CHAPTER

Transmission systems

9.1 Manual transmission

9.1.1 Clutch

A clutch is a device for disconnecting and connecting rotating shafts. In a vehicle with a manual gearbox, the driver pushes down the clutch when changing gear to disconnect the engine from the gearbox. It also allows a temporary neutral position for, say, waiting at traff c lights and a gradual way of taking up drive from rest.

The clutch is made of two main parts: a pressure plate and a driven plate. The driven plate, often termed the clutch disc, is f tted on the shaft, which takes the drive into the gearbox. When the clutch is engaged, the pressure plate presses the driven plate against the engine f ywheel. This allows drive to be passed to the gearbox. Pushing down the clutch springs the pressure plate away, which frees the driven plate. The diaphragm-type clutch replaced an earlier type with coil springs as it has a number of advantages when used on light vehicles (Figures 9.1 and 9.2):

Key fact

A clutch is a device for disconnecting and connecting rotating shafts.

Figure 9.1 Clutch cover and pressure plate

Figure 9.2 Clutch disc

Key fact

The clutch is made of two main parts: a pressure plate and a driven plate.

- not affected by high speeds (coil springs can be thrown outwards);
- low pedal force making for easy operation;
- light and compact;
- clamping force increases or at least remains constant as the friction lining wears.

The method of controlling the clutch is quite simple. The mechanism consists of either a cable or hydraulic system.

9.1.2 Manual gearbox

Key fact

Power travels in to the gearbox via the input shaft.

The driver changes the gears of a manual gearbox by moving a hand-operated lever called a gear stick or shift lever. All manual gearboxes have a neutral position; three, four or f ve forward gears; and a reverse gear. A few even have six forward gears now. The driver puts the gearbox into neutral as the engine is being started, or when a car is parked with the engine left running (Figure 9.3).

Power travels in to the gearbox via the input shaft. A gear at the end of this shaft drives a gear on another shaft called the countershaft or layshaft. A number of gears of various sizes are mounted on the layshaft. These gears drive other gears on a third motion shaft also known as the output shaft.

The gearbox produces various gear ratios by engaging different combinations of gears. For reverse, an extra gear called an idler operates between the countershaft and the output shaft. It turns the output shaft in the opposite direction to the input shaft.

Figure 9.4 shows the power f ows through a manual box in each of the different gears. Note how in each case (with the exception of reverse) the gears do not move. This is why this type of gearbox has become known as constant mesh. In other words, the gears are running in mesh with each other at all times. Dog clutches are used to select which gears will be locked to the output shaft.

Figure 9.3 Manual gearbox with a cable change mechanism (Source: Ford Media)

These clutches which are moved by selector levers incorporate synchromesh mechanisms.

A synchromesh mechanism is needed because the teeth of the dog clutches would clash if they met at different speeds. The system works like a friction-type cone clutch. The collar is in two parts and contains an outer toothed ring that is spring-loaded to sit centrally on the synchromesh hub. When the outer ring (synchroniser sleeve) is made to move by the action of the selector mechanism, the cone clutch is also moved because of the locking keys. The gear speeds up as the cones touch, thus allowing the dog clutches to engage smoothly. A baulking ring is f tted between the cone on the gear wheel and the synchroniser hub. This is to prevent engagement until the speeds are synchronised (Figure 9.5).

Key fact

A synchromesh mechanism is needed because the teeth of the dog clutches would clash if they met at different speeds.

A detent mechanism is used to hold the selected gear in mesh. In most cases, this is just a simple ball and spring acting on the selector shaft(s). Gear selection interlocks are a vital part of a gearbox. These are to prevent more than one gear from being engaged at any one time. On the single rail (one rod to change the gears) gearbox shown in the f gure, the interlock mechanism is shown at the rear. As the rod is turned (side-to-side movement of the gear stick) towards f rst–second, third–fourth or f fth gear positions, the interlock will only engage with either the f rst–second, third–fourth or f fth gear selectors as appropriate. Equally when any selector clutch is in mesh the interlock will not allow the remaining selectors to change position.

Key fact

Gear selection interlocks prevent more than one gear from being engaged at any one time.

Key fact

A detent mechanism is used to hold the selected gear in mesh.

9.1.3 Driveshafts and wheel bearings

Light vehicle driveshafts now fall into one of two main categories, the f rst being by far the most popular.

- **Driveshafts with constant velocity joints (FWD)** – transmit drive from the output of the f nal drive to each front wheel. They must also allow for suspension and steering movements.
- **Propshaft with universal joints (RWD) –** transmits drive from the gearbox output to the f nal drive in the rear axle. Drive then continues through the f nal

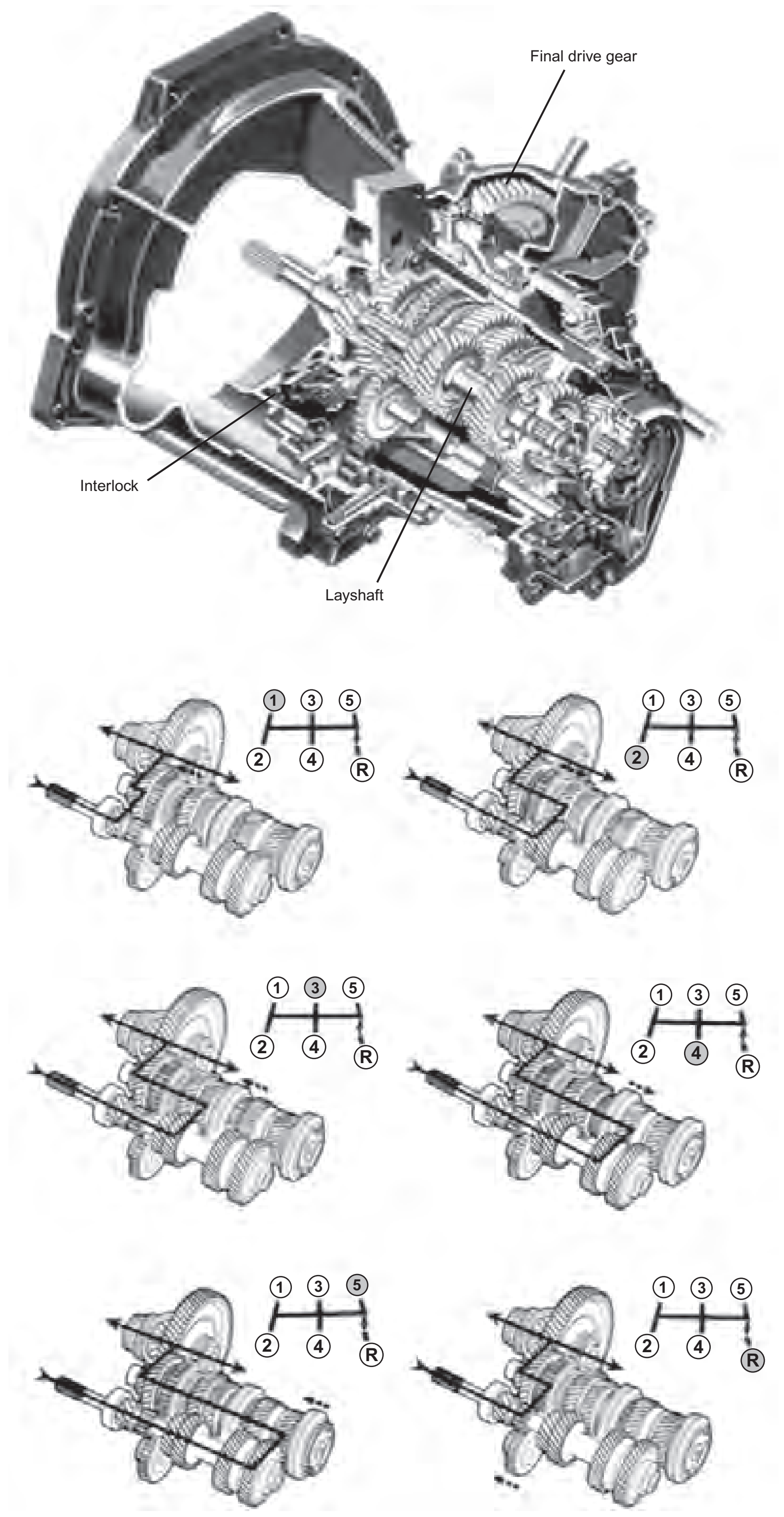

Figure 9.4 Five-speed manual gearbox and powerflows

drive and differential, via two half shafts to each rear wheel. The propshaft must also allow for suspension movements.

Wheel bearings are also very important. They allow smooth rotation of the wheel but must also be able to withstand high stresses such as from load in the vehicle and when cornering (Tables 9.1 and 9.2).

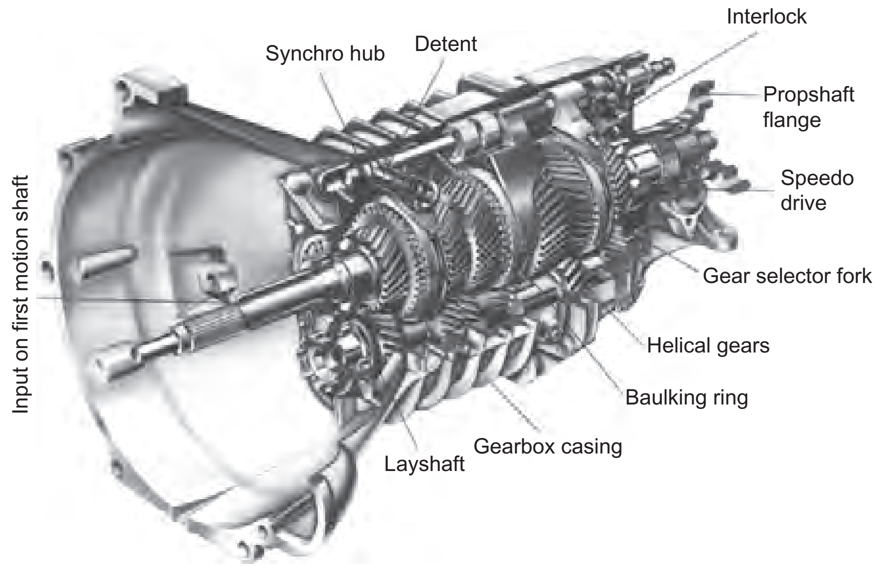

Figure 9.5 RWD manual gearbox

Table 9.1 Front bearings

Seal	Keep out dirt and water, and keep in the grease lubrication
Spacer	Ensures the correct positioning of the seal
Inner bearing	Supports the weight of the vehicle at the front, when still or moving. Ball bearings are used for most vehicles with specially shaped tracks for the balls. This is why the bearings can stand side loads when cornering
Swivel hub	Attachment for the suspension and steering as well as supporting the bearings
Outer bearing	As for inner bearing
Drive fange	Runs inside the centre race of the bearings. The wheel is bolted to this fange

Table 9.2 Rear bearings

Stub axle	Solid mounted to the suspension arm, this stub axle fits in the centre of the two bearings
Seal	Keep out dirt and water, and keep in the grease lubrication
Inner bearing	Supports the weight of the vehicle at the rear, when still or moving. Ball bearings are used for most vehicles with specially shaped tracks for the balls. This is why the bearings can stand side loads when cornering
Spacer	To ensure the correct spacing and pressure between the two bearings
Drum	For the brakes and attachment of the wheel
Outer bearing	As for inner bearing
Washer	The heavy washer acts as a face for the nut to screw against
Castle nut and split pin	Holds all parts in position securely. With this type of bearing, no adjustment is made because both bearings are clamped on to the spacer. Some older cars use tapered bearings and adjustment is very important
Grease retainer cap	Retains grease, but should not be overpacked. Also keeps out the dirt and water

9.1.4 Final drive and differential

Key fact

The final drive gears provide a fixed gear reduction.

Because of the speed at which an engine runs, and in order to produce enough torque at the road wheels, a f xed gear reduction is required. This is known as the f nal drive and consists of just two gears. These are f tted after the output of the gearbox, on front wheel drive, or in the rear axle after the propshaft on rear wheel drive vehicles. The gears also turn the drive through 90° on rear wheel drive vehicles. The ratio is normally about 4:1; in other words, when the gearbox output is turning at 4000 rpm, the wheels will turn at 1000 rpm.

Many cars now have a transverse engine, which drives the front wheels. The power of the engine therefore does not have to be carried through a right angle to the drive wheels. The f nal drive contains ordinary reducing gears rather than bevel gears.

The differential is a set of gears that divide the torque evenly between the two drive wheels. The differential also allows one wheel to rotate faster than the other does when necessary. When a car goes around a corner, the outside drive wheel travels further than the inside one. The outside wheel must therefore rotate faster than the inside one to cover the greater distance in the same time.

Some higher-performance vehicles use limited slip differentials. The clutch plates are connected to the two output shafts and hence if controlled will in turn control the amount of slip. This can be used to counteract the effect of one wheel losing traction when high power is applied.

Differential locks are used on many off-road type vehicles. A simple dog clutch or similar device prevents the differential action. This allows far better traction on slippery surfaces.

9.1.5 Four-wheel drive systems

Key fact

The transfer gearbox on some vehicles may also contain extra reduction gears for low ratio drive.

Four-wheel drive (4 WD) provides good traction on rough or slippery surfaces. Many cars are now available with 4 WD. In some vehicles, the driver can switch between 4 WD and two-wheel drive (2 WD). A vehicle with 4 WD delivers power to all four wheels. A transfer box is used to distribute the power between the front and rear wheels:

- transfer gearbox to provide an extra drive output;
- differential on each axle to allow cornering speed variations;
- centre differential to prevent wind-up between the front and rear axles;
- extra drive shafts to supply drive to the extra axle (Figure 9.6).

One problem to overcome, however, with 4 WD is that if three differentials are used, then the chance of one wheel slipping actually increases. This is because the drive will always be transferred to the wheel with least traction – like running a 2 WD car with one driving wheel jacked up. To overcome this problem and take advantage of the extra traction available, a viscous coupling is combined with an epicyclic gear train to form the centre differential.

The drive can now be distributed proportionally. A typical value is approximately 35% to the front and 65% to the rear wheels. However, the viscous clutch coupling acts so that if a wheel starts to slip, the greater difference in speed across the coupling will cause more friction and hence more drive will pass through the coupling. This tends to act so that the drive is automatically distributed to the most effective driving axle. A ‘Hyvo’ or silent chain drive is often used to drive from the transfer box.

Figure 9.6 4 WD transmission layout(Source: Ford Media)

9.2 Diagnostics – manual transmission

9.2.1 Systematic testing

If the reported fault is a slipping clutch, proceed as follows:

1 Road test to conf rm when the fault occurs.
2 Look for oil leaking from the bell housing or general area of the clutch. Check adjustment if possible.
3 If adjustment is correct, then the clutch must be examined.
4 In this example, the clutch assembly must be removed for visual examination.
5 Replace parts as necessary; this is often done as a kit comprising the clutch plate and cover as well as a bearing in some cases.
6 Road test and check operation of all the transmission.

9.2.2 Test equipment

Stethoscope

This is a useful device that can be used in a number of diagnostic situations. In its basic form, it is a long screwdriver. The probe (or screwdriver blade) is placed near the suspected component such as a bearing. The ear piece (or screwdriver handle placed next to the ear) amplif es the sound. Take care though; even a good bearing can sound rough using this method. Compare a known good noise with the suspected one (Figure 9.7).

Safety f rst

Note: You should always refer to the manufacturer's instructions appropriate to the equipment you are using.

9.2.3 Test results

Some of the information you may have to get from other sources such as data books or a workshop manual is listed in the following table:

Test carried out	Information required
Backlash or freeplay	Backlash data is often given, as the distance component will move. The backlash between two gears, for example, should be yersmall
Overdrive operation	Which gears the overdrive is meant to operate in

Figure 9.7 Stethoscope

9.2.4 Manual transmission fault diagnosis table 1

Symptom	Possible causes or faults	Suggested action
Clutch slipping	Clutch worn out Adjustment incorrect Oil contamination	Renew Adjust or check auto-adjuster Rectify oil leak – clutch may also need to be renewed
Jumps out of gear	Gearbox detent fault	Gearbox may require overhaul
Noisy when changing gear	Synchromesh worn	Gearbox may require overhaul
Rapid knocking noise when cornering	Driveshaft CV joints worn or without lubrication	Renew or lubricate joint. Ensure gaiter is in place and in good condition
Whining noise	Wheel bearing worn Other bearings	Renew Investigate and renew if possible
Diff cult to change gear	Clutch out of adjustment Clutch hydraulic fault Gearbox selectors worn	Adjust or check auto-adjuster Check system for air and/or leaks Gearbox may require overhaul

9.2.5 Manual gearbox fault diagnosis table 2

Symptom	Possible cause
Noisy in a particular gear (with engine running)	Damaged gear Worn bearing
Noisy in neutral (with engine running)	Input shaft bearings worn (goes away when clutch is pushed down?) Lack of lubricating oil Clutch release bearing worn (gets worse when clutch is pushed down?)
Diff cult to engage gears	Clutch problem Gear linkage worn or not adjusted correctly Work synchromesh units Lack of lubrication
Jumps out of gear	Gear linkage worn or not adjusted correctly Worn selector forks Detent not working Weak synchromesh units
Vibration	Lack of lubrication Worn bearings Mountings loose
Oil leaks	Gaskets leaking Worn seals

9.2.6 Clutch faults diagnosis table

Symptom	Possible cause
No pedal resistance	Broken cable Air in hydraulic system Hydraulic seals worn Release bearing or fork broken Diaphragm spring broken
Clutch does not disengage	As above Disc sticking in gearbox splines Disc sticking to flywheel Faulty pressure plate
Clutch slip	Incorrect adjustment Worn disc linings Contaminated linings (oil or grease) Faulty pressure plate
Judder when engaging	Contaminated linings (oil or grease) Worn disc linings Distorted or worn pressure plate Engine mountings worn, loose or broken Clutch disc hub splines worn
Noisy operation	Broken components Release bearing seized Disc cushioning springs broken
Snatching	Disc cushioning springs broken Operating mechanism sticking (lubrication may be required)

9.2.7 Drive shafts fault diagnosis table

Symptom	Possible cause
Vibration	Incorrect alignment of propshaft joints Worn universal or CV joints Bent shaft Mountings worn
Grease leaking	Gaiters split or clips loose
Knocking noises	Dry joints Worn CV joints (gets worse on tight corners)

9.2.8 Final drive fault diagnosis table

Symptom	Possible cause
Oil leaks	Gaskets split Drive shaft oil seals Final drive output bearings worn (drive shafts drop and cause leaks)
Noisy operation	Low oil level Incorrect pre-load adjustment Bearings worn
Whining noise	Low oil level Worn differential gears

9.3 Automatic transmission

9.3.1 Introduction

Safety f rst

The selector will not move out of park unless you are pressing the brake pedal on many cars. This is a ẏwer good safety feature as it prevents sudden movement of the vehicle.

An automatic gearbox contains special devices that automatically provide various gear ratios, as they are needed. Most automatic gearboxes have three or four forward gears and reverse. Instead of a gearstick, the driver moves a lever called a selector. Some automatic gearboxes have selector positions for park, neutral, reverse, drive, 2 and 1 (or 3, 2 and 1 in some cases). Others just have drive, park and reverse. The engine will only start if the selector is in either the park or neutral position. In park, the drive shaft is locked so that the drive wheels cannot move. It is now quite common when the engine is running to be able to move the selector out of park only if you are pressing the brake pedal. This is a very good safety feature as it prevents sudden movement of the vehicle.

For ordinary driving, the driver moves the selector to the drive position. The transmission starts out in the lowest gear and automatically shifts into higher gears as the car picks up speed. The driver can use the lower positions of the gearbox for going up or down steep hills or driving through mud or snow. When in position 3, 2 or 1, the gearbox will not change above the lowest gear specif ed.

9.3.2 Torque converter operation

The torque converter is a device that almost all automatic transmissions now use. It delivers power from the engine to the gearbox like a basic f uid f ywheel but also increases the torque when the car begins to move. The torque converter resembles a large doughnut sliced in half. One half, called the pump impeller, is bolted to the drive plate or f ywheel. The other half, called the turbine, is connected to the gearbox input shaft. Each half is lined with vanes or blades. The pump and the turbine face each other in a case f lled with oil. A bladed wheel called a stator is f tted between them.

The engine causes the pump to rotate and throw oil against the vanes of the turbine. The force of the oil makes the turbine rotate and send power to the transmission. After striking the turbine vanes, the oil passes through the stator and returns to the pump. When the pump reaches a specif c rate of rotation, a reaction between the oil and the stator increases the torque. In a f uid f ywheel, oil returning to the impeller tends to slow it down. In a torque converter, the stator or reactor diverts the oil towards the centre of the impeller for extra thrust. Figure 9.8 shows a gearbox with a cutaway torque converter.

When the engine is running slowly, the oil may not have enough force to rotate the turbine. But when the driver presses the accelerator pedal, the engine runs faster and so does the impeller. The action of the impeller increases the force of the oil. This force gradually becomes strong enough to rotate the turbine and move the vehicle. A torque converter can double the applied torque when moving off from rest. As engine speed increases, the torque multiplication tapers off until at cruising speed when there is no increase in torque. The reactor or stator then freewheels on its one-way clutch at the same speed as the turbine.

Key fact

To improve efciency, many transmissions now include a lock-up clutch.

The f uid f ywheel action reduces eff ciency because the pump tends to rotate faster than the turbine. In other words, some slip will occur (approximately 2%). To improve eff ciency, many transmissions now include a lock-up clutch. When the pump reaches a specif c rate of rotation, this clutch locks the pump and turbine together, allowing them to rotate as one.

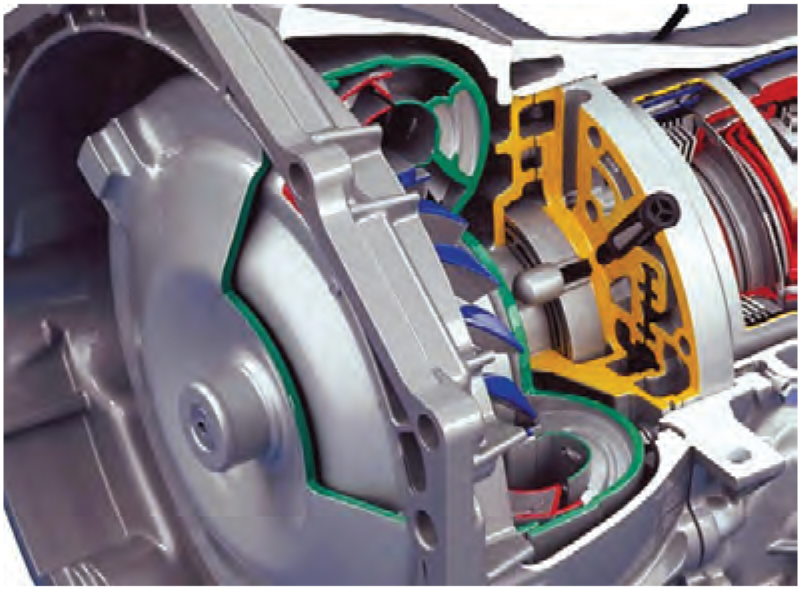

Figure 9.8 Cutaway torque converter (green, red and blue)

9.3.3 Epicyclic gearbox operation

Epicyclic gears are a special set of gears that are part of most automatic gearboxes. They consist of three elements:

1. a sun gear, located in the centre;
2. the carrier that holds two, three or four planet gears, which mesh with the sun gear and revolve around it;
3. an internal gear or annulus is a ring with internal teeth, which surrounds the planet gears and meshes with them.

Any part of a set of planetary gears can be held stationary or locked to one of the others. This will produce different gear ratios. Most automatic gearboxes have two sets of planetary gears that are arranged in line. This provides the necessary number of gear ratios. The appropriate elements in the gear train are held stationary by a system of hydraulically operated brake bands and clutches. These are worked by a series of hydraulically operated valves in the lower part of the gearbox. Oil pressure to operate the clutches and brake bands is supplied by a pump. The supply for this is the oil in the sump of the gearbox (Figure 9.9).

Unless the driver moves the gear selector to operate the valves, automatic gear changes are made depending on just two factors:

1. **throttle opening** – a cable is connected from the throttle to the gearbox;
2. **road speed** – when the vehicle reaches a set speed, a governor allows pump pressure to take over from the throttle.

The cable from the throttle also allows a facility known as ‘kick down’. This allows the driver to change down a gear, such as for overtaking, by pressing the throttle all the way down (Figure 9.10).

Many modern semi-automatic gearboxes now use gears in the same way as in manual boxes. The changing of ratios is similar to the manual operation except that hydraulic clutches and valves are used.

Key fact

Any part of a set of planetary gears can be held stationary or locked to one of the others.

Key fact

Modern semi-automatic gearboxes have paddle change but also work in a fully automatic mode.

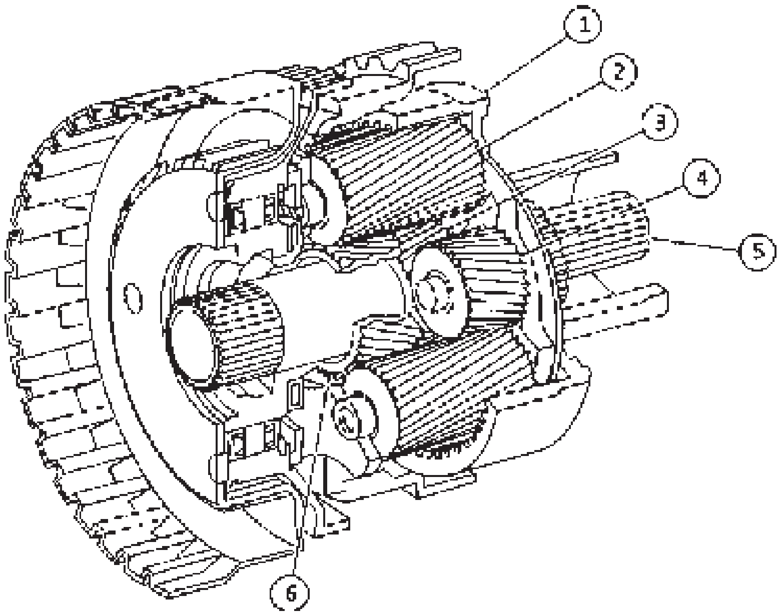

Figure 9.9 Ravigneaux gear set: 1 – ring gear; 2 – long planet gear; 3 – small planet gear; 4 – short planet gear; 5 – transmission input shaft; 6 – large sun gear (Source: Ford Motor Company)

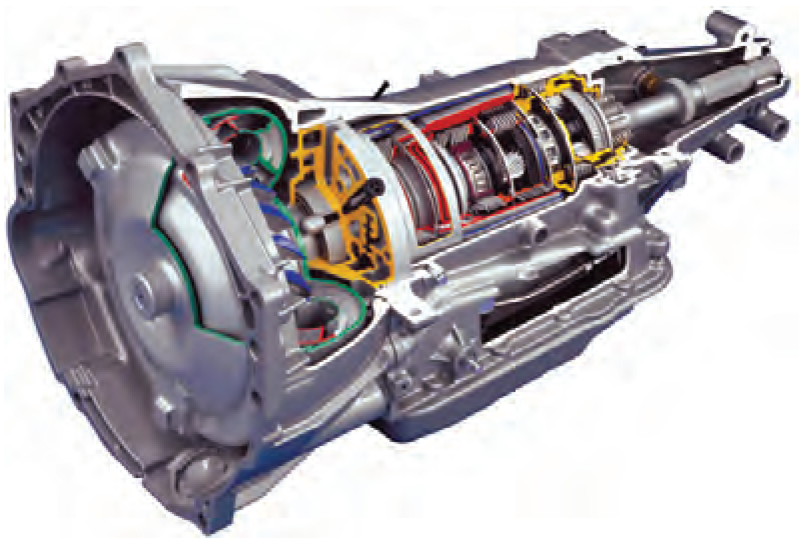

Figure 9.10 RWD automatic gearbox (Source: GM Media)

9.3.4 Constantly variable transmission

Definition

CVT: Constantly variable transmission.

Figure 9.11 shows a constantly variable transmission (CVT). This kind of automatic transmission uses two pairs of cone-shaped pulleys connected by a metal belt. The key to this system is the high friction drive belt.

The belt is made from high-performance steel and transmits drive by thrust rather than tension. The ratio of the rotations, often called the gear ratio, is determined by how far the belt rides from the centres of the pulleys. The transmission can produce an unlimited number of ratios. As the car changes speed, the ratio is

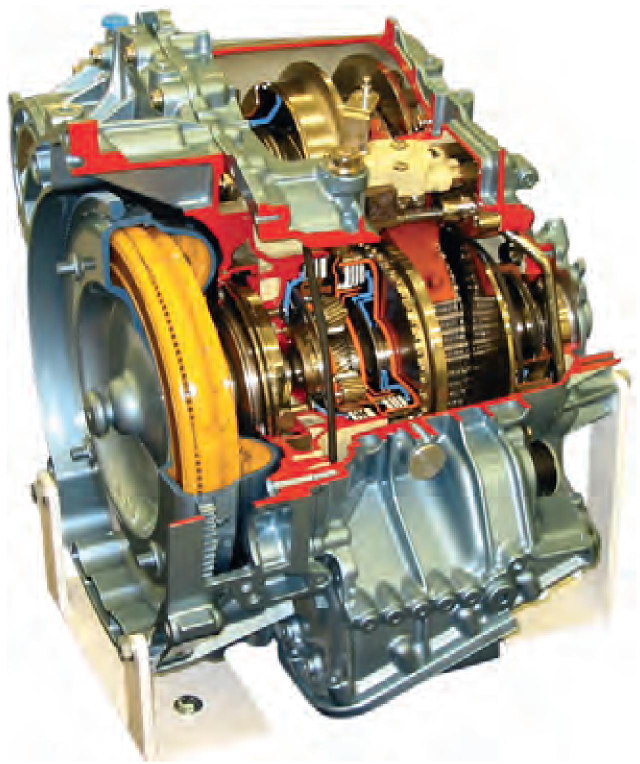

Figure 9.11 Constantly variable transmission(Source: Ford Media)

continuously adjusted. Cars with this system are said to use fuel more eff ciently than cars with set gear ratios. Within the gearbox hydraulic control is used to move the pulleys and hence change the drive ratio. An epicyclic gear set is used to provide a reverse gear as well as a f xed ratio.

Key fact

A CVT transmission can produce an unlimited number of ratios.

9.3.5 Electronic control of transmission

The main aim of electronically controlled automatic transmission (ECAT) is to improve on conventional automatic transmission in the following ways:

- gear changes should be smoother and quieter;
- improved performance;
- reduced fuel consumption;
- reduction of characteristic changes over system life;
- increased reliability.

The important points to remember are that gear changes and lock-up of the torque converter are controlled by hydraulic pressure. In an ECAT system, electrically controlled solenoid valves can inf uence this hydraulic pressure. Most ECAT systems now have a transmission ECU that is in communication with the engine control ECU (Figure 9.12).

With an ECAT system, the actual point of gearshift is determined from pre-programmed memory within the ECU. Data from other sensors is also taken into consideration. Actual gearshifts are initiated by changes in hydraulic pressure, which is controlled by solenoid valves.

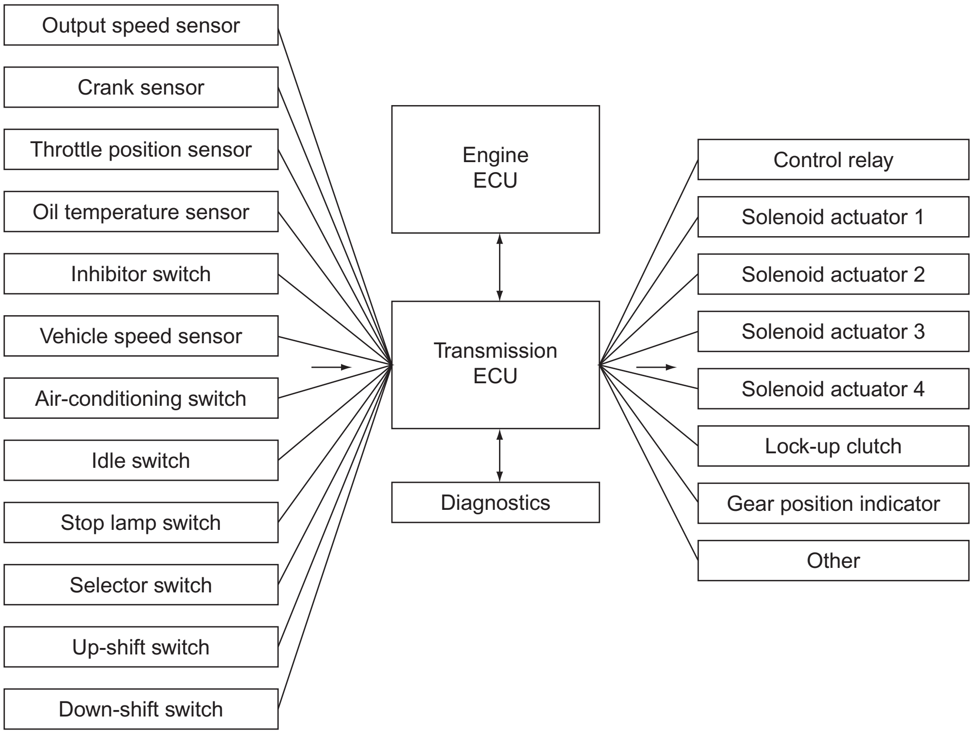

Figure 9.12 ECAT block diagram

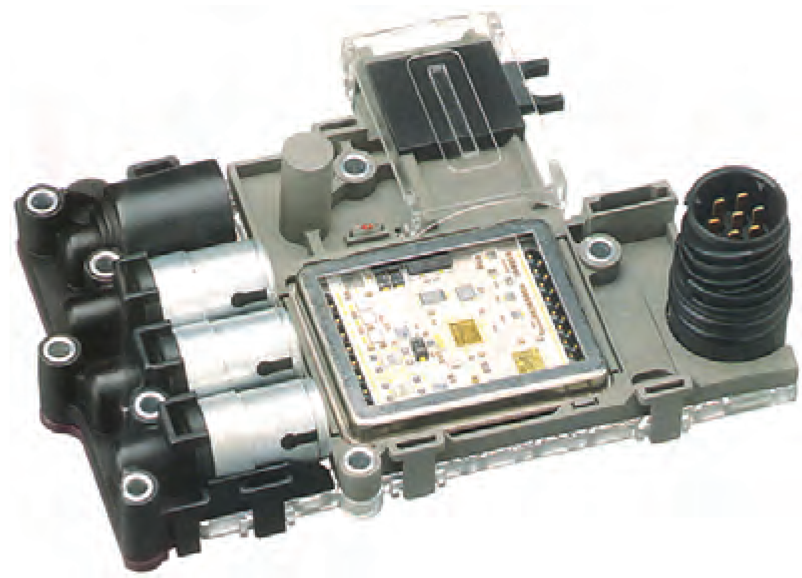

Figure 9.13 Electrohydraulic valve block

The two main control functions of this system are hydraulic pressure and engine torque. A temporary reduction in engine torque during gear shifting allows smooth operation. This is because the peak of gearbox output torque which causes the characteristic surge during gear changes on conventional automatics is suppressed. Because of these control functions smooth gearshifts are possible and, due to the learning ability of some ECUs, the characteristics remain throughout the life of the system (Figure 9.13).

The ability to lock up the torque converter has been used for some time even on vehicles with more conventional automatic transmission. This gives better fuel economy, quietness and improved driveability. Lock-up is carried out using a hydraulic valve, which can be operated gradually to produce a smooth transition. The timing of lock-up is determined from ECU memory in terms of the vehicle speed and acceleration.

Def nition

DSG: Direct shift gearbox.

9.3.6 Direct shift gearbox

The direct shift gearbox (DSG) is an interesting development as it could be described as a manual gearbox that can change gear automatically. It can be operated by 'paddles' behind the steering wheel, a lever in the centre console or in a fully automatic mode. The gear train and synchronising components are similar to a normal manual change gearbox (Figure 9.14).

Key fact

A DSG can be operated by 'paddles' behind the steering wheel.

The direct shift gearbox is made of two transmission units that are independent of each other. Each transmission unit is constructed in the same way as a manual gearbox and is connected by a multiplate clutch. They are regulated, opened and closed by a mechatronics system. On the system outlined in this section:

- 1st, 3rd, 5th and reverse gears are selected via multiplate clutch 1.
- 2nd, 4th and 6th gears are selected via multiplate clutch 2.

Key fact

One transmission unit is always in gear and the other transmission unit has the next gear selected ready for the next change.

One transmission unit is always in gear and the other transmission unit has the next gear selected ready for the next change, but with its clutch still in the open position.

Torque is transmitted from the crankshaft to a dual-mass f ywheel. The splines of the f ywheel, on the input hub of the double clutch, transmit the torque to the drive plate of the multiplate clutch. This is joined to the outer plate carrier of clutch 1 with the main hub of the multiplate clutch. The outer plate carrier of clutch 2 is also positively joined to the main hub.

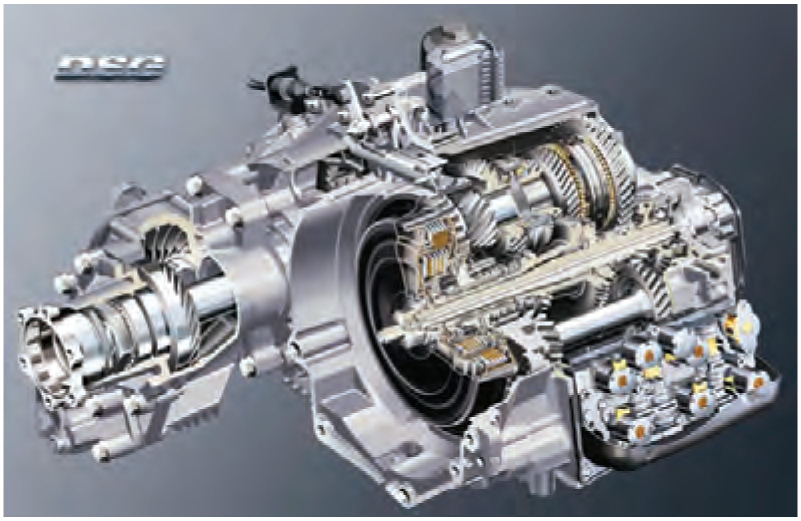

Figure 9.14 DSG (Source: Volkswagen Media)

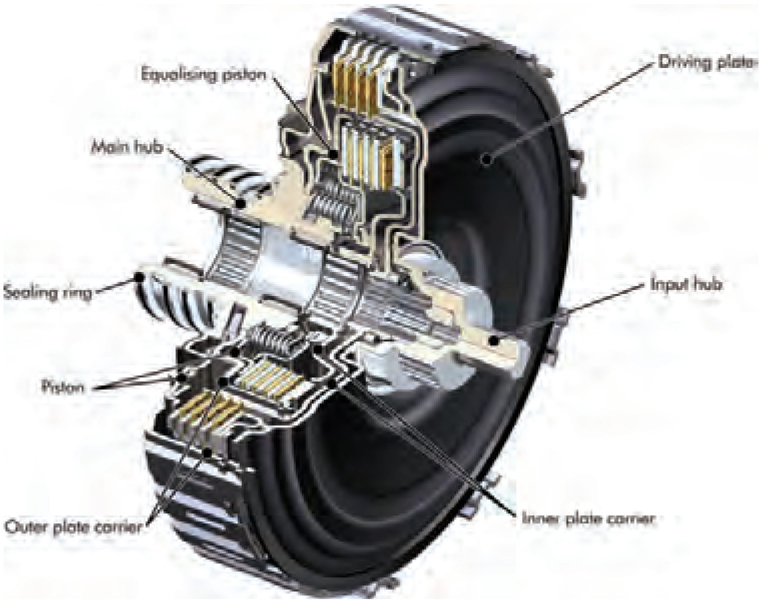

Figure 9.15 Multiplate twin clutch (Source: Volkswagen Media)

Figure 9.16 Ford twin-clutch transmission components (Source: Ford Media)

Torque is transmitted into the relevant clutch through the outer plate carrier. When the clutch closes, the torque is transmitted further into the inner plate carrier and then into the relevant gearbox input shaft. One multiplate clutch is always engaged (Figures 9.15 and 9.16).

9.4 Diagnostics – automatic transmission

9.4.1 Systematic testing

If the reported fault is that the kick down does not operate, proceed as follows:

1. Road test to conf rm the problem.
2. Is the problem worse when the engine is hot? Check the transmission f uid level. Has work been done to the engine?
3. If f uid level is correct, then you must investigate further. Work on the engine may have disturbed the kick down cable.
4. Check the adjustment/f tting of the kick down cable.
5. Adjust if incorrect.
6. Run and repeat road test.

Safety f rst

Note: You should always refer to the manufacturer's instructions appropriate to the equipment you are using.

9.4.2 Test equipment

Revcounter

A revcounter may be used during a stall test to check the operation of the torque converter and the automatic gearbox.

Pressure gauge

This is a standard type of gauge but with suitable adapters for connection to a gearbox. Figure 9.17 shows where various tests can be carried out on an automatic gearbox (Figure 9.18).

9.4.3 Test results

Some of the information you may have to get from other sources such as a data book or a workshop manual is listed in Table 9.3:

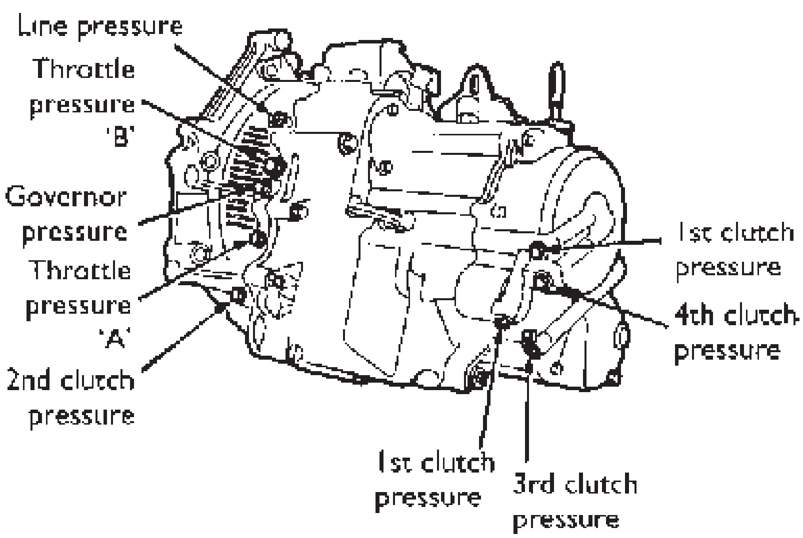

Figure 9.17 Transmission pressure testing points

Figure 9.18 Transmission system pressure test kit (Source: Snap-on)

Table 9.3 Tests and information required

Test carried out	Information required
Stall test	Highest revs expected and the recommended duration of the test
Kick down test	Rpm range in which the kick down should operate. For example, above a certain engine rpm, it may not be allowed to work

9.4.4 Automatic gearbox fault diagnosis table 1

Symptom	Possible faults	Suggested action
Slip, rough shifts, noisy operation or no drive	There are numerous faults that can cause these symptoms	Check the obvious such as fuid levels and condition Carry out a stall test Refer to a specialist if necessary

9.4.5 Automatic gearbox fault diagnosis table 2

Symptom	Possible cause
Fluid leaks	Gaskets or seals broken or worn Dip stick tube seal Oil cooler or pipes leaking
Discoloured and/or burnt smell to fuid	Low fuid level Slipping clutches and/or brake bands in the gearbox Fluid requires changing
Gear selection fault	Incorrect selector adjustment Low fuid level Incorrect kick down cable adjustment Load sensor fault (maybe vacuum pipe, etc.)
No kick down	Incorrect kick down cable adjustment Kick down cable broken Low fuid level
Engine will not start or start in gear	Inhibitor switch adjustment incorrect Faulty inhibitor switch Incorrect selector adjustment
Transmission slip, no drive or poor-quality shifts	Low fuid level Internal automatic gearbox faults often require the attention of a specialist

9.4.6 ECAT fault diagnosis table

Symptom	Possible fault
ECAT system reduced performance or not working	Communication link between engine and transmission ECUs open circuit Power supply/earth to ECU low or not present Transmission mechanical fault Gear selector switch open/short circuit Speed sensor inoperative Position switch fault Selection switch fault

9.4.7 Automatic transmission stall test

To assist with the diagnosis of automatic transmission faults, a stall test is often used. The duration of a stall test must not be more than approximately seven seconds. You should also allow at least two minutes before repeating the test. Refer to manufacturer's recommendations if necessary.

The function of this test is to determine the correct operation of the torque converter and that there is no transmission clutch slip. Proceed as follows:

1 Run engine up to normal operating temperature by road test if possible.
2 Check transmission f uid level and adjust if necessary.

Safety f rst

Warning: If the precautions mentioned are not observed, the gearbox will overheat. Check manufacturer's data to make sure a stall test is an acceptable procedure.

3. Connect a revcounter to the engine.
4. Apply handbrake and chock the wheels.
5. Apply foot brake, select ‘D’ and fully press down the throttle for approximately seven seconds.
6. Note the highest rpm obtained (2500–2750 is a typically acceptable range).
7. Allow two minutes for cooling and then repeat the test in ‘2’ and ‘R’.

CHAPTER 10

Learning activities

10.1 Introduction

This section contains information, activities and ideas to help you learn more about automotive diagnostics. The best place to start is, of course, to read the content of the book. However, do remember when you are doing this to be active – in other words, make some notes, underline or highlight things and do not expect to understand something straight away – work at it!

I have created lots of useful online material that you can use. If you are at a school or college that is licensed to use my full blended eLearning package, you already have access to everything. However, if not at a licensed school or college, I have created a special area for you to use free of charge. Just go to: www.automotive-technology.co.uk and follow the links from there to f nd

- Multimedia (that includes some amazing animations)
- Practical activities
- Multiple-choice questions
- Short answer questions
- Glossaries
- Virtual toolboxes
- And more…

In this chapter, I have not created specif c assessment and learning activities for every subject; instead I have suggested types of activity and made a list of subjects or systems that can be the topic of the work. However, doing an assignment after each section of the book is a good way to check progress.

10.2 Knowledge check questions

To use these questions, you should f rst try to answer them without help, but if necessary, refer back to the content of the chapter. Use notes, lists and sketches as appropriate to answer them. It is not necessary to write pages and pages of text!

10.2.1 Chapter 1 Introduction

1. State the meaning of the terms ‘fault’ and ‘symptom’.
2. Explain how to reduce the risk of a short circuit when testing electrical systems.

3 List the main headings that could be used for a standard report.
4 State the two main pieces of knowledge necessary to diagnose faults.
5 Describe the potential dangers of running an engine in an enclosed space without exhaust extraction.

10.2.2 Chapter 2 Diagnostic techniques

1 List the six-stage diagnostic process in your own words.
2 Explain how the six-stage process is used by giving a simple example.
3 State the length of a standard piece of string and explain why this is relevant to diagnostics!
4 Describe how to carry out tests for an electrical short circuit.
5 Explain using a sketch, what is meant by 'black box' faultf nding.

10.2.3 Chapter 3 Tools and equipment

1 Explain why a good multimeter has a high internal resistance.
2 List three advantages of using an oscilloscope for testing signals.
3 Describe how a scanner is connected to a vehicle and what information it can provide.
4 State what is meant by the term 'accuracy'.
5 List f ve tests carried out on a vehicle using a pressure gauge.

10.2.4 Chapter 4 Sensors, actuators and oscilloscope diagnostics

1 Explain the terms 'timebase', 'amplitude' and 'voltage scale'.
2 Make a sketch of ignition primary and ignition secondary waveforms. Label each part and state which aspects indicate that no faults are present.
3 Describe how to connect an oscilloscope to examine the signal supplied to a single-point (throttle body) injector.
4 State the typical output voltage (peak to peak) of an inductive crankshaft sensor at cranking, idle and 3000 rpm. Sketch the waveform to show the aspects that indicate engine speed and engine position.
5 Explain with the aid of a sketch why current limiting is used on the primary circuit of an ignition system.
6 Explain how a knock sensor operates and why it is used.
7 Describe how to test the operation of a Hall sensor using a multimeter.
8 List in a logical sequence how to diagnose a fault with one fuel injector on a V6 multipoint system.
9 Outline two methods of testing the operation of a sensor that uses a variable resistor (throttle pot or vane-type airf ow sensors for example).
10 Explain with the aid of a sketch, what is meant by 'duty cycle' in connection with an idle speed control valve.

10.2.5 Chapter 5 On-board diagnostics

1 State the main reasons why OBD was developed.
2 Explain what is meant by OBD monitors and list the most common.

3 Describe how the P codes are used to indicate faults.
4 Explain with the aid of a sketch, how the 'before and after cat' lambda sensor signals are used by the OBD system to monitor catalyst operation.
5 Explain what is meant by 'healing of the fault memory'.

10.2.6 Chapter 6 Engine systems

1 Describe how a VAT is used to check battery condition.
2 List in a logical sequence a series of tests that would determine why an engine, which is cranking over correctly, will not start.
3 Describe how the colour of smoke from a diesel engine can be used as an aid to fault diagnosis.
4 Make a block diagram to show the main components of an engine management system and how it can be considered as a series of inputs and outputs.
5 Describe how a cylinder leakage tester is used to check the condition of an engine.

10.2.7 Chapter 7 Chassis systems

1 Describe how to test the operation of an ABS wheel speed sensor.
2 List in a logical sequence a series of tests to determine the cause of steering pulling to one side when braking.
3 Describe a method of testing a damper (shock absorber).
4 Make a sketch to show three different types of tyre wear and state a possible cause for each.
5 Explain why it may be necessary to check the run-out on a brake disc (rotor) and describe how this is done.

10.2.8 Chapter 8 Electrical systems

1 Explain what is meant by 'controller area network (CAN)' and why it is used to connect ECUs or nodes together.
2 List in a logical sequence a series of steps to diagnose why a wiper motor operates on slow speed but not on fast speed.
3 Describe how to check that an on/off relay is operating correctly.
4 Describe how to test the output of a road speed sensor used as part of a cruise control system.
5 Make a sketch of a fuel gauge circuit and describe how to check it for correct operation.

10.2.9 Chapter 9 Transmission systems

1 Describe how to use a road test to diagnose a suspected CV joint fault.
2 Explain why a stall test may be used to diagnose automatic transmission faults.
3 List in a logical sequence a procedure for checking the operation of an electronically controlled automatic transmission.
4 Describe a procedure used to test for a slipping clutch.
5 Describe a series of steps that could be used to diagnose the source of a 'rumbling' noise from a transmission system.

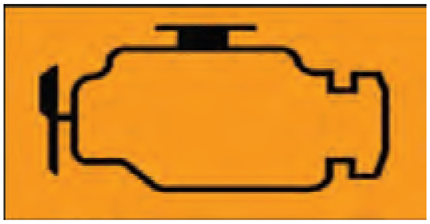

Figure 10.1 Check engine!

10.3 Assignments

Using the information in this book, the resources on www.automotive-technology.co.uk and other Web sources, such as Wikipedia, there are lots of assignments you can carry out.

For example, referring to the subjects/systems listed below, you could

- Write a report to explain the operation and important features of *<insert subject or system here>.* Include images diagrams, tables, charts, bullets as needed. Remember that any report should have a beginning, a middle and an end – in other words, an introduction, the main bit, and a summary or conclusion.
- List the important aspects of *<insert subject or system here>.*
- Outline the diagnostic methods used to trace a fault in *<insert subject or system here>.*
- List the key types and functions of test equipment used to diagnose faults in *<insert subject or system here>.*
- State the reasons why and how a scanner is used to determine fault codes on *<insert subject or system here*>.
- Make a simple sketch to show how tests are carried out on *<insert subject or system here*>.

Your assignments could be 200, 500 or 1000 words long (or more) as appropriate, or as determined by your teacher, instructor or lecturer …. Note that Table 10.1 is pretty much the contents page of this book, but I have removed some parts and edited others to make it more appropriate for this section.

Table 10.1 List of assignment activities

(1) Introduction
(a) Safe working practices
(2) Diagnostic techniques
(a) Diagnostic process
(b) Diagnostics on paper
(c) Mechanical diagnostic techniques
(d) Electrical diagnostic techniques
(e) Fault codes
(f) Systems
(g) Data sources
(3) Tools and equipment
(a) Basic equipment
(b) Oscilloscopes
(c) Scanners/fault code readers and analysers
(d) Emission testing
(e) Pressure testing
(4) Sensors, actuators and oscilloscope diagnostics
(a) Sensors
(b) Actuators
(c) Engine waveforms
(d) Communication networks

(Continued)

Table 10.1 (Continued)

(5) On-board diagnostics
- (a) History
- (b) Misfire detection
- (c) OBD2
- (d) EOBD
- (e) Monitors and readiness flags
- (f) Future developments in diagnostic systems

(6) Engine systems
- (a) Engine operation
- (b) Fuel system
- (c) Ignition
- (d) Emissions
- (e) Fuel injection
- (f) Diesel injection
- (g) Engine management
- (h) Air supply and exhaust systems
- (i) Cooling
- (j) Lubrication
- (k) Batteries
- (l) Starting
- (m) Charging

(7) Chassis systems
- (a) Brakes
- (b) Antilock brakes
- (c) Traction control
- (d) Steering and tyres
- (e) Suspension
- (f) Active suspension

(8) Electrical systems
- (a) Electronic components and circuits
- (b) Multiplexing
- (c) Lighting
- (d) Auxiliaries
- (e) In car entertainment (ICE) security and communications
- (f) Body electrical systems
- (g) Instrumentation
- (h) Heating, ventilation and air conditioning (HVAC)
- (i) Cruise control
- (j) Air bags and belt tensioners

(9) Transmission systems
- (a) Manual transmission
- (b) Automatic transmission

10.4 Tips to help you learn

A good way to learn is to compare one method of doing something with another, for example:

1 What are the differences between OBD1 and OBD2?

2 How do the features of an oscilloscope compare to those of a multimeter?

Another good way to learn is to consider the advantages and disadvantages of things, for example:

1 What are the advantages and disadvantages of a simple test lamp?
2 What are the advantages of a battery discharge test compared to taking a voltage reading?

Also consider reasons why things have changed and developed in the way they have.

1 Why is almost everything now controlled by electronics?
2 Why is a modern scanner an essential tool?

Even thinking of these types of questions is a good way to learn, so I will leave the rest to you!

Safety f rst

Before starting any practical work you should have been trained or be supervised

10.5 Practical work

Remember, before starting any practical work, you should have been trained or be supervised. Also there are some key things you should always do:

1 Fit a vehicle body protection kit.
2 Prepare your standard tool kit.
3 Get the latest information and/or service manual.
4 Comply with personal and environmental safety practices associated with clothing; eye protection; hand tools; power equipment; proper ventilation; and the handling, storage, and disposal of chemicals/materials in accordance with all appropriate safety and environmental regulations.

10.6 Case studies

10.6.1 Introduction

This section outlines f ve short diagnostic case studies. The details are based on real-life situations posted on the International Automotive Technicians Network (IATN) website. I fully recommend this organisation, which is open to you if you are fully qualif ed or suitably experienced. Visit www.iatn.net for more information. Technicians can post information about a problem and ask questions. Others then make suggestions and, after the fault is f xed the original person states the actual fault and the associated repair.

I have edited and made the following case studies anonymous and added a few thoughts of my own. After reading each of these case studies in turn, see if you agree with me and also ask yourself three questions:

1 Was the process logical?
2 Were mistakes made?
3 Would you have done it differently?

This exercise is not meant to be critical of those who requested help. It is hard out there, particularly when customers are involved and are applying pressure – and often not wanting to pay much! However, a reminder to follow a logical process helps all of us. Figure 10.2 represents the recommended six-stage process.

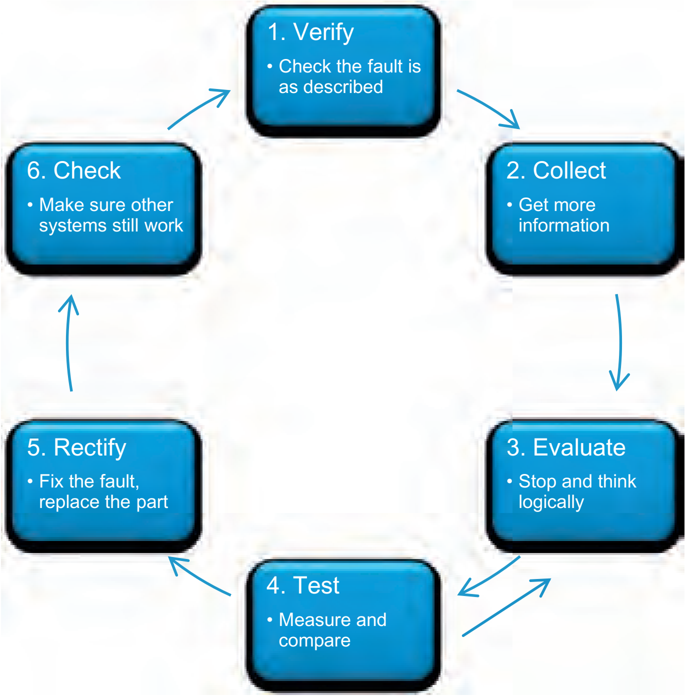

Figure 10.2 Six-stage diagnostic process

10.6.2 1997 Land Rover Discovery

- Mileage: 115 000 mi
- Engine: 4.0 L, 8 cyl, Gas/Petrol
- Trans: 4-speed Automatic
- Delivery: Fuel Injection
- Emissions: OBD-II Compliant
- Symptoms: Excessive Emissions, Hesitation, Misf re, Mil Lamp On
- Occurs: Hot

Related Repair History:

- Replaced items: fuel f lter, fuel pressure regulator, MAF sensor, fuel pump relay, IAC, cam sensor, all O_2 sensors, cat converters, coil pack, plugs, cleaned plenum, TPS

Computer Codes and Descriptions:

- 0152 – O_2 high volts bank 2 sensor1
- 0153 – O_2 high volts bank 1 sensor1
- 1191 – Fuel/air metering high

The car was brought to us with the above parts replaced by a do-it-yourself person. Upon road testing, starting f ne, but loss of power as it warms up. It has a high idle when warm. The scanner reported the O_2 sensors are not responding and are set at 4.5 V. We checked the new ones for correct connections and that they were the correct parts. All parts are OEM Land Rover. Continuity from the ECM to all O_2 sensors was OK.

I understand that the ECM varies the resistance to this type of O_2, thereby varying voltage from 1 to 5 V toggling rich to lean. Does the ECM on these older vehicles just default rich? I understand GEMS need to be reprogrammed if a TPS or other sensors are changed. Is that true for O_2 sensors? It seems to me there is an ECM problem.

Fault:

Intake manifold vacuum leaking. An updated intake gasket was installed. Upon removal we noted that all intake bolts were only f nger tight.

Tom's comment:

It's always a worry when a DIYer has been involved. Some are very good but in this case it appears that random parts were bolted on to try and f x the fault. I think this threw the technician in the repair shop off course at the beginning, which is why he started thinking ECM problems. However, he was thinking and that is the key, and did test like checking that the sensors were the correct ones.

The biggest clue to pick up on here I think, is that because the O_2 (lambda) sensors were giving an incorrect output on both banks (this is a V engine) the fault was most likely to be something in common with both sides.

Remember, a DTC from an O_2 sensor does not mean that the sensor is faulty; it simply means that the reading from the sensor is out of its normal range.

10.6.3 1999 Audi A4 Quattro

- Mileage: 83,000 mi
- Engine: 2.8 L, 6 cyl, Gas/Petrol
- Trans: 5-speed Automatic Transaxle (Electronic)
- Delivery: Fuel Injection

Technician's description:

This Audi has been to many workshops in the city and came to me with a fed-up customer! The problem is in the ABS system. There are no codes. It has the symptoms of the ABS coming on at 20 miles an hour and lower with moderate to heavy braking. I have resistance checked all the speed sensors at the ABS Module connector and came up with an average of 1.2 kohms. I have checked the voltages of all four sensors and they all produce between 0.2 to 0.6 AC volts with me spinning the wheel by hand with the car on the lift. I have checked the waveforms and they seem OK. Don't see any of them dropping out. Customer states that this problem happened a few years ago and he took it to a dealer where they found both rear wheel sensors were out of adjustment and the locking sleeve on the left rear sensor was missing. That cured the problem up until now.

My question is how do I check the adjustment of these sensors to the reluctor wheel? And are there any other items to check or methods to use to identify which sensor is causing this problem? I haven't been able to f nd any adjustment specs or procedures to set it to specs.

Fault:

First thing I did was to try and pull out the ABS Sensors in the R.F. R.R. and L.R. The L.F. Sensor and Axle were replaced by another shop that tried to f x the problem and then gave up. Because of rust I broke all three sensors getting them out. I inspected all three pulse rings in the open holes and found the L.R. axle to have a broken one.

Tom's comment:

Most ABS problems do turn out to be sensor related and suspecting incorrect adjustment was the right thing to do. However, the broken pulse ring would have shown on a waveform. The diff culty is getting similar waveforms to compare because spinning the wheels by hand means they are likely to be checked at different speeds. Perhaps testing each sensor output at the ECU with the car driving at say 15 mph, and saving the waveform, would have shown the problem up. And the rust? Just unlucky for the customer in this case!

10.6.4 2002 Ford Ranger

- Mileage: 139 000 mi
- Engine: 3.0 L, 6 cyl, Gas/Petrol
- Trans: 5-speed Automatic (Electronic)
- Delivery: Fuel Injection
- Emissions: OBD-II Compliant
- Symptoms: Hesitation
- Occurs On: Acceleration

Related Repair History:

- Recent tune up, new plugs leads/wires and coil, DPFE (Differential Pressure Feedback of EGR) and control solenoid

Technician's description:

Vehicle came in with lack of power complaint. It seems to run f ne except a slight miss at idle, but you can barely tell. As soon as you try to accelerate it has no power. It does not fall on its face it just has no power. There are no fault codes in the computer. This vehicle is a commercial owned vehicle and is not well taken care of. All other sensor readings seem OK. The only one that I don't like is the TPS (throttle position), which reads 16% at idle, and the fuel trims seem really low. I am leaning towards cam sensor and syncro but I am not sure if anyone out there has come across this; it would greatly help me out if you could share what you know.

Fault:

It ended up being the transmission slipping just enough to feel like no power.

Tom's comment:

A recent tune up and new parts and no fault codes do suggest that the engine was OK but the symptoms contradicted this. A great example of a ref ected fault, i.e. a fault in one system that appears to show symptoms in another. We can also learn from this to always expect the unexpected!

10.6.5 2005 Volkswagen Jetta

- Mileage: 114 000 mi
- Engine: 2.0 L, 4 cyl, Gas/Petrol
- Trans: 6-speed Standard Transaxle (Electronic)
- Delivery: Fuel Injection
- Misc: P000? P0340

Technician's description:

This 2005 VW 2.0T Jetta has loud tapping noise while engine is running. The customer drove at 130–140 km/h for 4–5 hours long distant almost every week. When it came to our workshop, the oil level was below minimum level, but I don't think this would cause the engine damage. He was driving for about 4 hours on this occasion and when he slowed down the speed to 80–100 km/h he noticed that engine had the tapping noise. He continued to drove another hour and parked it at home. The next day he brought it to our repair shop (1st time customer for us). He does not have the car regularly serviced. He owned this car for two years. I am almost certain that engine top end is damaged; a cam lobe or lifter collapsing maybe, but I don't know why it happened.

Would driving 130–140 km/h for a long distance with minimum oil level do this? I would like to know the possible causes before we take the engine apart.

One more thing at one point the 'check engine light' came on. The DTCs were 'P000?' and 'P0340' (cam-position sensor).

Fault:

We used oil f ush before oil change for about 5 minutes; then replaced the oil and f lter. The loud tapping engine noise was still there for 5–6 minutes. We turned off engine, let it sit for 15 minutes, and when we restarted engine the noise disappeared after a short while. There was a very faint (knocking) noise on heavy acceleration. But it was so small that the customer will not hear it. We recommend to this customer that he should avoid heavy acceleration for a while and try to listen for any engine noise from now on because it may have damaged a bearing. And also we should replace the oil again after 4000–5000 km since it was using synthetic oil.

Tom's comment:

> *Having a car regularly serviced always saves money in the long term. I too suspect a cam lobe or lifter or similar. The technician did well here to think to try to oil f ush before stripping down the engine. I wonder if this customer appreciates how much money this saved him.*

10.6.6 2004 Honda Accord

- Mileage: 95 000 mi
- Engine: 3.0 L, 6 cyl, Gas/Petrol
- Trans: 5-speed Automatic Transaxle (Electronic)
- Delivery: Fuel Injection
- Affected: Air Flow
- Conditions: Not Cold

Related Repair History:

- Compressor and receiver drier replaced

Technician's description:

On this Honda Accord with automatic dual climate air conditioning, we replaced a compressor and drier because the passenger side air is cold, but the driver's side is lukewarm. The temperature f ap motors work like they are supposed to, that is, switching from hot to cold with no binding. I am thinking maybe the evaporator is partially plugged or the expansion valve is faulty. Everything else seems to be working f ne.

Fault:

Cleaned out evaporator and all OK, blocked on one side

Tom's comment:

The technician here missed out vital piece of information. If the passenger side AC was working OK, then the majority of the AC system such as the compressor and drier must also be OK. He did check the f aps which were a likely cause and got to the evaporator in the end but I wonder how much the new compressor cost the customer. Remember when evaluating evidence, it is always useful to know that something is NOT faulty because then you can use that fact to look further into the system. In this case, the concentration should have been only on what was common to just the driver side.

10.6.7 Summary

The main thing to learn from this section is that automotive diagnostics is never easy and that external factors can have an undue inf uence on our thinking processes if we do not take care. Always believe your test results but also consider the wider possibilities of what may cause them. Overall, the real secret is logic.

10.7 Software

I have created a simulation program that can be used to help you learn more about engine management systems and how to diagnose faults. It is a great teaching aid and covers some complex topics in an easy-to-understand way. It is even possible to set faults in the system and then, using built-in test equipment, carry out diagnostic tests.

You can set or control the operating inputs to the system. For engine management control, these are engine speed, engine load, temperature and so on. The system will then react and control the outputs in just the same way as a real vehicle. Be warned the unregistered version runs out of fuel!

WWW

Web

Shareware and other great resources are available from: www.automotive-technology.co.uk

10.8 Summary

Modern motor vehicles are highly sophisticated machines that incorporate the latest developments in electrical, electronics, software and mechanical engineering. They are a marvel of modern engineering practice and truly show how all these technologies can be integrated and harmonised for maximum benef t to the end user. It is clear that this level of technology produces the safest, quietest and most eff cient road vehicles we have ever known.

However, the disadvantage of this level of sophistication becomes apparent when something goes wrong. Clearly, the more sophisticated the device, the more diff cult it will be to repair, or understand in order to repair. It is often the case that it may be perceived that no faults can be found or f xed without specialised manufacturer equipment which is only available at dealers. This is not the case. The fundamental principles of diagnostics in conjunction with an applied, logical thought process are the most powerful tools that you have. Any specialist equipment will still only be as good as the person using it.

Def nition

Laws of physics: “Ya cannae change them”.

Modern vehicle systems are certainly sophisticated, but the fundamental principles apply. An ECU is only monitoring voltages from its sensors. These voltages are the inputs to the ECU; its outputs are voltages and currents which drive actuators (injector, idle speed control valves, etc.), they are all the same and applied logic can f x most problems. Engines and chassis are also complicated subsystems of the vehicle, but in all cases the laws of physics apply, and all engines do the same thing in more or less the same way. They are just energy converters. The basic principles are still valid; for example, the ignition still needs to be advanced under cruise conditions when the mixture is weaker, whether this is done mechanically or electronically. Likewise, any electrical circuit not conducting a current – is broken – somewhere.

There are always a few simple rules to follow:

- Do not overlook the obvious.
- Look for simple solutions f rst.
- Always get as much information as possible up front.
- Never assume anything … check it yourself.
- Be logical when diagnosing faults.
- Most of all, have conf dence in your ability.

Follow these rules, never be afraid to ask for help and learn from the experience. In this way, you will build up a portfolio of useful experience and knowledge that will help develop your career as a diagnostic expert. There is nothing that quite beats the feeling of solving a problem, especially if you know that it has puzzled other people before you – to the point that they have given up.

One f nal point, see the red thing in the middle of the following picture? Do not forget to check the obvious, no matter how complex a vehicle may appear to be (Figure 10.3)!

Well, that’s it, if you have arrived here, after having read all the book, done all the assignments, completed all the practical tasks, used the website: www.automotive-technology.co.uk resources and can remember everything, then well done.

Or did you just start reading the book from the back?

Figure 10.3 Even the BMW M3 engine needs oil

Glossary of abbreviations and acronyms

OBD2/SAE terminology

ABS *antilock brake system*
A/C *air conditioning*
AC *air cleaner*
AIR *secondary air injection*
A/T *automatic transmission or transaxle*
B+ *battery positive voltage*
BARO *barometric pressure*
CAC *charge air cooler*
CFI *continuous fuel injection*
CKP *crankshaft position sensor*
CKP REF *crankshaft reference*
CL *closed loop*
CMP *camshaft position sensor*
CMP REF *camshaft reference*
CO *carbon monoxide*
CO_2 *carbon dioxide*
CPP *clutch pedal position*
CTOX *continuous trap oxidiser*
CTP *closed throttle position*
DEPS *digital engine position sensor*
DFCO *decel fuel cut-off mode*
DFI *direct fuel injection*
DLC *data link connector*
DPF *diesel particulate f lter*
DTC *diagnostic trouble code*
DTM *diagnostic test mode*
EBCM *electronic brake control module*
EBTCM *electronic brake traction control module*
EC *engine control*
ECL *engine coolant level*

ECM	*engine control module*
ECT	*engine coolant temperature*
EEPROM	*electrically erasable programmable read only memory*
EFE	*early fuel evaporation*
EGR	*exhaust gas recirculation*
EGRT	*EGR temperature*
EI	*electronic ignition*
EM	*engine modif cation*
EPROM	*erasable programmable read only memory*
ESC	*electronic stability control*
EVAP	*evaporative emission system*
FC	*fan control*
FEEPROM	*f ash electrically erasable programmable read only memory*
FF	*f exible fuel*
FP	*fuel pump*
FPROM	*f ash erasable programmable read only memory*
FT	*fuel trim*
FTP	*federal test procedure*
GCM	*governor control module*
GEN	*generator*
GND	*ground*
HC	*hydrocarbon*
H_2O	*water*
HO2S	*heated oxygen sensor*
HO2S1	*upstream heated oxygen sensor*
HO2S2	*up or downstream heated oxygen sensor*
HO2S3	*downstream heated oxygen sensor*
HVAC	*heating ventilation and air conditioning system*
HVS	*high-voltage switch*
IA	*intake air*
IAC	*idle air control*
IAT	*intake air temperature*
IC	*ignition control circuit*
ICM	*ignition control module*
IFI	*indirect fuel injection*
IFS	*inertia fuel shutoff*
I/M	*inspection/maintenance*
IPC	*instrument panel cluster*
ISC	*idle speed control*
KOEC	*key on, engine cranking*
KOEO	*key on, engine off*

KOER	*key on, engine running*
KS	*knock sensor*
KSM	*knock sensor module*
LTFT	*long-term fuel trim*
MAF	*mass airf ow sensor*
MAP	*manifold absolute pressure sensor*
MC	*mixture control*
MDP	*manifold differential pressure*
MFI	*multiport fuel injection*
MIL	*malfunction indicator lamp*
MPH	*miles per hour*
MST	*manifold surface temperature*
MVZ	*manifold vacuum zone*
NVRAM	*non-volatile random access memory*
NOX	*oxides of nitrogen*
OBD	*on-board diagnostics*
OBD I	*on-board diagnostics generation one*
OBD II	*on-board diagnostics, second generation*
OC	*oxidation catalyst*
ODM	*output device monitor*
OL	*open loop*
O2S	*oxygen sensor*
OSC	*oxygen sensor storage*
PAIR	*pulsed secondary air injection*
PCM	*powertrain control module*
PCV	*positive crankcase ventilation*
PNP	*park/neutral switch*
PROM	*program read only memory*
PSA	*pressure switch assembly*
PSP	*power steering pressure*
PTOX	*periodic trap oxidiser*
RAM	*random access memory*
RM	*relay module*
ROM	*read only memory*
RPM	*revolutions per minute*
SAP	*accelerator pedal*
SC	*supercharger*
SCB	*supercharger bypass*
SDM	*sensing diagnostic mode*
SFI	*sequential fuel injection*
SRI	*service reminder indicator*

SRT *system readiness test*
STFT *short-term fuel trim*
TB *throttle body*
TBI *throttle body injection*
TC *turbocharger*
TCC *torque converter clutch*
TCM *transmission or transaxle control module*
TFP *throttle f uid pressure*
TP *throttle position*
TPS *throttle position sensor*
TVV *thermal vacuum valve*
TWC *three-way catalyst*
TWC+OC *three-way+oxidation catalytic converter*
VAF *volume airf ow*
VCM *vehicle control module*
VR *voltage regulator*
VS *vehicle sensor*
VSS *vehicle speed sensor*
WU-TWC *warm up three-way catalytic converter*
WOT *wide open throttle*

OEM and other terminology

A *amps*
AAV *anti-afterburn valve (Mazda)*
ABS *antilock brake system*
ABSV *air bypass solenoid valve (Mazda)*
A/C *air conditioning*
AC *alternating current*
ACTS *air charge temperature sensor (Ford)*
AERA *Automotive Engine Rebuilders Association*
A/F *air/fuel ratio*
AFM *airf ow meter*
AFS *airf ow sensor (Mitsubishi)*
AIR *Air Injection Reaction (GM)*
AIS *Air Injection System (Chrysler)*
AIS *automatic idle speed motor (Chrysler)*
ALCL *assembly line communications link (GM)*
ALDL *assembly line data link (GM)*
API *American Petroleum Institute*
APS *absolute pressure sensor (GM)*

APS *atmospheric pressure sensor (Mazda)*
ASD *automatic shutdown relay (Chrysler)*
ASDM *airbag system diagnostic module (Chrysler)*
ASE *Automotive Service Excellence*
A/T *automatic transmission*
ATC *after top centre*
ATDC *after top dead centre*
ATF *automatic transmission f uid*
ATMC *Automotive Training Managers Council*
ATS *air temperature sensor (Chrysler)*
AWD *all-wheel drive*
BARO *barometric pressure sensor (GM)*
BAT *battery*
BCM *body control module (GM)*
BHP *brake horsepower*
BID *Breakerless Inductive Discharge (AMC)*
BMAP *barometric/manifold absolute pressure sensor (Ford)*
BP *backpressure sensor (Ford)*
BPS *barometric pressure sensor (Ford & Nissan)*
BPT *backpressure transducer*
BTC *before top centre*
BTDC *before top dead centre*
Btu *British thermal units*
C *Celsius*
C3 *Computer Command Control system (GM)*
C3I *Computer Controlled Coil Ignition (GM)*
C4 *Computer Controlled Catalytic Converter system (GM)*
CAAT *Council of Advanced Automotive Trainers*
CAFE *corporate average fuel economy*
CALPAK *calibration pack*
CANP *canister purge solenoid valve (Ford)*
CARB *California Air Resources Board*
CAS *Clean Air System (Chrysler)*
CAS *crank angle sensor*
CC *catalytic converter*
CC *cubic centimetres*
CCC *Computer Command Control system (GM)*
CCD *computer controlled dwell (Ford)*
CCEI *Coolant Controlled Idle Enrichment (Chrysler)*
CCEV *Coolant Controlled Engine Vacuum Switch (Chrysler)*
CCOT *clutch cycling orif ce tube*

CCP *controlled canister purge (GM)*

CCV *canister control valve*

CDI *Capacitor Discharge Ignition (AMC)*

CEAB *cold engine air bleed*

CEC *Crankcase Emission Control System (Honda)*

CECU *central electronic control unit (Nissan)*

CER *cold enrichment rod (Ford)*

CESS *cold engine sensor switch*

CFC *chlorof uorocarbons*

CFI *Cross Fire Injection (Chevrolet)*

cfm *cubic feet per minute*

CID *cubic inch displacement*

CID *cylinder identif cation sensor (Ford)*

CIS *Continuous Injection System (Bosch)*

CMP *camshaft position sensor (GM)*

COP *coil on plug ignition*

CP *canister purge (GM)*

CP *crankshaft position sensor (Ford)*

CPI *Central Port Injection (GM)*

CPU *central processing unit*

CSC *Coolant Spark Control (Ford)*

CSSA *Cold Start Spark Advance (Ford)*

CSSH *Cold Start Spark Hold (Ford)*

CTAV *Cold Temperature Actuated Vacuum (Ford)*

CTO *Coolant Temperature Override Switch (AMC)*

CTS *charge temperature switch (Chrysler)*

CTS *coolant temperature sensor (GM)*

CTVS *choke thermal vacuum switch*

CVCC *Compound Vortex Controlled Combustion system (Honda)*

CVR *control vacuum regulator (Ford)*

dB *decibels*

DC *direct current*

DEFI *Digital Electronic Fuel Injection (Cadillac)*

DERM *diagnostic energy reserve module (GM)*

DFS *deceleration fuel shutoff (Ford)*

DIS *Direct Ignition System (GM)*

DIS *Distributorless Ignition System (Ford)*

DLC *data link connector (GM)*

DOHC *dual overhead cams*

DOT *Department of Transportation*

DPF *diesel particulate f lter*

DRBII *Diagnostic Readout Box (Chrysler)*
DRCV *distributor retard control valve*
DSSA *Dual Signal Spark Advance (Ford)*
DVDSV *differential vacuum delay and separator valve*
DVDV *distributor vacuum delay valve*
DVOM *digital volt ohm meter*
EACV *electronic air control valve (Honda)*
EBCM *electronic brake control module (GM)*
EBM *electronic body module (GM)*
ECA *electronic control assembly*
ECCS *Electronic Concentrated Control System (Nissan)*
ECM *electronic control module (GM)*
ECS *Evaporation Control System (Chrysler)*
ECT *engine coolant temperature (Ford & GM)*
ECU *electronic control unit (Ford, Honda & Toyota)*
EDIS *Electronic Distributorless Ignition System (Ford)*
EEC *Electronic Engine Control (Ford)*
EEC *Evaporative Emission Controls (Ford)*
EECS *Evaporative Emissions Control system (GM)*
EEPROM *electronically erasable programmable read only memory chip*
EFC *electronic feedback carburettor (Chrysler)*
EFC *electronic fuel control*
EFCA *electronic fuel control assembly (Ford)*
EFE *Early Fuel Evaporation system (GM)*
EFI *electronic fuel injection*
EGO *exhaust gas oxygen sensor (Ford)*
EGRPS *EGR valve position sensor (Mazda)*
EGR-SV *EGR solenoid valve (Mazda)*
EGRTV *EGR thermo valve (Chrysler)*
EI *electronic ignition (GM)*
ELB *Electronic Lean Burn (Chrysler)*
EMI *electromagnetic interference*
EOS *exhaust oxygen sensor*
EPA *Environmental Protection Agency*
EPOS *EGR valve position sensor (Ford)*
EPROM *erasable programmable read only memory chip*
ESA *Electronic Spark Advance (Chrysler)*
ESC *Electronic Spark Control (GM)*
ESS *Electronic Spark Selection (Cadillac)*
EST *Electronic Spark Timing (GM)*
EVP *EGR valve position sensor (Ford)*

EVRV *electronic vacuum regulator valve for EGR (GM)*
F *Fahrenheit*
FBC *feedback carburettor system (Ford & Mitsubishi)*
FBCA *feedback carburettor actuator (Ford)*
FCA *fuel control assembly (Chrysler)*
FCS *fuel control solenoid (Ford)*
FDC *fuel deceleration valve (Ford)*
FI *fuel injection*
FLS *f uid level sensor (GM)*
FMVSS *Federal Motor Vehicle Safety Standards*
ft. lb. *foot pound*
FUBAR *Fracked Up Beyond All Repair*
FWD *front-wheel drive*
gal *gallon*
GND *ground*
GPM *grams per mile*
HAIS *Heated Air Intake System (Chrysler)*
HEGO *heated exhaust gas oxygen sensor*
HEI *High Energy Ignition (GM)*
Hg *mercury*
hp *horsepower*
IAC *idle air control (GM)*
IAT *inlet air temperature sensor (Ford)*
IATS *intake air temperature sensor (Mazda)*
IC *integrated circuit*
ICS *idle control solenoid (GM)*
ID *inside diameter*
IGN *ignition*
IIIBDFI *If it isn't broke don't f x it*
IM240 *inspection/maintenance 240 program*
IMI *Institute of the Motor Industry*
I/P *instrument panel*
ISC *idle speed control (GM)*
ISO *International Standards Organization*
ITCS *Ignition Timing Control System (Honda)*
ITS *idle tracking switch (Ford)*
JAS *Jet Air System (Mitsubishi)*
kHz *kilohertz*
KISS *Keep It Simple Stupid!*
km *kilometres*
kPa *kilopascals*

KS	*knock sensor*
kV	*kilovolts*
L	*litres*
lb. ft.	*pound feet*
LCD	*liquid crystal display*
LED	*light-emitting diode*
MACS	*Mobile Air Conditioning Society*
MAF	*mass airf ow sensor*
MAMA	*Midwest Automotive Media Association*
MAP	*manifold absolute pressure*
MAP	*Motorist Assurance Program*
MAT	*manifold air temperature*
MCS	*mixture control solenoid (GM)*
MCT	*manifold charge temperature (Ford)*
MCU	*Microprocessor Controlled Unit (Ford)*
MFI	*multiport fuel injection*
MIL	*malfunction indicator lamp*
MISAR	*Microprocessed Sensing and Automatic Regulation (GM)*
mm	*millimetres*
MPFI	*multi point fuel injection*
MPG	*miles per gallon*
MPH	*miles per hour*
MPI	*multi-port injection*
ms	*millisecond*
MSDS	*material safety data sheet*
mV	*millivolts*
NACAT	*National Association of College Automotive Teachers*
NATEF	*National Automotive Technician's Education Foundation*
NHTSA	*National Highway Traff c Safety Administration*
Nm	*Newton metres*
OBD	*on-board diagnostics*
OC	*oxidation converter (GM)*
OD	*outside diameter*
OE	*original equipment*
OEM	*original equipment manufacture*
OHC	*overhead cam*
ORC	*oxidation reduction catalyst (GM)*
OS	*oxygen sensor*
OSAC	*Orif ce Spark Advance Control (Chrysler)*
P/B	*power brakes*
P/N	*part number*

PA *pressure air (Honda)*
PAFS *Pulse Air Feeder System (Chrysler)*
PAIR *Pulsed Secondary Air Injection system (GM)*
PCM *powertrain control module (supersedes ECM)*
PECV *power enrichment control valve*
PERA *Production Engine Rebuilders Association*
PFI *port fuel injection (GM)*
PGM-FI *Programmed Gas Management Fuel Injection (Honda)*
PIP *prof le ignition pickup (Ford)*
PPM *parts per million*
PROM *program read only memory computer chip*
PS *power steering*
PSI *pounds per square inch*
pt. *pint*
PVA *ported vacuum advance*
PVS *ported vacuum switch*
QS9000 *Quality assurance standard for OEM part suppliers*
Qt. *quart*
RABS *Rear wheel Antilock Brake System (Ford)*
RFI *radio frequency interference*
RPM *revolutions per minute*
RPO *regular production option*
RWAL *Rear Wheel Antilock brake system (GM)*
RWD *rear-wheel drive*
SAE *Society of Automotive Engineers*
SAVM *spark advance vacuum modulator*
SCC *Spark Control Computer (Chrysler)*
SDI *Saab Direct Ignition*
SES *service engine soon indicator (GM)*
SFI *Sequential Fuel Injection (GM)*
SIR *Supplemental Inf atable Restraint (air bag)*
SMPI *Sequential Multiport Fuel Injection (Chrysler)*
SOHC *single overhead cam*
SPOUT *Spark Output signal (Ford)*
SRDV *spark retard delay valve*
SRS *Supplemental Restraint System (air bag)*
SS *speed sensor (Honda)*
SSI *Solid State Ignition (Ford)*
STS *Service Technicians Society*
TA *temperature air (Honda)*
TABPV *throttle air bypass valve (Ford)*

TAC *thermostatic air cleaner (GM)*
TACH *tachometer*
TAD *Thermactor air diverter valve (Ford)*
TAV *temperature actuated vacuum*
TBI *throttle body injection*
TCC *torque converter clutch (GM)*
TCCS *Toyota Computer Controlled System*
TCS *Transmission Controlled Spark (GM)*
TDC *top dead centre*
TIC *thermal ignition control (Chrysler)*
TIV *Thermactor idle vacuum valve (Ford)*
TKS *throttle kicker solenoid (Ford)*
TP *throttle position sensor (Ford)*
TPI *Tuned Port Injection (Chevrolet)*
TPMS *Tyre Pressure Monitor System*
TPP *throttle position potentiometer*
TPS *throttle position sensor*
TPT *throttle position transducer (Chrysler)*
TRS *Transmission Regulated Spark (Ford)*
TSP *throttle solenoid positioner (Ford)*
TV *throttle valve*
TVS *thermal vacuum switch*
TVS *thermal vacuum switch (GM)*
TVV *thermal vacuum valve (GM)*
V *volts*
VAC *volts alternating current*
VAF *vane airf ow sensor*
VCC *viscous converter clutch (GM)*
VDC *volts direct current*
VDV *vacuum delay valve*
VIN *vehicle identif cation number*
VSM *vehicle security module*
VSS *vehicle speed sensor*
WOT *wide open throttle*
WOT *wide open throttle switch (GM)*
WSS *wheel speed sensor*

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