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One-Way Clutches (Freewheel)

The one way clutch consists of an inner and outer ring with a locking device between the two. The one way clutch is designed to lock in one direction and to allow free rotation in the other direction. Currently there are two types of one way clutches used in BMW transmissions:

- Roller type which consists of spring loaded rollers between the inner and outer race of the one way clutch. (Roller type is also used without springs on some applications)
- Sprag type which consists of asymmetrically shaped wedges located between the inner and outer race of the one way clutch.

Roller Type One Way Clutch



Sprag Type One Way Clutch



In both versions of the one way clutch (freewheel), rotation is only allowed in one direction. Using the diagrams above, imagine that the inner races were locked stationary. The outer race would only be allowed to turn counter clock wise. In the clock wise direction, the outer race of both versions would be locked. In the roller type, the helper springs would push the rollers up the ramp on the outer race. This would force the rollers in to the smaller area which would cause the outer race to lock, In the sprag type, the asymmetrical wedges would lock between the inner and outer race.

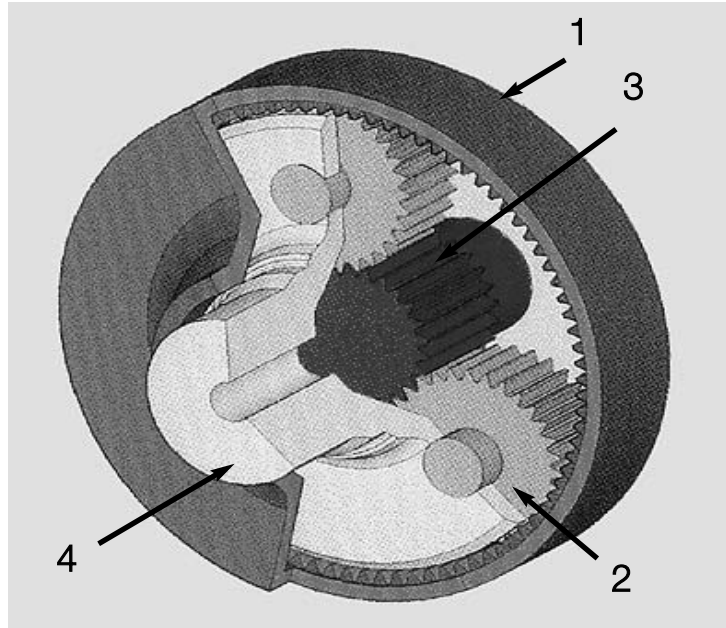
The one way clutches are used in the transmission to prevent an interruption of drive torque during certain gear shifts and to allow engine braking during coasting. Also there is a one way clutch in the stator of the torque converter.

Planetary Gear Set

Planetary gear sets are compact gear units that receive input drive torque and provide the required output ratios for all forward gears and reverse gear. The planetary gear set consists of four main components:

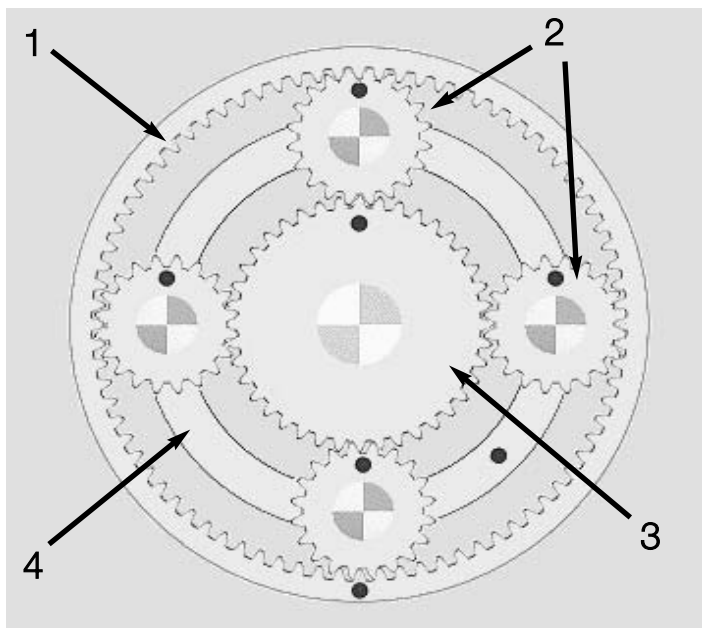
- 1: Internal Ring Gear
- 2: Planetary Gears (pinions)
- 3: Sun Gear
- 4: Planetary Gear Carrier

Various ratios are obtained by driving or holding different components in the planetary gear set. The example shown at right is a simple planetary gear set. Today's modern transmissions use a combination of multiple planetary gear sets referred to as a compound planetary gear set.



Advantages of Planetary Design

There are distinct advantages to the planetary gear set in comparison with a standard transmission gear set. Primarily, drive torque does not need to be interrupted to change gears. The planetary members are in constant mesh and there are more teeth engaged in any given ratio. This allows more torque to be transferred through the transmission.



Basic Power Flow

In the example shown at left, let's follow through an example of powerflow in reverse gear:

The Planetary gear carrier (4) is held stationary. The sun gear (3) is driven in a clockwise direction. The planetary pinions (2) are driven counter-clockwise, which in turn drives the internal ring gear (1) counter clockwise as well.

Compound Planetary Gear Sets

Compound planetary gear sets use multiple planetary components which are a variation on the simple planetary gear set. Since the inception of the simple planetary gear set, there have been numerous compound gear sets introduced. BMW transmissions use the following gear sets:

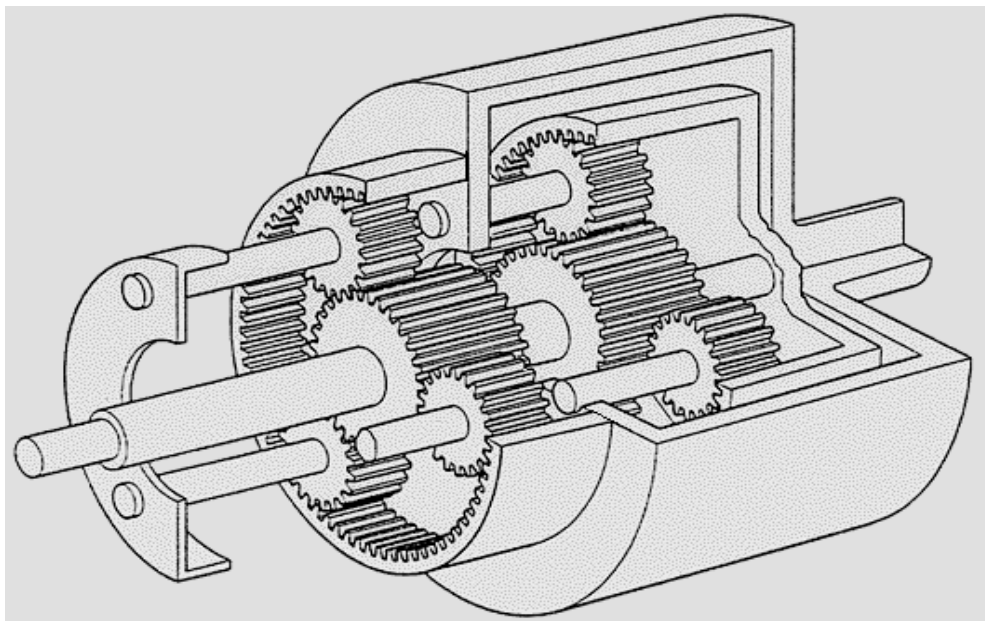
- Simpson Gear Set - used on 4HP22 and 4HP24
- Ravigneax Gear Set - used on A4S270R, A4S310R, A5S310Z, A5S325Z, A5S360R and A5S390R.
- Wilson Gear Set - used on A5S440Z and A5S560Z
- Lepelletier Gear Set - used on the GA6HP26Z.

Simpson Gear Set

The Simpson Gear Set is one of the early variations on the simple set. It is capable of 3 forward gears and one reverse. On BMW transmissions, the Simpson Gear set is used in the 4HP transmission which is a four speed automatic. Fourth gear (overdrive) is obtained by the addition of an auxiliary gear set (simple).

Characteristics of the Simpson Gear set are as follows:

- Two Internal Ring Gears, one rear input ring and one attached to the rear planetary carrier.
- Two Planetary carriers, each containing three planetary pinions.
- One common Sun gear, which meshes with both sets of planetary pinions.



Ravigneaux Gear Set

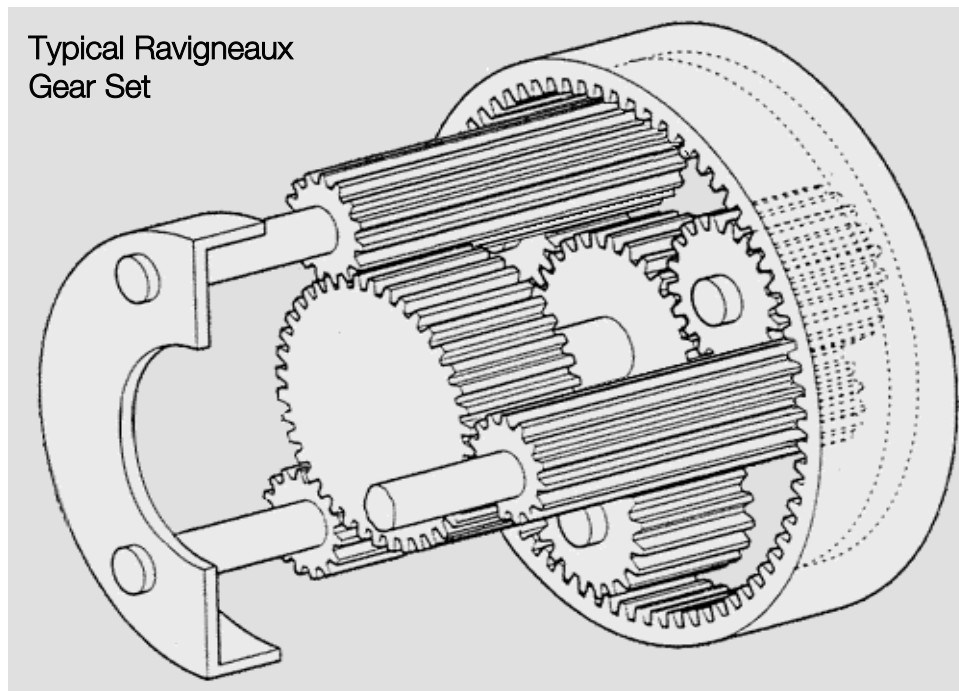
A new variation on the planetary design is the Ravigneaux gear set. This gear set is capable of 4 forward gears and one reverse. However, depending upon application it may be used with an auxiliary gear set. Here are some examples:

- A4S310/270R uses the Ravigneaux set for 3 forward gears and one reverse. Overdrive is obtained by the auxiliary gear set.
- A5S310Z uses a combination of the Ravigneaux gear set and the auxiliary gear set to obtain 5 forward gear and one reverse. First, second and reverse gears are achieved by using a combination of both gear sets.
- The A5S360/390R uses a modified version of the ravigneaux set that provides five forward gears and one reverse. There is no auxiliary gear set used.

Characteristics of the Ravigneaux Gear Set are:

- One planetary carrier which is common to both sets of planetary pinions. *
- Two sets of planetary pinions, one long set with small diameter and one short set with large diameter. *
- Two sun gears, one input sun gear and one reaction sun gear. *
- One common ring gear. *

* Note: The Ravigneaux Gear Set shown below is a typical representation. There are a few variations of this arrangement used on BMW transmissions.



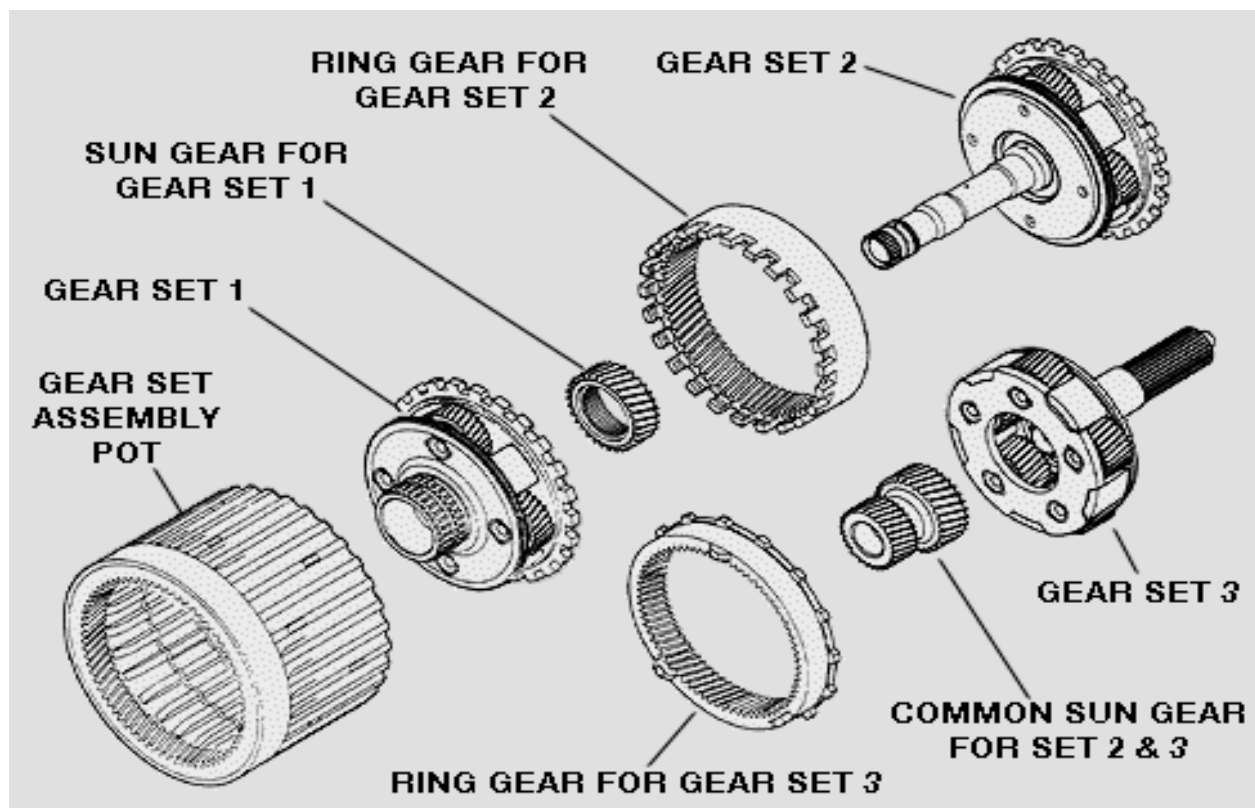
Wilson Gear Set

On BMW transmissions, the Wilson gear set is only used on the A5S440Z and A5S560Z. The Wilson Gear Set consists of three planetary gear sets.

The ring gear of the first gear set, the planetary carrier of the second gear set and the ring gear of the third planetary gear set and directly connected to the “Pot”. The “Pot” is a cylindrical device that slides over all of the components to unitize the individual gear sets into an assembly.

The characteristics of the Wilson Gear Set are:

- Three planetary carriers.
- Three ring gears, with ring gear 1 and 3 meshed to “Pot” assembly.
- Three sun gears, sun gear 2 and 3 are common. (Attached). Sun gears 2 and 3 are also referred to as the “Double Sun Gear”

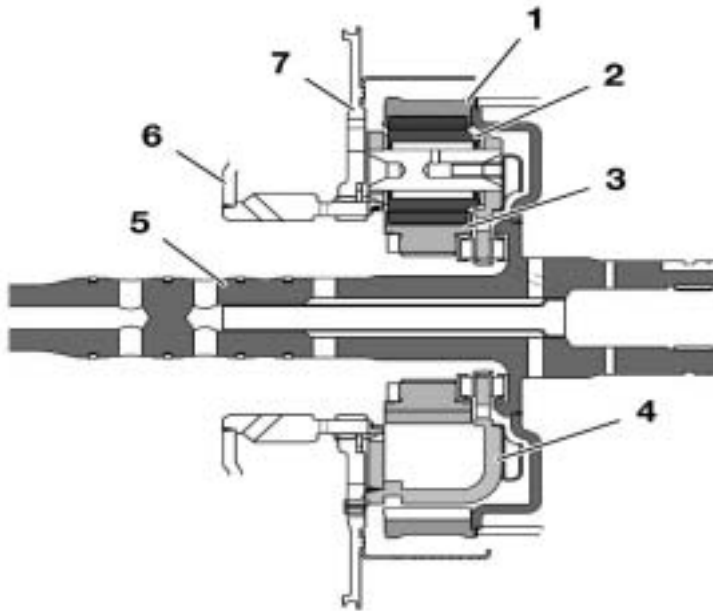


Lepelletier Gear Set

The Lepelletier Gear Set was introduced to BMW on the ZF GA6HP26Z. This gear set allows for 6 forward speeds and one reverse gear using a light weight design. The planetary gear train consists of a single carrier planetary gear train and a downstream double planetary gear train.

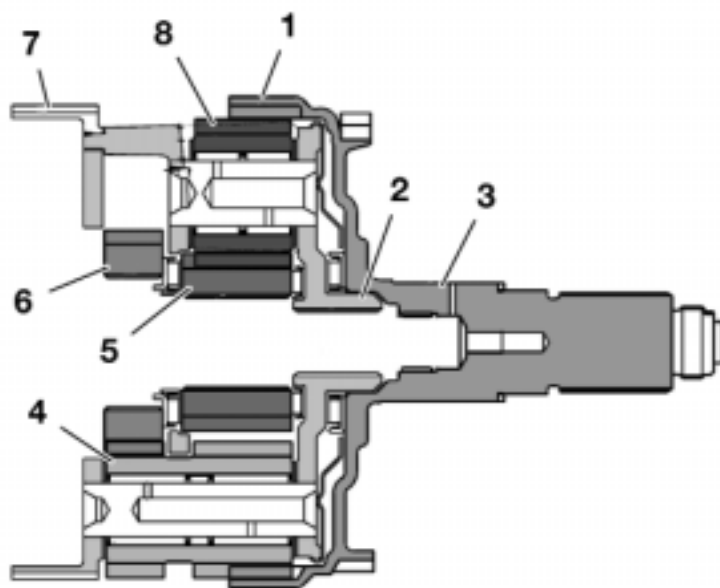
Lepelletier Gear Set

1. Internal Ring Gear 1
2. Planet Gear (pinion)
3. Planet Carrier
4. Planet Carrier
5. Turbine Shaft
6. Cylinder A
7. Pressure Plate A



Double Planetary Set

1. Internal Gear 2
2. Planet Carrier Clutch E
3. Output
4. Double Planet Gear Long
5. Sun Gear 3, Clutch E
6. Sun Gear 2, Clutch A
7. Planer carrier 1
8. Planet Gear (short)

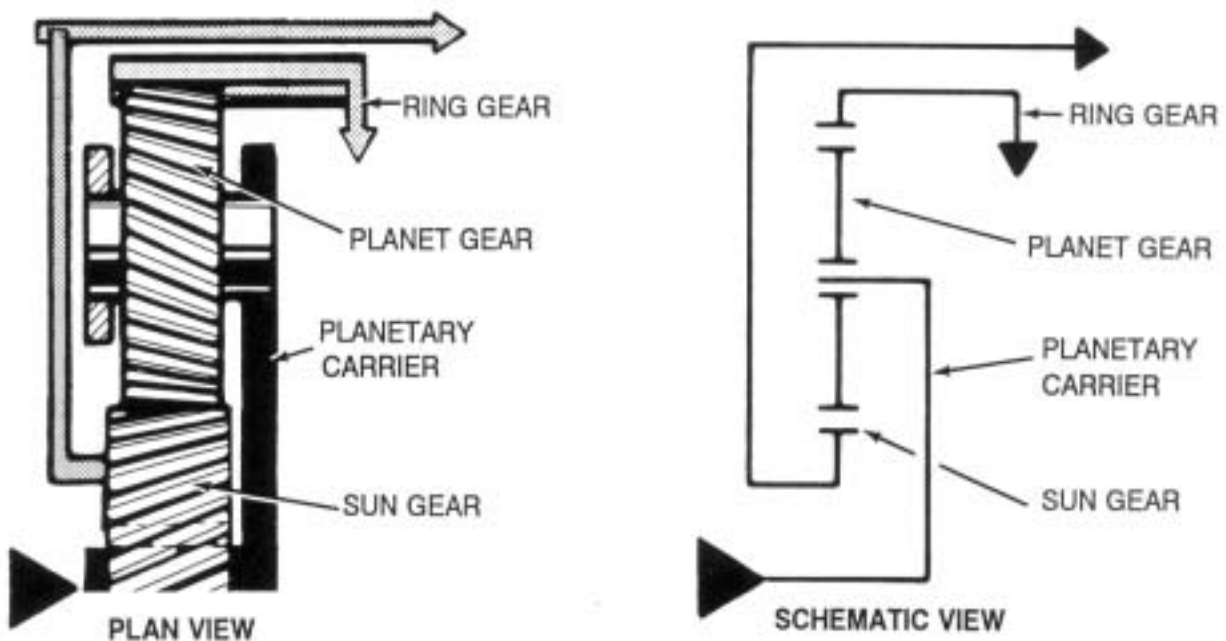


Planetary Gear Set Operation

In order to understand planetary gear set operation, it is important to understand some basic rules of operation.

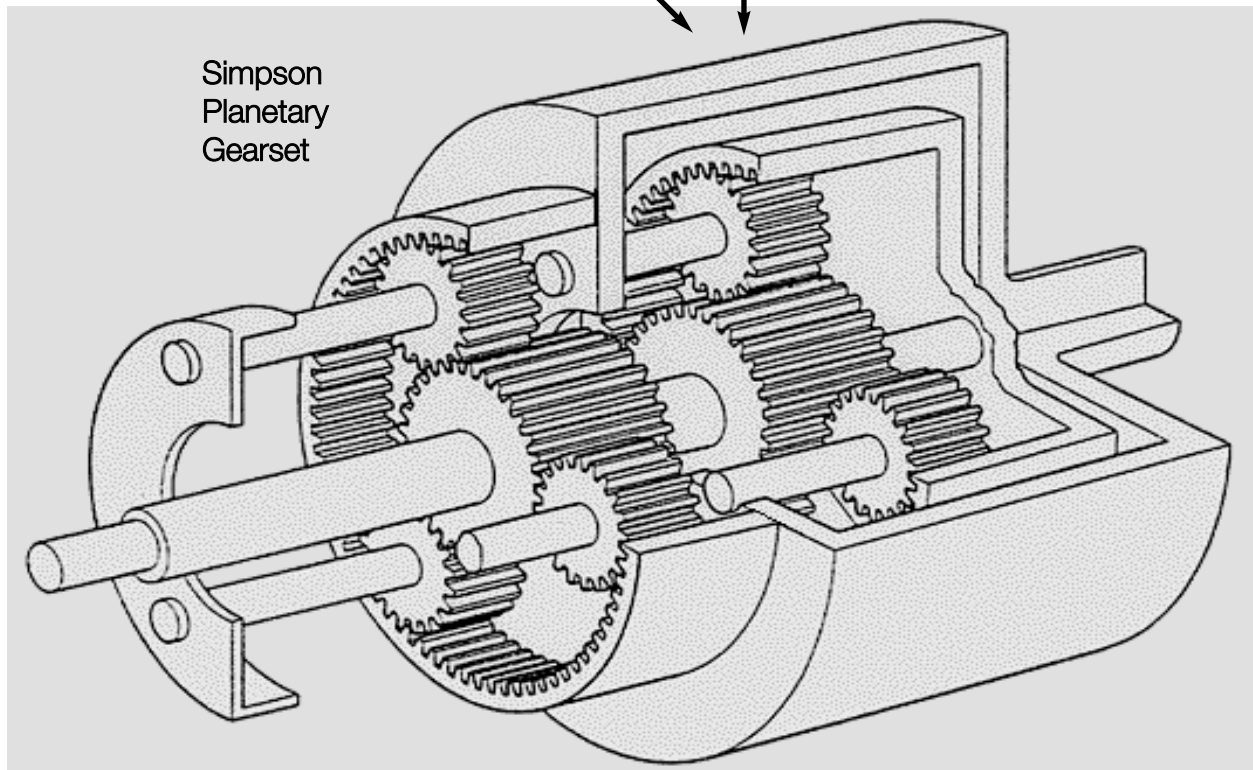
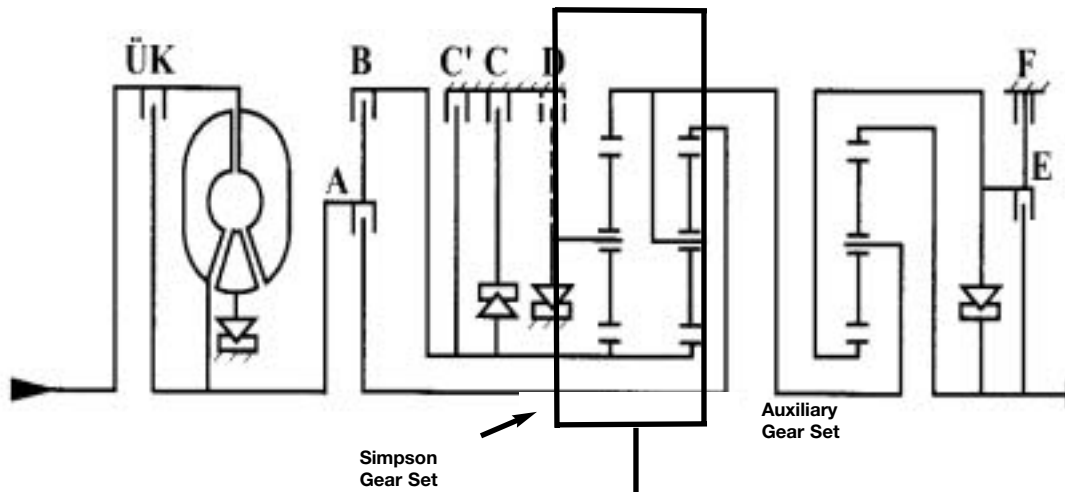
- It is assumed that engine rotation is clockwise when referring to power flow chart s and diagrams.
- Planetary pinions will always rotate in the same direction as the internal ring gear.
- When the sun gear is driven clockwise and the planetary carrier is held stationary the internal ring gear will rotate counter clockwise (reverse gear).
- When two or more planetary members are locked together, the assembly will rotate together. The ratio from input to output is 1:1.
- When the sun gear is held stationary and the planetary carrier is driven clockwise, the ring gear will be driven clockwise in an overdrive ratio. (i.e. .75:1)

When trying to understand powerflow schematics, it is important to be able to draw a comparison between the actual planetary components and the schematic symbols. The diagram below outlines the relationship between these components and the powerflow schematic. The schematic is a representation of a cross section of the transmission, but you only see the top half of the cross section. The transmission is shown as though it has been quartered lengthwise.

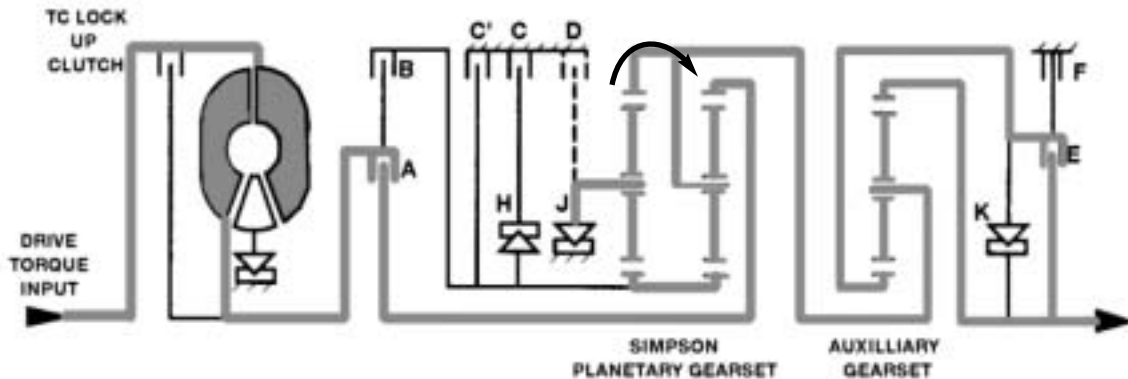


Power Flow Schematic

In order to understand power flow schematics, a relationship must be drawn between the actual components and the schematic representation. In our example, we are going to use the 4HP22/24 powerflow schematic. The 4HP22/24 transmission uses a Simpson Planetary Gearset and an auxiliary gearset. The auxiliary gear set is a simple planetary gearset.



Power Flow Schematic

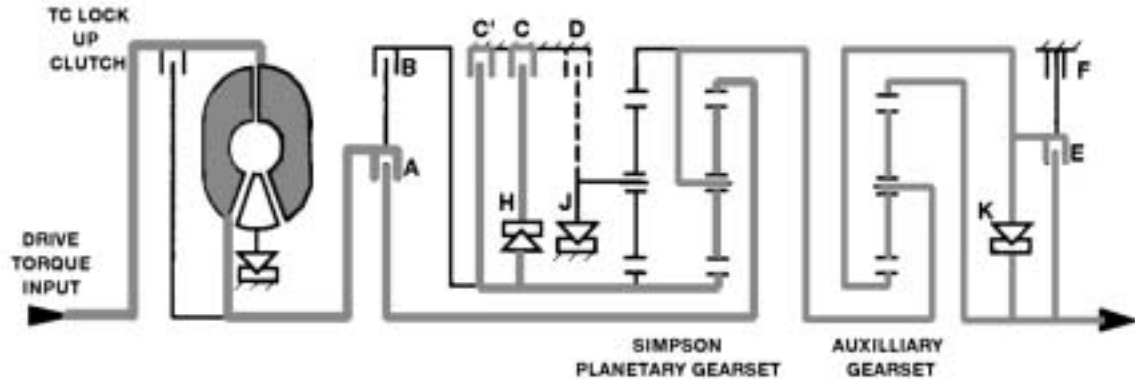


Power flow in first gear - Drive torque is applied to the torque converter impeller and transferred to the turbine. The turbine shaft rotates clockwise (CW). The “A” clutch locks the turbine shaft to the rear input ring gear. The rear input ring gear rotates CW driving the rear planet pinions CW. The planetary pinions drive the common sun gear CCW, which in turn drive the front planet pinions CW. The front planetary carrier is held from rotating CCW by one way clutch “J”. The front planetary pinions which are rotating CW drive the front ring gear/rear carrier CW. The rear planetary carrier is rotating CW and is driving the planetary carrier from the auxiliary gear set. The “E” clutch in the auxiliary gear set is holding the Sun gear and the ring gear together. Therefore the auxiliary gear set is locked in a 1:1 ratio.

One Way Clutch “J” is locked prevent the front planetary carrier from rotating CCW. One Way Clutch “H” is not used and One Way Clutch “K” is locked. One way clutch “K” is used to prevent an interruption in power flow before the “E” clutch is locked during the 4-3 shift.

POSITION GEAR	D				3			2		1	R
	1	2	3	4	1	2	3	1	2	1	
Clutch A	X	X	X	X	X	X	X	X	X	X	
Clutch B			X	X			X				X
Clutch C'		X				X			X		
Clutch C		X	X	X		X	X		X		
One Way Clutch H		X				X			X		
Clutch D										X	X
One Way Clutch J	X				X			X		X	
Clutch E	X	X	X		X	X	X	X	X	X	X
One Way Clutch K	X	X	X		X	X	X	X	X	X	X
Clutch F				X							

Second Gear

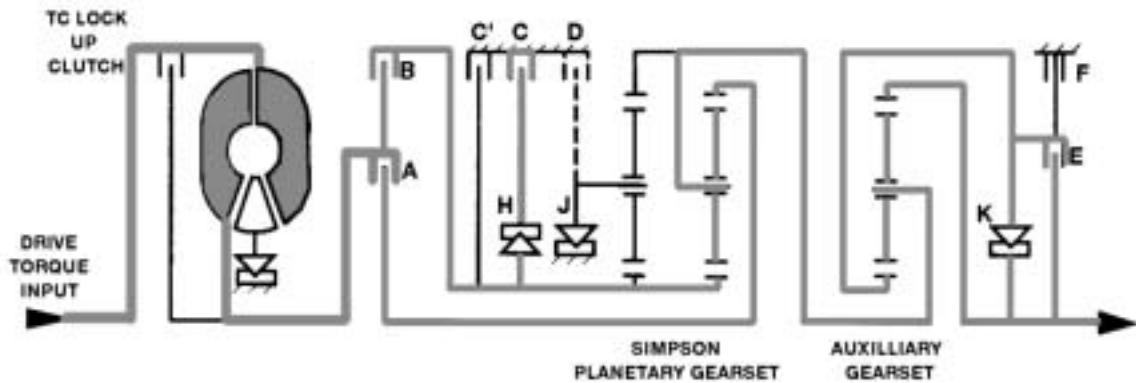


Second Gear - Drive torque is applied to the torque converter impeller and transferred to the turbine. The turbine shaft rotates clockwise (CW). The “A” clutch locks the turbine shaft to the rear input ring gear. The rear input ring gear rotates CW driving the rear planet pinions CW. The sun gear is held stationary by the C’ clutch. The rear planet pinions rotate around the fixed sun gear CW. The rear planetary carrier will rotate CW. The rear planetary carrier will drive the auxiliary gear set will will rotate as a complete unit. The auxiliary gear set is locked in a 1:1 ratio due to the “E” clutch locking the sun and ring gear together.

The “C” clutch is locking the outer race of the “H” freewheel to the case. This is used for the 3/2 downshift. Freewheel “J” is not active and Freewheel “K” is locked.

POSITION GEAR	D				3			2		1	R
	1	2	3	4	1	2	3	1	2	1	R
Clutch A	X	X	X	X	X	X	X	X	X	X	
Clutch B			X	X			X				X
Clutch C'		X				X			X		
Clutch C		X	X	X		X	X		X		
One Way Clutch H		X				X			X		
Clutch D										X	X
One Way Clutch J	X				X			X		X	
Clutch E	X	X	X		X	X	X	X	X	X	X
One Way Clutch K	X	X	X		X	X	X	X	X	X	X
Clutch F				X							

Third Gear

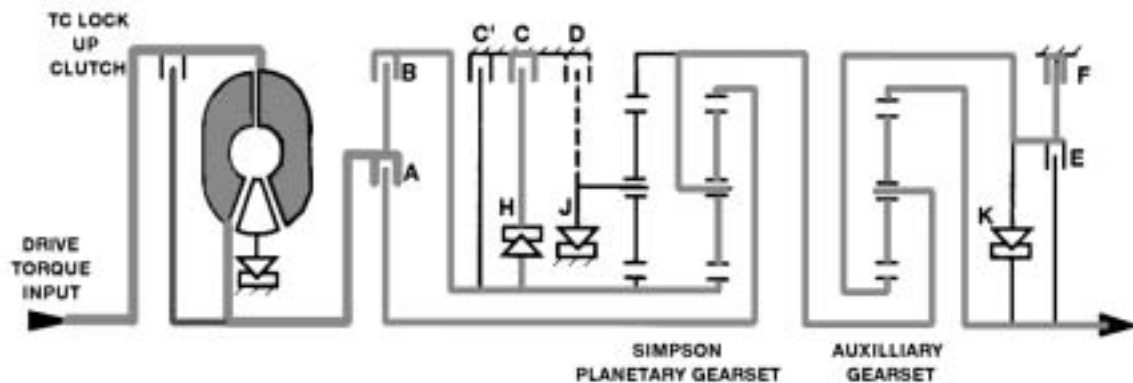


Third Gear - Drive torque is applied to the torque converter impeller and transferred to the turbine. The turbine shaft rotates clockwise (CW). The “A” clutch and the “B” clutch are locked, this causes the rear input ring gear to be locked to the sun gear in the Simpson Gear set. The Simpson gear set is locked in a 1:1 ratio. The “E” clutch is locked which locks the ring gear to the sun gear in the Simpson gear set. The entire transmission planetary system is now locked in a 1:1 ratio.

Freewheel “H” is overrun and freewheel “J” is not used. Freewheel “K” continues to be locked.

POSITION GEAR	D				3			2		1	R
	1	2	3	4	1	2	3	1	2	1	R
Clutch A	X	X	X	X	X	X	X	X	X	X	
Clutch B			X	X			X				X
Clutch C'		X				X			X		
Clutch C		X	X	X		X	X		X		
One Way Clutch H		X				X			X		
Clutch D										X	X
One Way Clutch J	X				X			X		X	
Clutch E	X	X	X		X	X	X	X	X	X	X
One Way Clutch K	X	X	X		X	X	X	X	X	X	X
Clutch F				X							

Fourth Gear

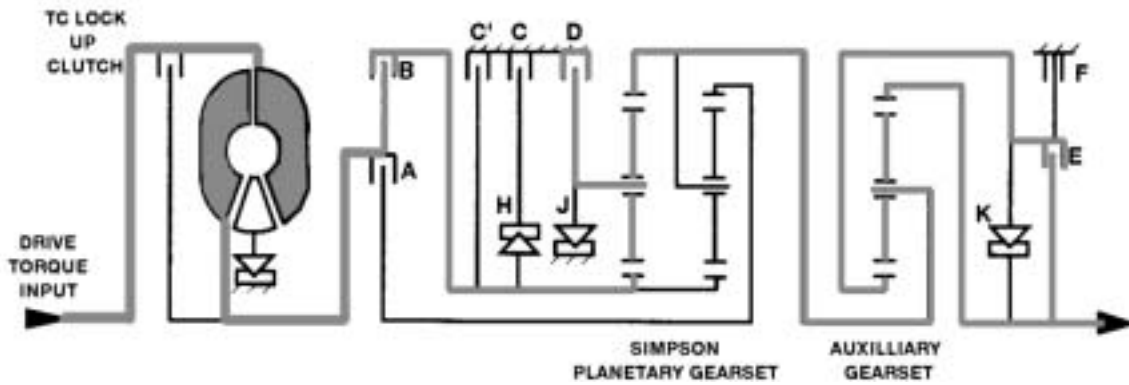


Fourth Gear - Drive torque is applied to the torque converter impeller and transferred to the turbine. The turbine shaft rotates clockwise (CW). (The turbine shaft can also be driven by the lock up clutch when engaged). The “A” clutch and the “B” clutch are locked, this causes the rear input ring gear to be locked to the sun gear in the Simpson Gear set. The Simpson gear set is locked in a 1:1 ratio. The “F” clutch is locked which locks the sun gear in the auxiliary gear set to the case. The Simpson gear set drives the planetary carrier CW. The planet pinions walk around the fixed sun gear in a CW direction. This causes the ring gear to rotate CW as well. The ring gear, which is the output of the transmission is driven in a overdrive ratio.

Freewheel “H” and “K” are overrun. Freewheel “J” is not used.

POSITION GEAR	D				3				2	1		R
	1	2	3	4	1	2	3	1	2	1	R	
Clutch A	X	X	X	X	X	X	X	X	X	X		
Clutch B			X	X			X					X
Clutch C'		X				X			X			
Clutch C		X	X	X		X	X		X			
One Way Clutch H		X				X			X			
Clutch D										X	X	
One Way Clutch J	X				X			X		X		
Clutch E	X	X	X		X	X	X	X	X	X	X	X
One Way Clutch K	X	X	X		X	X	X	X	X	X	X	X
Clutch F				X								

Reverse Gear



Reverse Gear - Drive torque is applied to the torque converter impeller and transferred to the turbine. The turbine shaft rotates clockwise (CW). The “B” clutch is locked which drives the sun gear in the Simpson gear set CW. The sun gear drives the planet pinions CCW. The planetary carrier is held stationary by the “D” clutch. The planet pinions cause the front ring gear to rotate CCW. The front ring gear (and rear carrier) drive the auxiliary gear set CCW which rotates at a ratio of 1:1 due to the “E” clutch locking the sun and ring gear of the auxiliary gear set.

Freewheel “H” and “J” are not used. Freewheel “K” is locked.

POSITION GEAR	D				3			2		1	R
	1	2	3	4	1	2	3	1	2	1	R
Clutch A	X	X	X	X	X	X	X	X	X	X	
Clutch B			X	X			X				X
Clutch C'		X				X			X		
Clutch C		X	X	X		X	X		X		
One Way Clutch H		X				X			X		
Clutch D										X	X
One Way Clutch J	X				X			X		X	
Clutch E	X	X	X		X	X	X	X	X	X	X
One Way Clutch K	X	X	X		X	X	X	X	X	X	X
Clutch F				X							

Shift Control

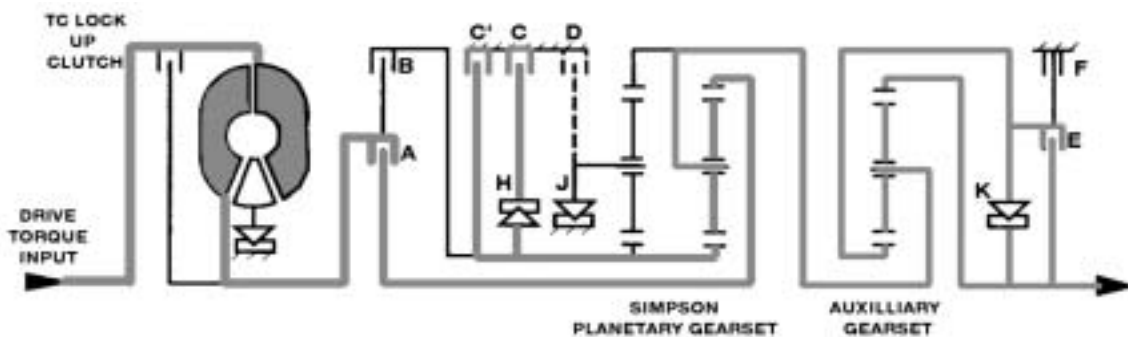
Freewheel Shifting

In order to prevent an interruption in power flow, freewheel (One Way Clutches) are used to lock members of the planetary gear set. Certain transmissions such as the 4HP22/24, A4S270/310R and the A5S360R use freewheel shifting on all gear shifts. Transmissions such as A5S310Z, A5S440Z, A5S560Z and GA6HP26Z use freewheel shifting for only specific shifts. Other shifts in these transmissions use overlap shifting technology.

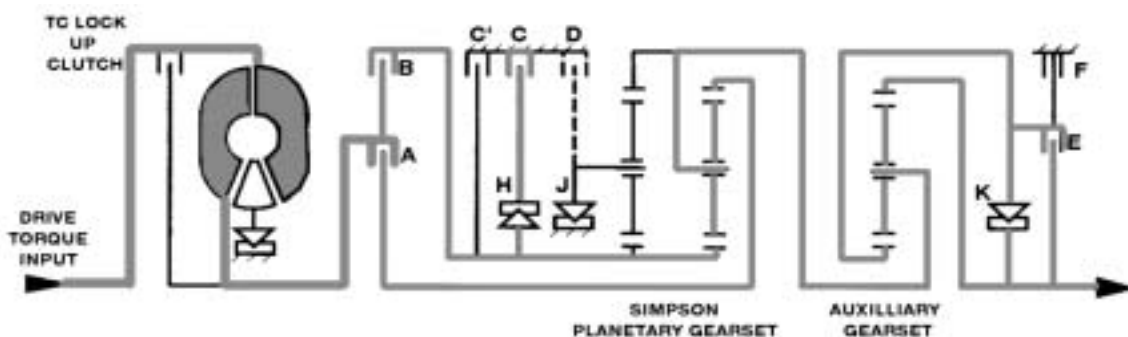
To demonstrate how the freewheel is used, we will examine freewheel “H” in the 4HP22/24 transmission.

In third gear, the sun gear is rotating clockwise. Freewheel “H” is overrun (unlocked) allowing the sun gear to rotate. Clutch “C” is active which locks the outer race of freewheel “H” to the case. During a 3/2 downshift, clutch “B” is released. The sun gear is held from rotating counter clockwise by freewheel “H” and the C’ clutch. Freewheel “H” is used to stop the counter clockwise rotation of the sun gear before the C’ clutch can engage. This prevents an interruption of power flow during the 3/2 downshift. If freewheel “H” fails to operate, there would be an increase in engine RPM from 3rd to 2nd gear.

Second Gear



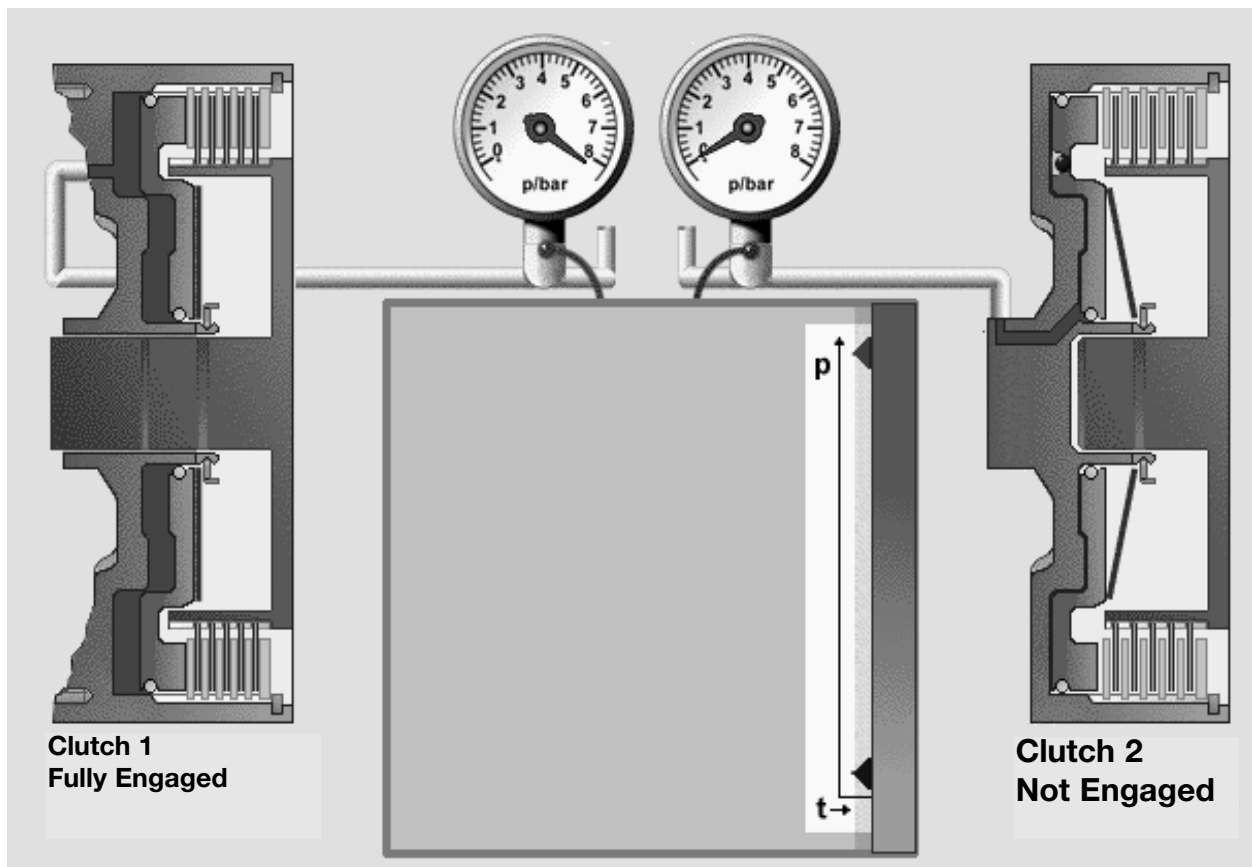
Third Gear



Overlap Shift Control

Overlap shift technology is currently used on ZF transmissions. The A5S310Z, A5S440Z, A5S560Z and the GA6HP26Z use overlap shift technology on most gear changes. The advantages of this design allows for the reduction of the use of One Way Clutches (free-wheel) and a significant improvement in shift quality.

During an overlap shift, the releasing clutch pressure is reduced at the same rate that the engaging clutch pressure is increased. The result is a smooth transfer of torque between gear ratios.

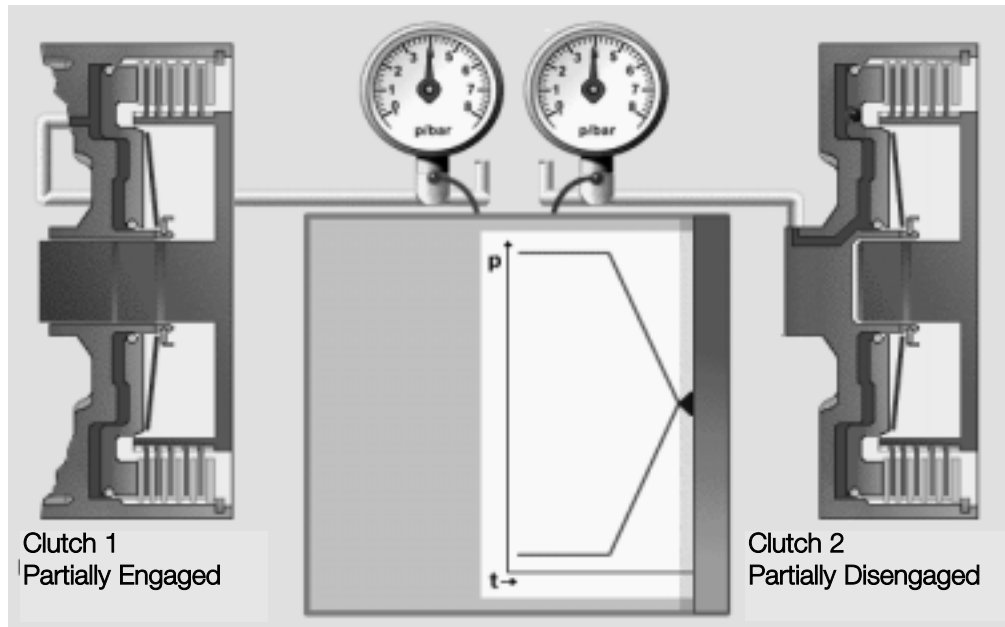


As shown in the diagram above, Clutch 1 is fully engaged with maximum pressure. Clutch 2 is fully released.

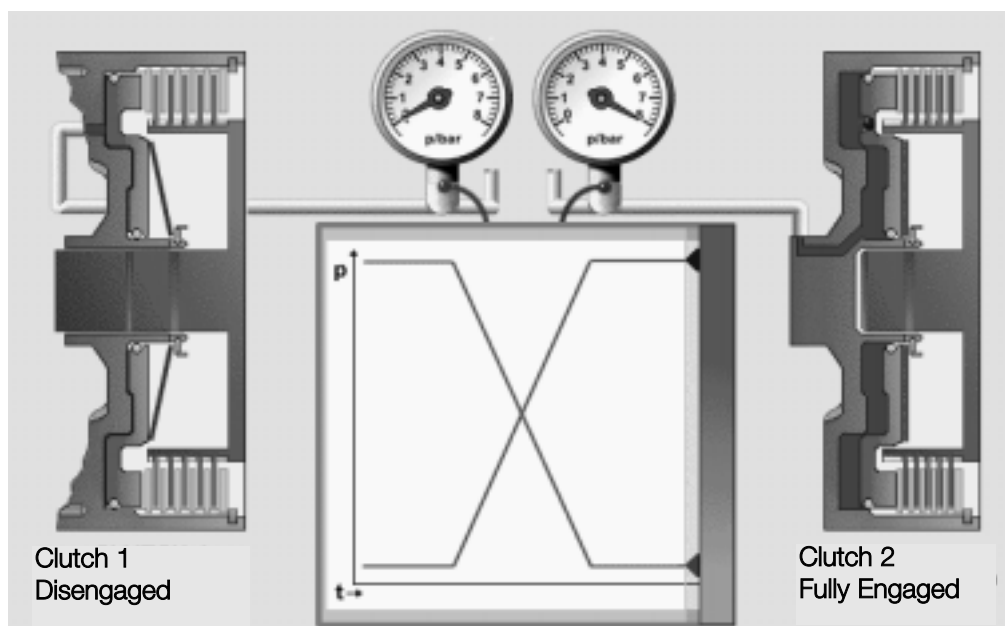
During overlap shifting, the TCM closely monitors the rotational speeds of the turbine (input) shaft and output shaft. The TCM then uses the EDS solenoids to control pressures during shifting to provide the optimum shift timing and overlap control.

Overlap Shifting

During the transition of overlap, the clutches run through a slip zone. The torque is gradually transferred from the clutch that is releasing to the clutch that is engaging.



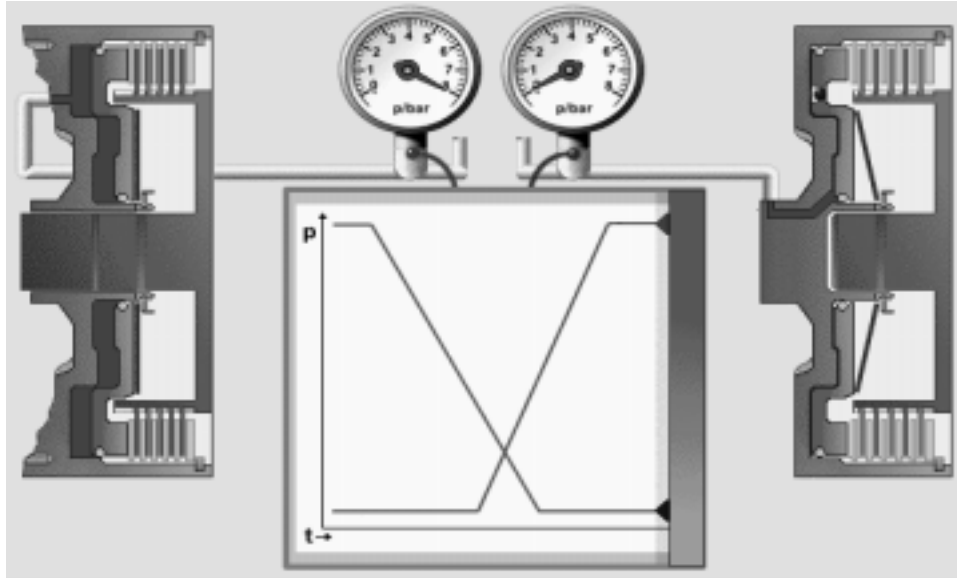
The new gear engages the moment the torque level exceeds that of the first clutch. This is described as overlap. If the overlap is correct, (zero overlap) the engaging clutch takes over as much torque as the disengaging clutch releases. The result is a seemingly unnoticed shift of the best quality.



Negative Overlap

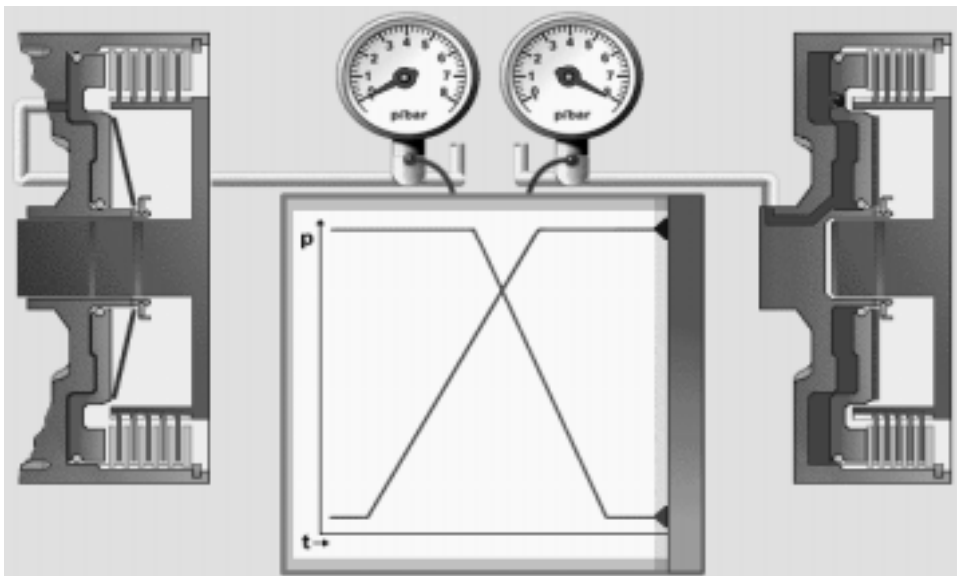
Negative overlap occurs when the engaging clutch takes over too late or the releasing clutch drops pressure too early.

The result is that the drive torque is briefly interrupted. When the engine is operating under load, the engine speed increases due to the interruption. When coasting the engine speed drops.



Positive Overlap

If positive overlap occurs, the engaging clutch takes over too early or the releasing clutch pressure drops too late. The gear set would become momentarily blocked if this condition occurs during an upshift. When this occurs the ratio of the gear set becomes 1:1 momentarily. The result is a loss in drive torque during a gear shift.



Transmission Control Module

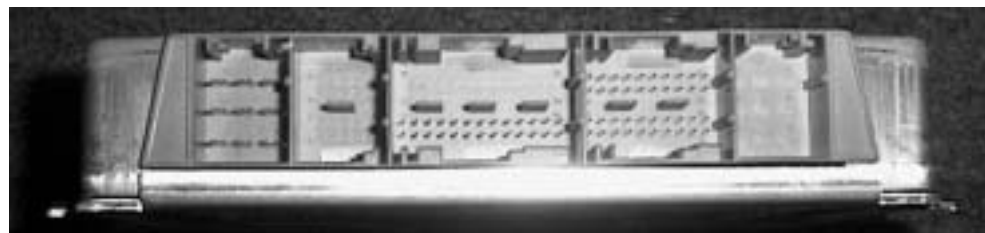
The TCM receives inputs, processes information and actuates the output elements to provide optimal shift points. The TCM is programmed for maximum shift comfort and fuel economy. The TCM on most BMW vehicles is located in the E-Box next to the ECM (DME).

There are several types of TCM housings:

- 35 Pin TCM (TCU) - used on the 4HP transmissions
- 55 Pin TCM used on the A4S310R (THM-R1)
- 88 Pin TCM used on all others up to 98
- 134 Pin TCM used on all BMW transmission from the 99 model year.
(Note- the 134 pin TCM was introduced on the 98 Models equipped with the A5S440Z).

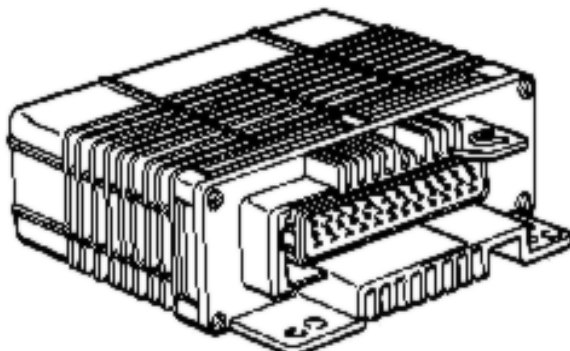
The 134 Pin TCM is also referred to as SKE (Standard Shell Construction). The SKE housing uses 5 separate connectors. On transmission applications only three connectors (1, 3 and 4) are used. Connectors 2 and 5 are blank and are NOT used. The connectors are blue in color to avoid confusion with the ECM (DME) connectors which are black.

**134 Pin TCM
with SKE housing**

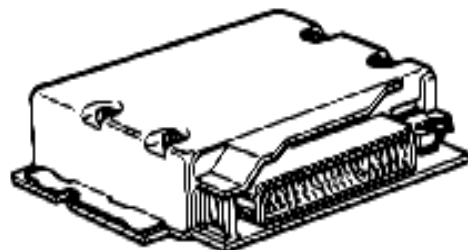


Connectors 1 2 3 4 5

55 Pin TCM



88 Pin TCM



Review Questions

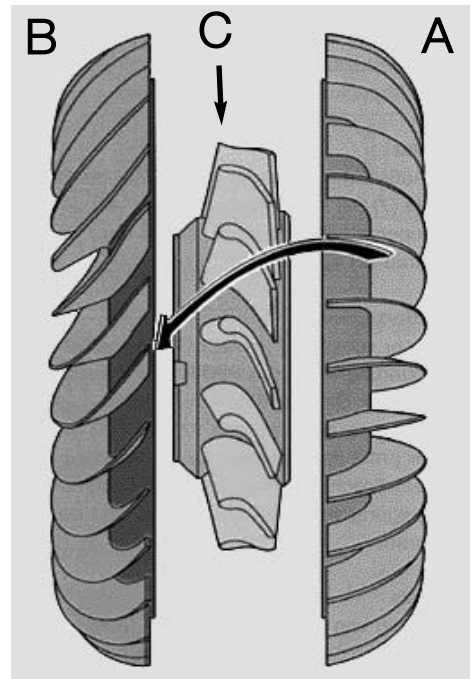
1. Place the letter of the transmission fluid next to the correct transmission:

- | | | |
|---------------------|----------------------|--------------------|
| A. ESSO LT 71141 | B. Shell LA2634 | C. Texaco ETL 7045 |
| D. Texaco ETL 8072B | E. Dexron III/Mercon | F. MTF LT-1 |

- | | | |
|---------------|---------------------|----------------|
| A5S440Z _____ | A5S390R _____ | 4HP22 EH _____ |
| A4S270R _____ | A5S560Z (E32) _____ | A5S325Z _____ |

2. Name the following components of a torque converter:

- A. _____
- B. _____
- C. _____



3. When at high engine speeds, the one way clutch in the stator of the torque converter is locked.

- A. True B. False

4. Which of the following transmissions use a Vane Type oil pump?

- | | | | |
|------------|------------|------------|------------|
| A. A5S560Z | B. A5S325Z | C. A4S270R | D. A5S360R |
|------------|------------|------------|------------|

5. Which of the following transmissions use a *gradual* application of the torque converter clutch?

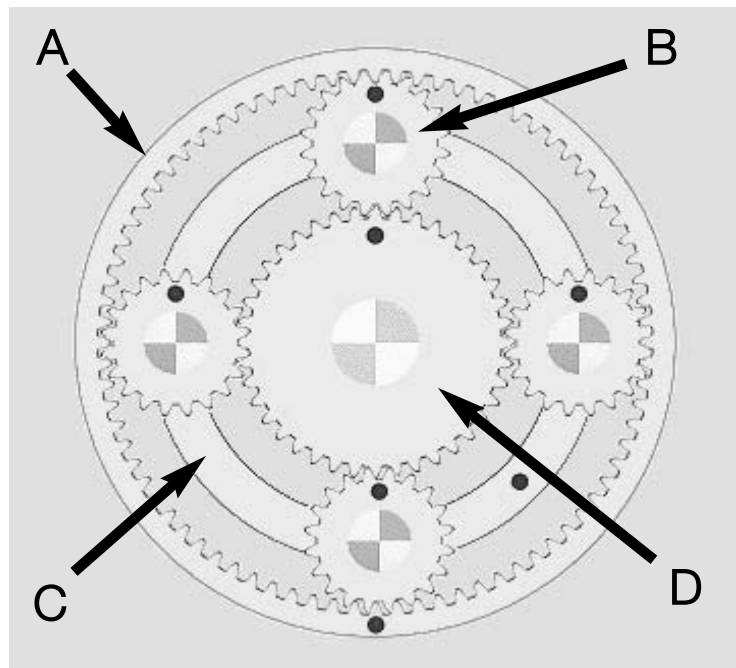
- | | | | |
|------------|------------|------------|-------------|
| A. A5S310Z | B. A5S560Z | C. A4S270R | D. 4HP24 EH |
|------------|------------|------------|-------------|

6. Which of the following transmissions use the Wilson Gear Set?

- A. A5S440Z B. A5S360R C. A5S310Z D. A4S310R

7. Name the following components of a planetary gear set:

- A. _____
B. _____
C. _____
D. _____



8. Which of the following transmissions uses overlap shift control?

- A. A5S360R B. 4HP22/24 C. A4S310R D. A5S560Z

9. Which of the following statements below best describes Negative Overlap?

- A. The engaging clutch takes over too early and/or the releasing clutch pressure releases too late.
B. The engaging clutch takes over too late and/or the releasing clutch pressure drops too early.
C. The engaging clutch takes over too early and/or the releasing clutch pressure drops too early.
D. The releasing clutch pressure is reduced at the same rate as the engaging clutch pressure.

10. Which of the following statements is **NOT** true regarding the operation of the torque converter?

- A. The impeller is connected to the input shaft via splines.
- B. The turbine is driven by fluid from the impeller.
- C. The stator re-directs fluid to the impeller at low speeds.
- D. The one-way clutch in the stator overruns (unlocks) at high speed.

11. List the two types of One-Way Clutches used in BMW automatic transmissions:

12. Place the letter of the gear set next to the appropriate transmission.

A. Simpson B. Wilson C. Lepeletier D. Ravigneaux

A4S270/310R _____ A5S360/390R _____

A5S440Z _____ A5S560Z _____

4HP22/24 _____ GA6HP26Z _____

A5S310Z _____ A5S325Z _____