ProVQ™

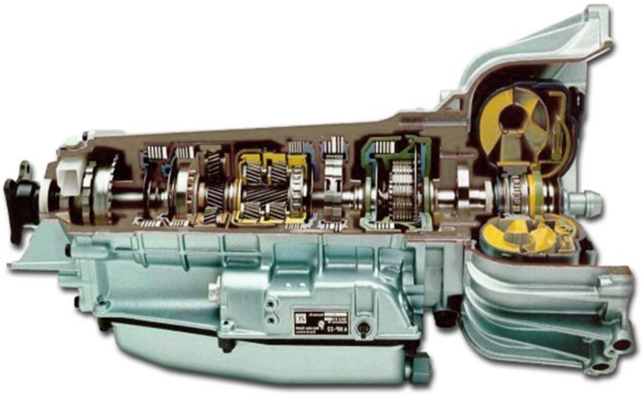
AUTOMATIC TRANSMISSION

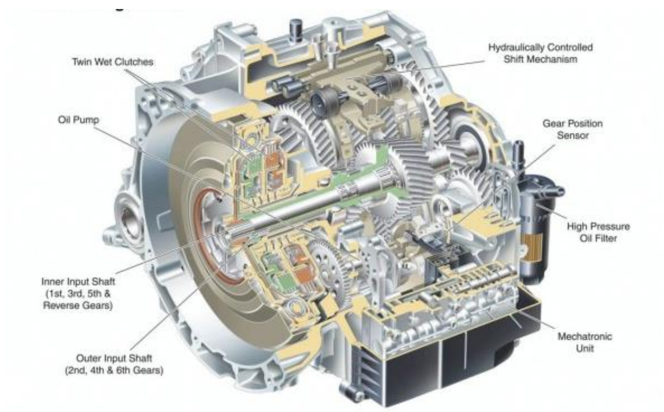
PHASE THREE

Contents

Introduction

Automatic transmissions are often considered complex systems. Getting to grips with the function and operation of the automatic transmission can seem like a massive task. As with any large job, to understand the operation of this system we need to divide the automatic transmission into a series of simple systems. This approach will also provide a good model for you to follow when troubleshooting automatic transmission problems.





Objectives

You will study the construction and operation of a simple 3-speed, hydraulic control, automatic transmission. At the end you should be able to:

- describe operation and function of each part of an automatic transmission
- assess the performance of an automatic transmission
- complete basic diagnostic tests
- analyse the results of performance and diagnostic tests in-order to identify the likely cause of problem symptoms
- carryout routine maintenance
- be aware of the general techniques for overhaul and repair of automatic transmissions.

Overview

Advantages and Disadvantages

An automatic transmission offers a number of advantages over a conventional manual transmission. The key advantages are:

- reduces driver fatigue
- reduces loading on the engine and driveline.

Changing gear is one of the more complex tasks for the driver. He or she must decide which gear is most appropriate for the road condition. Then carryout a number of complex actions to achieve the correct gear and all of this must happen while steering the vehicle, operating controls, checking lipstick etc. Getting the gear selection wrong will result in increased load on the engine or driveline.

The disadvantages of an automatic transmission

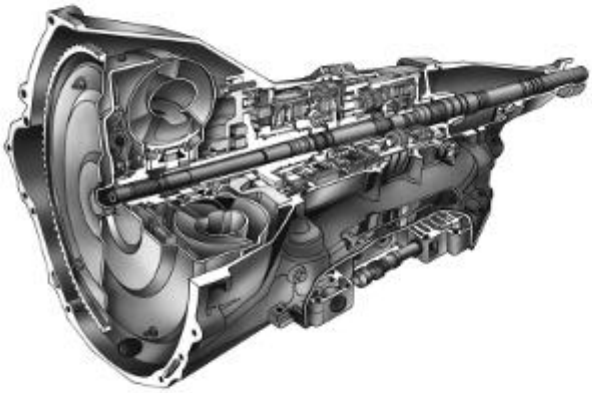
- torque converter uses some of the engine power reducing the efficiency of the transmission system
- lower number of gear ratios can reduce vehicle performance
- heavier and more complex construction
- more expensive.

Improvements in design and increased complexity has reduced the first two disadvantages but increased the last two. The introduction of "Lock-up" torque converters has increased efficiency and 5 speed automatic transmissions are becoming more common, some manufacturers have now started to introduce 6 speed automatic transmissions.

Different Types of Automatic Transmission

There are two different general types of automatic transmission.

- hydraulic control – hydraulic control of shift timing and gear change
- electro Hydraulic control – hydraulic gear change – ECU shift timing



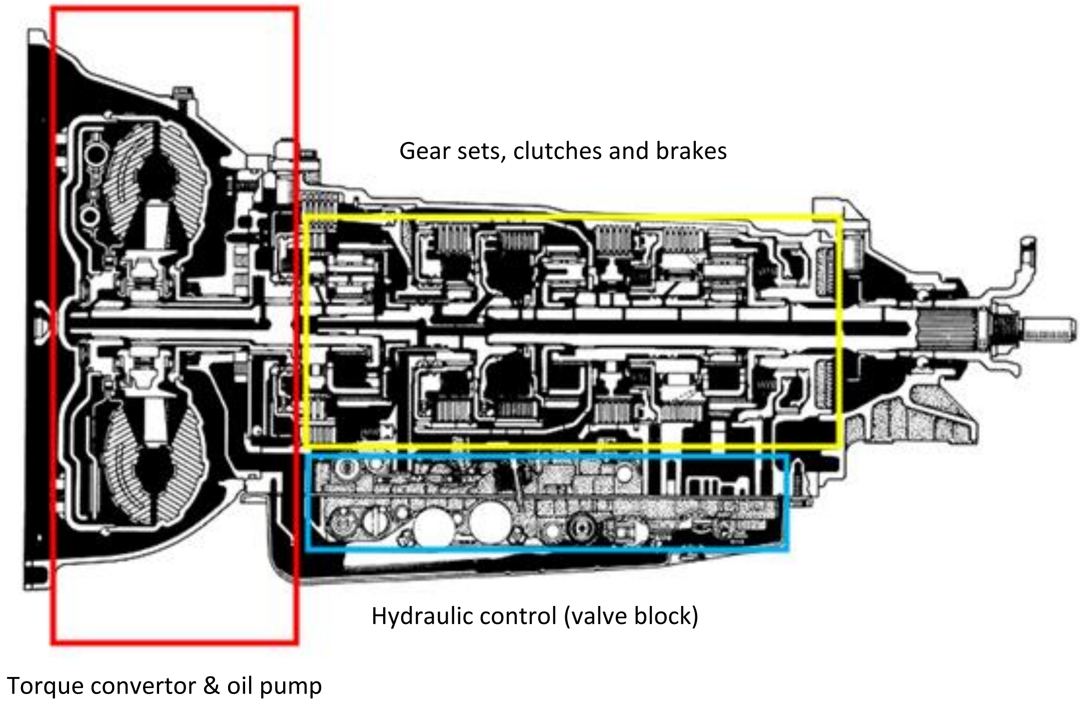
Hydraulic control

Electro hydraulic control

Components of the Hydraulic Automatic Transmission

When we consider what components are needed to achieve an automatic transmission they are in, general terms, the same as a manual transmission:

- mechanism for engaging and disengaging drive (torque) from the engine – Torque Converter
- gear set to provide different gear ratios – Planetary gear set
- mechanism to implement smooth engagement and disengagement of each gear ratio – Clutches and brakes
- actuator system to activate the change from one gear ratio to another – hydraulic pistons
- control system to implement the gear change – Hydraulic control system (valve block).



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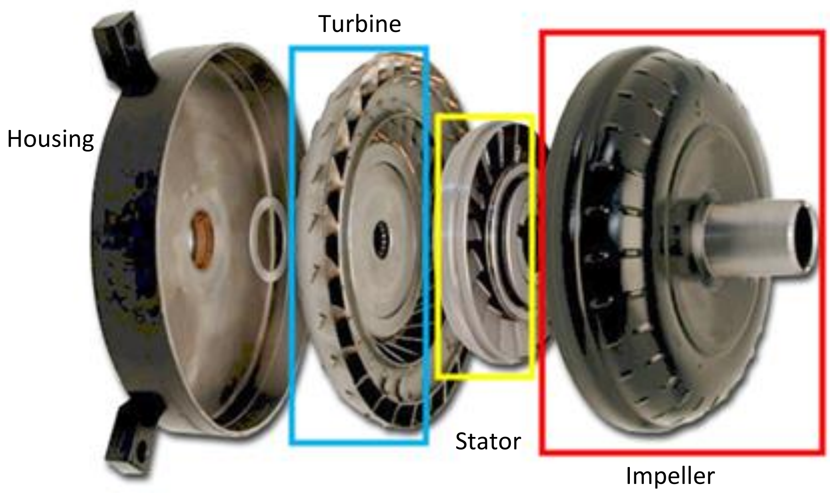
Torque Converter (Fluid Flywheel)

The torque converter is a key technology in hydraulic automatic transmissions. It utilizes the automatic transmission fluid (ATF) to form a fluid coupling between the engine and transmission providing a smooth transfer of torque.

The torque converter provides:

- mechanism for engaging and disengaging drive
- variable gear ratio
- torque multiplication.

This combination of features allows the design of the automatic transmission to be simpler. In effect the torque converter allows the transmission to use less gear ratios than a conventional manual transmission and still provide a useful spread of ratios.



Operating Principle

The torque converter has three main components:

- impellor (pump)
- turbine
- stator.

As shown above the impellor is an integral part of the converter case. Curved vanes are fixed around the radius of the casing and fixed to the vanes is a guide ring. Because it is part of the casing it is connected directly to the engine crankshaft via the drive plate.

The turbine is also constructed from vanes attached to plate. A guide ring is also fitted. The turbine vanes set in the opposite direction to the impellor vanes. The back plate is fixed directly to the input shaft of the transmission.

The stator sits between the impellor and turbine and also contains a number of vanes. It is mounted on a one-way clutch fixed to the transmission casing (detailed operation of the one- way clutch is covered in the clutches and brake section).

The converter case is filled with ATF from the transmission oil pump. The level of oil is maintained by regulator valve. The oil pump is driven by the torque converter case.

Experiment

To help use understand the operation of the torque converter we need to understand some basic principles.

If you consider a bowl of soup. What will happen to the soup if you spin the bowl?

Apart from the mess you have now created you should notice that the soup has been deposited in a radial pattern around the bowl.

What is the force applied to the soup to create this result?

Now consider the result of the same experiment if vertical plates divide the soup bowl?

The resulting pattern on the tabletop is different. You should see that the soup has now left the bowl at a tangent.

The new pattern is the result of centrifugal force applying outward acceleration to the soup and the vane in the bowl accelerating the soup in the direction of rotation.

To take the experiment a stage further, if we support a second bowl, also fitted with vertical plates above our first bowl, what will happen to the second bowl when you spin the first bowl?

You should see that the soup forced from the first bowl applies a rotational force to the second bowl.

Why does the second bowl rotate?

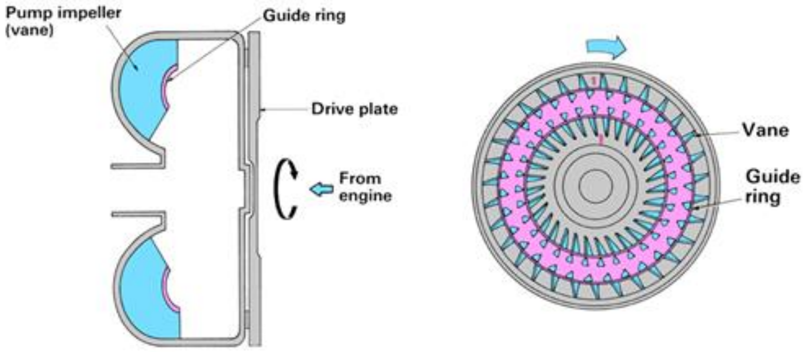
When the first bowl is spun the rotational force applied to the bowl is transferred to the soup in the form of acceleration. The soup has stored the rotational force from the bowl as kinetic energy. The kinetic energy of the soup is applied to the vanes of the second bowl. The second bowl extracts the kinetic energy from the soup and turns the second bowl. This is in effect a simple model of a fluid coupling.

Important note: Any laundry bills or criminal prosecutions as a result of repeating this experiment are the responsibility of the reader.

The key points of understanding from this experiment are:

- the impellor imparts energy from the engine to the ATF
- the ATF transfers energy from the impellor to the turbine
- the turbine extracts energy form the ATF and inputs energy to the transmission.

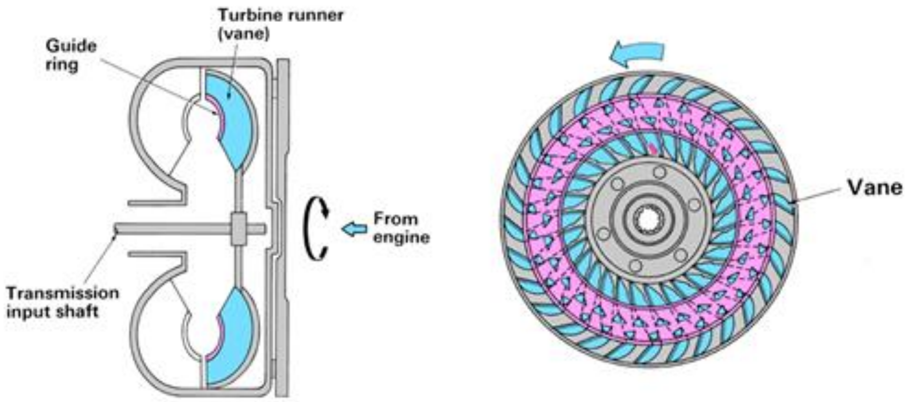
The operation of the torque converter



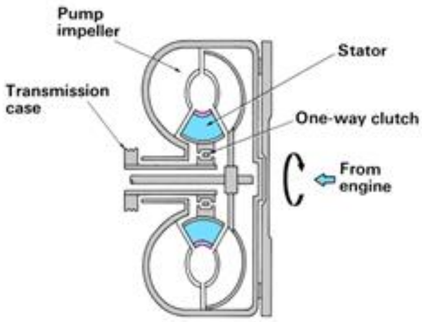
The rotational force of the engine is applied to the impellor and therefore to the ATF. The fluid in the impellor is subjected to centrifugal force and accelerates outwards along the vanes of the impellor. As the fluid moves to outside of the impellor the speed of the fluid increases until it is forced out of the impellor towards the turbine.

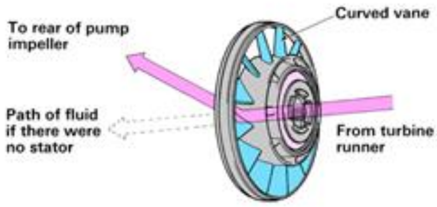
The ATF hits the outer part of the turbine vane and applies a force. The shape of the turbine vane affects the efficiency of the turbine. To understand this we need to consider how energy is transferred from the ATF or for that matter any fluid.

Consider a simple flat profiled vane, when the fluid impacts the surface some the energy will generate a reaction in the plate moving it in the same direction. Some of the energy is dissipated in the form of heat due friction generated in the impact. As soon as the fluid imparts energy to the plate the speed of the fluid is reduced. The fluid retains a significant amount of energy but is not transferred to the plate.



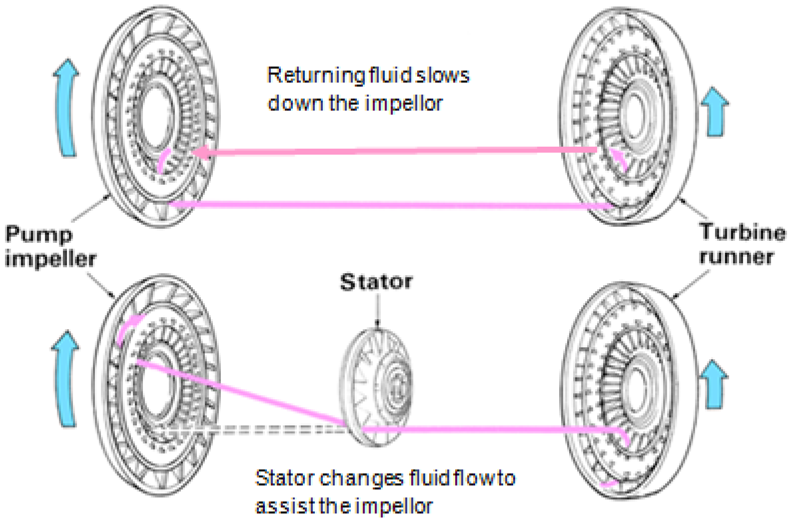
If we now consider the cured profile vane used in the torque converter The fluid impacts the outer part of the vane and again imparts energy to the turbine and heat due to friction. The speed of the fluid is reduced but the shape of the vane allows the fluid to remain in contact and impart more of its energy. The cured vane can extract energy from the fluid until it leaves the inside of the vane and is therefore much more efficient.





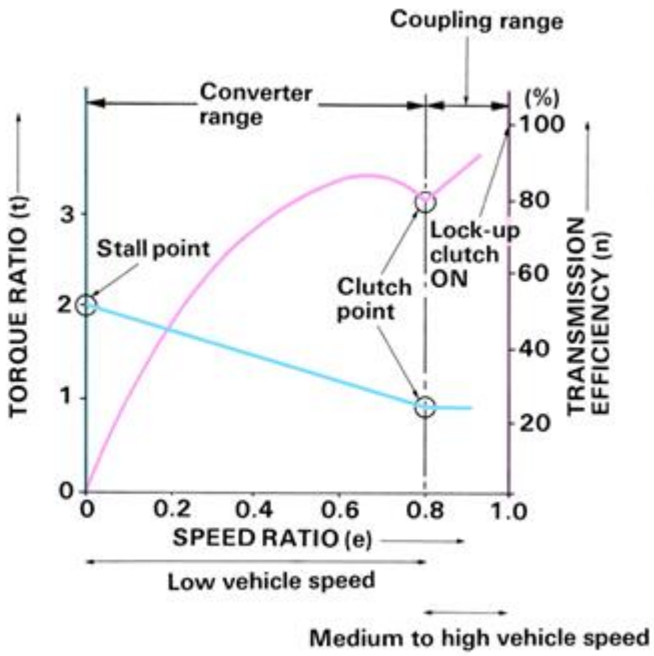
The fluid leaving the turbine still retains some energy. The function of the stator is to use this energy to create a torque multiplication. As we have already stated the fluid leaving the turbine still retains some useful energy but how to use it.

What is the effect of the fluid leaving the turbine on the pump?



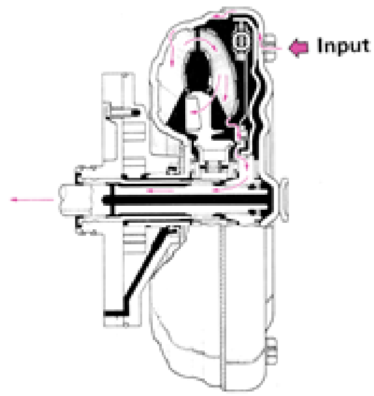
In the diagram above you can see that the path of the fluid will be opposite to the direction of rotation of the impellor. The energy of the returning fluid will work against the impellor and attempt to slow it down. We need to change the direction of the returning fluid. The stator sits between the impellor and the turbine. The vanes of the stator change the direction of the returning fluid, now the fluid acts in the same direction as the impellor. The impellor has both engine torque and the residual energy of the returning oil resulting in a torque multiplication. This phase of torque converter operation is called the "converter range".

Torque Multiplication

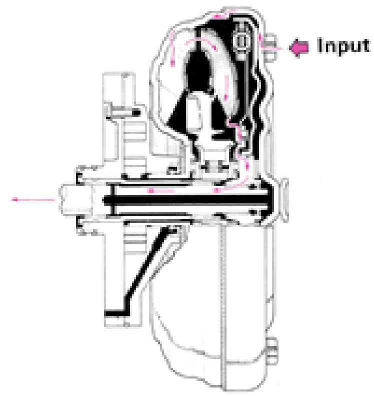


How much torque multiplication occurs is dependant on the speed difference between the impellor and the turbine. The highest torque multiplication occurs when the speed difference is at the maximum. The Blue line in the diagram shows the torque ratio. When the turbine is stationary and the impellor is at 1,000 rpm the energy stored in the ATF acts on the turbine. The turbine is stationary and therefore has a high inertia. Some energy from the ATF will start to overcome the inertia of the turbine but most of the energy will pass through the turbine and return to the impellor via the stator. At this point the torque multiplication is at its highest value. The impellor has the original torque from the engine plus almost the same torque again from the fluid returning from the turbine. The torque ratio at this point 2 and is general called the “Stall point.”
When the turbine is at 500 rpm and the impellor is at 1,000 rpm the turbine has now started to move so the inertia is reduced. More of the energy in the ATF is used to increase the acceleration of the turbine and therefore the energy of the ATF returning from the turbine to the impellor is reduced. The torque multiplication is reduced in proportion to the speed difference between the impellor and the turbine. The torque ratio is 1.75.

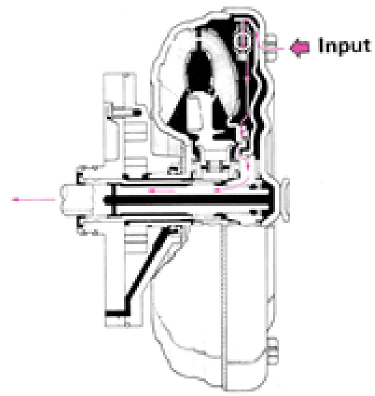
When the speed of the turbine and the impellor are the same, at this point the torque converter stops being a converter and becomes a fluid coupling. In this condition the fluid flow has changed. Previously the fluid flow could be seen as a spiral moving from impellor to turbine and back to the impellor. This spiral flow moved around the radius of the converter. This is called “Vortex Flow”. When operating as fluid coupling the flow is a “Rotary Flow” around the radius of the converter. Because the flow characteristics have changed the stator vanes will now resist the flow of fluid. To prevent this the stator is allowed to rotate with the flow of the fluid by means of one-way clutch. The point at which the stator begins to rotate is called the “Clutch Point”. The torque ratio is 1. This operation is called the “coupling range”.



Torque Multiplication
Converter Range
Vortex Flow



Fluid Clutch
Coupling Range
Rotary Flow



Mechanical Coupling
Lock-up

What driving condition produces the highest speed difference between the impellor and turbine?

What driving condition produces the lowest speed difference between the impellor and turbine?

Torque Convertor Efficiency

The efficiency graph of the torque converter shows how effectively the energy given to the impellor by the engine is transmitted to the turbine and therefore to the transmission. The graph shows the effect of torque multiplication and the transition to a fluid coupling.

At the stall point the efficiency is zero because even though maximum torque is applied the turbine speed is zero.

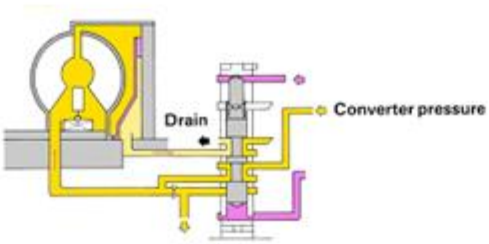
As turbine begins to turn the efficiency of the converter rapidly increases. The transmission efficiency will continue to rise until just before the clutch point. The drop in efficiency before the clutch point shows the effect of the fluid flow being to strike the back of the stator and the torque multiplication effect becoming impeded.

At the clutch point the force of fluid behind the stator is higher than the force striking the front. The Stator beings to rotate and we now have a fluid coupling. The torque ratio is now 1:1 and the efficiency increases in a linear relationship with speed. The transmission efficiency does not reach 100% because some of the energy in the ATF will be lost in the form of heat due to friction. Typically a torque converter can achieve 95% efficiency.

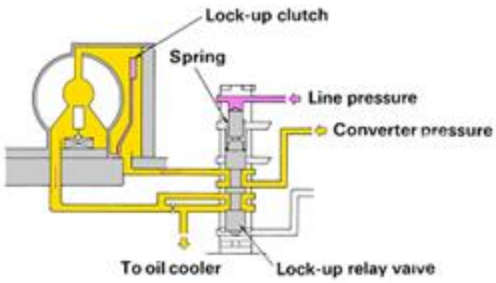
Lock-up

To achieve that final 5% efficiency, most modern designs will include a lock-up clutch. The lock-up clutch will fix the impellor mechanically to the turbine and therefore prevent any slip. When the lock-up is engaged the converter is 100% efficient, improving fuel consumption.

The lock-up clutch sits between the turbine and the back plate of the converter casing. It is attached to the turbine via a plate with torsion springs to absorb shocks. The lock-up piston is driven of this plate by dogteeth allowing the lock-up piston to move. A friction material is attached to outer radius of the piston and corresponding ring of material is bonded to the converter casing.



Lock-up ON



Lock-up OFF

Engaging and disengaging the lock-up is achieved by controlling the flow direction of the ATF into and out of the converter. To disengage the lock-up the ATF is pump into the converter between the lock-up piston and the converter case. The force of the fluid pushes the lock-up piston towards the turbine. To engage lock-up the flow of ATF is reversed. Fluid is allowed to escape from between the lock-up piston and the converter casing. Fluid flow form the pump is applied to the lock-up piston between the piston and the turbine. The pressure acting on the piston is now imbalanced. The lock-up piston moves in the direction of the converter case and the lock-up is engaged. The lock-up clutch can only be engaged when the converter is operating as a fluid coupling.

What vehicle speed and load conditions will allow lock-up to be used?

Hydraulic System

The oil pump is driven by the torque converter casing in most common applications but can be located anywhere in transmission provided it can be driven by the engine input. The most common type of pump used is the gear type arrangement.

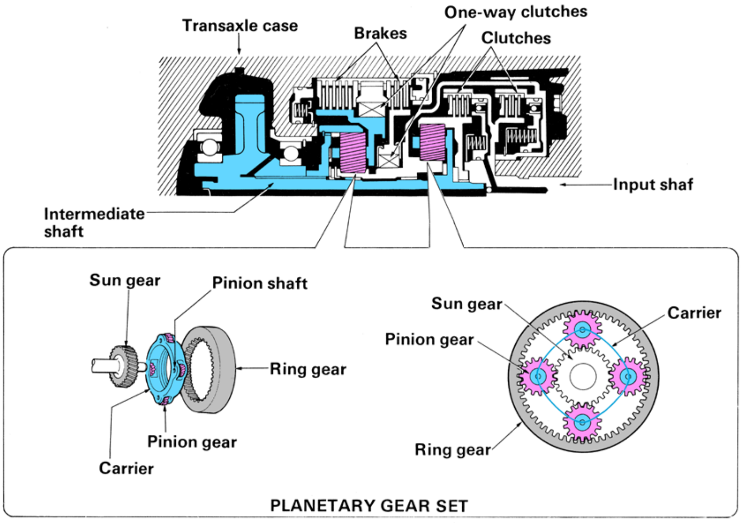
The planetary gears and bearings rely on oil pressure from the pump for lubrication. If a vehicle with an automatic transmission requires recovery towing with drive wheels in contact with he road will rotate some parts of the transmission and may lead to damage due to a lack of lubrication. It always advisable to recover a vehicle with an automatic transmission with the drive wheels lifted.

The sump pan forms the oil reservoir to feed the pump. The oil is drawn through a strainer or filters usually attached to the bottom of the valve block assembly. To supplement the strainer you will often find magnets attached to the sump pan or the valve block to capture small metal particles. Some manufactures specify a service interval for the oil strainer and it is critical to the performance of the transmission that the service specification is followed. In recent years improvements in design and oil performance have lead to the strainer and the oil to be non-service items.

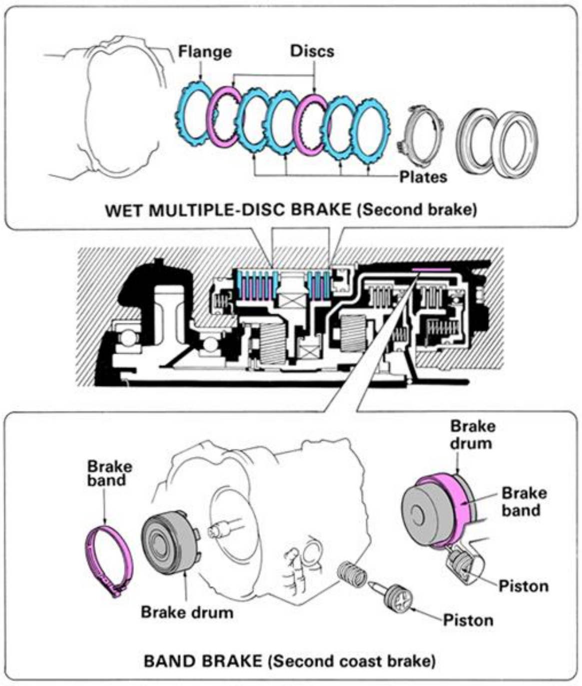
The oil flow from the pump is directed into the valve block.

Planetary Gear Train
Overview

The planetary gear unit is constructed from, a planetary (epicyclic) gear set which provides different gear ratios and hydraulic clutches and brakes used to control the engagement and disengagement of the different ratios.



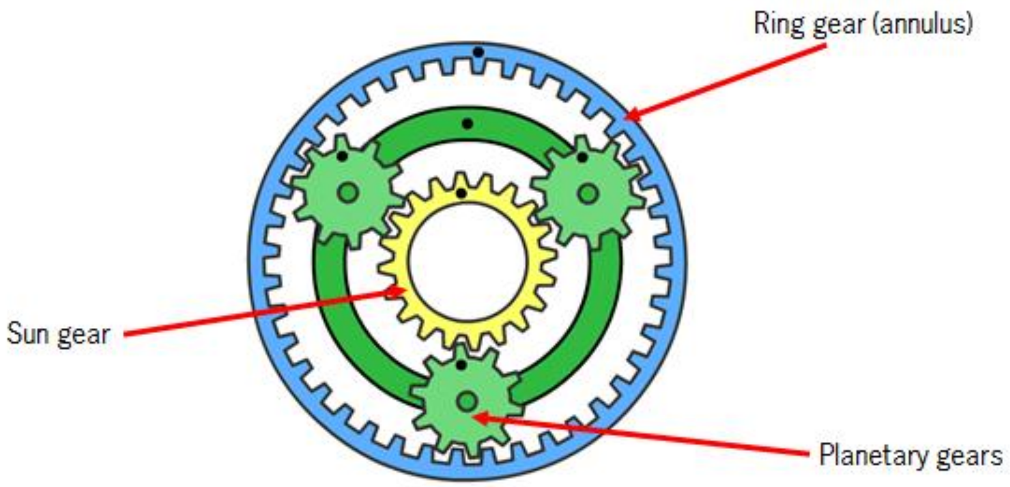
PLANETARY GEAR SET



The Planetary Gear

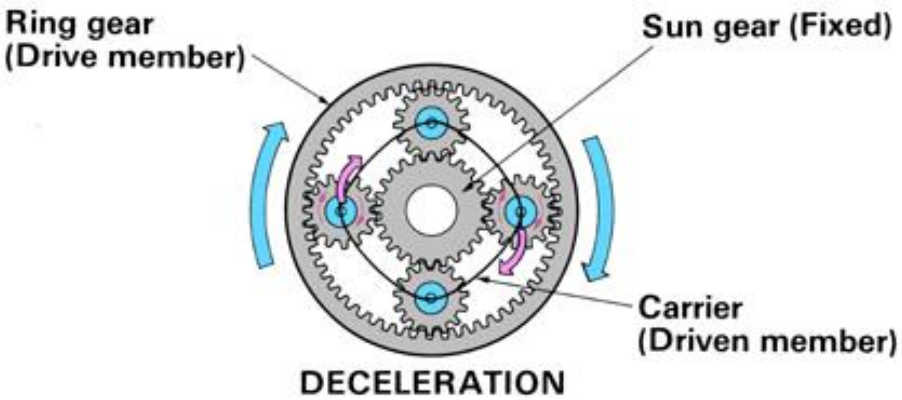
The planetary gear arrangement is constant mess gear set using three elements.

1. Ring gear (annulus)
2. Planetary gears supported by the planet carrier
3. Sun gear.



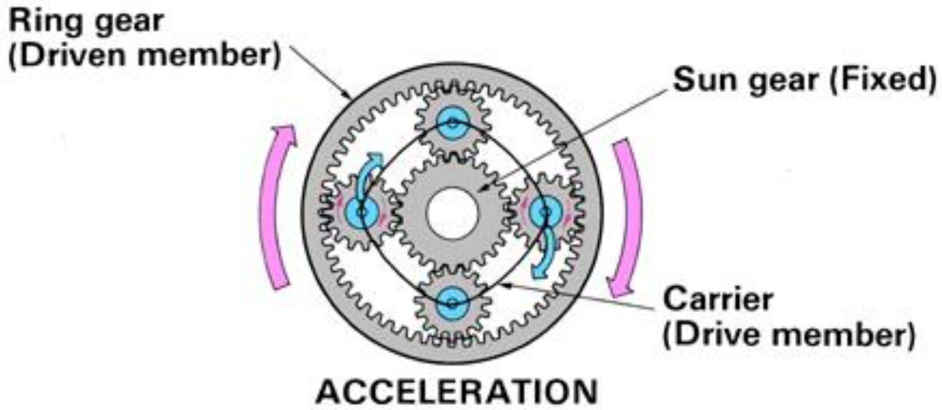
Different gear ratios can be achieved from the planetary gear set by controlling which of the three elements is the input, holding a second element and the remaining gear element becomes the output gear.

Example 1



Ring Gear – Drive member – input
Sun Gear – Fixed
Carrier – Driven member – output

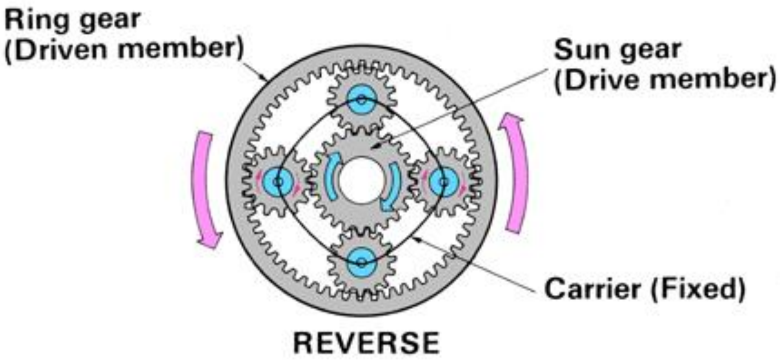
As the ring gear rotates clockwise the planetary gears are also rotated clockwise. The carrier is rotated in the same direction but at a lower speed than the ring gear. The amount of deceleration is related to the number of teeth on the ring gear and the sun gear.



Example 2

Ring Gear – Driven member – output
Sun Gear – Fixed
Carrier - Drive member – input

In this example the carrier is now the input and again rotates clockwise. This forces the planetary gears to rotate clockwise around the fixed sun gear. In turn the ring gear is also rotated clockwise but this time the gear ratio works the opposite way causing the ring gear to rotate faster than the carrier.

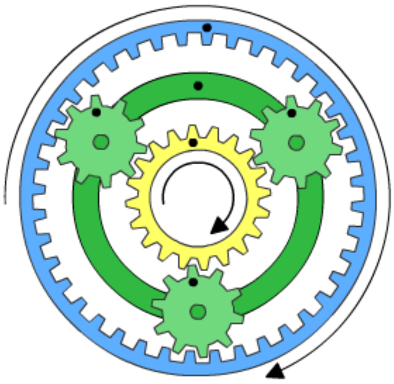


Example 3

Ring Gear – Driven member – output
Sun Gear – Drive member – input
Carrier – Fixed

In this case the sun gear rotates clockwise. The planetary gears rotate counter clockwise around the pinions held in the carrier. The ring gear must rotate in a counter clockwise direction at a lower speed than the sun gear.

Example 4



Ring Gear – Driven member – output
Sun Gear – Drive member – fixed
Carrier – Fixed

If two gears are locked together, the third gear is directly driven by the other two. This is known as direct drive. The ring gear is forced to rotate at the same speed as the locked gears.

Gear Ratio

You can see that a single planetary gear set can provide a wide range of different ratios. But can a single planetary gear set be used to build an effect transmission? To answer this question we need to calculate the gear ratios for our gear set. To calculate the gear ratio for planetary gear set we need to solve the following equation:

$$\text{Gear ratio} = \frac{\text{number of teeth of the driven element (output)}}{\text{number of teeth of the drive element (input)}}$$

It seems simple enough and the number of teeth on the sun gear and the ring gear can be easily understood by counting. The planetary carrier presents us with a problem, the planetary gears simply link the sun gear with the ring gear and are in effect idler gears. We need to calculate a theoretical number of teeth to describe the influence of the carrier on the gear ratio.

The number of teeth of the carrier (Z_C) =

number of teeth of sun gear (Z_S) + number of teeth of ring gear (Z_R)

Or $(Z_C) = (Z_S) + (Z_R)$

Example:

$Z_R = 79$
$Z_S = 33$
$Z_C = 79 + 33 = 112$

If the sun gear is the drive and the carrier is the driven we have:

$$\text{Gear ratio} = \frac{\text{number of teeth of the driven element (output)}}{\text{number of teeth of the drive element (input)}}$$

$$\text{Gear ratio} = \frac{\text{number of teeth of the carrier } (Z_C)}{\text{number of teeth of the sun gear } (Z_S)}$$

$$\text{Gear ratio} = \frac{(Z_S) + (Z_R)}{(Z_S)} = \frac{33 + 79}{33} = 3.394$$

What will be the gear ratio if we lock any two of the planetary gear elements together? Based on your calculations, do you think you can construct a viable 3-speed transmission with one planetary gear set?

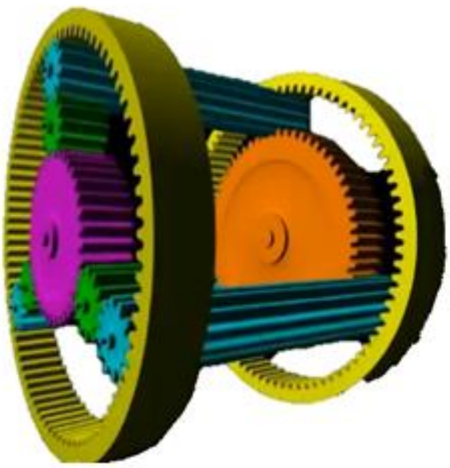
Although the planetary gear has six different gear ratios they are not all useful for you're a transmission. To achieve an appropriate set of gear ratios for a 3-speed transmission we need to use two planetary gear sets linked together.

There are two common arrangements used in automatic transmissions:

- ravigneaux type – combined carrier
- simpson type – combined sun gears.

The Ravigneaux type gear set is a compact design and is often used for smaller capacity engines. It is possible to configure this design for either 3 or 4 forward ratios and reverse.

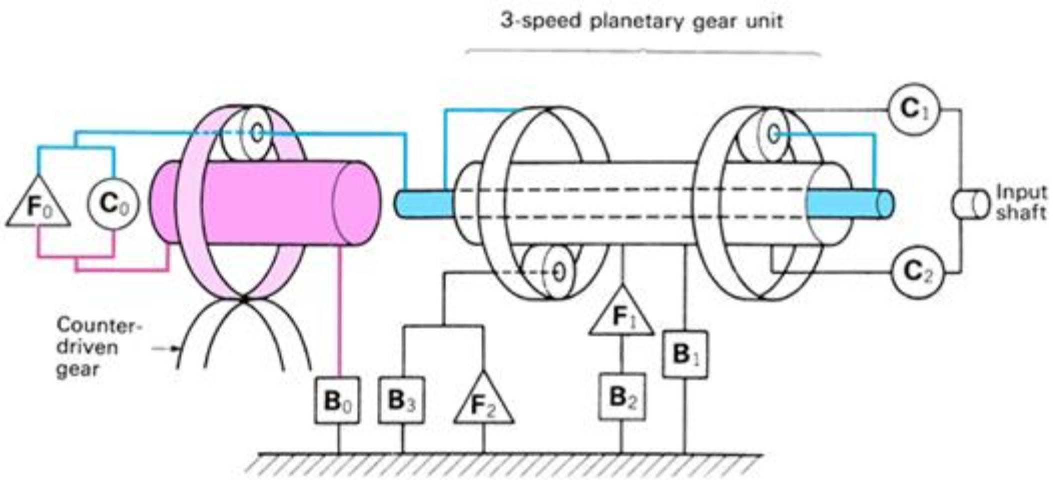
The Simpson type gear set is capable of transmitting higher levels of torque so tends to be used in conjunction with lager capacity engines. It provides 3 forward ratios and reverse. To study the principles of construction and control used in automatic transmission we will review the Simpson gear set in detail.



Ravigneaux type

Simpson type

Simpson Gear Set



The above diagram shows a 3-speed Simpson gear set combined with an additional planetary gear set used to provide a 4th forward gear. Also shown is the arrangement of clutches and brakes used to control which gear ratio is selected. This is a common arrangement and features most of the key design concepts used in automatic transmissions. The naming conventions used hear are not universal to all manufactures. In this the case the two gear sets are named for there position relative to the engine. Another manufacture may name the units with reference to the order they are installed into the casing i.e. the rear planetary gears could be called the 1st gear set. The clutches and brakes are either named to indicate there function or by a number. Again different manufactures can use different naming conventions.

Clutches and Brakes

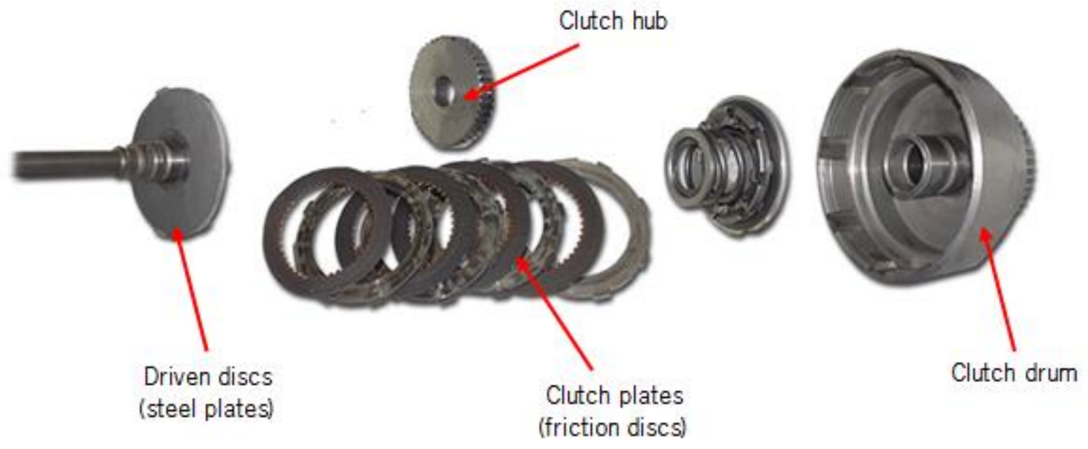
The clutches and brakes are used to connect the various elements of the planetary gear unit to the input shaft, to the transmission case (locked) or to other elements in the planetary gear set. Three types of clutch/brake are used in our transmission and most designs use either all of them or at least two of the designs.

When is a clutch a clutch and when is a clutch a brake?

A clutch connects to rotating parts together and a brake connects a rotating part to the case.

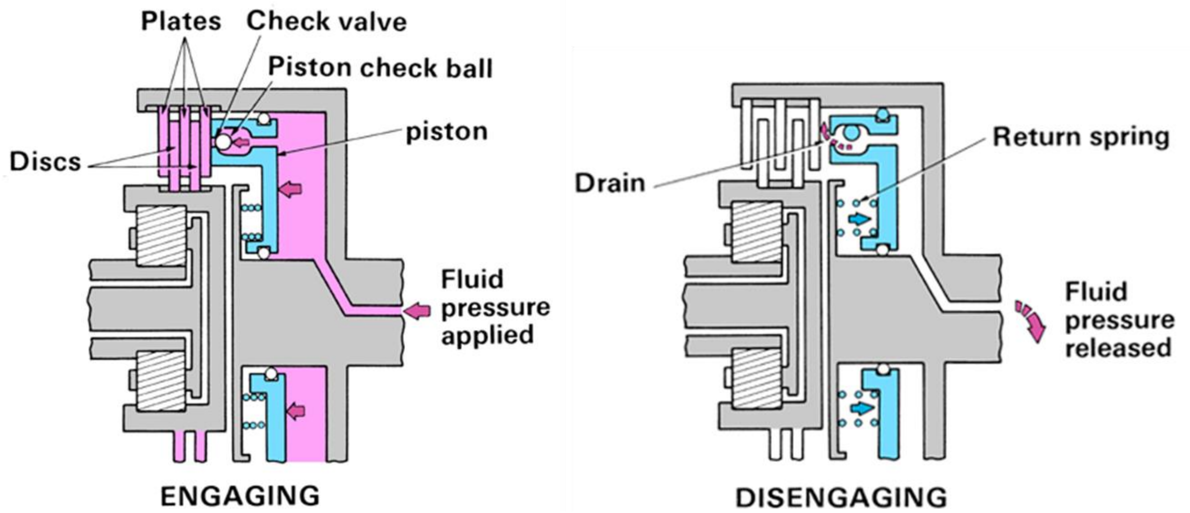
Multi-plate Clutch (brake)

The wet type multi-plate clutch is constructed from a series of friction discs and drive plates mounted alternately between the two components they will join together. The example on the previous page shows the C1 clutch unit. The C1 clutch unit sits inside a drum attached to the input shaft. The drive plates are splined to the inside of the drum and the friction plates are splined to the outside of the front ring gear. Inside the drum is mounted the hydraulic piston held any from the clutch discs by the return springs.



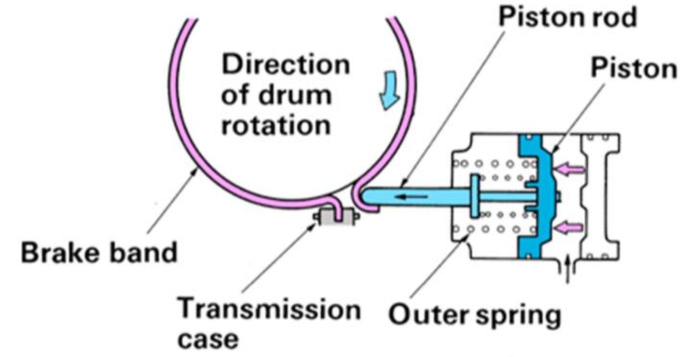
Operation

To engage the clutch, hydraulic pressure is applied behind the piston. The piston moves against the return springs and applies a clamping force to the clutch discs against the last drive plate called the flange. The flange plate will be thicker than the other drive plates.



To disengage the clutch the hydraulic pressure is released and the return spring starts to move the piston back to the rest position. A feature of a clutch piston is the check valve. When pressure is applied to the piston the check ball blocks the orifice and prevents the hydraulic pressure to build behind the piston. When the pressure is released the centrifugal force generated by the rotation of the drum fill tend hold fluid behind the piston and prevent the clutch from disengaging properly. The check ball will allow the fluid to escape from the front side of the piston using the same centrifugal force to speed up the piston release. The multi plate clutch used as a brake is the same basic construction but without the need for a check valve.

Band Brake



The band brake is a single strip of friction material with end fixed to the transmission case and the other controlled by a hydraulic piston. The in design we have studied the band is arranged around a drum that is attached to the front and rear sun gear. The actuator is constructed from a spring-loaded piston. The piston acts on a second spring and then to a rod that in turn acts on the brake band. The spring acting on the rod absorbs the vibrations generated when the brake band acts on the drum.

To engage the brake band hydraulic pressure moves the piston and via the spring the rod pushes the band towards the drum. As the band contacts the drum the rotational force acting on the band increases the clamping force due to the self-servo effect on the band. The clamping force achieved by the band is very high with a much lower hydraulic force when compared with a multi-plate type clutch.

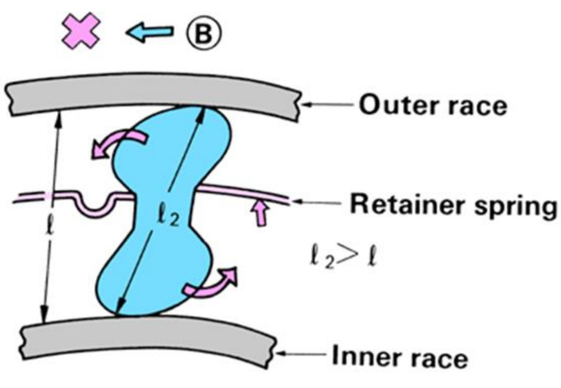
The down side of the design is that they are prone to wear and will therefore require some maintenance to ensure optimum operation.

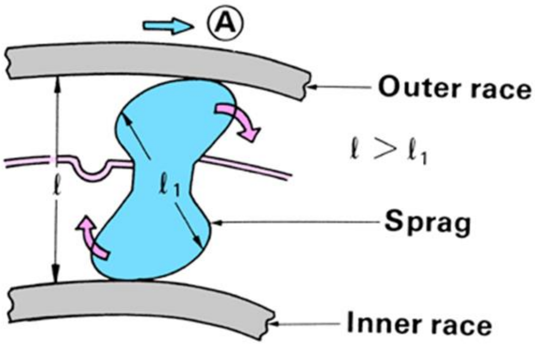
One-way Clutch (Sprag Clutch)

Two types of one-way clutch can be found in automatic transmission:

- roller bearing type
- sprag type.

The roller bearing type uses a series of roller bearing mounted between the inner and outer race. The inner race is sloped and the roller bearing is sprung loaded so that it tends to move up the slope. When the outer race rotates in opposite direction to the spring force the roller compress the spring and the outer race is allowed to rotate. When the rotation of the outer race is in the same direction as the spring force the roller bearing is wedged between the inner and outer race by the action of the spring and the rotational force of the outer race jams the roller between the two races and prevents rotation.





The sprag clutch as the name suggests, sprags mounted between two races. When the outer race rotates in one direction the top of the sprag is pushed in and the race is allowed to rotate. When the rotation is in the opposite direction, the top of the sprag is pulled outwards by the rotational force of the outer race. The shape of the sprag is longer in this direction and so jams between the inner and outer races, preventing rotation.

Function of Clutches and Brakes for a 3-speed Planetary Unit

Clutch/Brake Name	Function
Forward Clutch (C1)	Connects the input shaft to the front ring gear
Direct Clutch (C2)	Connects the input shaft to the front and rear sun gears
2nd Coast Brake (B1)	Locks the front and the rear sun gears to the transmission case preventing rotation in either direction
2nd Brake (B2)	Locks F1 to the transmission case and prevents the front and rear sun gear from rotating counter clockwise
1st and Reverse Brake (B3)	Locks the rear planetary carrier to the transmission case preventing rotation in either direction
1-way Clutch No1 (F1)	When B2 is activated F1 prevents the front and rear sun gears from rotating counter clockwise
1-way Clutch No2 (F2)	Prevents the rear planetary carrier from rotating counter clockwise

Operation of Clutches and Brakes for a 3-speed Planetary Unit

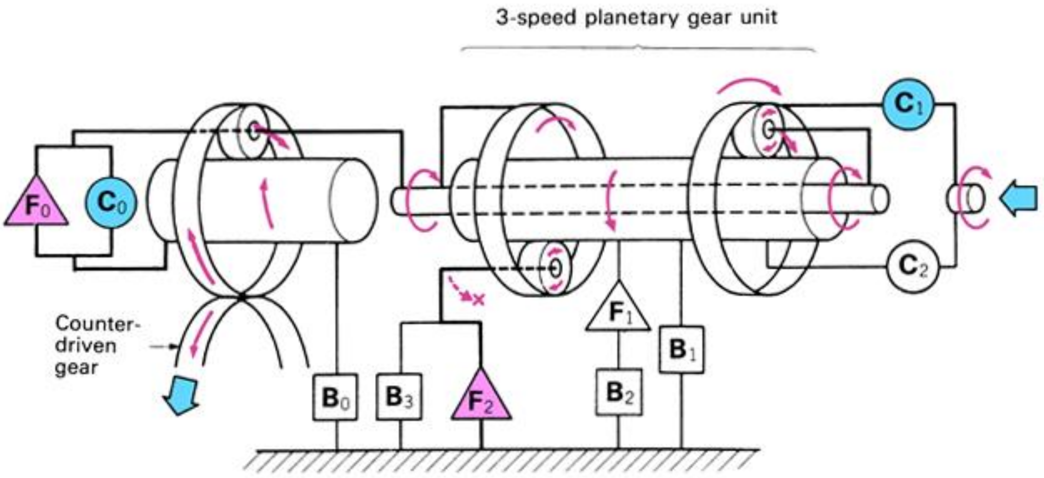
Shift Position	Gear	C1	C2	B1	B2	F1	B3	F2
P	PARK							
R	REVERSE		●				●	
N	NEUTRAL							
D, 2	FIRST	●						●
D	SECOND	●			●	●		
D	THIRD	●	●		●			
2	SECOND	●		●	●	●		
L	FIRST	●					●	●

Power Flow

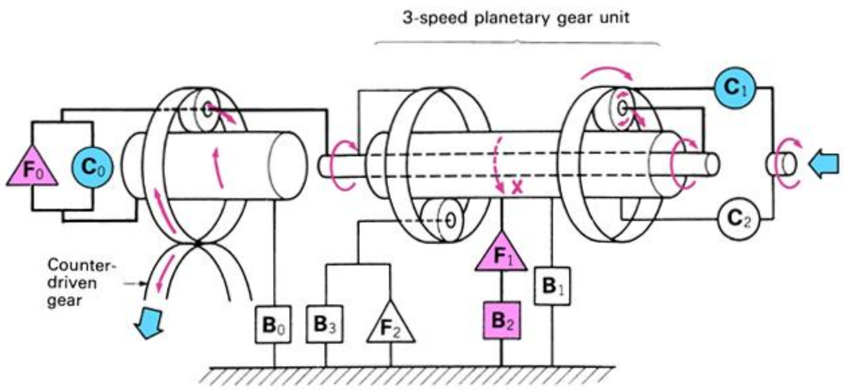
To understand why the clutches and brakes are arranged in the particular why we need to look at the power flow through the transmission in each gear. We will also seen how each of the gear changes is achieved.

In gears 1,2 and 3 the Co clutch is on. What elements of the planetary unit rotate and effect will this have on the overall ratio?

Shift Lever - “D” or “2” range
Gear - First.



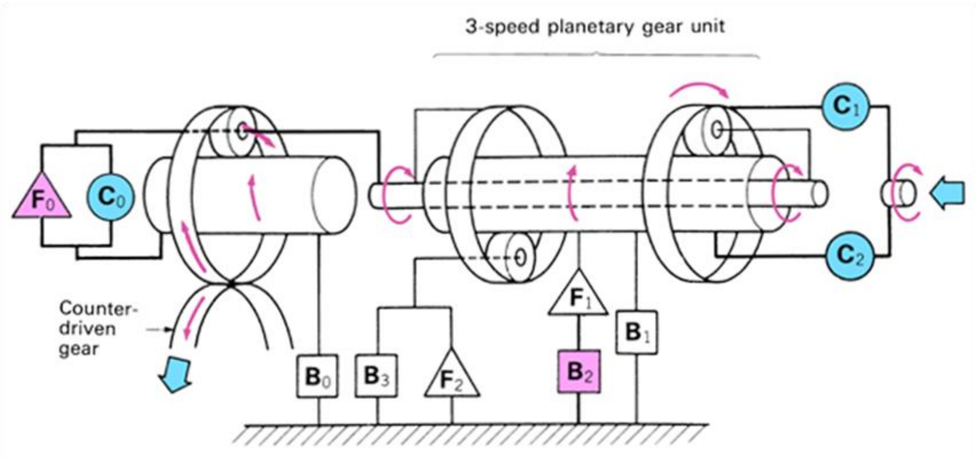
C1 clutch is activated connecting the input shaft to the front ring gear. The front ring gear is rotated clockwise and this causes the front planetary gears to also rotate clockwise. The rotation of the planetary gears causes the front planetary carrier to rotate clockwise and the front and rear sun gear to rotate counter clockwise. The rear sun gear rotates the rear planetary gears and will try to rotate the rear carrier counter clockwise. The rear carrier is locked by the action of F2 therefore the rear planetary gears act as idler gears causing the rear ring gear to rotate in the clockwise direction. Because the front planetary carrier and the rear ring gear are both connected to the output shaft the power flow is through both planetary gear sets.



Shift Lever - "D" range
Gear - Second.

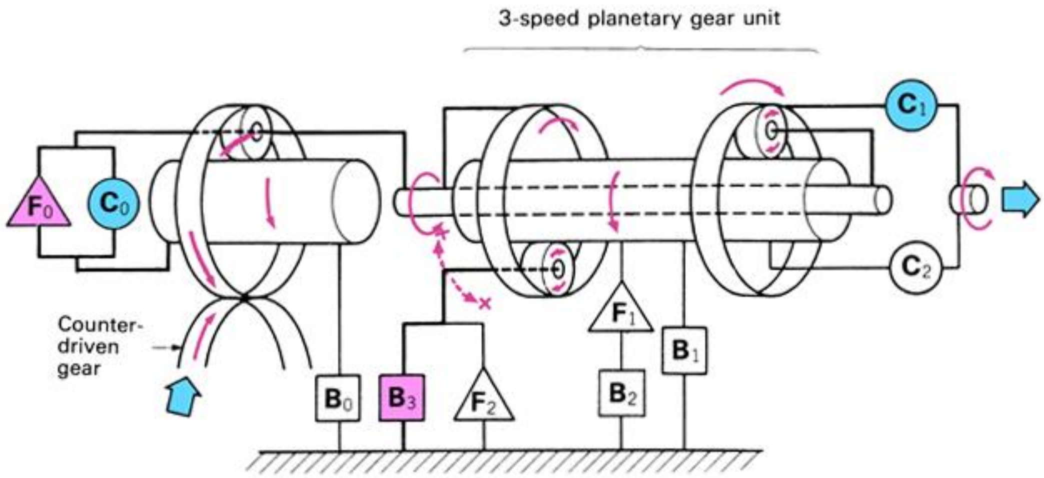
C1 clutch remains activated connecting the input shaft to the front ring gear. The front ring gear rotates clockwise rotating the front planetary gears in the same direction. The front and rear sun gear is prevented from rotating counter clockwise by the activation of B2 and the action F1. As result the front planetary carrier and therefore the output shaft is rotated clockwise.

Shift Lever - "D" range
Gear - Third.



C1 clutch remains activated. C2 is also activated connecting both the front ring gear and the front and rear sun gear to the input shaft. The front planetary gear set is now locked and rotates clockwise as a single assembly. The B2 brake remains activated but the action of F1 allows the front and rear sun gear to rotate clockwise. The output shaft is connected to front planetary carrier and is therefore also rotated clockwise.

Shift Lever - "2" range
Gear – Second (engine braking).



When the shift lever is in "D" range second gear is achieved by C1, B2 and F1. F1 and B2 prevent the front and rear sun gear from rotating counter clockwise. When the driver releases the throttle the drive path is reversed. The output shaft now becomes the input and causes the front planetary carrier to be rotated clockwise. The rotation of the planetary gears generates an anticlockwise rotation in the front ring gear and a clockwise rotation in the front and rear sun gear. F1 will allow the front and rear sun gear to rotate and the front planetary unit will freewheel, therefore no engine braking occurs.

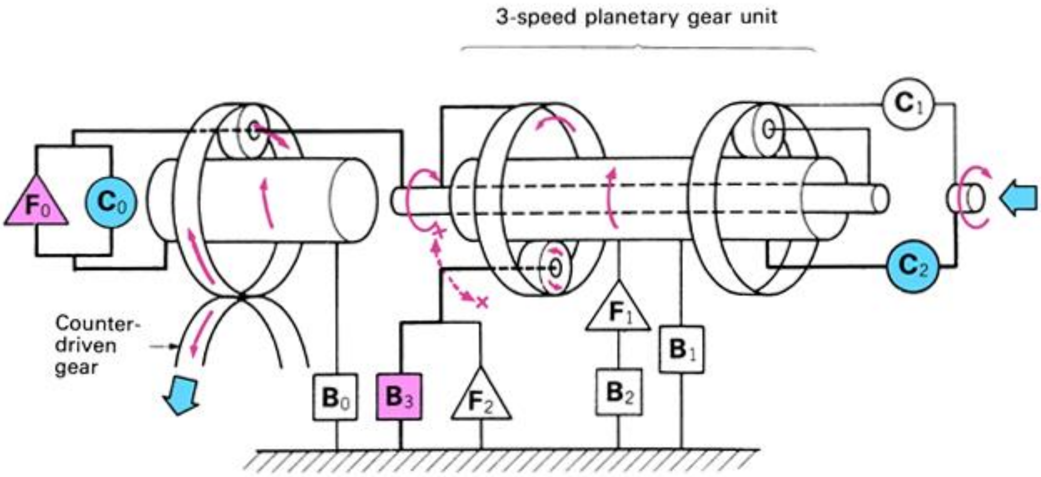
When the shift lever is in "2" range B1 brake is activated. This locks the front and rear sun gear preventing rotation in either direction. In this condition engine braking will occur.

Shift Lever - "L" range
Gear - First (engine braking).

For first gear the rear planetary carrier must be held to transmit power through the transmission. This is achieved by the action of F2. When the power follow is reversed the action of F2 allows the rear carrier to rotate and no engine braking occurs.

When the shift lever is in “L” range the B3 brake is activated locking the rear carrier and allowing power transmission. Engine braking is now possible.

Shift Lever - “R” range



Gear- reverse.

C2 is activated connecting the front and rear sun gear to the input shaft. The rear planetary carrier is locked by B3 so the planetary gears at as idle gears and cause the rear ring gear to rotate counter clockwise reversing the direction of rotation. The rear ring gear is connected to the output shaft.

Shift Lever - “P” or “N” range

In both “P” and “N” range C1 and C2 are both off. Therefore the input shaft is disconnected from the planetary gear set and no drive occurs.

In “P” range a mechanical lock is engaged to the output shaft to prevent the transmission from turning. The location of lock within the transmission will depend on the design of the gearbox. The front carrier, rear ring gear or directly to the output shaft are all possible locations on the transmission arrangement we have just studied.

You may have realised that a simpler arrangement of clutches and brakes could be used to achieve the same basic gear changes. For example B3 and F2 have similar functions and if we allowed engine braking in “D” range we could do away with F2. The same argument could be made for the B2 F1 combination and B1.

To understand why this extra complexity is necessary you need to remember that a key design criteria for an automatic gearbox is to ensure a smooth gear change.

Consider the gear change from neutral to first. Without F2 it would be necessary to engage C1 and B3 simultaneously. Even if a small miss timing occurred the transmission would “flare” (allow the engine revs to increase without drive to the wheels, similar to clutch slip).

Now consider the gear change from first to second. Without F2 and the B2 F1 combination it would be necessary to engage B1 and disengaged and B3 simultaneously. Again even a small miss timing could result in a severe shift shock.

Now consider the gear change from second to third. This time C2 engages and B1 disengages at the same time. During the down shifts the same problems could occur. The hydraulic control system would need to be extremely complex and the time required to carry each of the gear changes is likely to be much longer than is possible when F1, F2 and B2 are used in the design.

Hydraulic System

Overview

The hydraulic system main functions are:

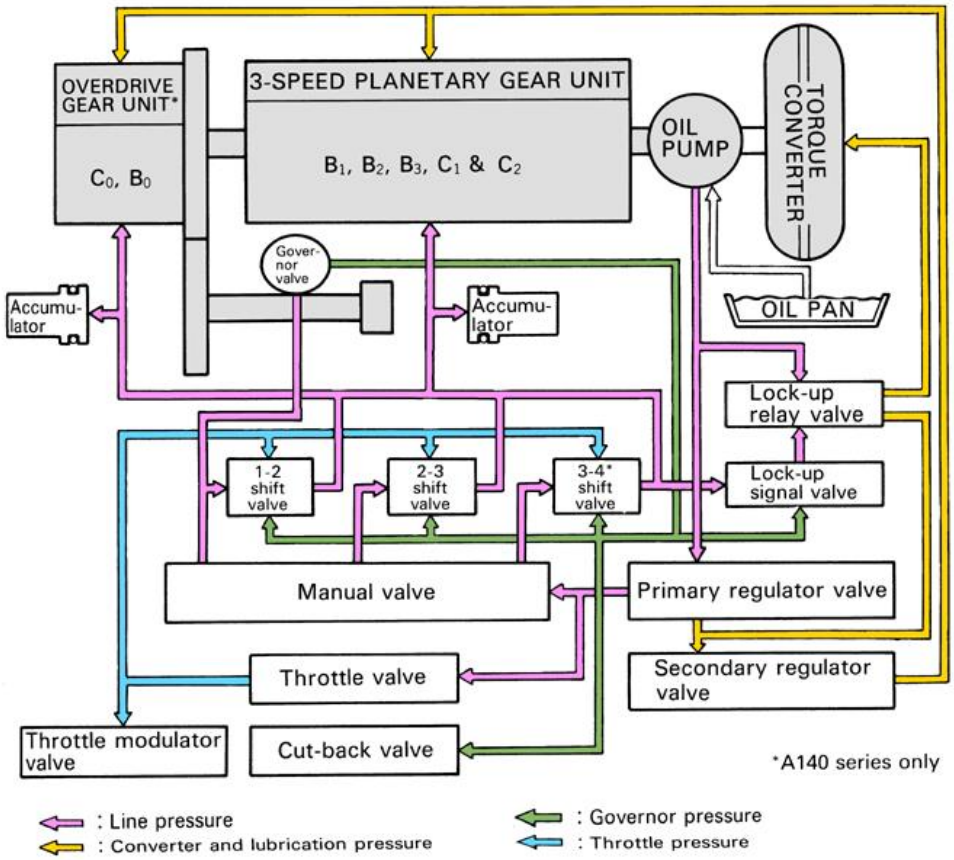
- regulate the oil pressure
- distribute oil pressure to the torque converter, clutches/brakes and lubrication
- controls the timings of gear changes.

To operate the gear change automatically the hydraulic system must be influenced by three basic factors:

- driver intention – position of the shift lever
- vehicle speed
- load condition.

These basic influences are converted into varying hydraulic pressures and these pressures are used to control the movement of valves in the valve block. In turn these valves control the passage of oil pressure to and from the clutches and brakes.

Overview of the hydraulic system.



Pressure	Control Valve	Function
Line Pressure	Primary Regulator	Provides the basic pressure for all of the other control pressures – provides the hydraulic pressure for the activation of the clutches and brakes.
Governor Pressure	Governor Valve	Based on the line pressure – provides a control pressure in proportion to the vehicle speed
Throttle Pressure	Throttle Valve	Based on line pressure – provides a control pressure in proportion to the throttle opening
Converter Pressure	Secondary Regulator	Based on line pressure – regulates the pressure in the torque converter and the lubrication circuit

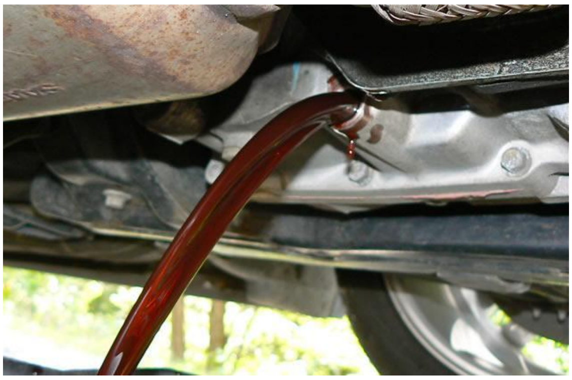
Automatic Transmission Fluid

The Automatic Transmission Fluid ATF is critical to the performance of the transmission. Using the correct specification oil and ensuring the fluid level is maintained correctly will ensure reliable function of the gearbox.

The ATF has the following roles:

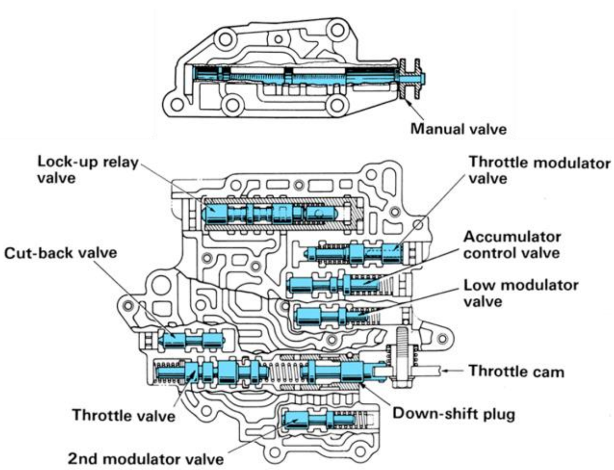
- transmit engine torque in the torque converter
- control and activate the clutches and brakes
- lubricate the moving parts of the transmission
- act as a coolant for the transmission of parts and especially the torque converter.

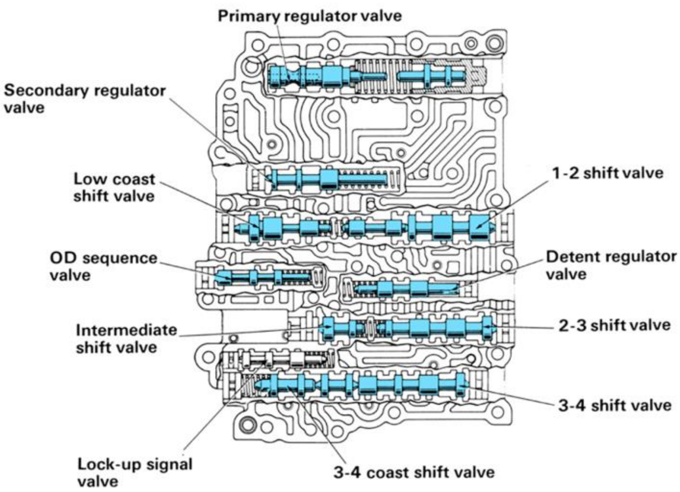
The most commonly used oil is known as Dexron 2 and is high-grade petroleum based mineral oil. As the complexity of the more modern transmission design has increased special semi-synthetic and fully synthetic oils have been developed to enhance the performance of these transmissions.



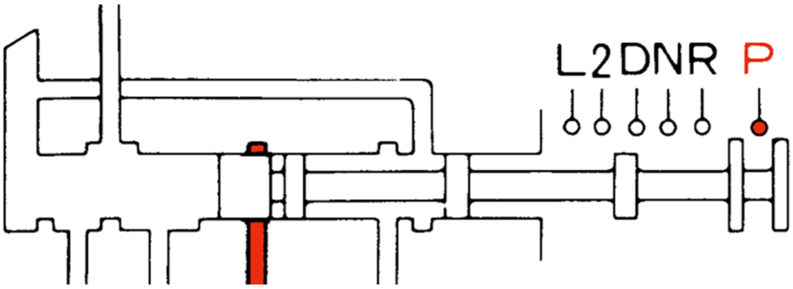
Valve Block Assembly Overview

The valve block assembly cast structure of passages for directing the oil to and from the various valves and then to the passages in the casing feeding fluid to the clutches and brakes. All of the control valves except the governor valve and mounted in the valve block.



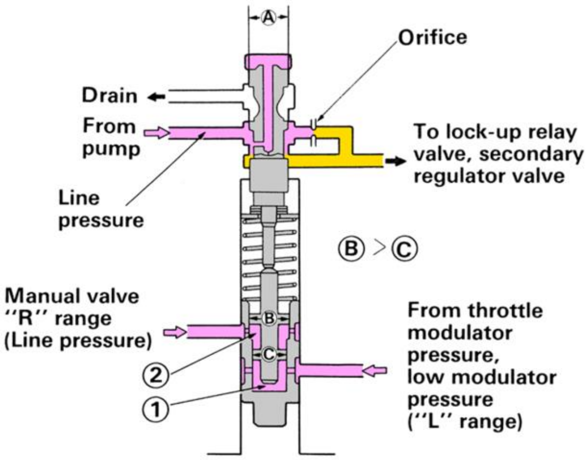


Manual Valve



The manual valve diverts line pressure from the primary regulator into different passages based on the position of the shift lever. Allows the driver to select the required driving range.

Primary Regulator Valve



Oil from the pump enters the top section of the valve and acts on the surface **A.** The force acting down on the valve is balanced by the force of the spring.

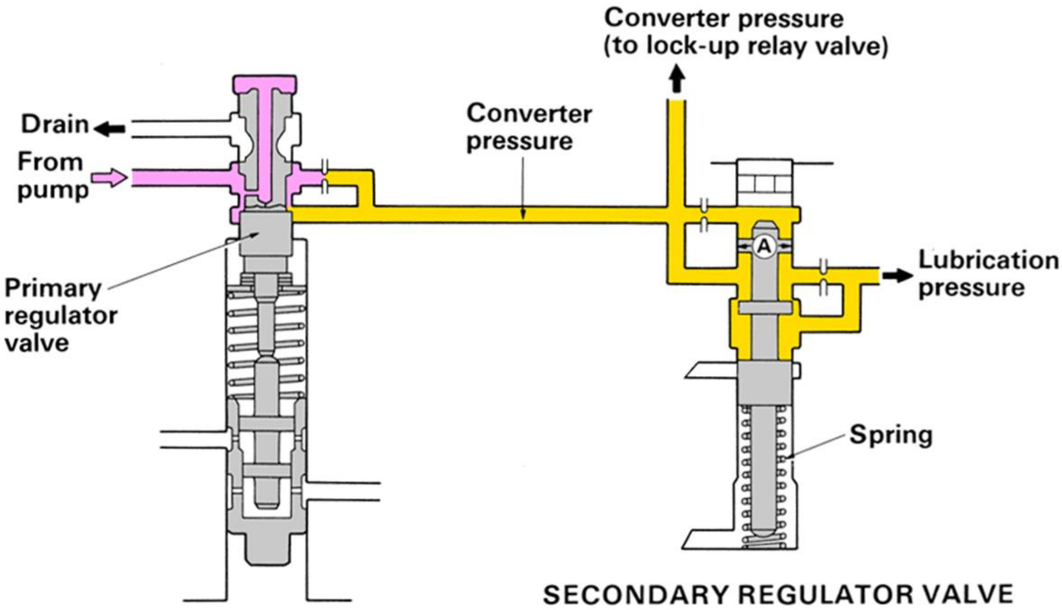
When the manual valve selects reverse, line pressure is applied to the valve at **2.** This pressure acts on the surfaces **B** and **C.** Because the surface area of **B** is larger than **C,** the lower section of the valve will move upwards assisting the spring. The line pressure is increased. When L range is selected, throttle modulator pressure is applied at **1** and will also apply additional force to the spring (**Fig 28**).

Increasing the line pressure for R and L range increases the clamping force of the clutches and reduces the possibility of slip in the clutches and brakes.

Why is there more chance of slip in R or L than in any other gear?

Secondary Regulator Valve

Pressure acts on the valve at surface **A**. This force is balanced against the spring controlling the pressure to the torque converter and the lubrication circuits.



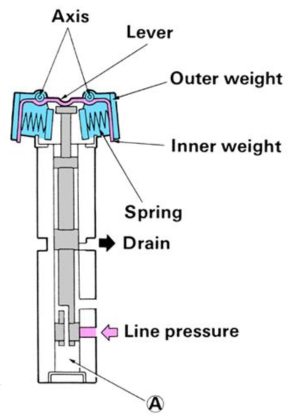
SECONDARY REGULATOR VALVE

Governor Pressure Control

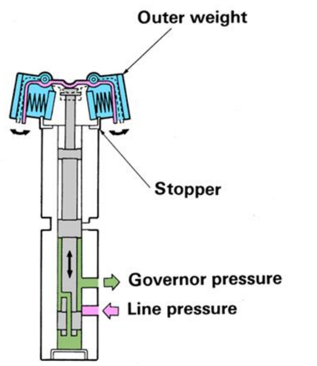
The governor valve must be influenced by the road speed of the vehicle so it is mounted on the output shaft of the gearbox or the final drive unit.

The movement of the valve is controlled by bob weights. As the valve is rotated centrifugal force causes the weights to open outwards against the force of the springs. This pushes the valve downwards increasing the pressure in the governor circuit in proportion to road speed.

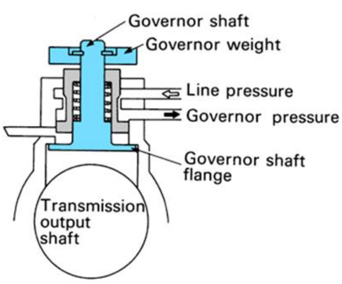
The example shown below a two-stage operation achieved by using an inner and outer set of weights. This allows for a move accurate control of the governor pressure.

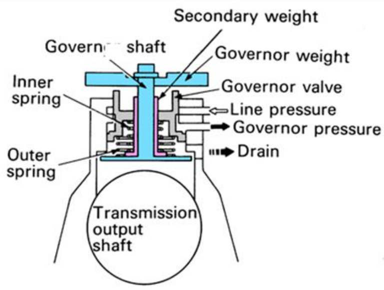


LOW SPEED

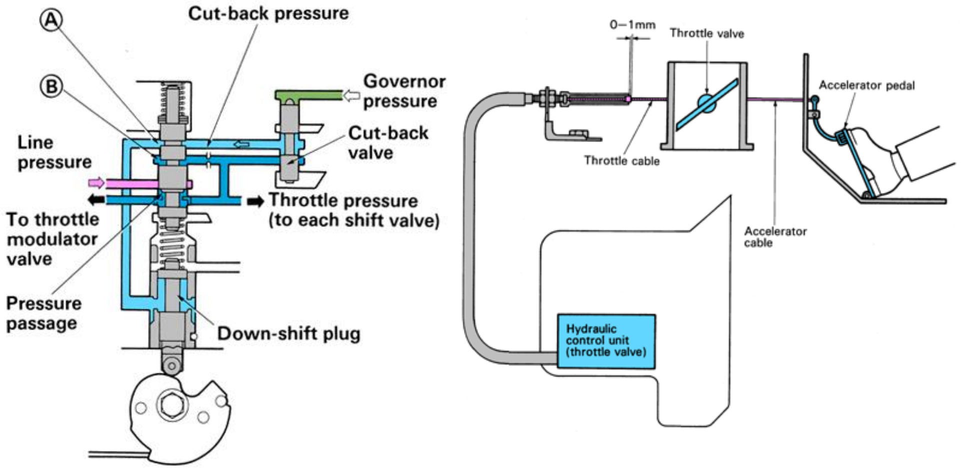


MEDIUM & HIGH SPEED





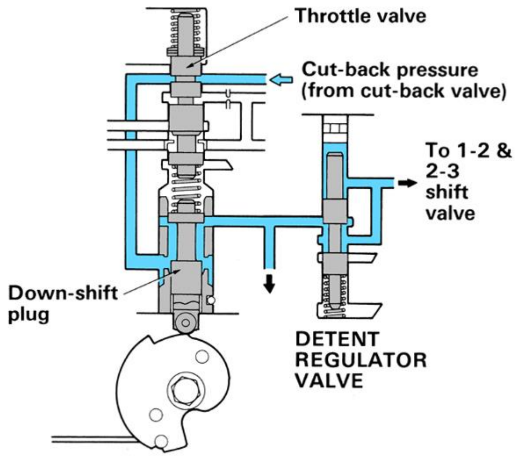
Throttle Pressure Control



The throttle valve controls the throttle pressure based on the balance between the two springs. The lower spring is influenced by the downshift plug, which in turn is connected to the throttle cam. As the driver accelerates the throttle cam moves the downshift plug up-wards and increases the force of the lower spring. The throttle valve moves and the throttle pressure is increased. In the example shown and Cut – back valve is used to generate a pressure based on the throttle pressure and governor pressure. This is directed to the top of the throttle valve and balances the action of the shift plug.

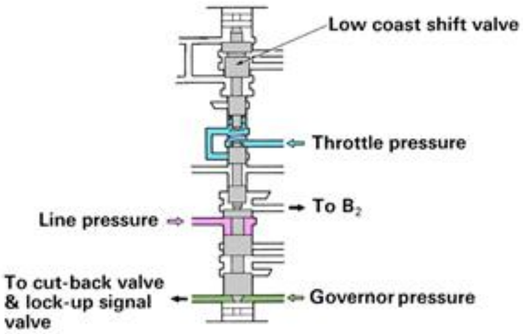
When the driver presses the accelerator to over 85% opening the cam and the movement of the shift plug opens a second passage to the shift valves implementing a forced kick-down.

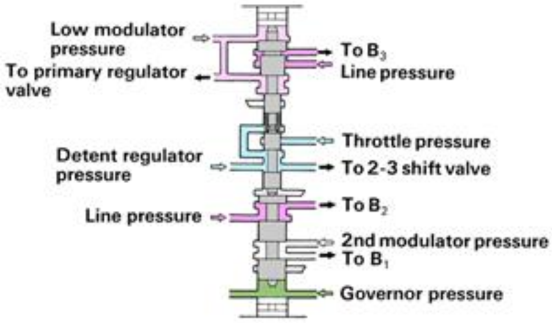
Throttle pressure is also directed to the primary regulator. The line pressure can be increased as the engine load is increased.



Kick -Down

Shift Valves





The shift valves control when the line pressure is directed to the clutches and brakes. The basic construction is similar for all of the valves. Governor pressure acts on one end of the valve and throttle pressure acts on the other. The point at which the valve will move and allow the line pressure to the clutch will depend on the balance between the two pressures.

If the vehicle is accelerating with a light throttle opening then the throttle pressure will be low. As the vehicle speed increases the governor pressure will soon overcome the throttle pressure and the shift valve will move sooner. If the throttle pressure is higher the gear change will be delayed and the transmission will hold the lower gear longer.

Other Valves and Components

The valves that we have studied in detail are all that is required to achieve a basic hydraulic control system. You we will see from the hydraulic diagrams on the following pages that the actual construction of the hydraulic control system is more complex. These additional components are used to modify the basic hydraulic control to improve the shift quality.

- regulator Valves – these valves are used to stabilize the hydraulic pressure in the relevant circuit
- modular valves – are used to reduce the basic pressure for a more accurate control to another valve
- accumulators – are placed in line with the clutches and brakes and act as dampers to ensure a smooth engagement. In some designs they will combine spring force with an accumulator back pressure proportional to throttle pressure
- check balls and orifice – these are usually an integral part of the plate that sits between the two halves of the valve block. They control speed of the oil flow to clutches and brakes and again improve the shift quality. They are constructed so that the fluid flow is forced through the orifice when the clutch or brake is applied but the return flow is allowed to pass unimpeded.

Changing Gears

Understanding how all of these valves work together is best understood by following a series of gear changes. The following pages show the hydraulic diagrams for 4 speed transmission using the Simpson gear arrangement and an additional planetary gear set used to provide the 4th speed. In this design the 4th gear is an overdrive ratio and consequently the clutch and brake used to control it are called Co, Bo and Fo.

Using your experience so far and the diagram of the planetary gear set complete the operation table?

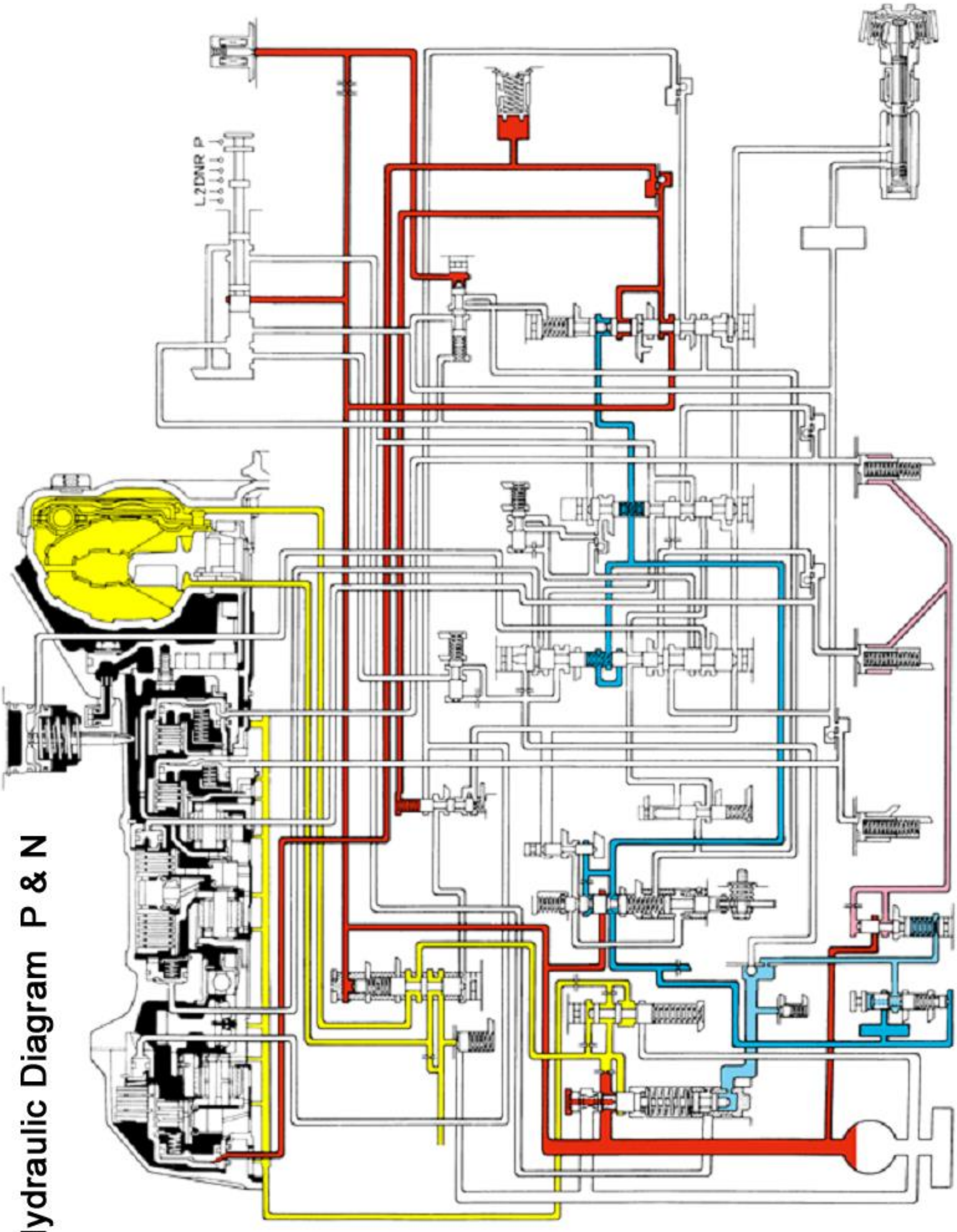
Shift Position	Gear	Co	Fo	C1	C2	Bo	B1	B2	F1	B3	F2
P	PARK										
R	REVERSE				●					●	
N	NEUTRAL										
D, 2	FIRST			●							●
D	SECOND			●				●	●		
D	THIRD			●	●			●			
D	OD			●	●			●			
2	SECOND			●			●	●	●		
L	FIRST			●						●	●

Co is activated in all gears except N, P and OD and Bo is active in OD. Fo works in parallel with Co.

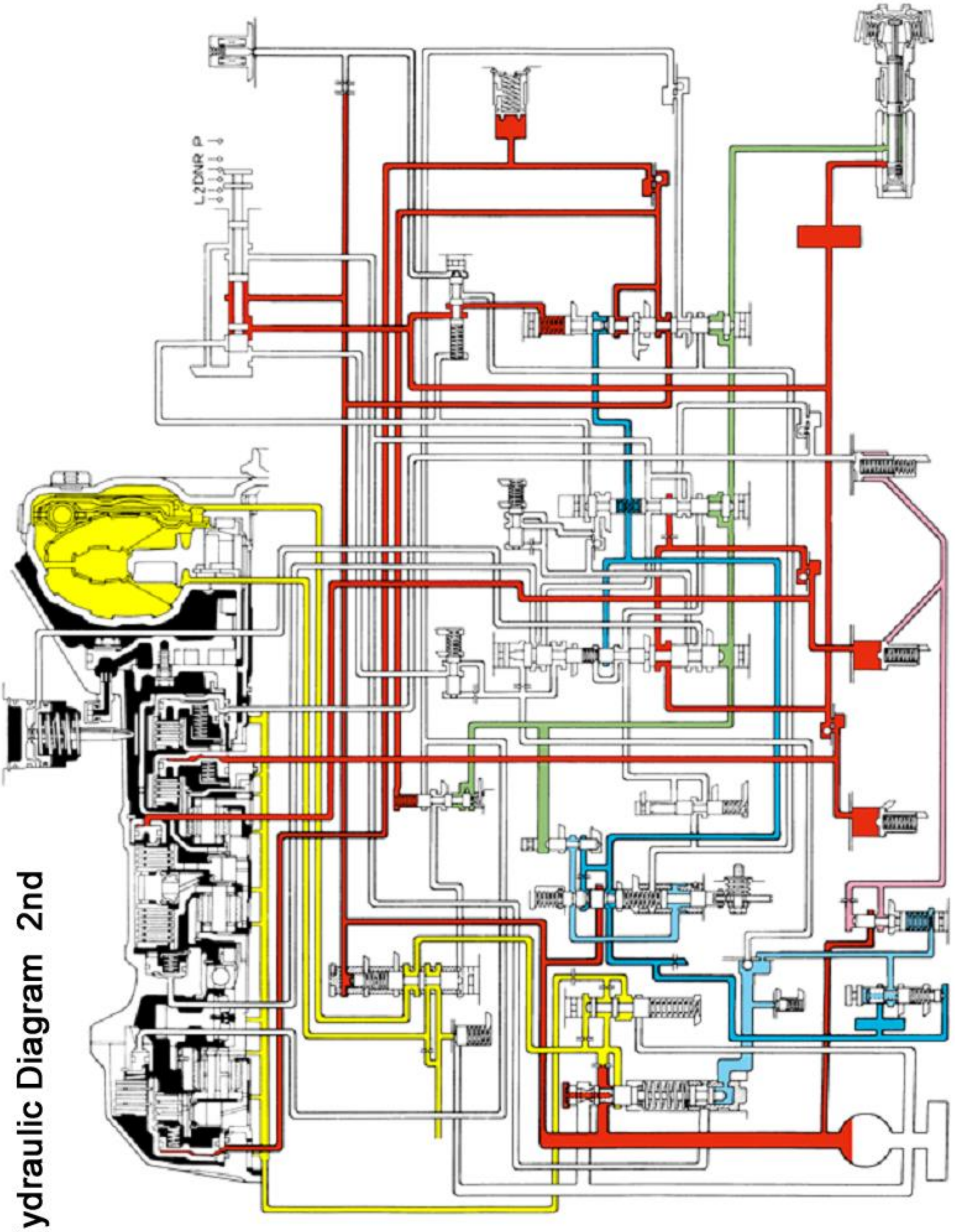
You will see in the hydraulic diagrams that Co is activated as soon as the engine starts.

Why do you think that Co is activated directly from the line pressure instead of the manual valve?

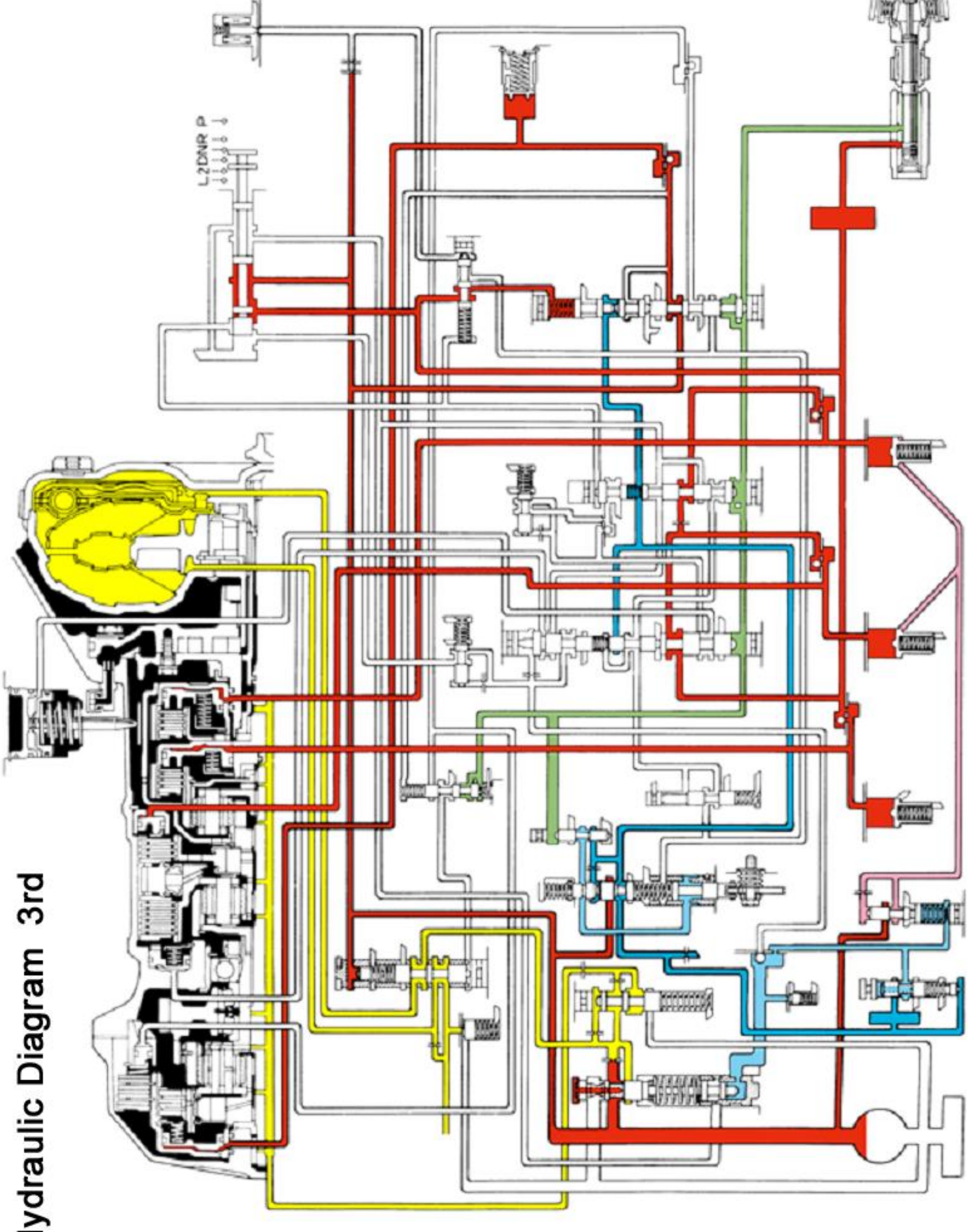
Hydraulic Diagram P & N



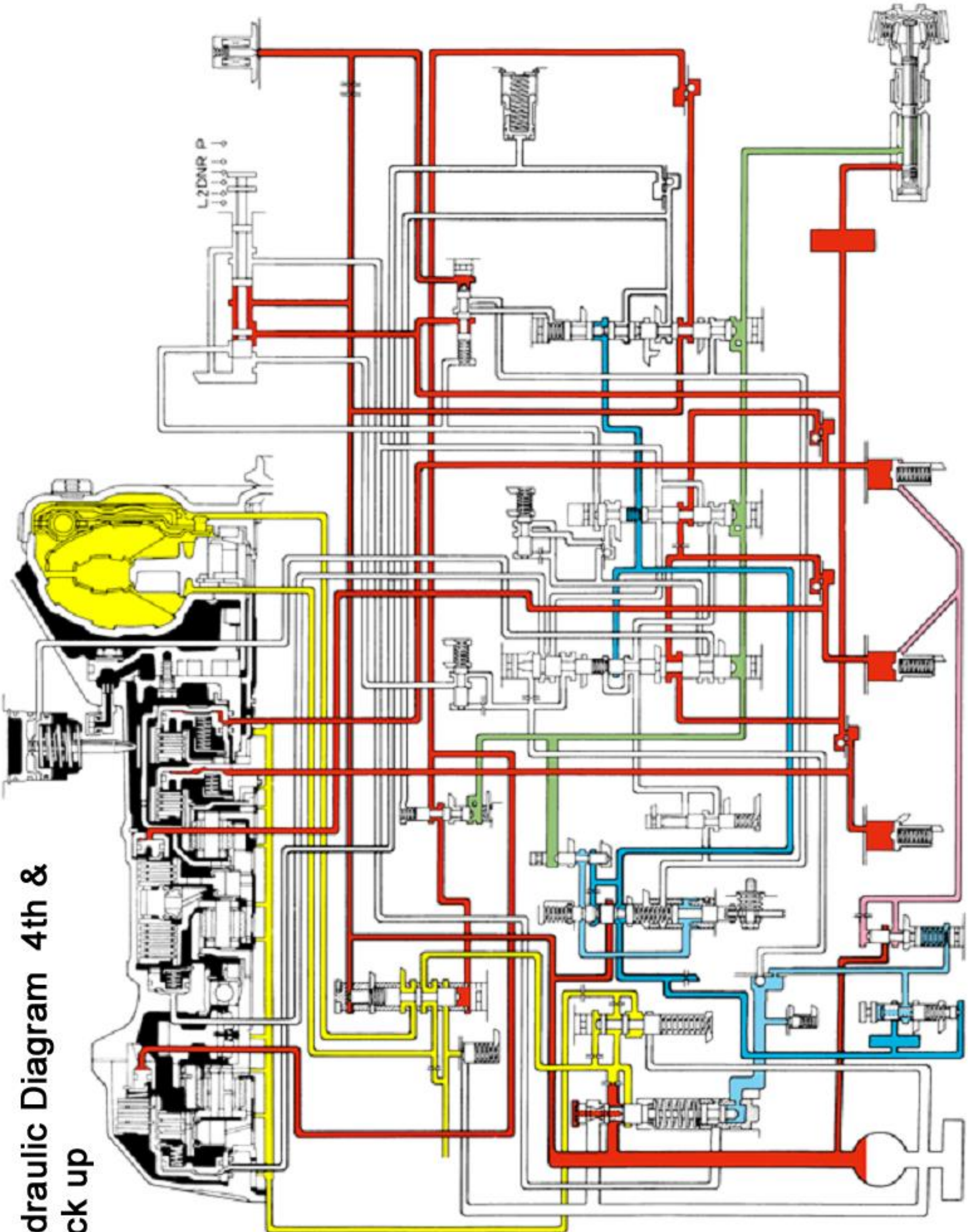
Hydraulic Diagram 2nd



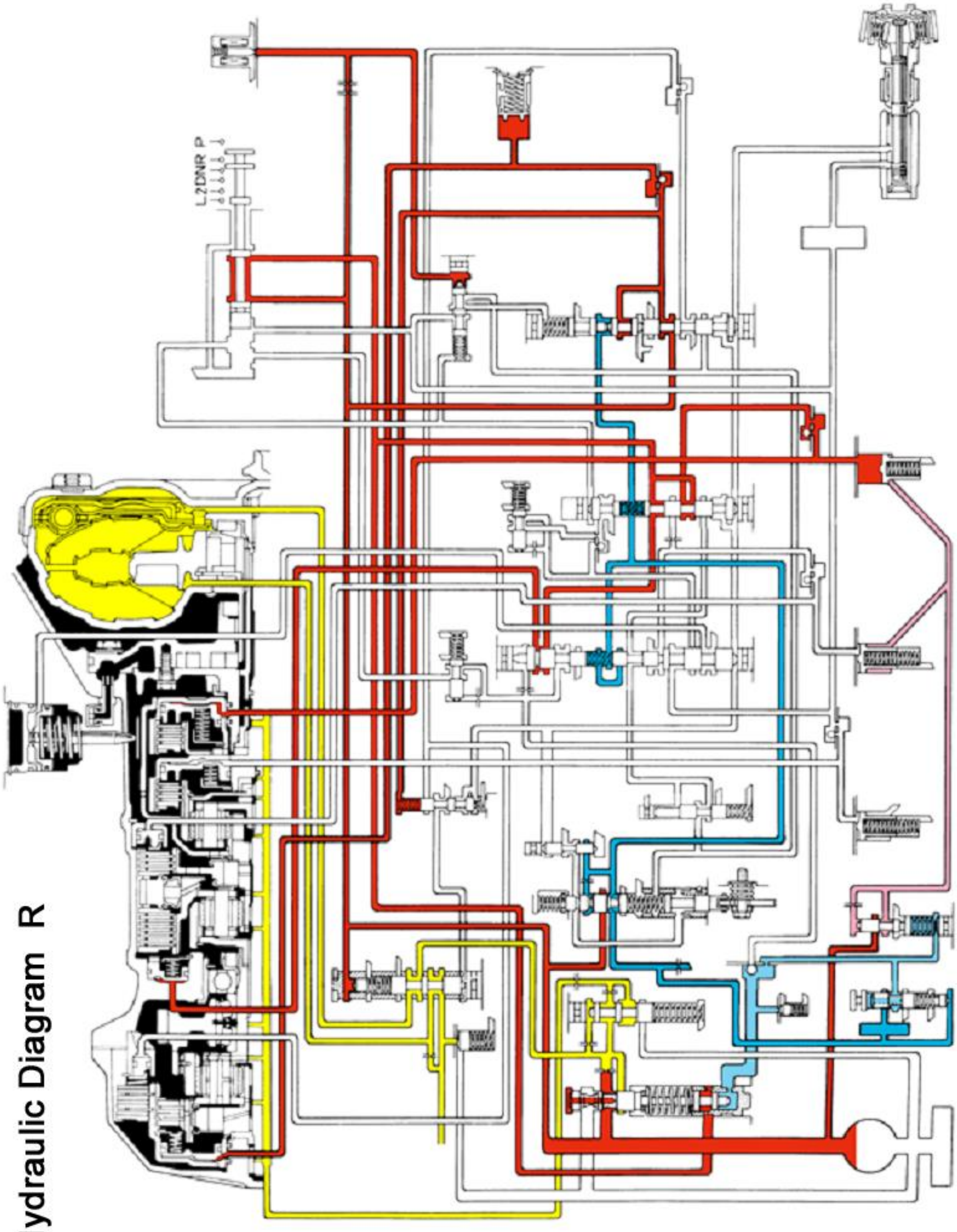
Hydraulic Diagram 3rd



Hydraulic Diagram 4th & Lock up



Hydraulic Diagram R



Troubleshooting

Analysis of Symptom

Successful diagnosis of automatic transmission problems depends of following a few basic rules. Always try to understand the basic construction and operation of the transmission you are working on. Manufactures repair manuals and training materials will provide enough information to understand the type of construction and basic operation. This knowledge will allow you to analysis the symptoms and relate them to specific components within the transmission.

For example, a shift quality problem could be the result of a large number of possible components:

- shift valve
- accumulator
- pressure regulator
- clutch piston
- clutch plates
- oil quality.

This is not by any means a complete list and we still have not decided which clutch or which shift valve etc. The point is that it is not very easy to check the line pressure or confirm that first gear L range is the same as D range when the gearbox is in pieces on bench.

The Golden Rule – Never strip a gearbox until you now what is wrong with it.

This means you must carry a very thorough investigation of the symptoms before attempting any repair.

Confirmation of Symptom

Confirming the symptom should always be more than simple checking what the customer has reported. To help us to understand the root cause of the problem you must check the complete performance of the transmission. Once you understand the operation of the transmission you can appreciate just how useful it is to understand the full extent of the problem. Remember, many customers may never use any other position than P, R, N and D.

Preliminary Inspection

Another part of the evidence gathering process is preliminary inspection.

- oil condition – this check will indicate the general condition of the clutches and brakes. Slipping will show up as brown colour in the fluid and a strong burning smell. Low or high oil level can be the root cause of shift quality problems

- cable adjustments – the throttle cable and shift cable adjustment are also important. The throttle cable will affect shift timing
- oil leaks – the last thing you want to do is turn a simple oil leak problem into a complete transmission overhaul, so always check for oil leaks before road testing.

Basic Tests

In conjunction with the points already raised there are some specific performance tests that will help you to diagnosis the root cause of the symptom.

- stall test – With the foot brake, handbrake applied and the wheels chocked the transmission is shifted to D range and then the throttle is held at maximum for about 30 seconds. The engine rpm (stall speed) achieved at full throttle tests the condition of the C1 clutch and the operation of the torque converter.
  Stall speed to low – Torque converter stator slipping – low engine power
  Stall speed to high – C1 slipping – line pressure low
- line pressure check – completed under the conditions as the stall test.
  Low line pressure – oil pump – primary regulator – internal leak
  High line pressure – primary regulator
- governor pressure – Measure the pressure under different road speeds.
  Not to specification – Line pressure to low – internal leak-governor valve
- time tag test – measure the time taken to change from N to D and N to R.
  Not to specification N to D – low line pressure – C1 worn – F0 worn
  Not to specification N to R – low line pressure – C2 or B3 worn – F0 worn.

Completing these tests and careful evaluation of the symptoms should enable to focus on one or two possible causes before the transmission is removed from the vehicle

Repair Methods and Precautions

Good Practice when Overhauling Automatic Transmission

Each manual manufacture will provide comprehensive instructions in the relevant repair manual but some general observations may be useful.

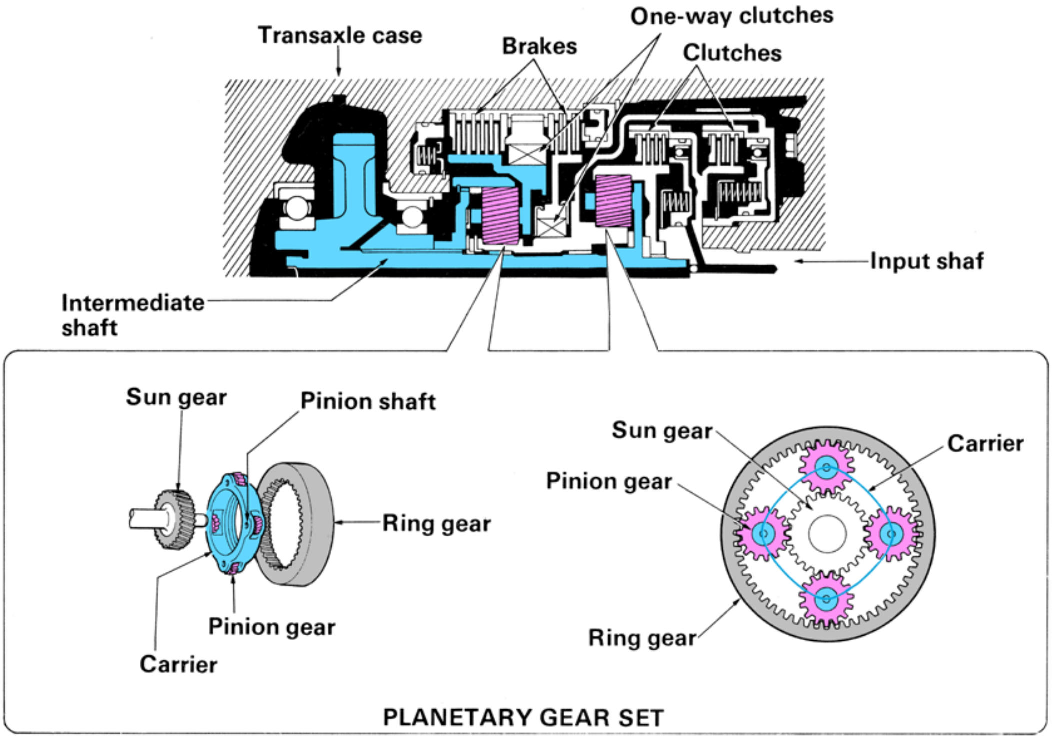
- always mark the position of the torque converter relative to the drive plate when removing the transmission
- always strip an automatic transmission in a clean and dust free environment
- be organised – keep transmission components in the order they were removed
- when rebuilding clutch and brake pistons – always check their operation before rebuilding the transmission
- thrust washers and bearings can held in place with petroleum jelly (it dissolves in ATF)

Electronic control

Review of Planetary Gear Trains

The construction and operation of the gear train remains same for both hydraulic or electronic shift control, the selection of each gear is still achieved by the distribution of hydraulic pressure to the clutches and brakes. To simplify our studies of the electronic control system we will use the same gear train arrangement to review the planetary gear train.

The pictures above show a 3-speed transmission using two epicyclic gear sets. In this design the sun gears of both gear-sets are joined.



What name is given to this arrangement?

The simplified diagram shows the same arrangement with the addition of a third gear-set to achieve a 4-speed arrangement.

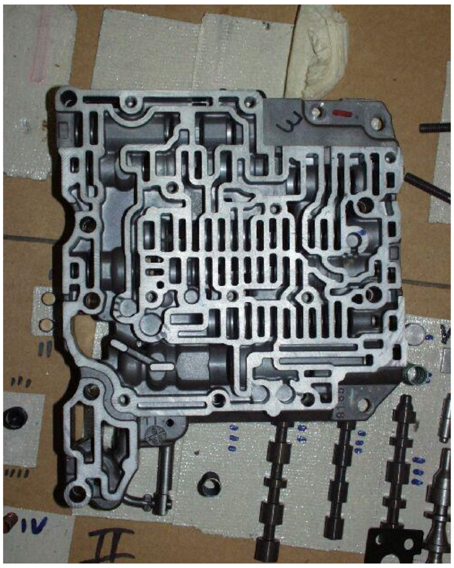
Valve block Assembly

The general construction of the valve block is the same whether the gearshift control is hydraulic or electrical. The most obvious difference is the addition of the electronic solenoids used to trigger the shift valves. The use of electronic control will in most designs reduce the hydraulic valves required to operate the automatic transmission. The result is that the valve block assembly in electronic control transmission will usually be smaller than the valve block in a similar hydraulic control transmission.

The functions of the valve block assembly in an electronically controlled transmission are:

- Regulate the oil pressure – the oil flows from the pump to the primary regulator valve. The resulting pressure is used for all other functions within the transmission and is generally called the line pressure. Line pressure will also be influenced by the action of the throttle pressure controlled by the throttle valve.

- Distribute oil pressure to the torque converter – the secondary regulator valve generates a constant flow of oil to the torque converter, generally known as converter pressure. This pressure is also used to engage and disengage the lock-up clutch.

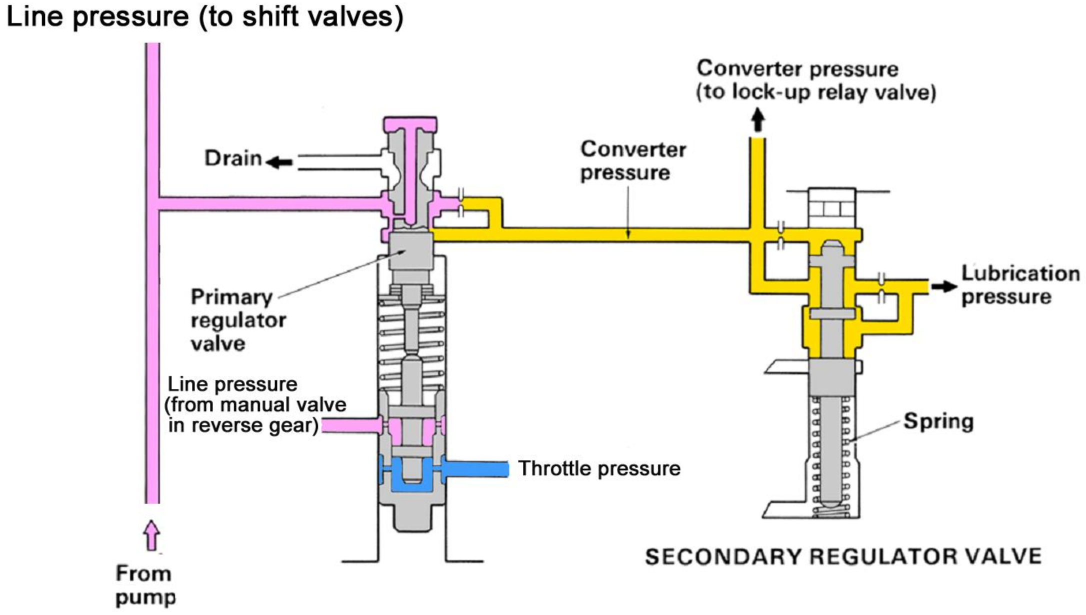


- Activating clutches and brakes – the line pressure is directed to the clutches and brakes by the shift valves. The movement of the shift valves and therefore the gear selection timing is determined by the operation of the electronic solenoids. The pressure acting on the clutches and brakes is modified to ensure smooth and quick engagement and disengagement.

- Lubrication – oil pressure from the secondary regulator is directed to the bearings and gear sets.

Oil pressure Control

The line pressure is the fundamental pressure that all other pressures in the



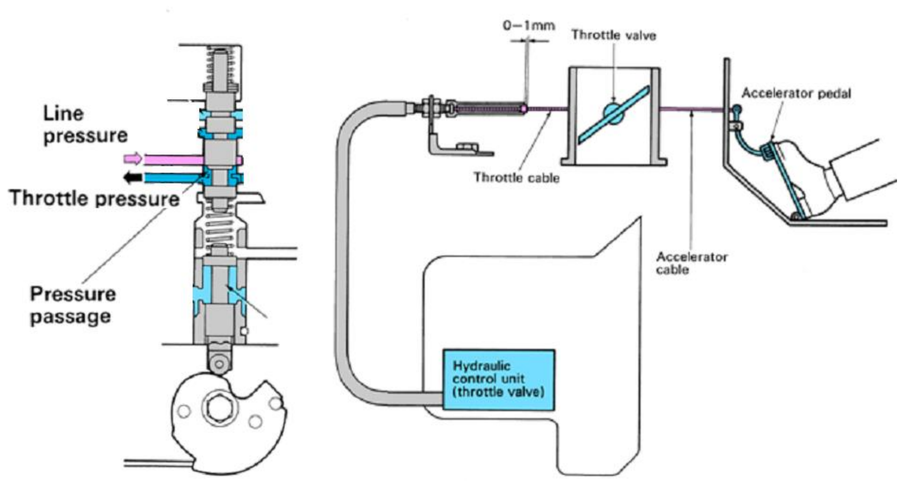
transmission are based on. It is the critical that the line pressure is correct to ensure correct operation of the transmission. It is controlled by the primary regulator valve and is set by the spring. If the manual valve is in reverse an additional force is added to the spring and the line pressure is increased. The throttle pressure will also influence the line pressure in similar way.

Why do you think the line pressure is increased for reverse gear?

The secondary regulator valve maintains a constant pressure to the torque converter and lubrication circuits. The layout and operation of the hydraulic valve block is similar to the hydraulic control

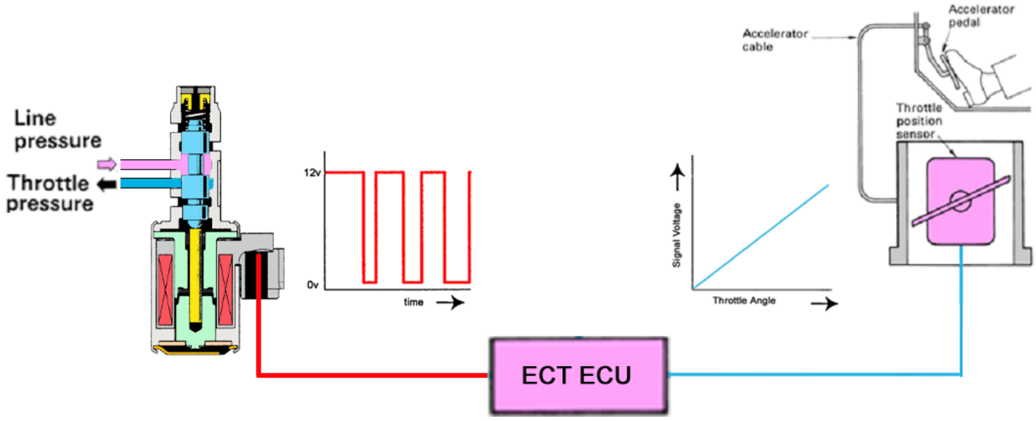
Throttle Pressure

In the electronically controlled transmission the throttle pressure is no longer used to control the shift timing of the gearbox. Instead its function is to modify the line pressure in accordance with the load on the transmission. The primary



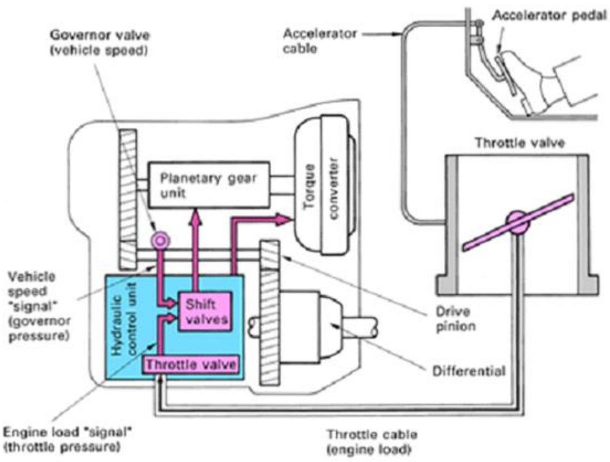
input to the valve assembly is the throttle position. For example, when accelerating the load on the clutch and brake discs will be increased and it is therefore desirable to increase the line pressure to compensate and reduce the possibility for slipping to occur.

Modern designs use an electronic solenoid in place of the throttle cable and cam linkage. This type of system will be controlled by the ECU using pulse width modulation (duty cycle) control signal. This arrangement offers more possibility for altering the line pressure based on wider range of conditions. In either case the main advantage of altering the line pressure in this way is to allow smoother gear changes when the load on the transmission is low and still prevent slipping occurring when under hard acceleration.



Changing Gears

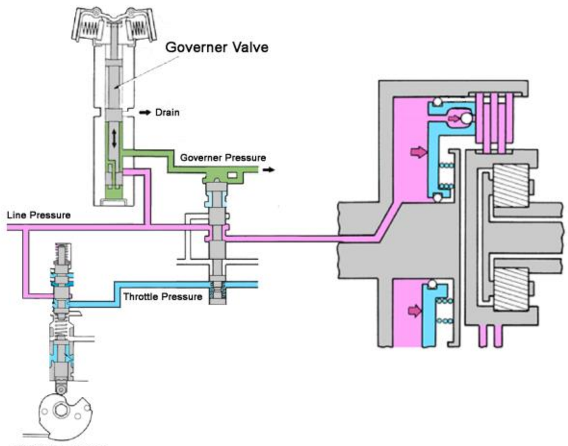
The method for controlling the movement and timing of the shift valves is different for electronically controlled transmissions. To understand the difference between the two control methods we will first review the method used in hydraulic control.



The hydraulic control system converts the vehicle speed and load condition directly into hydraulic pressure:

- throttle pressure – load
- governor pressure – road speed.

The timing of the gearshift is determined by the balance of the two pressures acting on each end of the shift valve. In its most basic form this design provides a simple self-contained control system for the transmission. However, the mechanical nature of the hydraulic control system places a number of limitations on the design.

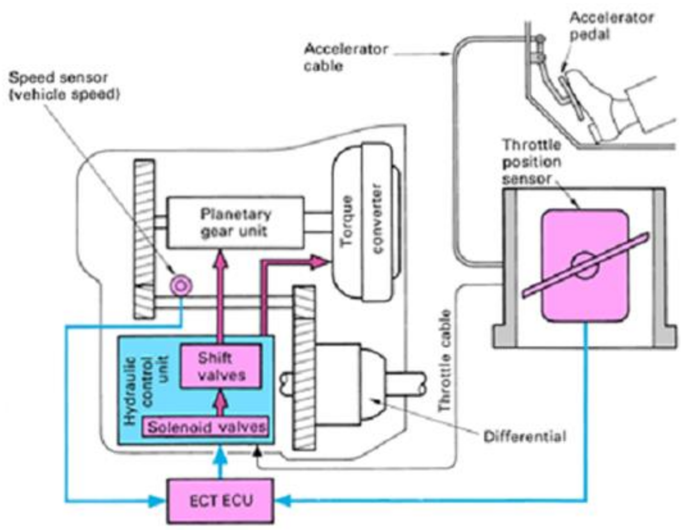


- throttle and governor pressure have a linear relationship to road speed and engine load. This means that altering the shift timing to suit all driving conditions requires ever more complex governor, throttle valve designs and additional hydraulic components to modify the pressures involved

- the control systems are based on mechanical devices, which are prone to wear. They require maintenance to ensure that optimum performance is maintained.

These limitations and the reducing cost of electronic components mean that the majority, if not all, modern automatic transmissions are now controlled electronically.

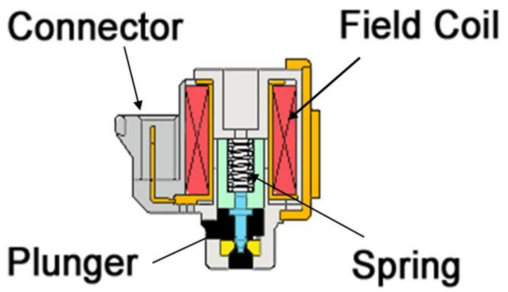
The shift control timing of the transmission is now controlled by the ECU. The ECU opens and closes hydraulic passages in the valve block by means of electronic solenoids. This in turn changes the position of the shift valves. Although the method of operation is completely different the basic criteria for judging when a gearshift should take place are the same as before.



Road speed and engine load are still the basic criteria to determine when the gear change occurs but the conditions are monitored by elect iconic sensors on the output shaft and throttle valve. The ECU measures these basic values and then controls the electric solenoids to achieve the appropriate gear change.

- construction of the valve block is simpler – Only line pressure to control
- gear change timing is not fixed to linear value – flexibility in programming the gearshift timing. The ability and additional sensors and provide better optimisation of the gearshift program
- more driver options – the driver can control the transmission through additional inputs e.g. sport mode button on dash.

Solenoids

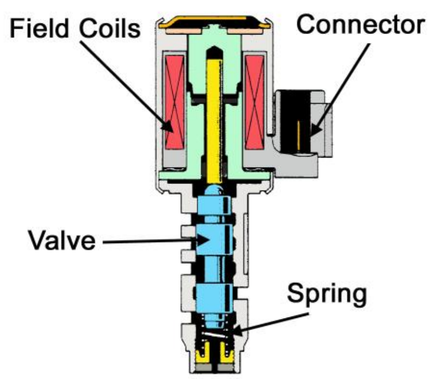


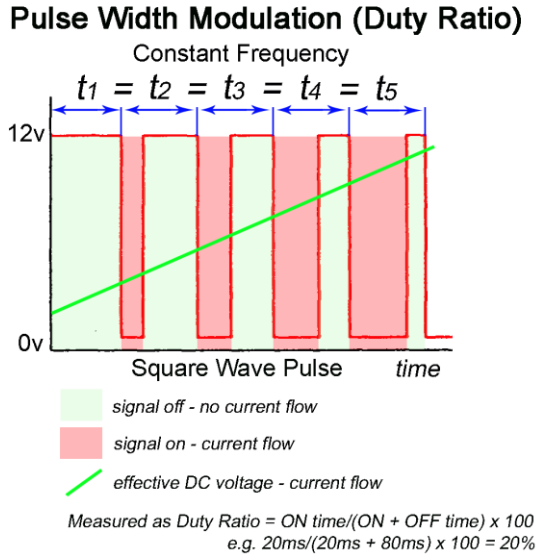
The solenoids are used to open close hydraulic passages within the valve block. There are two basic constructions that can be found in a modern transmission. The first and most common type is the ON/OFF type.

This type uses magnetic field coil acting on a sprung loaded plunger. The spring is normally arranged to hold the valve closed. The ECU sends a 12-volt supply to the field coils and the resulting magnetic field pulls the plunger against the spring.

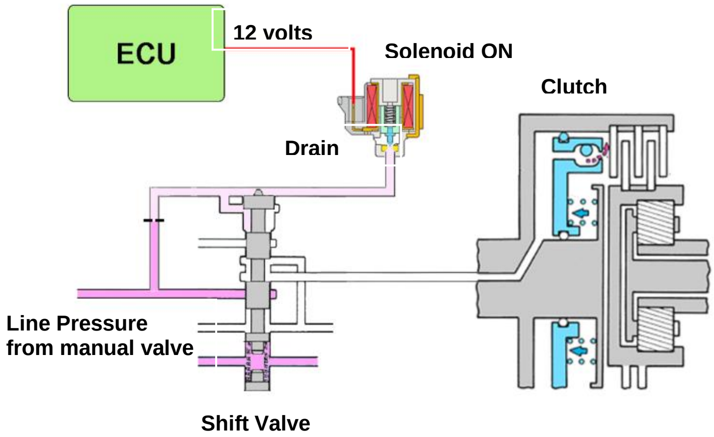
The second type is called the linear type solenoid. The construction is similar to the ON/OFF type but instead of a simple 12v/0v switch signal the ECU produces a Pulse Width Modulated (PWM) signal to control the field coil.

Linear Type Solenoid





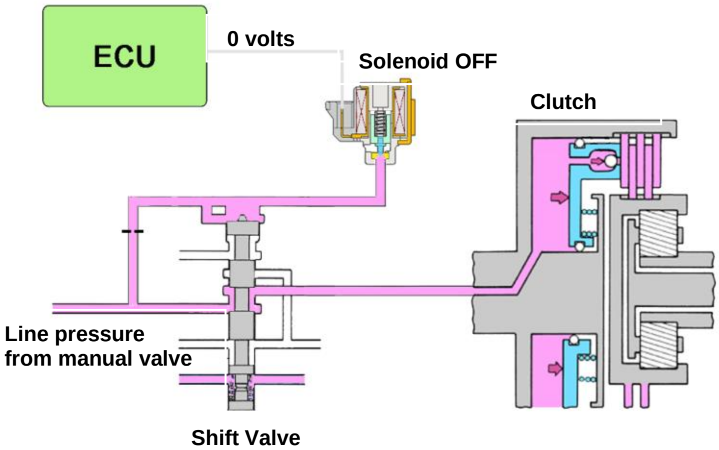
PWM or duty ratio signals are used to generate linear variation in current by fast switching a 12volt supply. The current acting on the solenoid will increase and decrease depending on the ratio of ON time compared to the ratio of OFF time. As the current increases and decreases so will the strength of the magnetic field generated in the field coils. The fluctuating magnetic field acts against the force of the spring and moves the valve. In the example shown the valve is designed to control throttle pressure.



Linear type solenoids allow the ECU to control hydraulic pressure progressively. They are most often used for throttle/line pressure control as seen in the example earlier but they are sometimes used for shift control. To control the shift timing with a solenoid the hydraulic pressure from one end of the shift valve is linked to the solenoid. In the simplified example shown, the position of the shift valve is determined by the balance of pressure acting on the top of the shift valve against the combined hydraulic pressure and spring force acting on the bottom.
The first condition shows the clutch disengaged. The ECU supplies the solenoid with 12 volts. The magnetic field pulls the plunger up against the spring and allows the hydraulic pressure to escape from the circuit acting on the top of the shift valve and drain back to the sump. A restrictor prevents the line pressure escaping from the rest of the hydraulic system.

The shift valve is forced upwards by the balance of forces and blocks the line pressure from the manual valve from passing to the clutch.

When the ECU decides to engage the clutch the 12-volt supply to the solenoid is removed. The force of the spring in the solenoid forces the plunger to block the drain.

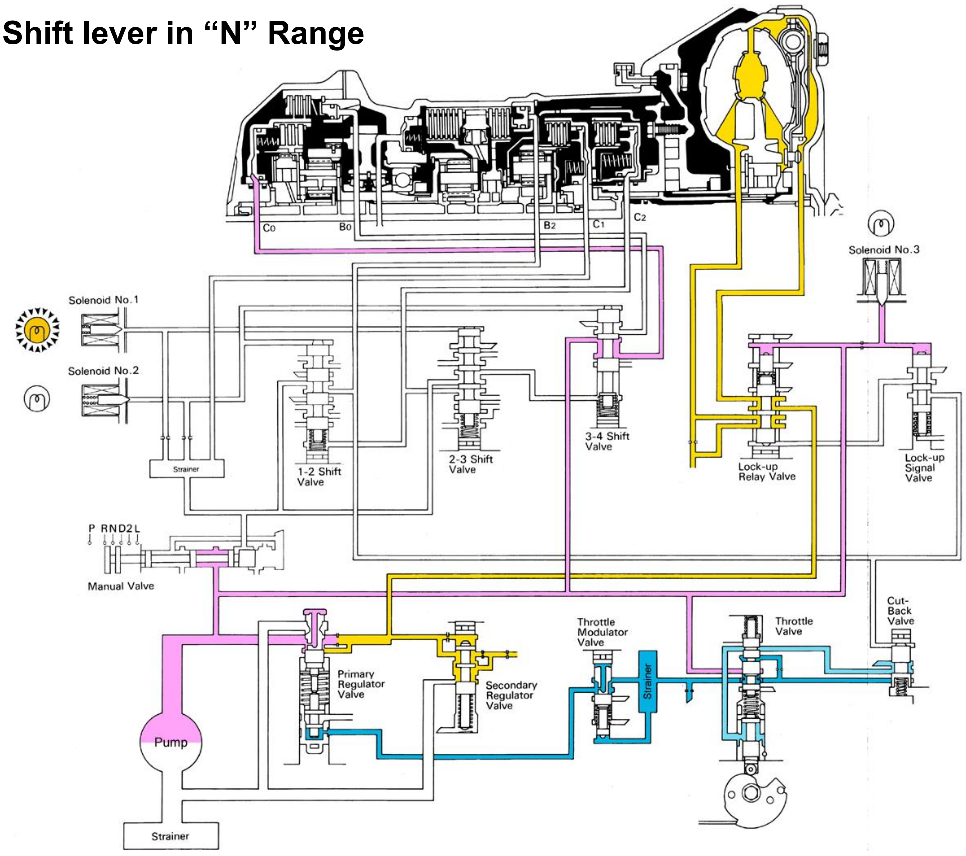


The pressure on the top of the valve is now the same as the pressure acting on the bottom of the valve. Because the surface area at the top of the valve is larger than the area at the bottom of the valve the force acting on the top of the valve is the largest. The shift valve is forced down and line pressure is passed to the clutch.

Hydraulic Diagram Exercise

We now have a basic understanding of the control method of the shift valves by electrical solenoid. To put this knowledge to some use you will find 4 diagrams showing the hydraulic circuit for a 4-speed transmission. The exercise is simply to trace the fluid flow for each of the 4 forward gears and study how each of the shift valves interact with each other and the solenoids. As an added bonus the 4th gear diagram also shows the lock-up clutch in the torque converter activated. As an example I will show you one I have completed earlier.

Shift lever in "N" Range



In the example shown line pressure passes to the manual valve and through the 3-4 shift valve to operate C1. S1 is also active but has no effect until the manual valve is moved to the "D" position. Converter pressure passes through the lock-up relay valve but does not activate the lock-up clutch because of the direction of flow.

Note that a number of hydraulic circuits have been left out of the diagrams. The operation of the “R” range, “2” range and “L” range are not shown. Although the shift control for the forward gears does use the solenoids the hydraulic circuits are arranged so that if the electrical circuits fail the transmission can still operate manually moving the shift lever.

For this design the operation of the transmission in the case of an electrical failure is:

Shift Lever Position	**Gear Selected**
“D” range	Fourth Gear
“2” range	Third Gear
“L” range	First Gear
“R” range	Reverse Gear

Summary of Hydraulic Control

We have looked at the construction and operation of a simple hydraulic control system. The control of the transmission using electronic solenoids simplifies the regulation of pressure within the transmission and reduces the complexity of the hydraulic valve block. The design we have studied achieves and 4-speed gear change control using just two solenoids. As the cost and size of electrical components has reduced over the years the trend is to reduce the complexity of the hydraulic valves and utilize more solenoids to control the gearshift timing. As the performance expectation of the customer and the power of the computers available to engineers increases solenoids are used to control the pressure acting on the clutches and brakes as well as the timing of the gear change. The advantage is to allow the transmission to engage and disengage each gear at high speed when the driver is accelerating hard but still retain smooth gear changes at other times.

We have also seen the use of linear type solenoids to control the line pressure and you will see them used to control the shift timing again to achieve a variable speed gear change. All of this added complexity is designed to enhance the ability of the transmission to meet the high demands of the modern driver.

The number of different methods used to control a modern transmission is increases with every new model and explaining each in detail is beyond the scope of this training program. However the fundamental principles you have studied applies to them all.

- all pressures in the hydraulic transmission are based on the line pressure – if it is wrong then they are all wrong

- all hydraulic control systems are designed to provide some basic gear changes if the electrics fail – this fact is useful for diagnosising transmission faults

- solenoids are simple electrical devices whether they are ON/OFF type or linear they can be easily tested – resistance, voltage or duty cycle

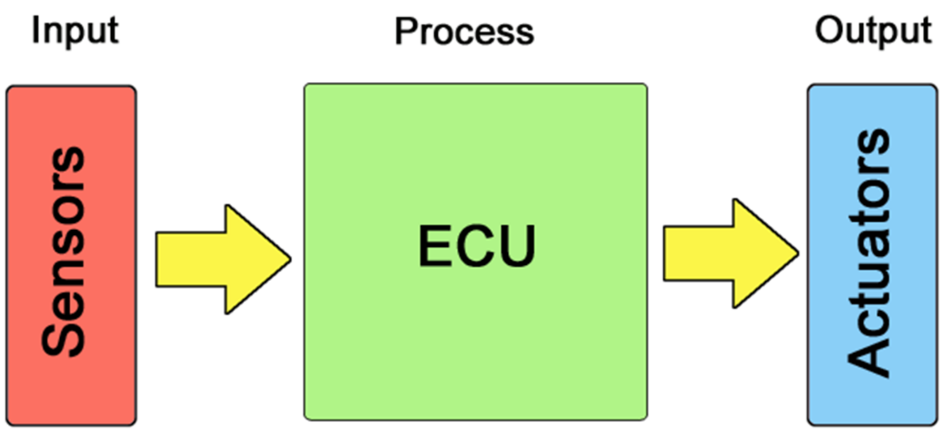
- the valve block is often simpler with less components – the inspection and repair process is the same for all types of transmission

- the construction and operation of the clutches and brakes is basically the same for all transmissions.

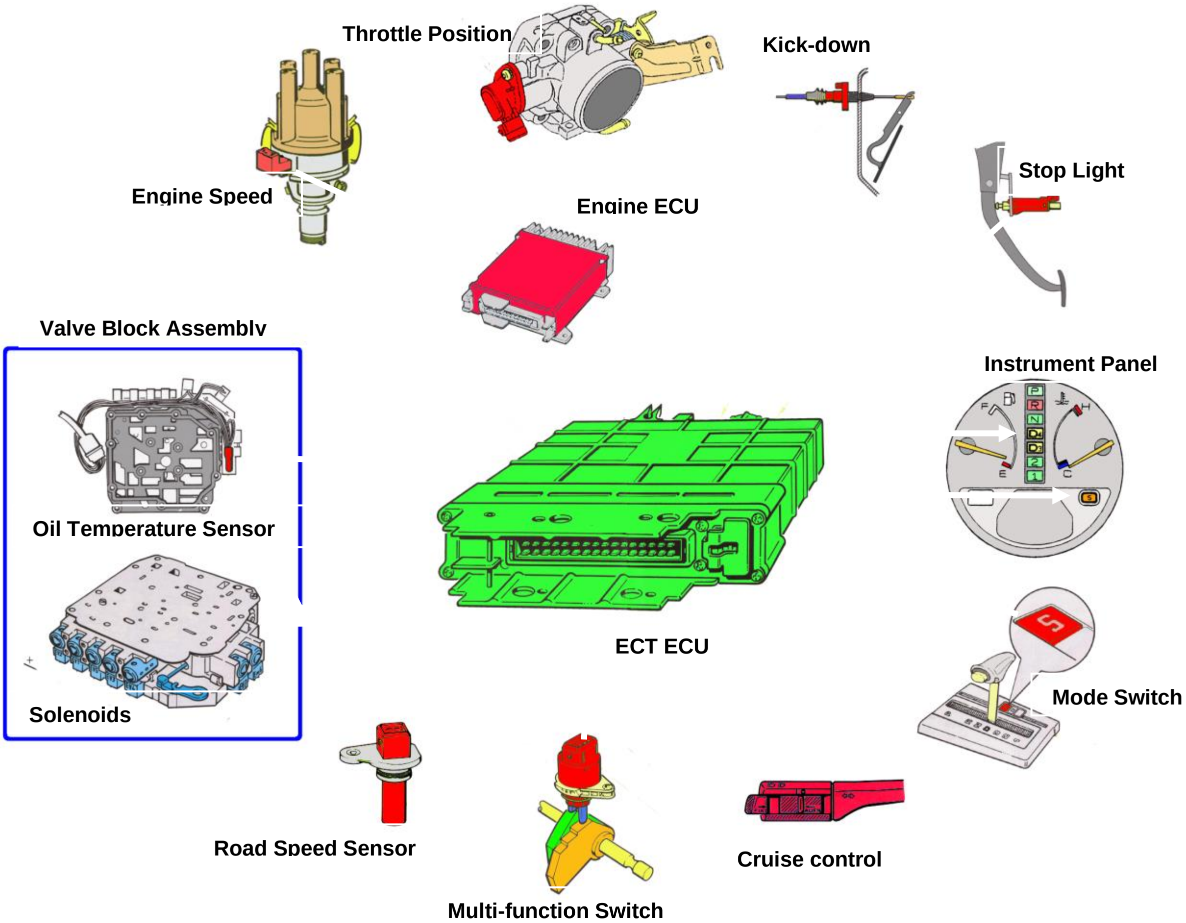
ECU Control

As we have seen already the basic criteria used to judge the timing of the gear change are still the road speed and the engine load. The ECU monitors these conditions through sensors on the transmission and engine. The input data from these sensors is compared to the data programmed into the ECU memory. When the ECU has judged that the input data has meet the criteria in the memory an output signal is generated to active the appropriate solenoid. In short the ECU control can be described in three distinct stages:

The layout and the number of sensors will vary depending on the design of the transmission. The diagram shows the sensors for a 4-speed transmission that might be found in a small to medium family car. In the table is a summary of the function of each sensor and actuator.



Sensor & Actuators Overview

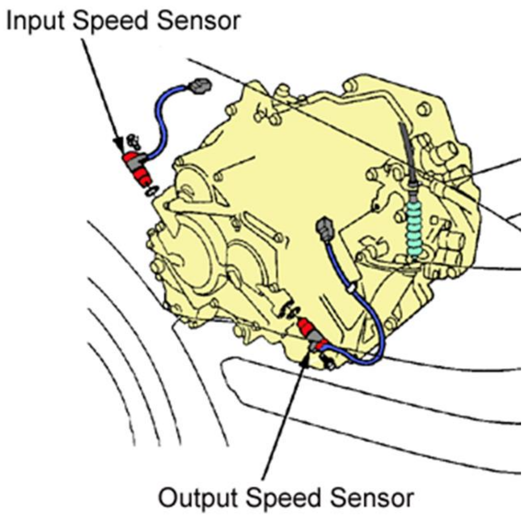


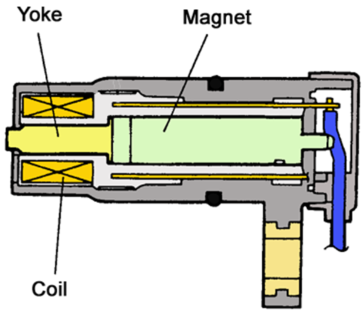
Sensors (Input Signals)

The sensors are the eyes and ears of the ECU. To be successful at diagnosis you will need to be able to assess the output of each sensor and to do this a fundamental understanding of there operation is essential. In detail there are many variations between the different manufactures but they all function on the same basic principles. In the following section we will study the construction and use of the sensors.

Speed Sensors

Speed sensors are usually mounted on the transmission and measure the speed of the output shaft. If the transmission features more sophisticated shift control you many find two speed sensors, one for the input shaft speed and one for the output shaft speed. The ECU will use the two signals to calculate the optimum gear change timing. The most common type of speed sensor is the magnetic pick-up type.





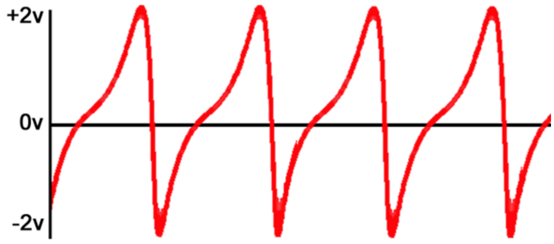
Magnetic type is the most common speed sensor used

The construction features a permanent magnet attached to yoke. The yoke is fitted inside a coil of wire. The magnetic field is inducted by the yoke a surrounds the coil of wire. The sensor is mounted close to a rotating element in the gearbox called a target. The target can be any part of the gearbox that features a regular shape for example a slotted ring fixed to a clutch housing.

As the target rotates the change in shape affect the magnetic field, pulling it through the coil of wire and then back. The movement of magnetic field inducts a voltage in the coil of wire generating an AC waveform. The frequency of the waveform is proportional to the speed of the target.

Outputs a analogue alternating wave form (AC)

Frequency increases with speed



There are two techniques for assessing the performance of this type of sensor.

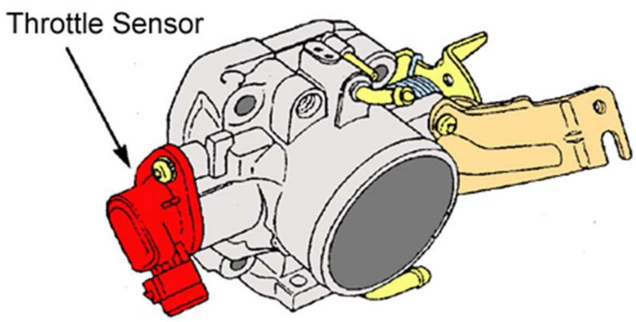
- resistance Check – The resistance check is the most common type of inspection specified. The resistance valve of the sensor will vary depending on the size of the coil and the temperature. This check is of limited valve as it only confirms the integrity of the sensor. It does not confirm the condition of the wiring or the relationship between the sensor and the target

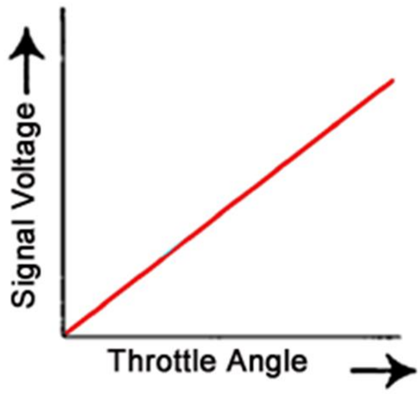
- signal Check – This can be done by measuring the frequency value of the signal at the ECU. This check confirms that the sensor is functional and that the sensor is correctly installed. The frequency test has the advantage of assessing the whole operation of the circuit at the same time in addition the frequency will show more clearly the intermittent type fault generated by a loose connection. An alternative is to use an oscilloscope, which also shows the shape of the signal.

Throttle Signal

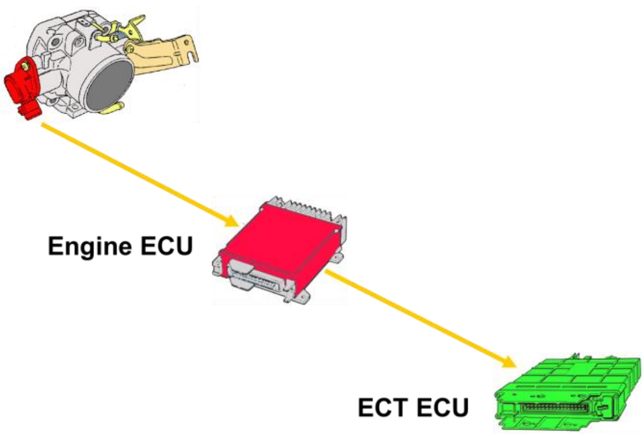
The throttle signal provides the ECU with the driver's intention. It is commonly mounted on the on throttle body or in the case of fly by wire systems, on the accelerator pedal. The throttle signal is also used for engine management so the engine ECU will often measure the signal and then transferred to the automatic transmission ECU.

The sensor converts the movement of the throttle to linear voltage by means of a resistor track and brush contact. They will a constant 12v or 5v supply, a ground contact and a signal wire to the ECU. The most common failure with this type of sensor is wear or contamination of the resistor track. The best method of checking the function of the sensor is to measure the output voltage at the ECU with a moving dial type voltmeter or an oscilloscope. This method will show up small defects more clearly than a digital meter.



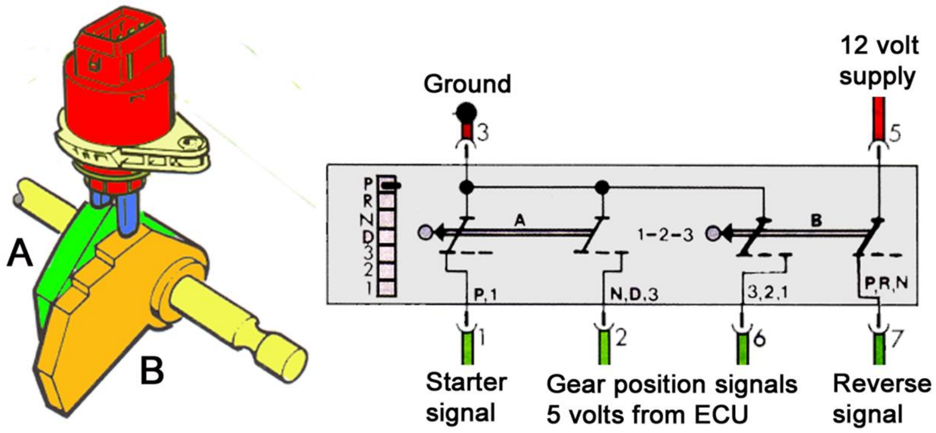


How is the throttle position sensor information received by the electronic transmission control?



Multi-function Switch

The multi-function switch measures the position of the gear lever. Depending on the position the ECU will prevent the transmission from changing to 4th or 3rd gear. The secondary function of this switch is to control the starter relay and prevent the engine from starting unless the transmission lever is in either “P” or “N” range. In some cases the switch will also control the indicator lights on the instrument panel showing the driver the position of the gear lever.

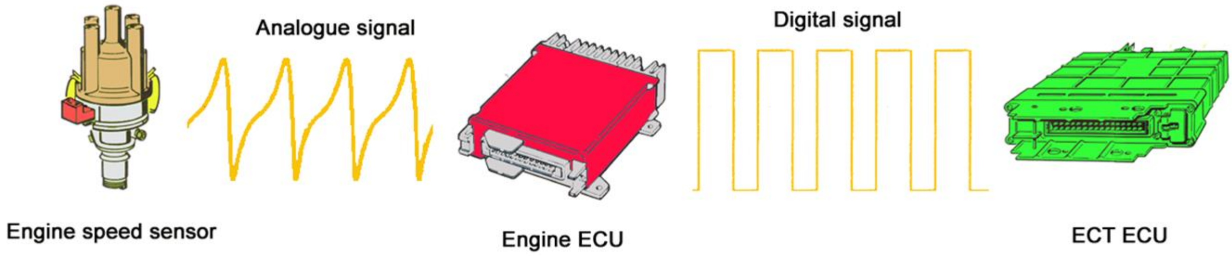


The construction of the switch is a simple slider switch or plunger. The movement of the slider or plunger makes and breaks copper contacts in the switch. They are general operated with a 12-volt supply.
To check the operation of the switch simple confirm the voltage signal to either the ECU terminal, instrument panel or starter relay. Resistance checks can also be used.

The switch is usually mounted on the selector shaft as it enters the transmission case. The design shown uses two plungers acting on quadrants on the select shaft. Some switches will have adjustment slots and must set up correctly.

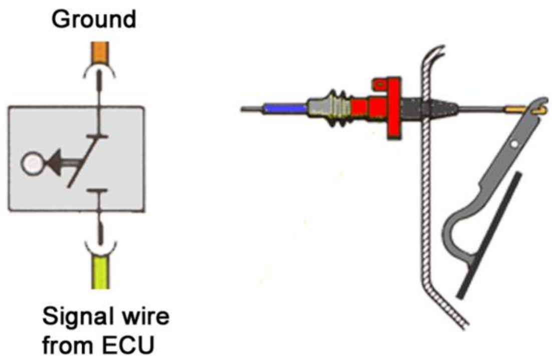
Engine Speed

The engine speed signal is used in conjunction with the throttle signal to calculate the load condition of the engine. In most modern designs the engine speed is measured by the engine ECU and then communicated to the ECT ECU. The construction and operation of the sensor is the same as the road speed sensor.



The analogue signal from the engine speed sensor is converted by the engine ECU to a digital signal and is then passed to the ECT ECU.

Kick-down Switch



The kick-down switch is a simple on/off signal. The switch can be integrated into the accelerator cable as shown in the diagram or as a switch under the accelerator pedal.

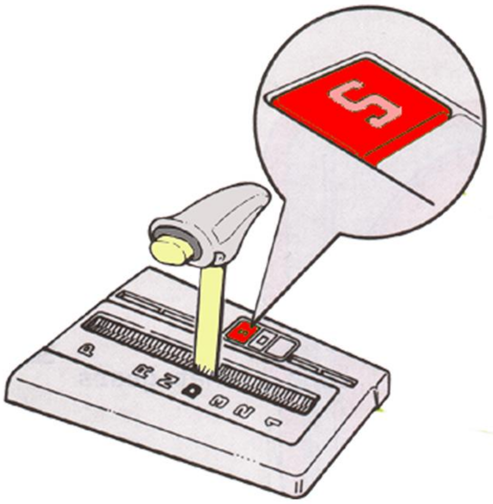
The switch will operate when the accelerator pedal is pressed beyond the fully open position. In the design shown the switch is attached to the outer casing of the accelerator cable. When the throttle is at the fully open position additional pressure applied to the pedal by the driver will pull the outer casing of the cable and close the switch.

This signal is used by the ECU to change the upshift and downshift timing.

Mode Switch

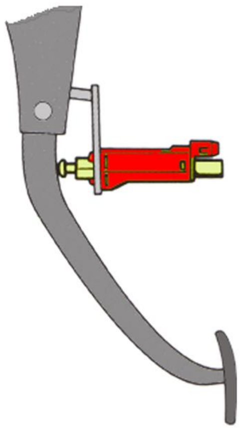
The mode switch allows the driver to alter the shift timing to suit different conditions. The most common type is a sport mode. This changes the up-shift and downshift timing of the gear change in a similar way to the kick-down switch but the change operates all the time.

This is a simple ON/OFF type switch.



Stop Light Switch

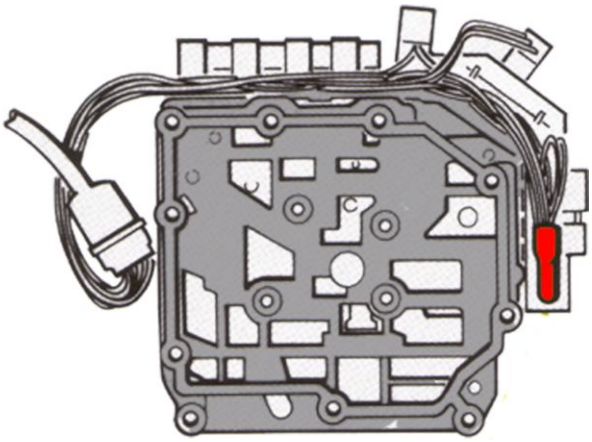
The stop-light switch influences the operation of the torque converter lock-up. The lock-up clutch will be disengaged when the brake pedal depressed. In some designs the stop light signal will influence the engagement of 1st gear.

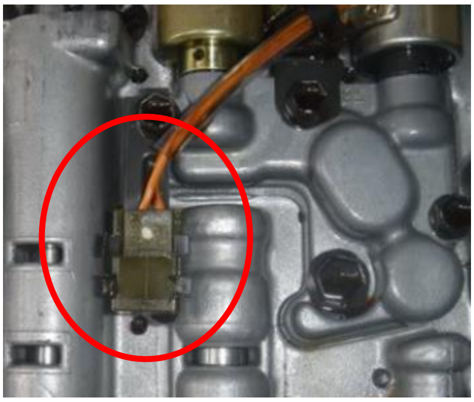


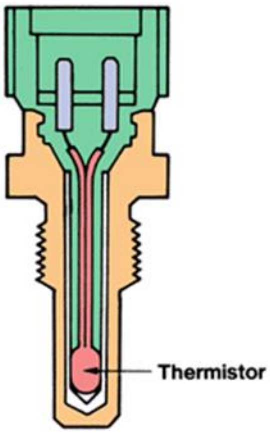
Oil Temperature Sensor

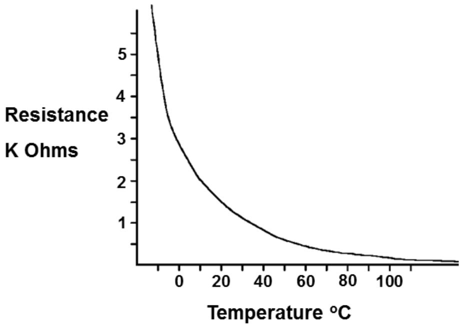
The oil temperature sensor is used to monitor the condition of the transmission oil. The effect this oil temperature has on the operation of the transmission will vary depending on the design of the transmission. The main use of this signal is to protect the transmission from damage if the oil starts to overheat. If the oil temperature rises the ECU will change up to a higher gear sooner. This will reduce the time that the torque converter operates in torque multiplication mode and reduce the temperature of the oil. In some designs the temperature of the oil is used to assess the viscosity of the oil and this is then used to modify the line pressure. This type of control is used to improve shift quality.

The sensor is a thermistor type usually installed on the valve block.









NTC sensor resistance

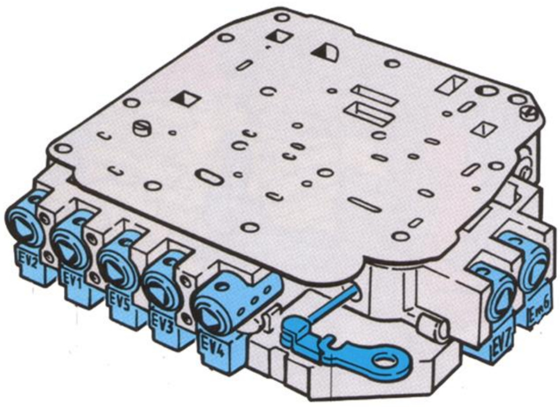
Cruise Control

The cruise control system can often influence the gearshift. The purpose is to allow the cruise control to change down from 4th to 3rd if the vehicle speed drops from the set speed, for example when the vehicle is travelling up hill.

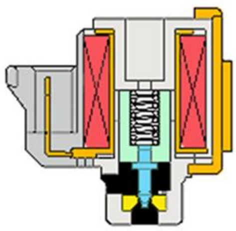
The cruise control ECU will send a signal to the ECT ECU to activate the down change.

Actuators (Outputs)

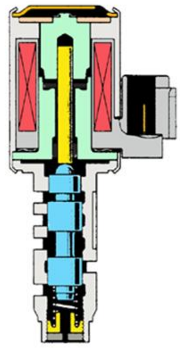
The main actuators are the solenoids. We have already studied the detail of the solenoids but we will just review the function here. Other outputs are provided for informing the driver of the status of the transmission. One critical output is the diagnosis system. We will study the function of the diagnosis system separately.



Valve Block Assembly



ON/OFF Type



Linear Type

Solenoids

The solenoids control the hydraulic pressure in the valve block assembly. The operation and the construction of the solenoids were discussed in the hydraulic system. They are responsible of the gear change timing, the oil pressure control and the lock-up operation.

Two basic types are used, the ON/OFF type and the linear type. The ON/OFF type uses a simple switch signal from the ECU. The linear type is controlled by a duty ratio pulse signal generated by the ECU.

Instrument Panel

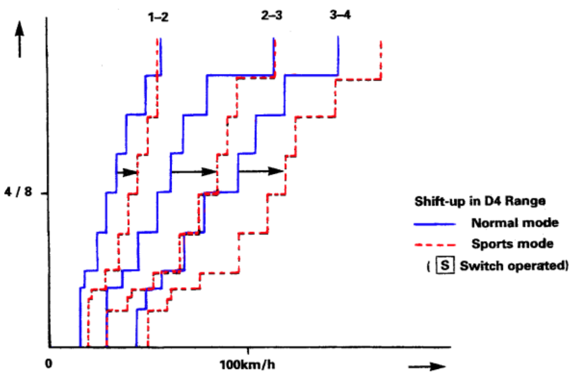
In most designs the gear lever position and the mode switch condition are informed to the driver by the instrument panel. The warning lights can be controlled either by the multi-function switch and mode switch directly or as output signals from the ECU.

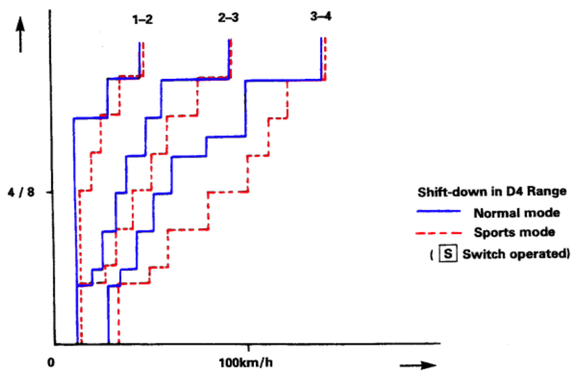
ECU Control

The ECU is the brains of the operation. In its memory are shift tables that will be used to calculate the shift timing. The shift timing function is the basic requirement of the ECU but as the power of the ECU and the development of the software that controls the timing has improved the number of additional controls that the ECU can carryout has increased.

Shift Timing Control

The two tables show the shift logic stored in the ECU. These are commonly called shift maps. Graph 1 shows the up-shift map and graph 2 shows the downshift map. The ECU will use these maps to decide when to implement the shift changes. For example, on graph one you can see that the road speed at which the up-shift from 1st to 2nd occurs will gradually increase in steps as the throttle opening increases. You can also see how the gearshift map changes when the driver has selected the sport mode (red dotted line). The downshift points are different to the up-shift points. This arrangement prevents the transmission hunting between two gears when the throttle opening is close to a shift point.

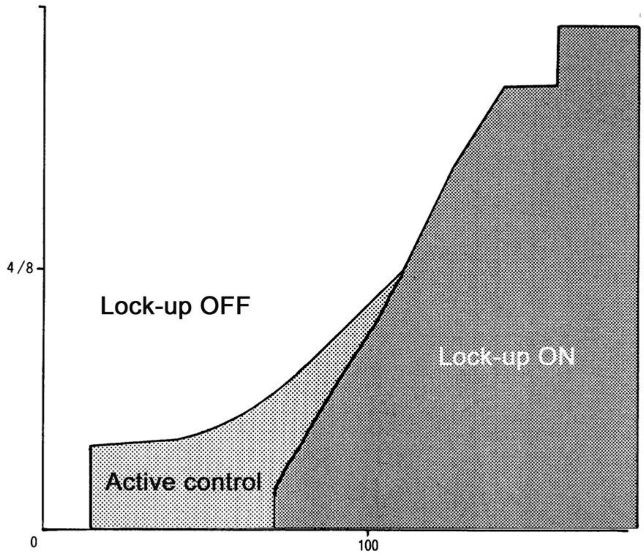




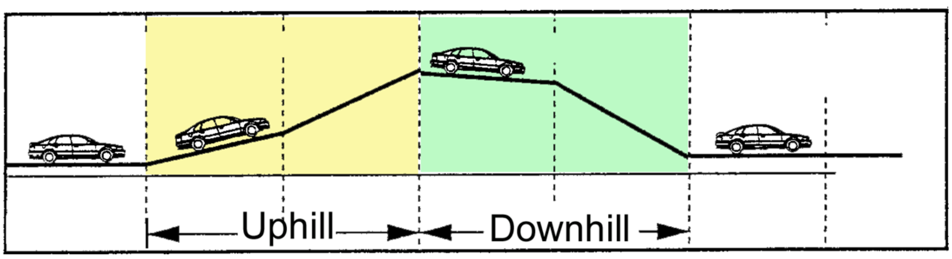
If the system has a kick-down switch the ECU downshift map will use a third map.

Lock-up Control

The torque converter lock-up system uses a similar map. The lock-up clutch can only be used under certain load and speed conditions, shown in as the dark grey area in the graph. If the lock-up clutch is used outside of this area the transmission will suffer harness shift real and driveline shunt. However, the longer the lock-up system is engaged the more efficient the transmission will be. To achieve this some modern systems use a partial lock-up control, which engages the lock-up clutch using a linear solenoid. The light grey area on the graph shows the load speed conditions when active control can be used. One side effect of this type of control is an increase in heat generated by the intentional slipping of the lock-up clutch. Transmissions using this type of control require improved transmission oil. To achieve this type of control the ECU measures the input shaft speed. This is compared with the engine speed and the ECU controls the speed difference between the two.



Down Hill Control



One of the advantages of ECT control is the ability to adapt the control of the transmission to suit all conditions. An example is the downhill control. The ECU can calculate whether the vehicle is travelling uphill, downhill or on the flat comparing the road speed, engine load and gear selected. For any given road speed in a particular gear the load on the engine will indicate which of three conditions are occurring.

If the ECU decides that the vehicle is travelling uphill it will change the shift map to hold lower gears for longer. This will ensure that the acceleration is available for climbing the hill. When travelling down hill the transmission will select a low gear to provide engine braking and help control the decent.

Other Control Examples

There are many control possibilities possible with ECT control. It would impossible to cover in detail every type used in every design but here are a few of the more common types used.

- anti-squat Control – The transmission will select 2nd and then 1st gear when the shift lever is moved from N to D range. This reduces the torque reaction in the driveline and reduces the tendency of the rear of the vehicle to squat

- “Snow” or “2nd” mode switch – Forces the transmission to take off in 2nd gear. Selected by the driver designed to help traction in slippery conditions

- line Pressure Control – Used to optimise the line pressure to ensure smooth shift control – see hydraulic control

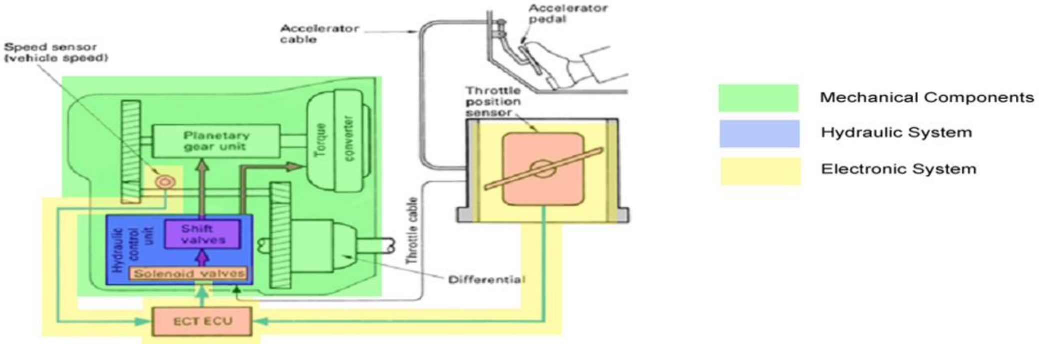
- clutch Pressure Control – additional solenoids are used to alter the pressure acting on the clutches and brakes. This allows the transmission to provide fast shifts when accelerating but still retain a smooth shift when driving at medium load conditions. Requires the use of two speed sensors

- accumulator Back Pressure Control – Some transmissions use spring loaded cylinders in the clutch and brake hydraulic circuits to act as dampers when operating the clutches and brakes. A refinement to this design is to apply pressure to the back of the pistons to compliment the spring force. This pressure can be adjusted by a linear solenoid to improve the smoothness of the gear change.

ECT control offers the design many control options. They help modern transmissions achieve high quality shift feel, increased shift speed and an increased flexibility. Although the number of electronic components has increased the hydraulic system can be much simpler and therefore more reliable.

Troubleshooting ECT Control Transmissions

Troubleshooting ECT control transmissions can appear to be a daunting task. But as with most complex systems a logical structured approach will allow you deal with the system in series of simple steps. The initial task is to separate the operation of the transmission into its key functions.



If we consider the overall structure of the transmission we can divide into three distinct areas:

- Mechanical
- Hydraulic
- electronic.

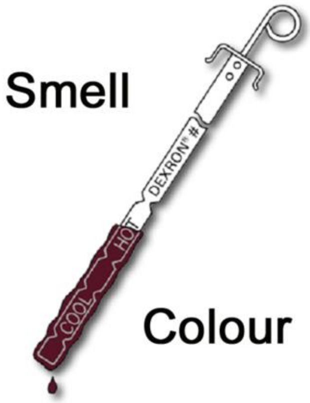
The diagnostic process is based on separating these three operation areas in order to identify which one is malfunctioning.

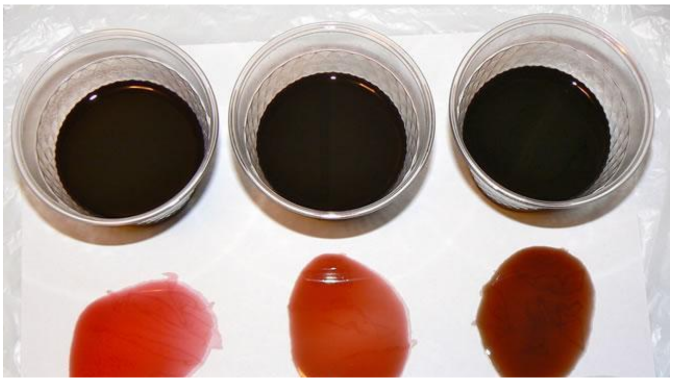
Inspection Procedures

The following is a review of the most common techniques used to troubleshoot ECT controlled transmissions. Which ones should be used will depend on the symptom that you are trying to resolve. Some will be familiar from your study of the hydraulic controlled transmission.

Visual Inspection – Before carrying any diagnostic process it is important to inspect the condition of the vehicle. You should assess the security of the hydraulic system and electrical connections. Make a note of any accessories that may effect the operation of the transmission, for example a tow bar may indicate that the transmission is subjected to high loads on a regular basis. Radio equipment and badly installed mobile phones could affect the electronics.

Oil Condition – Assess the condition of the oil.





Signs of clutch or brake slip will show up as dark transmission oil combined with a burnt smell. Make sure that the oil level is correct. The oil level in a modern transmission is critical. Too little and too much oil can severely affect the shift quality and in some transmissions lead to overheating and then clutch slip. Road testing the vehicle with an incorrect oil level could increase the damage already caused.

Road Test

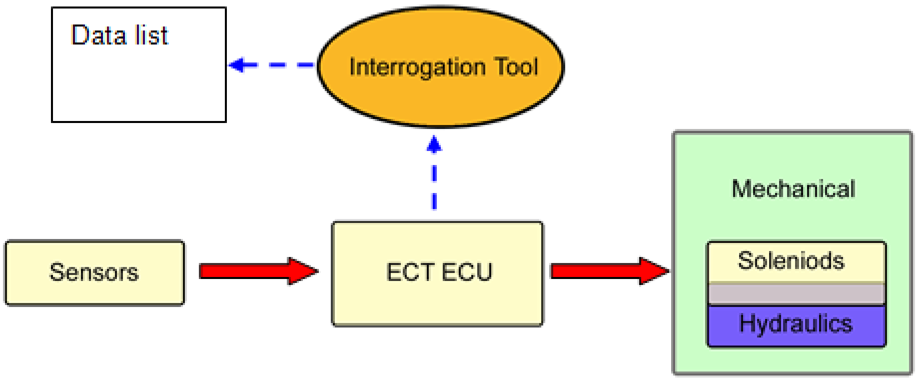
An effective road test is critical to the success of any troubleshooting process. It the first chance to gather the data you need to decide what inspections you with use in the following stages. You should approach the road test with two objectives. Confirm the reported symptom and to assess the overall performance of the transmission. Of course you need to confirm the symptom but you must remember that the driver of the vehicle may not use the full function of the transmission. For example the driver may report that the transmission will not select 1st gear but if you move the gear lever to "L" range and 1st gear does work you will have a much better understanding of the fault than if you simply confirm the fault. You should also pay attention to the shift timing and the quality of the shift feel.

On Board Diagnostics (OBD)

All modern ECT will use some form of OBD system. This could be a simple trouble code system, which monitors faults within the sensors or actuators. It will then output a flash code. Alternatively a full OBD system features codes, data streams and active tests accessed through an interrogation tool.

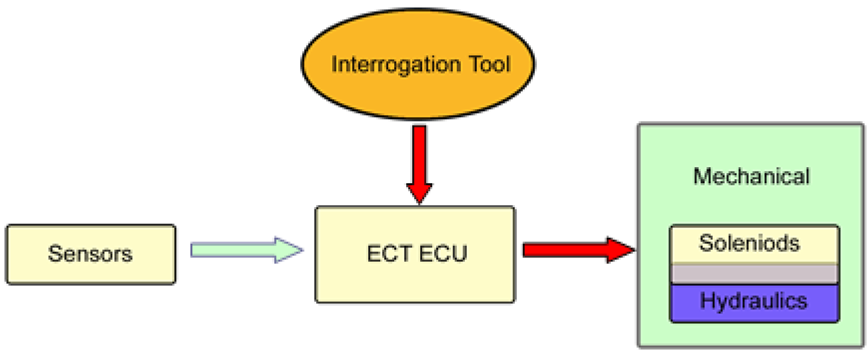
- using trouble codes – trouble codes are recorded in the ECU memory when the ECU detects one of the sensor or actuator values is outside some preset limits. This unusually means that it will indicate an open or short circuit condition very easily but will not always show loose connection or high resistance within the circuits. This is an important limitation to remember, one of the biggest mistakes people make when troubleshooting any electronic system is to assume that if no trouble codes are present then the electronic system is in good condition. You must always consider the nature of the symptom.

  Another factor to consider is that a trouble code will stay in the memory of the ECU until it is removed. This means that if you find a trouble code recorded it may not relate to the symptom you are investigating. To avoid being caught out you should always read the trouble code, record and then clear the code. If you retest the vehicle, reconfirm the symptom and the trouble code returns then you can be confident that the trouble code relates to your symptom



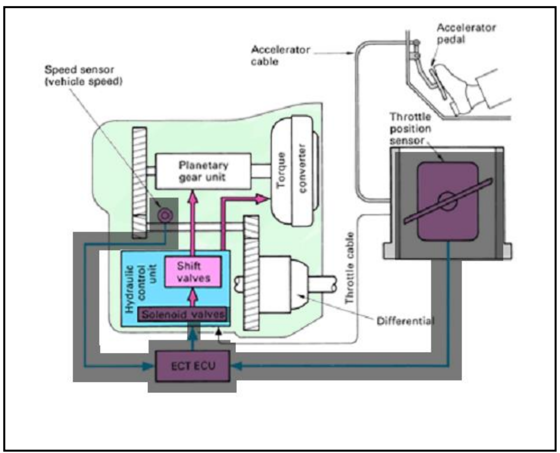
- data Lists or Sensor output Values – Integration tools will often feature the ability to display a data stream showing the electronic condition of the transmission. Even if the transmission ECU does not support the more modern type of interrogation tool they will often produce output voltage signal that can be used to understand the condition of the ECU. This type of inspection is one of the key tests that can be used to separate the electronic control from the hydraulic and mechanical systems. For example, if the reported symptom is that the transmission will select 4th gear. This could be because the ECU does not calculate the need for 4th gear due to a sensor fault or because the hydraulic control is defective. If the data list or output voltage indicates 4th gear is selected but the transmission remain s in 3rd then you will know that the sensors and ECU are functioning normally and the fault must be with the actuators, hydraulics or mechanical systems

- active tests – active tests provide you with the ability to control the shift timing. This can be achieved either with a switch box which will activate the solenoids in the correct sequence or by an interrogation tool sending commands directly to the ECU. This test compliments the data-list or sensor output signal inspection.



For example, again if the reported symptom is that 4th gear is not selected under normal driving but when the active test is carried out 4th gear is selected you can conclude that the hydraulic control, mechanical and actuator solenoids are functioning normally and the problem must be with the sensors or ECU. This test again separates the electronic system from the hydraulic and mechanical systems. Note that this test helps to confirm the operation of the actuators where as the data list or output voltage test confirms the operation of the input sensors.

Manual Shift Test – this test utilizes the failsafe design of the transmission to test the hydraulic and mechanical condition of the transmission. The principle is based on the fact that if the transmission looses all electrical control it will provide basic shift control by



moving the shift lever. If the transmission will not select a gear in normal driving but does if you disconnect the solenoid wiring then you can conclude that the mechanical and hydraulic circuits are good and the fault is in the electronic control.

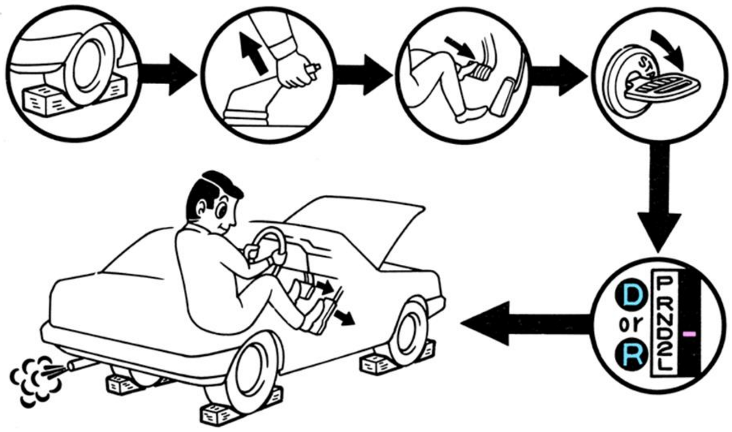
Failsafe Table

Shift Lever Position	**Gear Selected**
“D” range	Fourth Gear
“2” range	Third Gear
“L” range	First Gear
“R” range	Reverse Gear

Pressure Tests

Line pressure is fundamental to the operation of the transmission. A low line pressure can lead to slipping of the clutches and brakes. A high line pressure could produce shift shock. All other control pressures within the transmission are based on the line pressure so this test should completed for all situations that involve these symptoms.

Stall Test



A very basic inspection used to understand the condition of the clutches and the operation of the torque converter. The stall test is completed by selecting either “D” range or “R” range, then you apply full load to the engine with the wheels blocked.

The engine rpm should increase until it reaches the stall speed of the torque converter. If the engine RPM is higher than the stall speed then it would indicate that the related clutch is slipping. If the engine rpm is lower than the stall speed of the torque converter this would indicate that the stator one-way clutch is slipping or that the engine power is reduced. This test should not be done for more than 30 seconds. Extended testing will increase the temperature of the oil and may damage the transmission.
These tests provide you with a systematic approach to analysis the root cause of the system failure and combined with your understanding of the construction of a transmission will allow you to quickly and effectively diagnosis problems. All of the tests will provide you method of understanding the operation of the different parts of the control system. Your ability to understand the results of these tests hinges on your understanding of the construction of the transmission you are working on. This can be achieved by studying the operation diagrams and repair manuals.

'Sure' control is used in some modern designs. The basic principle is to control the pressure acting on the clutch and brake assemblies to improve shift quality.

A modern automatic transmission is better able to judge shift timing and circumstances under which shift is necessary and therefore enhance the driving experience.

Shift valve limitations

As we have seen, shifting is controlled by pressure acting on the shift valve. An even pressure is applied to the top and the bottom of the valve, but due to the difference in surface area over which this pressure acts, the valve will move against spring pressure effecting a shift. This mechanical approach has its limitations.
In order to overcome these limitations an Electronic Control Unit (ECU) can control shift timing. The ECU activates the hydraulic system by means of electronic solenoids, which control the flow of oil within passages formed in the valve block.

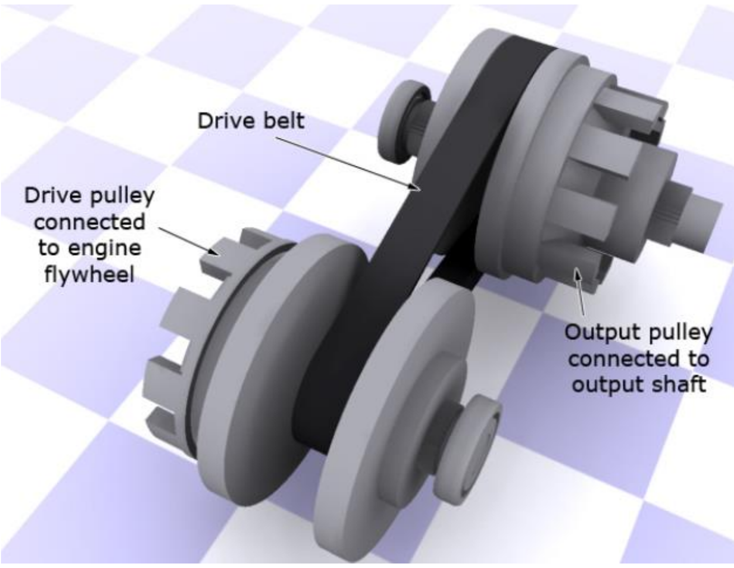
Controlling the timing of the gearshift is based on the same criteria for both hydraulic control and electronic control.

What two basic factors affect the timing of the gearshift?

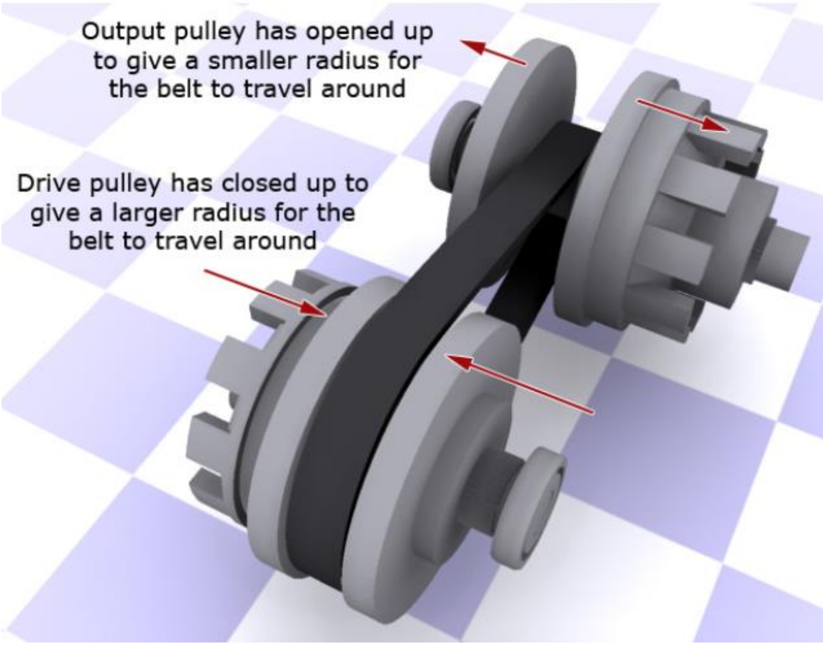
Engine load and engine speed

Continuously variable transmission CVT

So how does this magical CVT work? The most basic CVT has two variable pulleys and either a steel-core rubber pull-belt or a steel alloy push-belt. One pulley is connected to the flywheel and the other to the gearbox output shaft. The belt loops around between the two. On simple scooter-type CVTs, the pulleys change geometry simply by rotational forces - the faster the engine pulley spins, the more it closes up and the faster the output pulley spins, the more it opens out. In automotive applications, the geometry of the pulley is governed by a hydraulic piston connected to the ECU. The pulley itself is basically a splined shaft with a pair of sliding conical wedges on it (called 'Sheaves'). The closer the wedges are together, the larger the radius 'loop' the belt has to make to get around them. The further they are apart, the smaller the radius 'loop' the belt has to make. Based on the principles established right at the top of the page when I was talking about intermeshing gears, if the flywheel pulley has a small radius and the output pulley has a large radius, then the transmission is essentially in low gear. As the car gets up to speed, the two pulleys are adjusted together so that they present an infinitely changing series of radii to the belt which ends up with the flywheel pulley having the largest radius and the output pulley having the smallest.



The image above shows the basic layout of a pulley-based CVT with the two sliding pulleys and the drive belt. This is the equivalent of 'low gear' - the drive pulley spins two or three times for each rotation of the output pulley. It's the equivalent of a small gear meshing with a large gear in a regular manual gearbox.

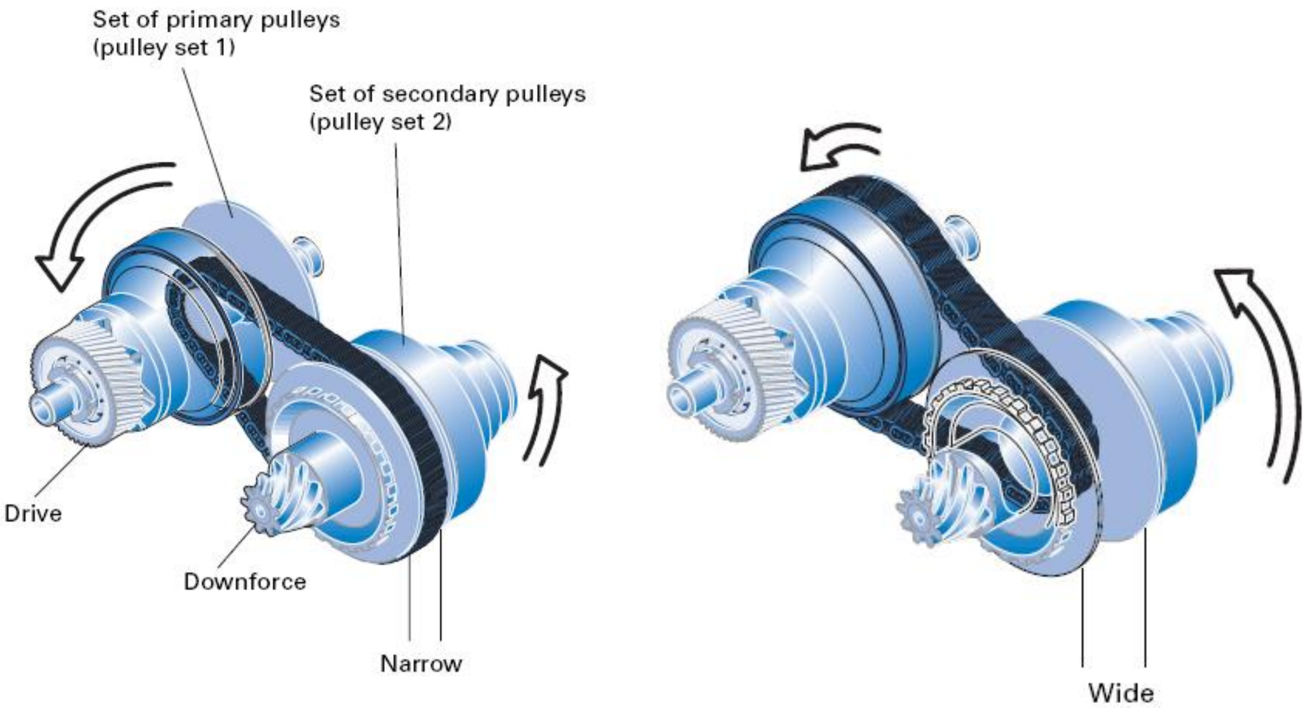


The image above shows the same system in 'high gear'. The drive pulley has closed up forcing the drive belt to travel a larger radius. At the same time, the output pulley has pulled apart giving a smaller radius. The result is that for each turn of the drive pulley, the output pulley now spins two or three times. It's the equivalent of a large gear meshing with a small gear in a regular manual gearbox. The difference here is that to get from the low gear to the high gear, the infinite adjustment of the position of the pulleys basically means an infinite number of gears with no point where the drive is ever disconnected from the output.

Multitronic system (Audi)

The key component part of the multitronic® is the variator. It allows reduction ratios to be adjusted continuously between the starting torque multiplication ratio and the final torque multiplication ratio. As a result, a suitable ratio is always available.

The engine can always operate within the optimum speed range regardless of whether it is optimised for performance or fuel economy. The variator comprises two tapered disc pairs - a set of primary pulleys (pulley set 1) and a set of secondary pulleys (pulley set 2) - as well as a special chain which runs in the V-shaped gap between the two tapered pulley pairs. The chain acts as a power transmission element.
Pulley set 1 is driven by the engine by means of an auxiliary reduction gear step. Engine torque is transmitted via the chain to pulley set 2 and from here to the final drive. One of the tapered pulleys in each of the sets of pulleys can be shifted on the shaft for variable adjustment of the chain track diameter and transmission ratio. The two sets of pulleys must be adjusted simultaneously so that the chain is always taut and the disc contact pressure is sufficient for transmission purposes.

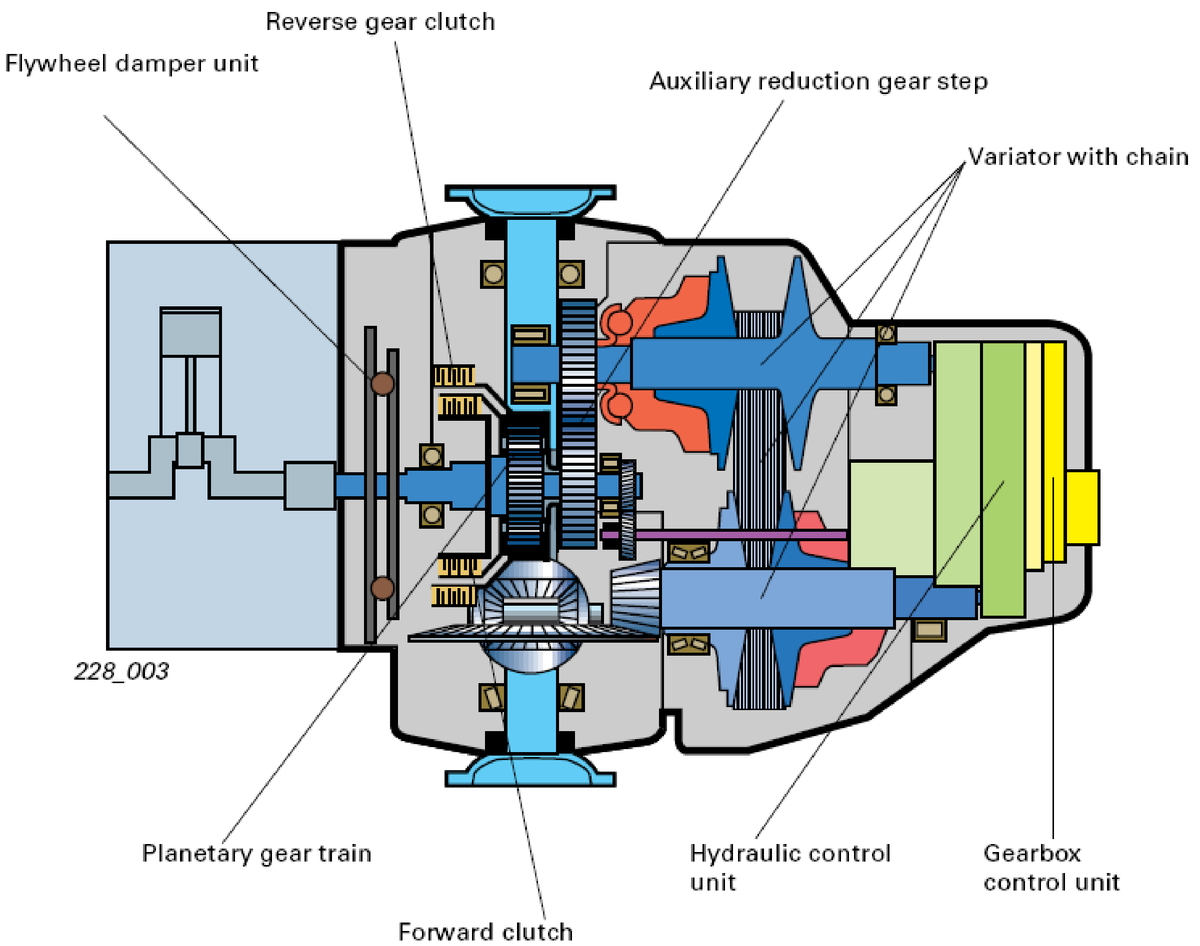


This gearbox is known as a chain drive transmission because of its design.

The concept

Engine torque is transmitted to the gearbox through either a flywheel damper unit or a dual-mass flywheel depending on engine output. There is one "wet" plate clutch for forward travel and one for reverse travel; both act as starting clutches. The rotational direction for reverse is changed by means of a planetary gear train. The engine torque is transmitted to the variator via an auxiliary reduction gear step and transferred from there to the final drive.

It is worth mentioning the innovative concept for torque transfer by means of a pull chain (refer to description of variator and pull chain). The electro-hydraulic control, together with the gearbox control unit, forms a unit which is accommodated in the gearbox housing. The Tiptronic function provides 6 "speeds “for manual gear selection.

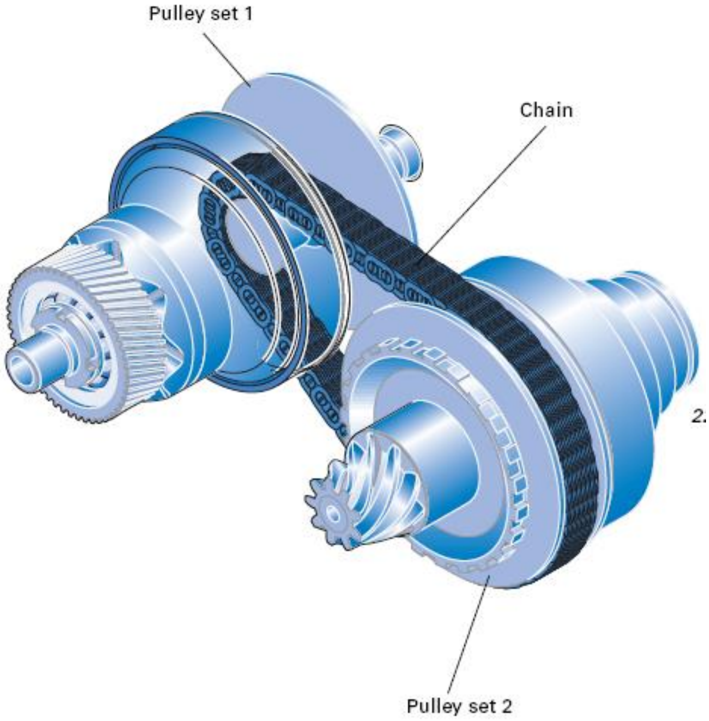


The chain

The chain is a key component part of the variator of the multitronic®. This is the first time that a chain is for used as a driving means in a CVT gearbox. The chain is a new development and has the following advantages over previously conventional driving means such as sliding link belts or V-belts:

• Very small track radii make possible a large “spread” despite the small size of the variator.

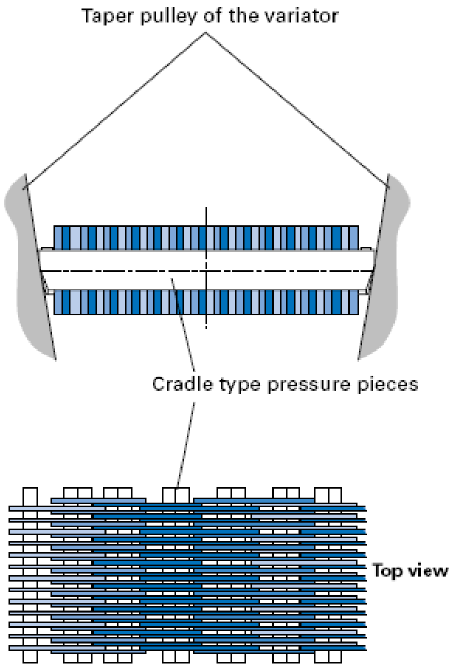
- High transferable torque
- High efficiency



Design

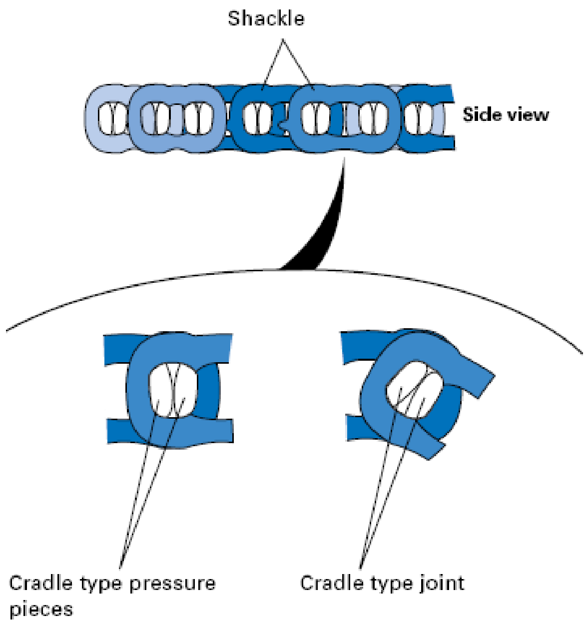
On a conventional chain, the chain link plates are interconnected non-rigidly via the joint pins. For torque transmission, a gear tooth moves into engagement with the pins between the chain link plates.

The CVT chain comprises adjacent rows of chain link plates linked continuously by means of cradle type pressure pieces (two per link).



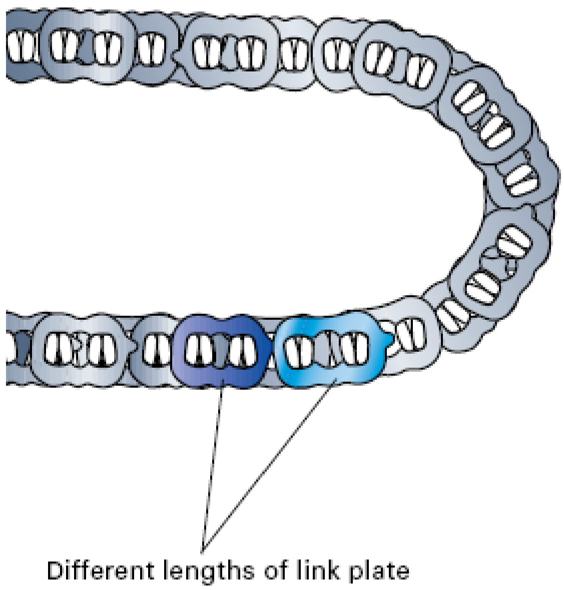
On the CVT chain, the cradle type pressure pieces are "jammed" between the taper pulleys of the variator, i.e. the taper pulleys are pressed against one another. The torque is transmitted only by the frictional force between the frontal areas of the cradle type pressure pieces and the contact faces of the taper pulleys.

Each of the cradle type pressure pieces is permanently connected to a row of link plates in such a way that it cannot be twisted. Two cradle type pressure pieces form a so-called cradle type joint. The cradle type pressure pieces now roll off one another almost frictionless as they "drive" the chain within the track radius of the taper pulleys. In this way, lost power and wear are minimised despite the high torque and the large angle of bend. The result is long service life and optimal efficiency.



Noise reduction

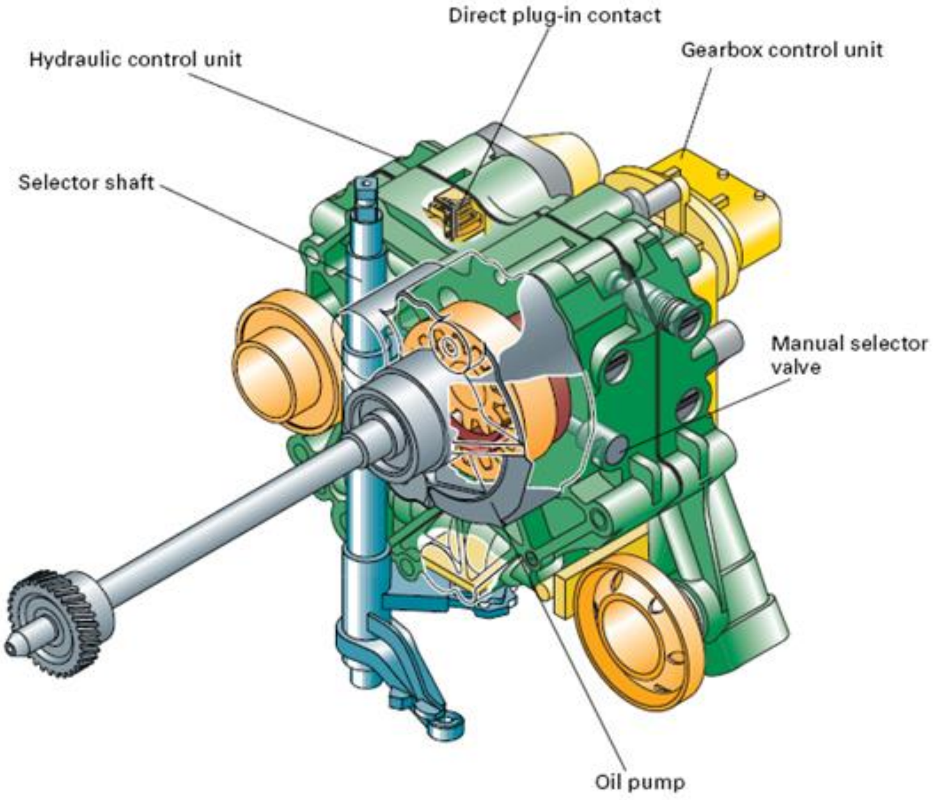
Two different lengths of link plate are used in order to ensure that the chain runs as quietly as possible. When using a constant length of link plate, the cradle type pressure pieces strike the taper pulleys at uniform intervals and induce vibrations which cause a noise nuisance. Using different lengths of link plate counteracts resonance and minimises running noise.



Electrohydraulic control

A new development is that the oil pump, hydraulic control unit (valve body) and gearbox control unit are combined as a compact, fully assembled unit.

The hydraulic control unit comprises the manual selector valve, nine hydraulic valves and three electromagnetic pressure control valves. The hydraulic control unit and the gearbox control unit are interconnected electrically by direct plug-in contacts.



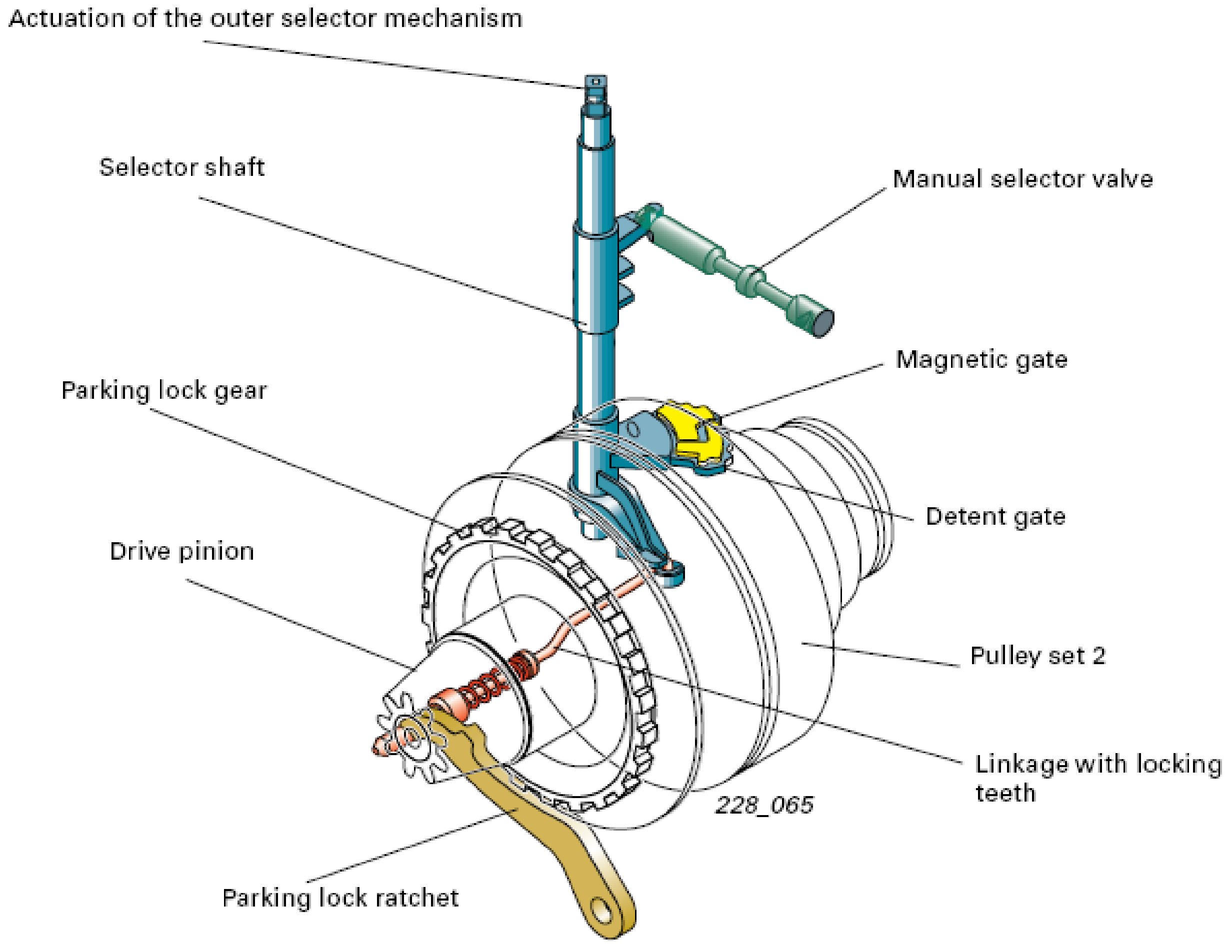
Selector shaft and parking lock

A mechanical connection (cable pull) for transmission of selector lever positions P, R, N and D still exists between the gate selector lever and the gearbox. The following functions are executed via selector shaft:

• Actuation of the manual selector valve in the hydraulic control unit, i.e. hydromechanical control of vehicle operating state (forward/reverse/neutral).

• Operating the parking lock
• Actuation of the multi-functional switch for electronic recognition of the selector lever position.

In selector lever position P, the linkage with locking teeth is displaced axially in such a way that the parking lock ratchet is pressed against the parking lock gear and the parking lock is engaged. The parking lock gear is permanently connected to the drive pinion.

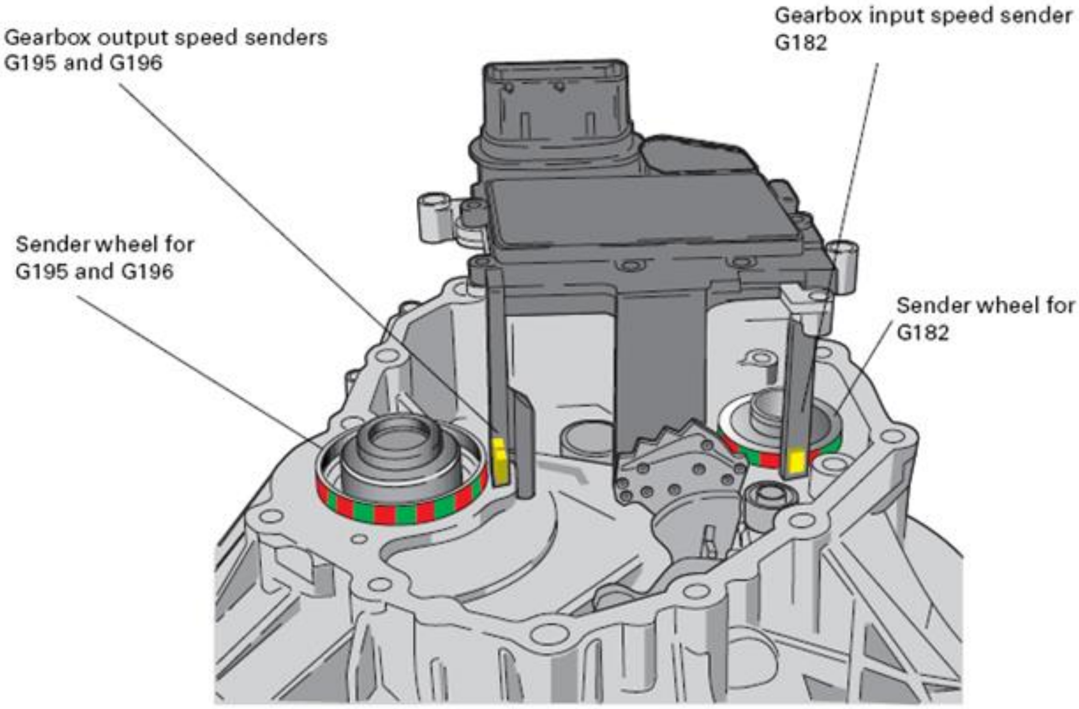


Sensors

The signals generated by the sensors can no longer measured with conventional equipment due to the fact that the control unit is integrated in the gearbox. A check can only be performed with the Diagnostic Testing and Information System by means of the “Read out fault” and “Read out data blocks” functions.
If a sensor fails, the gearbox control unit generates substitute values from the signals from the other sensors as well as the information from the networked control units. Vehicle operation can thus be maintained.

The effects on handling performance are in part so small, the driver will not notice the failure of a sensor immediately. A further fault can, however, have serious effects.

A magnetic ring comprising a row of 40 magnets (for G182) or 32 magnets (for G195 and G196) is located on the end face of the sender wheel; the magnets act as N/S poles.



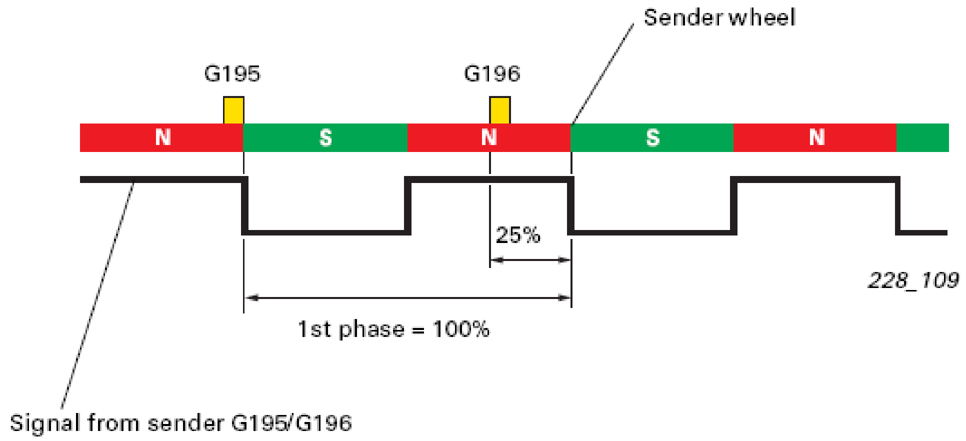
Sender G182 registers the rotation speed of pulley set 1 and therefore represents the actual gearbox input speed. Gearbox input speed is used together with engine speed for clutch control (for more detailed information, refer to “Micro-slip control”) serves as the reference input variable for transmission control (for more detailed information, refer to “Transmission control”).

Senders G195 and 196 register the rotation speed of pulley set 2 and with it the gearbox output speed. The signal from G195 is used for registering rotation speed. The signal from G196 is used for recognition of direction of rotation and therefore also for distinguishing between ahead travel and reverse travel (refer to “Creep control”).

Heavy contamination of the magnetic ring (metal swarf caused by wear) can impair the performance of G182, G195 or G196. Therefore, metal swarf adhering to the magnetic ring should be removed before performing repairs.
How the direction of rotation is registered

A magnetic ring comprising row of 32 individual magnets (N/S poles) is located on the end face of the sender wheel for G195 and G196.

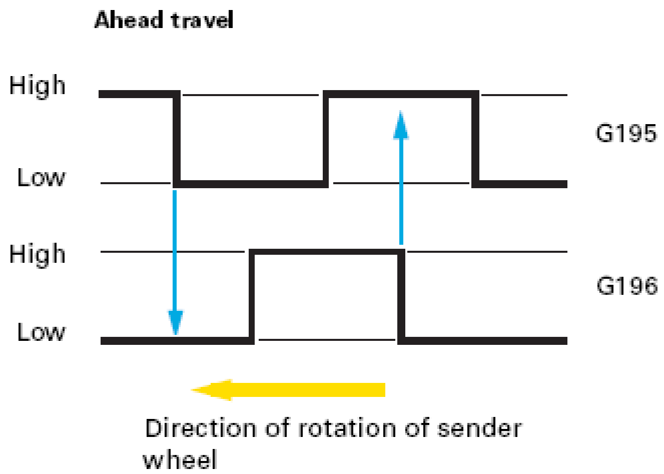
The position of sender G195 relative to sender G196 is offset in such a way that the phase angles of the sensor signals are 25% out of phase with one another.



After ignition "ON", the control unit observes the falling edges of the signals from the two sensors and records the level of the other sensors.

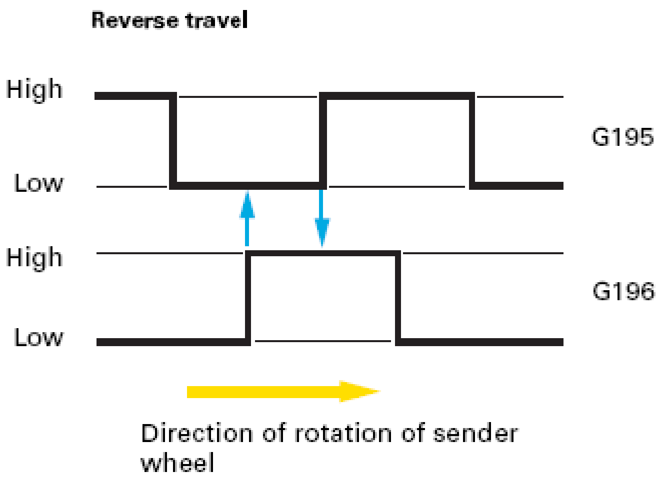
Forward

As shown in the example below, the level of sensor G196 is "Low" at the falling edge of the signal from sensor G195 and the level of G195 is "High" at the falling edge of the signal from sensor G196. The gearbox control unit interprets this "pattern" as ahead travel.



Reverse

In this example, the level of sensor G196 is "High" at the falling edge of the signal from sensor G195 and the level of G195 is "Low" at the falling edge of the signal from sensor G196. The gearbox control unit interprets this "pattern" as reverse travel.

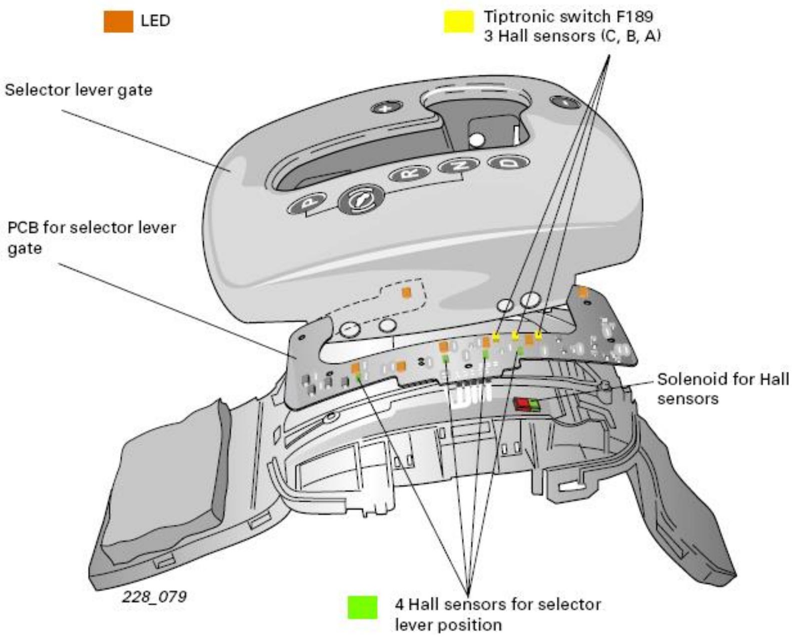


Tiptronic switch

Tiptronic switch F189 is integrated in the pcb of the gear change mechanism. It comprises 3 Hall sensors which are actuated by a magnet located on the shutter.

A - Sensor for downshift
B - Sensor for tiptronic recognition
C - Sensor for upshift

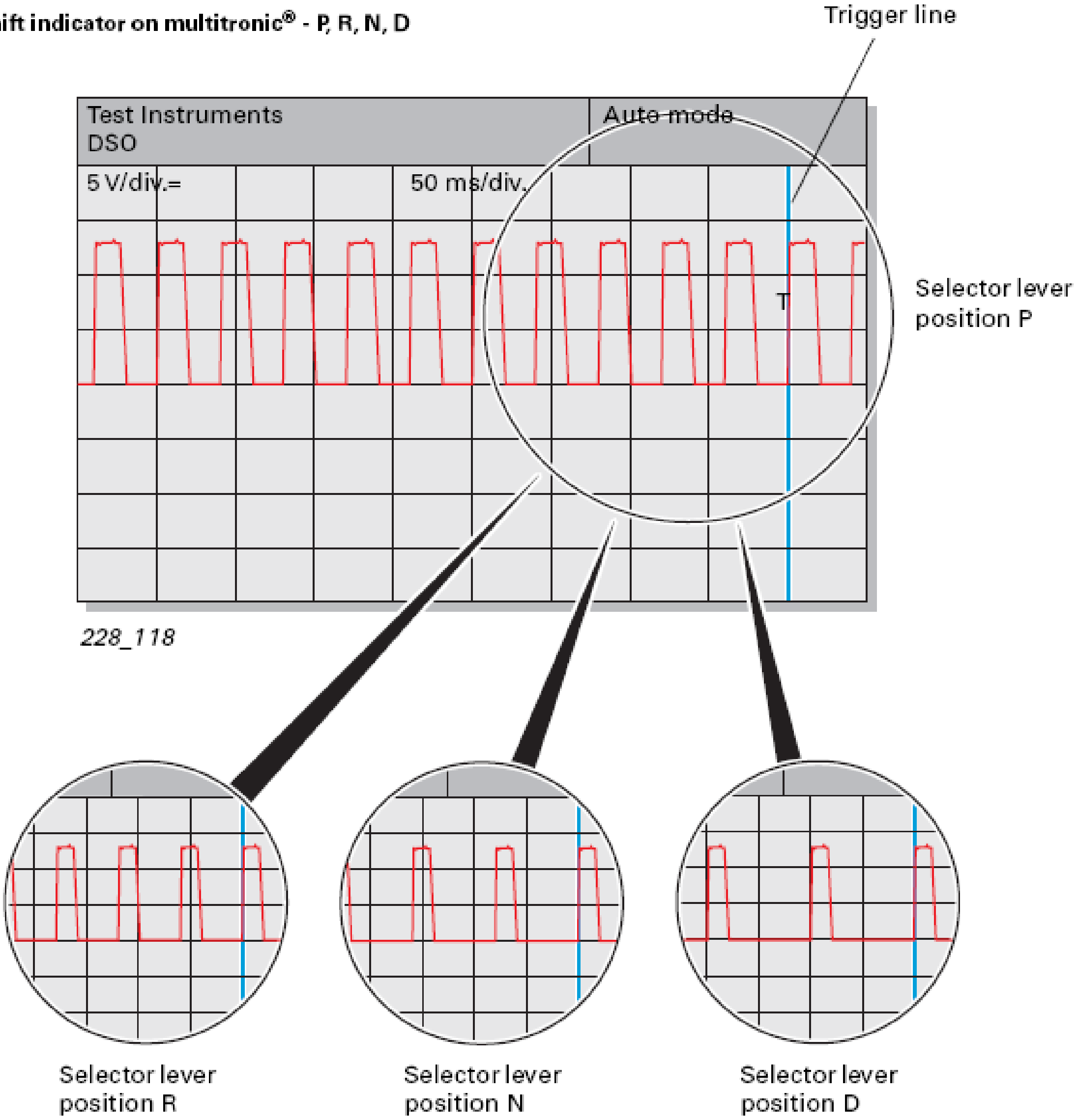
7 LEDs are located on the pcb: 1 for each selector lever position, 1 for the “Brake actuated” symbol, and 1 of each for the + and – symbols on the tiptronic gate. Each selector lever position LED is controlled by a separate Hall sensor.



Signal for shift indicator

The signal for shift indicator is a square-wave signal generated by the gearbox control unit with a constant high level (20 ms) and variable low level. Each selector lever position or each “gear” (in the tiptronic function) is assigned to a defined low level. The selector lever position indicator or the shift indicator in the dash panel insert recognises by the low-level duration what selector lever position or what gear is selected and indicates this accordingly.

Signal for shift indicator on multitronic® - P, R, N, D



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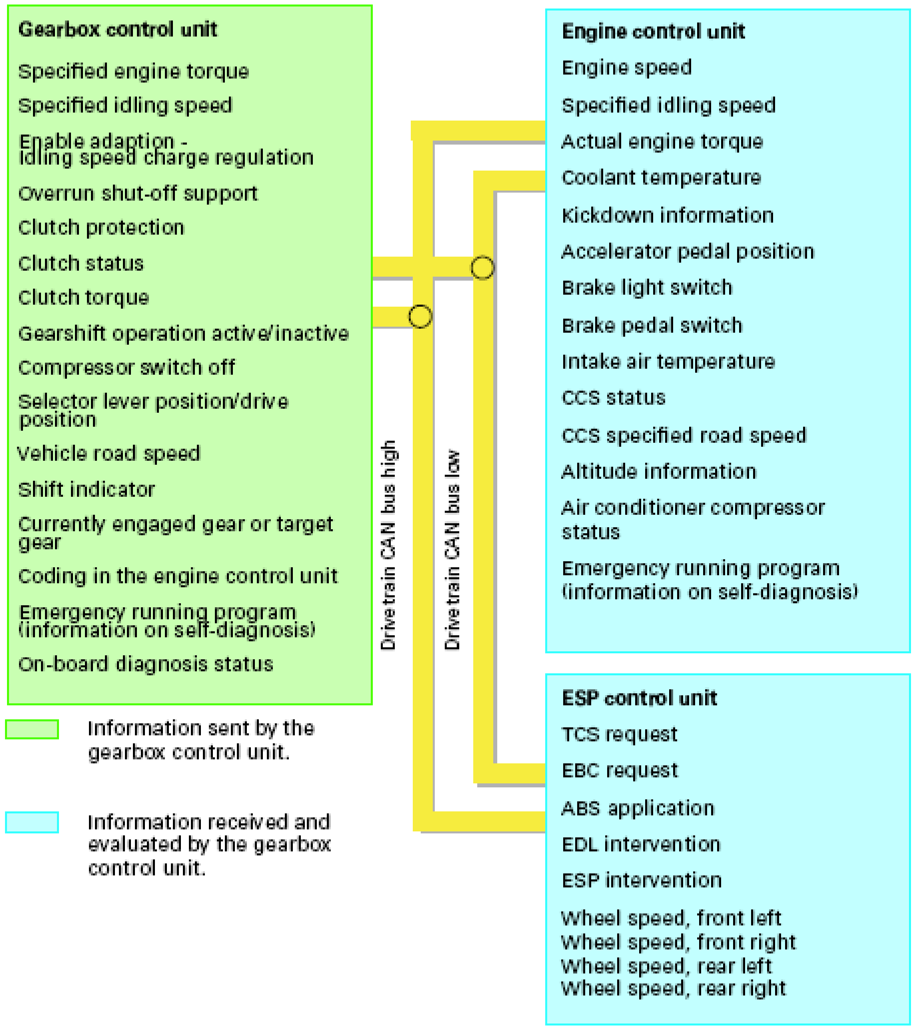
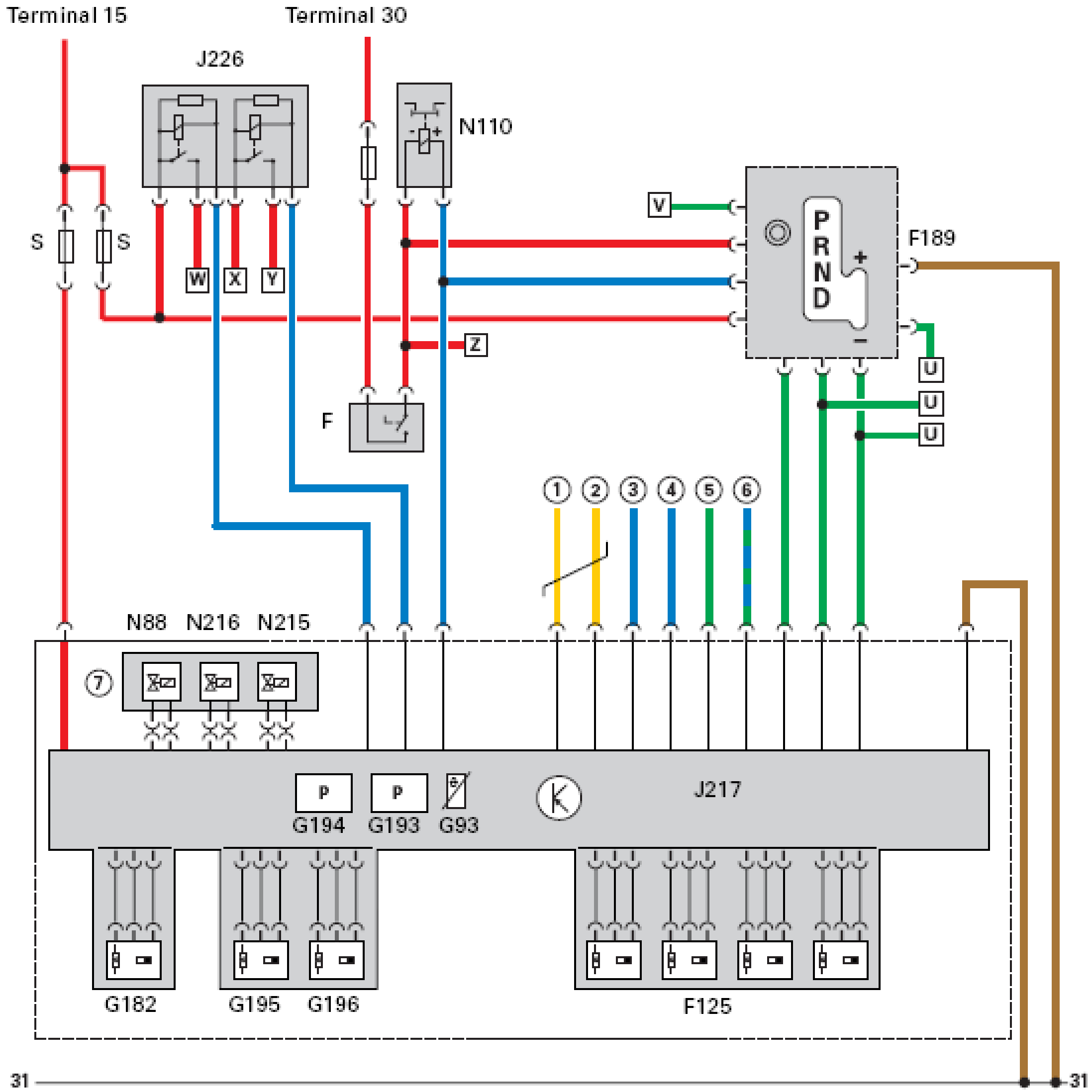
CAN information exchange on multitronic®

In the multitronic® information is exchanged between the gearbox control unit and the networked control units, apart from only a few interfaces, across the CAN bus (drivetrain CAN bus). The system overview shows information which is supplied by the gearbox control unit across the CAN bus and received and used by the networked control units.



Electrical overview



F Brake light switch
F125 Multi-functional switch
F189 Tiptronic switch

G93 Gearbox oil temperature sender
G182 Gearbox input speed sender
G193 Automatic gearbox hydraulic pressure sender -1- (clutch pressure)
G194 Automatic gearbox hydraulic pressure sender -2- (contact pressure)
G195 Gearbox output speed sender
G196 Gearbox output speed sender -2-

N88 Solenoid valve 1 (clutch cooling/ safety shut-off)
N110 Selector lever lock solenoid
N215 Automatic gearbox pressure control valve -1- (clutch control)
N216 Automatic gearbox pressure control valve -2- (transmission control)

J217 Control unit for multitronic
J226 Starter inhibitor and reversing light relay

S Fuses

= Input signal

= Output signal

= Positive

= Earth

= Bidirectional

= Drivetrain CAN bus

multitronic®

(7) Fitted in the hydraulic control unit

Connections and auxiliary signals

U To tiptronic steering wheel (option)
V From terminal 58d
W To the reversing lights
X From ignition switch terminal 50
Y To starter terminal 50
Z To the brake lights

1 Drivetrain CAN bus Low
2 Drivetrain CAN bus High
3 Signal for shift indicator
4 Signal for road speed
5 Signal for engine speed
6 K-diagnostic connection

Semi-automatic

Currently, the world of transmission is dominated in Europe by manual gearboxes and in the USA and Japan by automatic gearboxes. Both types of gearboxes have specific advantages and disadvantages.

The advantages of a manual gearbox are, for example,

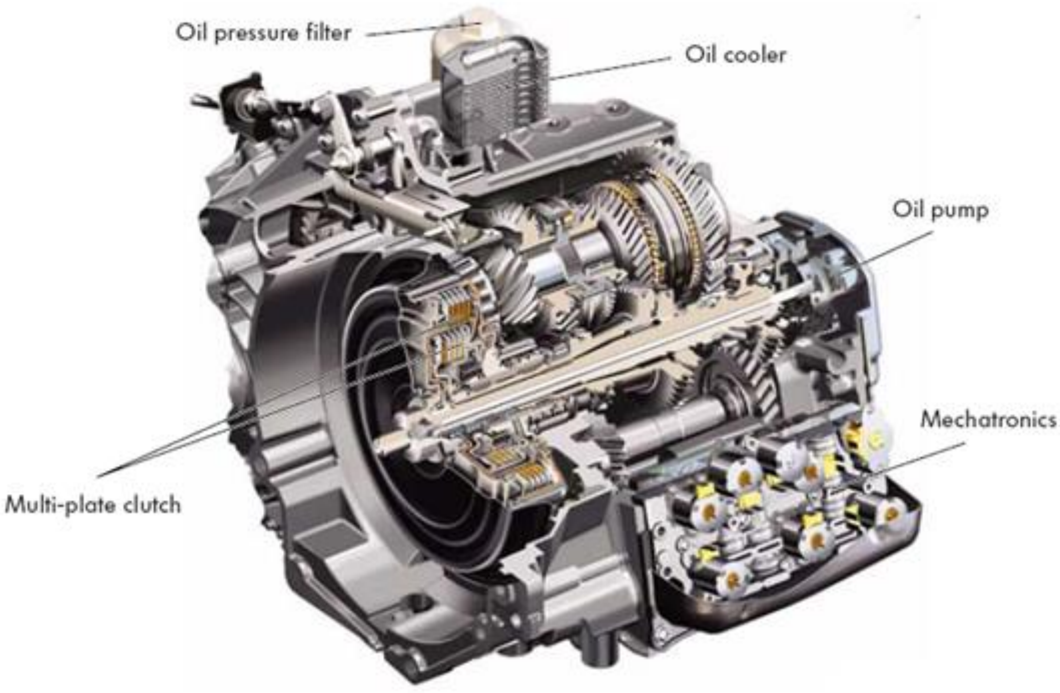
• high degree of efficiency

• robust and sporty characteristic.

The advantages of an automatic gearbox are, for example,

• a high level of comfort, above all in gear changes, as there is no interruption in tractive power.

This formed the framework for vehicle manufacturers to combine both transmission concepts into one completely new gearbox generation: the direct shift gearbox.



Thanks to the double multi-plate clutch design and different automatic gear selection programmes, it is well capable of meeting the high demands in comfort from drivers who favour automatic gearboxes.

Furthermore, with direct selection and lightning fast, jolt-free gear changes, it also offers a high level of driving enjoyment to drivers who favour manual gearboxes. In both cases, fuel consumption is at a par with economical vehicles fitted with manual gearboxes.

The direct shift gearbox is distinguished by:

• Six forward gears and one reverse gear

• Normal driving program "D", sports program "S" as well as Tiptronic selector lever and Tiptronic steering wheel levers (optional)

• Mechatronics, electronic and electro-hydraulic control unit form one unit and are housed in the gearbox

• Hillholder function – if the vehicle begins to move when stationary, with just light brake application, the clutch pressure is increased and the vehicle is held in position

• Creep regulation – allows creeping of the vehicle, when parking for example, without accelerator pedal application

• Emergency mode In the event of a fault, the vehicle can still be driven, with emergency mode activated, in 1st and 3rd gear or just in 2nd gear.

Designation	DSG 02E (direct shift gearbox)
Weight	Approx. 94 kg front-wheel drive, 109 kg 4motion
Torque	Maximum 350 Nm (depending on engine)
Clutch	Two multi-layer wet plate clutches
Gear stages	Six forward, one reverse gear (all synchronised)
Operating mode	Automatic and Tiptronic
Oil volume	7.2 ltr. DSG oil G052 182

Operation

The selector lever is actuated in the vehicle in the same way as an automatic gearbox. The direct shift gearbox also offers the option of Tiptronic gear selection. As in vehicles with automatic gearboxes, the selector lever features lever locks and an ignition key lock. The function of the locks remains unchanged. The design, however, is new. The gear selector lever positions are:

P – Park

To move the selector lever out of this position, the ignition must be "on" and the brakes applied. Furthermore, the release button on the selector lever must be pressed.

R - Reverse gear

To engage reverse gear, the release button must be pressed.

N - Neutral position

In this position, the gearbox is at idle. If, for a length of time, the gear selector lever is left in this position, the brake pedal must be pressed for it to be moved.

D – Drive

In this position, the forward gears are selected automatically.

S – Sport

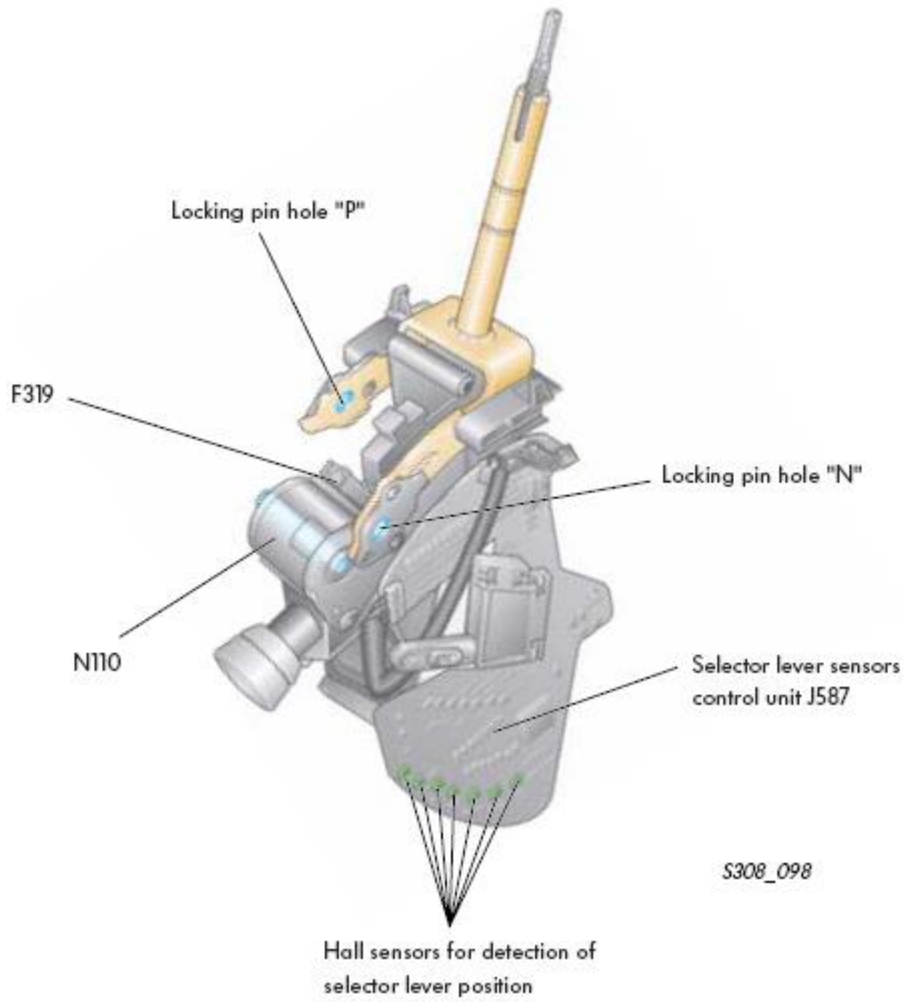
Gears are selected automatically using a "sporty" program stored in the control unit.

+ and –

The Tiptronic functions can be used with the selector lever in the right gate and with the steering wheel gear selectors.

Gear selection

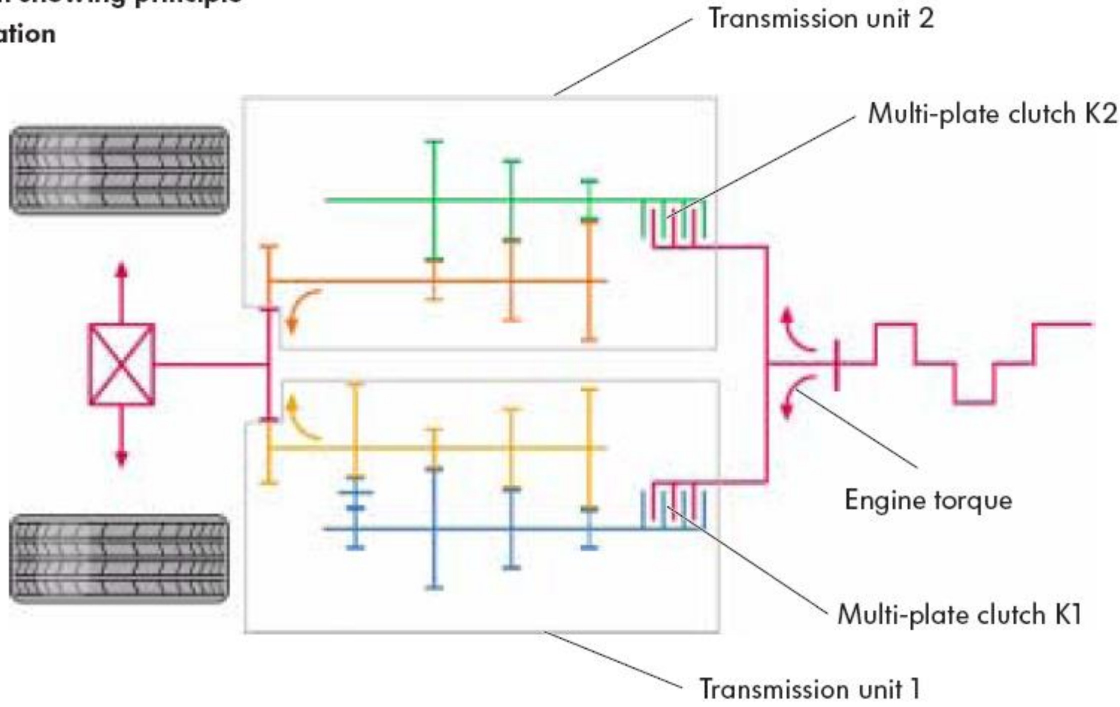
Hall sensors in the gear selector lever mounting detect the position of the selector lever and make the positions available to the mechatronics via the CAN bus .



Construction of the DSG unit

The direct shift gearbox comprises in essence of two transmission units that are independent of each other. Each transmission unit is constructed in the same way as a manual gearbox. Allocated to each transmission unit is a multi-plate clutch. Both multi-plate clutches are of the wet type and work in DSG oil. They are regulated, opened and closed by the mechatronics system, depending on the gear to be selected.
1st, 3rd, 5th and reverse gear are selected via multi-plate clutch K1. 2nd, 4th and 6th gear are selected via multiplate clutch K2. One transmission unit is always in gear and the other transmission unit has the next gear selected in preparation but with the clutch still in the open position. Every gear is allocated a conventional manual gearbox synchronisation and selector element.

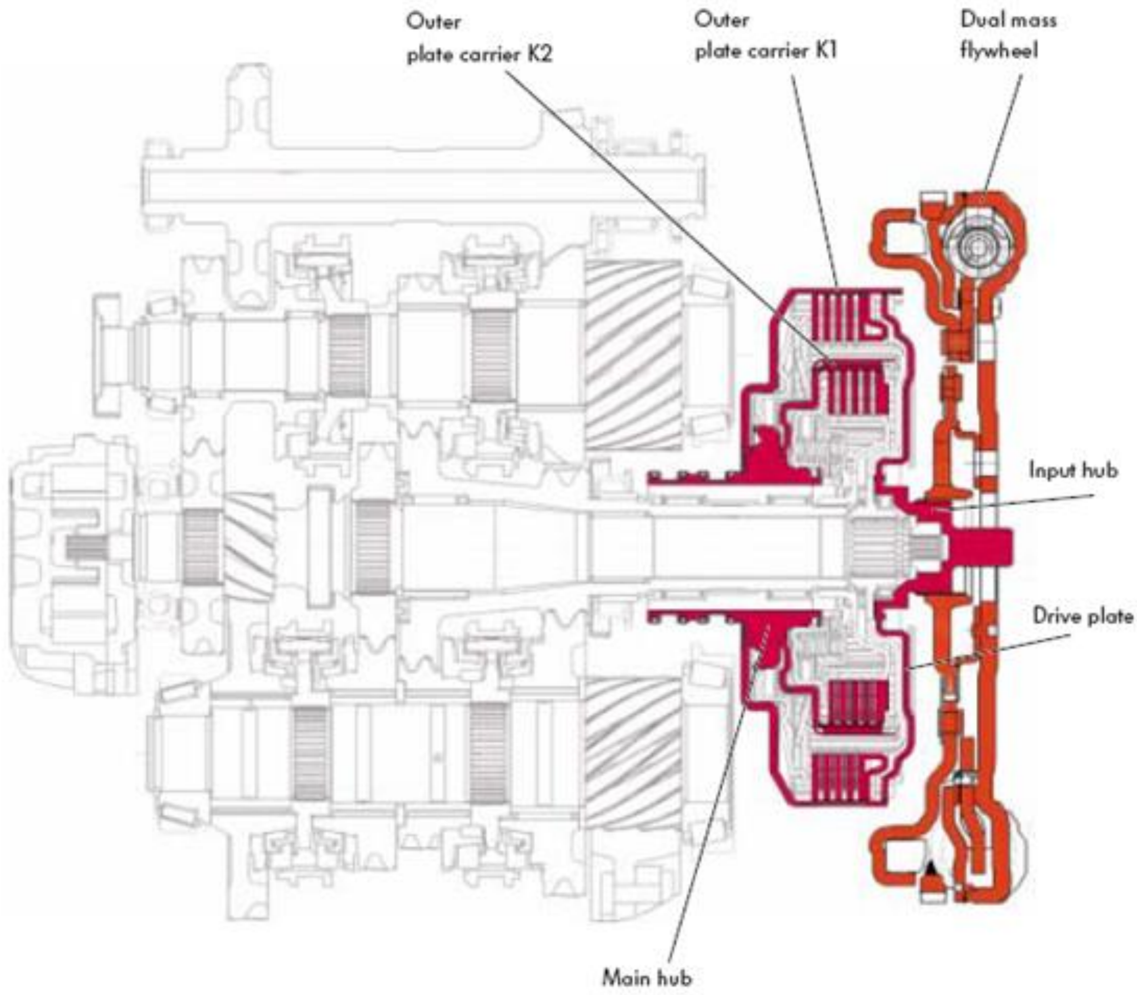
Diagram showing principle of operation



Torque input

The torque is transmitted from the crankshaft to the dual mass flywheel. The splines of the dual mass flywheel on the input hub of the double clutch transmit the torque to the drive plate of the multi-plate clutch.

This is joined to the outer plate carrier of clutch K1 with the main hub of the multi-plate clutch. The outer plate carrier of clutch K2 is also positively joined to the main hub.



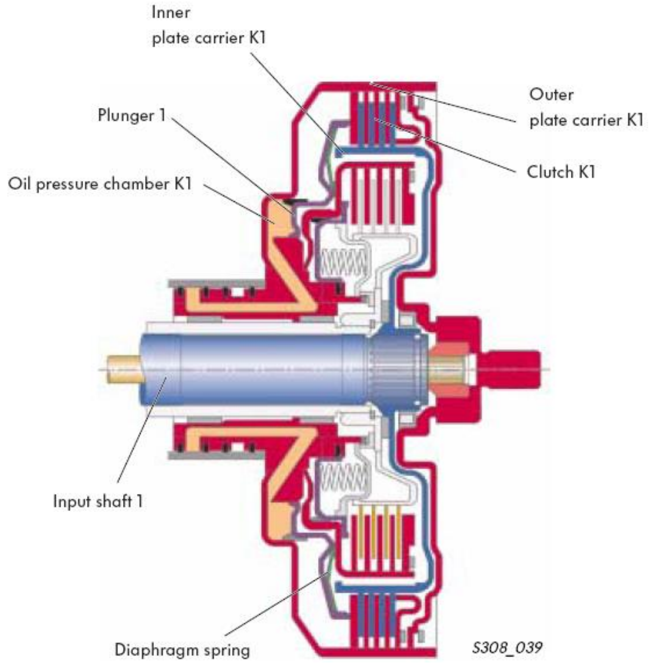
Multi-plate clutches

The torque is transmitted to the relevant clutch through the outer plate carrier. When the clutch closes, the torque is transmitted further to the inner plate carrier and then to the relevant input shaft. One multi-plate clutch is always engaged.

Multi-plate clutch (K1)

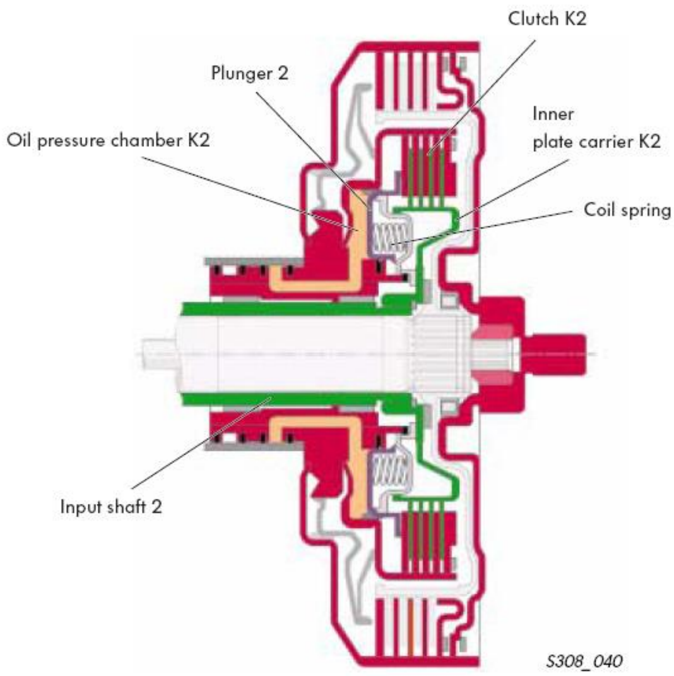
Clutch K1 is of the multi-plate type. It is the outer clutch and transmits torque to input shaft 1 for 1st, 3rd, 5th and reverse gear. To close the clutch, oil is forced into the oil pressure chamber of clutch K1.

In this way, plunger 1 is pushed along its axis and the plates of clutch K1 are pressed together. Torque is transmitted via the plates of the inner plate carrier to input shaft 1. When the clutch opens, a diaphragm spring pushes plunger 1 back to its start position.



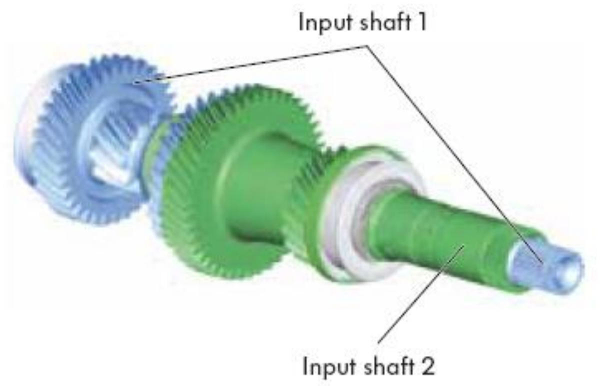
Multi-plate clutch K2

Clutch K2 is of the multi-plate type. It is the inner clutch and transmits torque to input shaft 2 for 2nd, 4th and 6th gear. To close the clutch, oil is forced into the oil pressure chamber of clutch K2. Plunger K2 then joins the drive via the plates to input shaft 2. The coil springs press plunger 2 back to its start position when the clutch is opened.



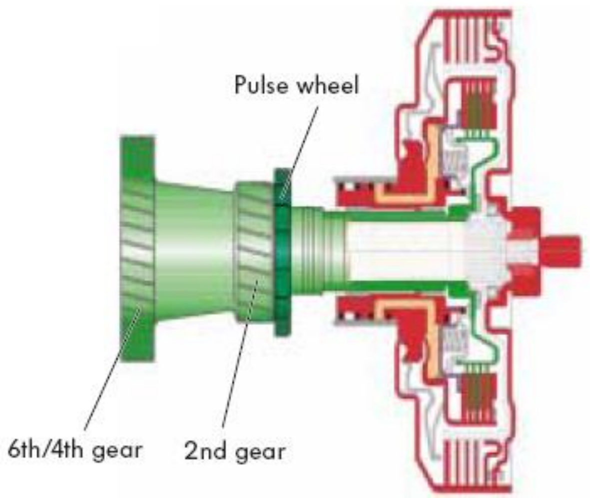
Input shafts

The engine torque is transmitted to the input shafts from multi-plate clutches K1 and K2.



Input shaft 2

Input shaft 2 is shown in relation to the installation position of input shaft 1.

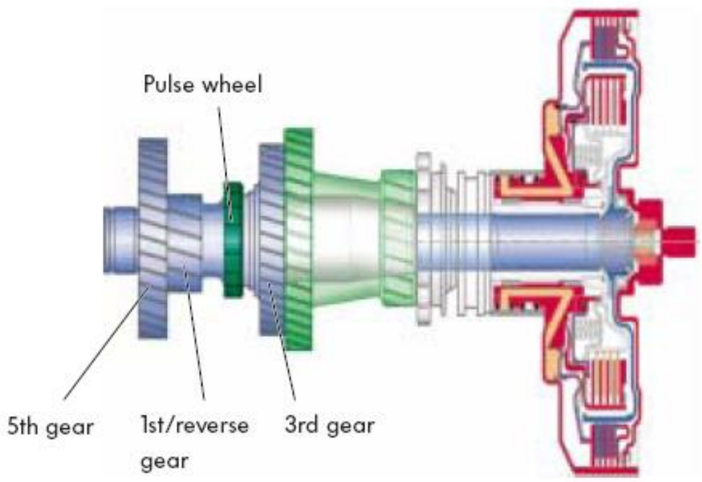


Input shaft 2 is a hollow construction and is joined via splines to multi-plate clutch K2. The helical gear wheels for 6th, 4th and 2nd gear can be found on input shaft 2. For 6th and 4th gear, a common gear wheel is used.

To measure the speed of this input shaft there is a pulse wheel for input shaft 2 speed sender G502 adjacent to the gear wheel for 2nd gear.

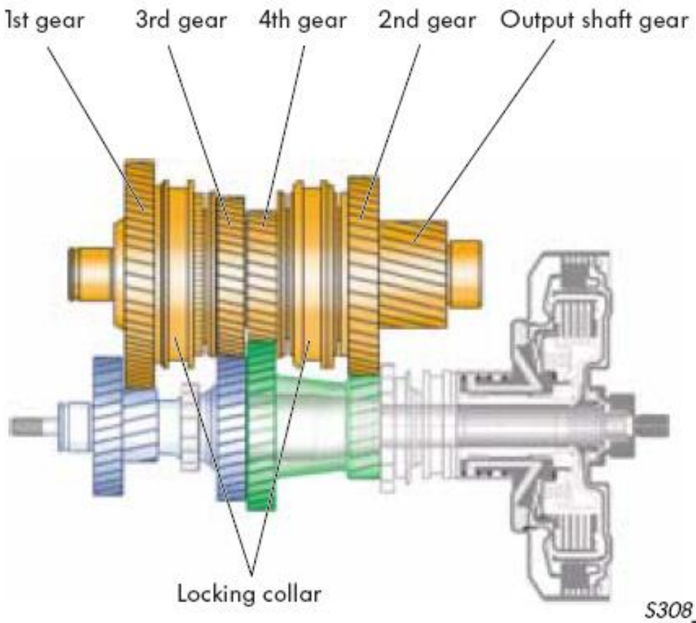
Input shaft 1

Input shaft 1 rotates inside input shaft 2, which is hollow. It is joined to multi-plate clutch K1 via splines. Located on input shaft 1 are the helical gear wheels for 5th gear, the common gear wheel for 1st and reverse gear and the gear wheel for 3rd gear. To measure the speed of this input shaft there is a pulse wheel for input shaft 1 speed sender G501 between the gear wheels for 1st/reverse gear and 3rd gear.



Output shafts

In line with the two input shafts, the direct shift gearbox also features two output shafts. Thanks to the common use of gear wheels for 1st and reverse gear and 4th and 6th gear on the input shafts, it was possible to reduce the length of the gearbox.



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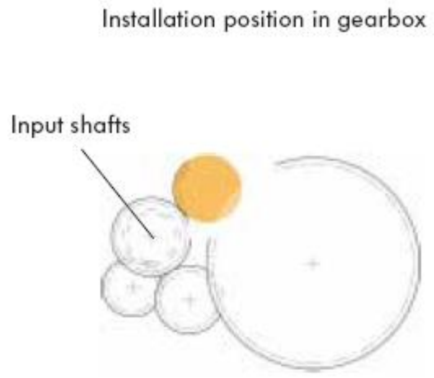

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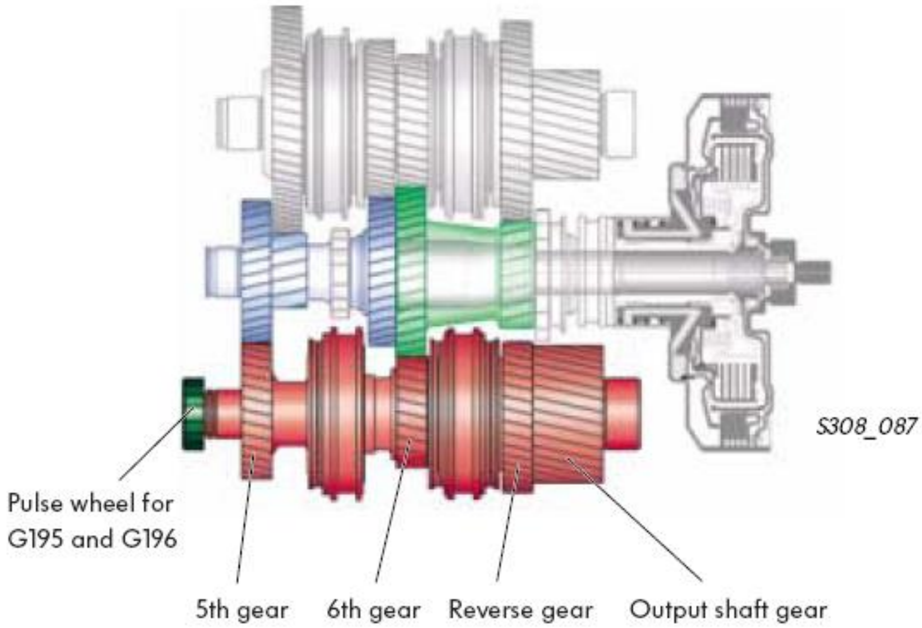
Located on input shaft 1 are:

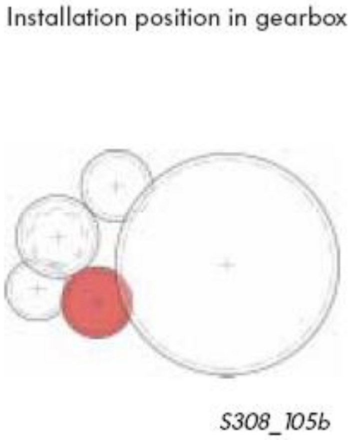
- the three-fold synchronised selector gears for 1st, 2nd, 3rd gears
- the single synchronised selector gear for 4th gear
- the output shaft gear for meshing into the differential.

The output shaft meshes into the final drive gear wheel of the differential.

Output shaft 2

Both output shafts transmit the torque further to the differential via their output shaft gears.



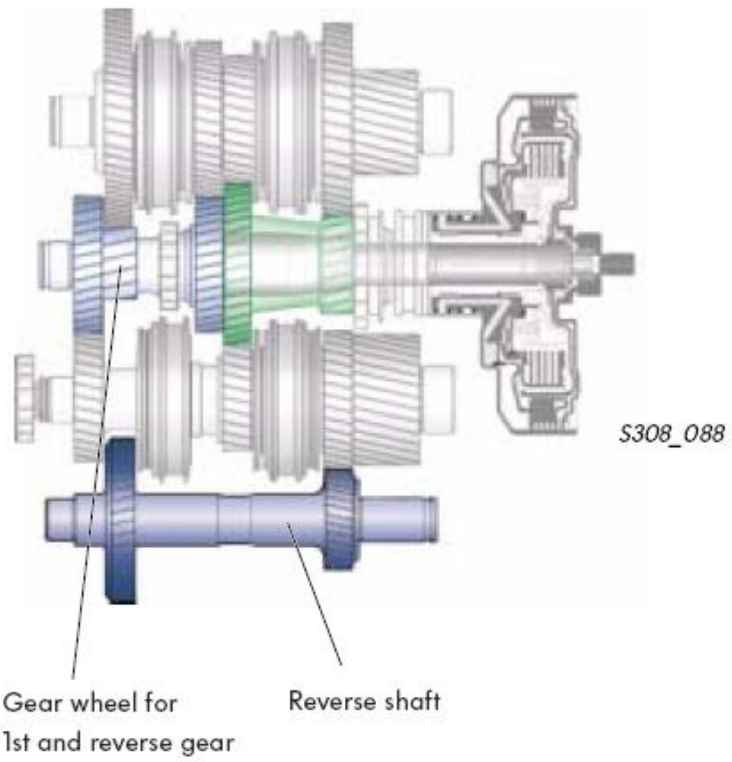


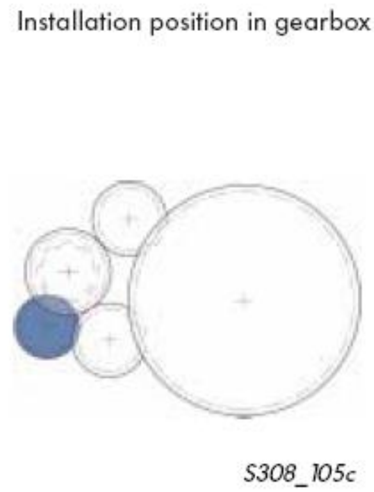
Located on input shaft 2 are:

- the pulse wheel for gearbox output speed
- the selector gears for 5th, 6th and reverse gears
- the output shaft gear for meshing into the differential.

Reverse shaft

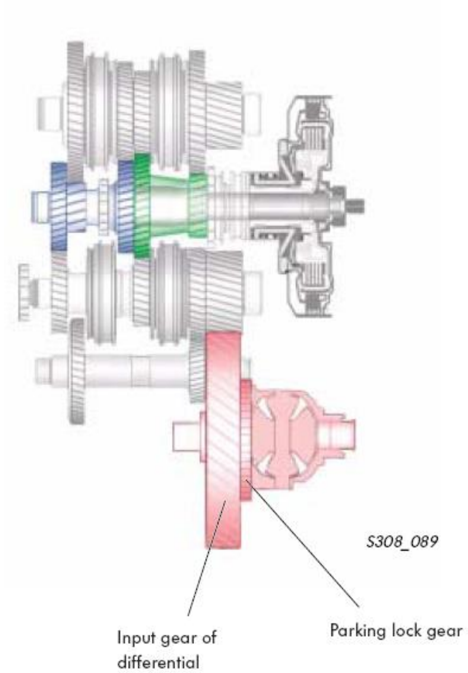
The reverse shaft changes the direction of rotation of output shaft 2 and thereby also the direction of rotation of the final drive in the differential. It engages in the common gear wheel for 1st gear and reverse gear on input shaft 1 and the selector gear for reverse gear on output shaft 2.





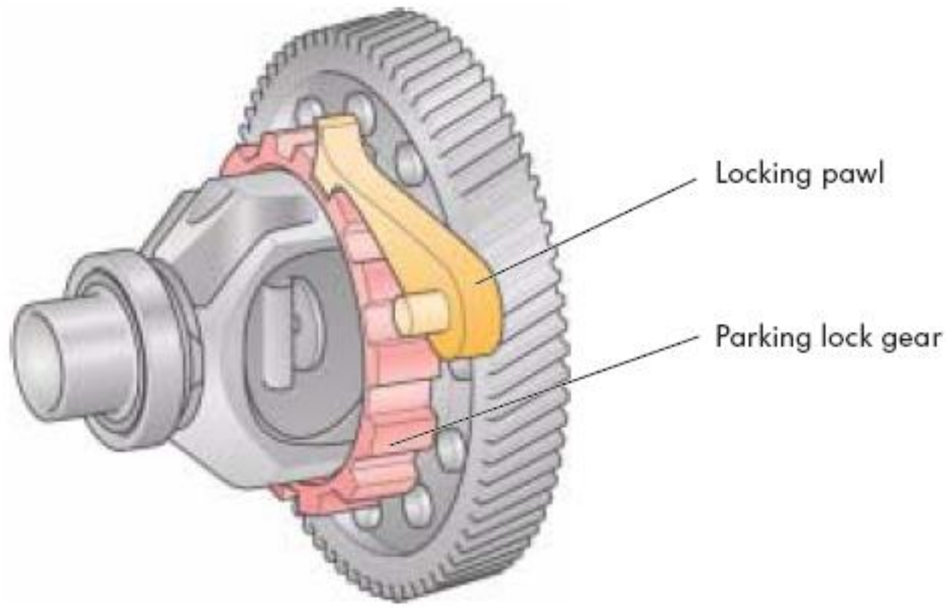
Differential

Both output shafts transmit the torque to the input shaft of the differential. The differential transmits the torque via the drive shafts to the road wheels. Integrated in the differential is the parking lock gear.



Parking lock

A parking brake is integrated in the differential to secure the vehicle in the parked position and to prevent the vehicle from creeping forwards or backwards unintentionally when the handbrake is not applied. Engagement of the locking pawl is purely by mechanical means via a cable between the selector lever and the parking brake lever on the gearbox. The cable is used exclusively to actuate the parking lock.



Gear selection

The torque in the gearbox is transmitted either via the outer clutch K1 or the inner clutch K2.

Each clutch drives an input shaft.

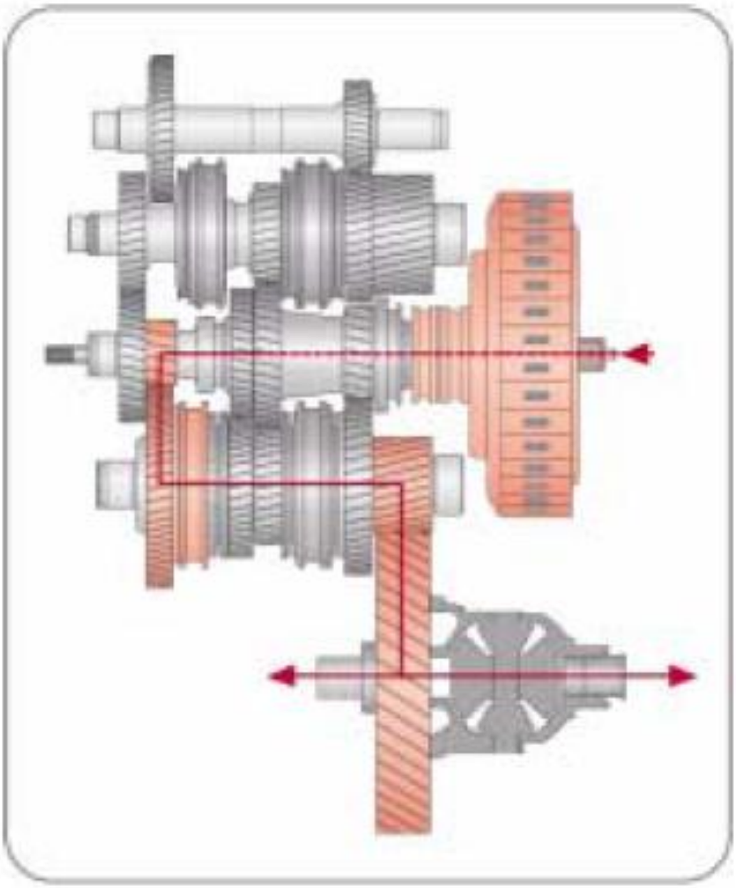
Input shaft 1 (inner) is driven by clutch K1 and
input shaft 2 (outer) is driven by clutch K2.

Power is transmitted further to the differential via

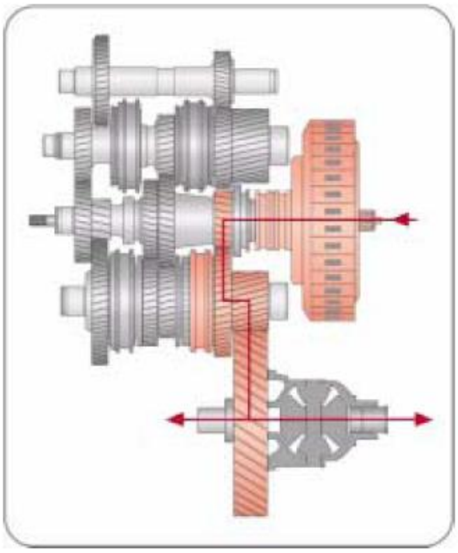
- output shaft 1 for 1st, 2nd, 3rd, 4th gears
- output shaft 2 for 5th, 6th and reverse gears

1st gear

- Clutch K1
- Input shaft 1
- Output shaft 1
- Differential

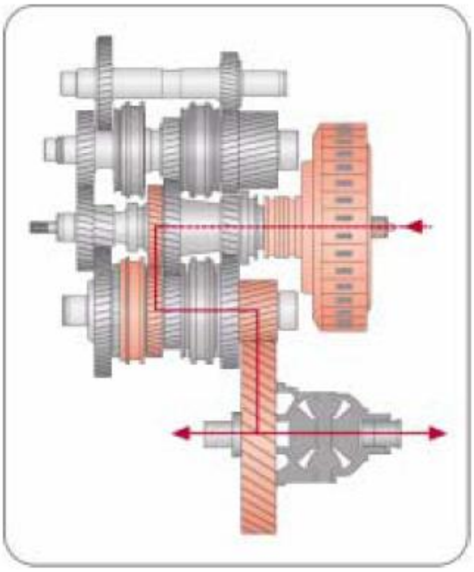


Gear selection cont.



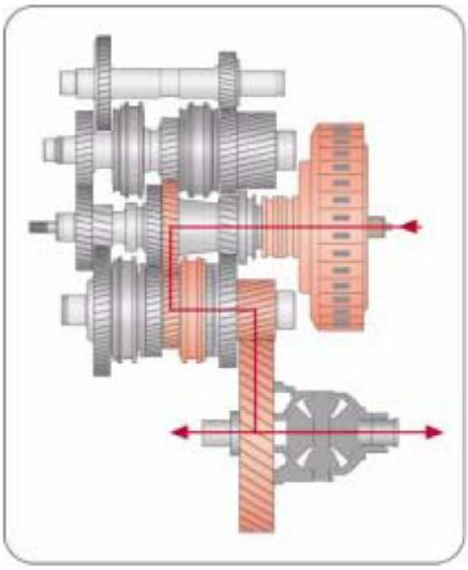
2nd gear

- Clutch K2
- Input shaft 2
- Output shaft 1
- Differential



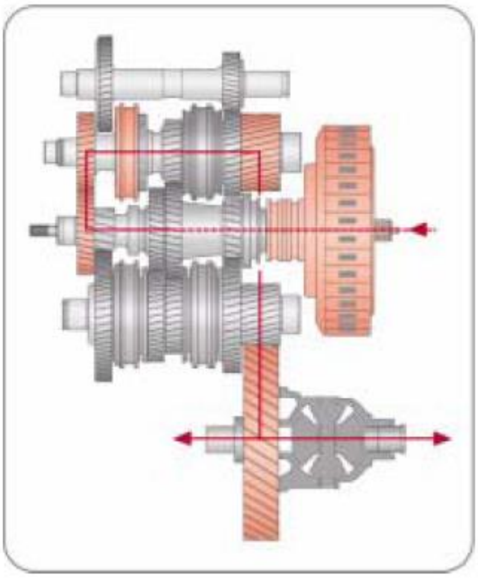
3rd gear

- Clutch K1
- Input shaft 1
- Output shaft 1
- Differential



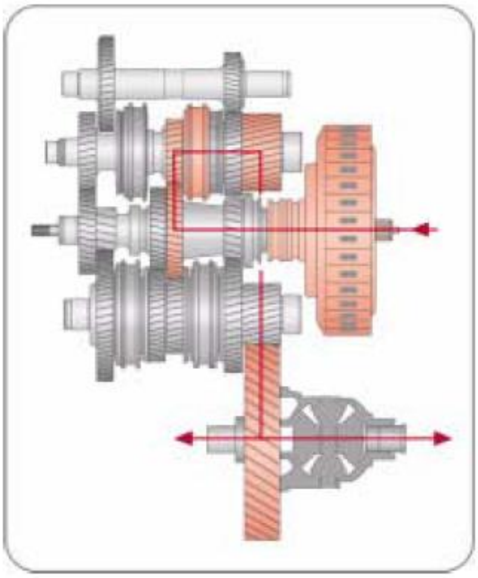
4th gear

- Clutch K2
- Input shaft 2
- Output shaft 1
- Differential



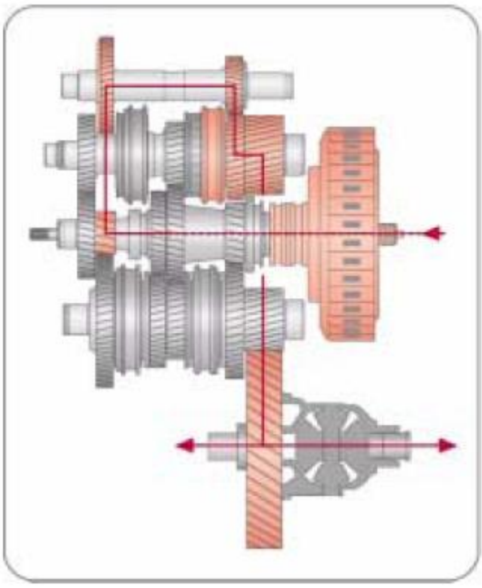
5th gear

- Clutch K1
- Input shaft 1
- Output shaft 2
- Differential



6th gear

- Clutch K2
- Input shaft 2
- Output shaft 2
- Differential



Reverse

- Clutch K1
- Input shaft 1
- Reverse shaft
- Output shaft 2
- Differential

The change in direction of rotation for reverse gear is carried out via the reverse shaft.

Control

The mechatronics are housed in the gearbox, surrounded by DSG oil. They comprise of an electronic control unit and an electro-hydraulic control unit. The mechatronics form the central control unit in the gearbox. All sensor signals and all signals from other control units come together at this point and all actions are initiated and monitored from here. Housed in this compact unit are twelve sensors. Only two sensors are located outside the mechatronics system.

By hydraulic means, it controls or regulates eight gear actuators via six pressure modulation valves and five selector valves and it also controls the pressure and flow of cooling oil from both clutches. The mechatronics control unit learns (adapts) the position of the clutches, the positions of the gear actuators when a gear is engaged and the main pressure.

The advantages of this compact unit are:

- The majority of sensors are integrated within.
- The electric actuators are located directly on the mechatronics.
- The electrical interfaces required on the vehicle side are joined at one central connector.

As a result of these measures, the number of connectors and amount of wiring has been reduced. That means there is greater electrical efficiency and lower weight. It also means that a high degree of thermal and mechanical stress is placed on the control unit. Temperatures of –40 °C to +150 °C and mechanical vibrations of up to 33 g should not be allowed to impair the operability of the vehicle.

Oil lubrication circuit

The DSG has a common lubrication circuit for all gearbox functions. The volume of direct selection gear oil is 7.2 litres.

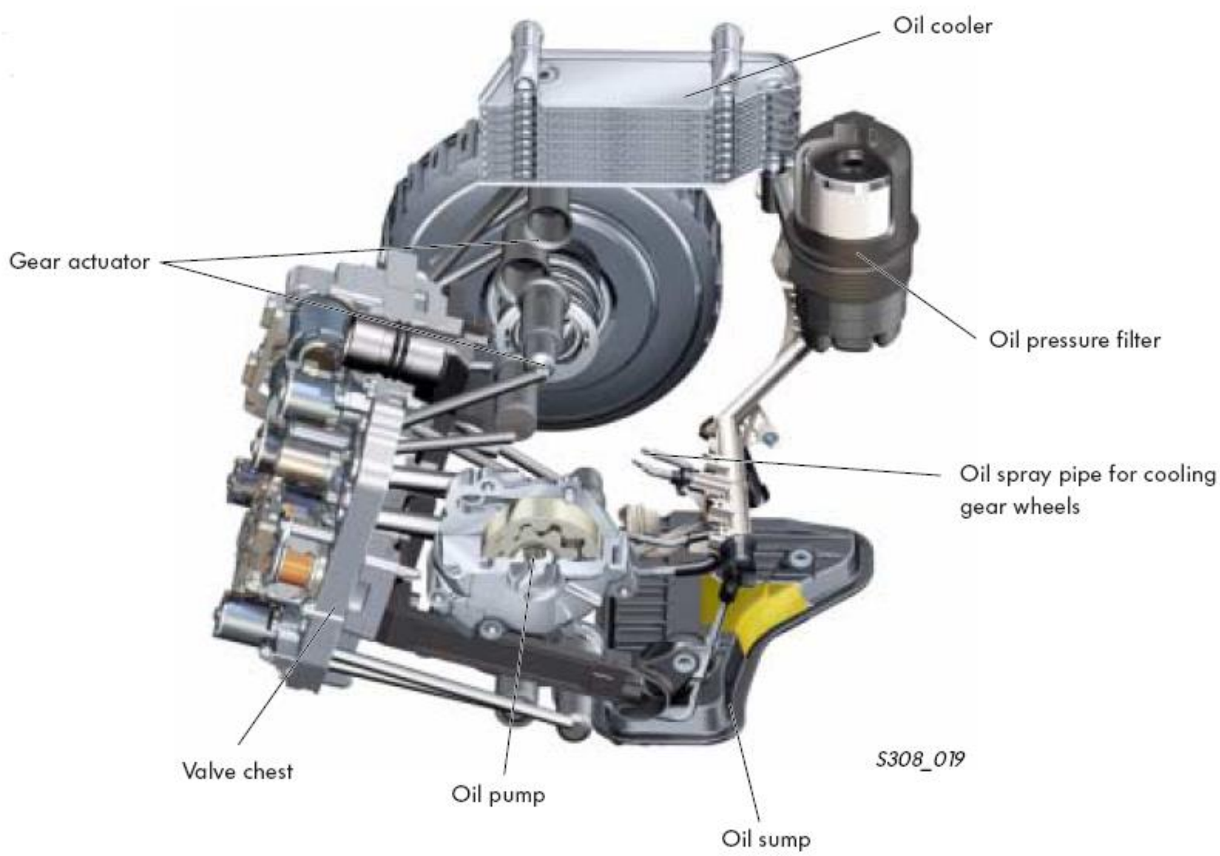
The oil must meet the following demands:

- Assure clutch regulation and hydraulic control
- Stabile viscosity across the whole temperature range
- Resistant to high mechanical stress
- Does not allow foaming

The oil has the task of:

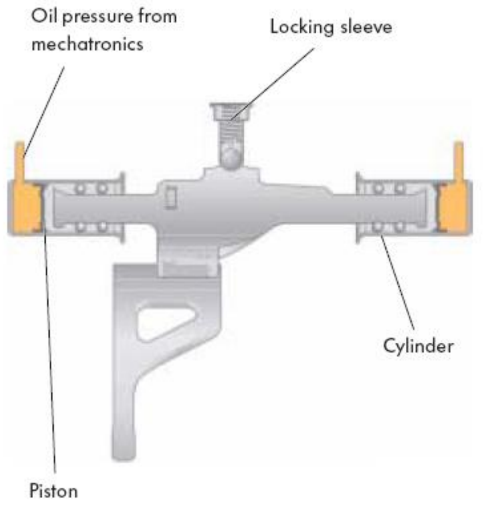
- lubricating/cooling the double clutch, the gear wheels, shafts, bearings and parts of synchronisation
- actuation of the double clutch and gear actuator plungers

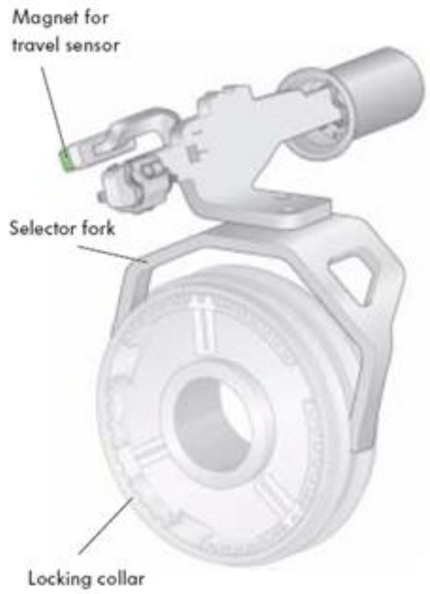
The oil temperature is kept from rising above 135 °C by an oil cooler, which is regulated by coolant from the engine.



Gear selection

The gears are selected via selector forks in the same way as a manual gearbox. Two gears are selected by each selector fork. Actuation of the selector forks is hydraulic on the direct shift gearbox and not by means of selector rods, as on conventional manual gearboxes. The selector forks run on ball bearings in a cylinder.





To select a gear, oil is fed into the left cylinder by the mechatronics. Since the right cylinder is not under pressure, the selector fork is moved and actuates the locking collar. This results in gear engagement. Once the gear is engaged, the selector fork is moved to a "no pressure" position. The gear is held in place by a chamfer on the selector teeth and by a locking mechanism on the selector fork. When the selector fork is not actuated, it is held in place in the gear casing (gearbox) by a locking mechanism. A permanent magnet is fitted to each selector fork. The permanent magnet allows the travel sensor in the mechatronics to detect the precise position of the selector forks.