MGF 2000 MY UPDATE

Technical brochure

11–14–MG-W: Ver 3

MGF product overview

MGF history

When the MGF was launched in 1995 it was seen as a major milestone in the history of MG. After years of neglect the car breathed new life into the brand. Many MG enthusiasts saw it as the end of a long barren period and the fulfilment of a dream.

Marketing goals

The theme of the 2000MY MGF is to deliver increased customer delight by combining the innovative application of technology and enhancing the visual appeal of the product. Incorporating these elements successfully will assist in reinforcing the MGF is position in the sports car sector and further differentiate the MGF from its competitors and other cabriolet products.

The marketing goals for the MGF are:

- Freshen and widen the product appeal
- Maintain competitiveness
- Enhance brand image
- Provide a new incentive for existing customer to re-purchase
- Widen the range of options and accessories to help customers personalise their MGF
- Continue the development of the MG brand

Key product changes

2000MY is the first significant change to MGF since it was launched in 1995. The changes are composed of two main elements, interior styling and the introduction of the Em-CVT gearbox.

The interior changes strengthen the appeal and set it apart from its competitors. The steptronic transmission is a first for this sector which offers not only a fully automatic capability but a six speed manual function controlled by buttons mounted on the steering wheel or by moving the gear lever forwards or backwards (up/down).

The 2000MY MGF has five key product changes. These are:

- The introduction of the steptronic gear box, including the formula 1 style steering wheel controls and a six speed manual mode.
- The introduction of a tilt adjustable steering wheel.
- The introduction of 'one shot down' electric windows and electric adjustable door mirrors.
- A revised interior with a 'jewelled' theme and Revised seat styles.
- An increased range of options.

Interior enhancements

The original MG*F* was designed to build upon the success of the original MG brand and was seen as a contemporary successor to the original MGs. Thus the design of any changes to the interior would be in keeping with and enhancing the current vehicles specification. The 2000MY MG*F* interior has not been re-designed but enhanced to add distinction and set our interiors apart from our competitors.

The overall changes have focused on improving the tactility of the interior. The design teams focus has been to bring the jewelled theme from the exterior (fuel filler cap surround) to the interior. This has been achieved by the use of real bright materials such as used in the fuel filler flap design and adds a level of authenticity.

The seats have been enhanced to include new stitch patterns and new seat foams to create a more sporty look to the seats and a more ergonomic shape to the seat. The VVC and steptronic variants have part leather seats and the base model will have cloth trim as standard

The following section details the main changes made to the interior of the 2000MY MG*F*.

Adjustable steering column

An improvement with 2000MY MG*F* is the inclusion of a rake adjustable steering column as standard on all vehicles (see Figure 1). This steering column gives a +/- 2° (12mm) adjustment from the current MG*F* static position.

Figure 1

The steering wheel is adjusted by releasing the clamping handle on the side of the steering column, positioning the steering wheel and locking the clamping handle.

To minimise the adjustment loads the mass of the steering wheel is compensated for by the use of a return spring.

Quality issues

Some MGF owners have complained of a smell of fuel in the vehicle. To improve this situation a dual walled petrol tank is now being fitted.

With the introduction of the Em-CVT transmission a new exhaust down pipe will be introduced.

In line with other group products ’angel hair’ is being introduced on the MGF. Angel hair is used as the material layer which sits between the cushion foam and the Pullmaflex (the suspension part of the seat) and is very similar in appearance to a sheet of fibreglass.

Some overseas customers have experienced problems with the vehicles battery going flat while in transit to deep sea ports. The resolution of this is the inclusion of an electronic transit isolator switch which cuts the power supply from the battery to all but the essential components. This switch is removed at Port Of Entry and returned to the Supplier for recycling.

Audio

Although the original audio units fitted to the MGF were of excellent quality it became obvious that a great deal of after market units were being fitted to the vehicle.

The existing four speaker system has been replaced with an improved six speaker system. The twin coaxial door speakers have been replaced by a dedicated bass unit in the original speaker position and a tweeter unit mounted higher up the door panel (see Figure 2). This provides a more conventional hi-fi configuration and gives an improved overall frequency response.

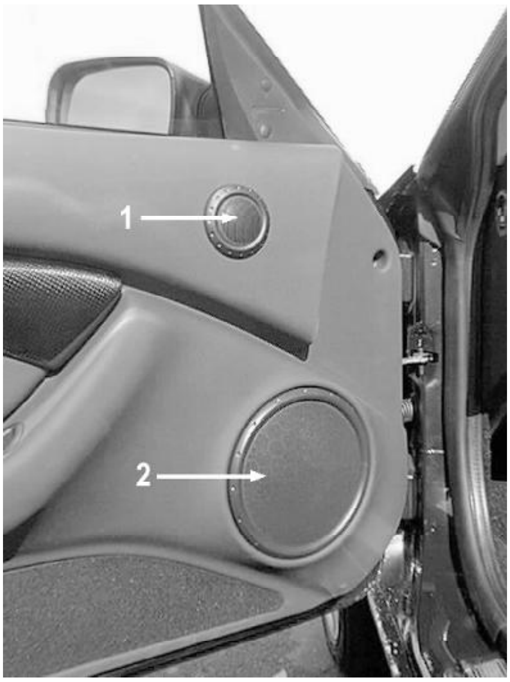

Figure 2

1.Tweeter
2.Bass unit

In addition to the improvements in the door speakers there is a speaker enclosure directly behind the drivers and passengers heads (see Figure 3). This specially developed speaker enclosure contains two 6 x 4 inch elliptical Inductive Coupling technology (ICT) speakers. The enclosure is tuned to resonate at the lower bandwidth frequencies of the drive unit to provide optimum bass performance.

Figure 3

Electric adjustable door mirrors and electric windows

The electric door mirrors are now a standard fitting and provide an easier and safer adjustment of both the door mirrors. The electric door mirror controls are located on the facia adjacent to the instrument illumination rheostat (see Figure 4).

Figure 4

The introduction of a 'one shot down' function to the electric windows will also enhance the driver appeal of the vehicle. The window switches are located in the centre console at either side of the switch bank (see Figure 5).

Figure 5

1.Electric window 'one shot down'

Cubby boxes, cup holders and stowage tray

The existing cubby boxes and cup holders were criticised for their shut quality (some opening in transit) and the size of the recesses for the cup holders. 2000MY MGF addresses the cubby box problems by new tooling in thew manufacturing process to improve the quality of the components fit. The components are also foam filled to improve the shut quality and the opening in transit problem.

The cup holders have also been re-designed to cater for the leather covering and they are now recessed further into the box to improve the holding of the cups. The cup holders also now cater for specific Japanese size cups and cans.

A new style stowage tray has been recessed into the base of the centre console in front of the gear lever to replace the flip down tray in the middle of the centre console. The stowage tray has an integrated rubber traction mat to aid the stability of articles stored.

Trim details

The use of these materials can be seen in the gear knob which uses a real alloy finish with an etched design to mirror the exterior 'jewellery'. Other alloy features include the gearshift surround, new silver dials and silver HEVAC controls. The speakers also get the jewel treatment with the inclusion of intricate detailing on the fret surrounds. The doors get an optional casing insert to match the facia finish, (see Figure 6) if no door casing finisher is selected as an option a bright insert is fitted as standard. To complete the door the current bright door release is carried over to 2000MY MGF. There are two optional facia and door casings which are wood and carbon fibre.

Door casing

Figure 6

Instrumentation

The current speedometer and odometer are mechanically driven by a cable from the gearbox. The speedometer and odometer fitted to 2000MY MGF use an electronic movement which is fed a signal from a transducer mounted on the gearbox. The odometer uses an LCD (liquid crystal display) to display the odometer and trip readings in the from of a digital read out. Because of the electronic read out the unit is tamper proof.

To support the new Em-CVT part of the odometer LCD has an auto gear display. This displays the current state of the gear selector. If the lever is in P, R, N or D the LCD will display the corresponding letter (P, R, N, D). When Sport mode is selected the display will show D together with a SPORT legend. In the manual sport mode the display will show 1, 2, 3, 4, 5, or 6 according to the engaged gear ratio.

The MGF speedo tachometer fuel and temperature gauges have a metallic silver finish. This has been done to refresh the dials to match the latest trends and fashions within the motor industry.

Exterior enhancements

The basic design of the exterior has not been altered for 2000MY MG***F***. The vehicle was designed to stand the test of time and was deliberately designed not to be a radical design including classic elements.

Exterior improvements have been directed to the inclusion of detail enhancements and accessories.

Some of the detail enhancements include chrome grills covering the air intakes and this is followed through with chrome inserts on the door handles.

Other enhancements include standard alloy wheels (see Figure 7) and an increased range of optional alloy wheels (see Figure 8 & 9).

Standard alloy wheels 16" square spoke

Figure 7

15" square spoke design alloy wheels

Figure 8

Six spoke alloy wheel

Figure 9

Other options and their availability are shown in the following table.

Option availability	1.8i	1.8i Steptronic	1.8i VVC
air conditioning	optional-Std Japan	optional-Std Japan	optional-Std Japan
passenger air bag	optional-Std Australia	optional-Std Australia	optional-Std Australia
hard top	optional	optional	optional
wooden steering wheel	optional	optional	optional
single CD player	optional	optional	optional - Std UK
Chrome pack	optional	optional	optional
paint (two solid, three metallic, four pearlescent)	optional	optional	optional
wood centre console	optional	optional	optional
wooden door casing inserts			
carbon fibre pack (door casing)	optional	optional	optional
leather pack (five colourways)	optional	optional	optional
oxford leather (two premium colourways)	optional	optional	optional
Centre high mounted stop lamp (CHMSL)	optional Std-Japan, Australia	optional Std-Japan, UK, Australia	optional Std-Japan, UK, Australia
16" alloy wheels (three styles) (16" square spoke will be standard fit)	optional	optional	optional
Anti lock brakes	optional Std-Australia	Std	Std

ABS

ABS brakes are standard on VVC models and optional on 1.8i models in the UK market. The current ABS5 system has been improved by Bosch and will be replaced on MGF 2000MY with ABS5.3. The benefits of the new system will be seen in both weight and cost savings.

Security

The MGF already has an impressive list of security features as standard such as volumetric and peremetric alarms and passive immobilisation, all of which are Thatcham approved. An improvement introduced for MGF 2000MY is ’friendly’ immobilisation. On MGF pre 2000MY the immobilisation is set by

1. Turning the ignition off
2. Opening the drivers door
3. 30 seconds later the immobilisers will set
4. Alternatively the immobiliser will always set when the car is locked and the alarm is armed

This method of immobilisation is called 'passive arming'. The main concern with this method of arming is that the immobiliser would set itself when the vehicle was being fuelled etc. this causes customer annoyance when they have to re-start the vehicle, when they would have to operate the remote transmitter to turn the immobilisation off. With MGF 2000MY the re-mobilisation is done by the following process

1. Assume the immobiliser is set
2. The security controller ECU detects the ignition is being turned on
3. It then uses an energiser coil to produce a magnetic field around the steering column area
4. A small receiver component in the remote transmitter handset detects the magnetic field and causes the remote transmitter to produce a re-mobilise engine message, which is transmitted in the normal way.

This signal is subtly different to the usual unlock message but the process for the whole system is the same.

Advantages of electronic power steering

The MGF, since launch, has been available with electronic power assisted steering. It has been optional on K1.8 vehicles but comes as standard on vehicles fitted with the VVC engine.

Electronic power steering is a system which provides the driver with positive assistance when turning the steering wheel. It is tuned to provide a greater assistance at lower vehicle speeds. Unlike conventional power steering this system has no hydraulic components, the system is entirely electrical in nature using an electric motor to provide the assistance.

The advantages for a mid engine vehicle of having electronic power steering are:

- No lengthy 'plumbing' of hydraulic pipes from the engine to the steering rack
- Compact design with the system being entirely located at the foot of the steering column
- A reduction in the operational noise of the steering system
- Low maintenance costs, no serviceable items
- Increased fuel economy (no need for the engine to drive a pump all the time)
- Improved control over emissions (no sudden movements of the steering unexpectedly loading the engine)
- The ability to fine tune the performance of the steering (by engineering only, not adjustable by TestBook)
- Provide the driver with a very positive 'feel' of the road conditions

Since the launch of the MGF, the EPAS system has albeit remained the same, now for the 2000MY a new system has been introduced known as electronic power assisted steering II (EPAS II).

This new system operates the same as EPAS I, but has slightly different mechanical components (including an adjustable steering column), sensing configuration, a more powerful motor and a new ECU (see Figure 10). The new ECU has improved algorithms, thus allowing engineers more control to optomise the 'feel' of the steering.

Steering column

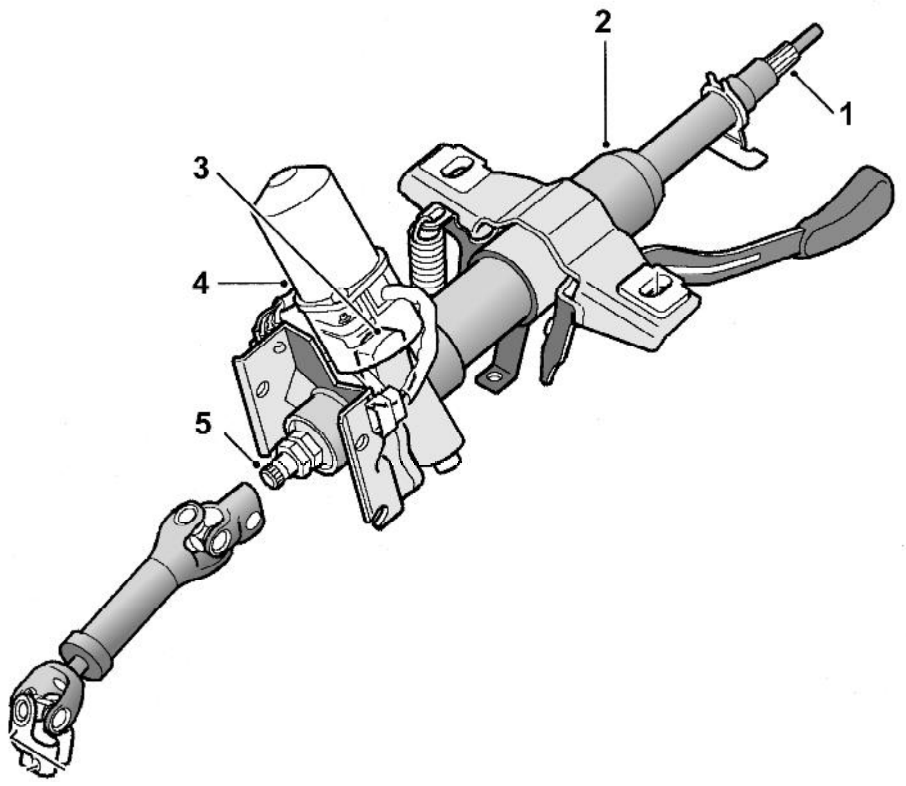

Figure 10

1.Steering wheel spline
2.Steering column
3.Gear assembly
4.Motor and clutch
5.Steering column output spline

The ECU now provides the following added features;

- A algorithm to overcome steering system friction (the force needed to overcome the initial movement of an object and then progressively move that object to its desired position)
- A algorithm to provide a damping effect on severe aggressive steering manoeuvres when the vehicle is travelling at speed
- A algorithm to compensate for the mechanical inertia of the system, thus improving the 'feel' and response under rapid manoeuvres

All these advantages are designed to improve the 'feel' of the steering to the driver rather than to provide a more powerful power steering system, or a radical change in the way power assistance is achieved.

System components

The EPAS II system consists of the following units and system inputs/outputs:

- EPAS II ECU
- Steering column unit
- Road speed input
- Engine speed input
- Ignition switch status
- Permanent power supply
- Warning lamp

The following section will briefly explain each of the above items.

Electronic power assisted steering electronic control unit

The EPAS II ECU is located on the bulkhead, just above the glovebox. The EPAS II ECU controls three items, the steering motor, steering motor clutch and the EPAS warning lamp. The EPAS ECU has diagnostic capability which is accessed through TestBook.

The EPAS II ECU has two connectors (see Figure 11).

Electronic power steering control unit

Figure 11

Steering column

The steering column is the unit that contains the gearing, motor and feedback potentiometer. The motor has been up-rated to provide more torque (if needed). The motor is controlled by the EPAS II ECU via a pulse width modulated (PWM) signal. In the straight-ahead position the EPAS II ECU provides a low current base voltage to both sides of the motor of $\approx$ 1.0 volts (see Figure 12).

Motor supply straight-ahead position

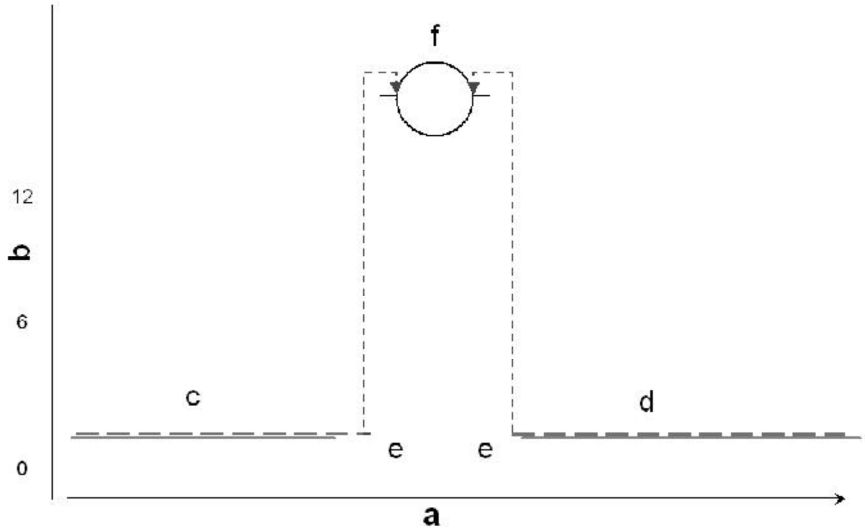

Figure 12

a.Time
b.Voltage
c.Supply to right side of motor
d.Supply to left side of motor
e.Average current
f.Motor

When the system is providing full assistance, there is a potential difference of ≈ 1.0 volt to one side of the motor and a duty cycle of ≈ 90% (average of 90% battery voltage) provided to the other side (see Figure 13). This will drive the motor with maximum power. This system of control can be said to be equivalent to a current control system, as the amount of work done by the motor will effectively be controlled by how much current is allowed to flow at a constant rate by the 'on'/'off' duty cycle.

Motor supply turning

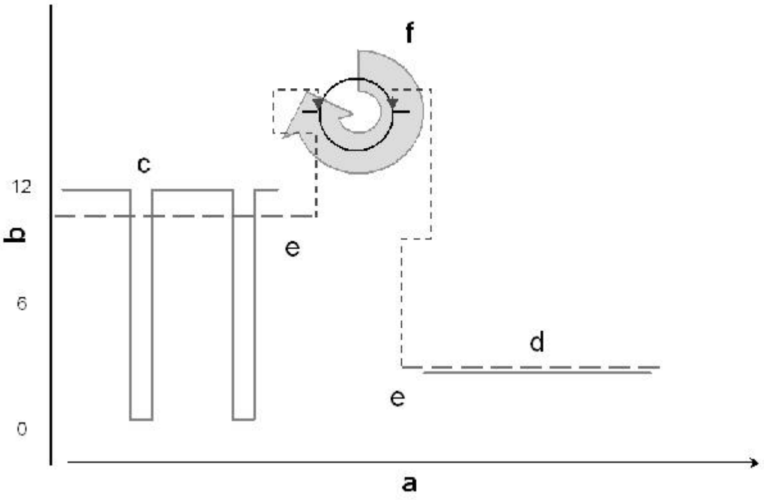

Figure 13

a.Time
b.Voltage
c.Supply to right side of motor
d.Supply to left side of motor
e.Average current
f.Motor

The EPAS ECU has several checks which it makes on the motor to ensure that the system is operating correctly. These checks are:

- If the measured current to the motor is >33 Amps
- If the measured current is >6 Amps over the programmed target current
- If the measured current is <2 Amps with the desired current exceeding 4 Amps
- If the measured voltage is >8.5 Volts or is <0.2 Volts for more than 0.5 seconds on both sides of the motor

If any of these above parameters are exceeded, the EPAS system will switch 'off' and will not try to operate until the ignition is switched to the 'off' position and then back to the 'on' position. The relevant fault code will also be stored.

The motor is not directly connected with the steering shaft. Assistance can only be given if a clutch is activated which connects the motor to the worm drive gears (see Figure 14). This clutch acts as a fail-safe system. If the EPAS ECU detects a fault, the clutch is disengaged and the vehicles steering reverts to total manual control.

The motor, gearing and clutch are all integral parts of the steering column and as such are not replaceable separately.

The steering shaft housing also contains a high specification potentiometer (see Figure 14). This potentiometer has a twin track, but unlike EPAS I it has a common power supply and path to ground. This gives a total of four wires, not as the previous systems six wires. It is possible that the harness may contain six wires, if this is the case two of them are ignored by the EPAS II ECU.

Sectioned steering column

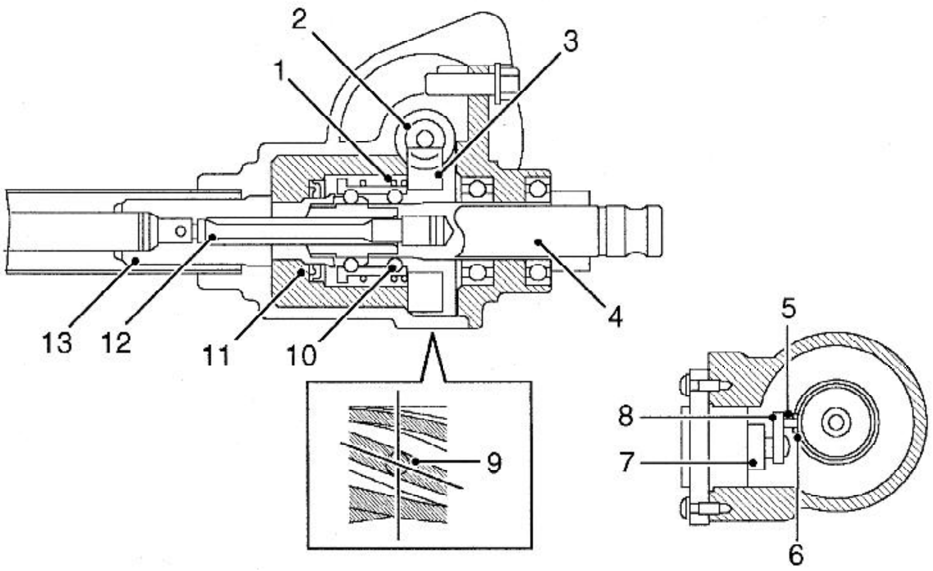

Figure 14

1.Spring
2.Worm gear
3.Worm wheel
4.Output shaft
5.Ball bearing
6.Pin
7.Rotary potentiometer
8.Lever pin
9.Ball
10.Ball
11.Slider
12.Torsion bar
13.Input shaft

The potentiometer return ≈ 2.5 volts in the straight-ahead position, the main potentiometer return will increase its value as the steering is turned in a clockwise direction. The sub potentiometer also returns ≈ 2.5 Volts but will decrease its value as the steering is turned in a clockwise direction. The EPAS ECU monitors the signal for integrity, if either signal exceeds 94% of the supplied voltage or less than 10%, the EPAS ECU will stop providing assistance and store a fault code.

The potentiometer is not replaceable and is set to the correct position at the time of manufacture. It is very important that the position of this sensor is not disturbed, if the potentiometer does not feedback the straight-ahead position because of a mechanical fault, the driver will always need to correct the steering of the vehicle. It should be noted that a vehicles steering may pull to one side because of various mechanical maladjustment's or failures. It is more likely that one of these conditions will cause a problem with the steering than a fault with the potentiometer. The EPAS ECU monitors the potentiometers and knows which way it is driving the motor. If there is a torque input signal in excess of 4.4 Nm in a direction which is opposes the direction the motor is driving the steering column, the system will switch 'off' and a fault code will be stored.

The potentiometer is moved by the driver applying a force to the steering wheel. This force twists a torsion bar which in turn moves a spindle up or down dependant upon the direction of turn. This movement alters the position of the potentiometer as thus informs the EPAS ECU of the amount of effort the driver is exerting on the steering wheel.

Road speed input

The road speed signal originates from a road speed transducer located on the gearbox, regardless of whether the vehicle is fitted with an ABS system or not. The transducer produces a square wave signal in a range of 1 - 12 Volts. It provides approximately 4000 pulses for every mile travelled.

The EPAS II system will give more assistance as the driver applies more ’force’ to the steering wheel, the level of assistance will be reduced as the vehicle speed increases. The changes in assistance for both driver applied torque (measured by the potentiometer), and vehicle speed (from road speed transducer), are predetermined by the ECU.

The EPAS ECU will store a fault code if the vehicle speed is 0 km/h and the engine speed exceeds 4000 rpm for a time period in excess of 20 seconds. The engine speed threshold to record this fault reduces after a period of 5 minutes to 2500 rpm. It should be noted that if the EPAS ECU does not receive a road speed signal, the system will provide assistance as though the vehicle is stationary. It will continue to do this until the above criteria has being satisfied, at this moment the EPAS ECU will store a fault and revert to minimal assistance strategy.

The EPAS ECU will start to provide assistance again even if the above parameters have been exceeded after it monitors a vehicle speed signal that indicates a vehicle speed in excess of 5 km/h or the ECU experiences a ignition ’off’ - ’on’ cycle.

Engine speed input

The engine speed input is provided by one of three engine management systems (EMS) used by the different derivatives. The speed signal is a square wave 1- 12 Volts with the equivalent of two pulses per engine revolution.

The EPAS ECU will only provide assistance if the engine speed is greater than 225 rpm. The EPAS ECU will store a fault if the vehicle speed is in excess of 50 km/h for a period of 20 seconds and the engine speed is below 225 rpm.

The EPAS ECU will restore assistance if the above condition has been recorded when it monitors an engine speed in excess of 375 rpm or the ECU experiences a ignition ’off’ - ’on’ cycle.

Ignition switch status

The EPAS ECU receives two power supplies.

1. A permanent battery supply (40 Amp max.)
2. An ignition dependant supply provided by fuse 1 in the passenger compartment fusebox

The ignition power supply is used as a signal to indicate when the ignition is ’on’. The EPAS ECU monitors the battery voltage and if it goes above 17.5 Volts or below 8.5 Volts the EPAS ECU will store a fault code and stop giving assistance. The EPAS ECU will resume operation after the battery voltage has fallen below 17.5 Volts or has risen above 9.5 Volts or the ECU experiences an ignition ’off’ - ’on’ cycle.

Warning light emitting diode

The EPAS ECU controls the EPAS warning light emitting diode (LED) located in the instrument pack of the vehicle. It will illuminate the light until the EPAS ECU receives an engine speed signal. It should be noted that the EPAS ECU supplies 12 volts to switch the light **’off’** and a path to ground to illuminate the light. The instrument pack requires a path to ground for the warning LED to extinguish. If the EPAS ECU is unplugged the warning lamp will extinguish, as the wire will become open circuit, and the path to ground will be broken.

Fault handling

The EPAS ECU as explained throughout this subject has many diagnostic routines to ensure the safe efficient operation of the system. The ECU will store a fault code and keeps the fault code in its memory until it has cycled through 60 ignition ’off’ - ignition ’on’ cycles without sensing the fault again.

The EPAS ECU has three possible actions which it can affect when it senses a fault. It can:

1. Switch off the steering motor
2. Switch off the steering motor clutch
3. Illuminate the LED

When a fault is detected, the EPAS ECU always switches off the motor and motor clutch when a fault is detected, with the exception of a road speed input fault or engine speed signal fault. In both these cases the amount of assistance is reduced because of the default values assumed. These two fault codes are also the only two that will allow a resumption of operation without the ECU experiencing an ignition ’off’ - ignition ’on’ cycle. The EPAS LED will be illuminated on all but two faults, a vehicle speed failure and battery voltage too high failure.

Pin-out details

The following tables list the pins-out of the connector C0317.

Connector C0317

Pin No.	Function	Expected value, normal operation
1	Battery supply	Battery voltage
2	Motor + (right turn)	With no steering input ≈ 1 volts average, requires an oscilloscope to view PWM signal
3	Power ground	0 Volts
4	Motor + (left turn)	With no steering input ≈ 1 volts average, requires an oscilloscope to view PWM signal

Pin-out details

The following tables list the pins-out of the connector C0316.

Connector C0316

Pin No.	Function	Expected value, normal operation
1	Clutch ground	0 Volts
2	Warning lamp	LED 'off' ≈ 12 Volts, LED 'on' ≈ 1 Volt
3	Unused	Not connected
4	Torque sensor ground	0 Volts
5	Torque sensor main	2.5 Volts (no steering input), range between 1 - 4 Volts
6	Torque sensor supply	5 Volts
7	Road speed input	1 - 12 Volts square wave
8	Ignition sense input	≈ 12 volts
9	Clutch supply	≈ 12 volts
10	Unused	Not connected
11	Unused	Not connected
12	Unused	Possibly connected but not used
13	Torque sensor supplementary	2.5 Volts (no steering input), range between 1 - 4 Volts
14	Unused	Possibly connected but not used
15	Engine speed input	1 - 12 Volts square wave
16	Diagnostic connector	Standard diagnostic bus line (varying voltage)

Introduction to continuously variable transmission

The origins of the continuously variable transmission (CVT) dates back to 1974 with, at that time, a revolutionary rubber drive belt. After several years of development, a new generation of continuously variable transmission has evolved, incorporating the use of steel drive belts.

The stepless shifting pattern of the transmission, provides a very comfortable drive, as well as having full vehicle performance, available at any time (see Figure 15).

Continuously variable transmission

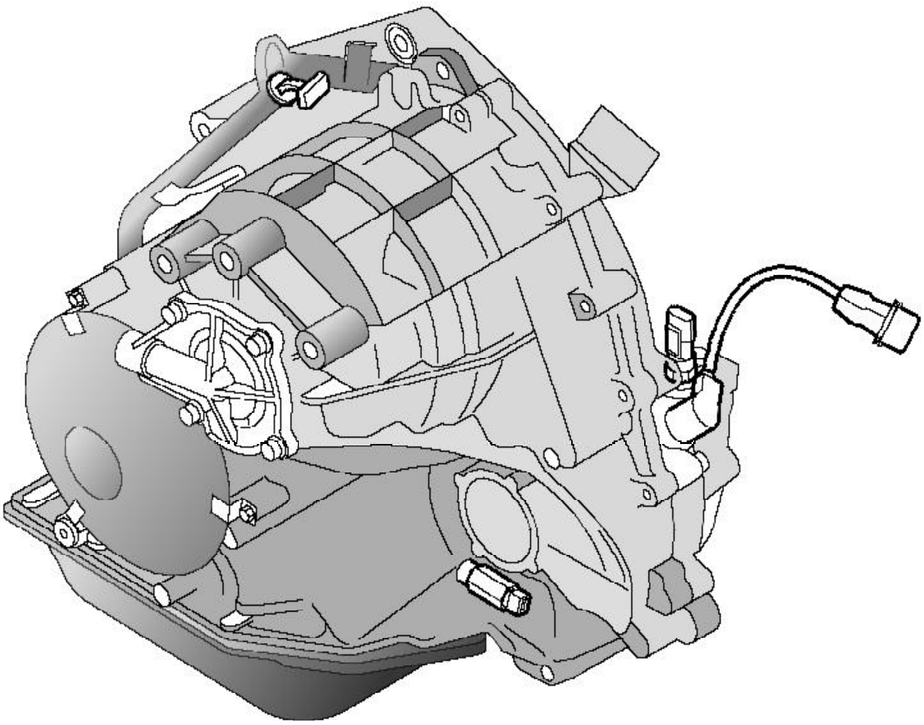

Figure 15

The advantages of using a gearbox of this type are:

- Low engine revolutions at constant speeds
- Improved emission control
- Low noise, vibration and harshness levels
- Smooth acceleration
- Flexible mountain driving

An Electro mechanical-continuously variable transmission (Em-CVT) is fitted to the MGF K-series 1.8i. The engine is connected to the input shaft in the gearbox, via a torsional damper, instead of the torque converter from the more conventional automatic transmission.

There is a five position selector lever to cope with all possible driving conditions (park/reverse/neutral/drive and sport) (see Figure 16).

Selector lever

Figure 16

To obtain 'sporty' performance, the driver can change from 'drive' to 'sport' even when the car is on the move. Top speed can be obtained in 'drive' or 'sport' but the engine must be started in 'neutral' or 'park', as with any automatic transmission. The operation of the gearbox during driving has no comparison with that of conventional automatic transmission. If the accelerator pedal is depressed sharply, the engine rpm will rise considerably more than in relation to the speed of the car! This, therefore, gives the sensation that something is slipping inside the gearbox. Driver education is of utmost importance.

Basic principles of continuously variable transmission

Unlike conventional planetary automatic gearboxes that provide a limited number of gear ratios, usually three, four or five, the continuously variable transmission, as its name suggests, continuously varies the gear ratio. A low gear (low ratio) makes it easier to pull away from a rest position, the drive gear being relatively small, while the driven gear is large by comparison (see Figure 17).

Low ratio (pulling away)

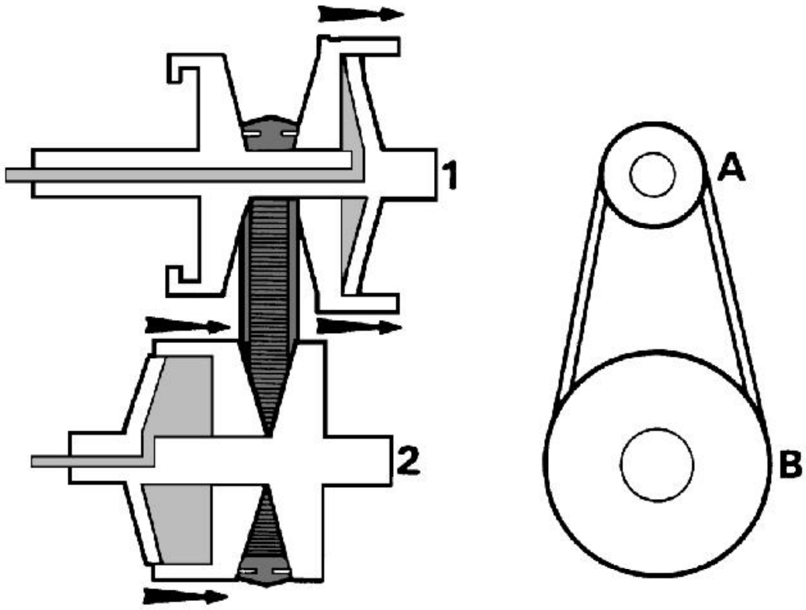

Figure 17

a.Drive gear at the start of acceleration (pulling away)
b.Driven gear at the start of acceleration (pulling away)
1.Input from the engine
2.Output to the wheels

The belt is used to transmit power and torque. As acceleration takes place it becomes possible to select a higher ratio by increasing the diameter of the drive gear while at the same time decreasing the size of the driven gear. This degree of change can be controlled to ensure that the most suitable ratio is provided.

If acceleration continues to take place, further ’up’ changes may be made until the drive gear diameter is as large as possible and the driven gear diameter is as small as possible. Therefore, for every revolution of the drive gear the driven gear revolves several times (see Figure 18).

High ratio (overdrive)

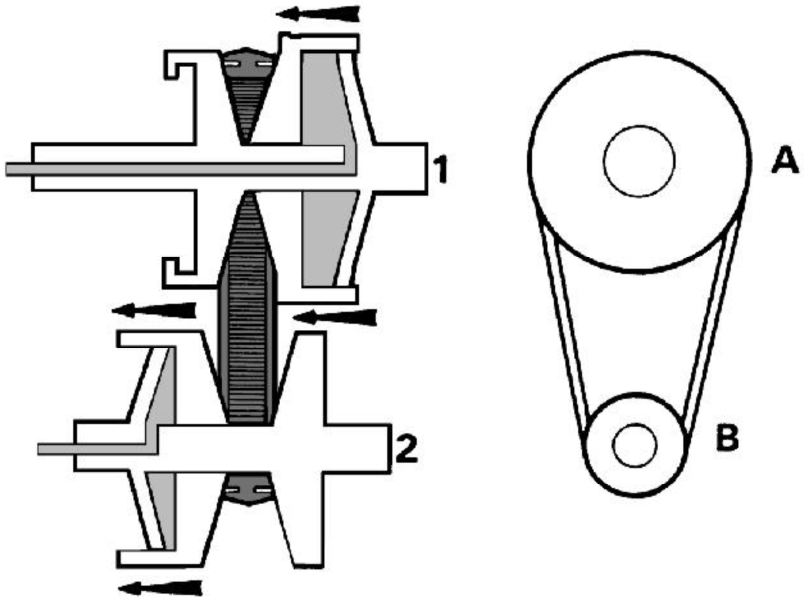

Figure 18

a.Drive gear at maximum (overdrive)
b.Driven gear at maximum (overdrive)
1.Input from the engine
2.Output to the wheels

The CVT uses a primary pulley instead of a drive gear and a secondary pulley replaces the driven gear. Both pulleys have one fixed half and one mobile half controlled by hydraulic pressures. The position of the belt on the pulleys will determine the ratio. If the mobile half of the pulley is close to its opposite half then the belt is forced to travel around the outer circumference. Whereas if the pulley is open wide then this circumference is reduced. The primary and secondary pulley mobile halves are diagonally opposed so when the belt diameter is reduced on the primary pulley, it increases on the secondary pulley.

As with a bicycle, to pull away, a low ratio is required. To provide this, the primary pulley is open, allowing the belt to sit down into the pulley and forcing it to run around the outer of the closed secondary pulley.

As vehicle speed increases, a higher gear ratio is required. To do this, the primary pulley gradually moves towards its fixed partner, increasing the pulley circumference. At the same time the secondary pulley is forced apart reducing pulley diameter, therefore creating a higher gear ratio. An overdrive ratio is obtained when the primary pulley is fully closed and the secondary pulley is fully open. The secondary pulley is now forced to rotate approximately two and a half times for every turn of the primary pulley.

Selector lever in the park or neutral position

In this condition motion is not transferred to the wheels as both clutches for reverse (2) and forward gears (4) are disengaged (see Figure 19).

- The gearbox input shaft (1) turns at the same speed as the engine
- The reverse gear clutch (2) is disengaged
- The forward gear clutch (4) is disengaged
- The planetary gears (3) idle around the sun gear
- As the sun gear does not move, neither does the primary pulley (5), the secondary pulley (7) and, subsequently, the vehicle

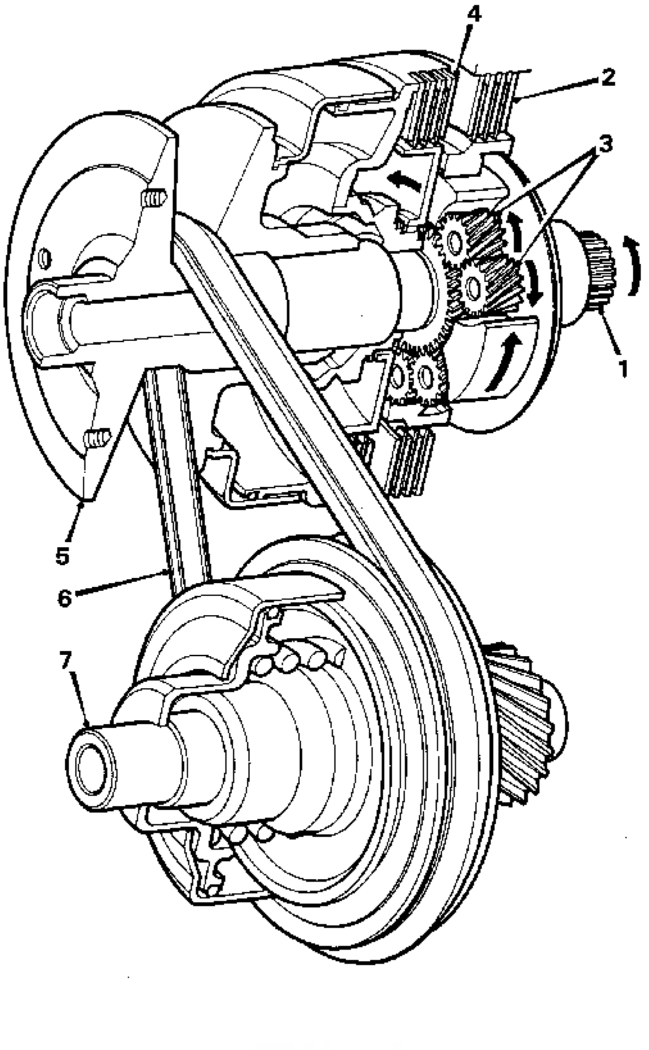

Figure 19

Selector lever in the drive position

Under these conditions, the epicyclic set of gears, the planetary gears (3), the sun gear and the outer ring gear are held by the forward clutch (4) which is engaged (see Figure 20).

Therefore, the gearbox input shaft (1) is directly connected to the primary pulley (5), which will turn in the same direction and at the same speed as the engine, namely in a forward gear.

- The gearbox input shaft (1) turns at the same speed as the engine
- The reverse clutch (2) is disengaged
- The forward clutch (4) is engaged
- The planetary gears (3) the sun gear and the annular ring gear of the epicyclic train will rotate together
- The primary pulley (5) turns at the same speed as the engine in the forward gear direction
- The secondary pulley (7) turns in the forward gear direction at a speed which depends upon the belt ratio for that operating condition

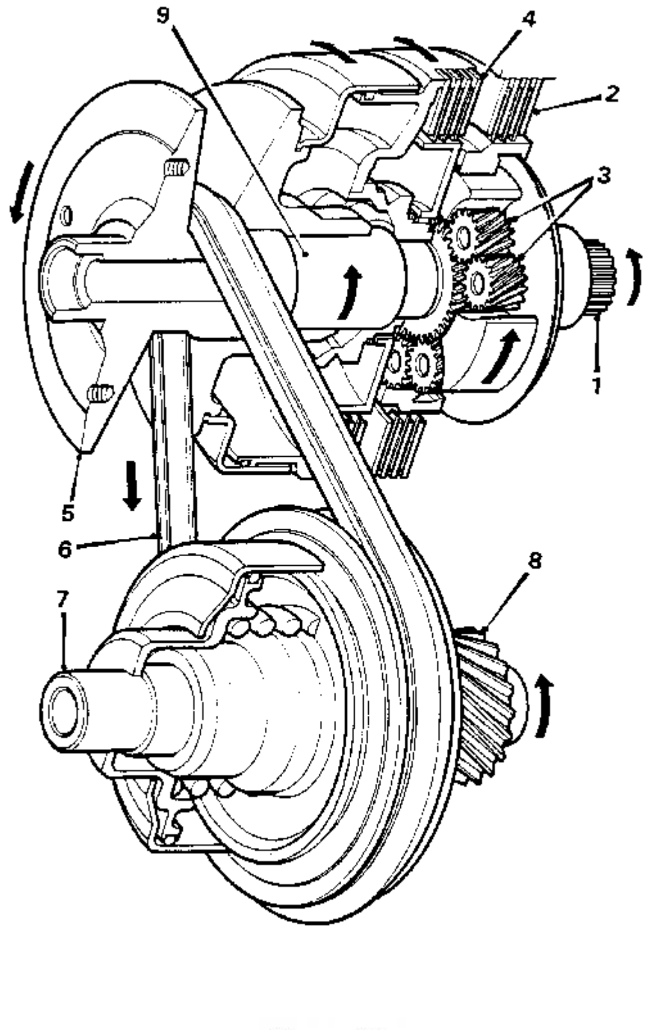

Figure 20

Selector lever in the reverse position

Under this condition, the reverse clutch (2) is engaged and makes the annular ring gear (9) lock with the epicyclic gear train of the gearbox. The planetary gears (3) force the sun gear (10), the primary pulley (5) and the secondary pulley (7) to turn in the opposite direction to the gearbox input shaft (1). Therefore reverse gear is now obtained (see Figure 21).

- The gearbox input shaft (1) turns at the same speed as the engine
- The reverse clutch (2) is engaged
- The forward clutch (4) is disengaged
- The annular gear (9) is held stationary with the gearbox by means of the reverse clutch (2)
- The planetary gears (3), which are driven directly by the gearbox input shaft (1), turn around the annular gear (9). Therefore they force the sun gear (10), the pulley (5) and the secondary pulley (7) to turn in the reverse gear direction

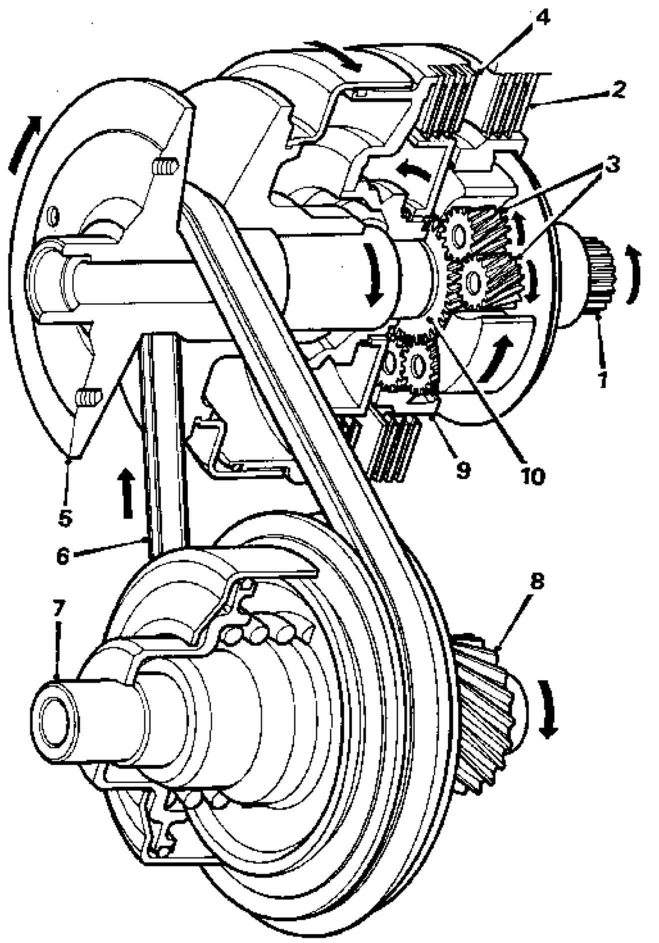

Figure 21

Electro mechanical-continuously variable transmission

The Em-CVT is based on a standard CVT unit with electronic components fitted to control the gear ratio. This gives the driver a choice between an automatic gearbox and a semi-automatic steptronic manual gearbox.

The gearbox can be operated as a conventional CVT unit by selecting park/reverse/neutral or drive with the selector lever. Moving the selector lever across the gate trips a microswitch and puts the gearbox into sport mode.

In sport mode, the gearbox still operates as a conventional CVT unit, but becomes more responsive to changes in driver demands. Engine speed is higher in this mode which improves acceleration. If required, manual gear changes can be performed sequentially using either the selector lever or the steering wheel switches (see Figure 22).

Steering wheel switch

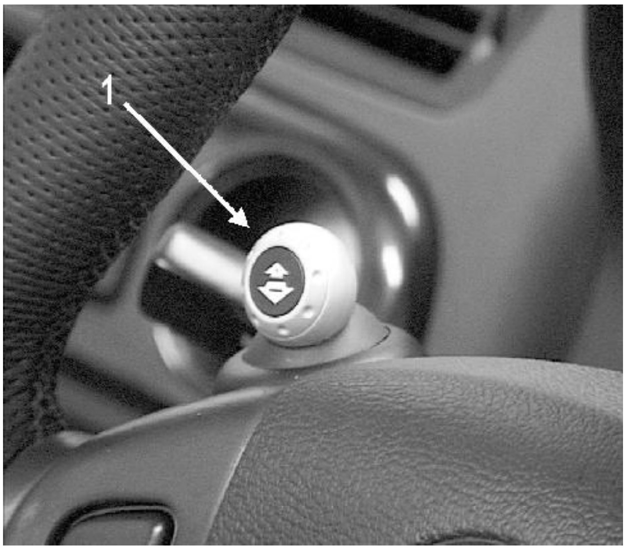

Figure 22

1.Steering wheel switch

Movement of the selector lever in a forward direction, plus (+), changes the gearbox up the gear ratios and movement in a rearward, minus (–), direction changes the gearbox down the ratios. Either of the '+' and '–' switches on the steering wheel perform the same function as the selector lever when in sport mode.

The system protects the transmission, while in manual mode, against shifts that could be potentially dangerous or could damage the powertrain, for example, shifting to first gear at 90 mph, or shifting to top gear at 10 mph. In addition, if the driver does not shift up, the next gear will be automatically selected when the engine revolutions reach 6000 rpm. Equally, if the driver does not shift down when reducing vehicle speed, the system performs the down-change automatically.

When changing from a CVT drive mode to a manual drive mode, the system looks at current road speed and driving conditions and selects the appropriate ratio.

The Electro mechanical-continuously variable transmission steptronic unit

When in automatic mode, the Em-CVT provides an infinite number of ratios within its operating range. The stepless shifting pattern of the transmission provides a smooth transfer of power to the road wheels while allowing full vehicle performance to be available at all times.

In sport mode, the Em-CVT operates as in automatic mode but with a higher engine speed under all driving conditions which gives improved responsiveness.

In manual mode, the Em-CVT provides electronic selection of six predetermined ratios, in relation to the input and output speed of the gearbox. Selection is made by the driver using the selector lever or the steering wheel switches.

See table 'Selector lever positions' for positions supported by the, automatic, sport and manual modes.

Selector lever positions

Position	Description
P	Park
R	Reverse
N	Neutral
D	Drive
D/Sport	Manual/sport
1	Sport first ratio
2	Sport second ratio
3	Sport third ratio
4	Sport fourth ratio
5	Sport fifth ratio
6	Sport sixth ratio

The gear selected is displayed in the instrument pack (see Figure 23).

Instrument pack

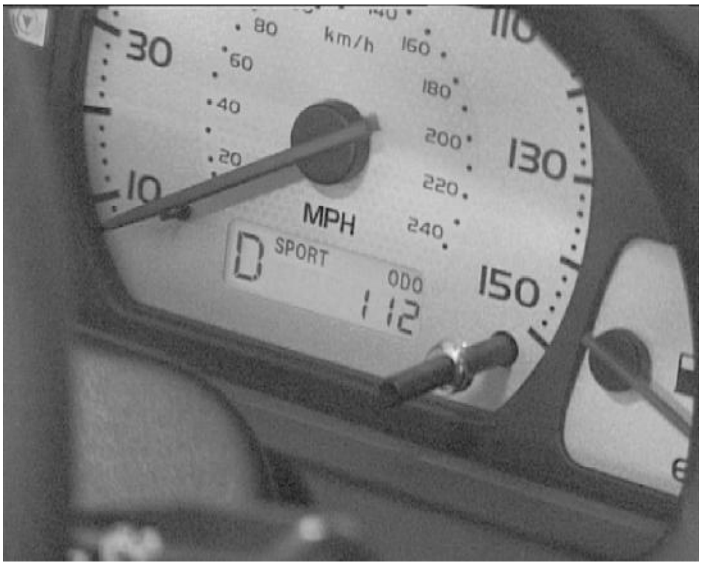

Figure 23

The Em-CVT unit comprises mechanical and electrical components which work together to provide the automatic and manual operation of the gearbox.

The Em-CVT unit comprises the following mechanical components:

- Torsion damper
- Planetary gear set
- Clutches
- Pulleys and steel belt
- Pinion shaft
- Differential unit
- Hydraulic pump (hydraulic system)
- Oil cooler

Torsion damper

The transmission is driven from the engine via a torsion damper. The torsion damper is attached to the flywheel with six bolts and is constructed similar to a conventional clutch drive plate, but without the clutch lining. The torsion damper has a splined hub which engages with the gearbox input shaft. The hub is located on an inner plate and contains compression springs. Engine power is transmitted from the flywheel and damper attachment to the hub via the compression springs which absorb torsional vibrations from the engine and provide a smooth power delivery to the gearbox (see Figure 24).

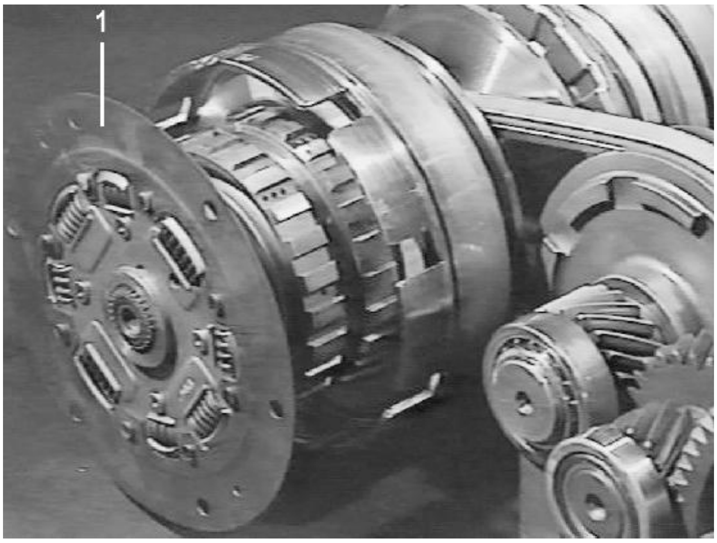

Figure 24

1.Torsion damper

Planetary gear set

The planetary gear set enables the gearbox to provide a rotational output to the drive shafts in two directions to provide the vehicle with forward and reverse selections (see Figure 25).

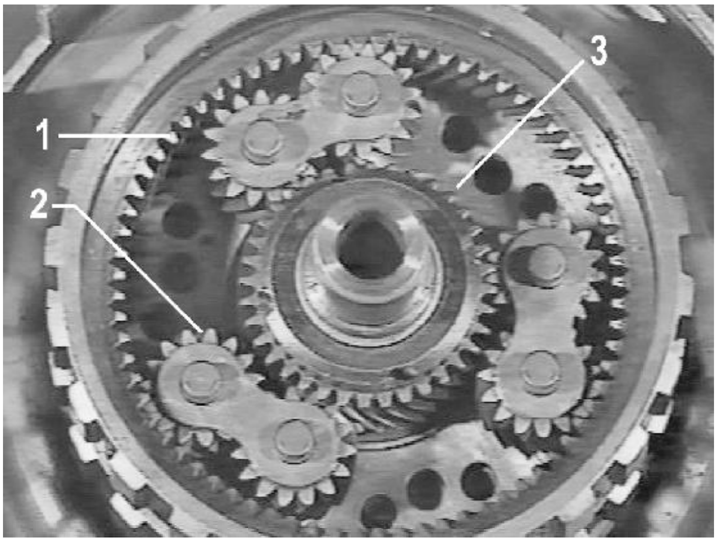

Figure 25

1.Annular gear
2.Planet carrier gears
3.Sun wheel gear

Engine torque is transmitted from the engine and the torsional damper to the input shaft which is attached to the planet carrier.

When a forward gear is selected, the carrier is connected directly to the sun wheel by the drive clutch. The epicyclic gear set rotates as one unit and engine torque is passed directly to the primary pulley.

When reverse is selected, the annulus of the planetary gear set is held stationary by the reverse clutch. Three pairs of planet gears then drive the sun wheel in the opposite direction rotating the primary pulley in the reverse direction.

Clutches

There are two multiplate wet clutch packs; one forward and one reverse. Each pack has three friction plates providing six friction surfaces. Hydraulic pressure controls the clutches to allow the vehicle to move away smoothly regardless of the degree of throttle opening. Oil from the oil cooler is directed to the clutch plates to prevent overheating of the friction surfaces (see Figure 26).

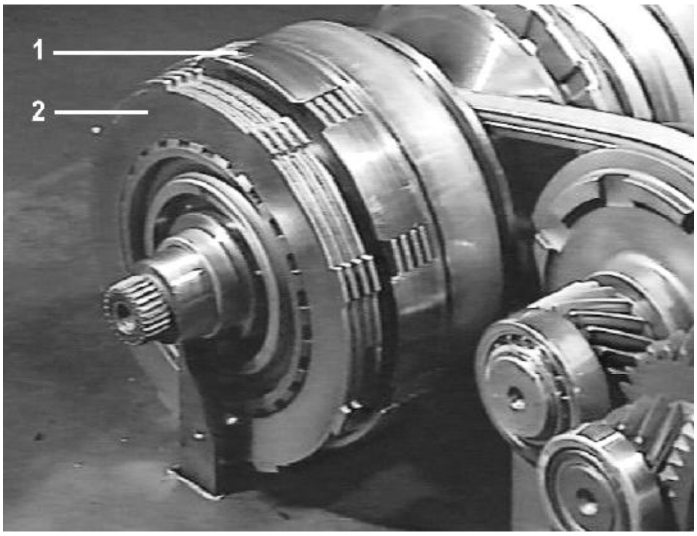

Figure 26

1.Forward clutch pack
2.Reverse clutch pack

Pulleys and steel belt

The major drive components of the gearbox are a pair of vee shaped pulleys and a steel drive belt. Each pulley comprises of one fixed half and one moveable half. Both moveable halves are positioned diagonally opposite each other to prevent misalignment of the belt during shift changes. Each moveable half is operated by an hydraulic cylinder and piston, with hydraulic pressure controlled by the hydraulic control unit. The moveable halves are located on ball splines which prevents them rotating in relation to the fixed halves.

Rotation of the planetary gear set rotates the primary pulley. The V-belt transfers the primary pulley rotation to the secondary pulley whose torque and speed is controlled by the position of the V-belt on the two pulleys.

A 24 mm wide steel V-belt is used to transfer engine torque between the two pulleys (see Figure 27). The belt is cooled and lubricated by an oil jet.

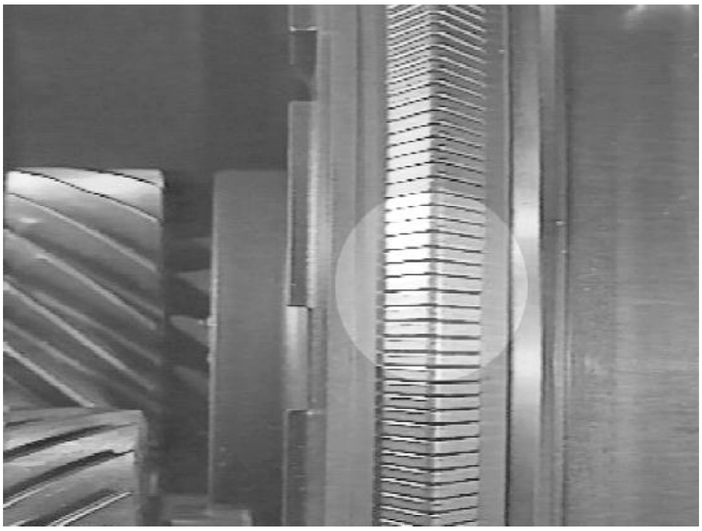

Figure 27

The belt comprises of two sets of steel bands (see Figure 28) each constructed from twelve steel strips (see Figure 29).

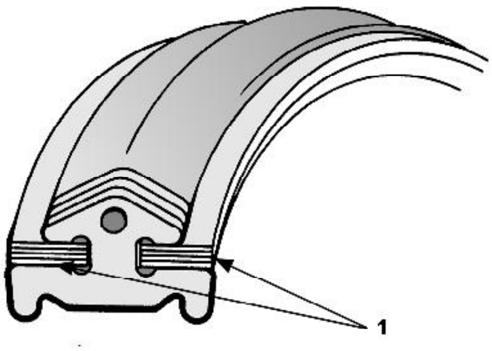

Figure 28

1.Steel bands

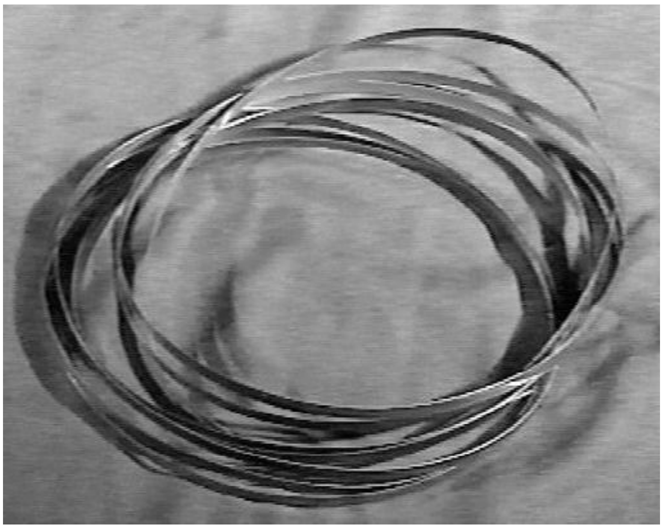

Figure 29

The belt contains approximately 350 steel segments which abut each other to allow the belt to transmit torque by compression. The belt has several different thicknesses of steel segments which reduce the noise of the segments contacting the pulleys by changing the harmonic frequencies (see Figure 30).

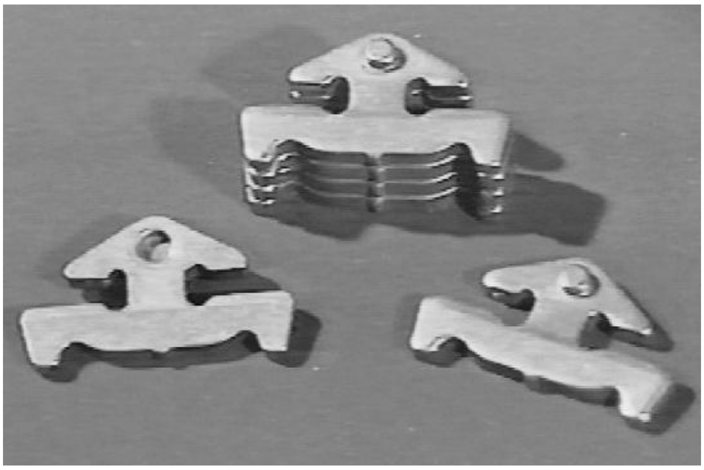

Figure 30

Note: *When handling the belt, always squeeze the perimeter, otherwise it may fall apart.*

Pinion shaft

The pinion shaft, which is supported on two tapered bearings, provides location for two gears which gives a two step helical gear reduction between the secondary pulley and the differential crown wheel and provides the correct rotational direction of the drive shafts.

Differential

Drive from the final reduction gear is transferred to the differential crown wheel. The crown wheel is bolted to the differential case with eight bolts. Drive from the crown wheel is transferred via bevel gears to the drive shafts. The differential is supported on tapered bearings.

Hydraulic system

The functions of the hydraulic system are:

- To match the steel belt clamp pressure with engine torque to prevent belt slip
- To control the operation of the forward and reverse clutches during take off and driving
- To provide the optimum transmission ratio for all driving conditions

Belt Clamp Pressure

The amount of clamp pressure applied to the steel belt depends upon the engine torque to be transmitted and the transmission ratio (the higher the ratio, the lower the required belt clamp pressure). Excessive clamp pressure would consume engine power unnecessarily whereas inadequate clamp pressure would allow the belt to slip. The hydraulic system therefore ensures optimum belt clamp pressure at all times. The belt is clamped by the movement of the secondary pulley closer together, when under secondary pressure.

Pulley Chambers

The primary pulley chamber has a larger surface area than the secondary, so if the same pressure is applied to both, the primary will always govern the secondary, as it has a higher clamping force.

Hydraulic pump

The hydraulic pump is located on the opposite side of the gearbox to the planetary gear set. The pump is driven directly from the torsion damper via a shaft which is located through the centre of the input shaft. The shaft is splined to the planet carrier which always rotates at engine crankshaft speed (see Figure 31).

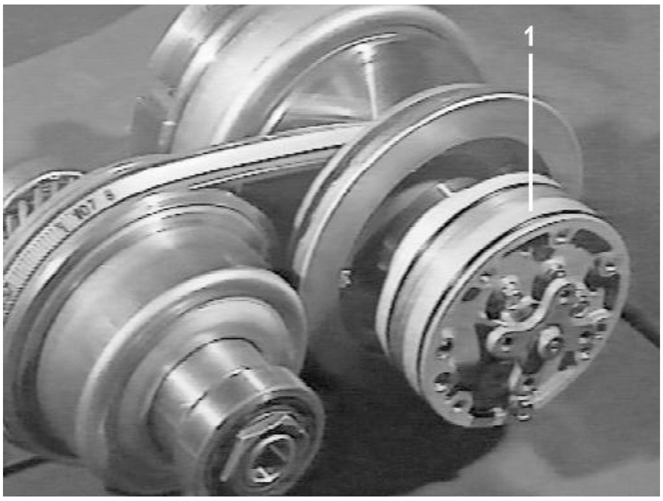

Figure 31

1.Hydraulic pump

The pump has a swept volume of 8.85 cc per revolution and can produce a pressure of up to 40 bar (580 lbf/in) for the highest torque requirement. The pressurized oil from the pump is used for gearbox lubrication and transmission control.

The oil enters the pump through a suction filter in the sump. CVT fluid is used in order to obtain the correct clutch engagement characteristics.

Primary valve

The function of the primary valve is to regulate primary pressure, controlling the primary pulley, and changing the transmission ratio. The pressure in the primary cylinder defines the position of the primary pulley mobile half. The greater the distance between the halves, the smaller the primary radius of the belt and the higher the transmission ratio.

The primary valve is electronically controlled by the ratio control motor via control springs.

Secondary valve

The function of the secondary valve is to supply pressure to the secondary pulley to ensure that there is always adequate clamping force onto the belt for all load conditions. The higher the clamping force the greater the torque that can be transmitted.

Oil cooler

The oil cooler is located at the front of the vehicle behind the bumper, in front of the engine cooling radiator (see Figure 32). The oil cooler comprises eight horizontal tubes which allow oil to flow across from one side of the cooler to the other. Each tube is joined by thin fins which aid heat dissipation.

Two fluid lines from the gearbox, comprising of alloy pipes and flexible hoses, provide the oil cooler feed and return.

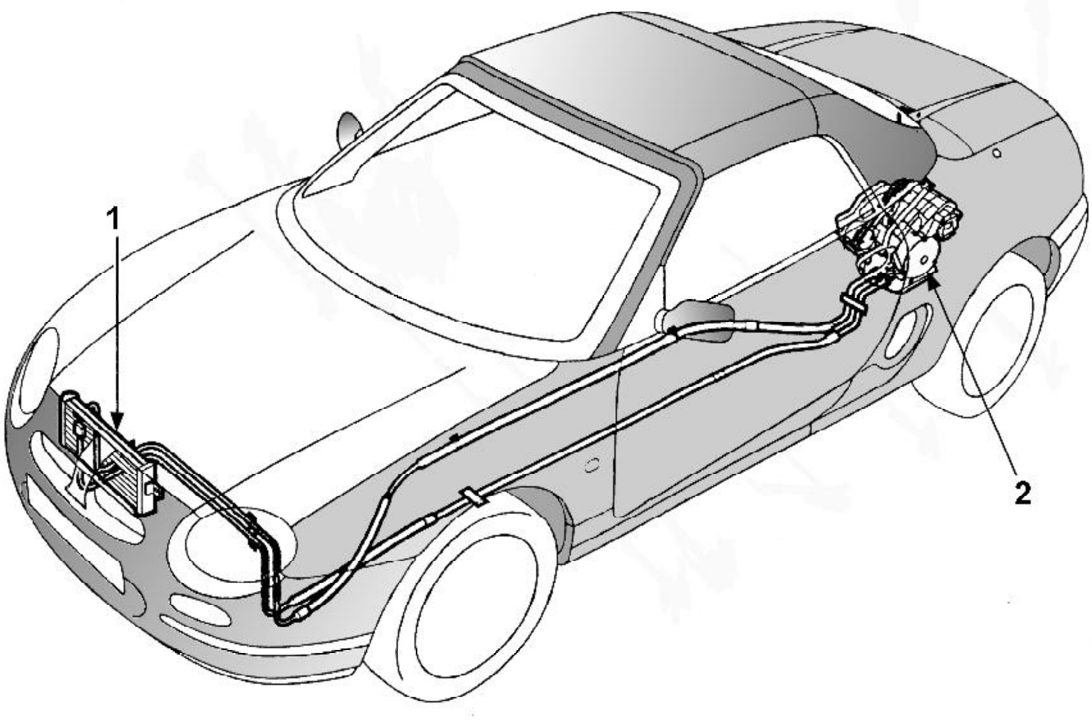

Figure 32

1.Oil cooler
2.Electro mechanical-continuously variable transmission

Clutch control

When the accelerator pedal is pushed, from a standstill, to a certain position, the transmission will react in the following way:

The position of the accelerator pedal (throttle opening) corresponds with an engine torque curve. This torque curve can be converted into a required clutch pressure. The relation between clutch pressure and transmittable torque is determined by the clutch design. With a given position of the accelerator pedal, the engine will increase its speed. The rpm cannot increase because all the torque is dissipated through the clutch. During this acceleration phase, part of the power accelerates the car and the rest is dissipated in the slipping clutch. When the primary pulley speed equals engine speed, the engine can rev up further without slip in the clutch. The most severe situation for the clutch is a stall condition. The value at which the maximum clutch pressure is limited depends upon the engine. Maximum clutch pressure (fully applied) is at approximately 2000 rpm. The creep behaviour of the vehicle is also a result of the clutch control strategy. With the selector lever in ’drive’, ’drive/sport’, ’manual’ or ’reverse’ and the brakes released, the vehicle will creep forwards or backwards with a constant creep torque. This reminds the driver of the selected direction and is considered to be a safety feature. By pressing the brake pedal the driver can hold the vehicle stationary.

Towing of the vehicle

If the vehicle has to be towed it is recommended that the vehicle does not exceed 30 mph or distances of over 30 miles. With a manual transmission it still is possible to start the car by pushing or towing. This is not possible with the CVT because there will be no oil pressure (as the engine and the pump are not running) meaning that both clutches are disengaged and that there is no connection between the engine and to the wheels. No pressure also means that the belt is in the low ratio. When towing, the secondary pulley is driven via the final drive. The secondary sheaves are only pushed together by spring force. Therefore the spring was designed to provide enough clamping force onto the belt preventing it from slipping, even at zero secondary pressure.

The Electro mechanical-continuously variable transmission operation

The transmission is driven from the engine via a torsion damper bolted to the flywheel. The torsion damper drives the input shaft which in turn drives the planet carrier. Depending on whether forward or reverse is selected, the primary pulley will rotate, transferring torque to the secondary pulley causing the vehicle to move in the required direction.

The steel belt is fitted between the primary and secondary pulleys. Each pulley consists of one fixed sheave and one axially moveable sheave. The moveable pulley sheaves are located diagonally opposite to each other to reduce misalignment of the belt during shift changes.

Each moving pulley sheave is connected to an hydraulic cylinder which is controlled by hydraulic pressure generated by the integral pump running at engine speed. Moving the pulley sheaves together increases their effective diameter and moving them apart decreases the diameter due to the conical faces of each pulley. In this way the gear ratios of the Em-CVT unit are achieved.

The Em-CVT unit has two multiplate wet clutch packs; one forward and one reverse. Each pack comprises three friction plates. The clutches are hydraulically controlled which enables the vehicle to move smoothly from standstill irrespective of the throttle position. The clutches are fed hydraulic fluid from the oil cooler to prevent them overheating.

When the selector lever is in the ’park’ position, a spring and cone operated pawl mechanically locks the secondary pulley, consequentially locking the rear wheels. If ’park’ is selected when the vehicle is moving, the pawl will not engage until the vehicle speed falls to below 4 mph (7 km/h). A rattling sound may be heard if ’park’ is selected when the vehicle is moving.

Driving - Automatic mode

To pull away from a standstill a low ratio is required. The primary pulley is held fully open, reducing its diameter and allowing the belt to seat at the bottom of the pulley. The secondary pulley is held closed, forcing the belt to run in its increased diameter.

As the vehicle speed increases, higher ratios are required. As engine speed increases the fluid pressure generated by the pump increases. This increase in pressure is felt by the primary pulley cylinder which moves to gradually move the pulley sheaves together increasing its effective diameter.

Simultaneously, the secondary pulley sheaves move apart, reducing its diameter and increasing the gearbox ratio. When the primary pulley is closed and the secondary pulley is fully open, the gearbox operates in an overdrive ratio, with the secondary pulley rotating at approximately two and a half times the speed of the primary pulley.

Kickdown is achieved electrically. The engine control module (ECM) monitors the crankshaft sensor (engine speed), the throttle position sensor and the gearbox shaft sensor (road speed) to control the gearbox ratios.

When kickdown is requested, the engine control module (ECM) transmits a message to the gearbox interface unit (GIU) to control the ratio control motor accordingly. The GIU adjusts the ratio control motor which, in turn, moves the hydraulic control valve to lower the gearbox ratio to achieve the required acceleration.

Driving - Manual/Sport mode

In manual/sport mode the gearbox functions as a conventional CVT unit or a semi-automatic manual transmission in the manual steptronic mode. In sport mode, the engine speed is higher under all driving conditions which gives improved acceleration. If required, the driver can make sequential gear selections using either the selector lever or the steering wheel mounted switches.

The six ratios available equate to six predetermined positions for the primary and secondary pulleys. The ratios are initiated by the GIU which powers the ratio control motor to a position corresponding to the required ratio.

Driver plus/minus (+/–) selections using the selector lever or one of the steering wheel mounted switches are passed to the GIU. The GIU transmits a message to the ECM which grants the ratio change if conditions are correct. The GIU powers the ratio control motor, which in turn moves the hydraulic control unit to adjust the pulleys to the required spacing for the ratio selected.

The GIU checks if a requested gear change made by the driver is permitted. Gear changes will be ignored if the driver requests a change which is dangerous or could damage the transmission. If a shift up is required and the driver has not made the required selection using the selector lever or the steering wheel switches, the next higher gear will be selected when the engine speed reaches maximum rpm. If the driver does not make a required shift down when the vehicle is slowing, the next lower gear will be selected automatically. The liquid crystal display (LCD) in the instrument pack will always display the current gear.

Manual/sport mode is de-selected by moving the selector lever back to the 'drive' (automatic) position.

Maintenance

For technical data regarding the Electro mechanical-continuously variable transmission, see table 'Technical data'

Technical data

Capacity • Dry fill • Service fill	 • 4.9 litres • 4.5 litres
Oil type	Unipart sureflow CVT fluid (EZL 799 Esso CVT fluid)
Service interval	24,000 miles (40,000 Km)
Special tools • Input shaft seal • Differential seals • Bearing replacer • Thrust button • Bearing remover	 • 18G 1509 • 18G 134 and 18G 134BD • 44–021 • 44–022 • 44–023

Fluid level check

Carry out the following procedure when a fluid level check is required:

1. Ensure the vehicle has been properly warmed up (i.e. four mile road test)
2. Park vehicle on level ground and apply handbrake
3. Run through all gears three times, (PRND/Sport) with the engine idling and foot on the brake. Allow the engine to idle for one minute
4. With the engine idling and the vehicle in park. Remove the dipstick. Wipe with a clean lint free cloth and re-insert, withdraw and ensure that the level is to the maximum mark
5. If the level is low top up as necessary with the correct CVT fluid through the dipstick tube to bring the oil level to the ’MAXIMUM’ (see Figure 33)

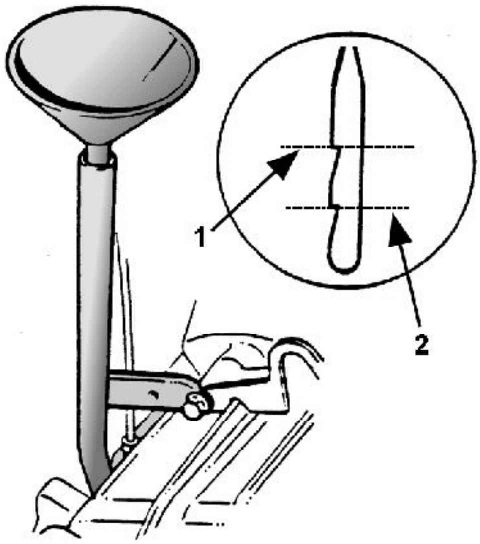

Figure 33

1.Maximum level
2.Minimum level

Fluid drain and refill

Always ensure that the transmission is fully warmed before draining and a new sealing washer is fitted to the drain plug each time it is refitted. Refill the box through dipstick tube and check level as above, do not overfill.

Note: *Approximately one litre of fluid is retained within the transmission when drained.*

Electro mechanical-continuously variable transmission: communication

As stated, the electro mechanical-continuously variable transmission (Em-CVT) is based on a standard CVT unit with electronic components fitted to control the gear ratio. The location of the components that make up the Em-CVT steptronic transmission are illustrated in the figure titled 'Em-CVT component location' (see Figure 34).

Em-CVT component location

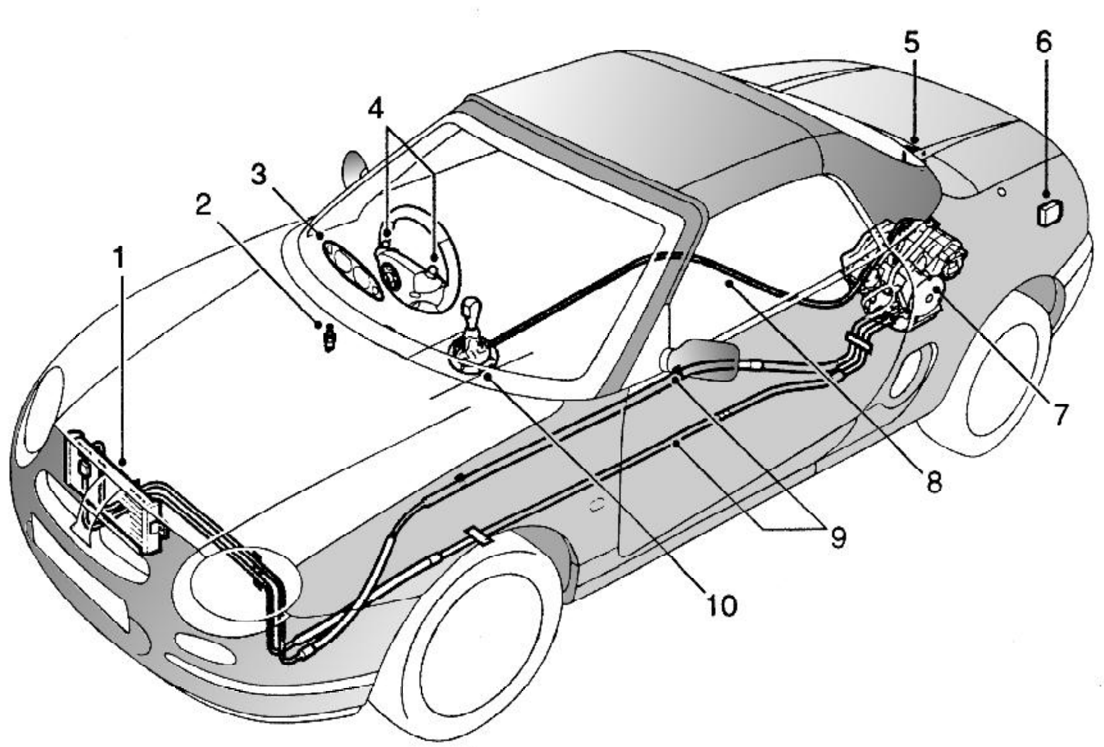

Figure 34

1.Oil cooler
2.Brake switch
3.Instrument pack
4.Steering wheel switches
5.ECM
6.Gearbox interface unit (GIU)
7.Em-CVT Steptronic gearbox
8.Selector cable
9.Oil cooler feed/return pipes
10.Gear selector lever

All of the control methods associated with the gearbox are run as part of the Engine Management System software. MEMS3 receives inputs from the main sensors of this system, communicates with the gearbox interface unit (GIU) to control the gearbox, accepts driver input, and also provides information to the driver via the instrument pack. The GIU acts as a 'slave' for the engine management system.

The control of the gearbox is via a closed loop system which ultimately controls the position of the ratio control motor (see Figure 35).

All inputs and outputs of the Em-CVT control system pass through the engine management system and the Gearbox interface unit. The engine management system monitors the speed of the gearbox output shaft and communicates with the GIU to select the correct gear ratio to suit the current driving conditions. The GIU drives the PRND LED module to display the selected gear next to the gear selector lever and the instrument pack display is driven by the engine management system.

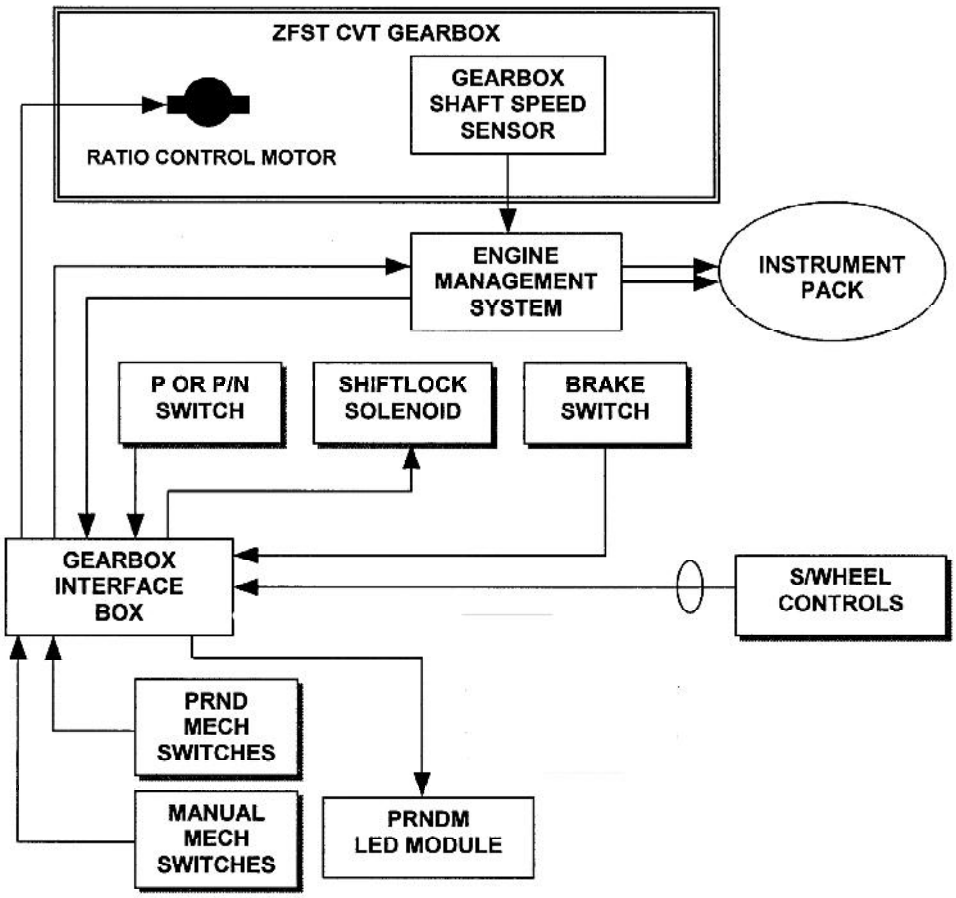

Figure 35

Gearbox interface unit

The gearbox interface unit (see Figure 36) is also known as the electronic automatic transmission (EAT) ECU and is located in the left hand side of the luggage compartment behind the trim. The main function of the GIU is to allow communication between the automatic transmission and the engine management system. The GIU has the following functions:

- Conversion of switch inputs from the PRND mechanism and steering wheel switches into serial data stream to the EMS
- Drives LED's to display gearbox mode
- Conversion of the signal from the ECM, which represents the requested position of the linear actuator, into electrical signals to drive the actuator

Gearbox interface unit inputs

There are many inputs the GIU required for correct functionality:

- PRND mechanical switches
- Manual mechanical switches
- Steering wheel switches
- Brake switch (Shift interlock)
- Park/Neutral switch
- Engine management system

Gearbox interface unit

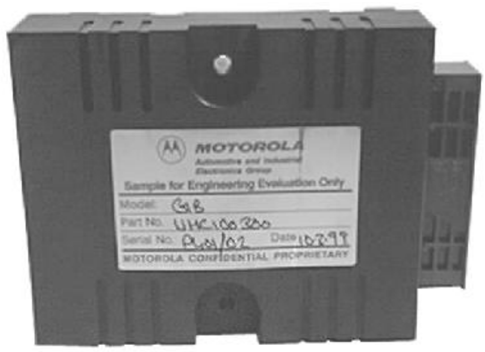

Figure 36

Park, reverse, neutral and drive mechanical switches

The PRND switch is located on the driver's side of the selector lever and is secured to the die cast plate with two screws. The switch is connected to the main harness by a six pin connector (C1452).

The PRND switch has a sliding contact which moves with the selector lever. The switch has four latching contacts which correspond to the PRND positions. Each contact is connected to the GIU which communicates with the EMS, which in turn calculates the control strategy for the selection made.

PRND pin-out table (connector 1452)

Pin No	Function	Connected to:	Wire colour
1	Ground	Ground	Black
2	Park	GIU pin 31	Blue
3	Reverse	GIU pin 32	Yellow
4	Neutral	GIU pin 33	Blue/green
5	Drive	GIU pin 34	Green/yellow
6	Not used		

Manual mechanical switches

The ’M’ switch is a latching mechanical switch which holds the gearbox in manual/sport mode. The ’plus’ and ’minus’ switches are momentary switches.

The manual/sport switch is located on the die cast metal plate behind the selector lever and is secured to the plate with a metal strap. The switch is connected to the main harness by a four pin connector (C0675) which is shared with the sport +/- switches.

The manual/sport switch is a cam operated microswitch. A lever with a roller is attached to the switch body. When the selector lever is moved from automatic to the manual/sport position, the roller contacts a cam plate which depresses the lever and operates the switch. The switch contacts remain closed when the selector lever is in the sport position.

When the selector lever (see Figure 37) is moved to the manual/sport position, a dog tooth engages with a slotted abutment on the switch. When the lever is moved to the + or - position the dog tooth moves the switch completing a contact. This is sensed by the GIU which informs the engine management system the switch has been closed.

pin-out table (connector C0675)

Pin No	Function	Connected to:	Wire colour
1	**Ground**	**Ground**	Black
2	**Minus (–)**	**GIU pin 38**	Yellow/green
3	**Plus (+)**	**GIU pin 36**	Blue/black
4	**Manual /Sport**	**GIU pin 35**	Yellow/grey

Gear selector lever and switches

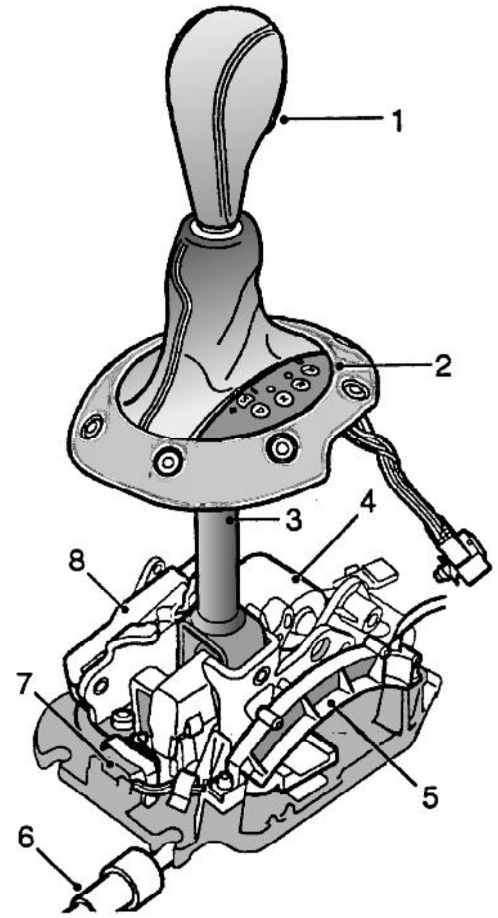

Figure 37

1.Park/reverse release button
2.LED module
3.Selector lever
4.Shiftlock solenoid (if fitted)
5.PRND switch
6.Selector cable
7.Manual/sport switch
8.Sport +/- switch

Steering wheel switches

Two additional selector momentary switches are located on the steering wheel. Each switch is a three position, spring biased to centre switch and are connected to the GIU. The switches can be pushed in either direction (+/-) to change the gearbox ratio. The switches provide the same functionality as the selector lever +/- switches and are only operative when the selector lever is in the manual/sport position.

Brake switch

The brake switch is located on the pedal box and is activated by operation of the brake pedal. The switch supplies an input to the GIU in addition to operating the brake lamps. When the brake switch is operated, a 12v feed is sensed by the GIU. This is used by the GIU to de-energise the shift lock solenoid providing that the ignition is on. This input is used only as part of the shift interlock function – where fitted.

Park/neutral switch

The park/neutral switch is screwed into the rear face of the gearbox below the LH drive shaft. The switch is connected to the main harness by a four pin connector (see Figure 38).

Em-CVT component location

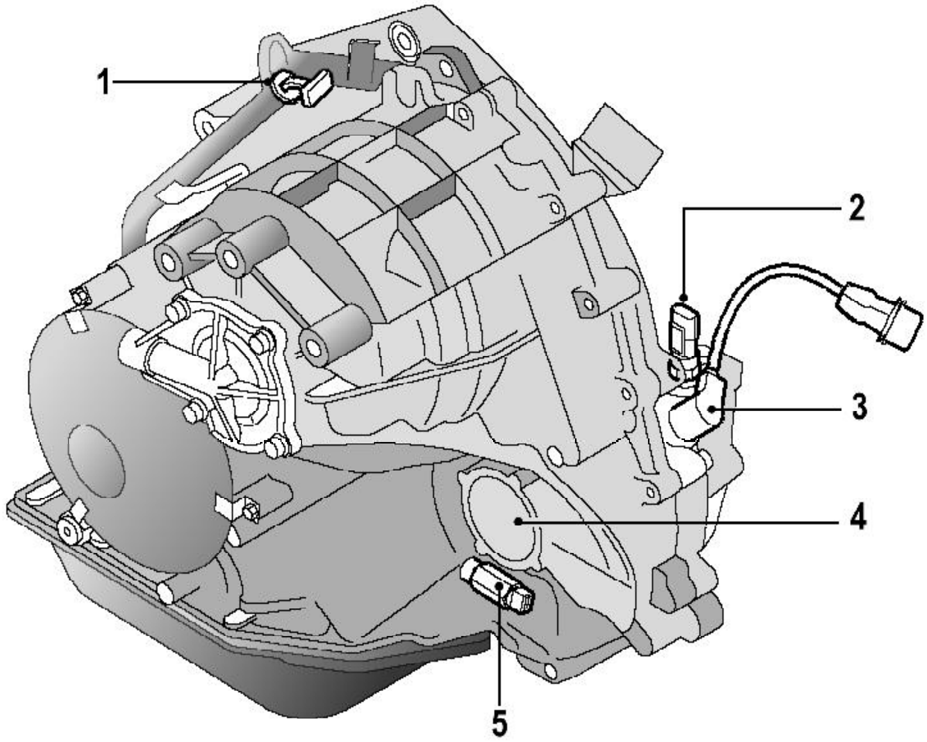

Figure 38

1.Fluid level dipstick
2.Road speed transducer
3.Gearbox output shaft speed sensor
4.LH drive shaft connection
5.Park/neutral switch

The switch is operated by a cam which also operates the hydraulic control unit within the gearbox. The cam is operated by the selector lever via a cable to the gearbox. The switch has two positions and performs several functions. When the transmission is in any position other than the Park (P) or Neutral (N) positions, the switch interrupts the starter relay coil earth path to the alarm ECU preventing starter operation.

This signal is also used by the ECM to adjust the stepper motor of the IAC valve to adjust the engine idle speed when Reverse (R) or Drive (D) is selected. When Reverse (R) is selected, the switch moves to its second position and activates the reverse lamps.

In selected markets, when the selector lever is in the ’P’ position and the ignition is switched off, the park/neutral switch input causes the GIU to de-energise a shift lock solenoid on the selector lever. This locks the lever in the ’P’ position. The selector lever cannot be moved from the ’P’ position until the ignition is switched on and the footbrake is applied.

Serial communication: Gearbox interface unit to engine management system

The gearbox interface unit converts all switch inputs/status into a digital format and transmits them to the engine management system via a serial data link. The messages will be in the form of a number of bytes each consisting of eight bits. A start bit will precede each byte and an end bit will follow each byte.

Start	Bit 0	B1	B2	B3	B4	B5	B6	B7	End

Each message will consist of at least four bytes:

1. Message header
2. Message length
3. Data
4. Checksum

The **message header** contains the identification of the message being transmitted to the engine management system and is one byte in length.

The **message length** is one byte long and corresponds to the overall length of the message being transmitted. It is used to enable the transmission of variable length messages and allows the receiver to calculate how long the message received is, against the message transmitted, and to ensure compliance. Any message received with its length not complying with the message length byte is ignored.

The **data** consists of at least one byte and corresponds to the actual message being transmitted, for example current selected gear.

All previous bytes in a message are added together and the product is sent as the **checksum**. The engine management system performs the same checksum on the received message and the result should equal the transmitted checksum. Any inconsistencies means the message will be ignored.

An example of a **data** message byte is shown in the table ’Output drive condition’

Output drive condition: message byte

Start	Bit 0	B1	B2	B3	B4	B5	B6	B7	End
	0.5	M o/c	M s/c	D o/t	SIL fault	E^2 default	Gen fault	Spare	

The least significant bit (Bit 0) of a message byte is transmitted first and in this message if the bit is present it informs the GIU to add half a step to the calculated motor position. The message also contains bits which would indicate an open circuit motor, a short circuit motor and a driver over temperature bit — Bits 1, 2 and 3.

The shift interlock (SIL) fault bit will be set if the shiftlock circuitry detects a fault with the shiftlock solenoid. If there is no fault or no shiftlock fitted this bit will be clear.

E^2 relates to the memory inside the GIU. The E^2 fault bit will be set if the GIU is using stored back up values of configurable data. The general fault bit will be set if the GIU detects an internal failure preventing its control of the actuator.

In order to protect the engine management system against serial link failures whilst reading data when the start bit of a message is received, a timer is started. This time is adequate for the delivery of all possible messages. After 60 m/s if the remainder of the message has not been received by the engine management system the timer expires and the message is ignored.

Note: *Though the GIU sends data about various faults it is not capable of storing faults. This is done by the EMS.*

Gearbox interface unit actuator control: engine management to Gearbox interface unit

The ratio control motor is housed inside the gearbox, adjacent to the oil cooler pipe connections (see Figure 39). The motor is connected to the main harness via a circular seven way connector with four connections used for the motor operation. The motor is operational in all transmission modes and controls the hydraulic control unit to adjust the primary pulley to the appropriate position.

Ratio control motor location

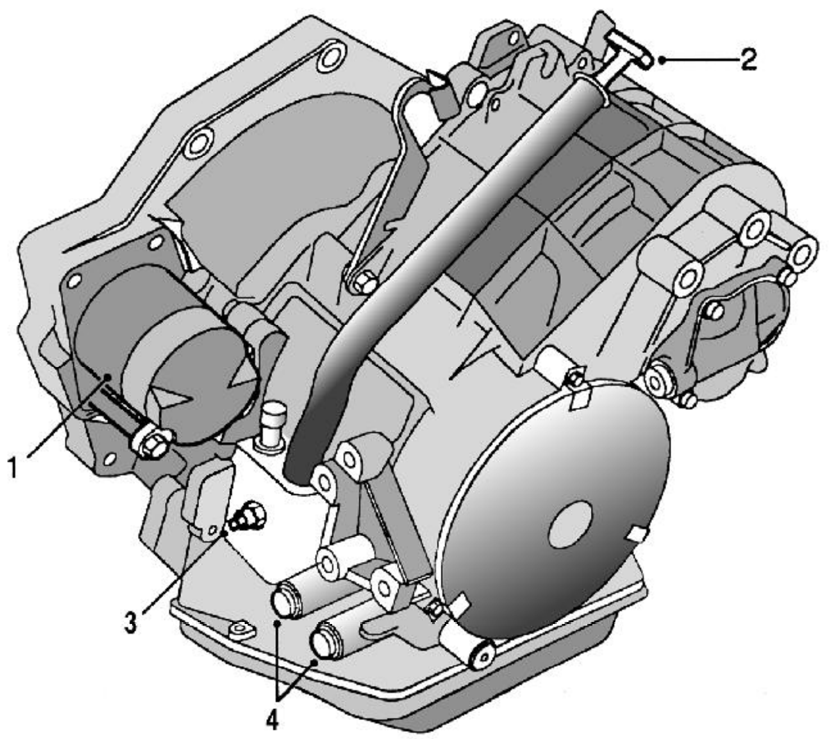

Figure 39

1.Starter motor
2.Fluid level dipstick
3.Ratio control motor
4.Oil cooler feed/return connections

The engine management system produces a pulse width modulated (PWM) output to request the actuator position from the GIU. The output is held high by an internal pull up resistor and pulled down for a period of time to create the signal. The frequency of the PWM supply is 500 Hz which equates to a time period of 2 milliseconds (1 ÷ 500) (see Figure 40).

Pulse width modulation

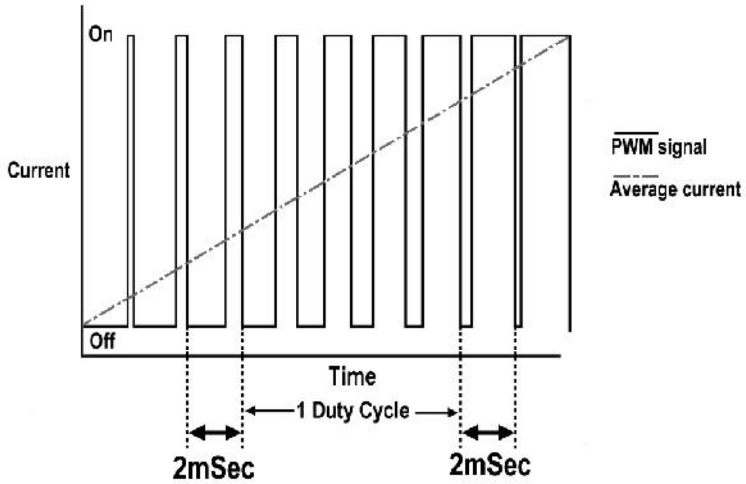

figure 40

The timer used to switch the PWM output has a resolution of 2 microseconds which means it can produce up to one thousand different duty cycles (0.002 ÷ 0.000002 = 1000). Values rising from 0 – 100% in 0.1 % increments.

The motor which controls the gearbox ratio is a linear actuator and is a bi-polar stepper motor almost identical to the idle speed stepper motor controlled by the engine management system. The stroke length of the actuator is nine millimetres which equates to 427 half steps and therefore 427 duty cycles are required. A half step is equal to 0.021mm (9 ÷ 427 = 0.021).

The control of the motor is achieved in absolute terms. The position is always requested as an absolute position and the PWM message sent relates to a certain motor position (a precise number of steps from its reference position).

The remaining duty cycle values are used for actuator initialisation and other motor commands. An error condition is assumed for duty cycles less than 5% and greater than 95% to protect against open circuit and short circuit of the PWM signal line. The GIU will move the actuator to a 'safe' position when a duty cycle which corresponds to an error condition.

Motor speeds

The motor is capable of operating at four different speeds: 50, 125, 166 and 250 steps per second. The speed selected and acceleration rate of the motor is defined by a strategy designed to protect the gearbox from damage and to ensure that the motor always delivers the precise position required.

Safe position and speed

For many fault conditions, the GIU is required to move the actuator to what is termed a ’safe position’. The actuator ’safe’ position is defined as 130 steps from the fully retracted position (zero position). The actuator is driven to the ’safe’ position on ’power down’ after an ignition cycle.

There is also a limit or ’safe’ speed that the actuator is permitted to travel at under fault conditions. The limit is 125 steps/sec.

ECM

The ECM receives messages from the GIU via a serial link and transmits a PWM output to the GIU to request ratio motor/actuator positions.

The table ’MEMS 3 pin out table’ outlines the connections to the MEMS 3 ECM which are used by the Em-CVT to achieve its functionality:

MEMS 3 pin out table

Pin No	Function
4	Crank positive/crank hall effect signal
9	Em-CVT road speed signal (from gearbox)
20	Throttle pot signal
30	Crank sensor negative/crank hall sensor ground
33	Coolant temperature sensor
45	Manifold pressure signal
48	IPK gear/mode display
63	Park/neutral switch
75	Linear actuator command position
77	Gearbox information
78	Rough road signal from GIU on non ABS

Gearbox road speed signal

A Hall Effect sensor is used to measure the output shaft speed of the gearbox (see Figure 41). The target wheel for the sensor has 81 teeth and is read directly by the EMS via pin 9. The sensor enables very accurate calculation of vehicle speed, and is unaffected by locking wheels or sharp cornering. Using this sensor allows the Em-CVT system to calculate the current gearbox ratio very accurately. This sensor is upstream of the differential, targeting the crown wheel on the main output driveshaft.

Figure 41

This sensor will be used on Em-CVT applications only to determine road speed. The sensor will be mounted in the gearbox housing. It is used for improved idle speed control to determine when the vehicle is near stationary, and to enable a more accurate calculation of true gearbox ratio.

Each sensor contains a microchip. The chip is supplied with a voltage from the battery. The circuit inside the chip contains a semiconductor through which a small current flows. Consequently, the sensors are termed ’active’ sensors, as opposed to ’passive’ sensors (inductive type sensors). The Hall effect sensor converts the physical value of rotational speed into an electrical signal which varies in relation to the position and speed of the crown wheel. It is the frequency of the signal which varies with the speed of the crown wheel. When the teeth of the crown wheel pass the sensor, the chip switches ’ON’ and ’OFF’, generating a varying voltage at the ends of the semiconductor. This voltage switches ’High’ and ’Low’ at a rate proportional to the speed of the crown wheel. This signal is relayed in the form of a ’square wave’ to the ECM and processed as road speed.

GIU pin-out table

The following table illustrates the pin-out details of connector C0932:

Connector C0932

Pin No	Description	Input/output
1	Shiftlock solenoid drive	Output
3	12v battery voltage from ECM relay module	Input
4	Earth	Input
5	Ratio control motor - Phase 1A (digital signal)	Input/output
6	Ratio control motor - Phase 1B (digital signal)	Input/output
7	Ratio control motor - Phase 2A (digital signal)	Input/output
8	Ratio control motor - Phase 2B (digital signal)	Input/output
13	Brake switch	Input
14	Park/neutral switch	Input
17	GIU to ECM serial data link	Output
18	ECM to GIU (ratio control motor position)	Input
22	Shiftlock solenoid drive (digital signal)	Output

Pin No	Description	Input/output
24	12V battery voltage from ECM relay module	Input
25	Earth	Input
26	Park (P) LED (digital)	Output
27	Reverse (R) LED (digital)	Output
28	Neutral (N) LED (digital)	Output
29	Drive (D) LED (digital)	Output
30	Manual (M) LED (digital)	Output
31	Park/Neutral switch	Input
32	Reverse switch	Input
33	Neutral switch	Input
34	Drive switch	Input
35	Manual/sport switch	Input
36	Selector sport UP (+) switch	Input
37	Steering wheel sport UP (+)	Input
38	Selector sport DOWN (-) switch	Input
39	Steering wheel sport DOWN (-) switch	Input
40	Snow mode switch	Input

Pins 1 and 22, and, 4 and 25 are connected together inside the GIU. Pin numbers not listed are not used.

Default strategies

If the EMS detects an error with the system, a default strategy may be engaged. These conditions shall be communicated to the driver via the fault indication in the instrument pack. Depending on the severity of the fault, the driver will experience different default driving modes.

If the system is still able to control the gearbox ratio, the standard limp-home is used to default the gearbox to a ratio approximating to 4th gear. This will protect the transmission under all driving conditions. Some drivers may not even notice this default mode. Under most driving conditions, the astute driver will notice that the engine speed is hanging around 4000 rpm at most road speeds.

The most serious fault will cause the driver to be stuck in a single gear ratio. If stuck in the lowest gear, the driver will very quickly see the engine speed increase to around to 6000 rpm and stay there. The maximum possible vehicle speed is approximately 30 mph. If stuck in the highest gear, the driver will experience very sluggish acceleration and engine speeds hanging around 2000 to 2250 rpm at vehicle speeds up to 50 mph.

Diagnostics

All diagnostics of the Em-CVT are carried out via the engine management system. Using TestBook the engine management system can request actions from the GIU and monitor the action of the GIU for correct performance.

A requirement has been identified for the GIU to perform an integrity check on its output drives. This mode will be engaged as part of the end of line testing during production, and also for garage diagnostic testing. In response to these signals, the GIU shall perform the following:

- Perform a test on the LED drives
- Test the Shift lock solenoid drive, if fitted
- Attempt to move the motor through a complete cycle

Fault finding

Once the operation of the MEMS 3 has been established, GIU operation should be established. The serial link between the GIU and the engine management system can be verified by observing the LCD display in the instrument pack. The display should change in accordance with the position of the gear lever shifter and is an indication that the shifter switches are operational and the drive from the engine management system to the instrument pack is operational.

Possible causes of transmission faults are described in the 'fault table'.

Fault table

Fault /symptom	Possible causes
Gearbox stays in highest ratio: Vehicle pulls away as normal but engine speed does not rise as normal.	• Faulty road speed sensor • Interference on road speed sensor • Faulty throttle potentiometer • Ratio control motor fault
Vehicle pulls away and accelerates sluggishly	• Gearbox malfunction
Gearbox stays in lowest ratio: Vehicle pulls away as normal but engine speed rises rapidly and reads approximately 6000rpm at 30kph	• Stuck primary valve • Ratio control motor fault • Ratio control motor wiring fault affecting phases • Gearbox malfunction
Engine speed stuck at 3000rpm: The ratio control motor is permanently at step 130. This is the default mode for the transmission which is protecting the transmission from damage	• PRNDM switch fault • Link lost between ECM and GIU • Ratio control motor fault • Speed sensor fault
No centre console LED illumination with ignition on	• Short circuit. If the GIU detects a short circuit in the LED module it will extinguish all LED's • Open circuit between GIU and PRNDM connector • GIU fault • Invalid PRNDM switch combination /PRNDM fault

Modular engine management system 3

System introduction

The engine management system fitted to the K1.8 engine (non VVC) with the continuously variable transmission (Em-CVT) is a modular engine management system 3 (MEMS 3). It has been designed to meet the new emission regulations which will come into force in the year 2000, for all new vehicles to the market place and the year 2001 for vehicles which fall into the category of existing models. The European Commission Directive Stage 3 (ECD 3) mandates the control over the level of exhaust emissions, evaporative emissions and on-board diagnostics (OBD) required by all vehicles manufactured from 1st January 2001. OBD gives the vehicle the ability to monitor system components, the failure of which would cause emissions to exceed legislated thresholds. The fault codes ('P' codes) are stored in the engine control module (ECM) memory. By 1st January 2001, under certain fault conditions, the driver will be made aware of a fault by the illumination of the malfunction indicator lamp (MIL) on the instrument panel. Before the activation of full European on board diagnostics (EOBD 1st January 2001), MEMS 3 will log all the fault codes but will not illuminate the malfunction indicator lamp.

The following pages will detail the system components, system interfaces and system strategies the MEMS 3 ECM uses to provide its refined performance and legal emissions obligations.

The MEMS 3 ECM is located in the engine compartment (see Figure 42). It has two connectors, both of a latching type.

MEMS 3 ECM

Figure 42

The ECM has advanced fault handling capacity with the ability to retain many different faults along with the engine conditions when the most recent of these faults was detected. As part of the on board diagnostics, the ECM is required to handle emission related faults in a way that will allow the engine to continue running but with emission levels kept within the legal limit. If the engine management system (EMS) cannot maintain emission levels it will inform the driver by illuminating the malfunction indicator light (EOBD compliant vehicles only).

When the ECM first detects a fault, it will record freeze frame data, consisting of:

- Warm up cycles from MIL off
- Fuel status code
- Coolant temperature
- Short term fuel trim
- Long term fuel trim
- Manifold pressure
- Engine speed
- Vehicle speed
- Calculated load
- Fuel level
- Distance travelled since fault

The ECM will store a fault code, provided the fault occurrence exceeds a predetermined threshold. A threshold for each fault code is programmed into the ECM so that an occasional spurious signal, caused by interference or an unusual mechanical event, will not trigger a fault code. In addition, the ECM 'debounces' a fault code before it will log a MIL event.

The ECM 'debounces' a fault over three drive cycles (EOBD) or two cycles (Californian Air Regulatory Board), before it will log a MIL event.

A drive cycle in this context can be defined as an engine start, followed by a driving mode where a fault would be detected (if the particular component or system was faulty), followed by a power down sequence.

Debouncing a fault code ensures that the fault is not a one-off event. If the same fault is seen on successive driving cycles, a MIL event will be logged. The freeze frame data stored will be that captured when the first fault occurred (assuming that another type of fault has not over written it).

If a fault clears itself, the MIL lamp will extinguish (only if MIL lamp is active on vehicle) after three consecutive fault-free driving cycles. The freeze frame data, however, will only be cleared from the ECM memory after forty engine warm-up cycles have occurred. A warm-up cycle is defined as a driving mode where the engine coolant temperature is below its lower threshold when the vehicle is started and enough time passes for the coolant temperature to climb above its upper threshold before the ECM experiences a power down sequence.

System inputs

The following is a list of all the components or signals from other systems, that provide information to the ECM:

- Crankshaft sensor
- Camshaft sensor
- Secondary speed sensor
- Throttle position sensor
- Coolant temperature sensor
- Oil temperature sensor
- Temperature, manifold absolute pressure (TMAP) sensor
- Air intake temperature sensor
- Oxygen sensor
- Evaporator temperature sensor
- Park/neutral switch
- Alternator load signal
- Inertia switch
- Immobilisation signal
- Fuel tank level signal
- Ignition switch signal
- Air conditioning request signal
- Rough road signal
- Gearbox information

Gearbox secondary speed

The Em-CVT gearbox has a dedicated secondary speed sensor located in the differential housing. This sensor is a Hall effect sensor and produces a pulse train ≈ 73000 pulses per mile. The sensor allows for more precise calculation of road speed down to lower speeds than previous systems.

The secondary vehicle speed sensor is located so that the sensor tip is close to the crown wheel of the differential. By sensing the crown wheel, the signal is not affected by the different wheel speed signals when the vehicle is cornering.

Park/neutral switch

An MG*F* fitted with a Em-CVT gearbox has an input from the gearbox park/neutral/reverse switch to the ECM (see Figure 43). This input informs the ECM of when the vehicle is in a parked or neutral position. The ECM will alter its idle strategy to compensate for the different amounts of engine load when the gearbox has drive or reverse selected

Continuously variable transmission

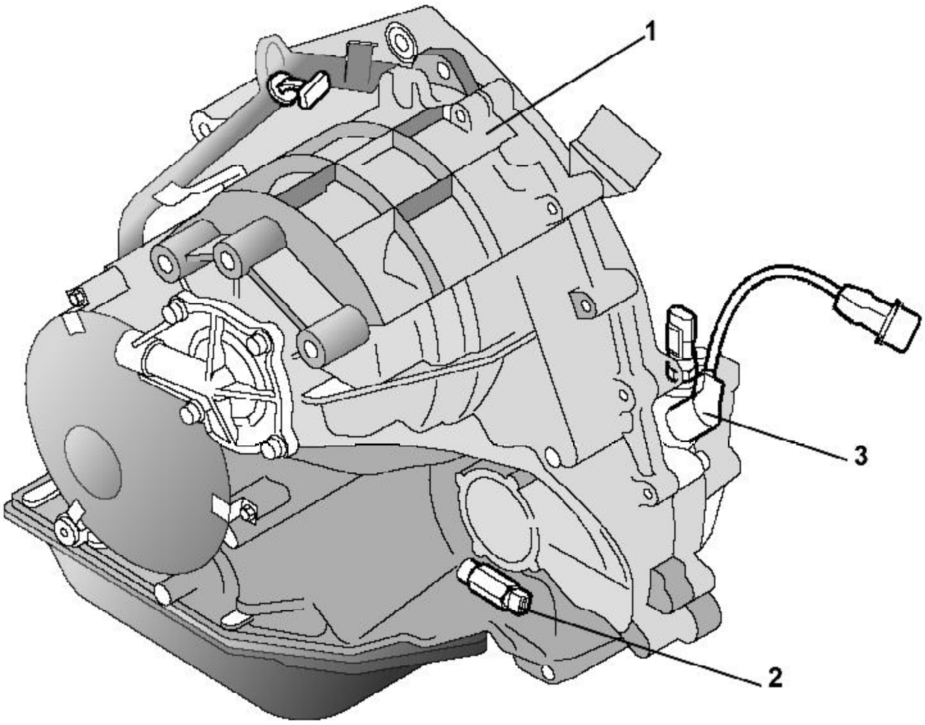

Figure 43

1.Em-CVT gearbox
2.Park/neutral/reverse switch
3.Secondary vehicle speed sensor

Alternator load

The load signal generated by the alternator is produced so that the EMS can alter its engine idle strategy to compensate for high current draw from the alternator. The signal is produced by the alternator and is constructed from a pulse width modulation (PWM) signal, with a varying frequency. The frequency is not important as it is the period or duty cycle that holds the information used by the ECM.

If the signal from the alternator fails, the customer may notice poor engine idle characteristics when the battery is in a state of low charge or there are many electrical loads switched 'on'. The ECM will store a fault code but this will not cause a MIL event.

Fuel tank level signal

The ECM monitors the engine for misfire. A misfire may be caused by a lack of fuel or air bubbles in the fuel rail. The ECM receives a signal from the fuel level sender unit, indicating the level of fuel in the fuel tank. When a misfire fault code is recorded, the ECM also records the fuel level. If this fuel level is under 15% of the tank capacity, a possible cause for the misfire may have already been found.

Rough road signal

Misfire detection must be disabled when the vehicle is travelling over 'rough roads'. This is necessary because the driving conditions can affect the continuity of the predicted crankshaft speed. If the crankshaft varies its speed in an unpredictable way, the ECM may read this as an engine misfire condition. The MEMS 3 detects 'rough road' via a hard wired output from the anti-lock braking system ECU, or dedicated wheel speed sensor fitted to the left hand side rear wheel (non ABS vehicles only). The affect on the wheel speed of a 'rough road' is transmitted by the wheel speed sensor to the ECM. The wheel speed sensor produces 48 pulses for every wheel revolution for non ABS vehicles and approximately 8000 pulses for every mile travelled if the vehicle is fitted with ABS. This pulse train is analysed for consistency, if the wheel is travelling over a rough road, the wheel will be accelerating and decelerating rapidly (see Figure 44) as the wheel navigates the bumps and ridges of the road, it is this variation that provides a rough road signal.

Rough road signal

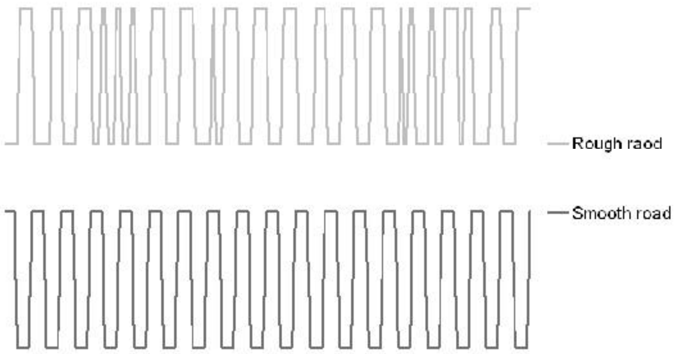

Figure 44

Gearbox information

The ECM talks directly to the Em-CVT gearbox interface unit (GIU) via two direct wires or buses. The GIU and the ECM have one bus for information from the GIU to the ECM and a PWM bus from the ECM to the GIU.

The gearbox receives the information detailed below every 50 ms (assuming the GIU is not reporting any fault information). If a fault occurs with a gearbox input, the ECM receives a fault message. It then knows that the next piece of data it receives will give more information on the fault and not the usual gearbox switch status. This effectively means that the ECM receives gearbox status information every 100 ms and fault information every 100 ms both at 50 ms intervals.

The GIU sends the ECM information on the following:

- The current status of the PRND switch
- The current status of the sport/manual switch
- The current status of the ± switches (steering wheel)
- The current status of the ± switches (gear lever)
- Fault status
- Brake switch input

System outputs

For the ECM to control the engine behaviour, it has to receive information on the current operating conditions as well as send outputs to control external devices. These devices, in turn, affect the engine operating conditions. The ECM inputs have been discussed in the section above. The following section details the units controlled by the ECM, either directly, or via outputs in the form of messages which control or provide information to other systems:

- Stepper Motor
- Purge valve
- Oxygen sensor heaters
- Ignition coils
- Injectors
- Engine bay cooling fan
- Air conditioning relay
- Engine cooling fan
- Tachometer drive
- Indicator lamps/display
- Main relay
- Fuel pump relay
- Engine information to gearbox GIU (automatic only)

Stepper motor

The stepper motor is located on the induction manifold. It is a bipolar type motor and controls an air bleed past the throttle butterfly. The ECM controls the exact amount of air bleed by operating the motor in either direction. As explained in the system input section, there are several devices that monitor engine load and running conditions so that the engine idle speed can be controlled at a constant level at all times.

The bipolar stepper motor, unlike a normal electric motor, will hold its position and resist external forces to move when stationary. The ECM controls the position by switching phases in and out and by altering the direction of the magnetic field. The stepper motor has four wires going to it and by either supplying a battery feed or an earth, the ECM will 'step' the motor in one direction (see Figure 45).

Stepper motor

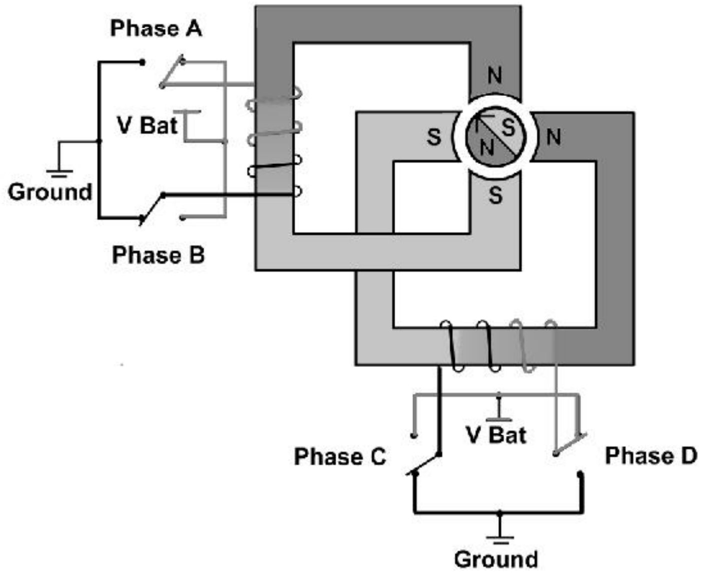

Figure 45

The ECM cycles through each phase change in turn until it reaches the desired position. The motor also contains gearing to reduce the effect of each rotational step and turn it into a linear movement of a plunger. As a result, the motors operation will have many steps from fully closed to fully open.

If the stepper motor loses its position due to the ECM losing power or a corrupted power down sequence, the ECM will reference the motor by driving the stepper motor against the end stop. This will allow its memory position to synchronise with that of the actual position. This process will take approximately three to five seconds.

If the ECM fails to control the motor correctly or there is an internal fault with the stepper motor, the driver will notice poor idle characteristics, stalling and poor starting. If the motor has stuck in a position which allows excessive amounts of air into the engine, the engine may race when hot.

Cooling fan

MEMS 3 controls the two cooling fans. The operation of the fans will depend on several inputs, these are:

- Coolant temperature
- Air conditioning status
- Gearbox request
- Air conditioning fan request
- Coolant temperature sensor reliability

The ECM monitors these inputs and can decide to operate the engine cooling fans in one of three conditions:

1. No operation
2. Single fan operation
3. Both fan operation

The table ’Cooling fan operation’ details the exact operation and conditions that need to apply for the ECM to switch the fan/fans on. Any parameter reading ’yes’ will activate the condition. For example, a single fan will operate if the air condition request is received by the ECM regardless of any other parameter or engine temperature.

Cooling fan operation

Fan operation	Coolant temp on °C	Coolant temp off °C	Air conditioning fan request	Trinary Switch active	Gearbox request	Coolant sensor status, Valid = No	Engine running status
Off	< 104	—	No	No	No	Valid	Yes
Off	< 114	—	No	No	No	Valid	No
Single	> 104	<98 or > 112	Yes	No	Yes	Valid	Yes
Both	> 112	< 106	No	Yes	No	Non-valid	Yes
Both	> 108	< 104	No	No	No	Valid	No

Tachometer drive

The ECM provides the instrument pack with an engine speed signal, 2 pulses for every engine revolution. The instrument pack then interprets the signal and drives the tachometer (see Figure 46).

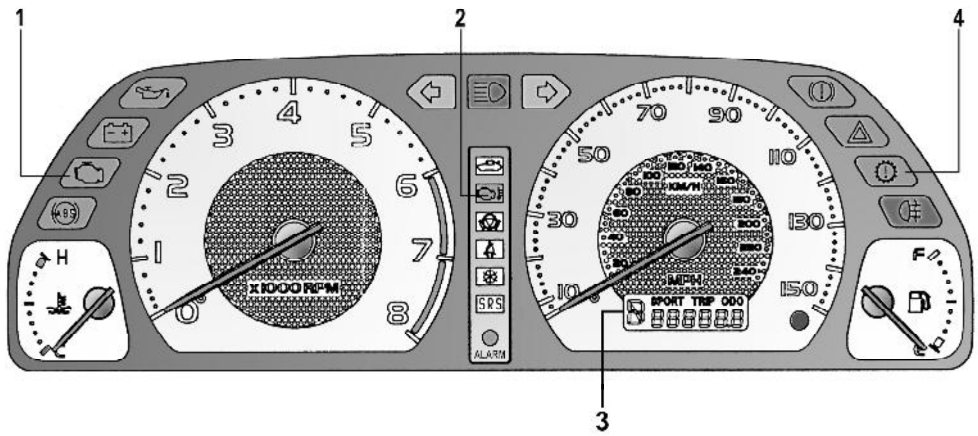

Figure 46

1.Malfunction indicator lamp
2.Engine bay over temperature warning lamp
3.Gear position and mode display
4.Gearbox malfunction indicator lamp

Indicator lamps

The MIL lamp is activated by the instrument pack when the ignition switch is moved from position I to position II. It will turn off when the engine is started. The ECM can ask the instrument pack to illuminate the MIL light emitting diode (LED) (see Figure 46) by supplying a path to ground.

The ECM will also illuminate a warning lamp/display for the following functions:

- If the engine bay gets too hot
- A gearbox warning if the ECM or the GIU reports a fault
- The current position of the gearbox PRND switch (if in automatic mode)
- The virtual gear position when the vehicle is in manual mode
- A display to indicate when sports mode is selected

Gearbox interface (automatic only)

The ECM provides information for the gearbox ECU via a PWM bus. The ECM controls the position of the ratio control motor indirectly (by means of instructing the GIU to control the motor to a given position).

The ECM can interrogate the GIU for fault diagnostics and to request real time data and system performance checks when the vehicle is connected to TestBook.

Gearbox control strategy

The gearbox control is incorporated into the ECM. The ECM, as previously explained, does not control the gearbox ratio directly but does provide all of the intelligence relating to the required position of the ratio control motor, it also provides the intelligence for how fast it should be operated.

The ECM controls the gearbox in one of four modes:

1. Em-CVT mode (normal driving)
2. Em-CVT sports mode
3. Manual mode
4. Fault mode

In Em-CVT modes, the control system operates by deriving a target engine speed based on current vehicle speed and throttle position. In manual mode, the system derives a target engine speed based on the vehicle speed and the current gear ratio. Having obtained an engine speed target, the system calculates the appropriate ratio control motor position and instructs the GIU to deliver this position.

The engine load calculation will depend on two factors:

1. The vehicles road speed
2. The drivers demand

The ECM also needs to control the speed of the ratio control motor in order to protect the gearbox from damage due to drive belt slippage. This is more likely to occur at low gearbox oil temperatures, and when the gearbox is delivering a large change in ratio (for example, after a manual gear change, or sudden throttle movement in Em-CVT mode). Four speeds are used by the system:

1. 50 steps per second
2. 125 steps per second
3. 166 steps per second
4. 250 steps per second

The motor is accelerated as appropriate to ensure the motor does not lose its reference, thereby compromising system control.

The ECM also knows the maximum torque that the belt can transfer across all possible ratio ranges. It is extremely important that the belt is not allowed to slip on the pulleys as this would cause excessive wear.

Target engine speed

As explained above, the target engine speed is critical in deciding the position of the ratio control motor. The ECM will keep changing the ratio of the motor to achieve the target engine speed. The target engine speed is mapped inside the ECM against two axes;

1. Road speed
2. Throttle position

The map is not linear. To achieve good driving characteristics the engine target speed map is programmed to overcome;

- the initial engine speed required to build pressure within the hydraulic clutch
- the hydraulic profile of the gearbox itself
- the engines power and torque profile

Representation of the target engine speed map

Road Speed km/h \ Throttle angle %	0	10	20	30	40	50	60	70	80	90
0	0	0	0	0	0	0	0	0	0	0
10	0	2300	↔	↔	3000	↔	↔	↔	4000	4000
20	0	2400			3200	↔	↔	↔	4000	4000
30	1500	2500	↔	3200	↔	↔	↔	4000	↔	4000
40	1600	2600	↔	3300	↔	↔	↔	4000	↔	4000
50	1700	2700	↔	3400	↔	↔	↔	4000	↔	4000
60	1800	2800	↔	3500	↔	↔	4000	↔	↔	4000
70	1900	3000	↔	3600	↔	4000	↔	↔	↔	4000
80	2000	3300	↔	↔	↔	4000	↔	↔	↔	4000
90	2100	3500	↔	↔	↔	↔	4000	↔	↔	4000
100	2200	3700	↔	↔	↔	↔	4000	↔	↔	4000
110	2300	4200	↔	↔	↔	↔	4600	↔	↔	4300
120	2400	4500	↔	↔	↔	↔	↔	4600	↔	4600
130	2500	4800	↔	↔	↔	↔	↔	4900	↔	4900
140	2600	5000	↔	↔	↔	↔	5100	↔	↔	5100
150	2700	5000	↔	↔	↔	↔	5400	↔	↔	5400
160	2800	5000	↔	↔	↔	5700	↔	↔	↔	5700
170	2900	5000	↔	↔	↔	6000	↔	↔	↔	6000
180	3000	5000	↔	↔	6000	↔	↔	↔	↔	6000

Figure 47

***Note**: the arrows in the chart indicates the movement between two values.*

It must be understood that the illustration titled “Representation of the target engine speed map” (see Figure 47) is only supplied to increase the understanding of ECM control, the values are not true representations of the actual map.

When the gearbox is operating in the Em-CVT mode (drive), the driver does not experience full engine power until the road speed exceeds 70 mph. The slight reduction between the power produced at 4,000 rpm and ≈ 5,200 rpm (maximum power) is approximately 4%. This slight loss of power is compensated for by a quiet, smooth, more natural response from the engine and gearbox.

Sports mode

Sports mode is selected by moving the gear lever to the left. The instrument pack will display the word 'SPORT' within it's LCD along with the letter 'D'. The ECM uses the same map programmed into the ECM as it uses for normal Em-CVT mode but applies a scalar function to the throttle angle. For example if the driver selects sports mode and has the throttle applied by 40%, the scalar function will be applied so that the ECM uses a throttle angle of 60% to calculate its target engine speed.

It is not possible for the ECM to exceed the maximum value of 90% throttle angle, as such, sports mode has less affect when the driver uses very large throttle angles.

Manual mode

Manual mode is selected by the driver moving the gear lever into the sports mode position and then by moving the steering wheel switches or gear lever in a plus or minus position. As soon as the ECM receives one of these switched inputs via the GIU the ECM stops displaying the 'SPORT' message and changes to one of six gear position displays. The ECM can control the gearbox so that the input shaft speed relative to the output shaft speed is fixed in one of six ratios. This gives the effect that the vehicle has a six speed manual box with a sequential gear change. The table titled 'Gear ratios' gives the ratios of these six positions.

Gear ratios

Gear position	mph per 1000 rpm	km/h per 1000 rpm
1	4.6	7.36
2	7.5	12.0
3	10.15	16.24
4	13.5	21.6
5	16.75	26.8
6	22.0	35.2

It is important to note that the primary and secondary pulleys do alter their position to maintain the gearbox input/output ratio. This is because the gearbox does not operate within a linear range over the entire engine/road speed range.

For most driving conditions, the driver has complete control over the current gear ratio and whether to change up or down. However there are some circumstances under which the ECM will force a gearshift to take place, or ignore a driver request, in order to protect the transmission.

- If the driver accelerates in any gear such that the engine speed exceeds about 6,000 rpm, an up-shift is forced to protect the gearbox
- If the driver attempts a down-shift and the target engine speed exceeds about 5,500 rpm, the shift is prohibited
- If the vehicle is coasting to a halt, the system automatically selects an appropriate gear to target

During downshift when coasting to a stop the ECM displays to the driver the gear it has selected. This happens so that the driver does not need to continually down-shift to pull away from rest. Of course, the driver can perform the down-shifts if so desired.

Fault mode

When the ECM or GIU detects a faul, the ECM will position the ratio motor at 130 steps (full range equalling 0-428 half steps, 213.5 full steps). In this position the vehicle still has reasonable driving characteristics. The driver will however notice, that the engine speed hovers around 2800-2500 for most driving conditions.

The ECM will also illuminate the warning lamp in the instrument pack and will not display any gear position in the LCD display.

There are five faults that the ECM will not default the gearbox into its limp home position. These are:

1. Gear lever + switch failure
2. Gear lever - failure
3. Steering wheel + switch failure
4. Steering wheel - switch failure
5. Sport mode switch failure

The ECM will not operate the sequential gear changes in manual mode if these switches are faulty.

The ECM handles the faults of the gearbox with a different strategy than that of the EMS faults. The ECM will illuminate the lamp without debouncing the fault first (on the first occurrence of the fault). The ECM will switch off the lamp if the fault clears itself within an ignition cycle.

Gearbox reset and reference

The ECM, as previously mentioned, controls the position of the ratio motor. It does this by sending the exact position (in steps) it wishes the GIU to set the stepper motor. The ECM then monitors the engine speed to ensure that the load from the gearbox has altered the engine speed in accordance with its expectations. If the engine speed does not follow its expectations it assumes the GIU has lost its position reference of the stepper motor. When this loss of position happens the ECM orders a reset. The GIU then resets its internal position counter to that of the ECM's. The ECM will also stop any 'learning' for that ignition cycle (see adaptions).

The ECM completes a reference every time the ignition is switched 'off' or 'on'. These two references are different because of the need to set the gearbox in the appropriate position.

Power down reference

The ECM completes the following procedure when the ignition is switched 'off':

- The ECM sends a command for the GIU to move the stepper motor 428 half steps (214 full steps) in the closed position (full range)
- The ECM sends a command for the GIU to move the motor 130 full steps out (default position)

The reason for sending the motor back to its fully closed position is that it ensures that the motor is fully retracted. A command to retract a fully retracted motor does not damage the motor. The reason for then positioning the motor at 130 steps is that if a failure happens when the ignition is switch 'off' the ratio motor will allow the driver to use the vehicle in the fault mode.

Power up reference

The ECM completes the following procedure when the ignition is switched 'on':

- The ECM sends a command for the GIU to move the stepper motor 428 half steps in the closed position (full range)
- The ECM sends a command for the GIU to move the motor 10 steps out (start position)

The reason for sending the motor back to its fully closed position is that it ensures that the motor is fully retracted. The reason for then positioning the motor at 10 full steps is that it prepares the vehicle to pull away.

Engine management adaptions

The ECM has many adaptions which it employes in order to provide optimal control of its functions and outputs. Most of the adaptions are used to ensure that the vehicles emission levels do not exceed the legislative requirements. Some of the adaptions are used to provide improved driving characteristics, for example the adaptions for the idle speed motor.

Two adaptions that require further explanation are the crankshaft adaption and the gearbox adaption. Both these adaptions require the technician to complete set procedures to set the base point for further automatic adaptions. The need for this arises when the ECM is replaced or other mechanical units/parts are replaced/disturbed.

Crankshaft position sensor

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

To set the flywheel adaptions, follow the procedure detailed below. This procedure should be carried out in an appropriate area off the public highway or in a quite road where speeds of approximately 80 kph (50 mph) can be obtained with room to decelerate at the natural deceleration rate of the vehicle until it reaches engine idle speed.

1. With the engine warm, >86°C (187°F), select 2nd gear
2. Accelerate the vehicle until the engine speed reaches at least 5,000 rpm
3. Release the throttle fully and allow the vehicle to decelerate until the engine idle speed is reached (or just above) without applying the brakes
4. Repeat the above procedure several times to ensure that the new value has been recorded
5. Check for any fault codes after this procedure using TestBook, clear any misfire faults.

If a new ECM has been fitted, TestBook can be used to view the crankshaft adaption to ensure that it is set. If any other component has been altered that effects this adaption, it is not possible to view the difference between the old adaption and the new one.

Gearbox adaption

Due to manufacturing tolerances in the gearbox, and since the Em-CVT system is subject to many strict legislative requirements, it is essential to put the control system through a learning procedure, before the gearbox can be controlled effectively.

The 'learn' mode can be recognised because the LCD gear display will alternately flash the current gear and the 'F' character. 'F' stands for 'Fast adaption'- the control system is being adapted to adjust its control thus optimising the performance of the gearbox within the particular vehicle. If the gearbox or EMS is changed in the future, the Fast adaption procedure must be repeated.

The gearbox hydraulic/mechanical characteristics can be mapped inside the ECM. The curve of the input shaft speed verses output shaft speed looks like a straight line up to approximately 2,500 rpm. It then plateau's before rising in a curved manner. This profile will be a similar shape for all gearboxes but its position plotted against engine speed will vary. If the gearbox had a linear response (a normal manual gearbox) the line would beapproximately equal to that of the line of best fit (see Figure 48). The figures quoted are only representative, due to the nature of the adaption, these may or may not be correct.

Gearbox profile

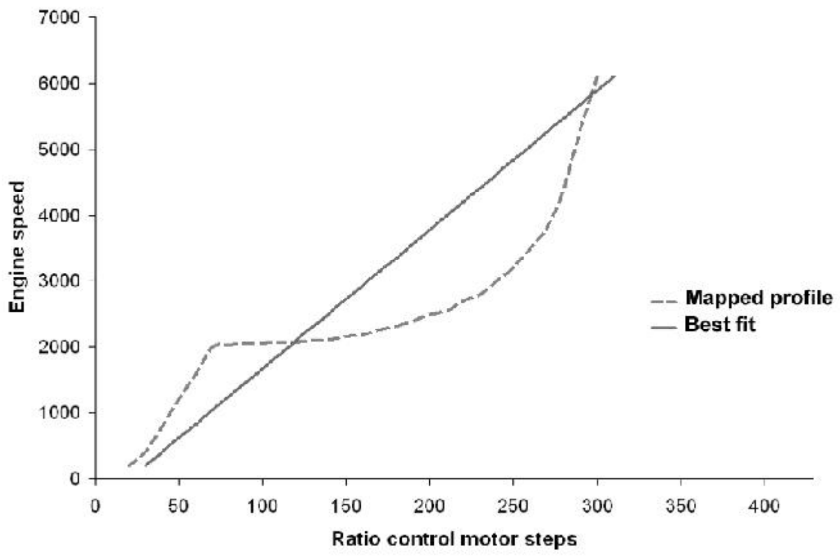

Figure 48

The ECM knows the shape of the profile and monitors the actual engine speed relative to the mapped engine speed. The ECM learns, through historical control, a new profile which is more representative to the actual gearbox characteristics. The ECM also monitors the amount this line moves from the mapped line, as long as this difference is within its tolerance band, the ECM accepts the value and learns from it (see Figure 49). If the actual value goes beyond the adaptive tolerance the ECM will perform a reset. If the value still exceeds the adaptive tolerance band, the ECM will store a fault code and place the gearbox into its default position.

Gearbox adaption

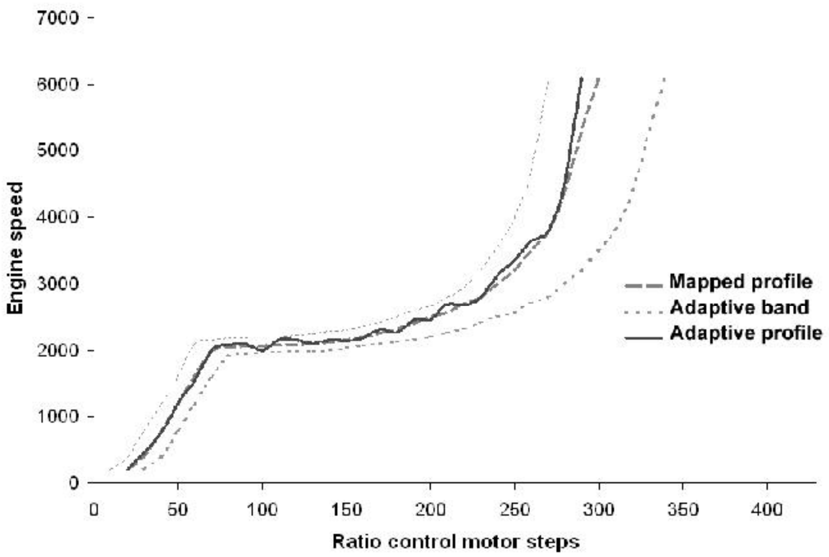

Figure 49

The figures quoted are only representative, due to the nature of the adaption, these may or may not be correct.

When setting the fast adaption, the control system will initially target 5,000 rpm in order to learn the actuator position at this engine speed. Once the vehicles powertrain is stable enough for an adaption to take place, the actuator position is noted and the control system will target 4,500 rpm. This process continues subsequently targeting 4,000, 3,500, 3,000, 2,500, 2,000, 1,900, 1,800, 1,700, 1,600, 1,500, 1,400. When the 1,400 rpm point has been adapted, normal operation will commence.

To set the fast adaption procedure drive the car, on a level road, at around 60kph in Em-CVT Drive mode, and then lift off the throttle. As the car decelerates (**do not** use the brakes) the adaptions will occur. If the vehicle speed drops too far before the process is complete, the engine speed will drop from its targeted speed back towards idle. The LCD will continue to flash ’F’, and the gearbox will not operate normally. If this happens, simply repeat the process by accelerating back to 60kph and lift off the throttle again to give the software a chance of learning the remaining points. When the procedure is complete, the display will stop flashing.

On the completion of a fast adaption, the lifetime adaption strategy will commence, fine tuning the response of the control system for the gearbox attached to a particular car. If either the MEMS 3 or gearbox is changed during the service life of the vechicle, the fast adaption strategies must be reset, which in turn will reset the lifetime strategy so it starts learning from the new base point.

Glossary

The following lists the abbreviations used within this document.

Acronym	Description
ABS	Antilock braking system
CVT	Continuously variable transmission
D	Drive
EAT	Electronic automatic transmission
ECD	European commission directive
ECM	Engine control module
EMS	Engine management system
EOBD	European on-board diagnostics
EPAS	Electronic power assisted steering
ECU	Electronic control unit
EM-CVT	Electro magnetically continuously variable transmission
EMS	Engine management system
GIU	Gearbox interface unit
HEVAC	Heating, ventilation and air conditioning
Hz	Hertz
IAC	Inlet air control
Km/h	Kilometers per hour
LCD	Liquid crystal display
LED	light emitting diode
LH	Left hand
M	Manual
MEMS	Modular engine management system
MIL	Malfunction indicator lamp
MM	Millimetres
MPH	Miles per hour
N	Neutral
OBD	On-board diagnostics
P	Park
RPM	Revolutions per minute
PWM	Pulse width modulation
SIL	Shift interlock
TMAP	Temperature manifold absolute pressure
VVC	Variable valve control