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Transmission Fundamentals

Subject **Page**

Model: All with BMW Automatic Transmission

Production: All

Objectives:

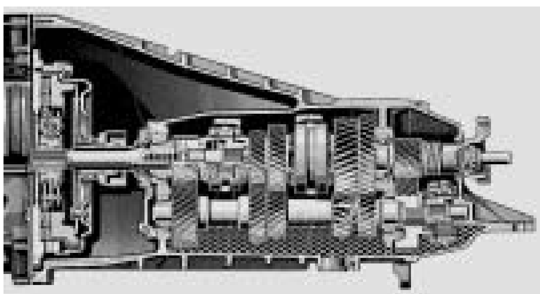
After completion of this module you will be able to:

- Recognize automatic transmission advantages.
- Identify BMW Automatic Transmissions.
- Understand Basic Transmission Hydraulics.
- Understand Transmission Fluid Application.
- Understand the Operation of Multi Plate Clutches and Brakes.
- Understand Torque Converter Operation.
- Understand Basic Planetary Gear Sets and Basic Power Flow.

Standard/Automatic Transmission Comparison

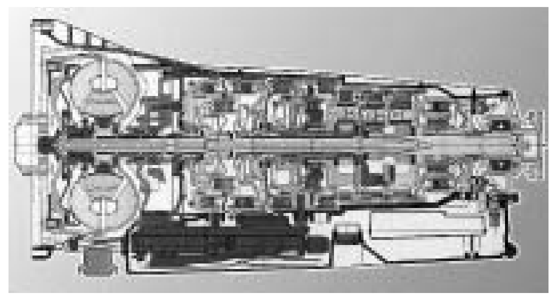
In today's modern vehicles, the automatic transmission has become a vital part of the powertrain. Automatic transmissions provide overall better fuel economy and efficiency while adapting to changing road conditions and driving habits. Standard transmissions offer more driver interaction with the vehicle, however automatic transmissions reduce driver fatigue and increase safety by shifting automatically. Automatic transmissions also offer improved driveability in stop and go traffic. If there is a disadvantage to an automatic transmission, it would be complexity and cost of manufacturing.

Standard Transmission



- Drive torque must be interrupted to change gears.
- Higher loads on driveline from abrupt clutch application.
- Clutch must be disengaged when vehicle is stopped to prevent stalling.
- High radial loads on housing.
- Gear set design requires more space than planetary type.
- Requires some Maintenance (clutch).
- Requires driver intervention for shifting.

Automatic Transmission



- Gear teeth are in constant mesh due to planetary design.
- Smoother application of drive torque reduces loads on driveline.
- Due to fluid coupling in the torque converter, transmission can stay in gear when vehicle is stopped.
- Minimal radial loads on housing.
- Compact design of gear set. Space requirement is minimized.
- Maintenance free operation. (Lifetime fluid and no clutch).
- Automatic shifting reduces driver fatigue and increases safety.

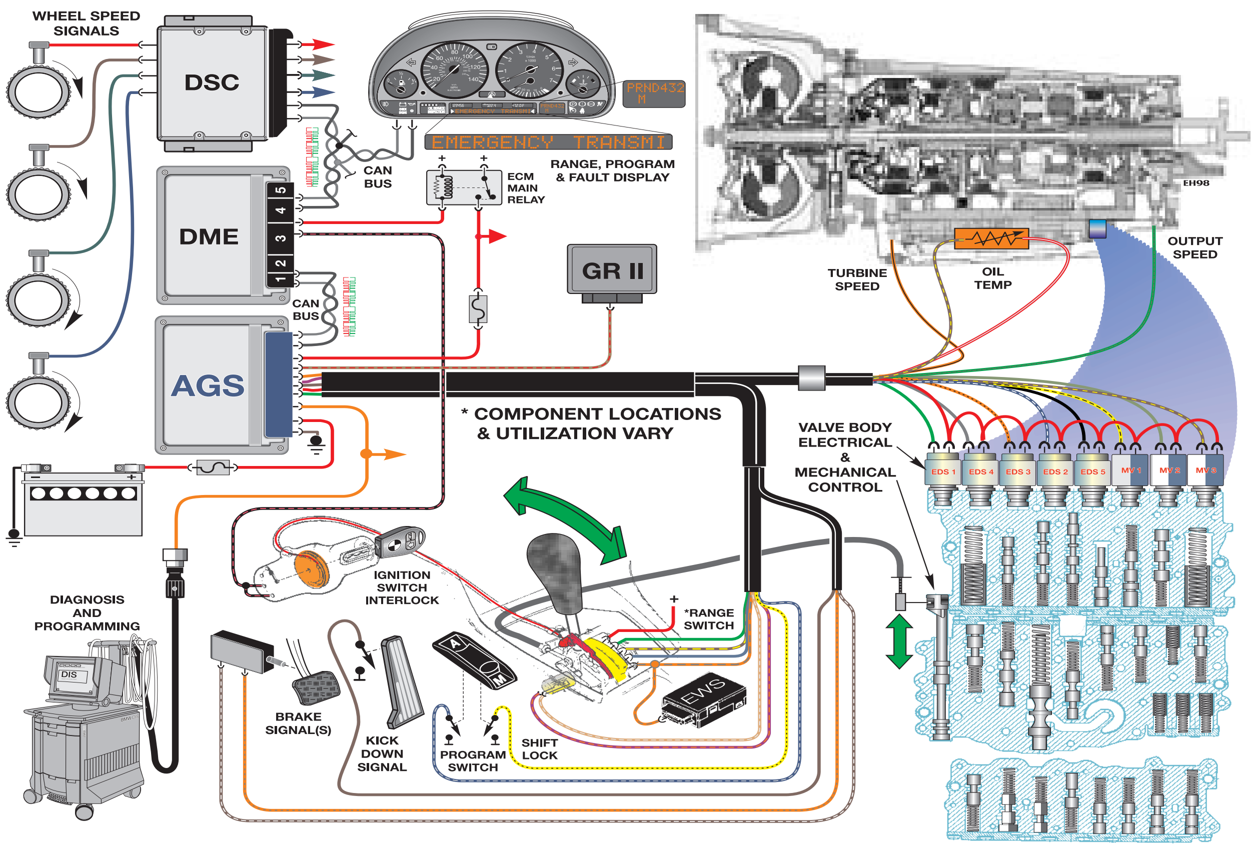
Hydraulic Transmission vs. Electro-hydraulic Transmission

Since the introduction of the automatic transmission there have been numerous refinements to improve shift comfort as well as fuel economy. Early automatic transmissions used only hydraulic control, there was no electronic intervention. In 1986 BMW introduced their first EH (Electro-Hydraulic) transmission into production vehicles.

The acronym EGS is used by BMW for its electronic transmission control system. EGS stands for "Electronic Transmission Control" which comes from the German words "**E**lektronisch **G**etriebe **S**teurung". In order to comply with SAE terminology we will refer to the EGS control module as the TCM "**T**ransmission **C**ontrol **M**odule".

EH controlled transmissions allow for optimized shift points by closely monitoring changing conditions. Engine speed, road speed and throttle angle are some of the inputs that are monitored by the TCM to determine optimal shift points. The TCM will then process this information and control shift point via electronic solenoids mounted on the valve body.

With the introduction of Adaptive Transmission Control, shift comfort and fuel economy was further improved. The TCM now monitors throttle angle deviations, wheel speeds and CAN Bus information to fine tune shift points.



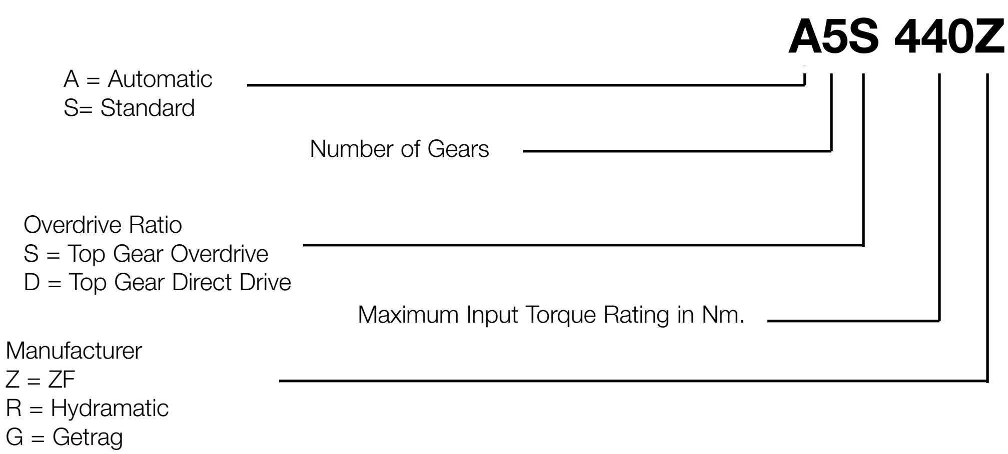
Transmission Identification

BMW automatic transmission are manufactured by two suppliers for the US market:

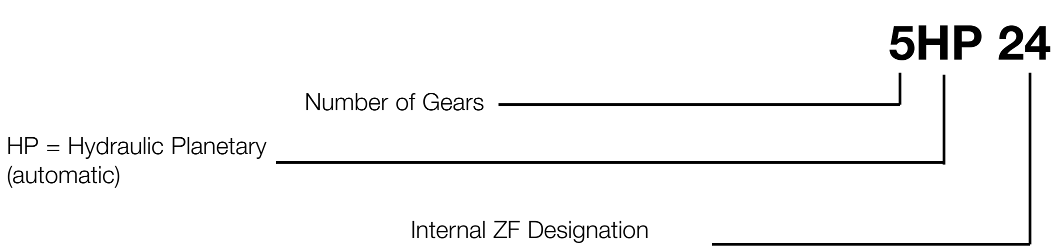
- **Zahnradfabrik Friedrichshafen:** Commonly referred to as ZF. ZF manufactures both manual and automatic transmissions.
- **GM Powertrain - Hydramatic:** Hydramatic is a manufacturing division of General Motors located in Strasbourg France. Hydramatic supplies automatic transmissions to BMW for four and six-cylinder vehicles.

BMW has developed an internal numbering system for their transmissions for parts ordering, information research and identification. Also each manufacturer uses their own internal identification system. Here is a breakdown of these identification codes:

BMW Identification Code Breakdown



ZF Identification Code Breakdown



Hydramatic Transmissions have internal designations as well, however there are not used often.

Transmission Hydraulics

Transmission Fluid (Oil)

The automatic transmission provides pressure regulated hydraulic fluid which is filtered for all of the transmissions functional requirements. All BMW automatic transmissions are designed to operate with specific fluids. Use of non-approved oil will cause malfunctions and irreparable transmission damage which is not covered by BMW warranty.

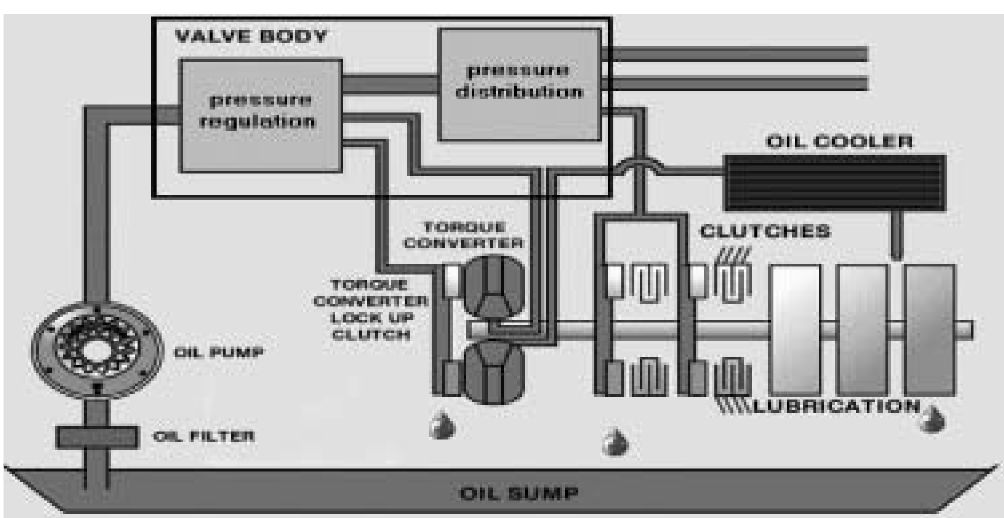
The transmission fluid provides the following functions:

- Lubricates mechanical components (planetary gears, bearings etc.).
- Removes heat and transfers heat to transmission cooling system. (Heat Exchanger).
- Removes debris and contaminants to sump and filter when circulated.
- Provides a transfer of kinetic energy in the torque converter.
- Allows hydraulic operation of mechanical components (clutches, brakes) via control of the valve body.

Also, transmission fluid has various properties to prevent oxidation and breakdown from heat and friction. Each type of transmission fluid has properties specific for each transmission application.

Fluid level is crucial in the proper operation of an automatic transmission. Improper fluid levels will cause improper operation and eventually irreparable transmission damage. Improper fluid level can cause:

- A low fluid level can cause an interruption in oil flow during fast acceleration or hard braking which can cause gear shift malfunctions.
- An excessively high fluid level can cause the rotating mechanical components to paddle in the oil. This produces foam which introduces air into the hydraulic system.
- A low fluid level can also cause transmission overheating causing premature transmission failure.



Transmission Fluid Application

There are numerous types of transmission fluid used in BMW transmissions. With the exception of the early transmissions (4HP22/24, A4S310/270R and the A5S310Z) all current BMW transmissions use “Lifetime Fill” transmission fluid. There is no maintenance required for these transmissions. It is important to use the correct fluid. Incorrect use of the transmission fluid can cause non-warrantable transmission damage.

When performing repairs on transmissions with lifetime fluid, it is important to drain the transmission fluid in to a clean container for re-use. New fluid should only be used for transmission replacement and for topping off after repairs.

Also, transmission fluid level is vital to the proper operation of the transmission. Refer to BMW Service Bulletin B 24 01 98 for proper fluid level checking procedures.

When servicing or repairing BMW automatic transmissions, refer to TIS for fluid capacities. For fluid types refer to the “Operating Fluids Manual”.

Transmission	Fluid Type	BMW Part #	Container	SIB Ref.
4HP22 **4HP24**	Dexron III Mercon	Available Commercially (Castrol or Texaco)	N/A	
A5S310Z 530i/iT (E34)	Dexron III	Available Commercially (Castrol or Texaco)	N/A	
M3 (E36)	ESSO LT 71141	83 22 9 407 807	20 liter contalner	B 24 03 95
A5S325Z	ESSO LT 71141	83 22 9 407 807	20 liter contalner	
A5S440Z	ESSO LT 71141	83 22 9 407 807	20 liter container	
A5S560Z 740 (E32), 540 (E34) 840Ci (E31- 6/93-12/94) 740i/iL-750iL (E38)	Shell LA2634	83 22 9 407 765	5 liter container	B 24 11 92
540i (3/96-12/96) 850Ci (10/94-6/97)	ESSO LT 71141	83 22 9 407 807	20 liter container	B 24 02 94
A4S310R **A4S270R** **(THM-R1)**	Dexron III Mercon	Available Commercially (Castrol or Texaco)	N/A	
A5S360R **A5S390R**	Texaco ETL 7045E Texaco ETL 8072B	83 22 0 026 922 83 22 0 024 359	25 liter container 25 liter container	
GA6HP26Z	Shell M1375.4	83 22 0 142 516		

Torque Converter

In standard transmissions the crankshaft is linked to the transmission input shaft via the clutch assembly. Power flows from the crankshaft through the flywheel. The pressure plate transfers power to the clutch disc which is splined to the transmission input shaft. The pressure plate is used to disconnect (or interrupt) power flow to the transmission input shaft. Because the engine is mechanically connected to the driveline, powerflow must be interrupted when the vehicle is stationary. Otherwise the engine would stall.

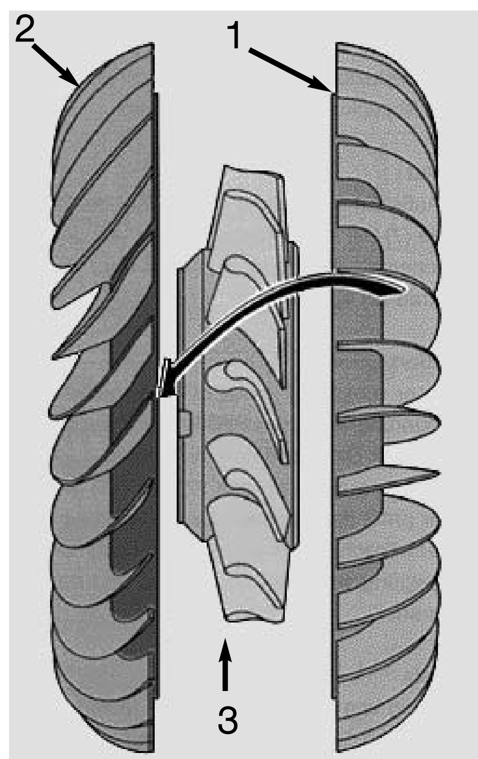
In automatic transmissions, there is a fluid coupling between the engine and transmission. This fluid coupling is more commonly referred to as the torque converter. In the torque converter there is no rigid connection between the engine and transmission (Except for lock up clutch). In order to understand the operation of the torque converter, we must first start with the components.

The breakdown of the components are as follows:

- The Impeller (1), which is rigidly connected to the torque converter housing.
- The Turbine (2) which is splined to the input shaft (turbine shaft) of the transmission.
- The Stator (3) which has a one-way clutch. The inner race of the one-way clutch is splined to a stationary shaft attached to the transmission.

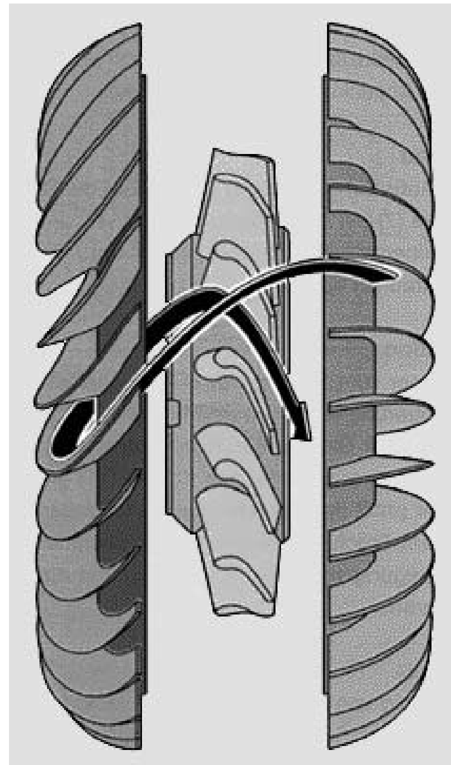
The addition of the stator allows the fluid coupling to be referred to as a torque converter. The stator provides for a multiplication of torque at low speeds. Without the stator there would be no multiplication of torque.

When the engine is running, the impeller which is directly connected to the converter housing, rotates at engine speed. Fluid is directed from the impeller blades to the turbine blades. The fluid drives the turbine which is splined to the input (turbine) shaft of the transmission. This functions the same way as a waterfall acting on a paddle wheel. The ratio of the impeller speed to turbine speed is approximately 1.1 to 1. This ratio is improved to 1:1 with the addition of the torque converter clutch which is discussed later.



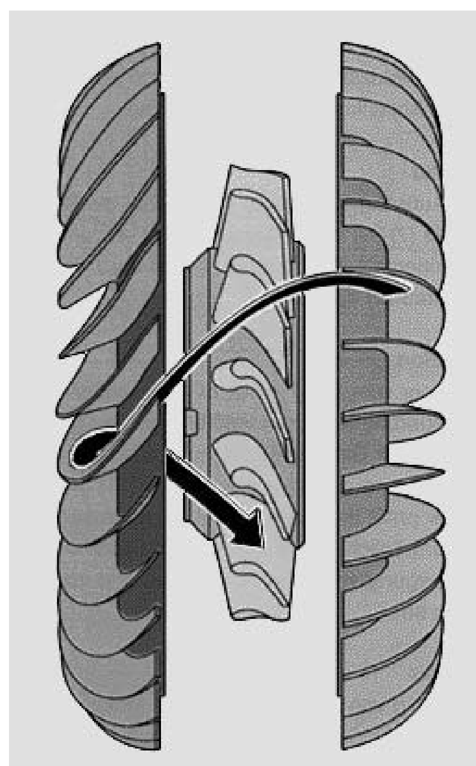
Torque Converter

Torque Converter Operation At Low Speeds



1. At low engine speeds there is a large difference in rotational speed between the impeller and the tur bine
2. Fluid flow is directed from the impeller to the tur bine. Fluid strikes the vanes of the turbine. The turbine is driven forward in the direction of engine rotation.
3. Fluid flow is then directed back towards the impeller.
4. Before the fluid reaches the impeller, the fluid strikes the vanes of the stator.
5. When the fluid strikes the stator, the one way clutch prevents the stator from rotating.
6. The fluid is then re-directed by the curved vanes of the stator. The fluid is now flowing in the same direction as the impeller.
7. The fluid that is acting on the impeller increases the force on the the impeller which multiplies torque.

Torque Converter Operation at High Speed



1. As engine speed increases, the turbine speed speed approaches the speed of the impeller.
2. The fluid flow is directed from the turbine to the back side of the impeller blades.
3. The one-way clutch in the stator unlocks and the stator blades turn in the direction of engine rotation.
4. Fluid is no longer re-directed and torque multiplication no longer takes place.
5. This is referred to as “Coupling Speed”. The turbine never reaches the same speed as the impeller as fluid flow would come to a halt. Ratio is approximately 1.1 to 1.

Torque Converter Clutch

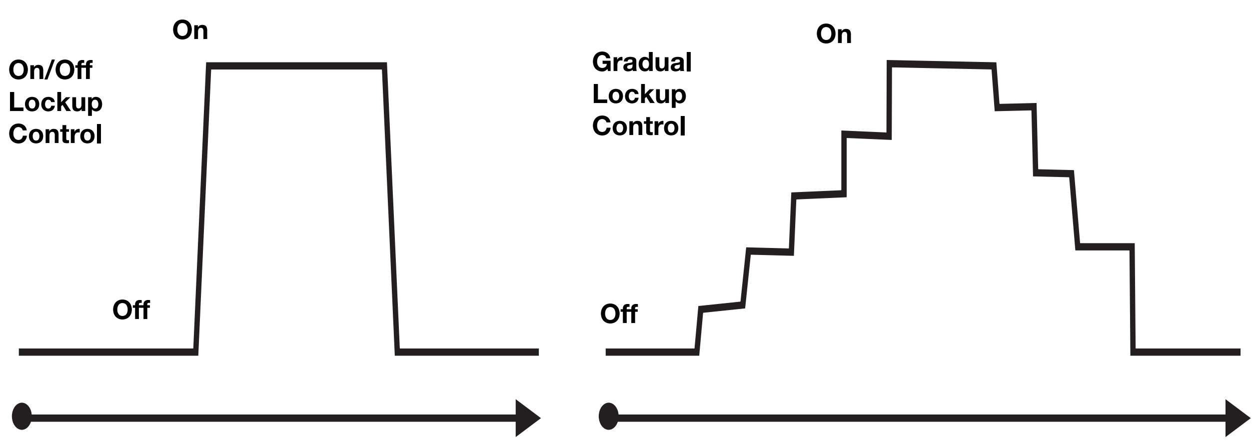
Since the efficiency of the torque converter at coupling speed is approximately 1.1 to 1, fuel economy is compromised. To offset this a torque converter clutch was added on EH controlled transmissions. The torque converter clutch locks the turbine to the converter housing. This creates a mechanical coupling with a ratio of 1:1. This can only be achieved at higher engine speeds, the torque converter clutch must be disengaged at low engine speeds to prevent stalling.

There are two methods for controlling the torque converter clutch on BMW transmissions:

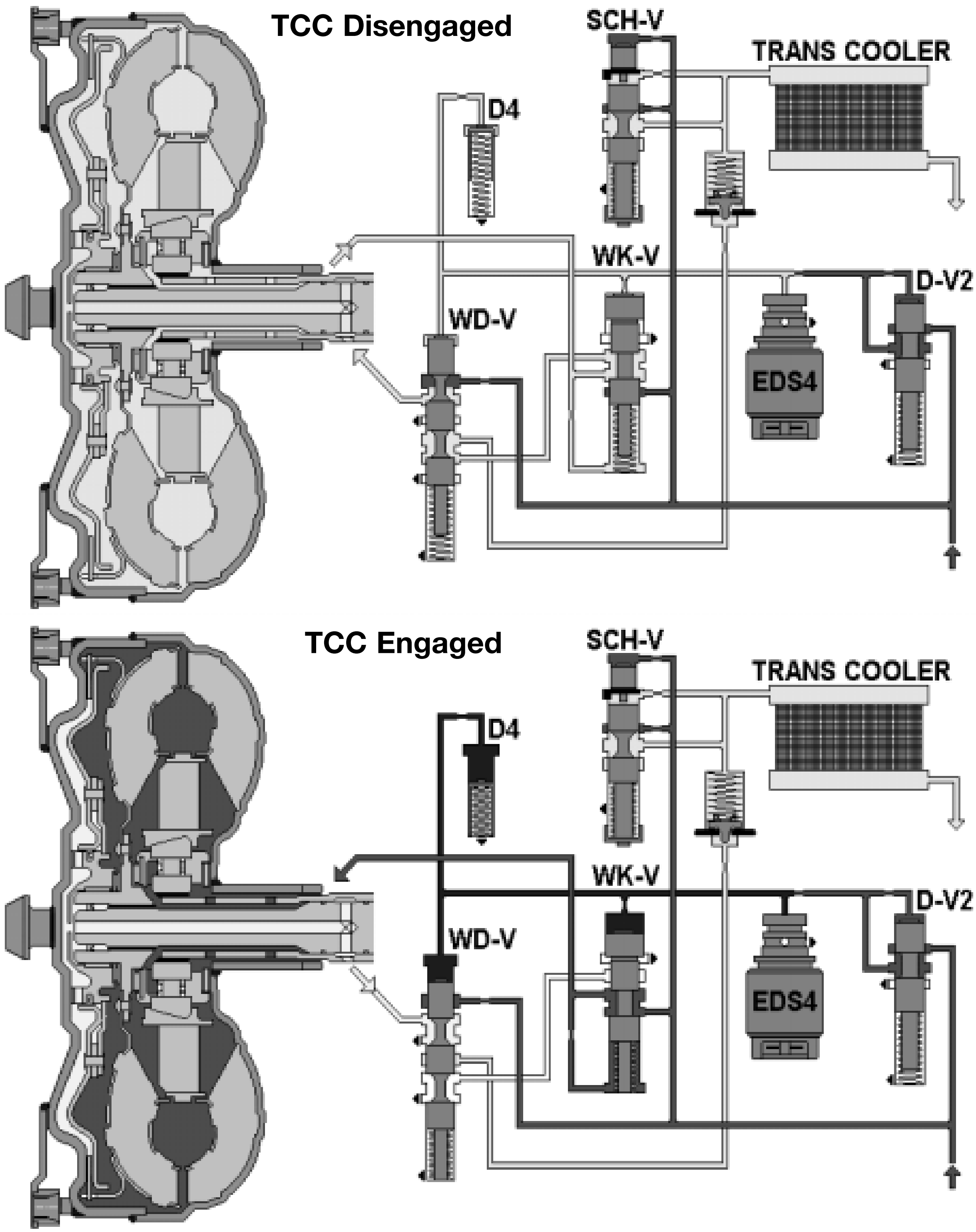
- **A4S310/270R, 4HP22/24 EH, A5S310Z** - These transmission use an on/off control method to lock and unlock the torque converter. The TCC is either completely engaged or completely disengaged. This method of engagement provides an abrupt sensation when the TCC is locking and unlocking. This abrupt sensation can be unpleasant and undesirable to some drivers.

- **A5S560Z, A5S440Z, A5S325Z, GA6HP26Z,A5S360/390R** - These transmissions use a gradual approach to TCC control. The TCC is gradually applied and released, this method reduces the abrupt feel of the on/off type TCC. The TCC solenoid is controlled by pulse width modulation. This allows fluid to be gradually introduced and released to the TCC.

The TCC is spring loaded to the engaged position. Pressurized fluid releases the TCC, when the pressurized fluid is released, the TCC is engaged. Depending on transmission application, the TCC can be engaged in 3rd, 4th or 5th gear. The TCC must be disengaged at low speeds to prevent stalling.



Example of TCC oil control circuit from the A5S440/560Z transmission.



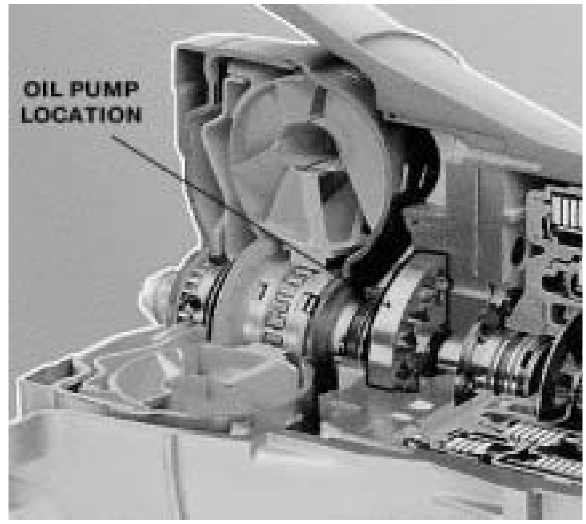
Oil Pump

The transmission oil pump is used to circulate oil and provide pressure for hydraulic operation.

The pump is driven by the torque converter shell and rotates with engine. Fluid is drawn from the sump through the filter and distributed to the various transmission hydraulic systems.

The output pressure is regulated to an operating pressure of approximately 25 bar.

Currently there are two types of oil pumps used in BMW transmissions; Crescent type and Vane type.



Crescent Type Oil Pump (All except A5S360/390R)

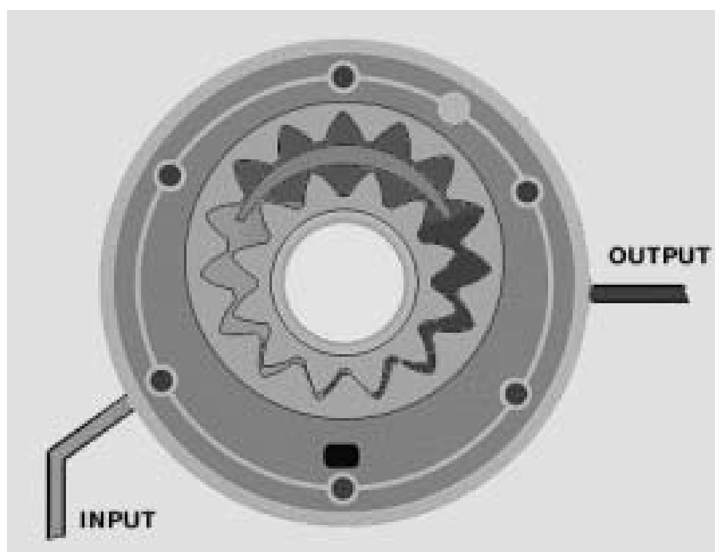
The crescent type is an internal gear pump containing a drive gear and a driven gear. The inner gear is driven by the torque converter and acts as the impeller. The outer gear is driven by the inner gear.

The gap between the teeth varies from the input, through the crescent and to the output of the pump.

A low pressure area is created on the input side of the pump by the widening gap between the gear teeth.

The oil is drawn to the crescent and transferred to the output side of the pump, where the pressure is increased by the narrowing gap between the gear teeth.

The output pressure of the pump is controlled by spring loaded pressure regulator.

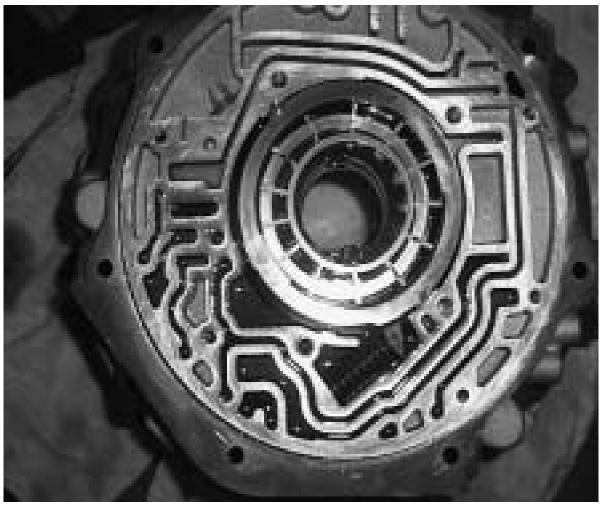


Oil Volume Control

On the A5S440Z transmission, oil pump output volume is controlled based on engine RPM. High oil volume is initially required at start up to quickly fill the transmission requirements. As engine RPM increases, the volume is greater than is required. The Oil Volume Control Damper regulates the pump output volume based on engine RPM. This helps improve fuel economy by reducing the load on the engine at high RPM.

Vane Type Pump (A5S360/390R)

The new A5S360/390R (GM5) transmission uses a vane type pump. The torque converter drives the pump rotor and 13 vanes.



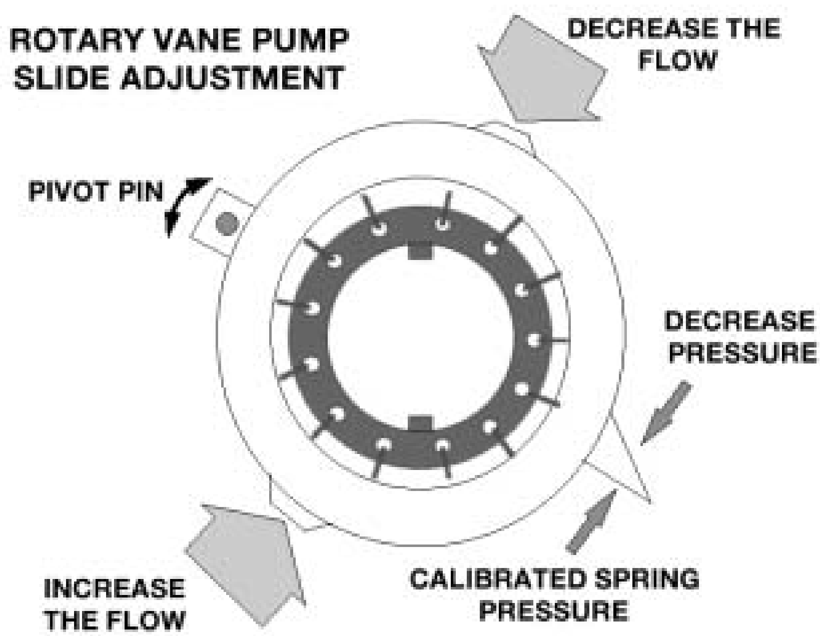
The rotor and vanes are placed inside a slide mechanism. As the rotor spins, the vanes sweep oil from the pump intake to the output along the mating surface on the vane ends and the interior surface of the slide.

The slide is mounted on a pivot pin. As it pivots, it changes the eccentricity of the rotor to slide mating surface. This in turn will alter the output oil volume. This provides the same function as the Oil Control Volume Damper on the A5S440Z.

The slide's position is influenced by a calibrated spring and hydraulic control pressure from the main pressure regulator solenoid on the valve body.

The benefit of changing the slide position is to optimize pump output volume to meet the the following operating conditions:

- Provide maximum volume during engine start-up. This condition provides a fast priming action of the pump for immediate lubrication and for hydraulic pressure operation.
- Regulated output volume at higher engine speeds. Maximum pump volume is not required at all times.



Hydraulic Control Components

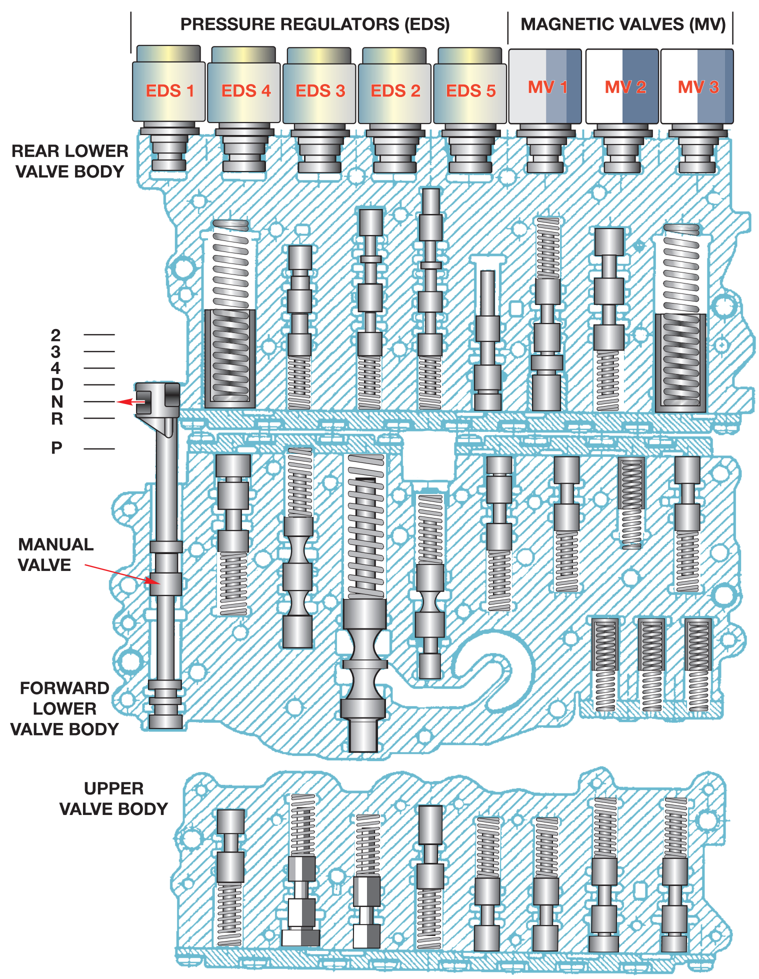
Electro/Hydraulic Valve Body

The valve body assembly is the main shift control element in the transmission. In non-EH transmissions the valve body was only hydraulically controlled. In the current EH (electro-hydraulic) transmissions the valve body is similar in design, but now also housing a number of shift solenoids which are controlled by the TCM.

The valve body consists of a number of sub-assemblies. Each sub-assembly contains a number of spool valves which are hydraulically controlled. Most spool valves are opposed by spring pressure. The spool valves are used to direct hydraulic fluid flow to the various shift elements in the transmission. There is also a manual valve which is connected to the shift assembly by a cable. The manual valve allows the drivers to select the basic operating mode (or ratio).

The valve body is responsible for the following:

- Regulating Main Pressure
- Controlling fluid flow to shift elements for Upshifts and Downshifts.
- Providing for manual operation by driver via manual valve.
- Reverse Lockout
- Failsafe Operation
- Shift Comfort through:
  Overlap Shift Control (ZF)
  Pressure Accumulators (GM)
- Torque Converter Control
- Distribution of lubrication.

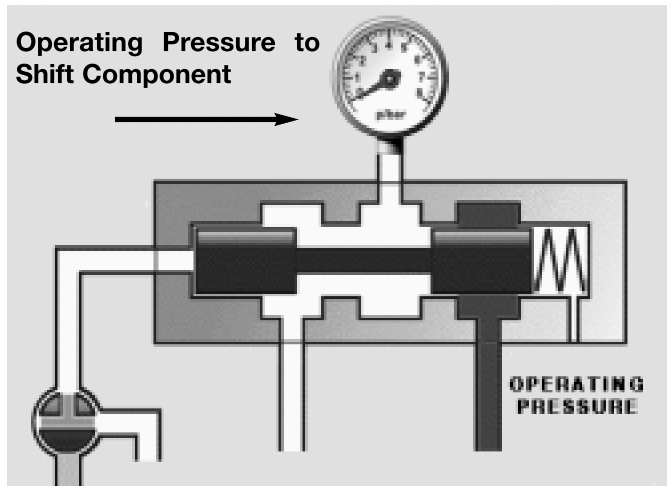


Shift Valves

Shift valves are used to direct application pressure to the various shift elements. Shift valves are regulated by spring pressure and control pressure for the shift solenoids. Shift valves come in various configurations depending upon application and transmission type. The most basic is the 3/2 shift valve. The 3/2 shift valve has 2 positions which are switched through one or two control pressures.

With no control pressure from shift solenoid present, the shift valve is moved to its end travel (left) by spring pressure.

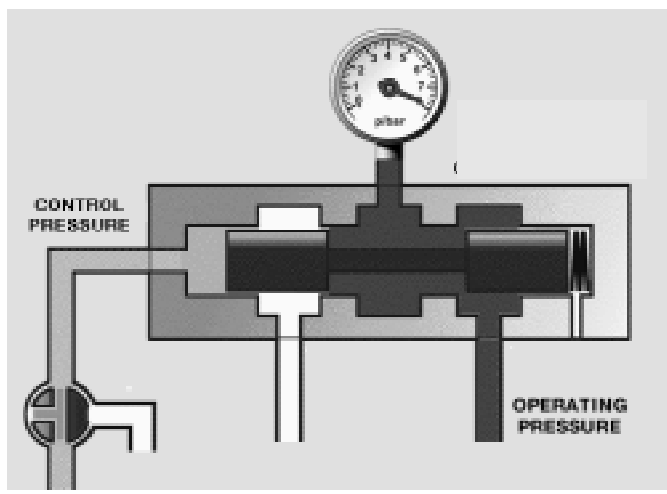
Operating pressure is blocked to the shift component. Also in this position any application pressure is drained from the shift component.



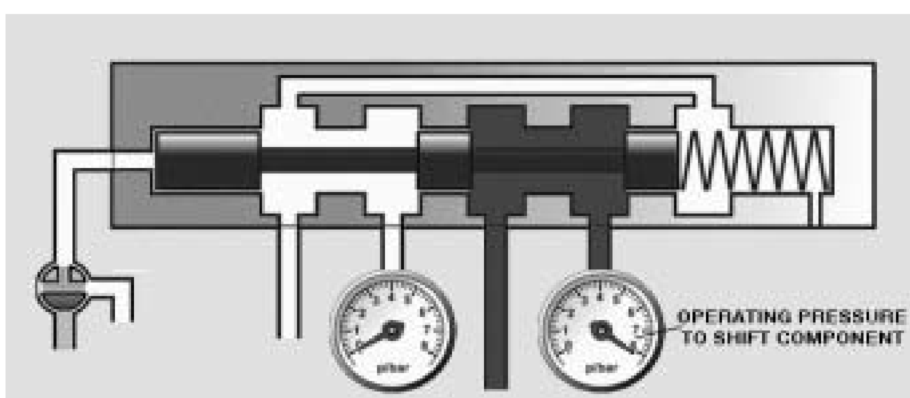
Once the control pressure is applied to the 3/2 shift valve, the shift valve moves to the right.

This allows operating pressure to reach the shift component.

When the control pressure is again reduced, spring pressure returns the 3/2 shift valve to the rest position. This drains and operating pressure from the shift component.



The example shown at right is a 4/2 shift valve. The operation is similar to the 3/2 valve. The primary difference is that the 4/2 shift valve affects 2 shift components.



Pressure Regulation

Pressurized oil from the pump must be regulated for use within the transmission. Otherwise, the high pressure directly from the pump would influence shift quality. The shifts would be more abrupt and harsh. In order to "fine tune" the pressures within the transmission, there is a pressure regulating valve and a pressure regulating solenoid. The pressure regulating valve is located in the oil pump housing or the valve body dependent upon transmission type.

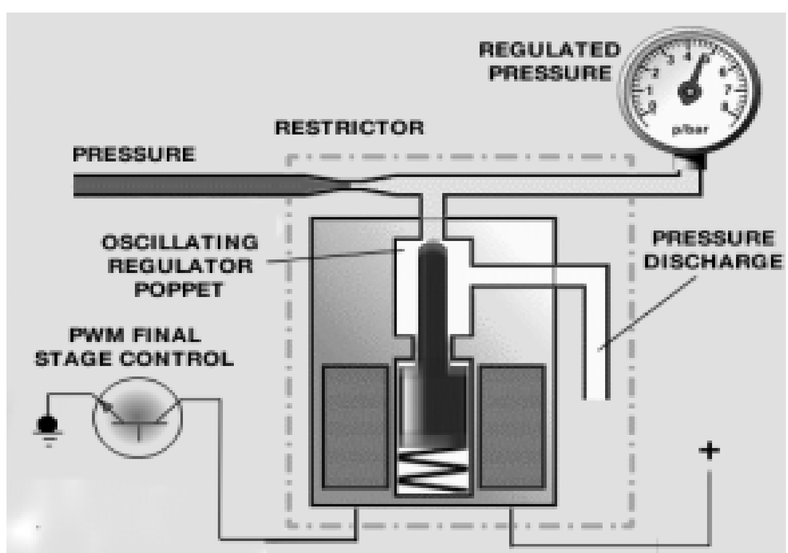
The pressure regulating solenoid is a pulse width modulated (PWM) solenoid. Current is controlled by the TCM. The pressure regulating solenoid is normally closed, there is maximum line pressure available when minimum (or no) current is applied to the pressure regulating solenoid. Depending upon application, pressure regulating solenoid can be PWM with B- or B+ control. GM transmissions use B+ control with a constant ground supply. ZF transmissions uses B- control with a constant B+ supply.

There are also pressure regulators used in ZF transmissions that are used to control shift pressures. The A5S440Z and A5S560Z both use EDS solenoids for "Overlap Shift Control" this will be explained later in this text.

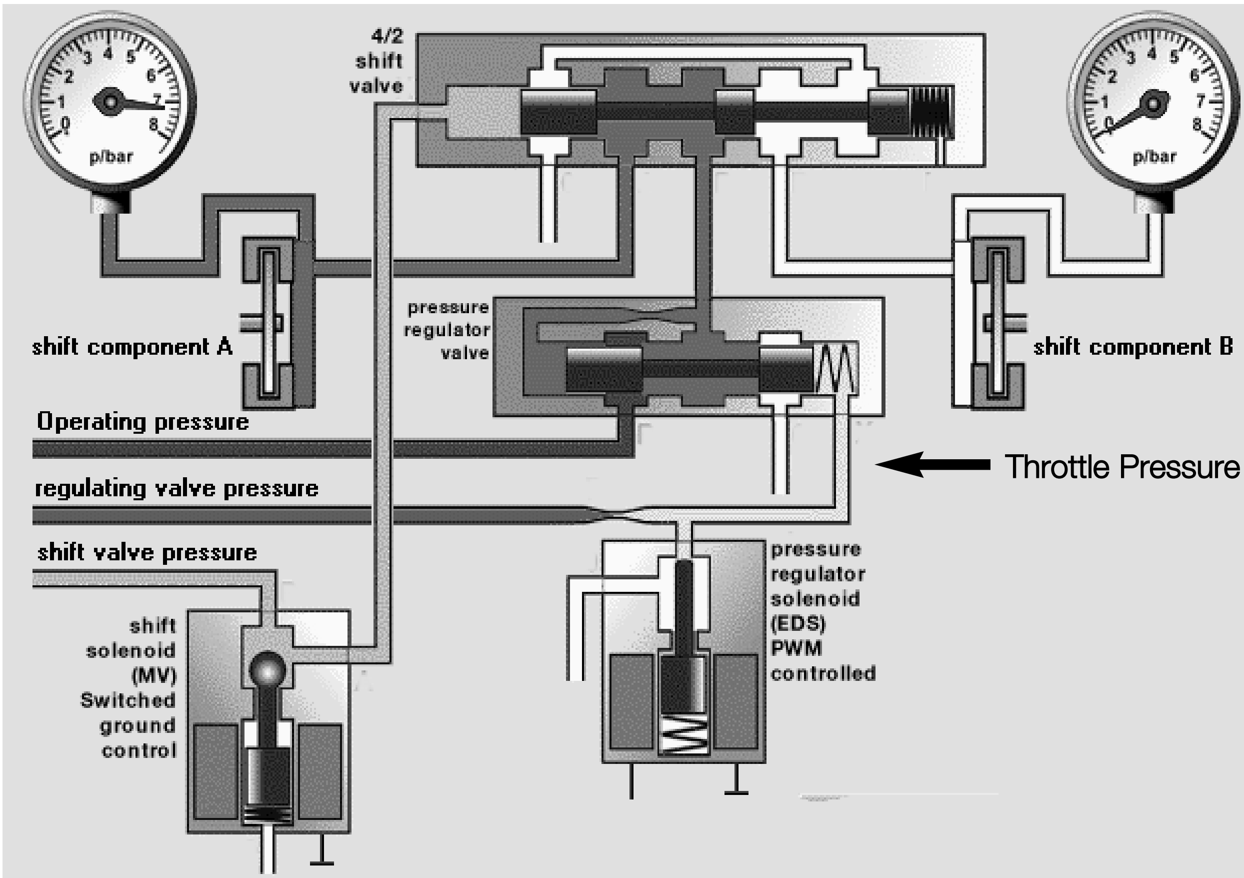
There are a few different names for pressure regulating solenoids depending upon the transmission type and manufacturer:

- ZF transmissions use the following terms - EDS solenoid (valve), or MV (magnetic valve).
- Hydramatic (GM) transmissions use the following terms: DR solenoid, Force Motor Solenoid or Variable Bleed Solenoid.

Transmission operating pressures are regulated based on engine speed, throttle angle and engine load. The regulated pressure from the pressure regulating solenoid is referred to as throttle pressure. This pressure is fed to the main pressure regulating valve.



Pressure Regulation



As the diagram shows, regulating valve pressure is fed to the pressure regulating solenoid. This pressure is then regulated to create throttle pressure. Throttle pressure is modified based on throttle angle, engine speed and engine load. Throttle pressure is then fed to the pressure regulating valve. As throttle pressure increases, the regulating valve piston is moved to the left (with respect to the diagram). As the regulating valve piston is moved to the left , operating pressure is increased to the 4/2 shift valve. The operating pressure to the 4/'2 shift valve will be fed to Shift Component A or Shift Component B depending the position on the 4/2 shift valve. The operating pressure to the shift components will be increased or decreased depending upon the throttle valve pressure. As engine speed and load are increased, the operating pressure will be increased to provide higher clamping forces on the shift components.

When there is no electrical power present to the pressure regulator solenoid, throttle pressure will be a maximum. Therefore maximum operating pressure will be available at the 4/2 shift valve. This condition would exist if the transmission was operating in failsafe mode.

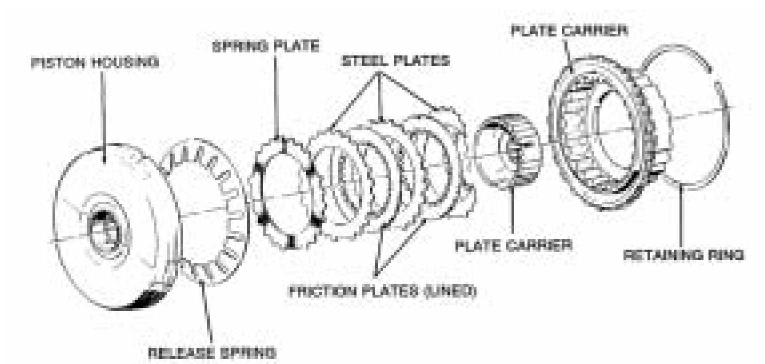
Apply Components

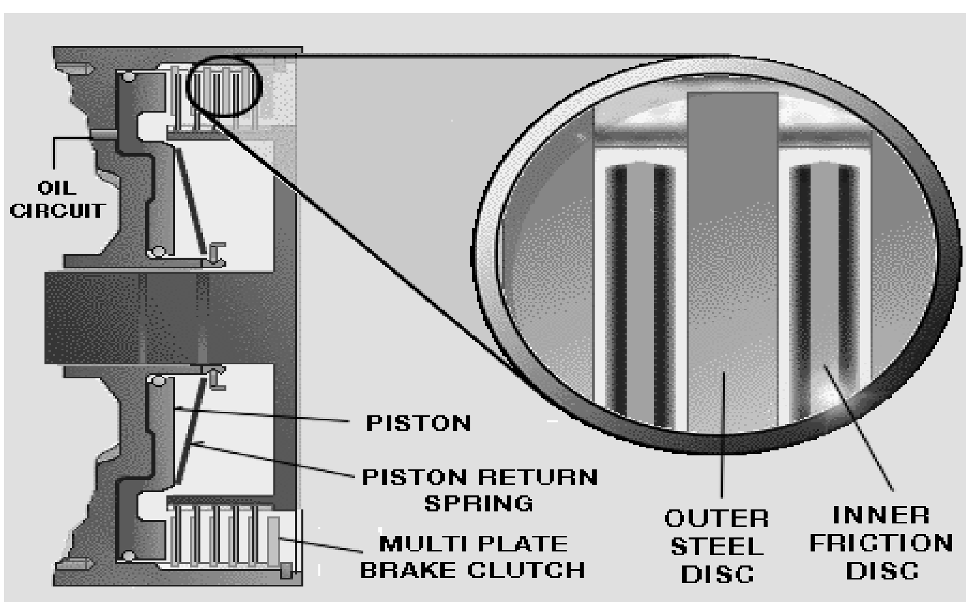
Multi - Plate Clutches and Brakes

Multi Plate Clutches and Brakes are used to drive or hold members of the planetary gear set. As a general rule, Multi Plate Clutches connect one planetary member to another. Multi Plate Brakes connect a planetary member to the case to hold it stationary.

The clutches and brakes consist of a number of friction discs and steel discs. The friction discs are coated with a friction material and have engaging lugs (splines) on the inner perimeter. The steel discs are steel on both sides and have engaging lugs located on the outer perimeter. The engaging lugs on the friction discs are usually engaged with a planetary member. The engaging lugs on the steel discs are usually engaged with the clutch piston housing.

In addition to the friction and steel discs, there is also an apply piston, housing and return spring. Once hydraulic fluid is applied to the clutch assembly, the friction discs and steel discs will be locked together. Once hydraulic pressure is released, the return spring will cause the clutch piston to return to its rest position which will unlock the clutch assembly.





Multi - Plate Clutch Operation

In order to carry out a shift in ratio, fluid needs to be applied or released from the Multi - Plate Clutch (or Brake). As shown in the example at the right, the following sequence occurs:

1. Fluid from a shift valve in the valve body is applied to the clutch assembly. (Figure A)
2. Fluid pressure builds behind the apply piston and overcomes the resistance from the diaphragm spring. (Figure A)
3. The friction and steel discs are compressed together and become locked, prevent ing any slippage between them. (Figure A)
4. Two planetary members are now locked together.
5. When fluid pressure is released, the steel and friction discs are allowed to unlock. (Figure B)
6. The diaphragm spring pushes against the apply piston and returns the piston back to the rest position. (Figure C)
7. The check ball in the apply piston is unseated by centrifugal force which allows the clutch to drain completely.

Figure A

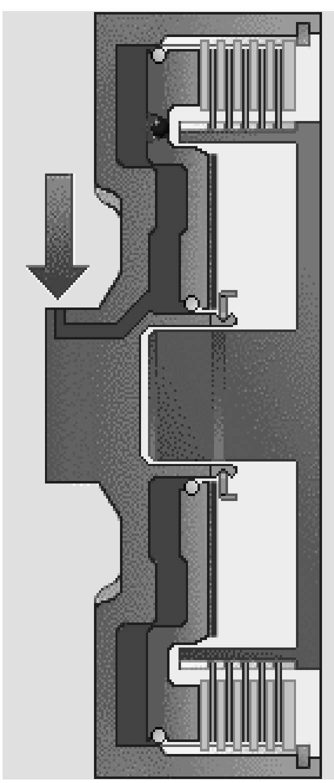


Figure B

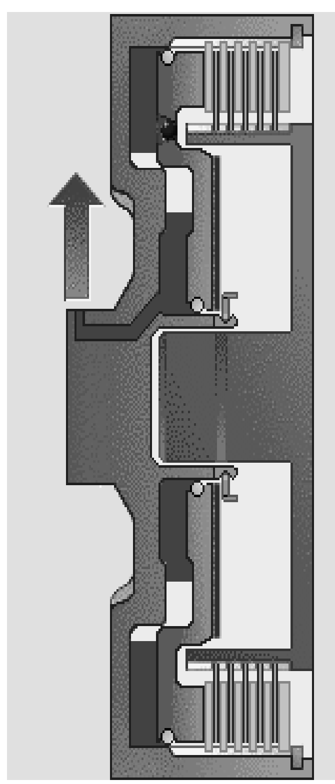
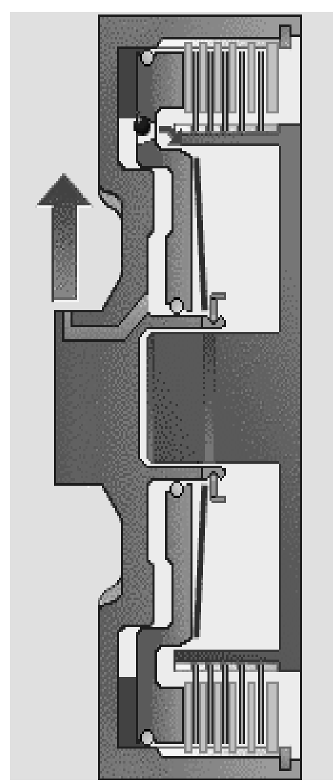


Figure C



Band Brakes

On some BMW transmissions there is a band type brake used for some applications. The A4S270/310R and the A5S310Z use a band type brake. The brake band is a circular band with friction material bonded to the inner surface. The band wraps around a particular planetary component (clutch drum) and locks that component to the transmission case. The brake band is applied and released by the clutch apply piston.

The brake band is not adjustable on the A5S310Z, however there is some adjustment allowed when needed on the A4S270/310R. Refer to repair instructions for proper procedures.

The brake band functions in the following manner on BMW transmissions:

- A4S270/310R - The brake band is active (applied) in first and second gear. The brake band holds the reaction sun drum stationary. The reaction sun drum is splined to the reaction sun gear.

- A5S310Z - The brake band is active (applied) in second, third and fifth gear. The brake band holds the forward sun gear to the case.