a HDC function fault. The signal is originated from the ABS ECU.
- *Engine Speed:* This signal is used to operate the tachometer. The signal is unfiltered with any damping performed by the instrument pack. The ECM also issues an engine speed error signal which is ignored by the instrument pack. Both signals are also used by the EAT ECU to assist shift timing and fluid pressure calculations and by the ABS ECU for traction control. The signal is originated from the ECM .
- *Engine Coolant Temperature:* This signal is used to operate the coolant temperature gauge. The signal is unfiltered with any damping performed by the instrument pack. The signal is also used by the EAT ECU for warm up cycle detection. The signal is originated from the ECM.
- *Glow Plug Lamp Status (Diesel Models Only):* This signal is used to illuminate the glow plug warning lamp. The signal is originated from the Electronic Diesel Control (EDC) ECM, which controls the time period for illumination dependent on engine coolant temperature.
- *Engine MIL Status (Service Engine Soon):* This signal is used to illuminate the MIL. The signal is originated from the ECM if an OBD related engine management fault occurs or on KV6 vehicles from the EAT ECU, via the ECM, if an OBD related gearbox fault occurs. The signal is also used by the EAT ECU to disable OBD fault monitoring in the event of an ECM fault.
- *Cruise Main Switch (Diesel Only):* This signal is used to illuminate the cruise control active warning lamp. The signal is generated when the cruise control switch is selected on. The signal from the switch is received by the cruise control interface unit. When the interface unit also receives a cruise active signal, it produces a hardwired signal to the instrument pack to illuminate the cruise control warning lamp.
- *Engine Status:* This signal is used to illuminate the engine malfunction (service engine) lamp. This lamp is illuminated for non OBD related faults which would not illuminate the MIL. The signal is originated from the ECM.
- *Fuel Consumption:* This signal is used to calculate the service interval announcement in the LCD. The signal is the sum of the volume of injected fuel, calculated from the injection periods minus the valve delay times, and the pitch of the corresponding injector. The injected volumes are calculated as they occur and transmitted on the CAN every 10ms for petrol engines and every 20ms for diesel engines. The signal is originated from the ECM.
- *Target Gear (Automatic Gearbox Only):* This signal is used in conjunction with the selector position signal to display the current gear selection in the LCD. The signal is the actual gear or target gear if gearbox is changing ratios. The signal is also used by the ECM to assist in engine load change prediction. The signal is originated from the EAT ECU.
- *Selector Position (Automatic Gearbox Only):* This signal is used in conjunction with the target gear signal to display the current gear selection in the LCD. The signal represents the actual selected gear position. The signal is also used by the ECM to assist in idle speed control. The signal is originated from the ECM.
- *Gear Shift Mode (Automatic Gearbox Only):* This signal is used to display the currently selected gearshift mode; drive, sport or manual in the LCD. The signal is originated from the EAT ECU.
- *Gearbox Fault Status (Automatic Gearbox Only):* This signal is used to display the status of the EAT ECU. If a gearbox fault occurs the EAT ECU will generate this message to alternately display 'F' and '4' in the LCD and initiate the default strategy for gearbox control.