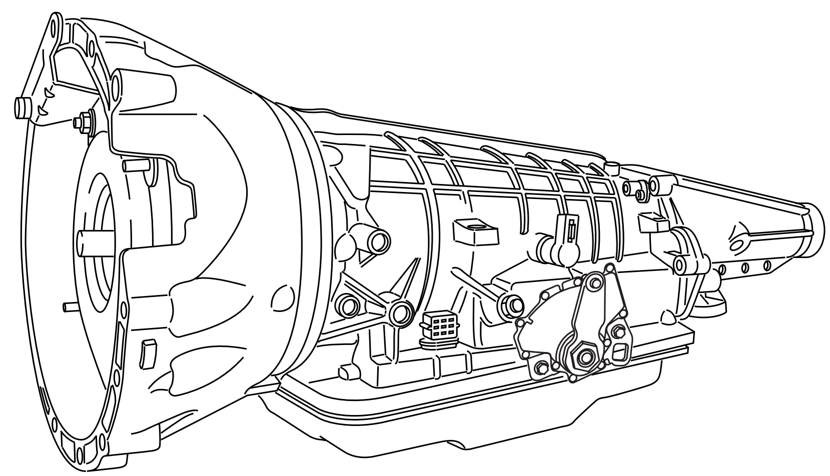
Technical Service Training

Global Fundamentals

Curriculum Training – TF1010014S

Automatic Transmission



Student Information

Ford Motor Company

FCS-13200-REF

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Global fundamentals training overview

The goal of the Global Fundamentals Training is to provide students with a common knowledge base of the theory and operation of automotive systems and components. The Global Fundamentals Training Curriculum (FCS-13203-REF) consists of nine self-study books. A brief listing of the topics covered in each of the self-study books appears below.

- Shop Practices (FCS-13202-REF) explains how to prepare for work and describes procedures for lifting materials and vehicles, handling substances safely, and performing potentially hazardous activities (such as welding). Understanding hazard labels, using protective equipment, the importance of environmental policy, and using technical resources are also covered.
- Brake Systems (FCS-13201-REF) describes the function and operation of drum brakes, disc brakes, master cylinder and brake lines, power-assist brakes, and anti-lock braking systems.
- Steering and Suspension Systems (FCS-13196-REF) describes the function and operation of the power-assisted steering system, tires and wheels, the suspension system, and steering alignment.
- Climate Control (FCS-13198-REF) explains the theories behind climate control systems, such as heat transfer and the relationship of temperature to pressure. The self-study also describes the function and operation of the refrigeration systems, the air distribution system, the ventilation system, and the electrical control system.
- Electrical Systems (FCS-13197-REF) explains the theories related to electricity, including the characteristics of electricity and basic circuits. The self-study also describes the function and operation of common automotive electrical and electronic devices.
- Manual Transmission and Drivetrain (FCS-13199-REF) explains the theory and operation of gears. The self-study also describes the function and operation of the drivetrain, the clutch, manual transmissions and transaxles, the driveshaft, the rear axle and differential, the transfer case, and the 4x4 system.
- Automatic Transmissions (FCS-13200-REF) explains the function and operation of the transmission and transaxle, the mechanical system, the hydraulic control system, the electronic control system, and the transaxle final drive. The self-study also describes the theory behind automatic transmissions including mechanical powerflow and electro-hydraulic operation.
- Engine Operation (FCS-13195-REF) explains the four-stroke process and the function and operation of the engine block assembly and the valve train. Also described are the lubrication system, the intake air system, the exhaust system, and the cooling system. Diesel engine function and operation are covered also.
- Engine Performance (FCS-13194-REF) explains the combustion process and the resulting emissions. The self-study book also describes the function and operation of the powertrain control system, the fuel injection system, the ignition system, emissions control devices, the forced induction systems, and diesel engine fuel injection. Read Engine Operation before completing Engine Performance.

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Objectives

Upon completion of this lesson, you will be able to:

- Identify the primary purpose of the transmission.
- Describe the functions of the three major transmission systems: torque converter, gear train, and hydraulic control system.
- Describe powerflow through the transmission.

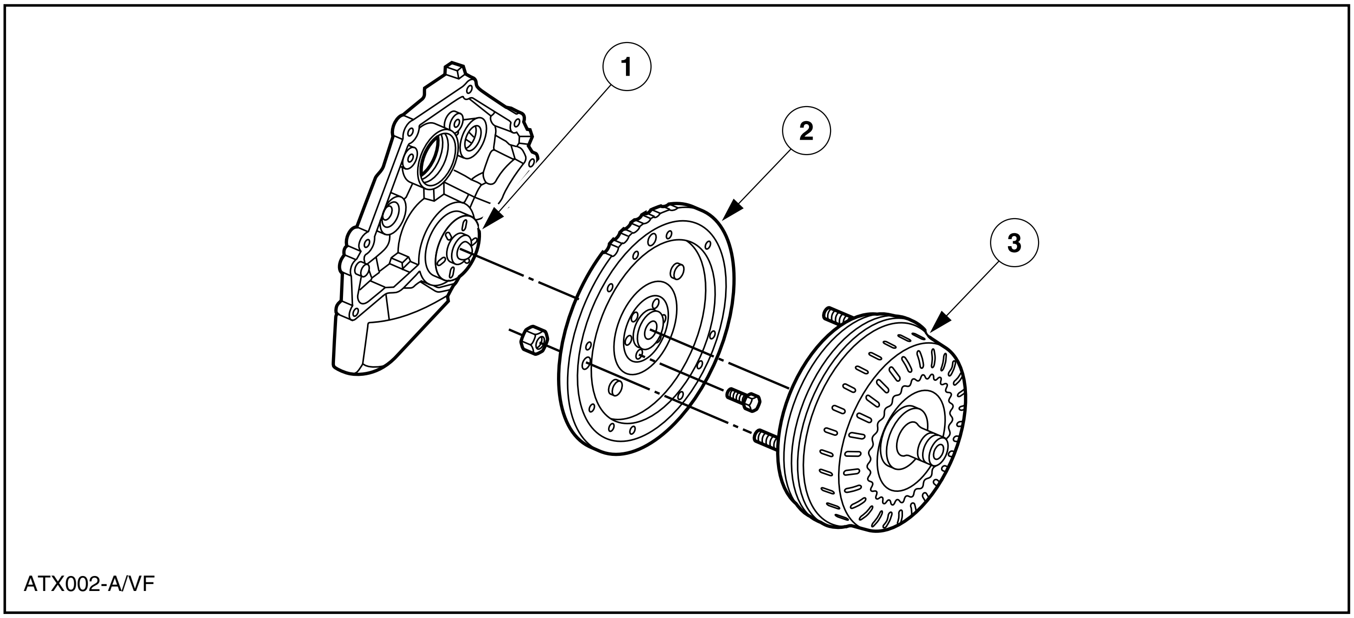
Automatic transmissions

The purpose of a transmission is to modify the engine's rotational force, or torque, and transfer it to the vehicle's drive axle. Through its torque converter and gear sets, the transmission provides the necessary force to move the vehicle. The transmission also allows the vehicle to be operated in reverse. This section introduces the basic operating principles of automatic transmissions.

Automatic transmissions have many design variations. However, they are all similar in that they use three basic systems:

- Torque converter
- Gear train
- Hydraulic control system

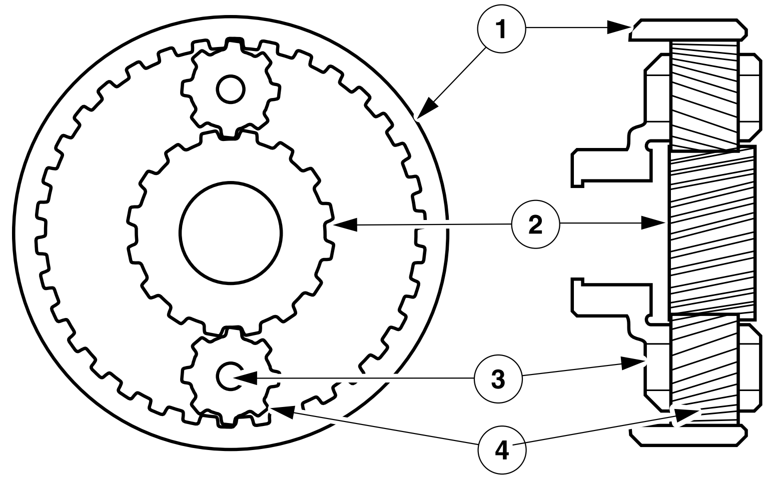
Torque converter



1 Engine crankshaft
2 Flex plate
3 Torque converter

The torque converter provides a fluid coupling that links the engine to the transmission gear train. (In a fluid coupling, the spinning motion of the transmission fluid transfers rotational force from the crankshaft to the transmission.) At low speeds, the torque converter multiplies the engine torque when operating as a fluid coupling. When equipped with a torque converter clutch, the converter also provides direct mechanical (lock-up) drive under certain operating conditions.

Gear train



Typical simple gear set

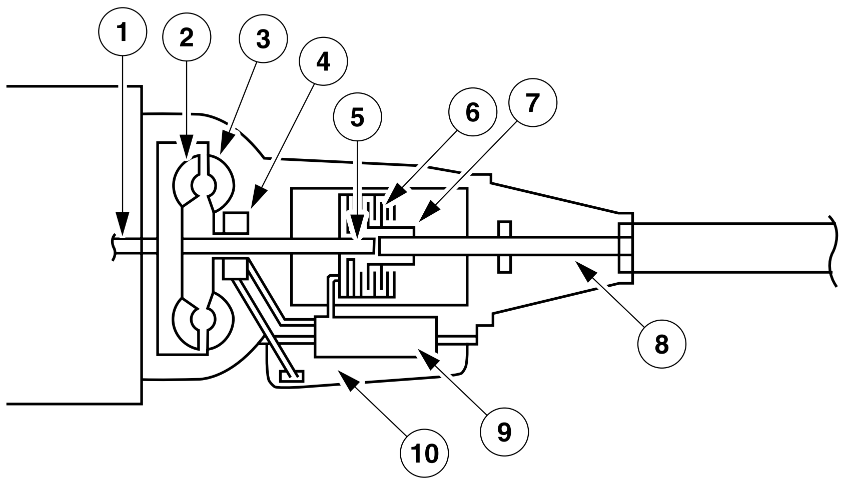
1 Ring gear
2 Sun gear
3 Planet carrier
4 Planet gears (pinions)

- A typical gear train includes the input shaft; planetary gear set, and output shaft.
- Two different types of gear trains are used. A simple, or "Simpson," gear train and a compound or "Ravigneaux" gear train.
- A planetary gear set has three members: the ring gear, the sun gear, and the pinion (or "planet") gears.
- These members are driven or held by friction (hydraulic) clutches, one-way (mechanical) clutches, and brake bands.
- The gear train provides the reduction gear ratios, as well as direct drive, overdrive, and reverse.

Hydraulic control system

- The hydraulic control system controls the clutches and bands needed to provide gear ratios and shift from one gear to another.
- This system also distributes oil to the torque converter and the transmission's lubrication and cooling systems.
- The hydraulic control system consists of a sump (oil pan), oil pump, valves to regulate pressure and redirect flow, and pistons to actuate the friction clutches or bands.

Basic powerflow



ATX004-A/VF

Typical powerflow

1 Engine crankshaft
2 Transmission turbine
3 Torque converter impeller
4 Oil pump
5 Input shaft
6 Friction clutch hub or drum
7 Planetary gear set
8 Output shaft
9 Valve body
10 Sump

- Power flows from the engine crankshaft through the torque converter, which turns the transmission input shaft. The planetary gear set transfers power from the input shaft to the output shaft.
- The torque converter impeller, which is attached to the engine, spins at engine speed and drives the oil pump.
- The oil pump draws automatic transmission fluid from the sump and sends pressurized oil to the valve body and torque converter.
- The pressurized fluid inside the converter forms a fluid coupling, which turns the transmission turbine and input shaft.
- The input shaft is connected to a friction clutch hub or drum.
- The clutch drum transfers power to the planetary gear set. A gear set member can be coupled to (driven by) the input shaft through a friction clutch. In some cases, a gear set member is held to the case by a friction clutch, one-way clutch, or band.
- The output member of the planetary gear set transfers engine power to the output shaft.

Objectives

Upon completion of this lesson, you will be able to:

- Identify the major components in a torque converter and explain their functions.
- Describe how the impeller and turbine provide a fluid coupling between the engine and transmission.
- Describe the operation of the stator and its one-way clutch.
- Explain how the stator, impeller, and turbine multiply torque.
- Describe the purpose of a lock-up converter.
- Explain how a centrifugal converter clutch provides a direct mechanical link between the engine and transmission.
- Explain how a hydraulically applied piston clutch provides a direct mechanical link between the engine and transmission.

Torque converter overview

The rotational force, or torque, of the engine is transferred to the automatic transmission through the torque converter. This section describes how the torque converter assembly components provide a fluid coupling, multiply torque at low speeds, and establish a direct mechanical link to the engine at high speeds.

The torque converter provides a fluid coupling between the engine crankshaft and the transmission. A flex plate is bolted to the rear of the crankshaft, and the torque converter is bolted to the flex plate.

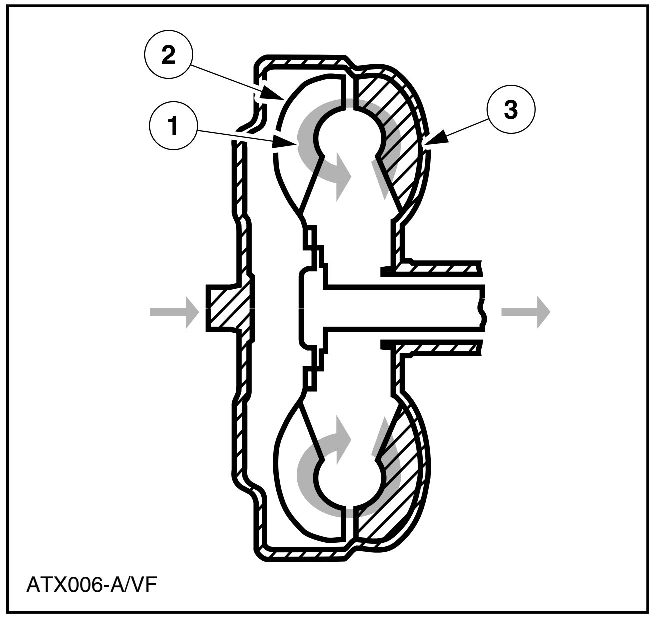
The automatic transmission fluid (ATF) in the torque converter transfers the spinning motion of the crankshaft to the transmission input shaft. Whenever the engine is running, the torque converter is spinning.

A simple torque converter has three basic elements: an impeller, a stator and a turbine. Most modern torque converters also have a clutch to lock the torque converter at the proper vehicle operating conditions.

Three-element converter

With the engine running and the torque converter empty of fluid, the input shaft will not turn. However, when the torque converter is filled with fluid, the shaft will not only turn, it will turn with enough force to drive the transmission internal components, which drive the vehicle. Therefore, the fluid in the torque converter makes the connection between the engine and the transmission.

Based on the simple three-element converter, there is no mechanical connection between the engine-driven portion of the converter and the transmission input shaft. Only the fluid in the torque converter couples the engine to the input shaft. The paragraphs on the following pages describe each component of the torque converter and explain how the hydraulic coupling is accomplished.



Basic torque converter

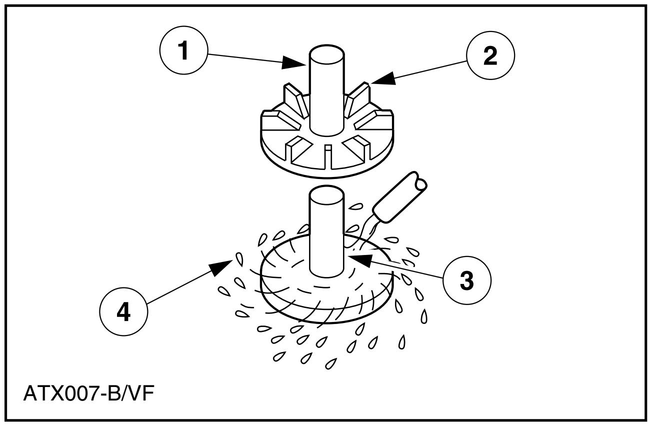
1 Fluid
2 Turbine
3 Impeller

Impeller

If you are familiar with the design of vehicle water pumps, then you already know what an impeller is. The impeller on a water pump is a round component with vanes that turns on a shaft. When the engine is running, the spinning impeller vanes force coolant to circulate through the coolant passages and radiator.

The impeller vanes on a torque converter work in a similar way. The spinning impeller forces hydraulic fluid to circulate via centrifugal force. The fluid is carried in a circular motion by the vanes, and, as speed increases, the fluid flows away from the center of the impeller.

As the fluid flows outward, the vanes carry it toward the upper edge of the impeller. As impeller speed increases, the fluid gains enough momentum to flow off the edges of the vanes and out of the impeller. The fluid comes out of the impeller with enough force to drive the transmission input shaft if the force is properly directed.

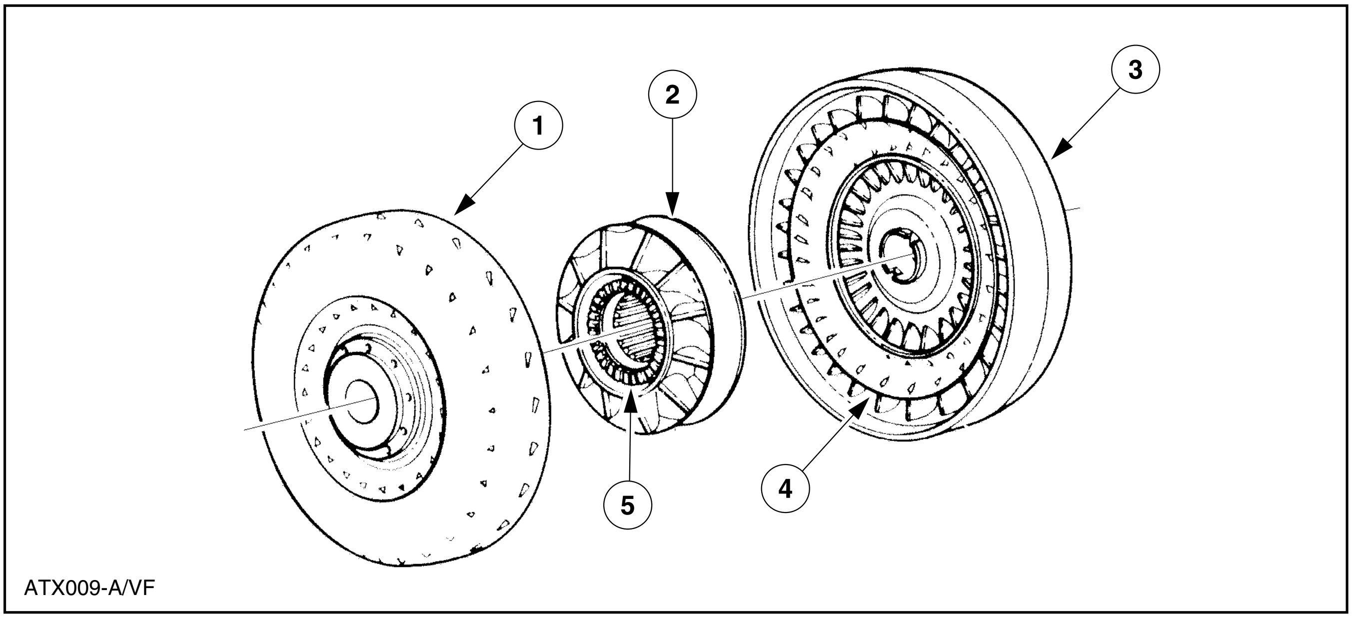


Impeller operation

1 Impeller shaft
2 Impeller vane
3 Spinning impeller
4 Coolant thrown outward by centrifugal force

Three-element converter (continued)

Turbine



Torque converter exploded view

1 Turbine
2 Stator
3 Impeller
4 Turbine blades
5 Stator one-way clutch

The turbine in a torque converter is similar in construction to the impeller. That is, the turbine is a round part with vanes, or blades. This construction makes sense when you consider that the turbine catches the fluid thrown off by the impeller.

As the fluid is thrown off the impeller, the blades on the turbine capture it, forcing the fluid to the center of the turbine. This force turns the turbine before the fluid flows back through the center of the turbine to the impeller.

The force of the fluid striking the turbine blades is related to engine speed. The faster the crankshaft rotates, the more force the fluid transfers from the impeller to the turbine. When the engine is idling, the fluid does not have enough force to turn the turbine against the holding ability of the brakes. The fluid is merely circulated from the impeller to the turbine, and back again.

The fluid leaves the impeller in a clockwise direction and returns from the turbine in a counterclockwise direction.

Stator (reactor)

The stator, or reactor, is positioned between the turbine and impeller. The purpose of the stator is to change the direction of fluid flow as it moves from the center of the turbine to the center of the impeller.

The fluid flows from the impeller to the turbine in a clockwise direction. However, as the fluid flows through the turbine, its direction is reversed to a counterclockwise direction.

If the fluid were allowed to return to the impeller in a counterclockwise direction, it would enter the impeller as an opposing fluid flow, which would reduce the pumping efficiency of the impeller. The impeller would have to spend part of the rotational force, or torque, it receives from the engine to redirect the fluid flow.

When the stator redirects the fluid to enter the impeller in a clockwise direction, no torque is wasted. In fact, the redirected fluid actually helps push the impeller, thus multiplying torque.

The stator consists of several blades attached to a hub which is mounted on a one-way clutch.

The clutch assembly has an inner and outer race, or ring, with the two races separated by spring-loaded rollers. The inner race is mounted on a splined, or grooved, stator support, which extends from the transmission into the torque converter. Because the inner race is splined to the stator support, it is fixed and cannot turn.

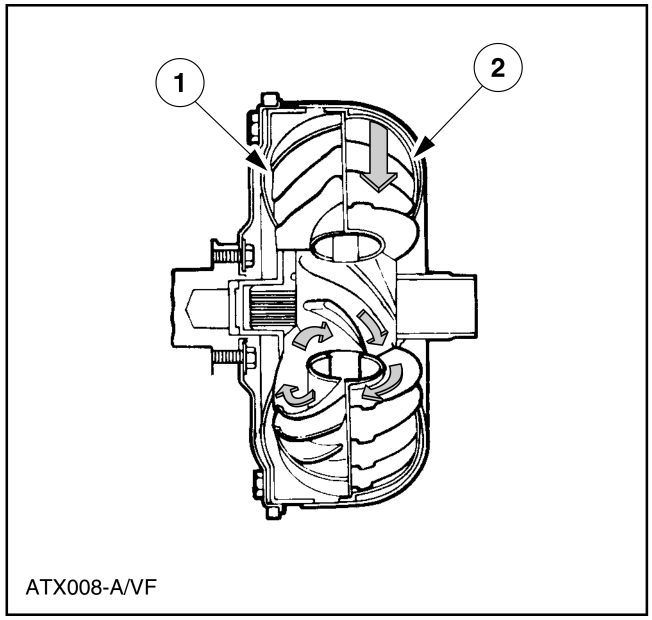
The outer race is placed over the inner race. The inner and outer race are separated by spring-loaded rollers. The rollers are positioned against the low end of ramps machined into the outer race. When the springs are installed, the rollers are held against the ramps.

The rollers, ramps, and races allow the outer race to turn in only one direction. When the stator turns clockwise, each roller moves down the ramp against the spring, allowing the stator to turn. If the stator is rotated in the opposite direction, the spring pushes each roller up the ramp, where it becomes wedged between the two races. With the rollers wedged, the stator is locked to the inner race and cannot rotate.

Fluid flow reversal

The counterclockwise flow of fluid leaving the turbine passes through the stator blades before reaching the impeller. The curvature of the stator blades reverses the direction of the fluid.

The change of direction allows the fluid to enter the impeller and join the fluid flowing along its blades. The first advantage of a stator is that engine torque is not wasted by having the impeller redirect the flow. A second advantage is that the fluid enters the impeller in a direction that applies a “helping push” along the impeller blades.



Reversing fluid flow

1 Turbine
2 Impeller

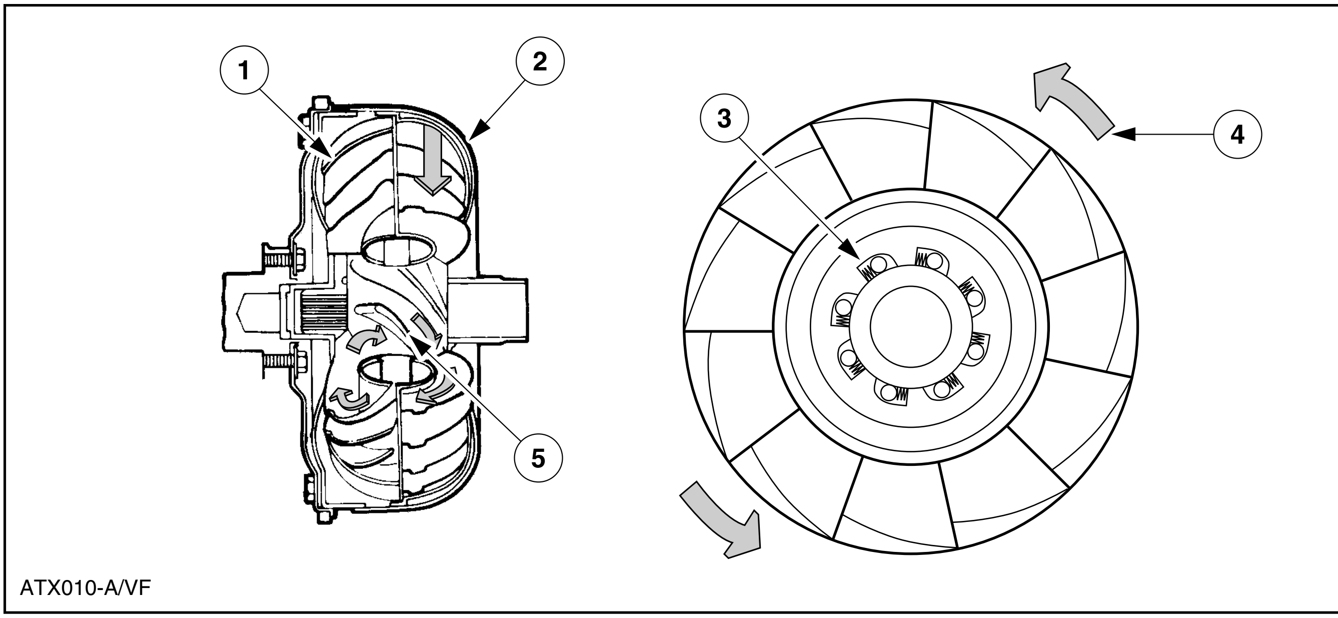
Torque multiplication

The influence of the stator means that the fluid entering the impeller is already in motion; the fluid does not have to be accelerated from a standstill. The fluid moves into the blades, where its momentum is accelerated. The acceleration whips the fluid through the impeller and throws it toward the turbine with greatly increased force.

Through this efficient management of the fluid, the turbine torque actually becomes greater than the engine’s torque. In effect, the torque is multiplied.

Torque multiplication by the stator is only possible when there is a great difference in speed between the impeller and the turbine. The greater the speed difference between the two, the greater the torque multiplication.

Torque multiplication



Stator one-way clutch operation

1 Turbine
2 Impeller
3 Rollers wedged between ramp and inner race (clutch lock-up)
4 Direction of force on stator
5 Vortex flow

The stator's one-way clutch plays an important role in multiplying torque. The fluid circulating between the impeller and the turbine is called vortex flow. This flow exists only when there is a difference in rotational speed between the impeller and turbine.

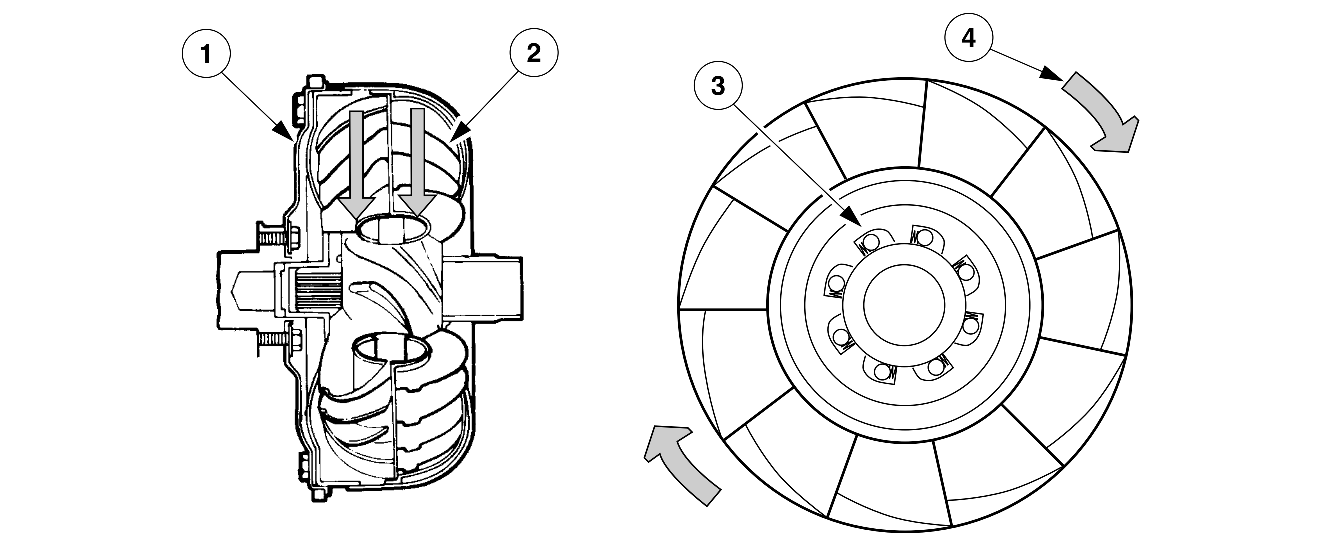
The greatest speed difference between these two components occurs when a vehicle first accelerates from a stop. At this point, the impeller is spinning, but the turbine is not. Because of the great difference in speed, vortex flow and torque multiplication are at maximum. The vortex flow passing through the stator blades tries to turn the stator counterclockwise. When this happens, the clutch rollers move down the ramps and lock the stator to its support.

As the vehicle accelerates, the turbine gradually gains speed in relation to the impeller. Eventually, the turbine speeds up to the point where the fluid begins to flow in one direction (clockwise).

As centrifugal force reduces vortex flow, torque multiplication is also reduced. Finally, when the turbine's speed reaches about 90 percent of the impeller's speed, the torque converter reaches "coupling" phase. In this phase, the torque converter simply transmits engine torque through the fluid coupling to the transmission input shaft.

Coupling does not necessarily occur at a specific road speed. For example, a vehicle may be moving at a steady speed with the torque converter coupled to the transmission. If the driver suddenly accelerates to pass another vehicle, the higher engine rotation increases the speed of the impeller, causing it to turn faster than the turbine. With a significant speed difference between the impeller and the turbine, torque multiplication (and vortex flow) again occurs, until the turbine "catches up" with the speed of the impeller.

Torque multiplication (continued)



Stator one-way clutch operation

1 Turbine
2 Impeller
3 Rollers moved away from ramp (clutch unlocked)
4 Clockwise direction of force on stator

As turbine speed increases and vortex flow decreases, the rotational force acting on the stator is reversed. The clutch rollers move away from their ramps, unlocking the clutch and allowing the stator to turn freely (clockwise). The direction of the fluid striking the stator blades also changes. Instead of flowing against the front of the stator blades, the fluid strikes the rear of the blades. If the clutch did not release the stator, its blades would generate turbulence in the flow, which would greatly reduce the torque converter's efficiency.

Hydraulic and mechanical coupling

Because the torque converter lacks a direct mechanical link to the engine, it loses some engine torque to fluid slippage. The speeds and loads imposed on the fluid cause the impeller and turbine blades to shear, or slip, through the fluid to a certain degree.

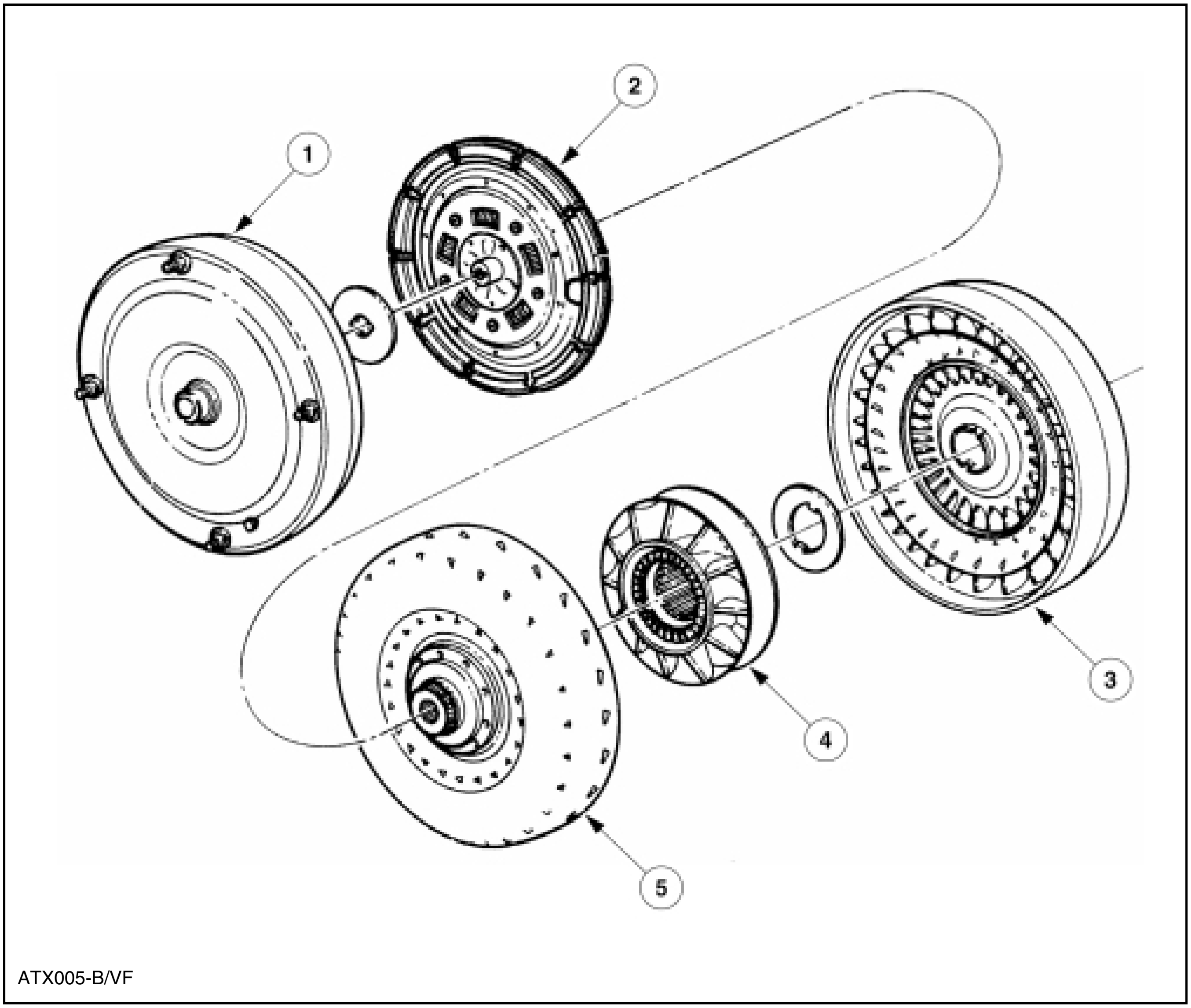
This fluid slippage causes some inefficiency, especially at higher vehicle speeds. The engine can run faster than the turbine or output shaft, thus wasting fuel. To eliminate this inefficiency, many torque converters provide a direct mechanical link (called lock-up) between the engine and transmission. At lock-up, the turbine and impeller turn at exactly the same speed. There is no fluid slippage, which helps to reduce heat build-up.

A lock-up converter is one of the most common ways of providing this mechanical link. A lock-up converter mechanically links the turbine to the converter cover at various operating speeds, depending on vehicle model and driving conditions. The cover is mechanically bolted to the engine. At lock-up, the converter cover drives the turbine. The hydraulic link is eliminated, and the engine and turbine are mechanically locked together, directly driving the transmission input shaft.

A lock-up converter requires a clutch to engage and disengage the mechanical link between the engine and the torque converter cover. Two major types of converter clutches are the centrifugal clutch and the hydraulically applied torque converter clutch.

The centrifugal type converter clutch was mainly used before 1990. The hydraulically applied clutch is mainly used in today's vehicles.

Centrifugal clutch



Torque converter assembly

1 Cover
2 Torque converter clutch
3 Impeller assembly
4 Stator
5 Turbine

A centrifugal clutch is splined to the turbine by a one-way clutch. As vehicle speed increases, the hydraulically driven turbine and the lock-up clutch splined to it turn with increasing speed. The centrifugal force on the clutch shoes increases as the clutch assembly turns faster and faster.

When the turbine and lock-up clutch are turning fast enough, centrifugal force causes the clutch shoes to move outward until they contact the inside surface of the converter cover. The face of each shoe “grabs” the cover and locks it to the turbine.

As vehicle speed drops, turbine speed and centrifugal force are reduced. The return springs retract the clutch shoes, the cover is released, and the turbine again becomes hydraulically driven.

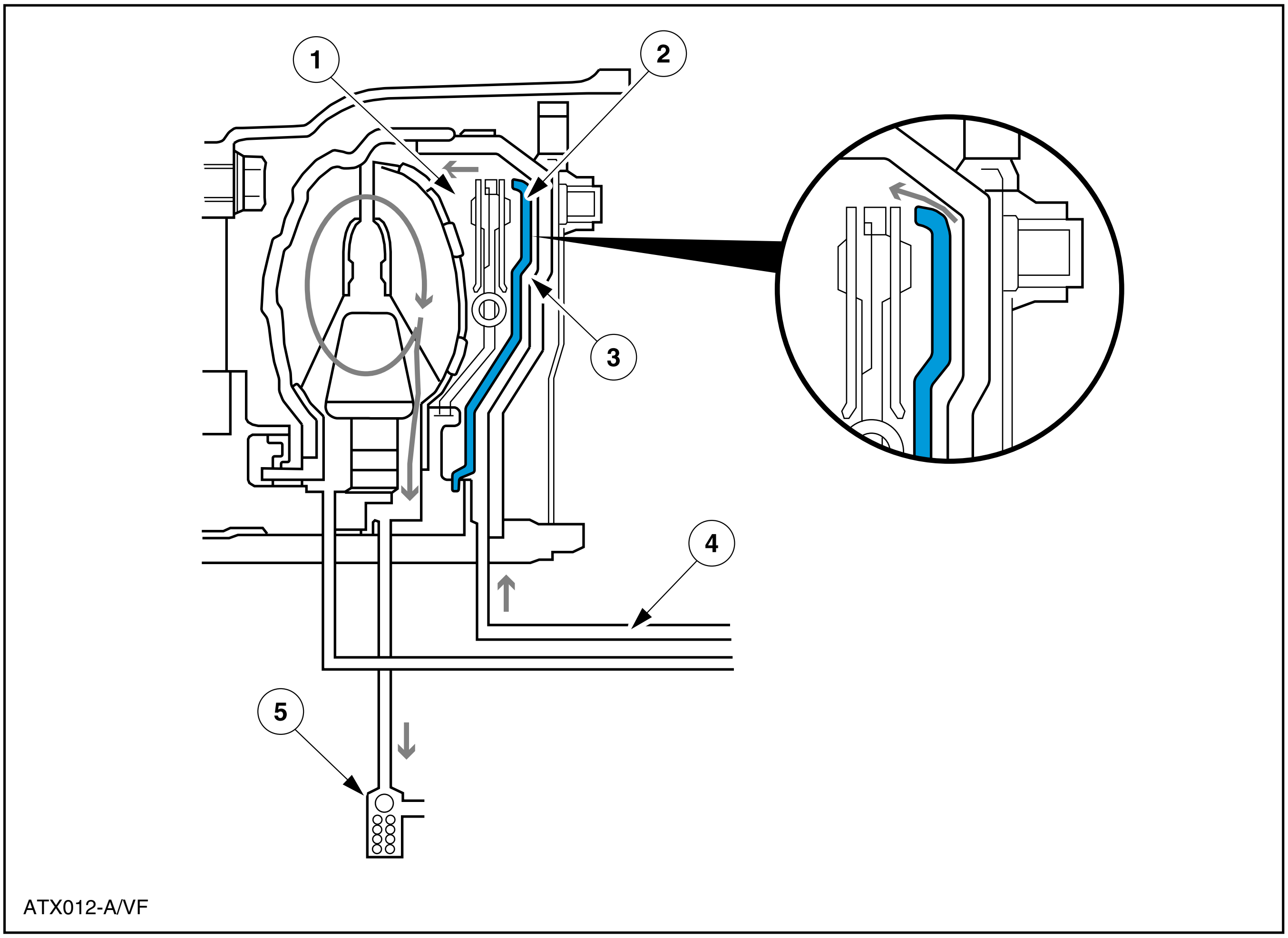
A one-way clutch drives the clutch assembly. With the clutch engaged, the driver may release the accelerator pedal slightly, allowing the vehicle to “coast.” This allows the engine and input shaft to turn at different speeds.

The friction shoes cannot release during coasting because centrifugal force holds them against the cover. Instead, the damper one-way clutch releases so the input shaft can turn faster than engine speed. When the driver accelerates, the damper one-way clutch again locks the turbine to the clutch and damper assembly.

The damper assembly one-way clutch ensures smooth operation of the torque converter. The dampener springs also contribute to smooth operation. These springs absorb engine vibrations and cushion the shoes as they engage the converter cover.

When torque demand during acceleration exceeds the holding ability of the friction shoes, some slip occurs. This slippage reduces torsional vibration during higher engine load.

Hydraulically applied torque converter clutch



Converter clutch released

1 Rear chamber
2 TCC
3 Front chamber
4 Converter pressure
5 Clutch control valve

Another method of connecting the engine and transmission directly is to use a torque converter clutch (TCC) with torsional dampening springs attached to the hub. The hub assembly is splined to the input shaft or turbine assembly.

Hydraulic clutch released

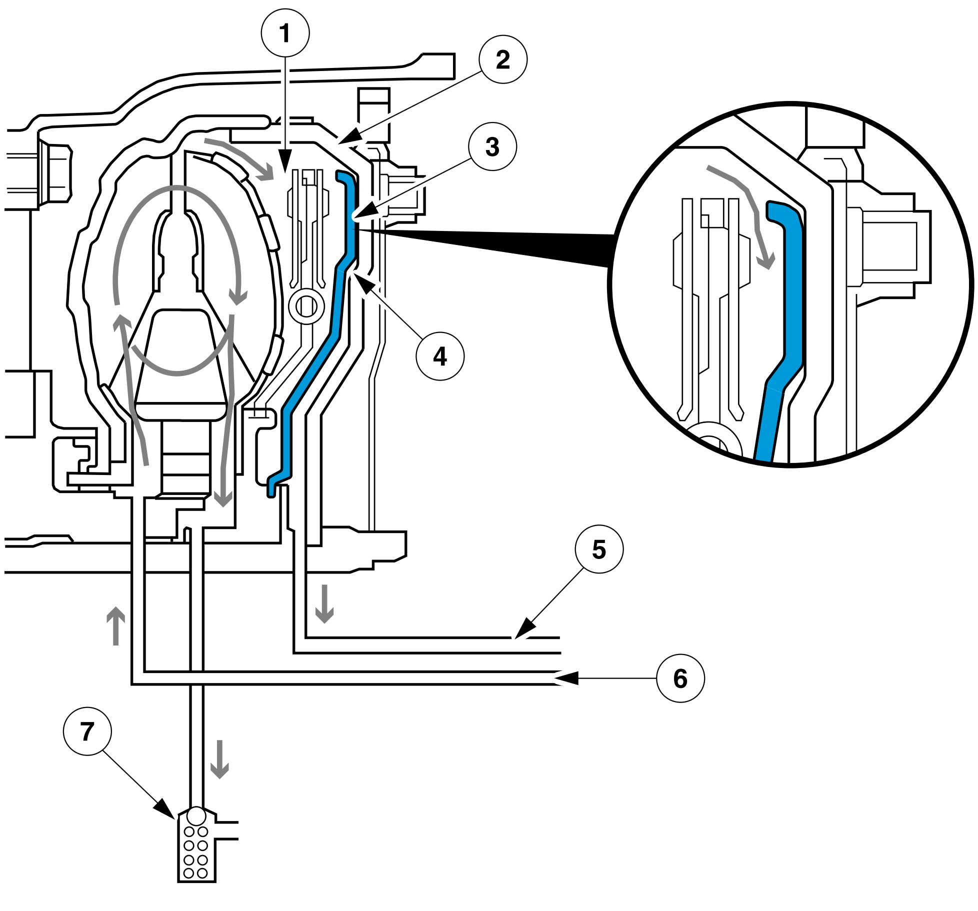
Signals from the control module control the application and release of the hydraulic converter clutch. The control module applies and releases the hydraulic clutch by turning the converter clutch solenoid on or off. A solenoid is a type of electric switch that includes a wire coil. When current is applied, the coil is magnetized. The magnetic field moves a rod that opens and closes a hydraulic passage.

Hydraulic pressure is applied to the area between the converter cover and the clutch piston plate. A converter feed circuit in the valve body provides the hydraulic pressure.

When the converter clutch solenoid is not activated by the control module, the solenoid remains open. Line pressure bleeds through the solenoid. The fluid is routed through the converter front chamber, between the TCC and the converter cover.

Hydraulically applied torque converter clutch (continued)

Hydraulic clutch engaged



Converter clutch engaged

1 Rear chamber
2 Converter cover
3 TCC
4 Front chamber
5 Drain to sump
6 Converter apply pressure
7 Clutch control valve

The converter clutch engages only when the control module energizes the converter clutch solenoid. The solenoid seals the bleed passage, allowing line pressure to build in the circuit. Fluid is routed to the rear chamber, and the fluid drains from the front chamber.

Hydraulic force pushes the TCC piston against the converter cover. This coupling directly transfers the engine torque through the damper assembly to the transmission input shaft. Since the impeller and turbine are turning at the same speed, torque multiplication is canceled, and the converter is in lock-up.

Objectives

Upon completion of this lesson, you will be able to:

- Identify the components in a transmission oil pump and describe how they provide fluid flow and pressure.
- Describe the three operating stages of the pump.
- Describe how the pressure regulator valve operates to maintain a desired system pressure.
- Describe how pressurized fluid transfers motion among moving parts.
- Describe a spool valve with multiple lands and explain how it opens and closes various hydraulic passages.
- Describe how the governor circuit operates to send road speed information to the hydraulic main control.
- Describe how the throttle valve (TV) can be connected to the engine to read throttle position or engine performance.

Hydraulics overview

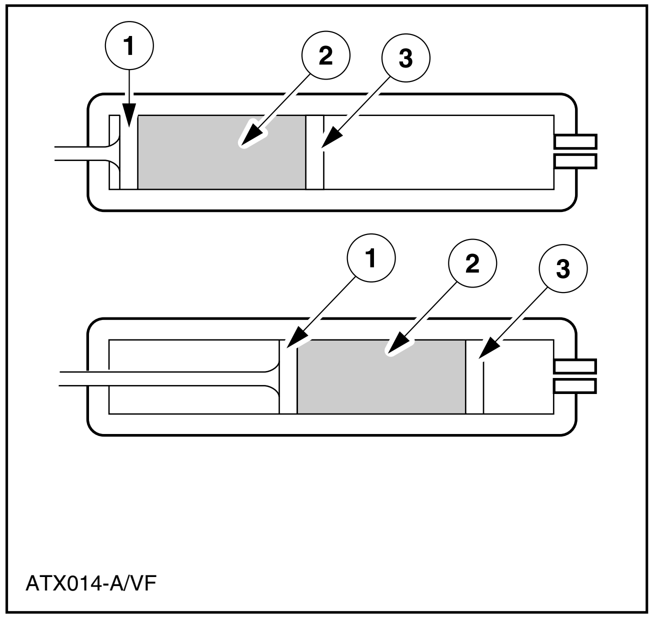
Hydraulics is the science that deals with the behavior of fluids. In the automatic transmission, we are specifically concerned with the behavior of fluid under pressure. This section describes the basic hydraulic principles at work in an automatic transmission.

When pressurized liquid is properly controlled, it can be used to transmit motion.

Fluid under pressure can be used to transfer motion from one piston to another.

When the applying piston moves within the cylinder, its motion is transmitted through the fluid to the output piston, which moves the same distance as the applying piston.

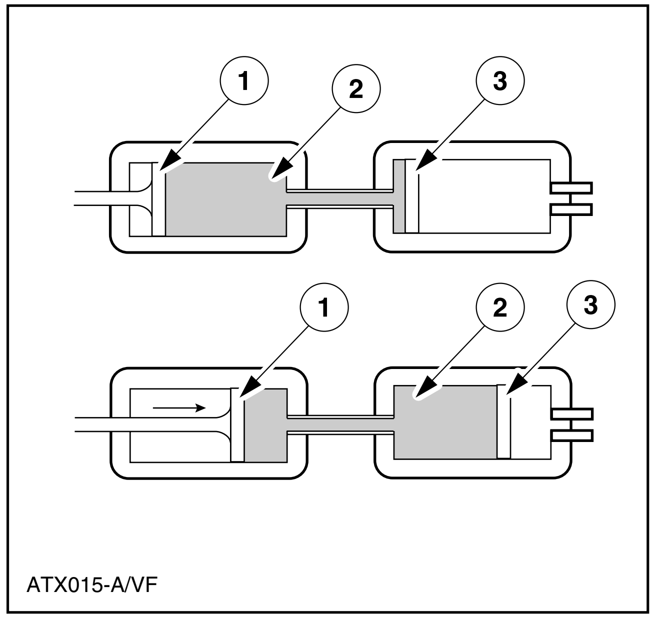
Of course, a mechanical link could be used to perform this simple task, but using fluid has a very big advantage: the two pistons do not have to be enclosed in the same cylinder. In fact, they can be widely separated in individual cylinders. All that is needed is a connecting tube to confine the fluid as it moves from cylinder to cylinder.



Single hydraulic cylinder

1 Applying piston
2 Fluid
3 Output piston

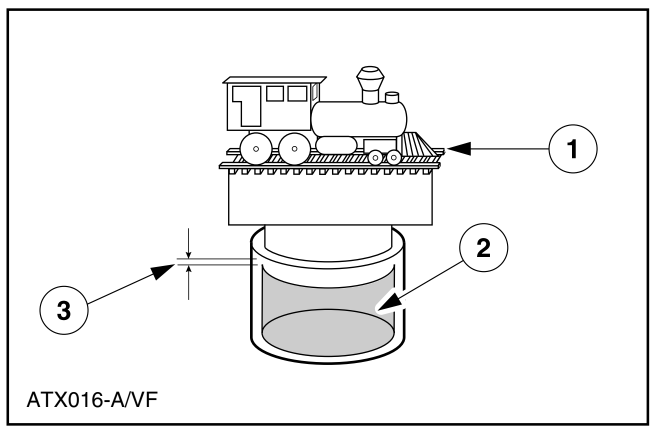
The applying piston transfers its motion through the fluid to the output piston.



Apply and output cylinders

1 Applying piston
2 Fluid
3 Output piston

The ability of a fluid to transmit motion comes from its incompressibility. That is, when a fluid is squeezed, or compressed, its volume does not shrink. So, for example, it would take 29,029 Kg (32 tons) to compress 6.45 cubic centimeters (one cubic inch) of water by 10 percent.



Compressing hydraulics

1 29,029 Kg (32 tons)
2 6.45 cubic centimeters (one cubic inch of water)
3 Compressed 10 percent

Oil pump purpose

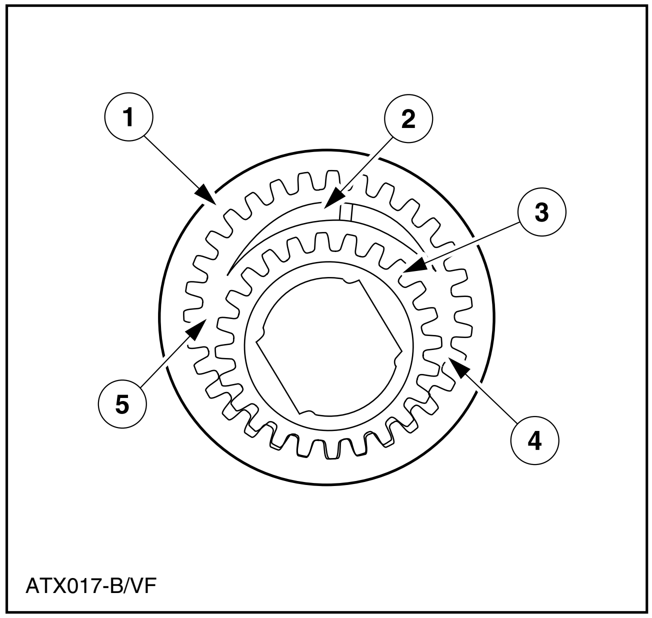
Because an automatic transmission requires pressurized fluid, it must have a pressure source – an oil pump. The oil pump is driven by the engine and provides a source of fluid flow.

Types of pumps

Three styles of pumps are used in most automatic transmissions:

- Rotary type
- Gear type
- Vane type

All pumps have an inlet and outlet port. The inlet port is attached to the transmission oil filter, which is submerged in the oil pan. Oil is pushed into the inlet port by atmospheric pressure and by the low pressure created by the rotating rotor, gear, or vane in the pump. The outlet (or discharge) port leads to the valve body.



Gear type pump

1 Driven gear
2 Crescent
3 Drive gear
4 Fluid squeezed out
5 Inlet (low pressure)

Rotary type

A rotary type pump uses an inner rotor and an outer rotor to create a low pressure. As fluid is drawn into the pump, it is squeezed between the rotor lobes, which carry the fluid around the pump housing to the outlet port.

Gear type

A gear type pump uses a large gear with internal teeth (called the driven gear) mounted over the drive gear on the hub. This larger gear is off center, so the teeth on the two gears only partially mesh. As the gears turn, a progressively wider gap is formed between the gear teeth. The gap creates a low pressure, which sucks the fluid into the pump.

Because this gap must be filled with fluid, another component, called the crescent, is added to the gear assembly. The crescent prevents the fluid from leaking back to the inlet port. As the gap between the gear teeth narrows, the fluid is squeezed out between the teeth and forced through the outlet port.

Vane type

A vane type pump uses centrifugal force to push fluid through the pump. As the fluid enters the inlet port, it is picked up by the rapidly spinning vanes. Centrifugal force slings the fluid off the end of the vanes and through the outlet port.

Typical pump operation

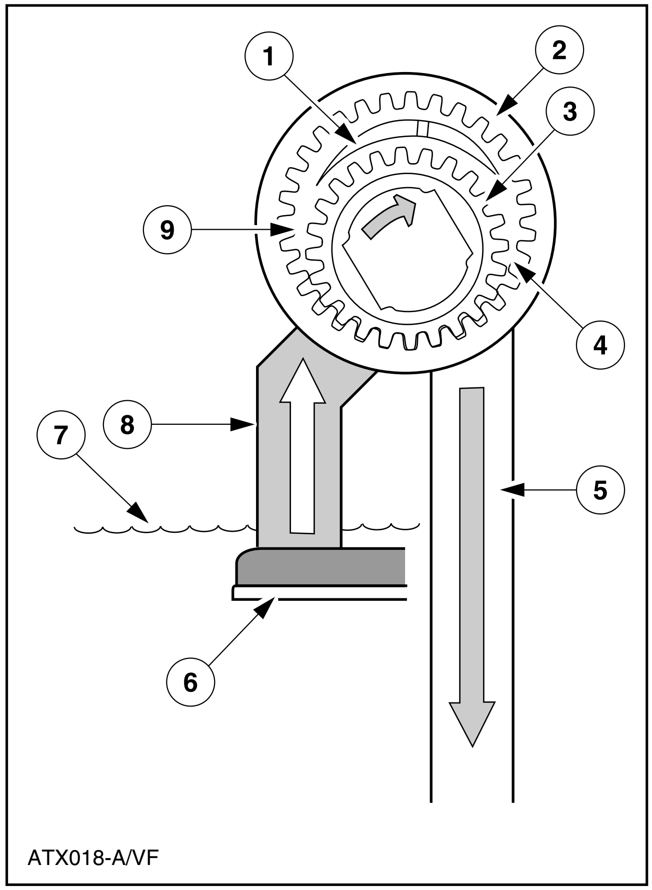
The inlet of the transmission oil pump is connected to a sump, or oil pan, in the bottom of the transmission case. As the fluid is drawn up from the sump, it passes through a filter, which removes particles and debris.

Fluid enters the pump inlet because air pressure pushes down on the surface of the oil. At sea level, air pressure is about 1.01 bar (14.7 psi). Air pressure cannot actually push the fluid up through the strainer into the pump. The pump first has to create a low pressure, or void, at the inlet port opening. Then atmospheric pressure can push the fluid into the pump to fill the void.

In a gear type pump, the pump creates a low pressure through the action of the gear teeth. The teeth are tightly meshed, but as they rotate, they begin to separate. This separation creates a low pressure between the gear teeth, and atmospheric pressure pushes the fluid in to fill this void.

Once in the pump, the fluid is trapped between the gear teeth, which carry it around the pump housing toward the outlet port. As the gear teeth approach the outlet, the gap between the gear teeth begins to narrow. The fluid cannot leak back toward the inlet port because the crescent blocks its path.

The gap continues narrowing until the gear teeth begin to mesh. At this point, the fluid is squeezed between the teeth until it reaches the outlet port. From the outlet, the fluid is discharged into the transmission hydraulic system.



Gear pump operation

1 Crescent
2 Driven gear
3 Drive gear
4 Fluid squeezed out
5 Pump outlet
6 Oil sump filter
7 Sump (fluid pan)
8 Pump inlet
9 Low pressure

Pressure regulation

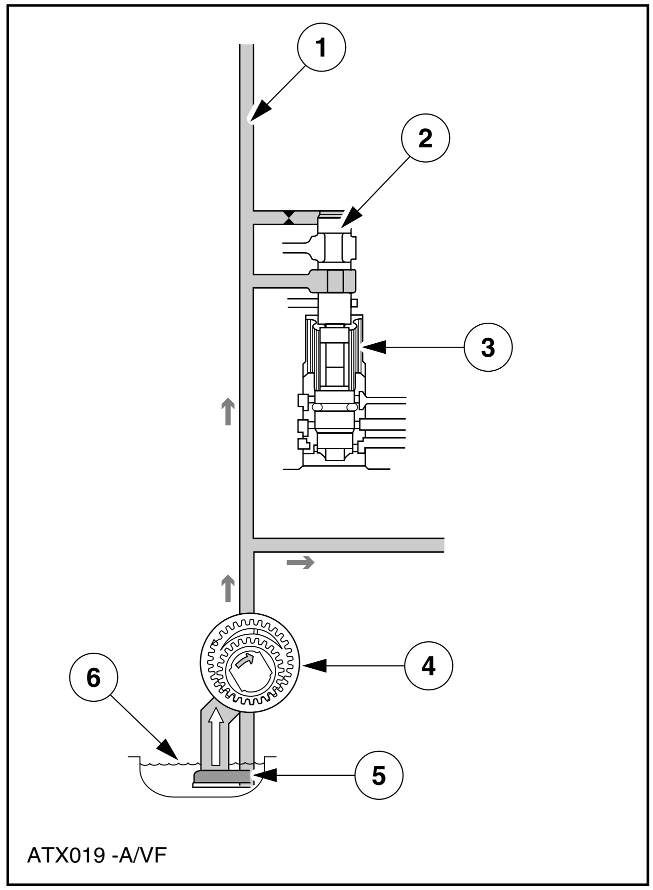
Transmission oil pumps are classified as positive displacement or variable displacement pumps.

A vane type pump is a variable displacement pump. This means that it supplies a fixed quantity of oil output once the engine reaches a specific speed. “Feedback” pressure from the valve body return circuit keeps the vane type pump from producing more output than is required. This feature helps conserve engine power by reducing the amount of horsepower required to drive the pump.

Rotary and gear type pumps are positive displacement pumps. This means that the pump must force out all the fluid that enters it. There is no other escape for the fluid except the outlet port. A positive displacement pump continues to pump out fluid even if the pressure on the outlet side is extremely high. In fact, if the outlet port is blocked, a positive displacement pump continues to operate until it eventually stalls from extremely high pressure.

To prevent stall, a positive displacement pump must have a method of rerouting the fluid flow if pressure becomes too high. As pump pressure builds, a pressure regulator valve opens and closes to maintain system pressure at a safe level.

Movement of the pressure regulator valve is controlled by a calibrated spring. The spring tension determines the opening pressure of the regulator valve.



Pressure regulator circuit

1 To system
2 Pressure regulator valve
3 Spring
4 Pump
5 Screen
6 Sump

Pressure regulation (continued)

Three stages of operation

The pressure regulator valve has three distinct stages of operation:

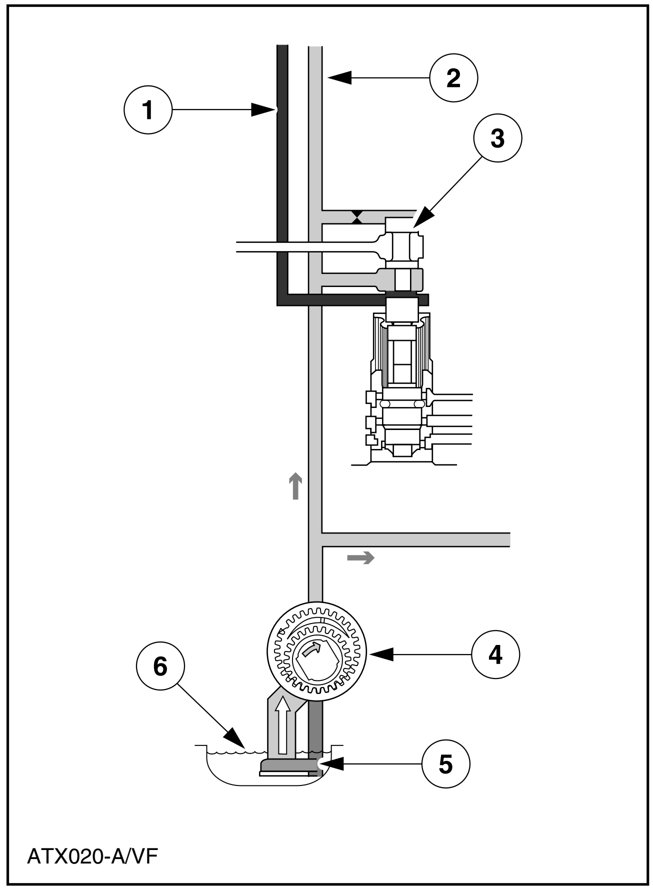
- Filling the lines
- Converter supply
- Sump supply

Filling the lines

Immediately after the vehicle is started, the lines are filled with fluid. At this stage, there is little resistance to flow in the system, so pressure does not build up. The spring below the regulator valve holds it in the up (or closed) position.

Converter supply

As pressure begins to rise in the system, the regulator valve is forced down against the spring, and another port is uncovered. Fluid from the pump flows through this port into the torque converter circuit. Since the torque converter is kept under constant pressure, another fluid outlet is required to prevent excessive pressure build-up.



Torque converter supply circuit

1 To torque converter
2 To system
3 Pressure regulator valve
4 Pump
5 Screen
6 Sump

Pressure regulation (continued)

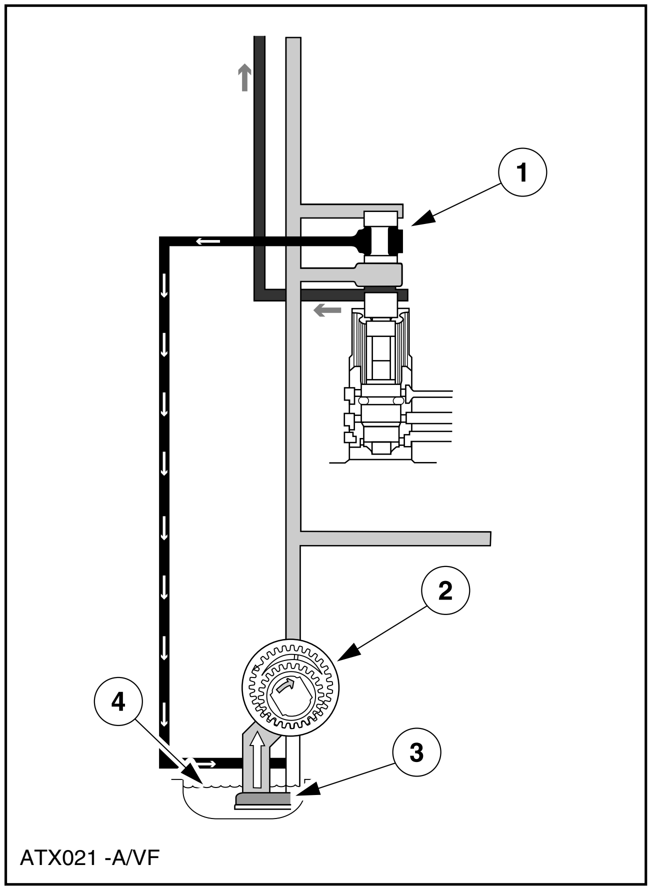
Sump supply

Pressure continues to build, and the regulator valve is forced down further against the spring. Another oil port is uncovered. This port connects to the sump in the bottom of the transmission case. All excess oil is returned to the sump, where it can be recirculated through the pump inlet. This final stage is the normal operating condition when the engine is running.

Balanced valve

Once the pressure regulator valve has reached stage 3, the pressure in the main control system is regulated by balancing the pressure against the force of the valve spring. The spring controls the pressure, and the valve adjusts itself automatically so that the spring force acting upward is equal to the hydraulic pressure acting downward.

If the pressure drops, the spring moves the valve up and cuts off part of the flow to the sump (and to the torque converter, if necessary) to maintain the regulated pressure. This valve is called a balanced valve, and the pressure it regulates is called control or line pressure. Line pressure can also be controlled by an electronic solenoid.



Sump supply circuit

1 Pressure regulator valve
2 Pump
3 Screen
4 Sump

Fluid flow

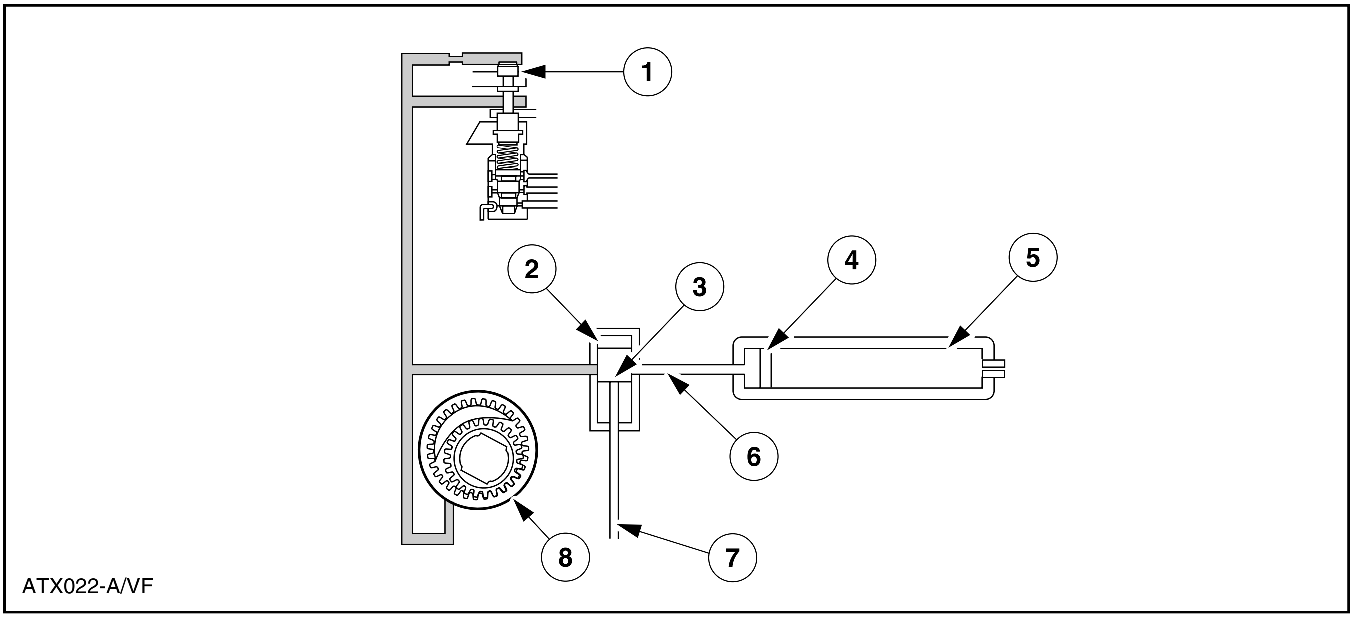
In an automatic transmission, fluid is routed through passages and bores. Although many of these are located in the case and pump housing, most bores and passages are in a master flow control device called the valve body. Fluid flow through these passages is controlled by either a single valve or a series of valves working in combination.

With the exception of two valves, all the control valves in the valve body operate automatically to direct the fluid to perform certain functions. For example, the shift from first to second gear, called the 1-2 shift, is a specific hydraulic function. When this shift happens, the fluid flows through specific bores, passages, and valves. This fluid flow is called an oil circuit.

An automatic transmission has an oil circuit for each hydraulic function. In fact, the pressure regulator valve described in the previous section is an oil circuit that controls pump pressure.

When you study an oil circuit, you are looking at a schematic, or kind of map, that shows the fluid path and valves for performing a specific function.

Flow control



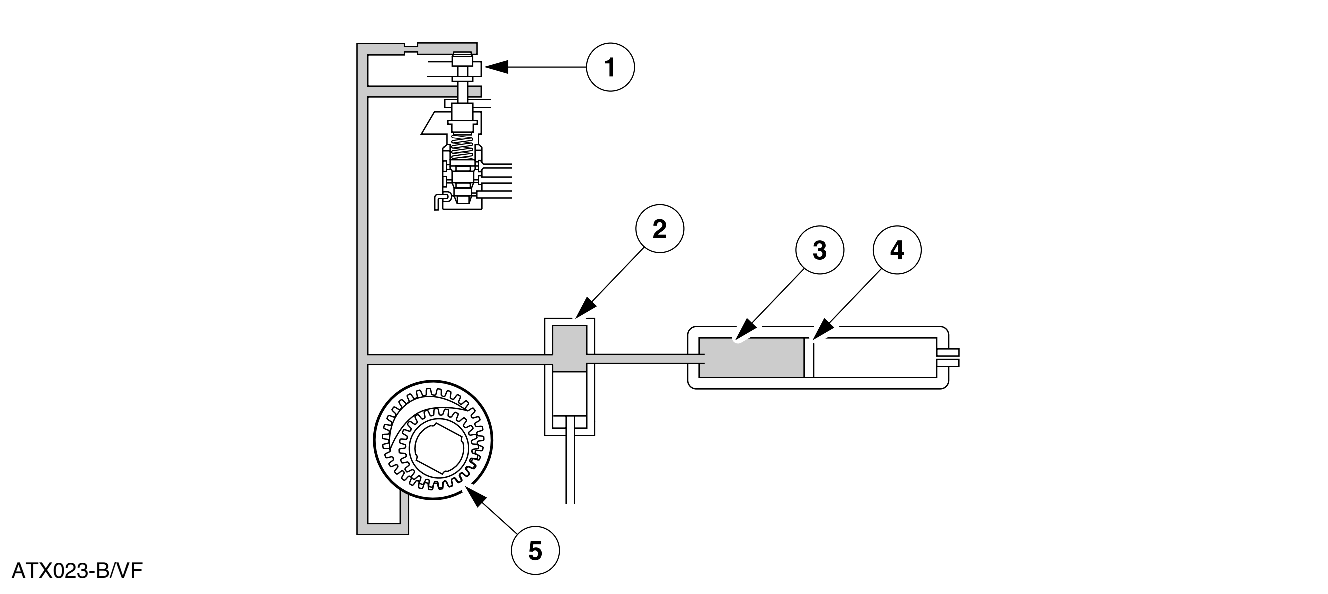
Flow control circuit – valve closed

1 Pressure regulator valve
2 Valve bore
3 Valve closed
4 Piston at top of stroke
5 Cylinder
6 Exit port
7 Rod
8 Pump

To demonstrate basic principles of flow control, we will examine a hypothetical valve bore. This bore is connected to the fluid flow from the pressure regulator valve.

Within this bore is a single-land valve connected to a rod that extends through one end of the bore. (A land is the round sealing surface of the valve.) On the sides of the bore are two ports: an inlet port joined to the fluid from the pressure regulator, and an exit port joined to a passage leading to a cylinder. Within this cylinder is a piston at the top of its stroke.

With the engine running, fluid flows from the pressure regulator circuit to the valve bore and stops. It cannot pass through the bore because the valve is blocking the inlet port.



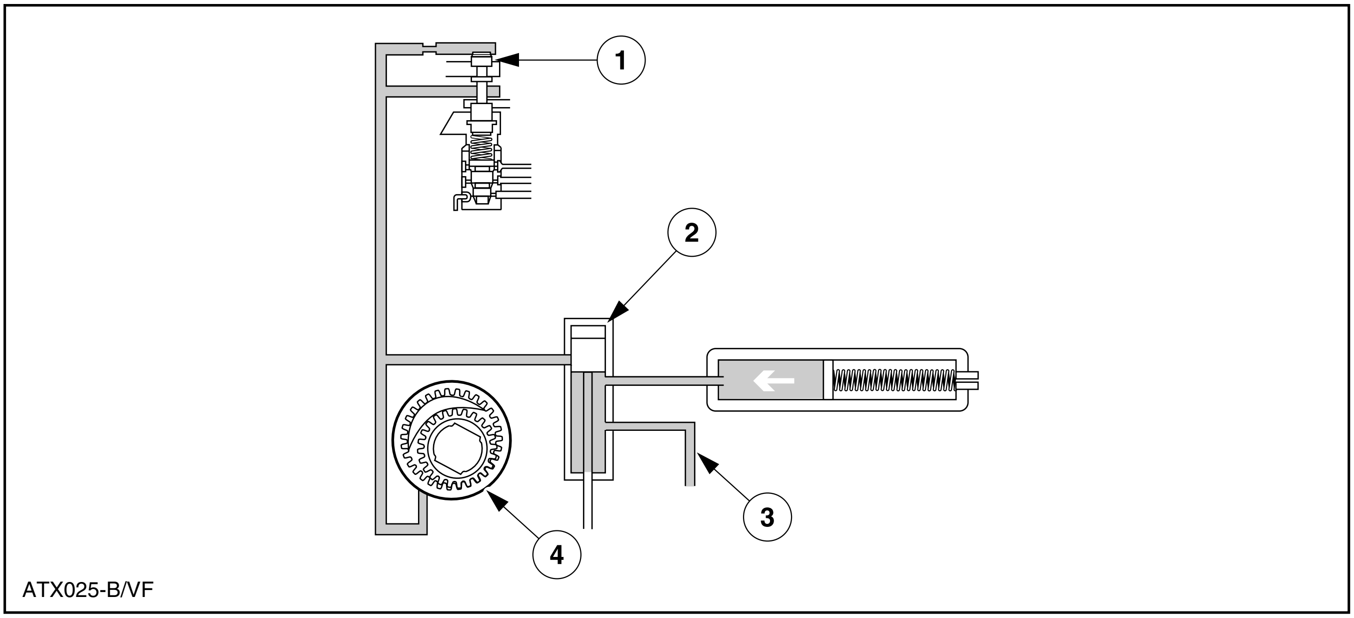
Flow control circuit – valve open

1 Pressure regulator valve
2 Valve open
3 Pressurized fluid in cylinder
4 Piston
5 Pump

If the valve is manually opened, fluid flows into the inlet port, through the bore, and out the exit port on its way to the cylinder.

When the fluid reaches the cylinder, it pushes on the piston surface, forcing it to move the length of the cylinder bore. The force generated by the pump is transferred to the piston.

Flow control (continued)



Flow control circuit – fluid pushed back by spring

1 Pressure regulator valve
2 Valve closed
3 Exhaust port
4 Pump

The oil circuit is functional, but it lacks one important feature: automatic reset. When the pressure is released, the piston does not automatically return to the top of the bore, ready for another stroke. To make the piston reset automatically, a spring is added behind the piston.

With the valve closed and the fluid flow stopped, the spring tension should push the piston back to the top of the cylinder. However, the spring cannot move the piston as long as pressurized fluid is trapped in the cylinder circuit. The spring cannot move the piston until the fluid is drained from the cylinder.

To provide an outlet for draining the pressurized fluid, the circuit must be reworked. Adding an exhaust passage to the sump and offsetting the cylinder passage allows the inlet port to be sealed without trapping fluid in the cylinder.

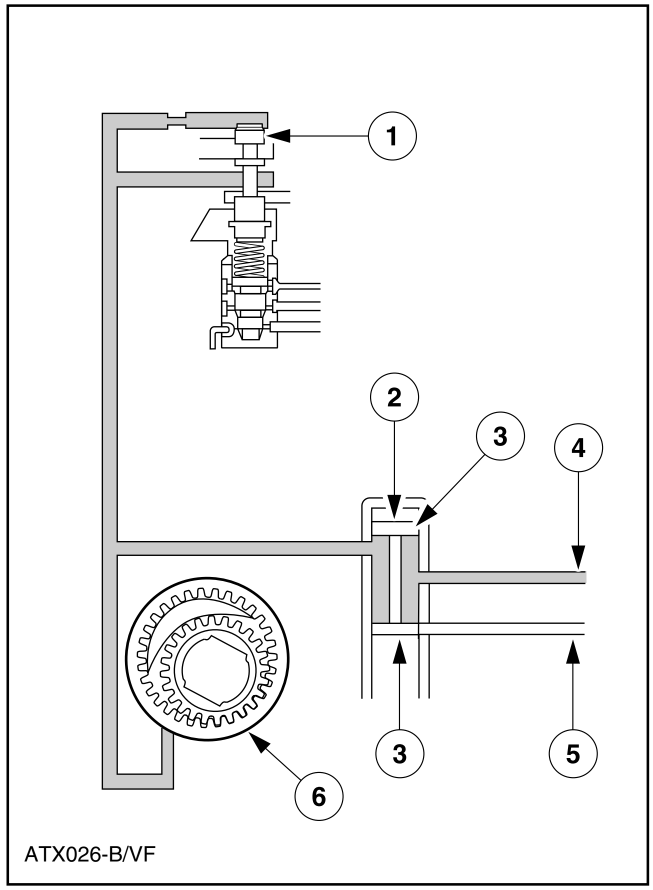
Now the valve can open the inlet port from the pump, as well as the exit port to the cylinder. At the same time, the valve seals the exhaust port to the sump, preventing any pressure loss.

When the valve closes the inlet port, it also opens the cylinder passage to the exhaust port. The fluid drains out of the exhaust port as the spring pushes the piston back through the cylinder.

Spool valve

The spool valve has two or more lands, or sealing areas, connected by a rod, giving the valve a spool shape. The area between the lands allows fluid to flow through the valve bore.

When a spool valve moves, the lands open and close various ports to direct fluid flow. For example, the upper land is at the top of the bore, opening the pump inlet. The lower land seals the exhaust port, allowing fluid to flow through the center of the cylinder bore.



Spool valve circuit

1 Pressure regulator valve
2 Spool valve
3 Valve land (sealing surface)
4 To cylinder
5 To sump
6 Pump

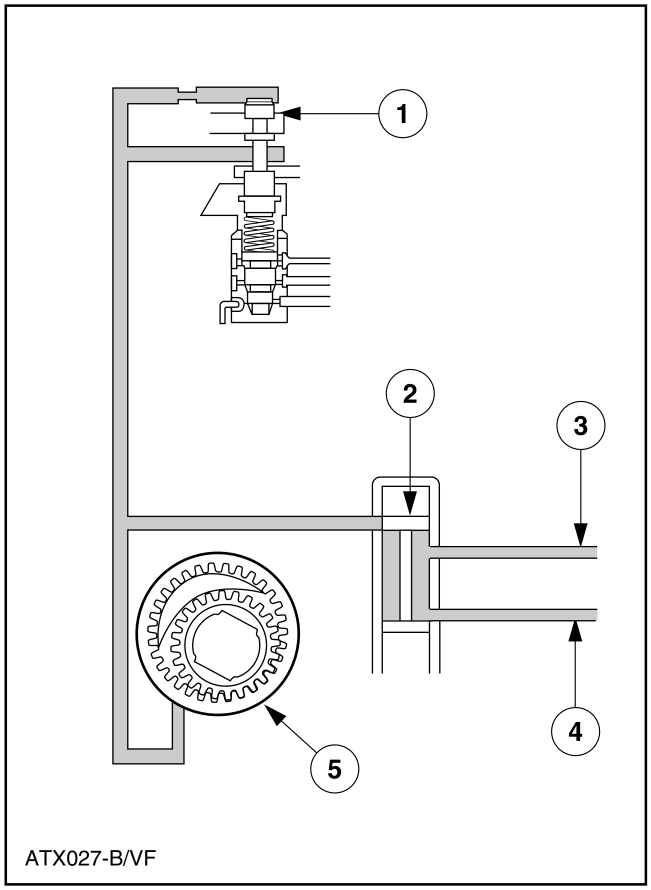
Flow control (continued)

The spool valve closes the pump inlet port and opens the exhaust port. This releases pressurized fluid from the cylinder and allows it to drain through the exhaust port back to the sump.

The valves described in this section illustrate the hydraulic principles that apply to the control valves in an automatic transmission. Pressure can be used to move:

- valves against spring pressure.
- valves back and forth in a bore.
- pistons in a cylinder.

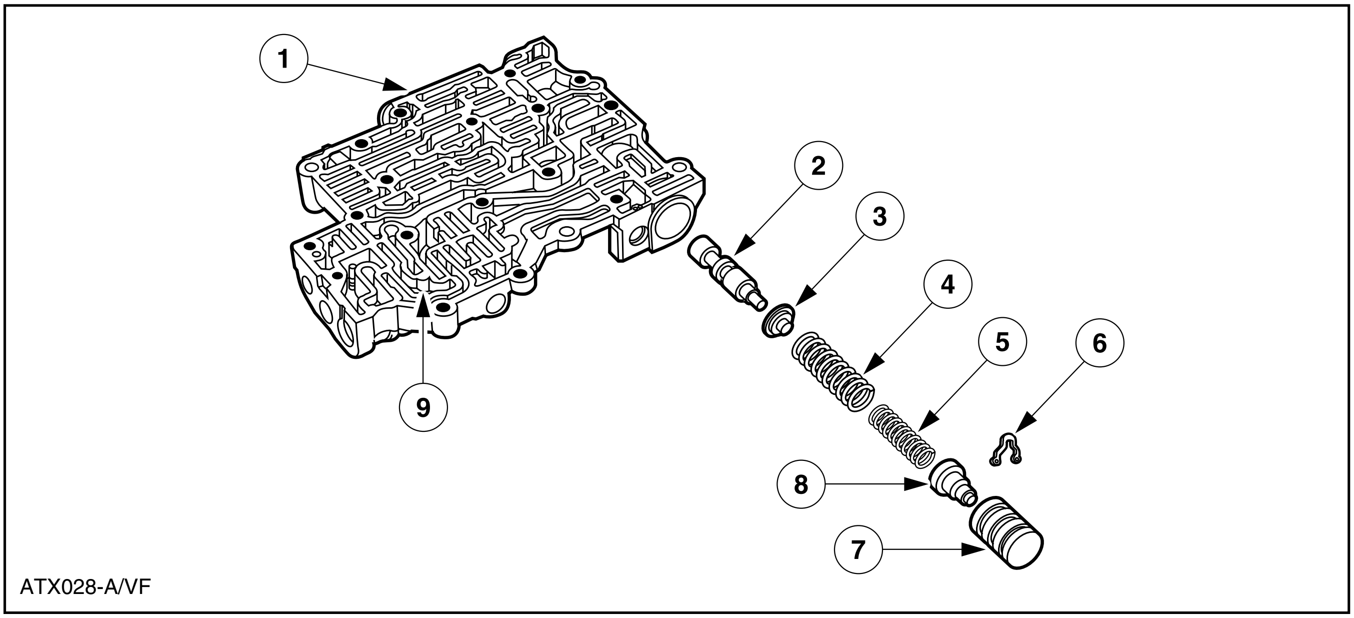
All of these operations occur in an automatic transmission to control fluid flow and maintain line pressure.



Spool valve circuit

1 Pressure regulator valve
2 Spool valve
3 From cylinder
4 To sump
5 Pump

Valve body



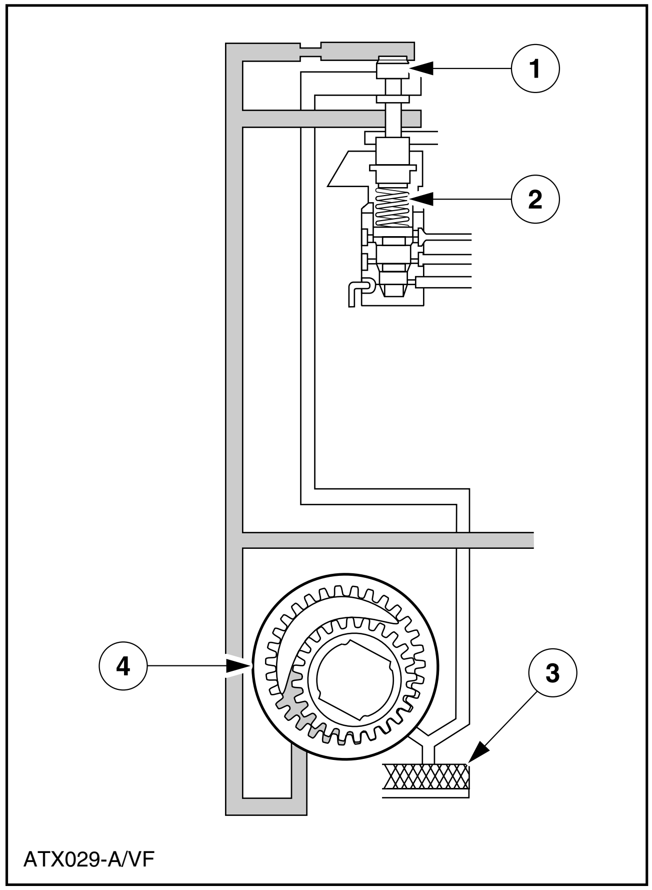
Typical valve body

1 Valve body
2 Pressure regulator valve
3 Spring seat
4 Spring
5 Spring
6 Retaining clip
7 Bore plug
8 Line pressure boost valve
9 Worm tracks

The valve body is the master flow control component for an automatic transmission. It contains a complex pattern of passages called worm tracks, as well as several bores containing multiple-land valves. Each passage, bore, and valve forms an oil circuit for a specific function.

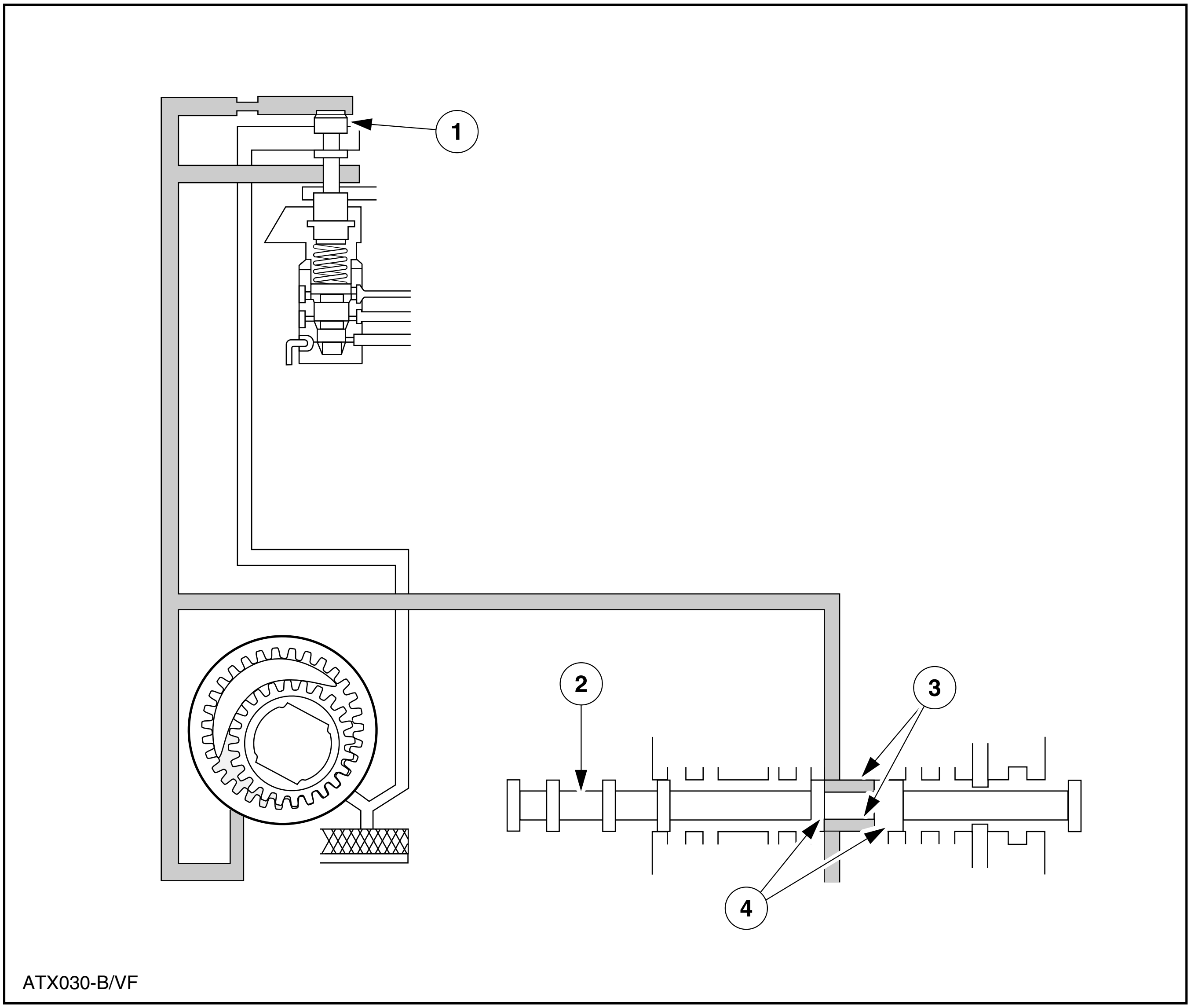
Fluid circuit diagrams

Using a flow diagram, you can trace an oil circuit and determine exactly which valves and passages are used to accomplish a specific transmission function.



Flow diagram – pressure regulator valve

1 Pressure regulator valve
2 Springs
3 Screen
4 Pump



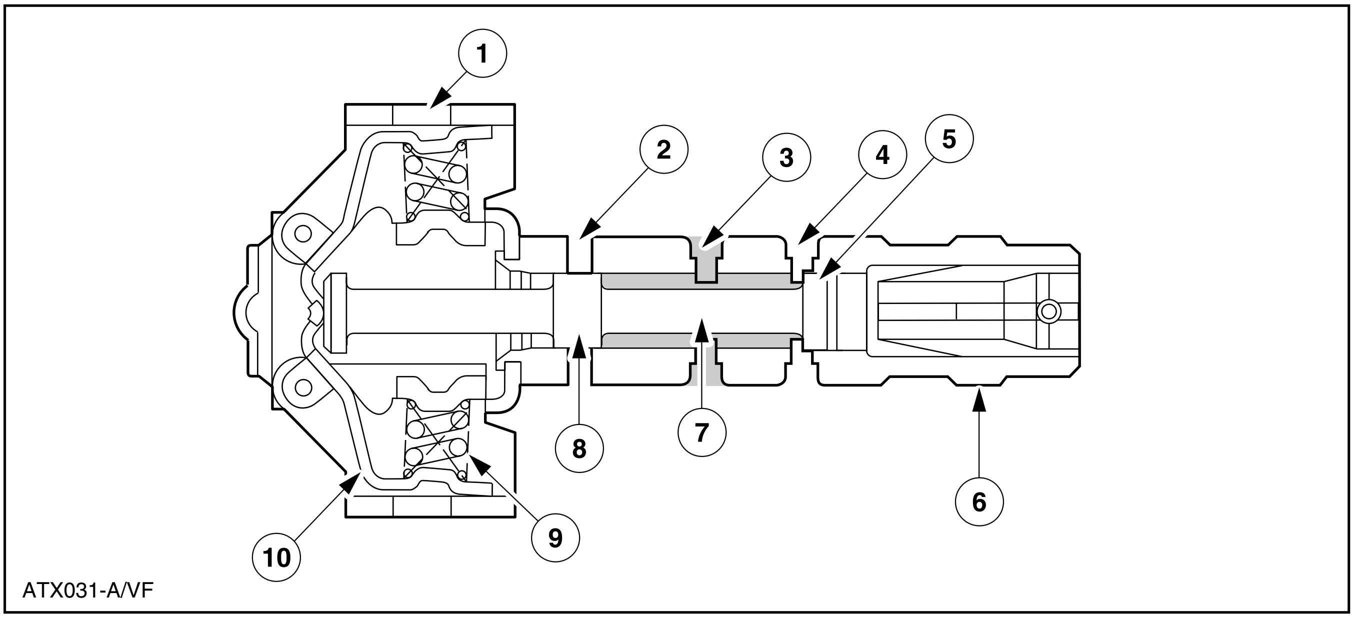
Flow diagram – manual valve

1 Pressure regulator valve
2 Manual valve
3 Trapped fluid
4 Valve lands

If you follow the pump flow away from the pressure regulator, you find the manual valve. This valve is connected through a mechanical linkage to the shift selector in the vehicle's passenger compartment. The manual valve moves in or out of its bore depending on the position of the shift selector (for example: "P," "R," or "D").

The line pressure stops at the manual valve because it is trapped between two lands. In other gear ranges, the valve lands move to redirect the flow to various valves, clutches, and servos.

Governor valve



Typical governor valve

1 Primary weight
2 Exhaust to sump
3 Governor pressure out
4 Line pressure in
5 Inner land
6 Sleeve
7 Governor valve
8 Outer land
9 Valve spring
10 Secondary weight

When the driver moves the shift selector lever to one of the drive positions, another important oil circuit becomes active. The governor valve circuit is used to time the shifts in an automatic transmission.

The governor valve takes the line pressure directed from the manual valve and transforms it into a pressure signal. This signal tells the shift control valves how fast the vehicle is moving. (The shift control valves direct the fluid flow that shifts gears, for example from first to second gear, or from third to second gear.)

In most cases, the governor valve is mounted on the output shaft, where it rotates with the shaft. In front-wheel drive vehicles, the governor is usually driven by gears at the final drive.

The governor assembly consists of a separate small valve body with three passages: one for line pressure, one for governor pressure, and one for exhaust to the sump.

When the vehicle is stopped, the fluid directed to the governor is blocked. As the vehicle begins to move, the governor rotates, and centrifugal force causes the weights to move outward. Depending on the rotation speed, the outward movement of the weights pushes the valve, allowing regulated pressure to enter the governor valve, where it is directed to the shift control valves.

On electronic controlled transmissions, the governor is replaced by a solenoid controlled by the control module.

Throttle valve circuit

To properly time a shift, the automatic transmission has to “know” more than just road speed. It also has to know what load the engine is under. Load refers to the amount of force the engine must overcome to generate power. For example, a vehicle going up a steep hill at 64 km/h (40 mph) places a heavier load on the engine than the same vehicle going down the hill at 40 miles per hour. In addition, running the air conditioning system at full power can also place a heavy load on the engine.

In an automatic transmission, the throttle valve (TV) circuit determines the engine load, transforms it into a pressure signal, and directs the signal to the shift control valves. Governor pressure could be used to signal all shifts, but the shifts would always occur at the same road speed and would not vary according to engine load.

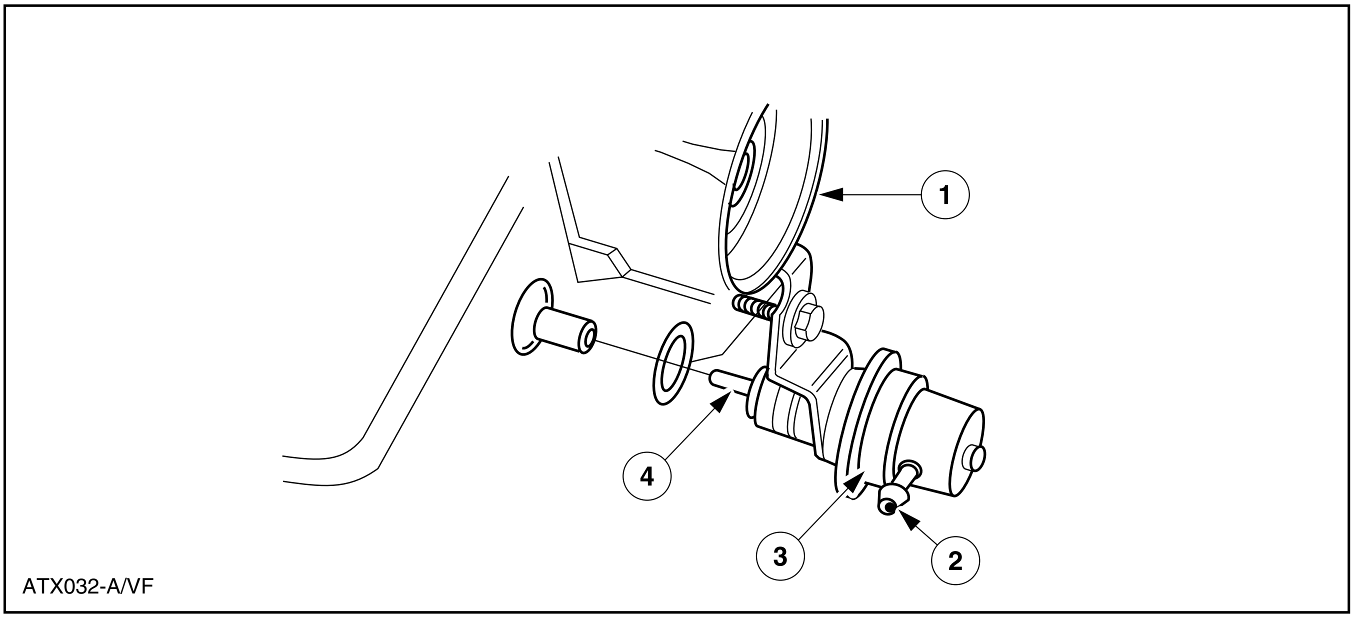
For example, during rapid acceleration, the engine is under a heavy load, and the transmission should remain in first gear longer to take advantage of the extra pulling power available in the lower gear ratio. If the governor circuit alone were controlling the shifts, the transmission would shift into second at a pre-determined road speed, and acceleration would slow dramatically. With the throttle valve and governor circuits working together, the transmission matches gear shifts to engine speed and load.

Throttle pressure also modifies line pressure. At idle, pressure is minimal to reduce “shift shock” when the gears engage. At full throttle, pressure is maximum so that clutches are squeezed tightly, preventing slippage.

Two types of throttle valve circuits are used in most vehicles. The first type “reads” engine load via a vacuum modulator. Vacuum is “negative pressure” generated by the engine when the pistons move down in their cylinders during the intake stroke. Vacuum decreases with the load placed on the engine. The second type of throttle valve circuit determines engine load through a mechanical linkage to the accelerator pedal.

On electronic controlled transmissions, the throttle value is replaced by solenoids and controlled by the control module.

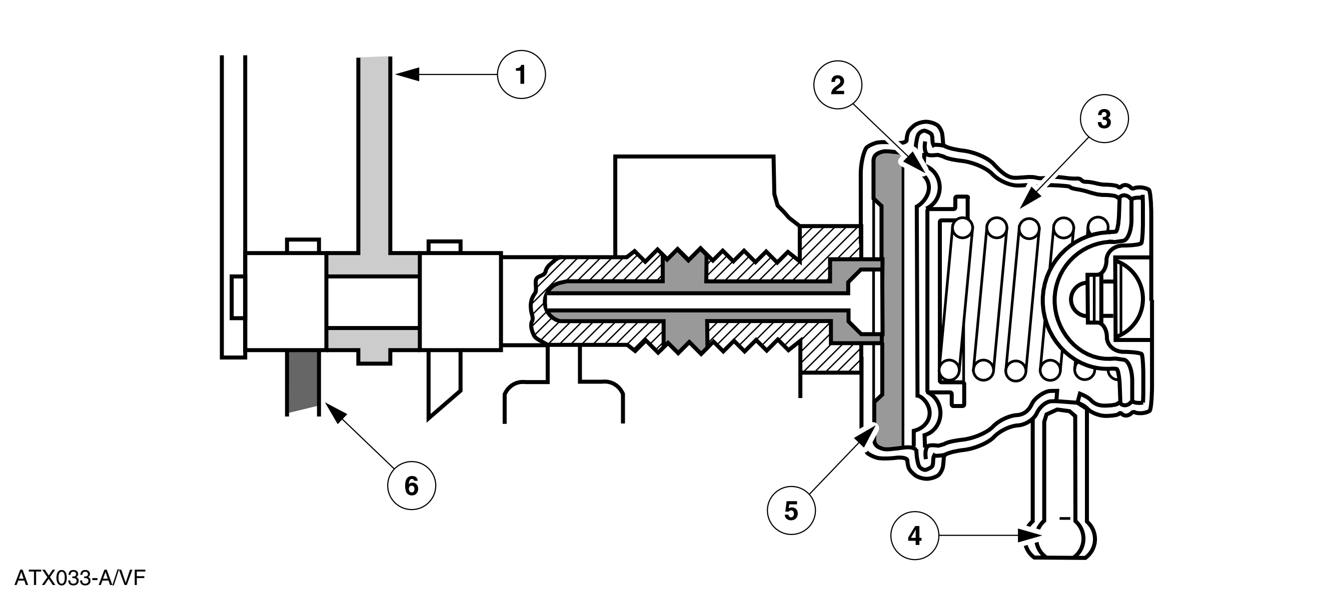
Vacuum modulator



Typical vacuum modulator valve

1 Main case
2 To engine vacuum
3 Vacuum modulator
4 Pin

When vacuum is used to determine load, a vacuum modulator is mounted on the valve body case.



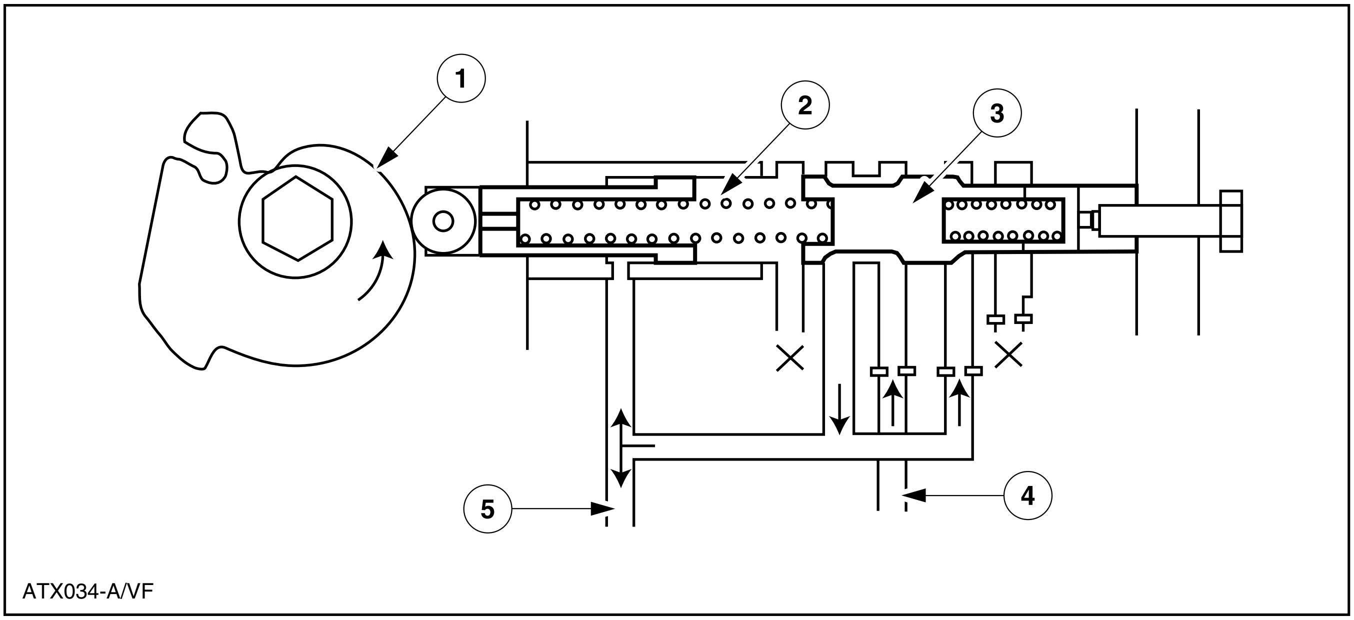
Vacuum modulator valve operation

1 Throttle pressure
2 Diaphragm
3 Manifold vacuum
4 To engine vacuum
5 Atmospheric pressure
6 Throttle valve (case)

The vacuum modulator contains two chambers separated by a spring-loaded diaphragm. A hose or tube connects one side of the diaphragm to the engine's intake manifold. The other side of the diaphragm is connected to a rod that extends into the valve body case.

As engine load varies, so does the vacuum in the intake manifold, and the diaphragm moves in and out with these variations. The movement of the diaphragm is transferred to the rod, which moves a valve in the throttle valve circuit. This valve constantly alters the pressure in the throttle valve circuit, which redirects pressure to the shift control valves.

Throttle valve



Typical throttle valve

1 Throttle cam
2 Spring
3 Throttle valve
4 Line pressure (from pressure regulator valve)
5 Throttle pressure (to throttle pressure modulator valve)

In a throttle valve circuit controlled by mechanical linkage, a throttle cam transfers the motion of the accelerator pedal to the throttle valve.

The throttle cam is mechanically linked to the accelerator pedal. When the pedal is pressed, the cam turns, moving the spring. The spring pushes the throttle valve to the right, opening the line pressure passage. This increases pressure to the throttle modulator valve.

As throttle pressure rises, it causes the spring to compress, moving the throttle valve back to the left. The line pressure port is closed, and throttle pressure drains. When throttle pressure falls, the spring again pushes the throttle valve to the right, opening the line pressure port and increasing throttle pressure. By repeating this cycle, the throttle valve constantly adjusts throttle pressure.

When the accelerator pedal is released, the cam turns in the opposite direction, releasing the spring. The throttle valve moves back to the left, closing the line pressure port, which decreases throttle pressure.

Throttle and governor pressures

Pressure from two separate circuits influences shift timing: throttle pressure, which is based on engine load; and governor pressure, which is based on road speed.

Each of these circuits receives line pressure from the pump and modifies it into a pressure signal. The modified pressures developed in the throttle and governor circuits exert force on the shift control valves, just as fluid forced the piston to move in the sample circuit described previously in this section.

Working with line pressure, the modified pressures from the governor and throttle circuits control the valves that automatically shift gears to match engine load and road speed. The valves in the valve body control fluid flow through circuits that connect line pressure to the various bands and clutches that control shifting.

Objectives

Upon completion of this lesson, you will be able to:

- Identify the components in a hydraulic multiple-disc clutch and describe their functions.
- Identify the components of a band and servo assembly and describe their functions.
- Describe the purpose of accumulator and modulator valves in the hydraulic control system.

Clutches and bands

When an automatic transmission shifts gears, various gear train components must rotate, while other components are prevented from rotating. This section describes how clutches and bands drive and hold gear train members in an automatic transmission.

Clutches and bands perform opposite but complementary functions in an automatic transmission. Clutches drive gear train members, forcing them to rotate. Bands, on the other hand, hold gear train members, preventing them from rotating.

Clutch overview

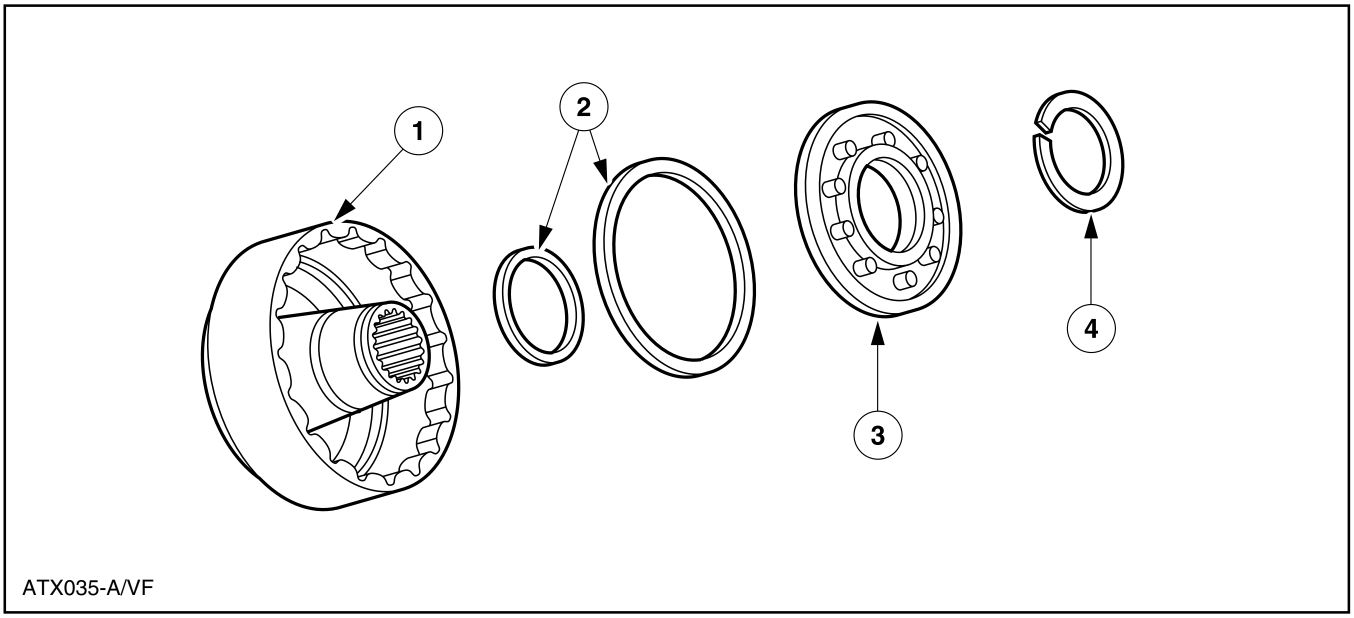
The clutch in an automatic transmission is similar to a manual clutch in that it connects and disconnects the engine from the transmission. If you turn the input shaft on an automatic transmission with the clutch released, the output shaft does not turn. But if you apply the clutch and turn the input shaft, the output shaft turns because the clutch forms a mechanical link between the two shafts.

Band overview

Instead of connecting two rotating parts, a band holds a component and prevents it from rotating. When a band is hydraulically applied, it clamps around a drum and keeps it from turning. The band is anchored to the transmission case, and its clamping force is strong enough to prevent the drum from rotating.

Multiple-disc clutch

Clutch housing and piston



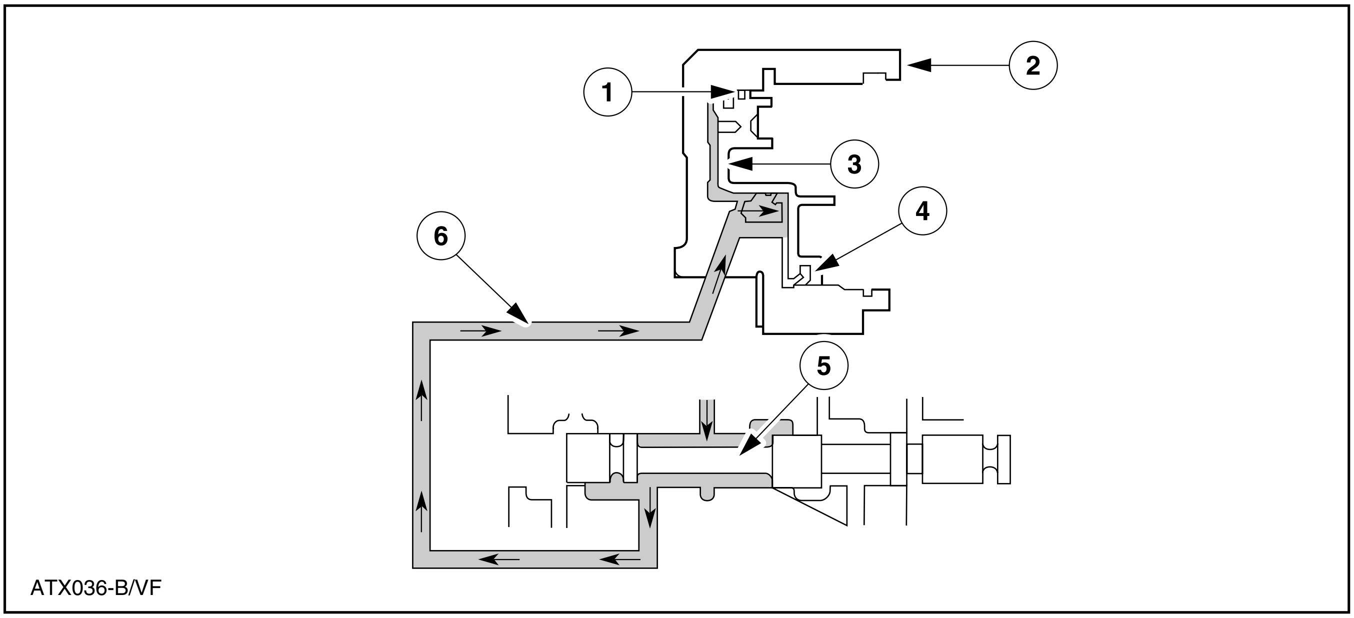
Typical clutch housing and piston

1 Clutch housing
2 Piston seals
3 Piston
4 Snap ring

Automatic transmissions use a multiple-disc clutch. The clutch assembly is made of several circular discs that work together to connect and disconnect the engine from the transmission.

Since the multiple-disc clutch is hydraulically operated, it includes a piston that moves back and forth in a clutch housing, or drum, when pushed by pressurized fluid. The piston and clutch housing are protected by seals that provide leak-proof surfaces between the piston and housing. A snap ring limits the amount of piston travel. Without the snap ring, the pressurized fluid would “blow” the piston completely out of the clutch housing.

Clutch apply circuit



Hydraulic apply circuit

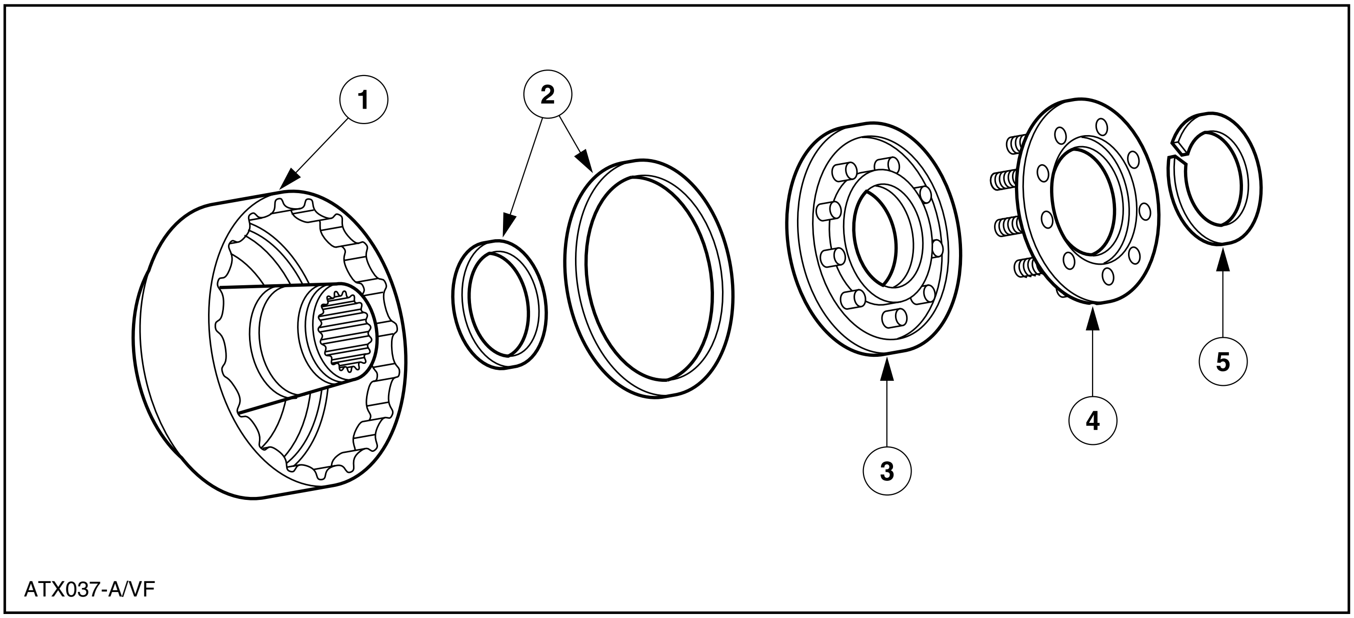
1 Piston seal (outer)
2 Clutch housing
3 Piston
4 Piston seal (inner)
5 Manual valve
6 Line pressure

To provide hydraulic flow to the clutch housing, a passage connects line pressure from the valve body to the housing.

The valve body controls fluid flow to the clutch housing. When the engine is running, fluid from the pump flows through the valve body into the clutch housing, where it pushes on the piston.

Multiple-disc clutch (continued)

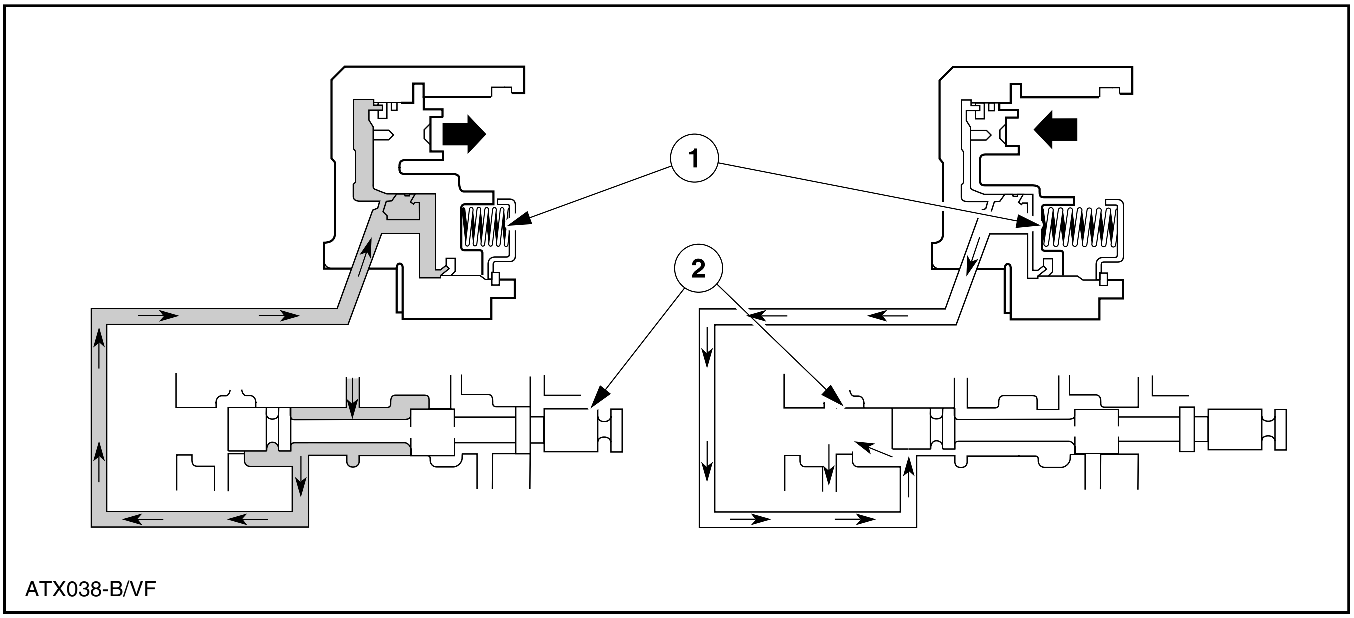
Clutch return spring



Typical clutch drum and return spring

1 Clutch housing
2 Piston seals
3 Piston
4 Piston return spring assembly
5 Snap ring

To automatically reset the piston, the clutch assembly includes return springs.



Manual valve circuit

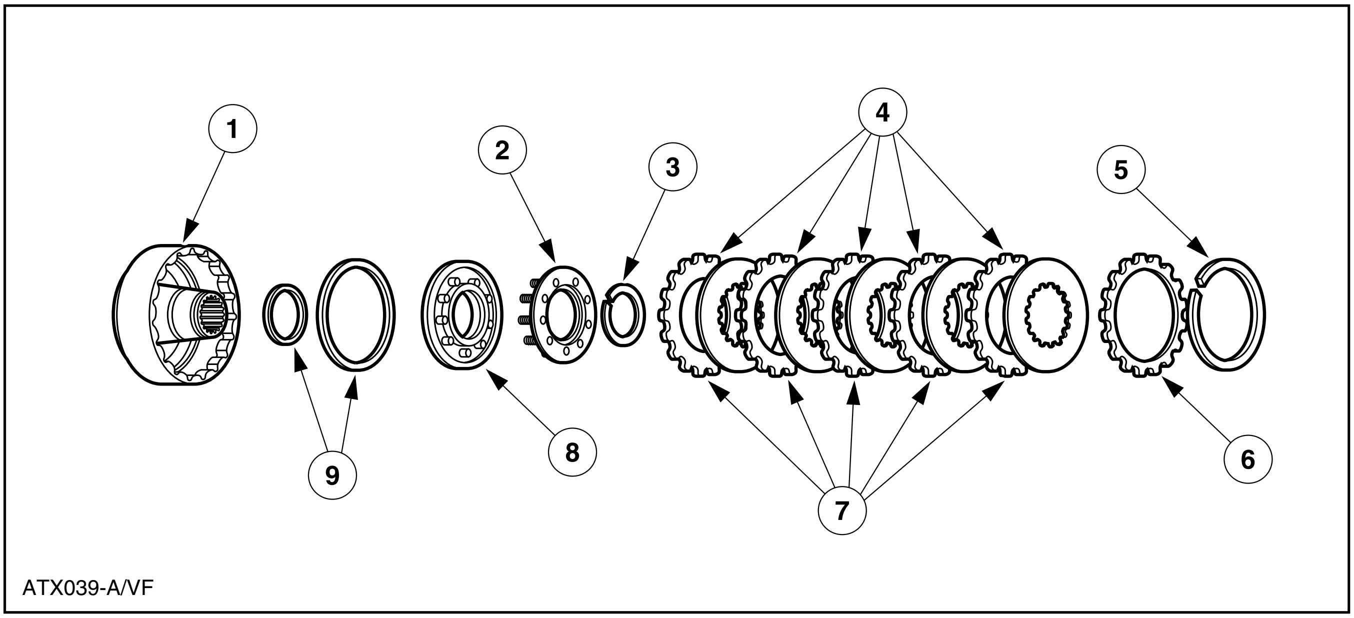
1 Piston return spring assembly

2 Manual valve

When fluid flow is cut off to the clutch housing, the springs push the piston back into the housing, and the fluid exhausts back through the circuit. Movement of the manual valve applies and releases the clutch piston.

Multiple-disc clutch (continued)

Clutch pack

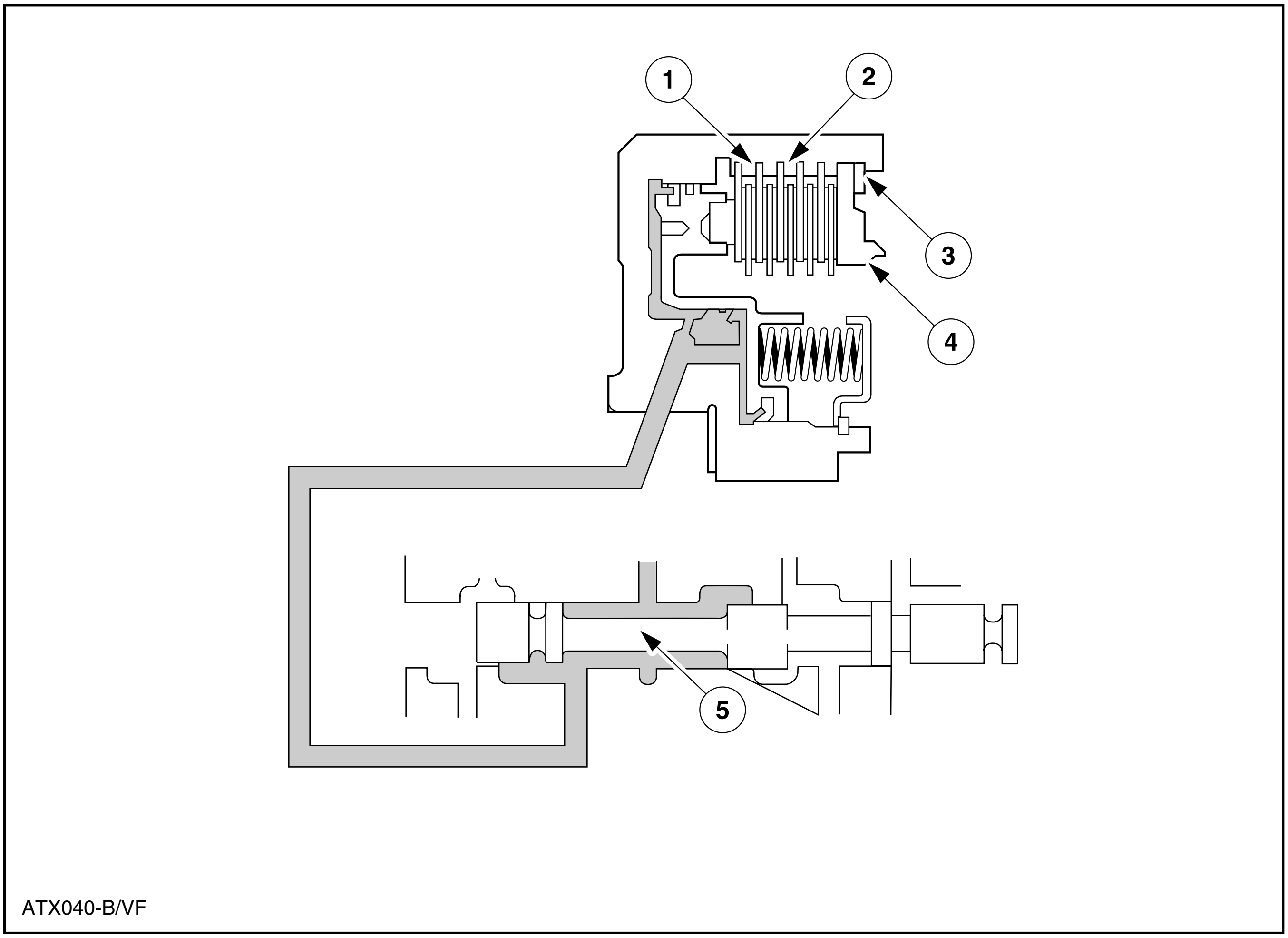


Typical clutch pack assembly

1 Clutch housing
2 Return spring
3 Snap ring
4 Steel plates
5 Snap ring
6 Pressure plate
7 Friction plates
8 Piston
9 Seals

To make the clutch functional, a clutch pack is installed behind the spring assembly. A clutch pack is a set of discs made up of two different types of plates. One set of plates is made of steel, with tabs on the outer diameter. The other plates are covered with a friction material similar to brake lining. These friction plates also have splines on their inner diameters.

The tabs on the steel plates fit into grooves machined into the inside diameter of the clutch housing. So when the clutch housing rotates, the steel plates also turn. The friction plates, on the other hand, are not directly connected to the clutch housing. They do not rotate with the clutch housing unless they press tightly against the steel plates.



Pressure plate cut-away

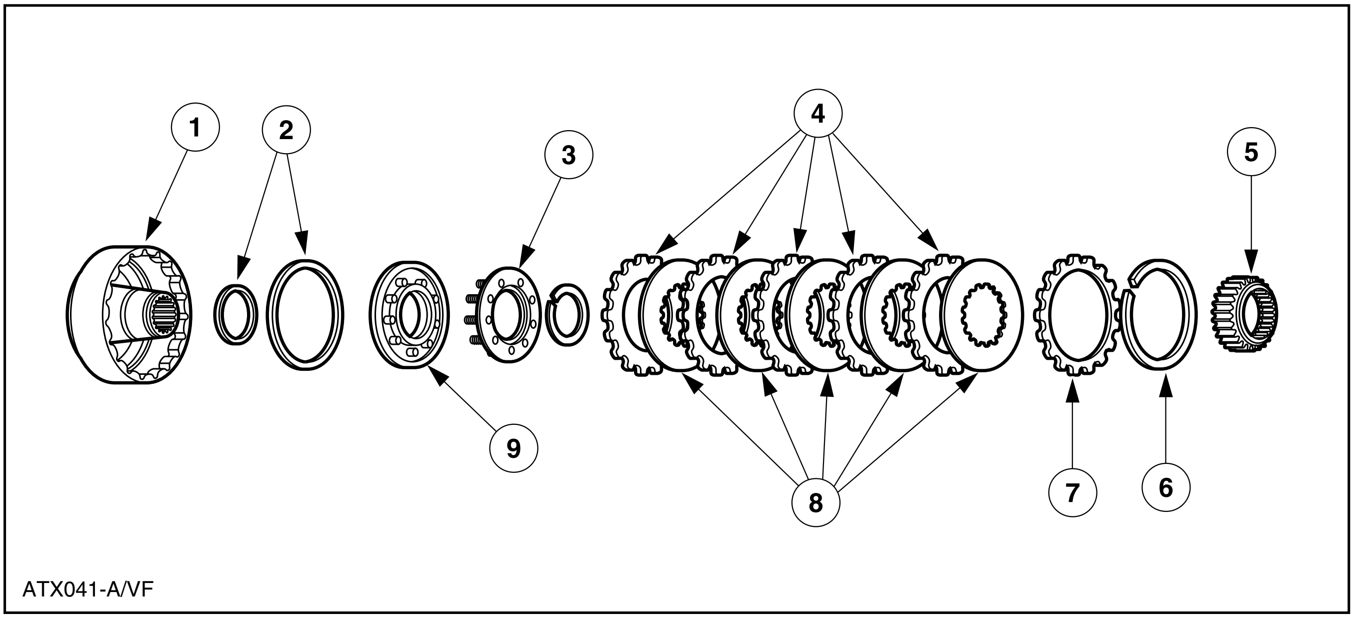
1 Steel plates
2 Clutch pack
3 Snap ring
4 Pressure plate
5 Manual valve

The clutch pack alternates steel plates and friction plates. The last plate in the stack is the pressure plate. It is thicker than the other steel plates so it strengthens the clutch pack. The pressure plate also keeps the clutch pack from bending when the piston is applied. The snap ring on the end of the clutch pack holds the plates in the clutch housing.

The clutch assembly mounts on the transmission input shaft, where splines on the inside diameter of the clutch housing mesh with splines on the input shaft. Since the input shaft is linked to the crankshaft through the torque converter, the clutch housing rotates when the engine is running.

Multiple-disc clutch (continued)

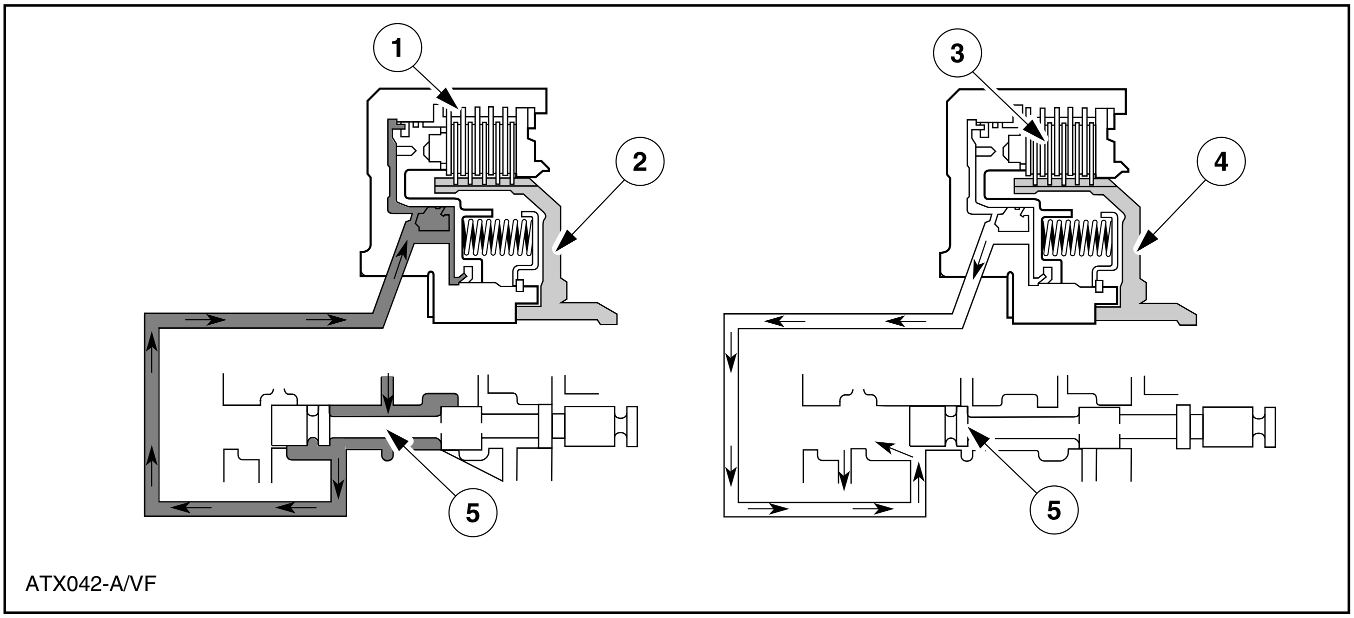
Clutch hub



Typical clutch hub assembly

1 Clutch housing
2 Piston seals
3 Return springs
4 Steel plates
5 Clutch hub
6 Snap ring
7 Pressure plate
8 Friction plates
9 Piston

The final component required to make the clutch functional is the clutch hub. The clutch hub is a smaller disc that fits inside the plates in the clutch pack. The hub has both external and internal splines. The external splines on the clutch hub match the splines on the inside diameter of the friction plates.

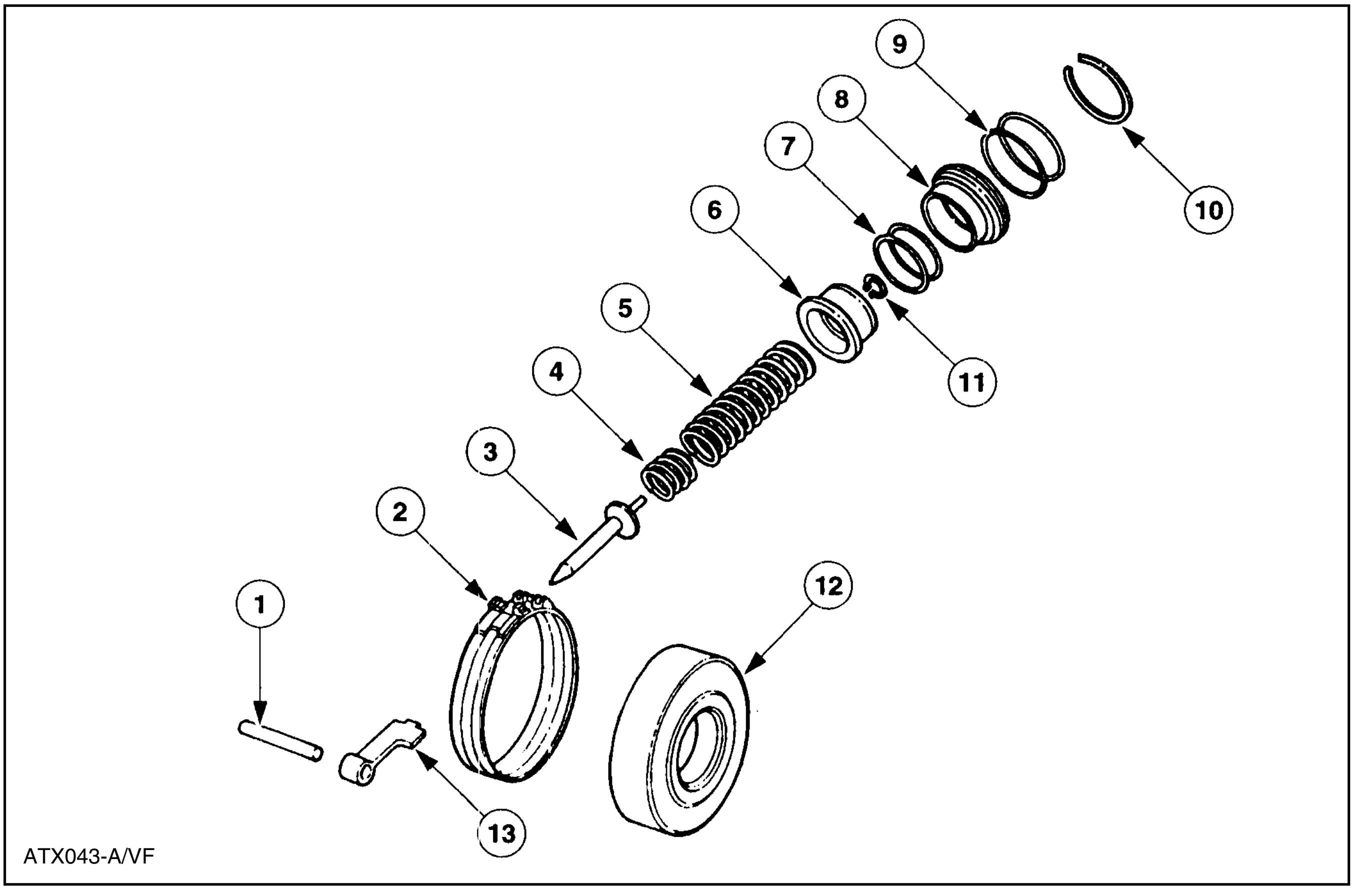


Clutch and hub cut-away

1 Friction plate, stationary
2 Clutch hub, stationary
3 Friction plate, rotating
4 Clutch hub, rotating
5 Manual valve

When fluid flow to the clutch housing is cut off, the piston moves back in the clutch housing and the clutch releases. The friction plates do not rotate since they are not connected to the clutch housing. Because the hub is splined to the friction plates, it also remains stationary.

Bands and servos



Typical band and servo assembly

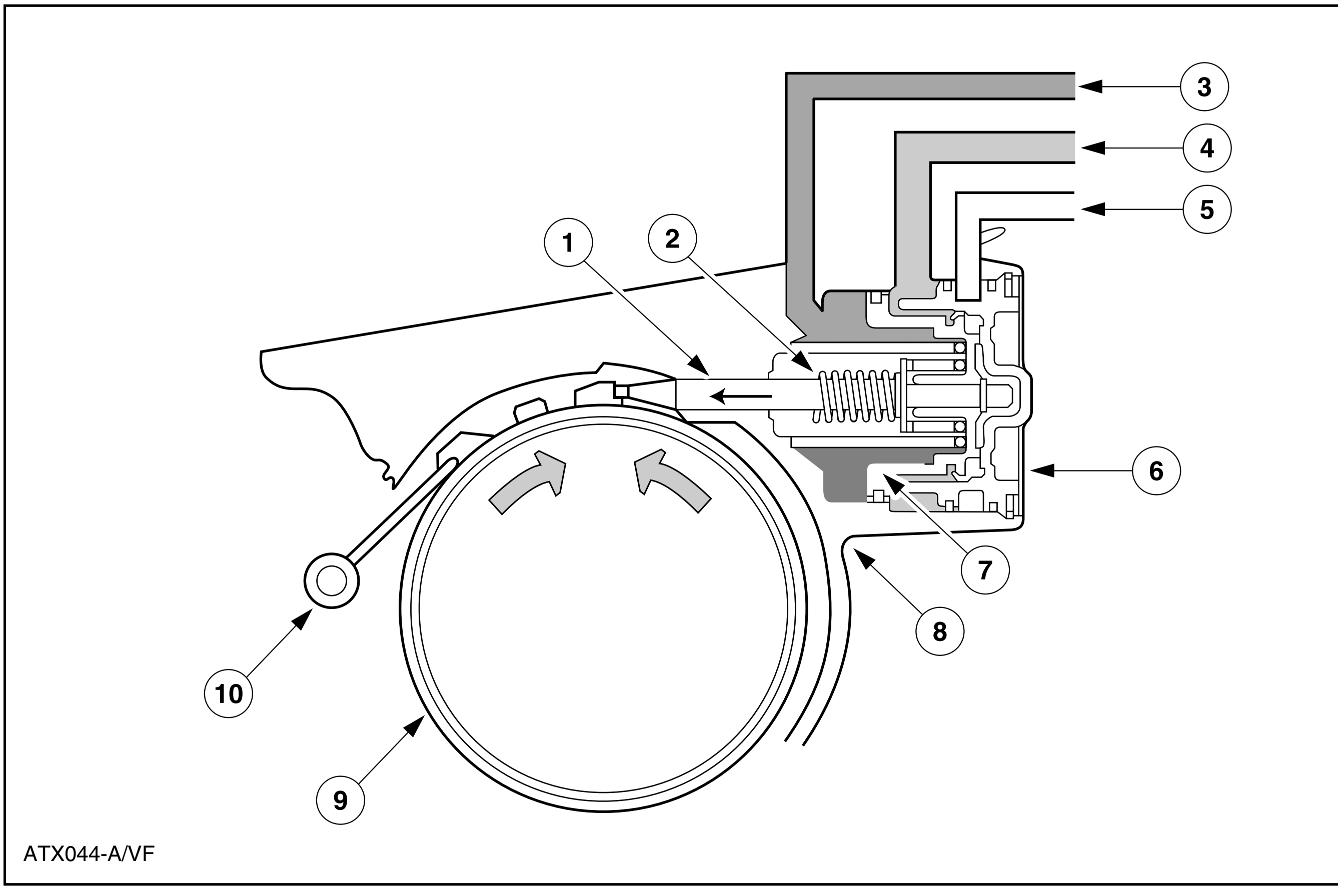
1 Pin
2 Band
3 Piston rod
4 Cushion spring
5 Return spring
6 Piston
7 Piston seals
8 Servo cover
9 Cover O-rings
10 Retainer snap ring
11 Snap ring
12 Drum and gear assembly
13 Anchor strut

The hydraulic system either holds or drives gear train components to provide the different gear combinations required in an automatic transmission. While clutches drive gear train components, bands are used to hold them.

The held member of a gear set is mechanically connected to a drum, with the band surrounding the drum. Friction material covers the inside surface of the band, allowing the band to grip the drum surface and prevent it from turning.

One end of the band is anchored to the transmission case, while the other end connects to a hydraulic device called a servo. A servo is a hydraulically applied piston.

Band operation



Typical band applied

1 Piston rod
2 Return spring
3 Release passages
4 Boost passage
5 Apply passage
6 Cover
7 Piston
8 Servo assembly
9 Band
10 Anchor strut

A case contains the servo, its springs, and hydraulic passages. A rod extends from the servo piston to the free end of the band. To squeeze the ends of the band together, hydraulic pressure pushes the servo piston through the bore. This motion forces the piston rod against the end of the band, squeezing the band around the drum. When pressure is released, the return springs move the piston back into the bore, and the band releases the drum.

When the servo has to provide an extremely tight grip on the band, the hydraulic system opens an additional passage on the applying side of the piston. This additional force, or boost pressure, holds the drum against the stronger torque generated by lower gears.

To release the band quickly, hydraulic pressure and spring tension work together. A shift valve in the valve body moves to open a “release” port. This port allows fluid to push against the release side of the piston while fluid is also present on the apply side. Because the release pressure side has a larger surface area than the apply side, it can overcome the apply pressure.

Purpose of accumulators and modulators

If the various oil circuits are traced, accumulator pistons, modulator valves, and accumulator valves are connected to the clutch and band circuits. These hydraulic controls "fine-tune" fluid flow to the various circuits so the amount of apply pressure matches the amount of torque directed through the transmission.

When the engine is operating with light throttle, a small amount of torque passes through the transmission, so the apply pressures can be reduced. With heavy throttle, engine torque increases greatly, so the hydraulic apply pressures are also increased.

If apply pressure does not match engine torque, the transmission does not operate smoothly. For example, high apply pressure at low torque causes harsh shifting, which may damage transmission components. On the other hand, low apply pressure with high torque causes slow engagement and slipping of transmission components. Excessive slipping produces heat, which can burn the friction material applied to many transmission parts.

The transmission regulates apply pressures in three different ways. First, modulator valves control, or modulate, line pressure by restricting flow (and pressure) through their outlet ports. Second, accumulator valves "cushion" the amount of apply pressure. Finally, accumulator pistons absorb some of the fluid pressure applied to servo pistons.

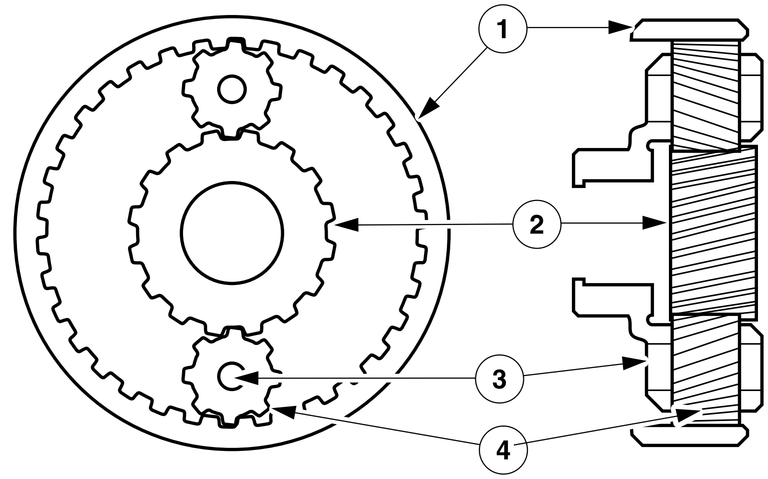
Accumulator and modulator valves are located in the valve body. Accumulator pistons may be part of the servo piston assembly, or they may reside in their own bores.

Objectives

Upon completion of this lesson, you will be able to:

- Identify the components in a basic planetary gear set and describe their operation.
- Describe the basic differences between a simple (Simpson) gear train and a compound (Ravigneaux) gear train.
- Describe powerflow in a simple (Simpson) gear train.

Purpose of a planetary gear set



Simple planetary gear set

1 Ring gear
2 Sun gear
3 Planet carrier
4 Planet gears (pinions)

The gear train in an automatic transmission transmits engine torque from the input shaft to the output shaft. The gear train includes a planetary gear set that provides the gear ratios required to move the vehicle. This section describes how planetary gear sets work, and describes two different types of planetary gears.

A planetary gear set gets its name from the arrangement of the gears in the set. The gears revolve around a central gear in the same way that the planets in the solar system revolve around the sun. In fact, the revolving gears are called planet gears (or pinion gears), and the central gear is called the sun gear.

A typical planetary gear set has the sun gear at the center. Around the sun gear is a ring with gear teeth cut into its inside diameter. This ring is the ring (or internal) gear.

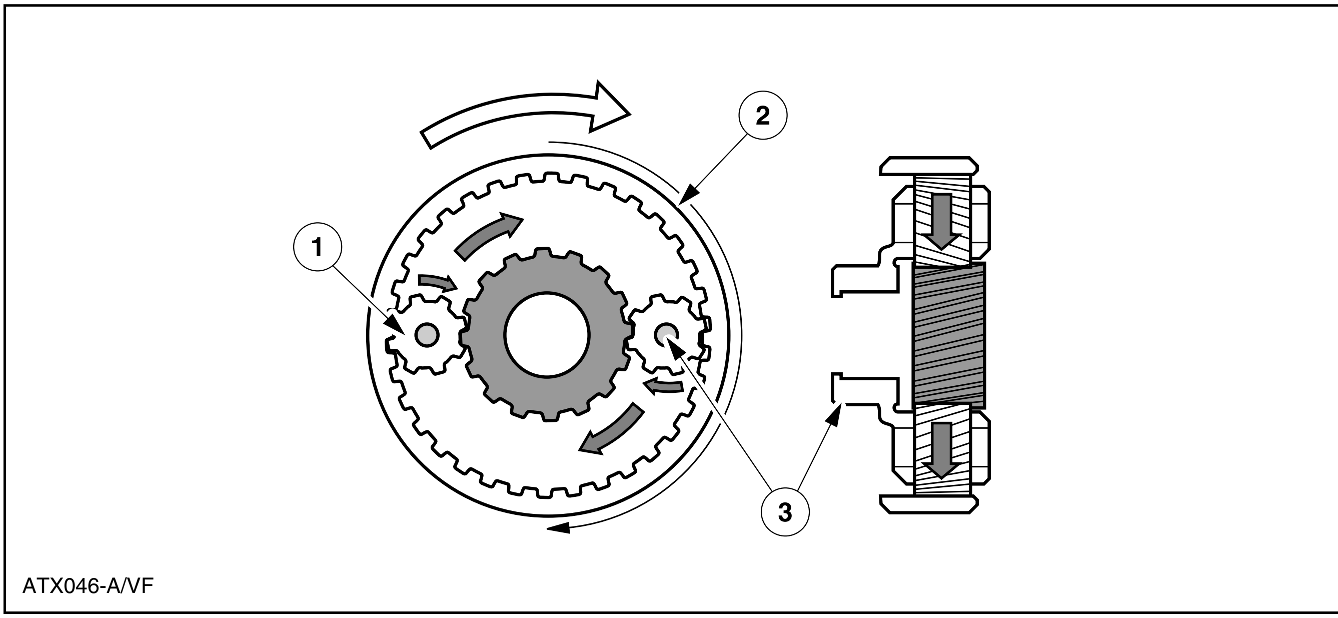
The planet gears connect the sun gear to the ring gear. The teeth on the planet gears mesh with both the sun gear and the ring gear. The planet gears are mounted on shafts that are interconnected through the planet carrier.

Therefore, a planetary gear set includes three members: the sun gear, the planet carrier, and the ring gear. By holding or driving the members in various combinations, a planetary gear set can produce three basic types of gear ratios:

- Reduction (low gear)
- Direct drive (high gear)
- Reverse

A compound, or Ravigneaux, gear set can produce an additional gear ratio called overdrive, which is described later in this section.

Reduction



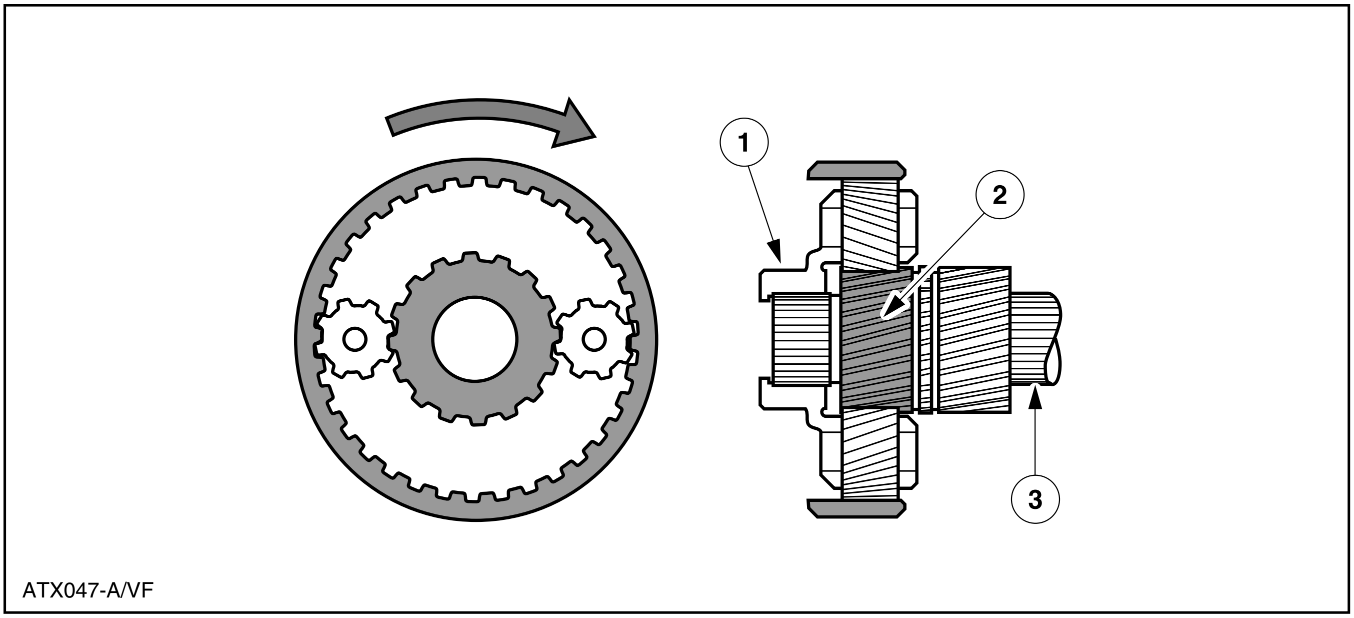
Planetary gear set in reduction

1 Planet gears “walk” around sun gear
2 Ring gear is driven
3 Planet carrier rotates

Reduction refers to the operation of lower gear ratios, where the output shaft turns slower than the input shaft. A vehicle accelerating from a stop begins in low gear so that engine speed can be transferred smoothly to the drive wheels of the vehicle.

When the sun gear is held and the planet carrier drives the ring gear, rotation of the ring gear makes the planet gears “walk” around the sun gear in the same direction the ring gear is turning. However, the planet gears turn slower than the ring gear, reducing the rotation speed of the output shaft.

Direct drive

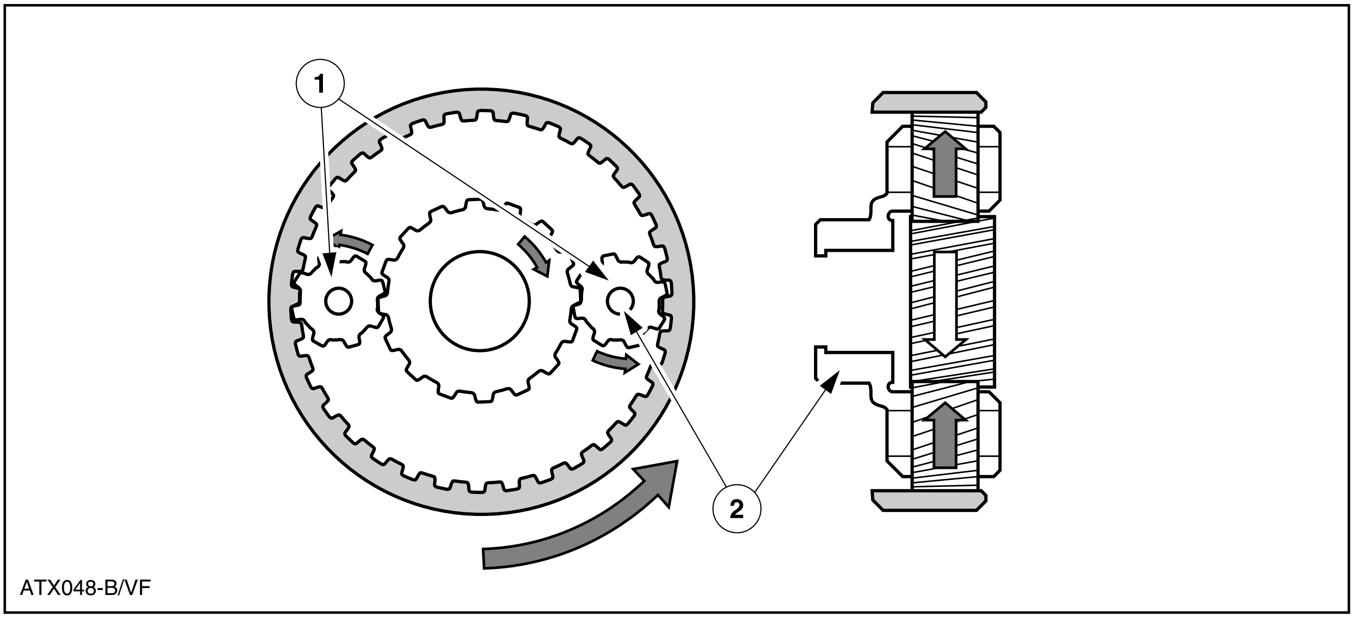


Planetary gear set direct drive

1 Planet carrier
2 Sun and ring gears are locked
3 Output shaft

In direct drive, the input and output shaft turn at the same speed. To achieve direct drive, any two members of the planetary gear set are held, forcing the set to turn as a single unit. In this illustration, the ring gear and sun gear are held, and the planet carrier applies direct drive to the output shaft.

Reverse



Planetary gear set in reverse

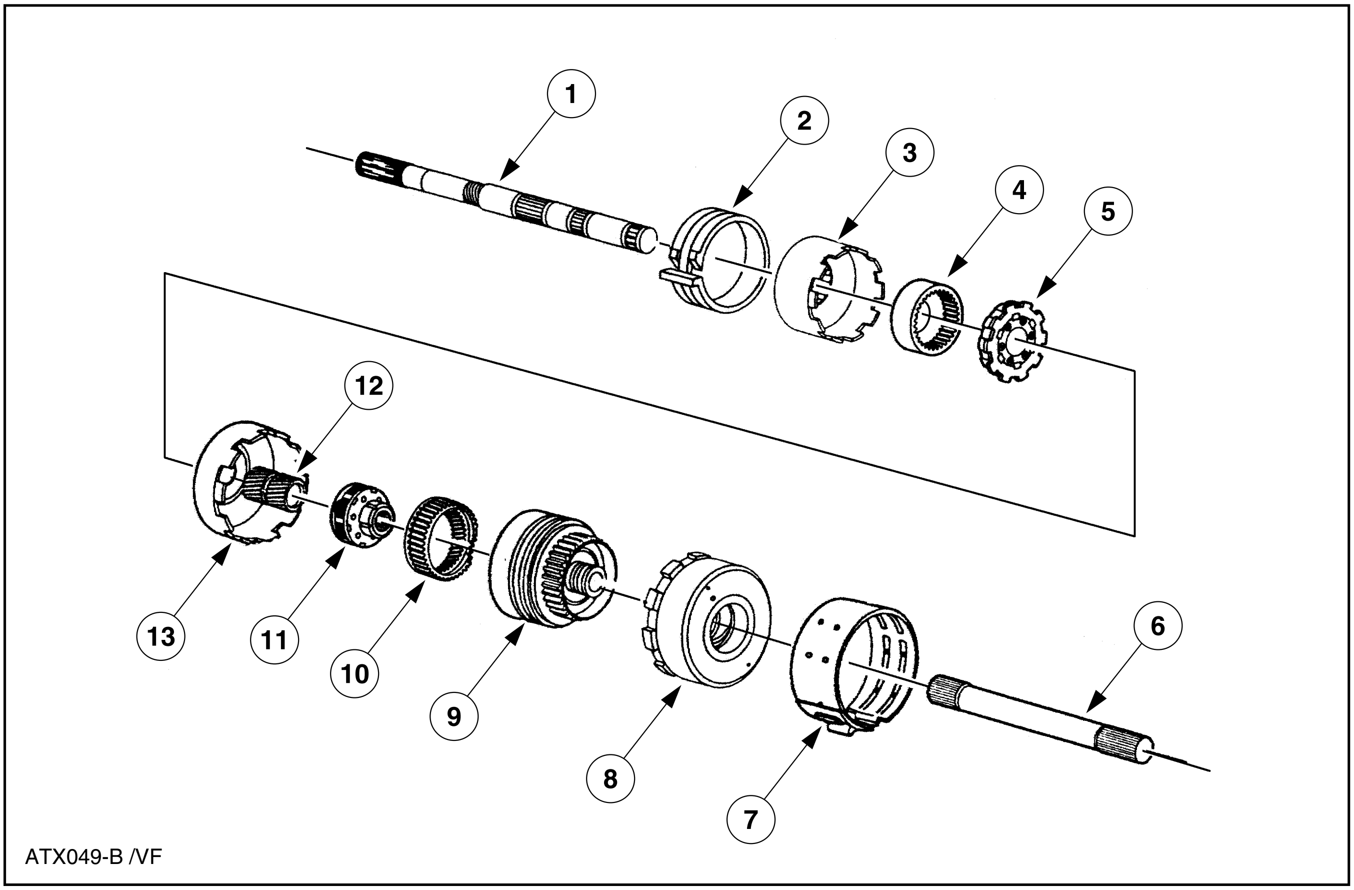
1 Planet gears turn counterclockwise

2 Planet carrier is held

To produce reverse output, the planet carrier is held and the sun gear is driven. In this situation, the planet gears simply turn on their shafts, acting as idler gears. An idler gear reverses the direction of rotation.

For example the sun gear rotates clockwise, while the planet carrier is held. This forces the planet gears to turn counterclockwise, which also causes the ring gear to turn counterclockwise.

Simple and compound gear trains



Simpson gear train exploded view

1 Output shaft
2 Low/reverse band
3 Low/reverse drum and one-way clutch
4 Output shaft ring gear
5 Reverse planet assembly
6 Input shaft
7 Intermediate band
8 Reverse/high clutch and drum
9 Forward clutch
10 Forward clutch hub and ring gear
11 Front planet assembly
13 Input shell
12 Sun gear

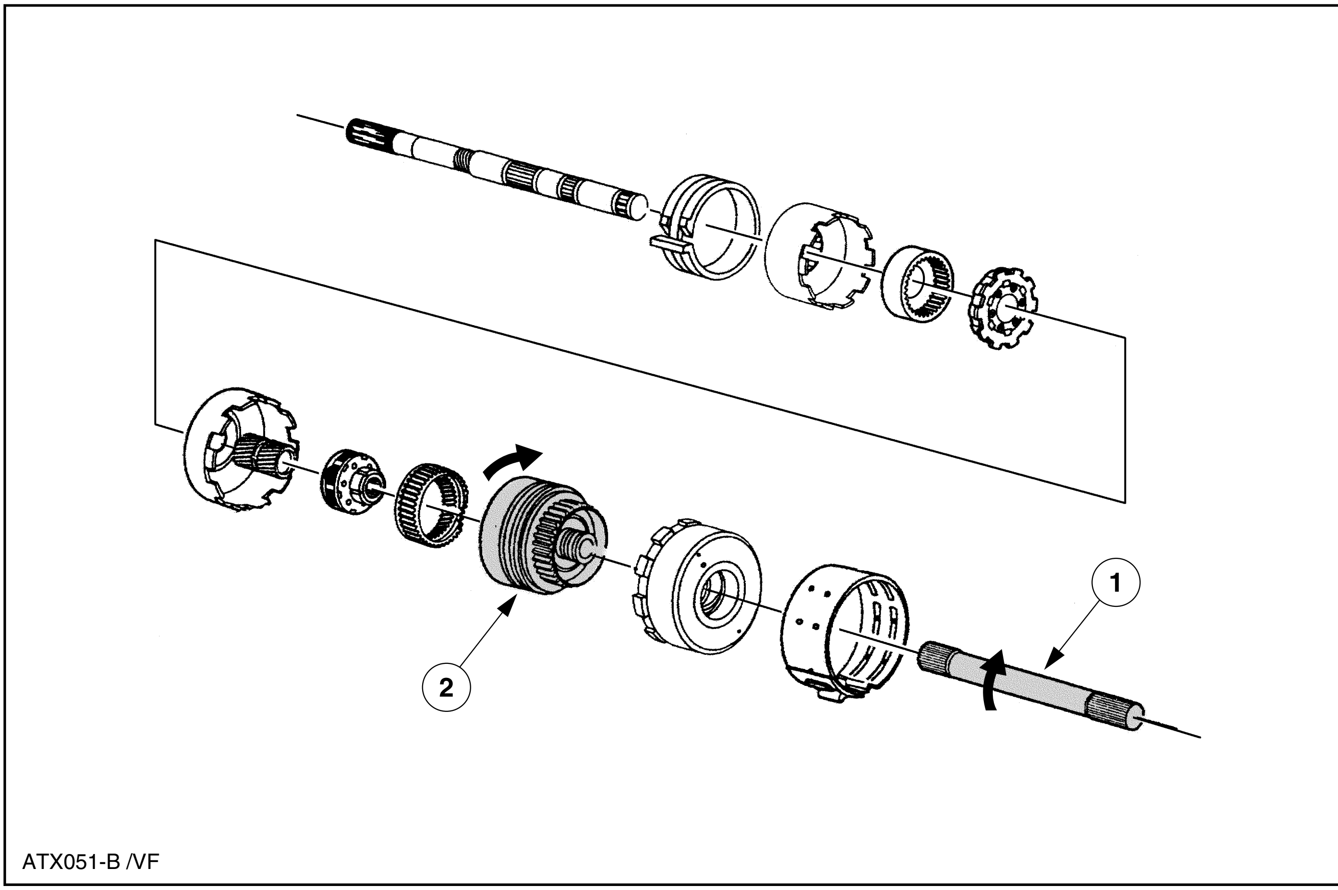
Two different types of planetary gear sets are used in most vehicles: the simple, or Simpson gear train; and the compound, or Ravigneaux, gear train.

The simple gear train contains two separate planetary gear assemblies, one for forward motion and one for reverse.

The compound gear train uses two planet carriers and two ring gears with a common sun gear.

Powerflow

Neutral



Simple gear train assembled

1 Input shaft
2 Forward clutch

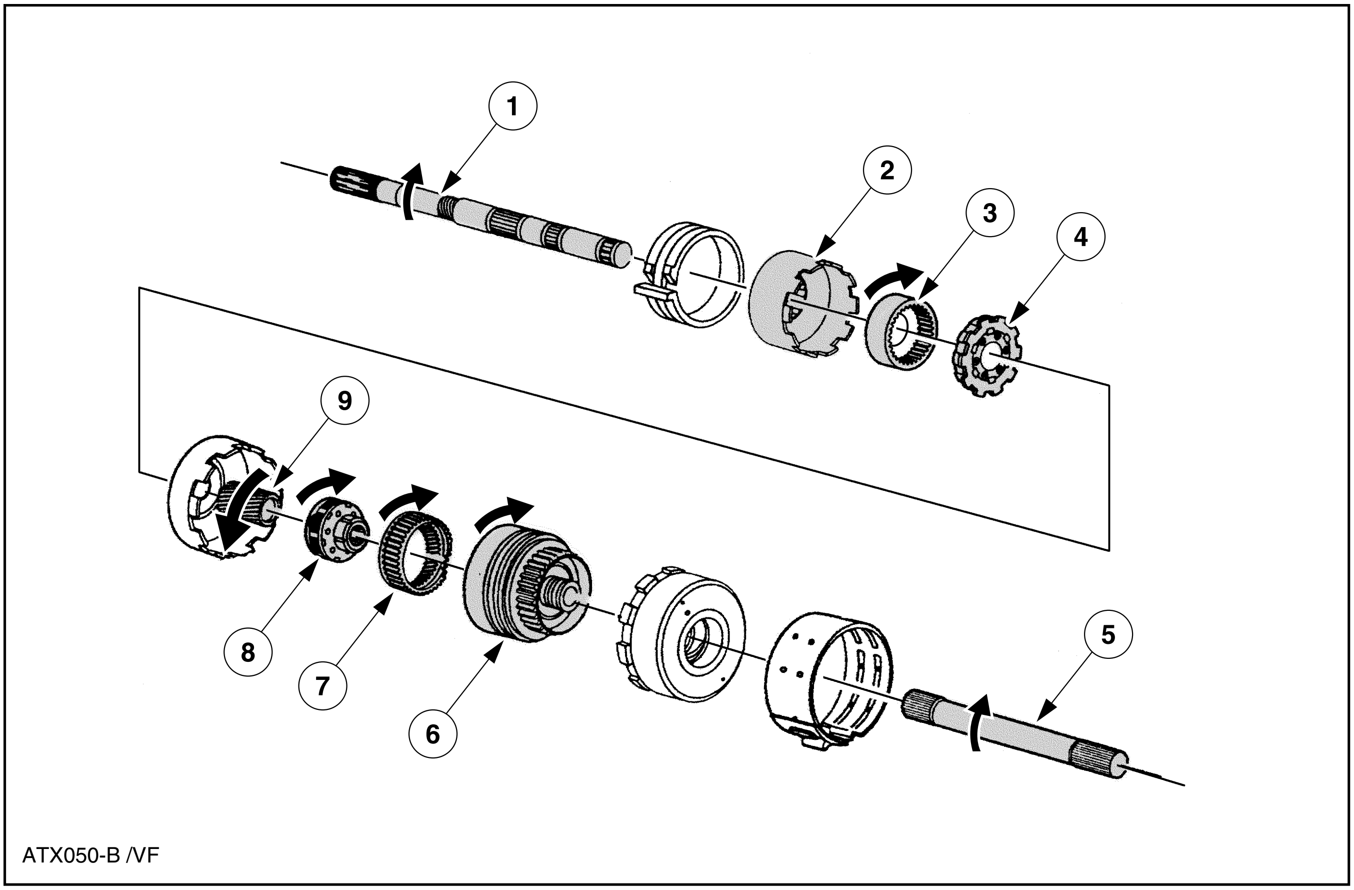
The simple gear train produces the following gear ranges:

- Neutral
- Reduction (first and second gears)
- Direct drive
- Reverse

In neutral, the converter turbine drives the input shaft, which drives the clutch housing. Because no clutch is applied, there is no further transfer of engine power.

Powerflow (continued)

First gear (low)



Simple gear train powerflow

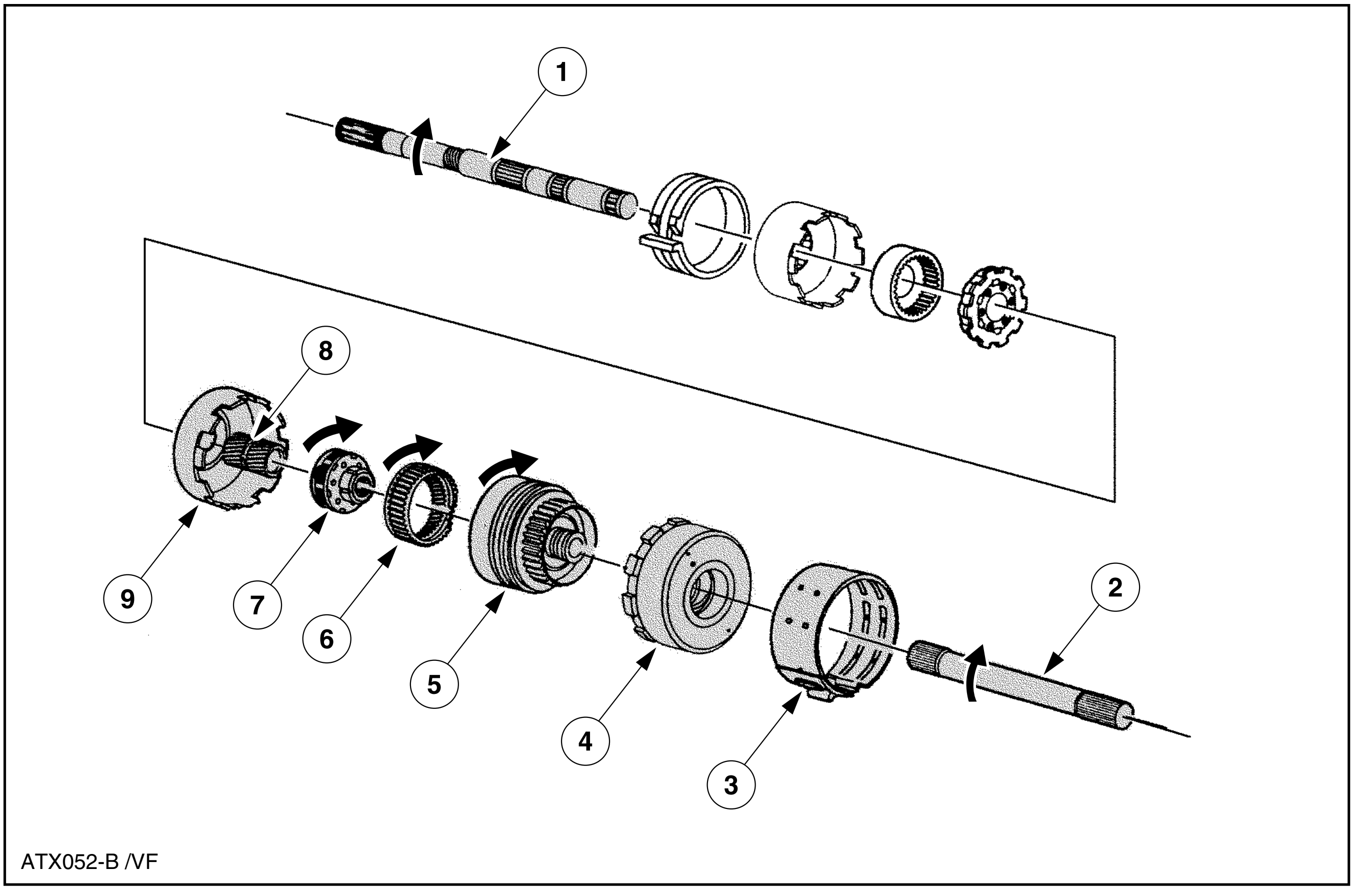
1 Output shaft
2 Low/reverse drum and one-way clutch
3 Output shaft ring gear
4 Reverse planetary assembly
5 Input shaft
6 Forward clutch
7 Forward clutch hub and ring gear
8 Forward planetary assembly
9 Sun gear

In first gear, powerflow is as follows:

- The converter turbine drives the input shaft clockwise.
- The input shaft drives the forward clutch housing clockwise.
- The forward clutch is applied, locking the input shaft to the front planetary ring gear. The input shaft drives the forward clutch ring gear clockwise.
- The forward clutch ring gear drives the front planet gears clockwise.
- The front planet gears drive the sun gear counterclockwise.
- The sun gear drives the reverse planet gears clockwise.
- A one-way clutch holds the reverse planet carrier stationary.
- The reverse planet gears drive the output shaft ring clockwise.
- The output shaft ring gear drives the output shaft clockwise.

Powerflow (continued)

Second gear (intermediate)



Simple gear train powerflow

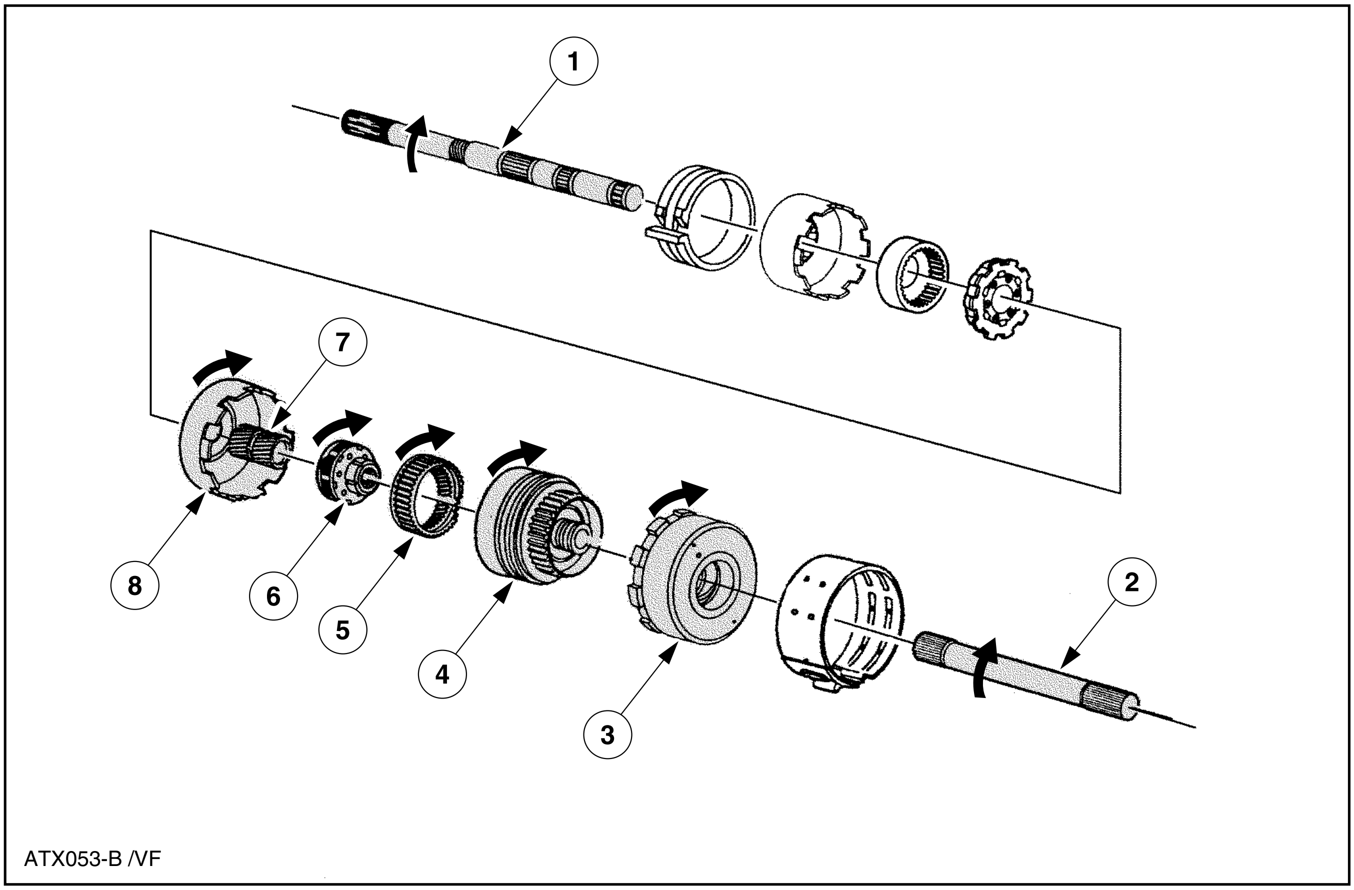
1 Output shaft
2 Input shaft
3 Intermediate band
4 Reverse/high clutch and drum
5 Forward clutch
6 Forward clutch hub and ring gear
7 Front planetary assembly
8 Sun gear
9 Input shell

In second gear, powerflow is as follows:

- The converter turbine drives the input shaft clockwise.
- The input shaft drives the forward clutch housing clockwise.
- The forward clutch is applied, driving the forward ring gear clockwise.
- The intermediate band holds the intermediate band drum. This drum connects to the sun gear and input shell, which are also held.
- The forward ring gear drives the front planetary gears clockwise. The planetary gears “walk” around the stationary sun gear.
- The front planet gears force the front planet carrier to turn clockwise.
- The front planet carrier turns the output shaft clockwise.

Powerflow (continued)

Third gear (high)



Simple gear train powerflow

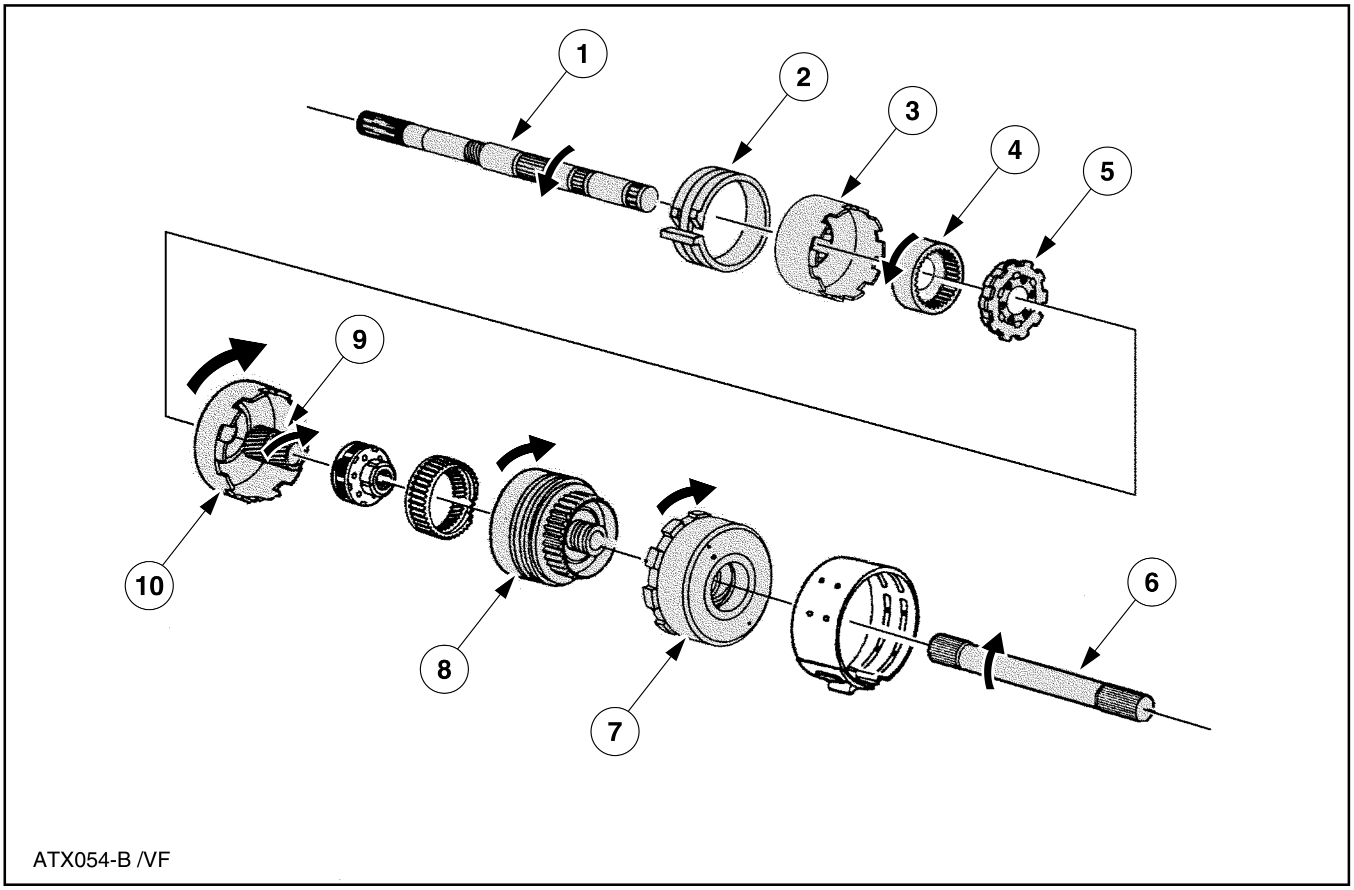
1 Output shaft
2 Input shaft
3 Reverse/high clutch and drum
4 Forward clutch
5 Forward ring gear
6 Front planetary assembly
7 Sun gear
8 Input shell

In third gear (high), powerflow is as follows:

- The converter turbine drives the input shaft clockwise.
- The input shaft drives the forward clutch housing clockwise.
- The forward clutch housing also forms the hub of the reverse/high clutch.
- The forward and reverse/high clutches are both applied.
- The forward clutch drives the applied reverse/high clutch clockwise.
- The reverse/high clutch drives the input shell and sun gear clockwise.
- The forward clutch drives the forward ring gear clockwise.
- The forward ring gear drives the front planet gears clockwise.
- Because the front planet gears are being driven by both the sun gear and the forward ring gear, a “lock-up” occurs. The front planet gears drive the front planet carrier.
- The front planet carrier is splined to the output shaft and drives it clockwise.

Powerflow (continued)

Reverse gear



Simple gear train powerflow

1 Output shaft
2 Low/reverse band
3 Reverse/low drum and one-way clutch
4 Reverse ring gear
5 Reverse planetary assembly
6 Input shaft
7 Reverse/high clutch and drum
8 Forward clutch
9 Sun gear
10 Input shell

In reverse gear, powerflow is as follows:

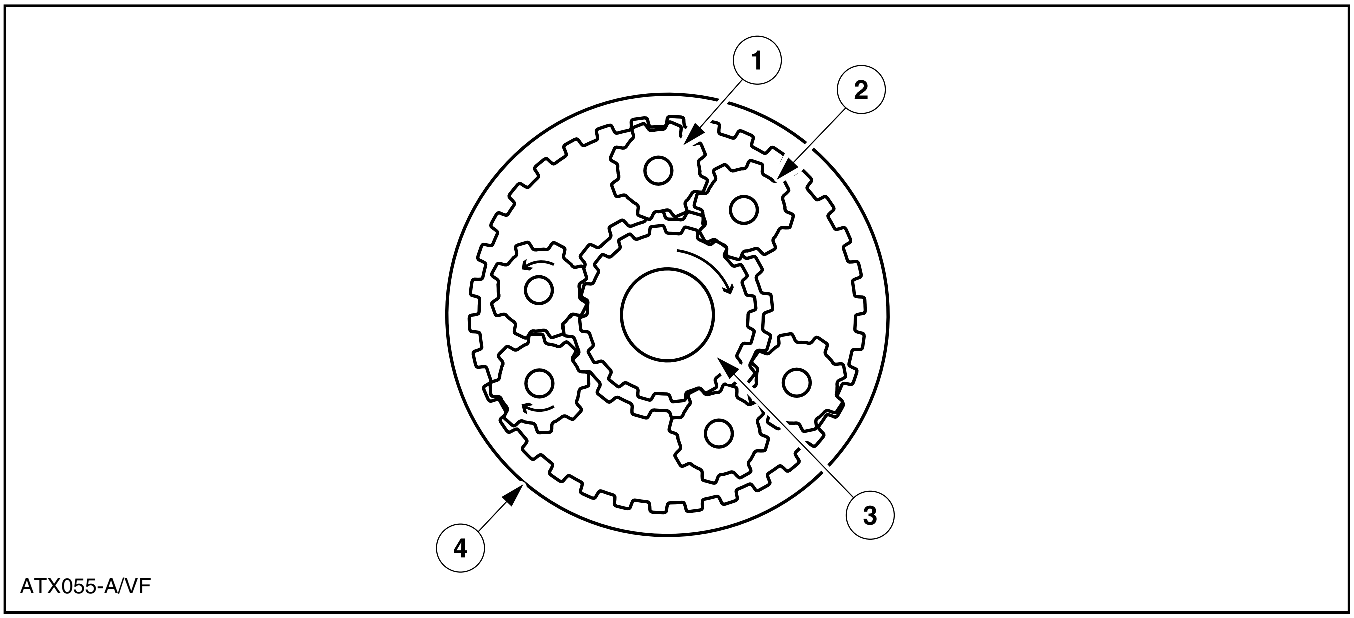
- The converter turbine drives the input shaft clockwise.
- The input shaft drives the forward clutch housing clockwise.
- The forward clutch housing also forms the hub of the reverse/high clutch.
- The forward and reverse/high clutches are applied. The forward clutch drives the applied reverse-high clutch clockwise.
- The reverse/high clutch drives the input shell and sun gear clockwise.
- The low/reverse band holds the low/reverse drum and reverse planet gear carrier stationary.
- The sun gear drives the reverse planet gears counterclockwise.
- The reverse planet gears drive the output shaft counterclockwise.

Advantages of planetary gear sets

Any time the planetary gear set members are driven or held, the gears are always in mesh. Therefore, they never “clash” or “grind” as gears sometimes do in a manual transmission. In addition, the arrangement of the planetary gear set allows several gear teeth to be in contact at any time. This means the gear set distributes torque loads over a wider area, resulting in a stronger gear set.

Another advantage of the planetary gear set is the compact size of the gear train. Unlike a manual transmission, which uses a cluster gear and separate shafts, the automatic transmission has planetary gear shafts mounted on a common centerline.

Compound gear train



Compound planetary gear set

1 Long planet gear
2 Short planet gear
3 Sun gear
4 Ring gear

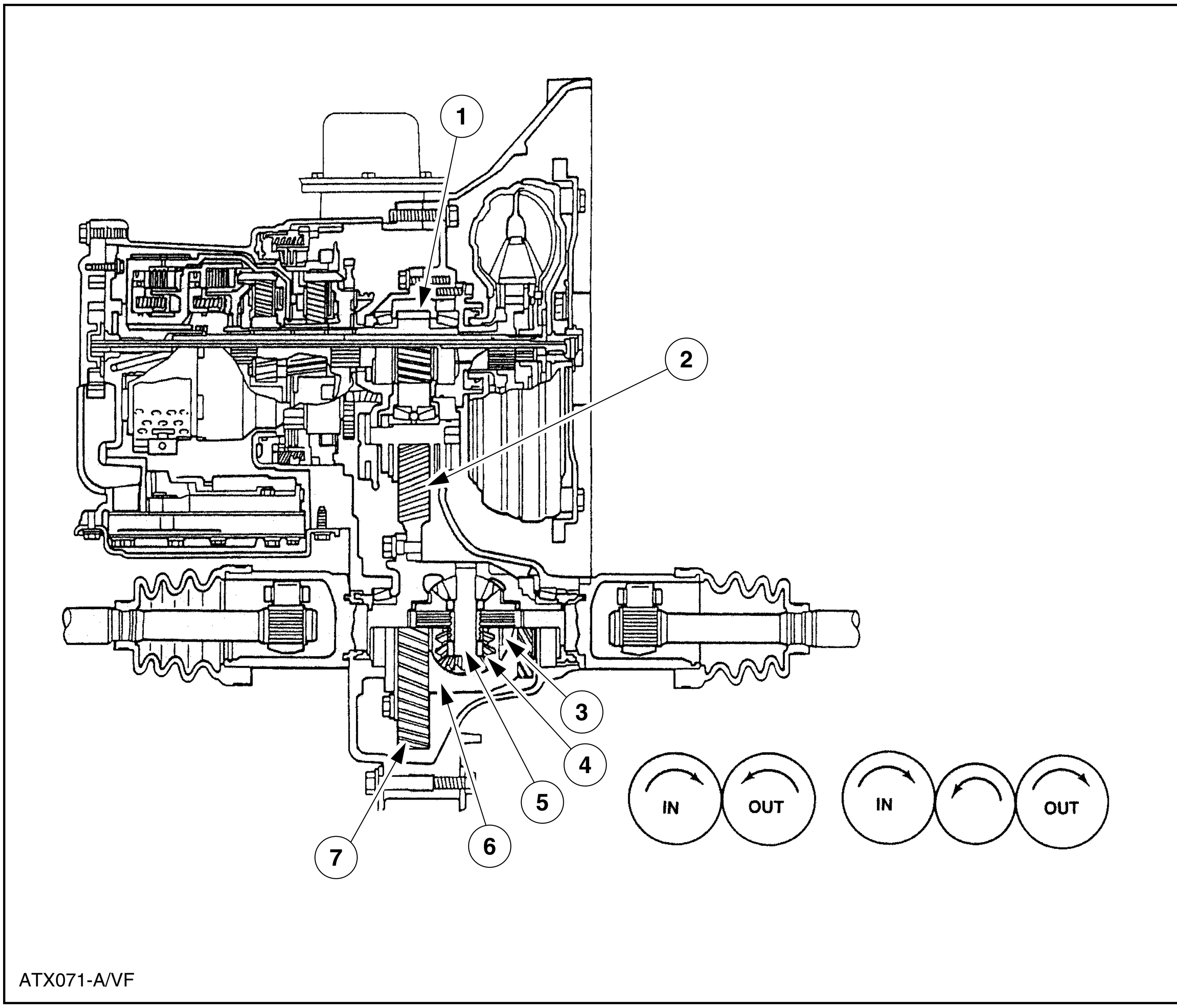
The second type of planetary gear set used in some vehicles is the compound, or Ravigneaux, gear train. A compound gear train uses two planet carriers and two ring gears with a common sun gear. Each planet carrier contains several pairs of planet gears. One gear in each pair is the long planet gear; the other is the short planet gear.

Objectives

Upon completion of this lesson, you will be able to:

- Identify the components of a transaxle chain drive and describe their functions.
- Identify the components of a transaxle final drive unit and describe their functions.
- Describe the differences between idler gear systems and chain drive (in-line) systems.
- Identify the components of a transaxle differential assembly and describe their functions.
- Describe how the transaxle differential assembly operates with the wheels straight and with the wheels turned.

Transaxle theory



Transaxle cut-away

1 Output gear
2 Idler gear
3 Side gear
4 Pinion gear
5 Pinion shaft
6 Differential gear case
7 Ring gear

A transaxle is a transmission for a front-wheel drive vehicle. Most of the principles that apply to rear-wheel drive transmissions also apply to transaxles. This section describes the differences that are unique to transaxles.

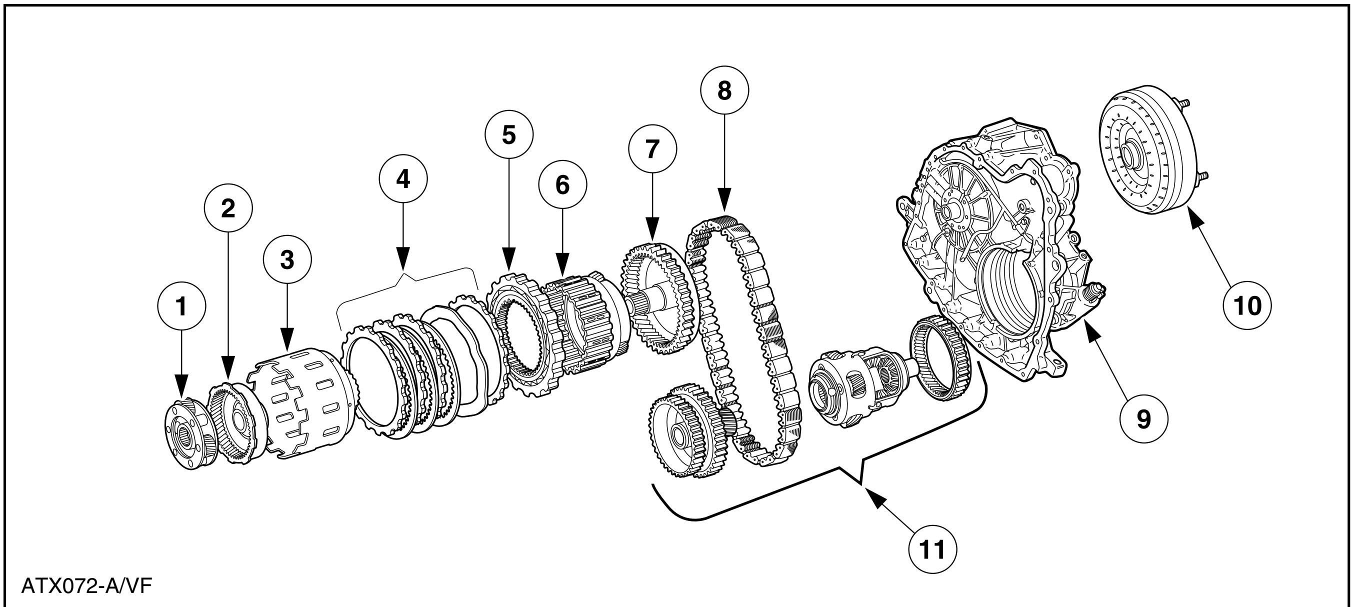
In a rear-wheel drive vehicle, power flows from front to rear – from the engine to the torque converter and input shaft, through the gear train to the output shaft, and through the rear axle to the rear wheels.

Transaxle theory (continued)

In front-wheel drive vehicles, however, power must be redirected to the front wheels. To accomplish this, a transaxle has a final drive/differential built inside the transaxle case. Placing the final drive unit in the case allows for a smaller package, which fits in the limited space of the engine compartment. In addition, an internal final drive allows the rotation of the transaxle planetary units to match the rotation of the wheels.

By definition, transaxles must change the direction of powerflow inside the unit. In most transaxles, either an idler gear system or a chain drive alters the direction of powerflow.

Chain drive system



Transaxle exploded view

1 Planet assembly
2 Planetary ring gear
3 Sun gear and drum
4 Clutch pack
5 One-way clutch
6 Planet assembly
7 Drive gear
8 Chain
9 Converter housing
10 Torque converter
11 Final drive and differential

In a chain drive system, the transaxles final drive is in line with the planetary gear train.

A chain drive transfers torque from the planetary gear sets to the final drive. The chain drive includes:

- Drive sprocket
- Driven sprocket
- Silent-type drive chain

The reverse/overdrive ring gear is an integral part of the drive sprocket. The final drive sun gear and parking gear are integral parts of the driven sprocket.

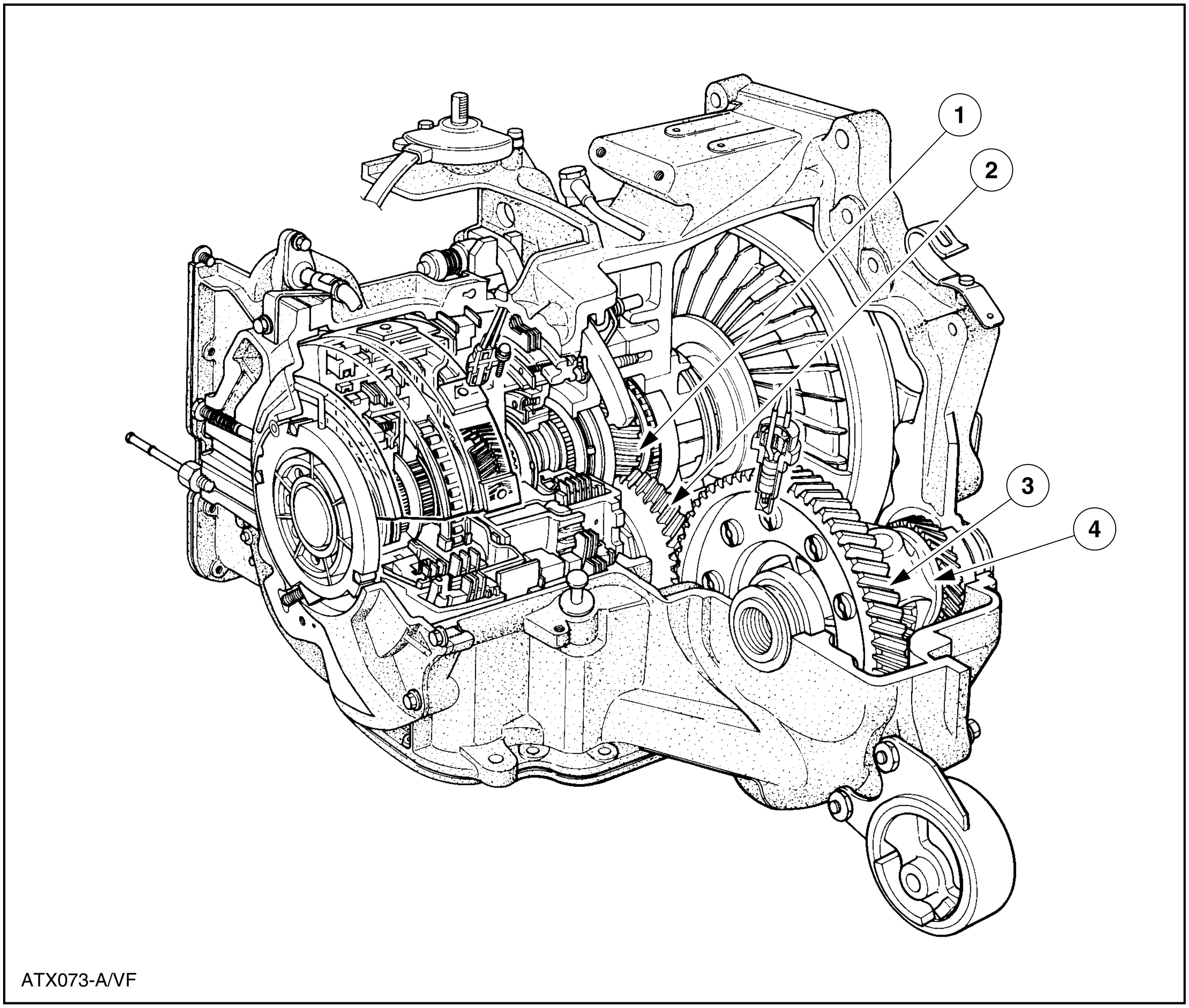
Chain drive system (continued)

Purpose

A transaxle final drive serves the same purpose as the rear axle differential assembly in a rear-wheel drive vehicle. That is, the final drive:

- allows the output rotation of the planetary gear set and the final drive to remain in the same direction.
- supplies the vehicle's final gear reduction.
- compensates for differences in axle rotation speeds when the vehicle is turning.

Idler gear type



Transaxle cut-away

1 Output gear
2 Idler gear
3 Ring gear
4 Differential case

Final drive components vary with the type of transaxle drive. A typical idler gear final drive assembly includes the final drive output gear, differential case, side gears, and pinion gears.

In an idler gear system, the final drive of the transaxle is parallel to the planetary gear train. The idler gear system changes the direction of power output.

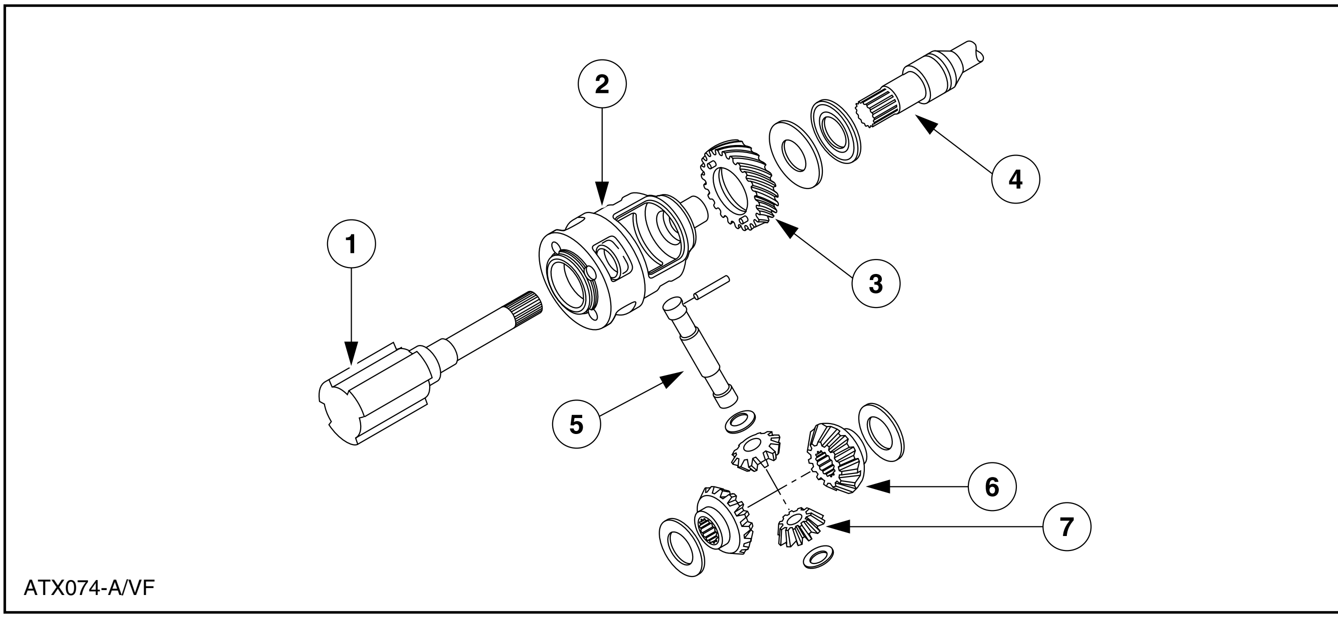
A final drive input gear (ring gear) connects to the planet carrier. The carrier drives this gear in the same direction and at the same speed as the carrier.

An idler gear transmits input gear torque to the output gear, so the direction of rotation is the same. The idler gear rests on two tapered roller bearings on the idler gear shaft. This shaft is supported by the transfer gear housing and transaxle case.

Idler gear type (continued)

The output gear corresponds to the ring gear in a rear-wheel drive gear train. It attaches to the differential case, where it is driven by the idler gear. The output gear always turns in the same direction as the input gear.

Chain drive type



Chain drive differential

1 Halfshaft
2 Differential carrier
3 Final drive gear
4 Halfshaft
5 Pinion shaft
6 Side gear
7 Pinion gear

The final drive of a typical in-line chain drive system includes a planetary gear set that transfers and multiplies torque from the drive chain to the differential.

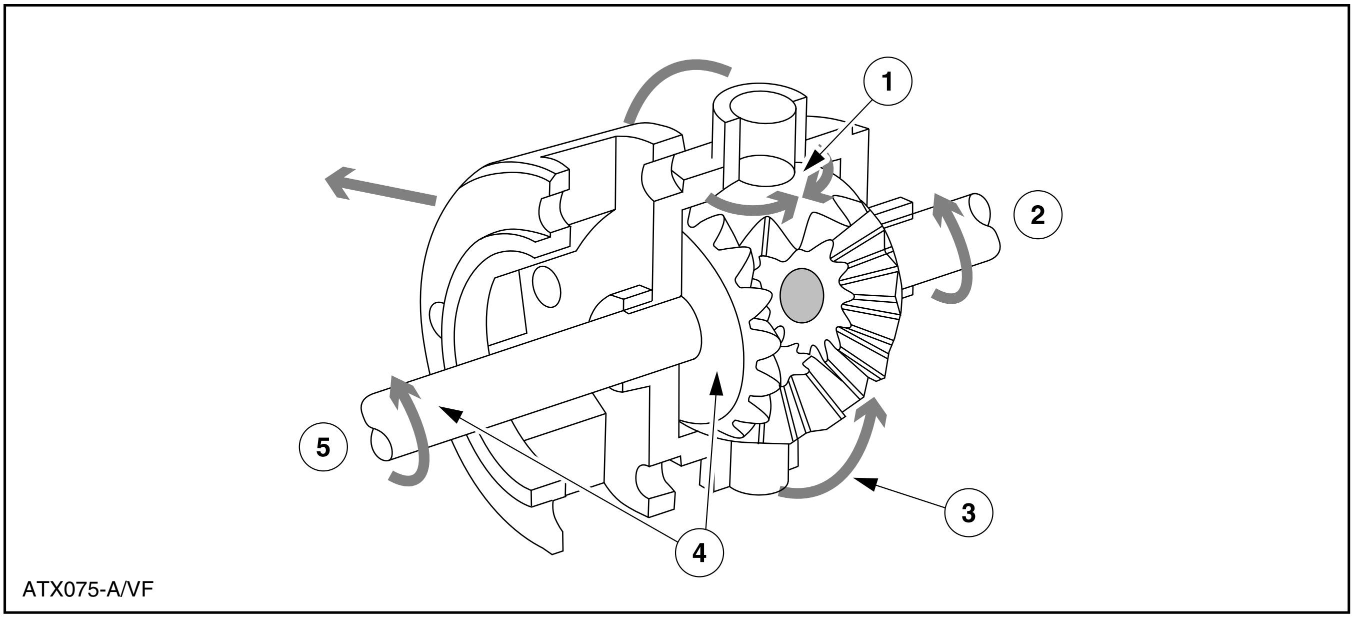
The final drive includes a:

- Sun gear (integral with the driven sprocket)
- Carrier (integral with the differential case)
- Ring gear

A differential case holds the side gears, the governor/ speedometer drive gear, and the final drive pinion gears.

Two differential pinion gears (and washers) mount on the pinion shaft. A pinion pin retains the shaft in the differential case. Two side gears (with washers) mesh with the differential pinion gears. The right gear is splined to the right halfshaft assembly, and the left gear is splined to the transaxle output shaft.

Operation – wheels straight



Differential cut-away – straight ahead driving

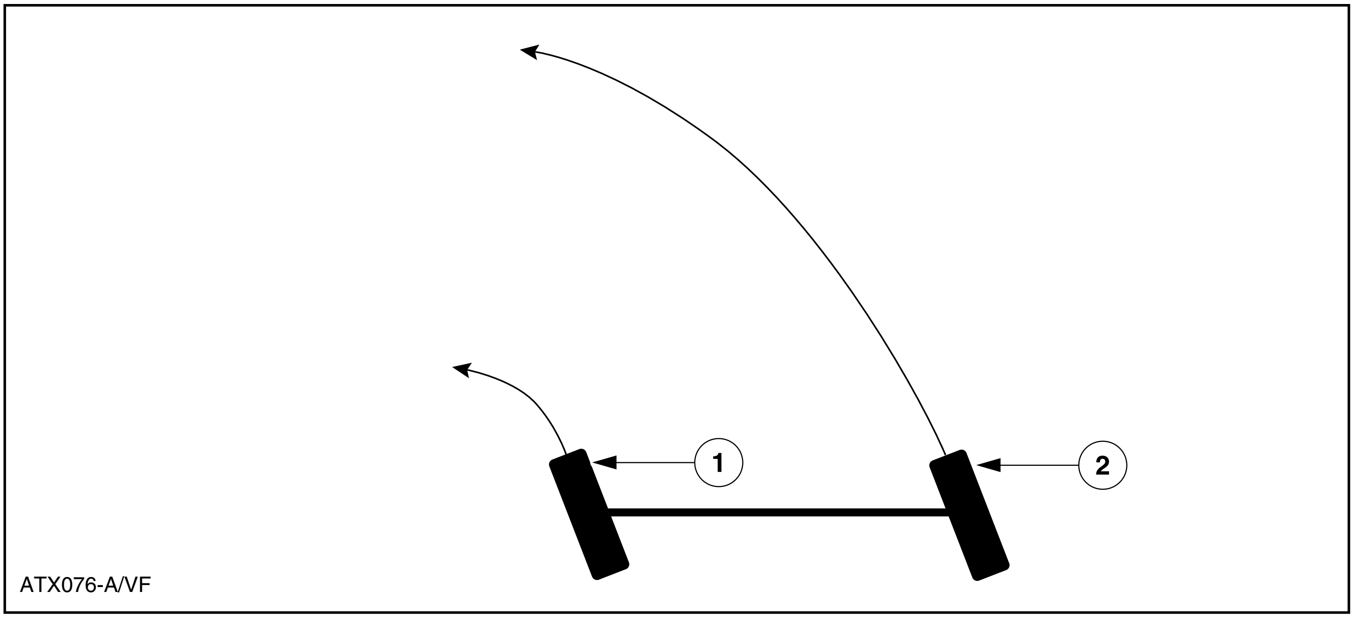
1 Pinion gears
2 100 rpm
3 Differential case
4 Side gears and halfshafts
5 100 rpm

When the vehicle is driven straight ahead, power flows through the differential.

- The final drive gear set turns the differential case.
- The pinion shaft and differential pinion gears drive the side gears. The side gears do not spin when the vehicle is driving straight ahead, but move as a unit. The side gears spin only when there is a speed difference between the left and right drive axles.
- The side gears drive the output shaft and right halfshaft at the same speed. The output shaft is splined to the left halfshaft. Each halfshaft drives its own wheel.

Both wheels receive the same amount of torque, about half the torque that is transmitted to the differential case.

Operation – wheels turned

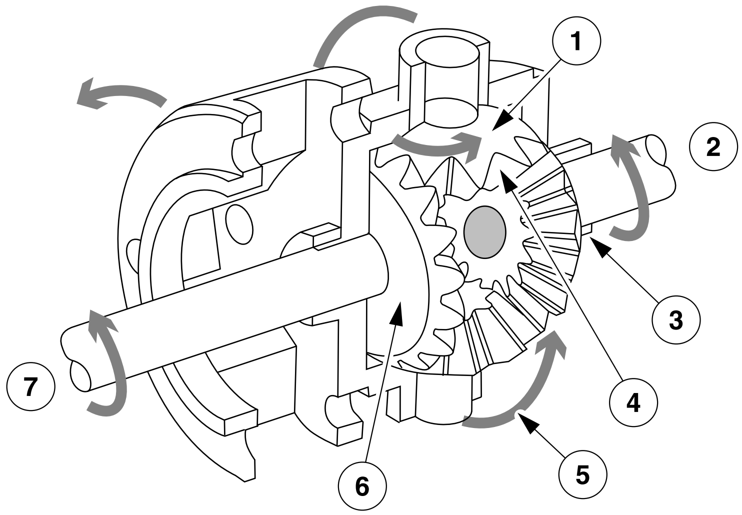


Tires traveling different distances during a turn

1 Inside wheel (rotates slower)
2 Outside wheel (turns faster)

When a vehicle is turning, the outer wheel must rotate faster than the inner wheel because the outer wheel has to travel a longer distance in the same amount of time.

Operation – wheels turned (continued)



Differential cut-away – driving around a curve

1 Pinion shaft
2 80 rpm
3 Side gear
4 Pinion gear
5 Differential carrier
6 Side gear
7 120 rpm

When one wheel is turning faster than the other, power flows through the differential.

- The final drive gear set turns the differential case.
- The pinion shaft and differential pinion gears drive the side gears.
- The side gear driving the inner wheel rotates slower than the outer wheel (or not at all).
- The differential pinion gears “walk around” the slower moving side gear, rotating on the pinion shaft.
- The pinions drive the side gear on the outer wheel faster than the inner wheel side gear.

The torque is split proportionally between the two wheels. For example, the inner wheel may rotate at 80 percent of the speed of the differential case, while the outer wheel rotates at 120 percent of case speed.

Objectives

Upon completion of this lesson, you will be able to:

- Describe how an electronic control system directs the operation of an automatic transmission.
- Identify the input sensors used in an electronic control system and describe how they operate.
- Describe the three types of solenoids used as system outputs.
- Identify the output solenoids used in an electronic control system and describe how they operate.

Control systems

The electronic control system for an automatic transmission reads information supplied by vehicle sensors and translates the data into output signals. These signals operate solenoids that control shift timing, shift feel, and torque converter clutch operation. This section identifies the parts of the electronic control system and describes how they operate.

Up to this point, we have described the basic theory and operation of hydraulically actuated transmissions. Because of improvements in technology, the governor and vacuum modulator systems used on hydraulically actuated transmissions have been replaced with electric solenoids, switches, and sensors.

The benefits of electronically controlled automatic transmissions are:

- Increased fuel economy and performance
- Improved shift quality
- Reduced noise and vibration
- More driver control
- Self-diagnosis

Electronic theory

The electronic control system is a specialized computer system that reads input signals from various sensors located in the vehicle. Based on the information provided by these sensors, the electronic control system sends output signals that operate various solenoids. (A solenoid is a type of electric switch that includes a wire coil. When current is applied, the coil is magnetized. The magnetic field moves a rod-shaped component that opens and closes the switch.) These solenoids control the hydraulic and mechanical functions that make the transmission operate. The electronic control system specifically directs shift timing, line pressure adjustment, and converter clutch operation.

Control module theory

The "brain" of the electronic control system is a module that contains electronic circuit boards, microprocessor chips, and input and output connectors.

Using the information the control module receives from the input sensors, the control module computes engine load, vehicle speed and conditions, and transmission conditions. The control module then controls the output solenoids by selectively grounding or applying voltage to certain electrical circuits.

Input and output signals

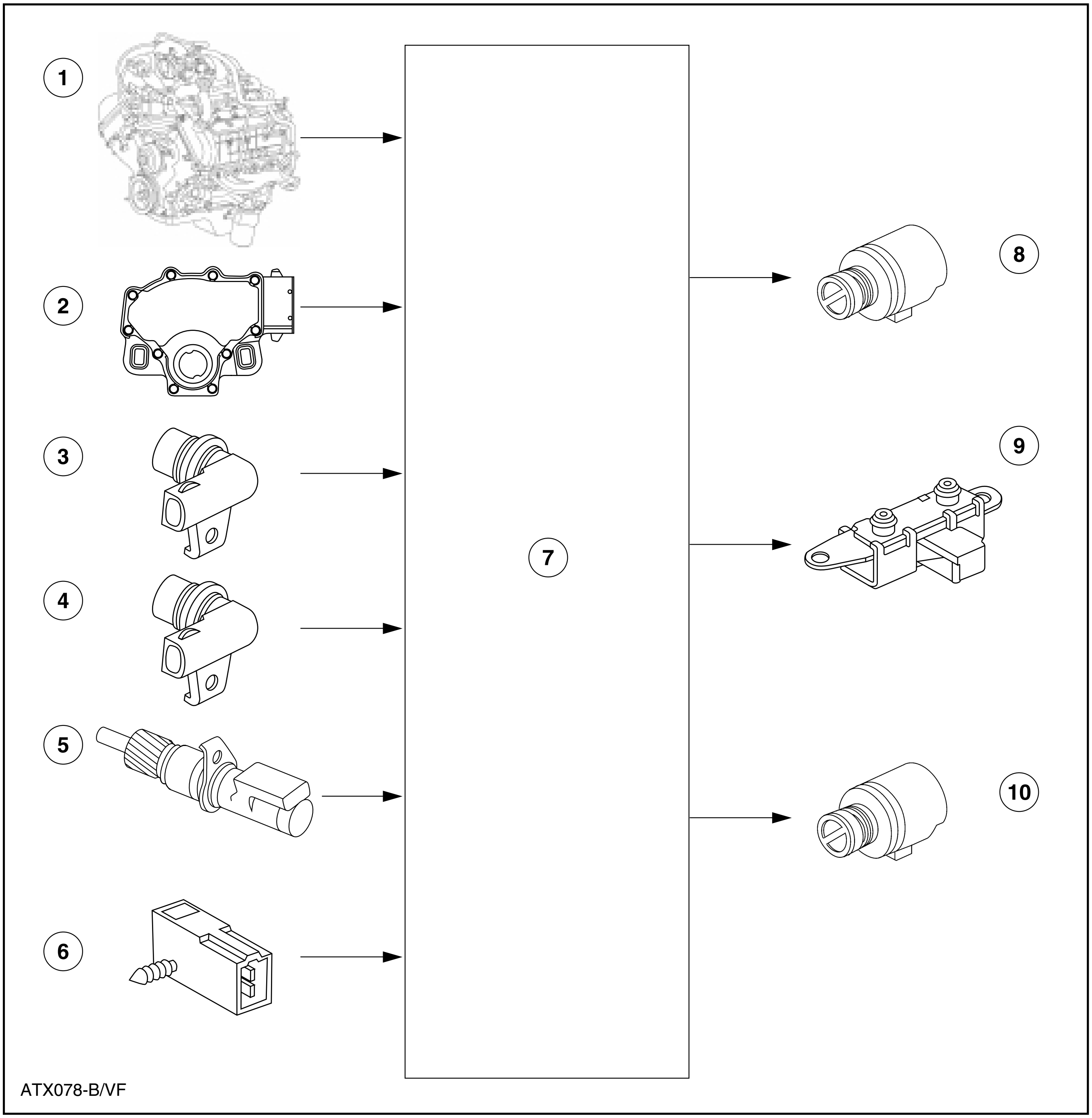
Some input signals come from engine-related sensors, such as the mass air flow sensor, intake air temperature sensor, and engine coolant temperature sensor. These sensors give the control module information about the engine's current operating state.

Other inputs are based on the driver's demands. For example, the throttle position sensor relays information about the position of the accelerator pedal. Still other inputs come from the transmission itself. For example, sensors provide information about output shaft speed, transmission fluid temperature, and gear range selection.

Using all these input signals, the control module determines when the time and conditions are right for a shift or a converter clutch application. The control module also determines the line pressure needed for the smoothest shift operation (also called shift feel).

To accomplish these functions, the control module typically controls four electronic solenoids: two for shifting, one for modulating the converter clutch, and one for controlling line pressure.

Control module inputs



System inputs and outputs

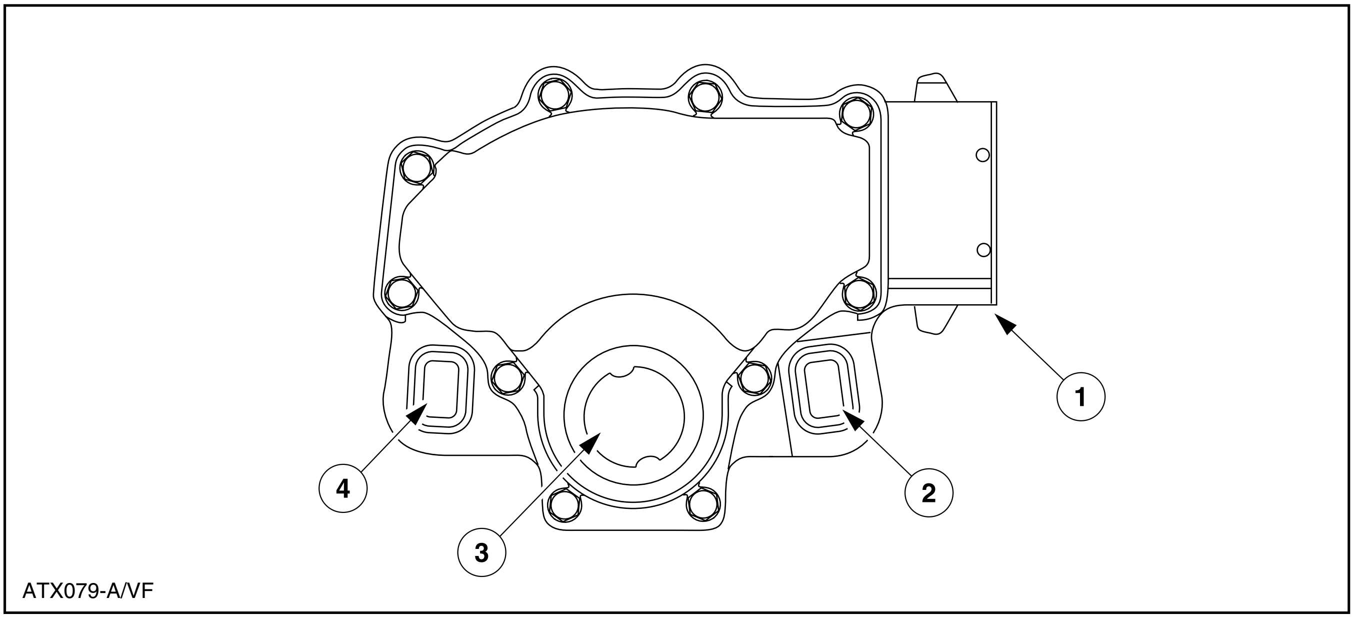
1 Engine inputs
2 Transmission range sensor
3 Input shaft speed (ISS) sensor
4 Output shaft speed (OSS) sensor
5 Vehicle speed sensor (VSS)
6 Transmission fluid temperature (TFT) sensor
7 Control module
8 Torque converter clutch control solenoid
9 Shift solenoids
10 Electronic pressure control solenoid

There are two basic types of control module input signals:

- Inputs related to items outside the transmission, such as the engine coolant and air conditioning clutch. These inputs include sensors that measure engine and driver demands.
- Inputs related to the transmission itself, such as output shaft speed and transmission fluid temperature.

These input signals are described on the following pages. The descriptions assume you are familiar with terms related to automotive electrical systems.

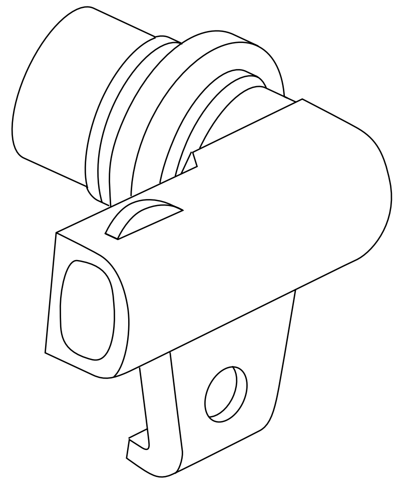
Control module inputs (continued)



Transmission range (TR) sensor

1 Electrical connector
2 Adjustment
3 Manual lever shaft
4 Adjustment

The transmission range (TR) sensor is located on the transmission case at the manual lever position. This sensor includes a series of step-down resistors that act as a voltage divider. The control module constantly monitors voltage readings in the TR sensor to determine the position of the manual lever (for example, P, R, N, D, or 1).

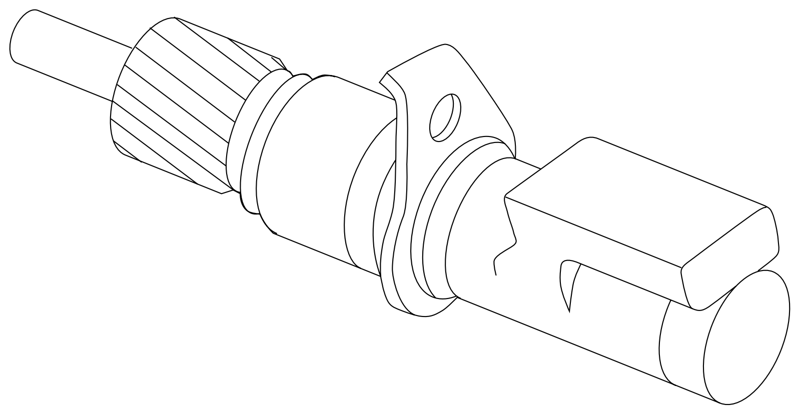


ATX080-A/VF

Output shaft speed (OSS) sensor and input shaft speed (ISS) sensor

The output shaft speed (OSS) sensor and input shaft speed (ISS) sensor are magnetic pickups. The OSS sensor sends a voltage signal to the control module that is proportional to the rotation speed of the output shaft ring gear. The ISS sensor sends a voltage signal to the control module that is proportional to the rotation speed of the input shaft. The control module uses this information to schedule shifts, adjust line pressure, and control the converter clutch.

Control module inputs (continued)

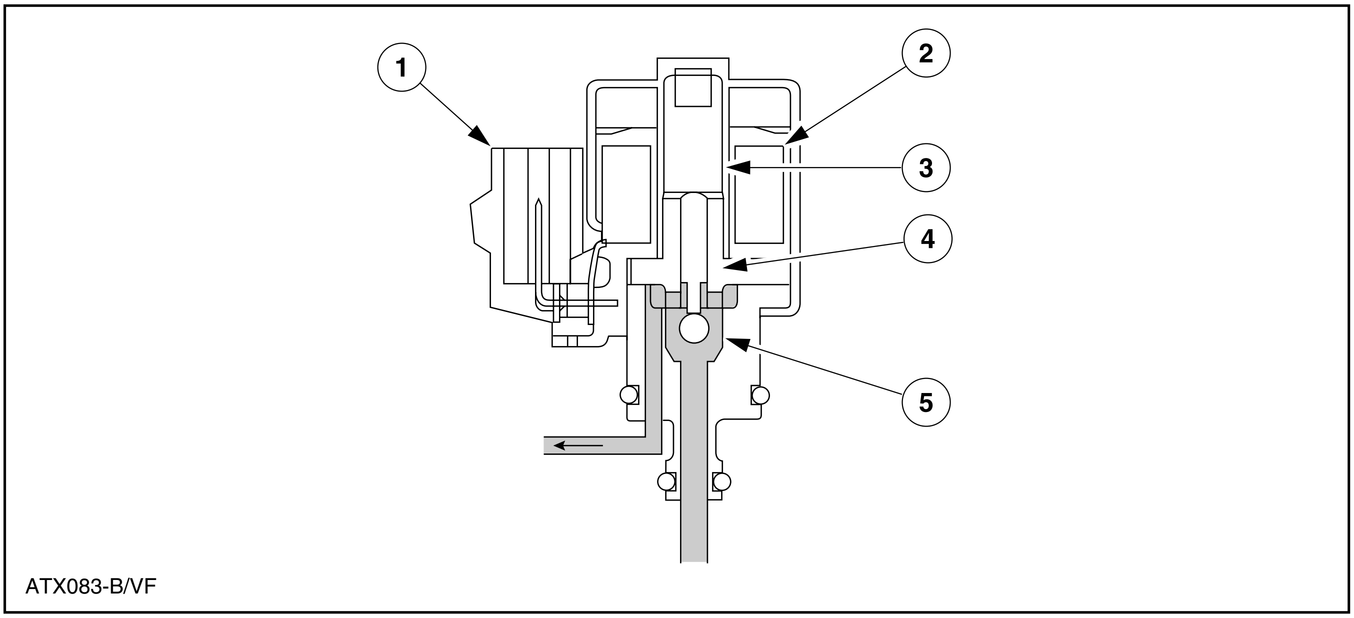


ATX081-A/VF

Vehicle speed sensor (VSS)

The vehicle speed sensor (VSS) is a magnetic pickup mounted near the rear of the transmission. Driven by a small gear, the VSS sends a voltage signal to the control module that is proportional to the rotation speed of the output shaft. The control module uses this signal as auxiliary input for modifying upshift scheduling only. (The OSS sensor provides the primary vehicle speed information to the control module.)

Some vehicles use a vehicle speed signal from a different system such as the ABS system.



Pulse-width modulated (PWM) solenoid

1 Connector
2 Coil
3 Armature
4 Push rod
5 Ball valve

A pulse-width modulated (PWM) solenoid controls the application and release of the torque converter clutch. When applied, this clutch locks the turbine and converter cover together, forming a mechanical link between the engine and the transmission input shaft.

The control module signals this solenoid to allow an appropriate amount of fluid into the converter clutch control valve. The amount of pressurized fluid controls the movement of the clutch piston. This solenoid is also called the torque converter clutch control (TCC) solenoid.

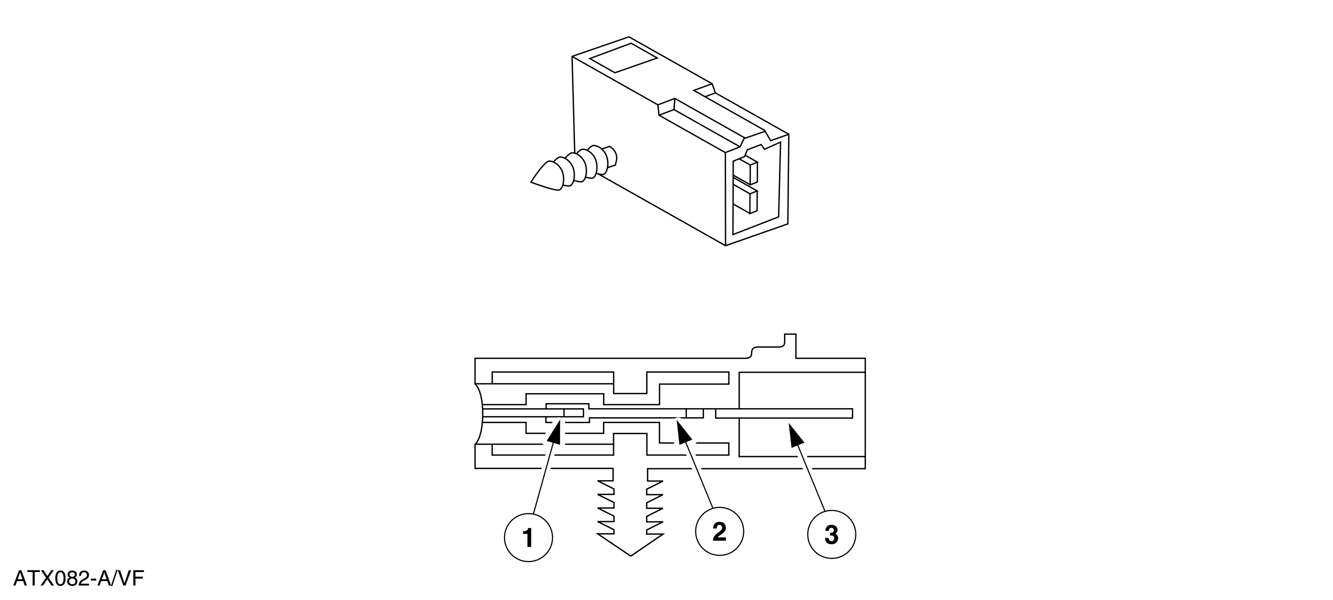
Control system outputs

Using input from the various sensors on the vehicle, the control module outputs signals to solenoids that control transmission operation.

Solenoid types

Three different types of solenoids are used as output devices:

- Pulse-width modulated solenoid – controls the converter clutch
- On/off solenoid – turns flow on or off to the shift valves
- Variable force solenoid – adjusts shift feel by controlling line pressure



Transmission fluid temperature (TFT) sensor

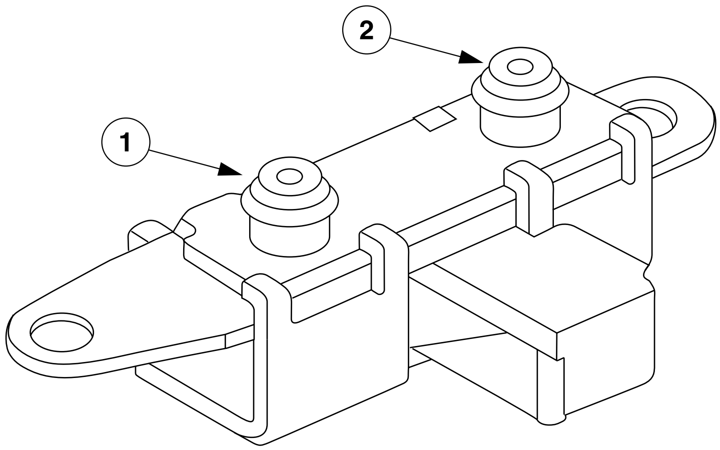
1 Thermistor
2 Wire
3 Connector pins

The transmission fluid temperature (TFT) sensor is a temperature-sensitive thermistor located on the transmission control valve body. Its resistance value varies with the temperature of the transmission fluid. The control module measures the voltage across the TFT sensor to determine fluid temperature.

The control module uses the TFT sensor signal to determine whether or not a “cold-start” shift schedule is required. When the transmission fluid is cold, the control module modifies normal shift scheduling and prevents the converter clutch from engaging.

The control module also uses the TFT sensor signal to lock-up the torque converter to reduce oil temperature.

Control system outputs (continued)



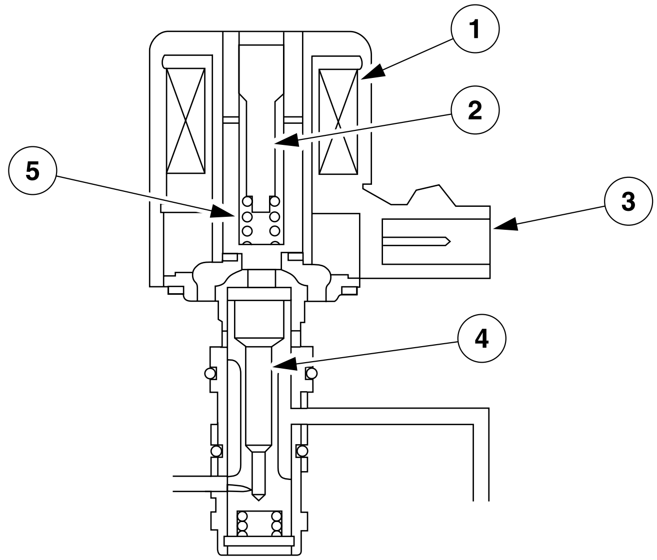
ATX084-A/VF

On/off solenoid

1 Shift solenoid one

2 Shift solenoid two

Two or three simple on/off solenoids mounted in a single housing control fluid flow to the shift valves. The solenoids may be called shift solenoid 1 (SS1) and shift solenoid 2 (SS2), or shift solenoids A, B, and C. These solenoids do not regulate the amount of fluid in the passages, they simply turn the flow on or off.



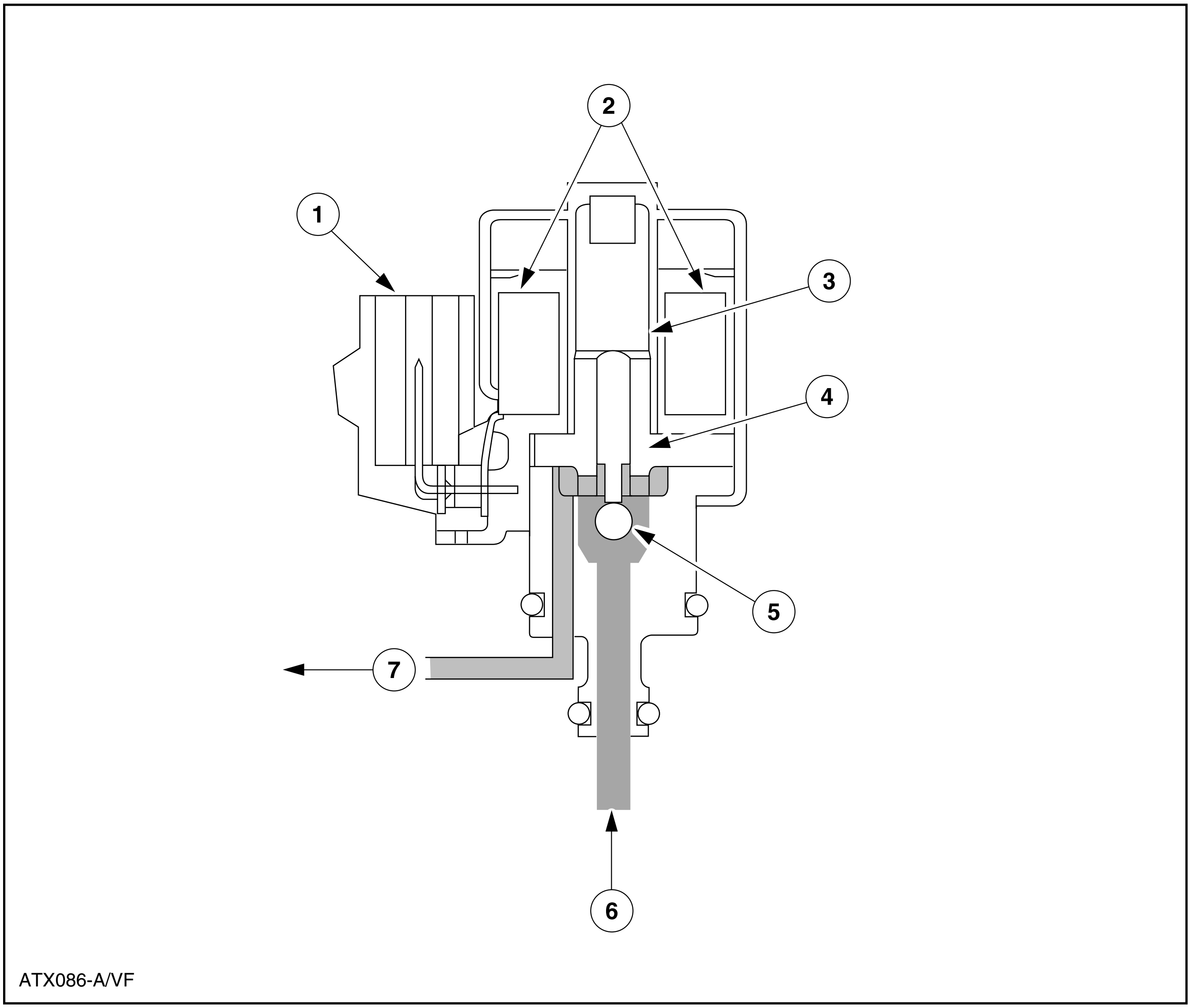
ATX085-B/VF

Variable force solenoid (VFS)

1 Coil
2 Armature
3 Electrical connector
4 Valve
5 Springs

A variable force solenoid (VFS) controls shift feel by adjusting line pressure to match engine and transmission conditions, as well as driver demands. By adjusting line pressure to match conditions, the electronic control system provides smoother shifts. The VFS that controls line pressure is called the electronic pressure control (EPC) solenoid.

Solenoid operations



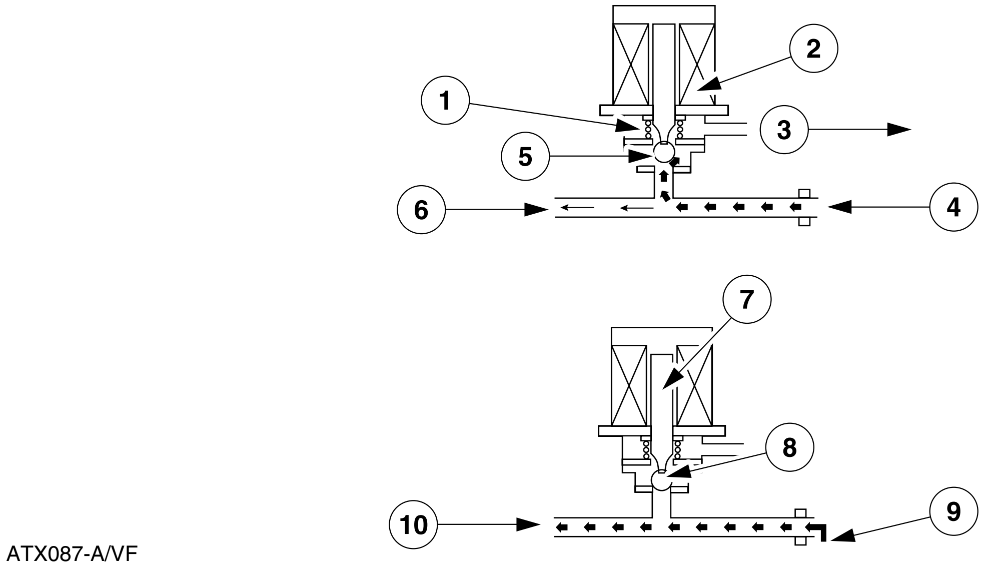
Torque converter clutch control (TCC) solenoid

1 Electrical connector
2 Coil
3 Armature
4 Armature pushrod
5 Ball valve
6 Fluid flow
7 Variable fluid output to converter clutch

The torque converter clutch control (TCC) solenoid supplies the clutch with full pressure, no pressure, or varying amounts of pressure. When the ball valve is closed, no pressurized fluid flows to the clutch control valve, and the clutch is released. When the ball valve is fully open, full pressure flows to the clutch, and it applies.

The TCC solenoid can also supply partial flow to the clutch for slip lock. During slip lock-up, the control module rapidly turns the solenoid on and off for varying lengths of time. The ball valve opens and closes, sending fluid in brief pulses to the clutch control valve. In this way, the TCC solenoid modulates pressure to the clutch, which enhances transmission smoothness and fuel economy.

Solenoid operations (continued)



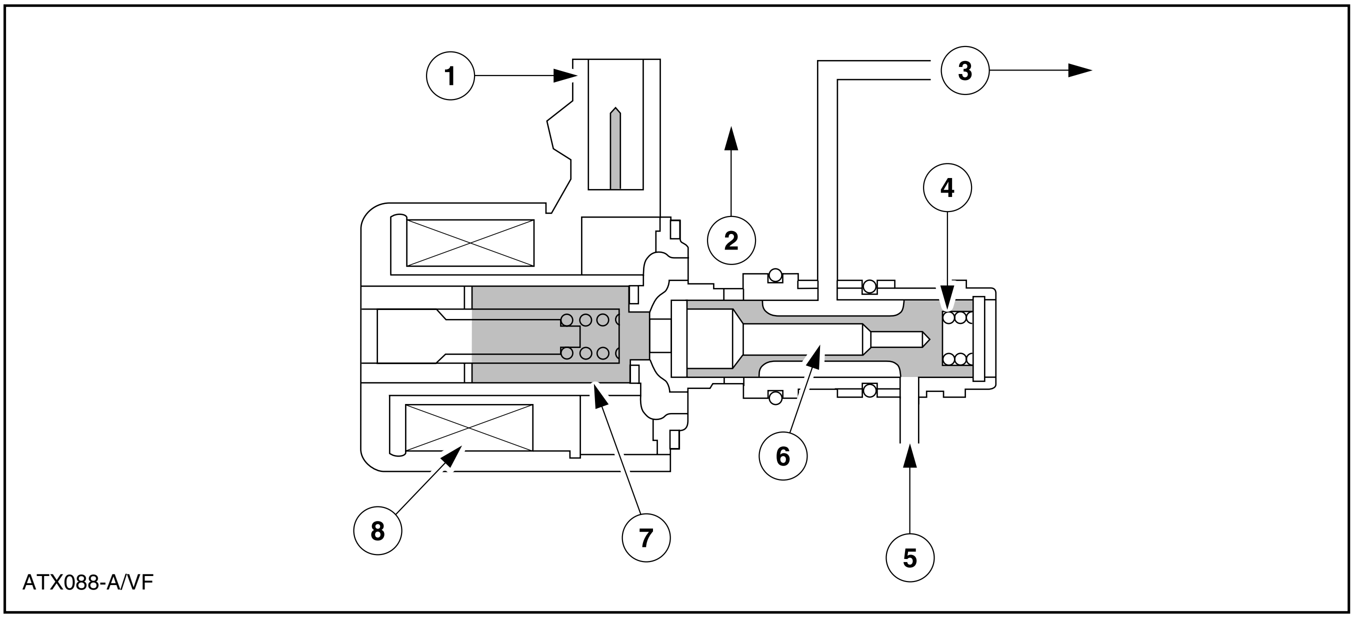
Electronic shift control solenoids

1 Spring
2 Coil
3 Exhaust to sump
4 Fluid from solenoid regulator valve
5 Ball valve open
6 Reduced fluid pressure to shift valve
7 Armature
8 Ball valve seated
9 Fluid from solenoid regulator valve
10 Full fluid pressure to shift valve

The control module controls automatic shift points by sending signals to the on/off shift control solenoids.

The solenoids can be turned on or off in different combinations. These combinations determine which shift valves operate. For example, SS1 is on and SS2 is off in manual first gear. In second gear, only SS2 is on.

The shift control solenoids are normally off unless electrically activated by the control module. When the solenoid is off, the ball valve opens and fluid flows back to the sump. When the solenoid is on, the ball valve closes, and fluid flows to the shift valves. Unlike the TCC solenoid, the electronic shift control solenoids have only two states, open or closed. They cannot provide partial flow.



Electronic pressure control (EPC) solenoid

1 Electrical connector
2 Exhaust to sump
3 Electronically controlled line pressure
4 Spring
5 Line pressure from pump/pressure regulator valve
6 Spool valve
7 Armature
8 Coil

The electronic pressure control (EPC) solenoid is a variable-force solenoid containing a spool valve. To control line pressure, the control module sends a varying amount of current to the EPC solenoid. When no current is supplied, the spool valve in the EPC solenoid opens all the way, and maximum line pressure flows out of the valve. As the control module increases current to the EPC solenoid, the spool valve closes proportionally, reducing line pressure.

Objective

Upon completion of this lesson you will be able to:

- Explain the symptom-to-system-to-component-to-cause diagnostic process.

Symptom-to-system-to-component-to-cause diagnostic process

Diagnosis requires a complete knowledge of the system operation. As with all diagnosis, a technician must use symptoms and clues to determine the cause of a vehicle concern. To aid the technician when diagnosing vehicles, the strategies of many successful technicians have been analyzed and incorporated into a diagnostic strategy and into many service publications.

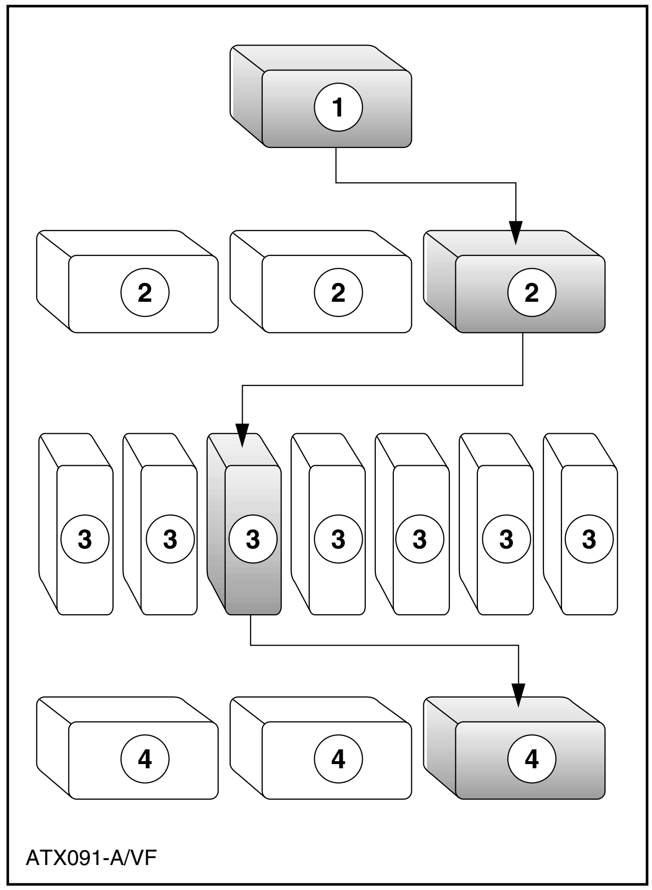
Symptom-to-system-to-component-to-cause diagnostic process

Using the Symptom-to-System-to-Component-to-Cause (SSCC) diagnostic process provides you with a logical method for correcting customer concerns:

- First, confirm the "Symptom" of the customer's concern.
- Next, determine which "System" on the vehicle could be causing the symptom.
- Once you identify the particular system, determine which "Component(s)" within that system could be the cause for the customer concern.
- After determining the faulty component(s) you should always try to identify the cause of the failure.

In some cases parts just wear out. However, in other instances something other than the failed component is responsible for the problem.

For example, if a torque converter clutch is damaged because of a bad torque converter solenoid, replacing the torque converter assembly may correct the problem. However, if the solenoid that caused the torque converter clutch failure is not corrected at the same time, the torque converter clutch will certainly fail again.



SSCC Diagram

1 Symptom
2 Vehicle systems
3 Components
4 Causes

Workshop literature

The vehicle workshop literature contains information for diagnostic steps and checks such as: preliminary checks, verification of customer concern, special driving conditions, road tests and diagnostic pinpoint tests.

ATF	**A**utomatic **T**ransmission **F**luid
EPC	**E**lectronic **P**ressure **C**ontrol
Input shaft	Turbine shaft
OSS	**O**utput **S**haft **S**peed
Planetary gears	Pinion gear
Planetary ring gear	Planetary internal gear
PSI	**P**ounds per **S**quare **I**nch
PWM	**P**ulse-**W**idth **M**odulated
SS1	**S**hift **S**olenoid **1**
SS2	**S**hift **S**olenoid **2**
SSCC	**S**ymptom-to-**S**ystem-to-**C**omponent-to-**C**ause
TV	**T**hrottle **V**alve
TCC	**T**orque **C**onverter **C**lutch
TCM	**T**ransmission **C**ontrol **M**odule
TFT	**T**ransmission **F**luid **T**emperature
TR	**T**ransmission **R**ange
Turbine shaft	Input shaft
VFS	**V**ariable **F**orce **S**olenoid
VSS	**V**ehicle **S**peed **S**ensor