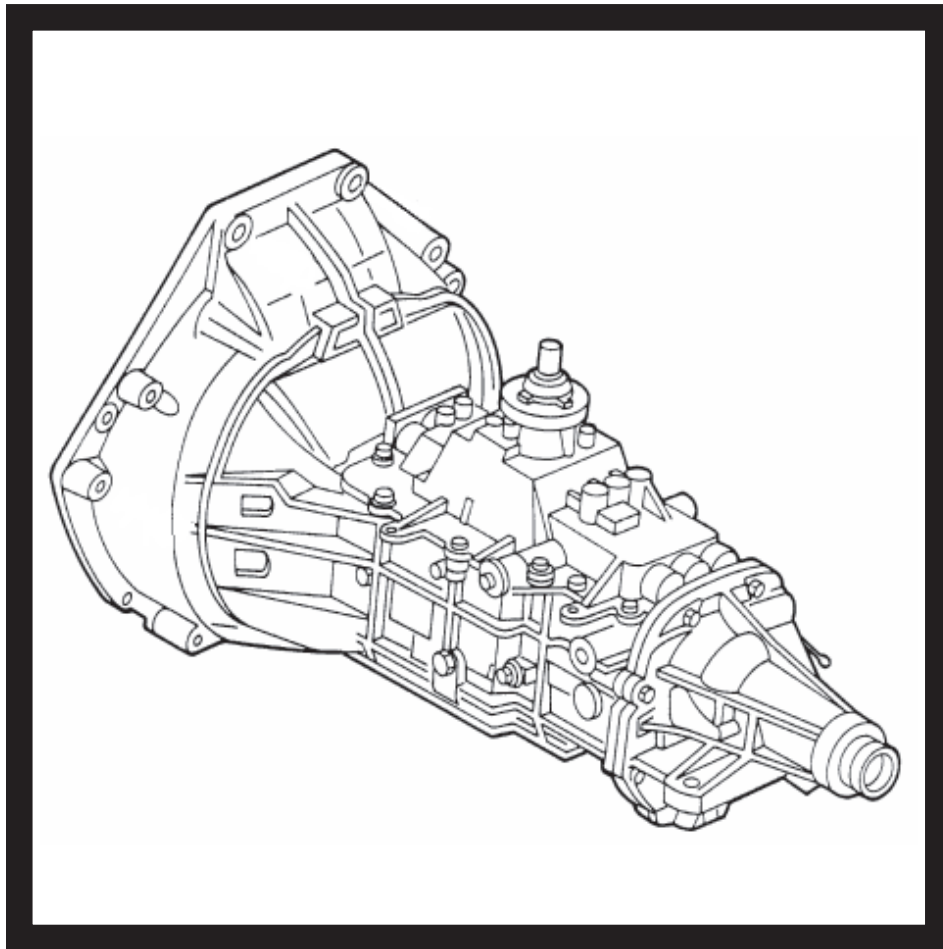


Technical Service Training

Global Fundamentals

Curriculum Training – TF1010013S

Manual Transmission and Drivetrain



Student Information

Ford Motor Company



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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:

- Explain the purpose and function of a drivetrain.
- Describe a drivetrain and identify the types.
- Identify the components of a drivetrain.
- Explain the theory and operation of a drivetrain.

Basic drivetrain

This course describes the purpose, function, theory and operation of the basic drivetrains that are used in many cars and light trucks. The drivetrain consists of a transmission, driveshaft and axle/differential or transaxle. To understand the purpose and function of the drivetrain it is essential to have an understanding of some basic terms that are common in any discussion of drivetrains. Those terms are power, torque, and powerflow.

Power

Power is the rate or speed of doing work. Adding power gets work done more quickly. For example, when a horse is connected to a plow and is plowing a field, it would take that single horse a certain amount of time to plow each row in the field. If another horse was attached to the plow, the two horses might be able to plow the field in half the time. In other words, the addition of more power reduced the amount of time needed to do the same amount of work.

The internal combustion engine creates the power that is transferred through the drivetrain to the wheels. The engine, however, only develops power within a very narrow range of rpm (revolutions per minute). In fact, most automotive engines only develop power between 1,000 and 6,000 rpm. As you will see, the drivetrain enables the vehicle to overcome the engine's power limitations.

Torque

As well as producing the power, the engine also produces torque. When the burning of fuel takes place in the engine's cylinders, the pistons and connecting rods force the crankshaft to turn. This rotary force is called torque. In simple terms, torque is a turning or twisting effort. When a technician uses a tool to tighten a bolt, torque is applied to the bolt. When the bolt is tight, the technician may not be able to turn it any more, but even though the bolt does not turn, the technician is applying torque. Torque, then is the force that produces, or tries to produce, rotation. Torque is measured in Newton meters (Nm) or foot pounds (lb-ft).

The drivetrain multiplies the engine's torque to allow the vehicle to operate. The drivetrain does both of these things by using gears in different combinations.

Powerflow

As we describe the operation of components of the drivetrain, we are concerned with the flow of power. The flow of power, or powerflow, is the path the power takes from the engine to the wheels that drive the vehicle.

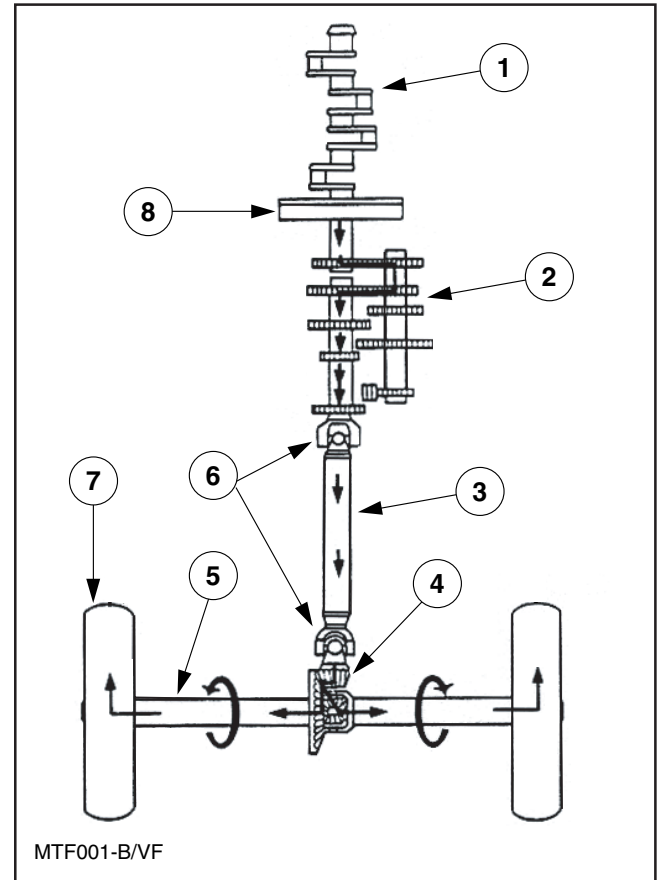
Understanding the powerflow through a drivetrain component is basic to understanding how the component works. The technician must understand how a component works in order to properly diagnose and repair a drivetrain concern.

Basic drivetrain

The purpose of the drivetrain is to transfer power from the engine to the drive wheels. There are many different combinations of drivetrain, but most fit into four basic types: Rear-Wheel Drive (RWD), Front-Wheel Drive (FWD), Four-Wheel Drive (4WD) or All-Wheel Drive (AWD).

Basic rear-wheel drive

On RWD vehicles power is transferred from the engine to the rear wheels by way of the transmission, driveshaft and rear axle/differential.



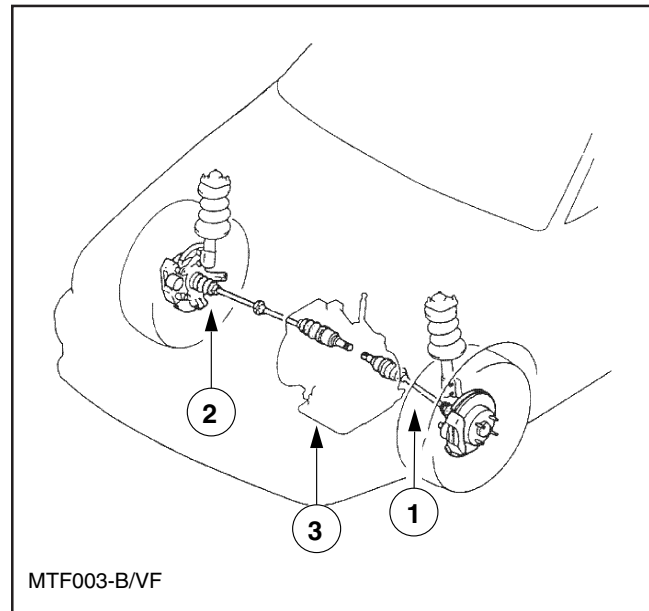
Basic rear wheel drivetrain

- 1 Engine
- 2 Transmission
- 3 Driveshaft
- 4 Rear differential
- 5 Rear axle
- 6 Universal joints
- 7 Tires
- 8 Clutch and flywheel

Basic drivetrain (continued)

Basic drivetrain front-wheel drive

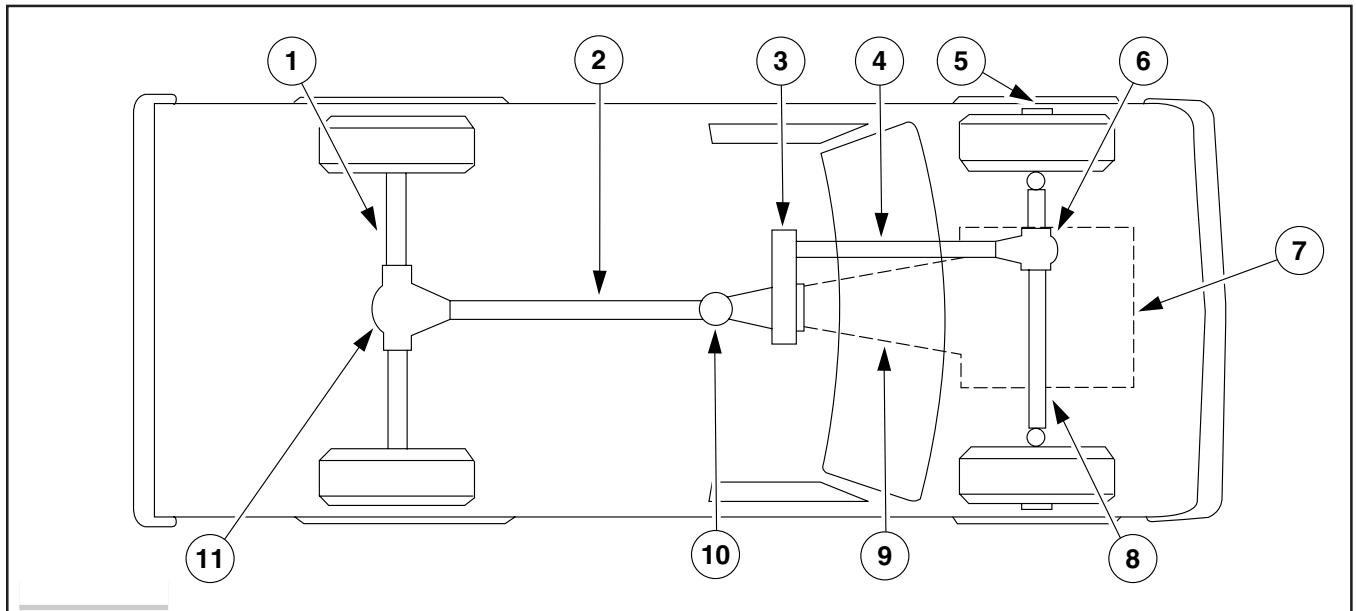
On FWD vehicles, power is transferred from the engine to the front wheels by way of the transaxle and halfshafts.



Basic front-wheel drivetrain

- 1 Left hand halfshaft
- 2 Right hand halfshaft
- 3 Transaxle

Basic four-wheel drive

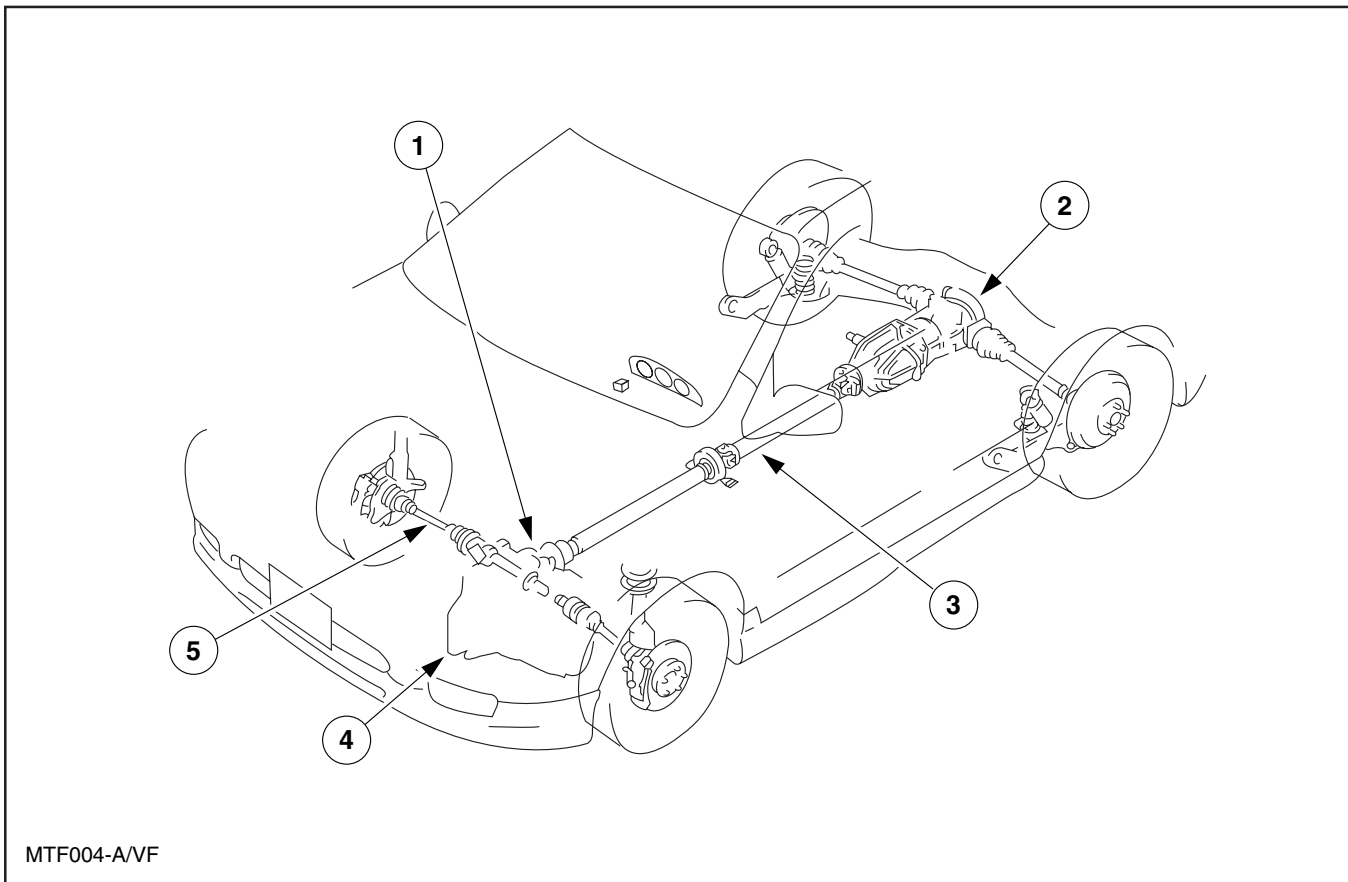


Basic four-wheel drivetrain

- | | |
|----------------------|----------------------|
| 1 Rear axle | 7 Engine |
| 2 Rear driveshaft | 8 Front axle |
| 3 Transfer case | 9 Transmission |
| 4 Front driveshaft | 10 Slip yoke |
| 5 Locking hubs | 11 Rear differential |
| 6 Front differential | |

On 4WD vehicles, power is transferred from the engine to the rear wheels by way of the transmission, transfer case, driveshaft and rear axle/differential.

Using an electronic switch or manual lever, the vehicle driver may also choose to have power delivered to the front wheels. Power is transferred to the front wheels by way of the transmission, transfer case, front driveshaft and front axle/differential.

Basic drivetrain (continued)**Basic all-wheel drive****Basic all-wheel drivetrain with a transaxle**

- | | |
|------------------|--------------|
| 1 Power take-off | 4 Transaxle |
| 2 Rear axle | 5 Halfshafts |
| 3 Driveshaft | |

On AWD vehicles, power may be transferred from the engine to the drive wheels in many ways depending on the vehicle. All AWD vehicles have a transaxle or transmission.

AWD vehicles with a transaxle transfer power to the front wheels by way of the transaxle and halfshafts. Power is sent to the rear wheels by way of the transaxle, Power Take-Off (PTO) driveshaft and rear axle/differential.

AWD vehicles with transmissions transfer power to the rear wheels by way of the transmission, transfer case, driveshaft and rear axle/differential. Power is transferred to the front wheels by way of the transmission, transfer case, front driveshaft and front axle/differential.

The typical 4WD vehicle can be switched between 2WD, 4WD high and 4WD low. The typical AWD vehicle cannot be switched between 2WD and 4WD.

Basic drivetrain components**Clutch**

The clutch connects and disconnects the engine from the transmission or transaxle.

Manual transmission

A manual transmission is a housing containing a number of gears. The gears in the transmission multiply the engine's torque to get the vehicle moving. The transmission also provides a reverse gear for the vehicle. Manual transmissions are used on some rear wheel drive and 4-wheel drive vehicles.

Transfer case

The transfer case is only used on 4WD or AWD vehicles. The purpose of the transfer case is to transmit power to the rear axle and to the front axle. Many transfer cases include a gear reduction mechanism to provide a lower range.

Driveshaft

The driveshaft transfers the rotation torque of the transmission or transfer case output shaft to the axle(s) and differential(s).

Rear axle and differential

The rear axle serves many purposes. It serves as a mounting point for suspension components and transfers power from the driveshaft to the rear wheels via the axle shafts. The rear axle also provides a gear reduction.

The purpose of the rear differential is to allow the rear axle shafts to be able to turn at different speeds.

Manual transaxle

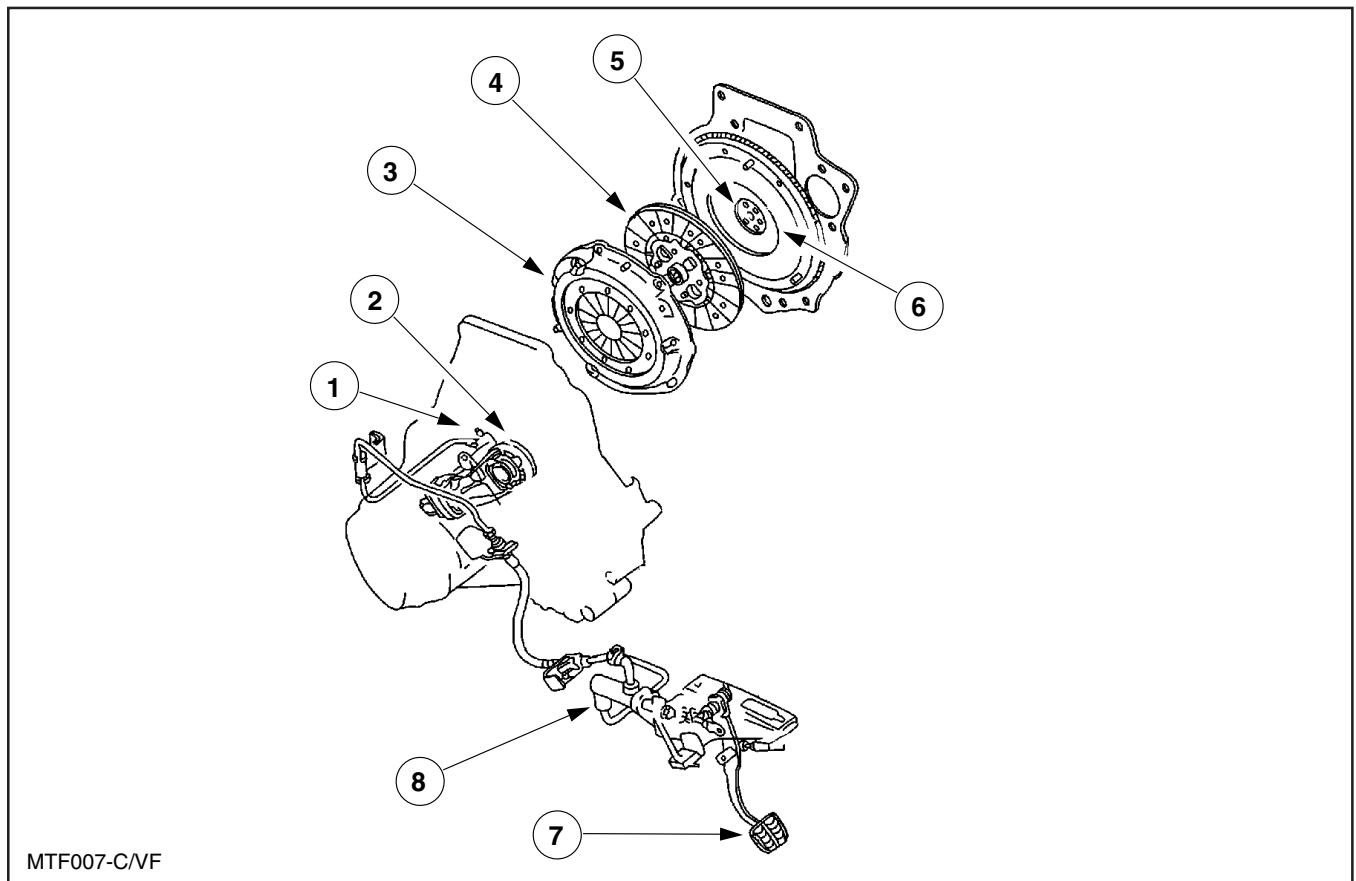
The manual transaxle contains gears to multiply engine torque received through the clutch. It also provides the differential action required by powered wheels that are rotating at different speeds. So basically it serves the same function as both the transmission and differential. Some all-wheel drive vehicles use a transaxle.

Objectives

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

- Explain the purpose and function of a clutch.
- Describe a clutch.
- Identify the components of a clutch.
- Explain the theory and operation of a clutch.

Clutch system



MTF007-C/VF

Transaxle clutch assembly

- | | |
|-------------------|--------------------------|
| 1 Slave cylinder | 5 Pilot bearing |
| 2 Release bearing | 6 Flywheel |
| 3 Pressure plate | 7 Clutch pedal |
| 4 Clutch disc | 8 Clutch master cylinder |

The purpose of the clutch is to transfer torque from the engine to the transmission in a controlled manner. The clutch disconnects the engine from the transmission or transaxle when the driver pushes down the clutch pedal. As the driver allows the pedal to come up, the engine connects to the transmission/transaxle, and the vehicle moves. The clutch must be designed so that this connecting (engaging) and disconnecting (disengaging) is smooth and can occur gradually. It must not jump abruptly from disengagement to engagement. To move a vehicle, the

engine must speed up to get enough power. It cannot in one moment bring the speed of the wheels up to the speed of the engine. Shifting gears in a moving car creates a similar situation. The driving wheels are not turning at the same speed as the engine. To make smooth shifts between gears, the clutch slips a little, takes hold gently at first, and gradually grabs harder and harder. Thus the driving wheels start to move slowly and gradually pick up speed, until finally everything is turning at the same speed and the clutch is solidly engaged.

Clutch components

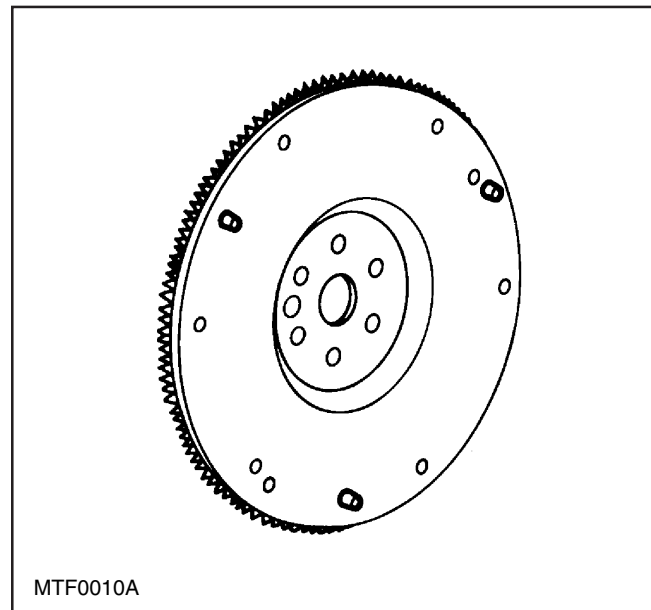
The size of clutch components varies based upon the type of vehicle in which they are used. Larger heavy-duty vehicles use heavy-duty components so the clutch can handle the load of the vehicle. However, the typical clutch uses seven major clutch components.

The clutch components are:

- Flywheel
- Clutch disc assembly
- Pressure plate assembly (cover, plate, internal springs and levers)
- Clutch fork
- Release bearing
- Pilot bearing
- Hydraulic or mechanical linkage

Flywheel

The flywheel is the foundation on which the entire clutch is attached. It is bolted to the engine crankshaft and rotates with it. The flywheel is machined smooth to provide a uniform friction surface. The mass of the flywheel is designed to dampen the firing pulses of the engine.

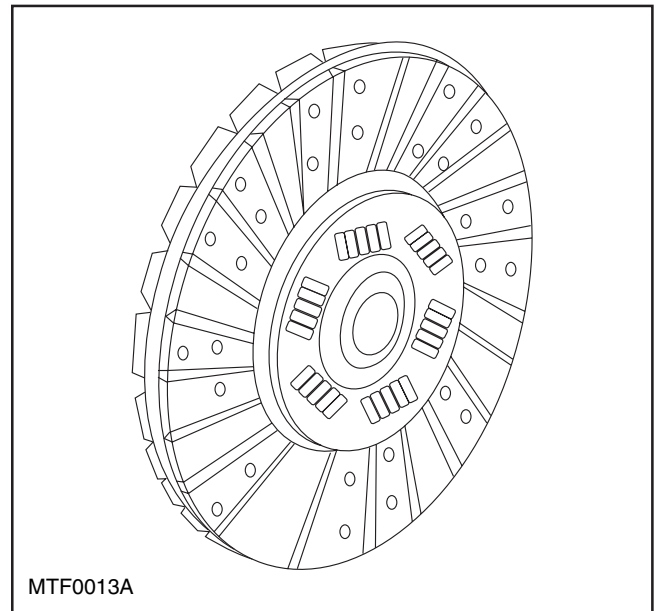


Typical flywheel

Clutch disc

The clutch disc receives the torque of the engine and transfers it through a splined hub to the transmission input shaft. The disc has grooved friction material on both sides where it contacts the flywheel and the pressure plate. These grooves allow cleaner disengagement action and enhance air flow over the disc for cooling. Dampening springs in the hub are used to absorb engine pulses.

NOTE: Most vehicles use a single-disc clutch system. Some vehicles use a multiple-disc clutch system for adequate torque transfer.



Typical clutch disc

Pressure plate

The pressure plate assembly is bolted to the engine flywheel. When engaged, it applies pressure against the clutch disc, holding it tightly against the surface of the flywheel. One side of the pressure plate is machined smooth. This side presses the clutch disc against the flywheel. On the other side of the pressure plate is the clutch cover. This cover bolts to the flywheel and provides the solid base for the pressure plate. Springs are used to force the pressure plate against the clutch disc and flywheel.

Pressure plate types

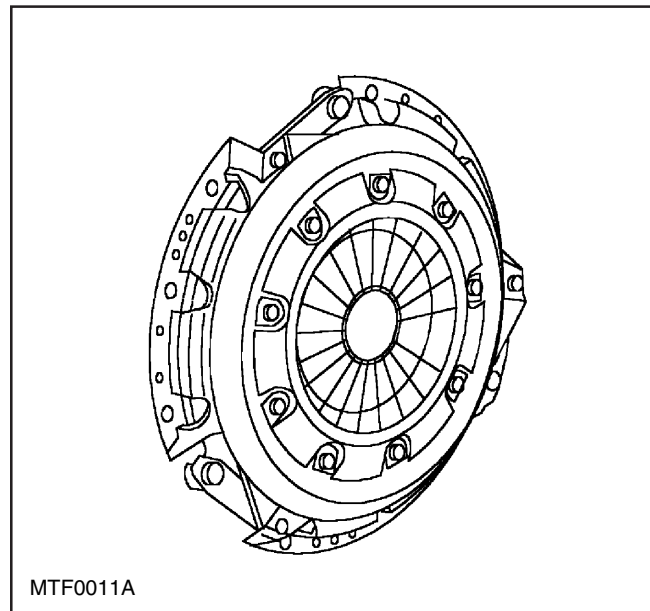
Although all pressure plates perform the same function, the types of pressure plates vary.

Diaphragm spring pressure plate

The diaphragm spring pressure plate assembly uses a conical piece of spring steel to press the pressure plate against the friction disc and flywheel. The center portion of the spring is slit into numerous fingers that act as release levers.

When the clutch is disengaged, the release bearing is forced against the fingers of the diaphragm spring, which causes the outer rim of the spring to move away from the flywheel. The force on the pressure plate is then released, which releases the friction disc from the flywheel.

Many vehicles with diaphragm-type pressure plates are self-adjusting. During clutch replacement, the self-adjuster must be set before the pressure plate is installed on the vehicle.

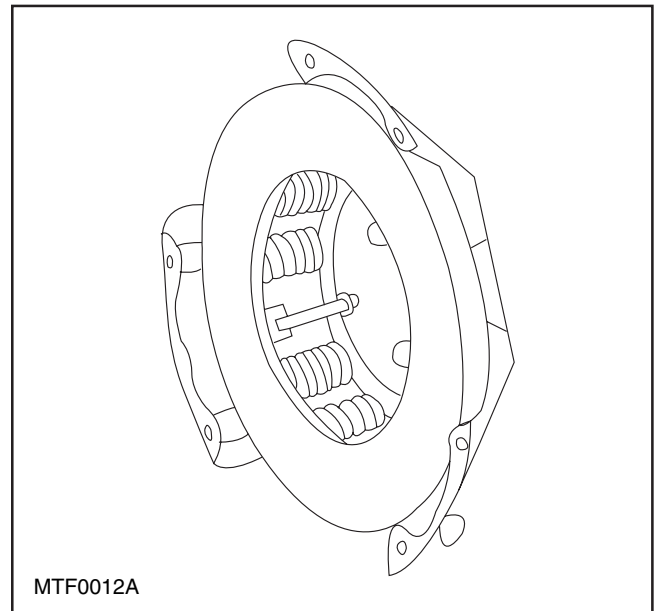


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Diaphragm spring pressure plate

Coil-spring pressure plate

Heavy-duty vehicles require that more force be applied to the clutch disc. These vehicles often use a coil-spring type pressure plate. On a coil-spring pressure plate, several coil springs are placed between the clutch cover and the pressure plate.

Some coil-spring pressure plates have weighted release levers that allow the centrifugal force of the rotating clutch to increase the force that the pressure plate applies to the clutch disc.

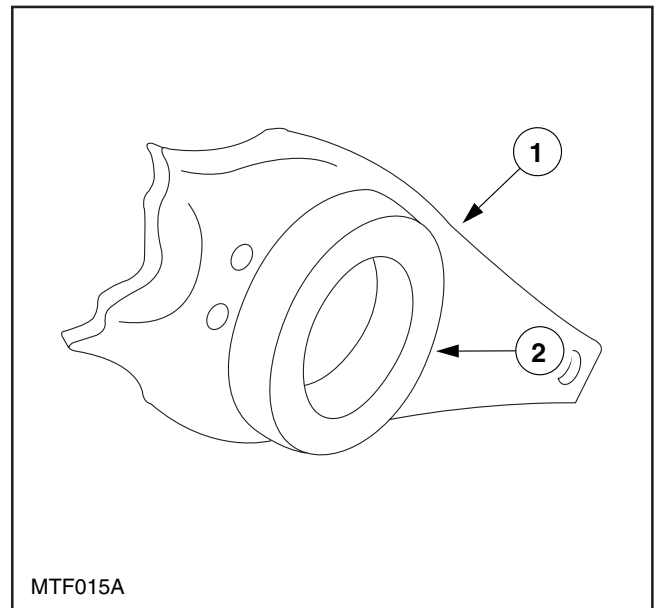


Typical coil-spring pressure plate

Clutch fork

A clutch fork is used on some clutch assemblies to move the release bearing into and out of the fingers or levers of the pressure plate. It mounts to a pivot ball on the transmission and uses mechanical leverage for application and release of the pressure plate.

Clutch forks are commonly used on transmissions with mechanical-type linkages. However, clutch forks are also used in combination with some hydraulic clutch systems.



Typical clutch fork

- 1 Clutch fork
- 2 Release bearing

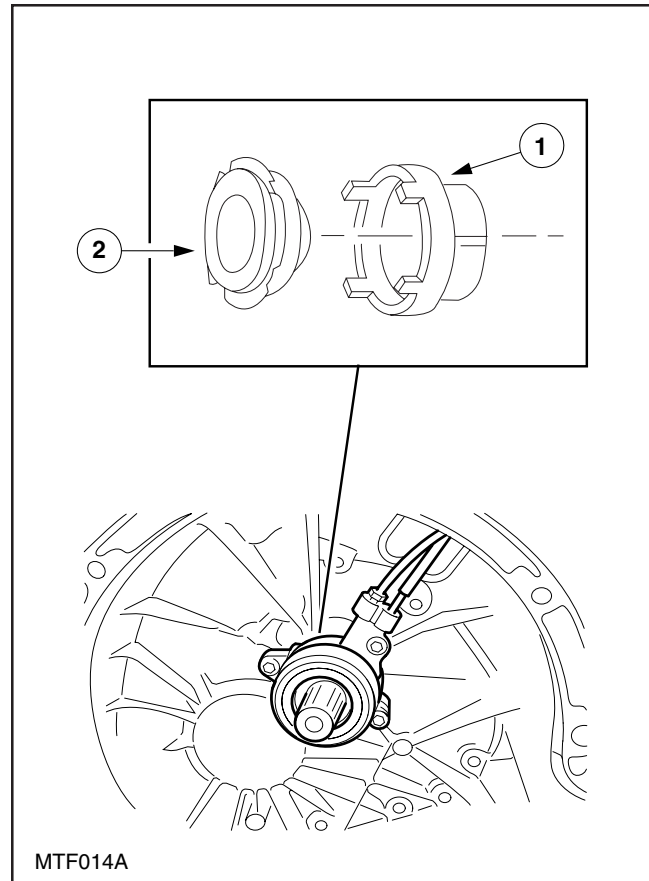
Pressure plate (continued)

Release bearing

The release bearing is a sealed ball bearing that acts upon the diaphragm fingers or release levers of the pressure plate to disengage the clutch.

The release bearing is mounted to either a release lever or hydraulic cylinder. When the driver presses the clutch pedal down, the release bearing is forced into the pressure plate release fingers or levers, forcing them inward. The pressure plate force is released and disengages the clutch. Often the release bearing is mounted in a carrier.

Many release bearings are designed to be in contact with the pressure plate fingers even when the clutch pedal is fully released.



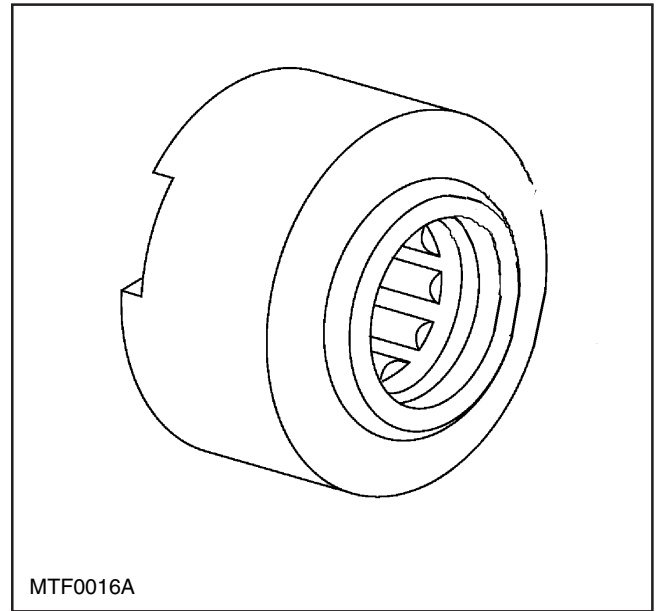
Typical release bearing

- 1 Bearing carrier
- 2 Release bearing

Pilot bearing

The pilot bearing is used on many vehicles. It mounts either in the center of the flywheel or in the rear of crankshaft. Its purpose is to support the input shaft of the transmission while allowing the shaft to rotate independently of the crankshaft.

Some front-wheel drive vehicles do not use a pilot bearing in their clutch systems.



Typical pilot bearing

Clutch linkage

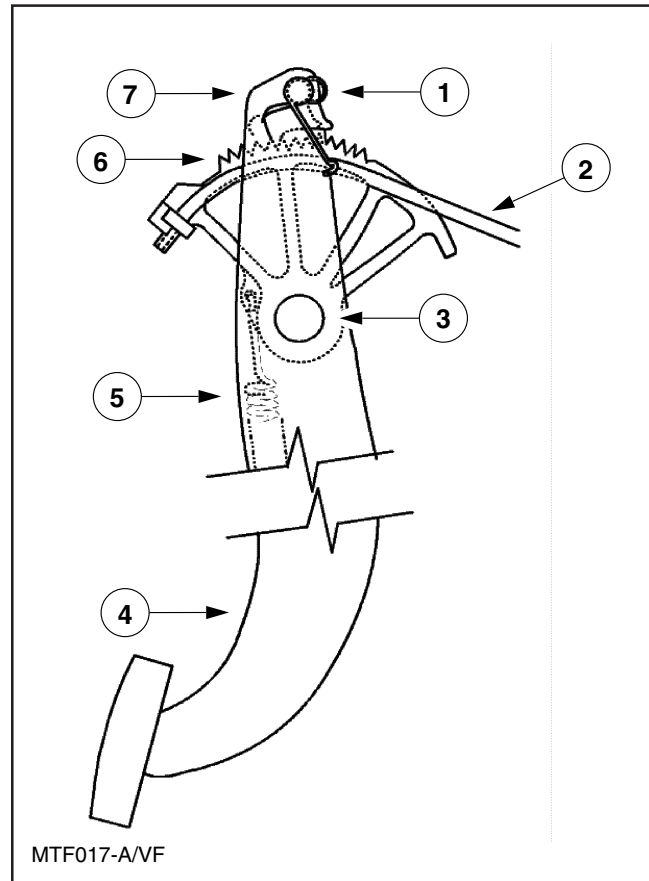
The connection between the clutch pedal and the release bearing is the clutch linkage. There are two basic types of clutch linkage:

- Manual linkage with self-adjuster
- Hydraulic linkage

Manual linkage

A cable linkage with self-adjuster is used on some vehicles. This type of linkage connects the clutch pedal to the release fork. At the top of the clutch pedal where the cable attaches is a self-adjuster that adjusts the cable as the clutch disc wears.

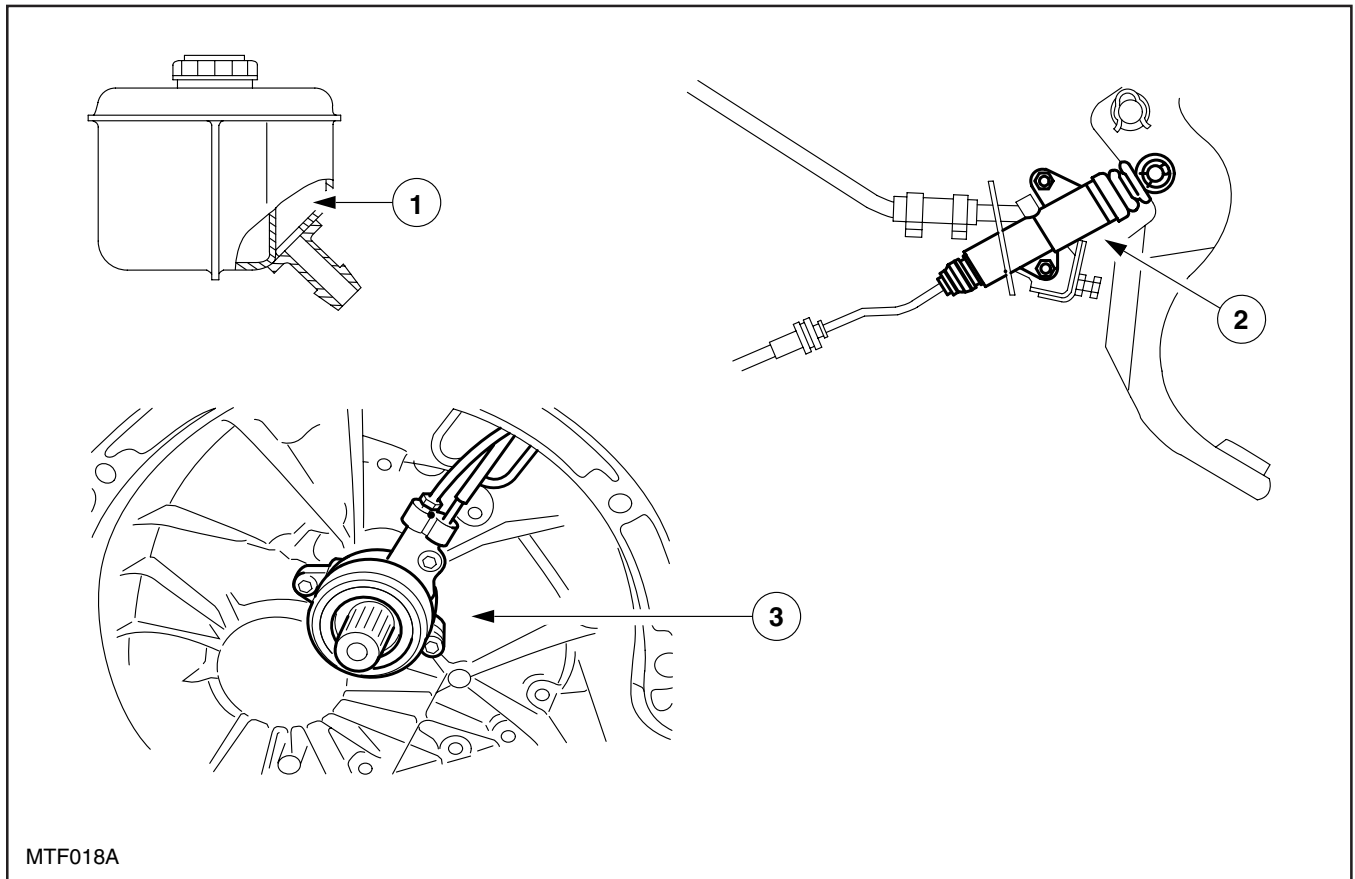
During operation there is a slight preload applied to the release bearing by a spring-loaded ratcheting pawl. This pawl engages into a toothed wheel (quadrant) that is mounted at the clutch pedal pivot point. When the clutch is disengaged, the pawl engages a tooth on the quadrant. As the clutch wears, the slack in the cable allows the pawl to move to the next tooth of the quadrant, automatically taking the slack out of the cable and maintaining the correct adjustment on the clutch.



Manual clutch linkage

- 1 Pawl tension spring
- 2 Clutch cable
- 3 Pivot
- 4 Clutch pedal
- 5 Quadrant tension spring
- 6 Quadrant
- 7 Pawl

Hydraulic system



Basic hydraulic system

- 1 Clutch master cylinder reservoir
- 2 Clutch master cylinder
- 3 Clutch slave cylinder with release bearing

Hydraulic clutch controls use hydraulic pressure to move the release bearing against the release fingers or levers of the pressure plate. Similar to a brake system, the hydraulic clutch has a master cylinder, hydraulic tubing, and a slave cylinder.

When the driver presses the clutch pedal, a linkage arm connected to the master cylinder forces the master cylinder piston down its bore.

- Pressure is applied to the brake fluid contained in the master cylinder, which sends this pressure to the slave cylinder.
- The piston in the slave cylinder changes this pressure into mechanical force by moving outward.
- This mechanical action forces the release bearing into the pressure plate release fingers or levers, disengaging the clutch.

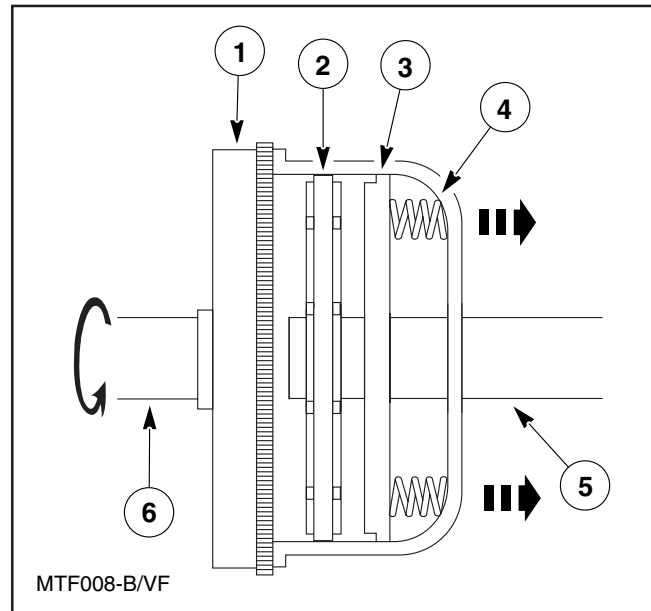
Clutch operation

Most cars and light trucks use a single dry-disc clutch. Basically, this system has one plate squeezed tightly between two other plates. The middle plate is driven. A strong spring or set of springs forces the two driving members together. This tightens their grip on the middle plate until all are turning together as one unit.

The engine flywheel is used for one of the driving members. The surface of the flywheel is machined very smooth where the friction plate pushes up against it.

The other driving member is called the pressure plate. The pressure plate is a heavy ring of cast iron that is smooth on one side. The pressure plate is fastened to the clutch cover, which is bolted to the flywheel, so they all turn together.

The driven plate is a flat disc of steel with friction material facing on each side. The disc is fastened by splines to the input shaft of the transmission. Since the clutch disc has internal splines, it fits on the transmission input shaft and must rotate when the input shaft rotates. The clutch disc is free to move back and forth on the input shaft due to its straight splines.



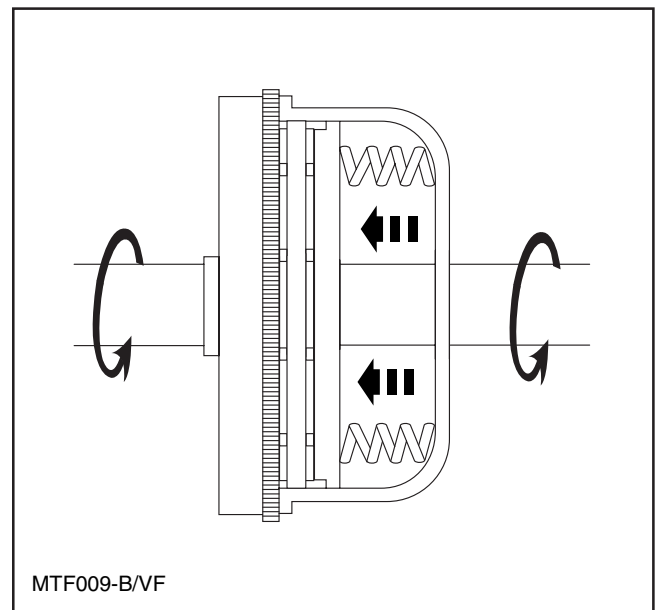
Clutch disengaged

- 1 Flywheel
- 2 Clutch disc
- 3 Pressure plate
- 4 Spring
- 5 Transmission input shaft
- 6 Crankshaft

When the driver pushes down the clutch pedal (clutch disengaged), the pressure plate is forced away from the flywheel. Since the clutch disc is no longer held against the flywheel, the engine no longer drives the clutch disc and transmission input shaft.

Clutch disengagement allows the transmission input shaft to stop rotating, so the vehicle can be stopped without stalling the engine. If the vehicle is moving, releasing the torque on the input shaft allows smooth shifts because the transmission/transaxle gears are not under a load.

When the clutch pedal is up (clutch engaged), the pressure plate assembly squeezes the clutch disc against the flywheel. This action forces the clutch disc to turn with the flywheel and drive the transmission input shaft.



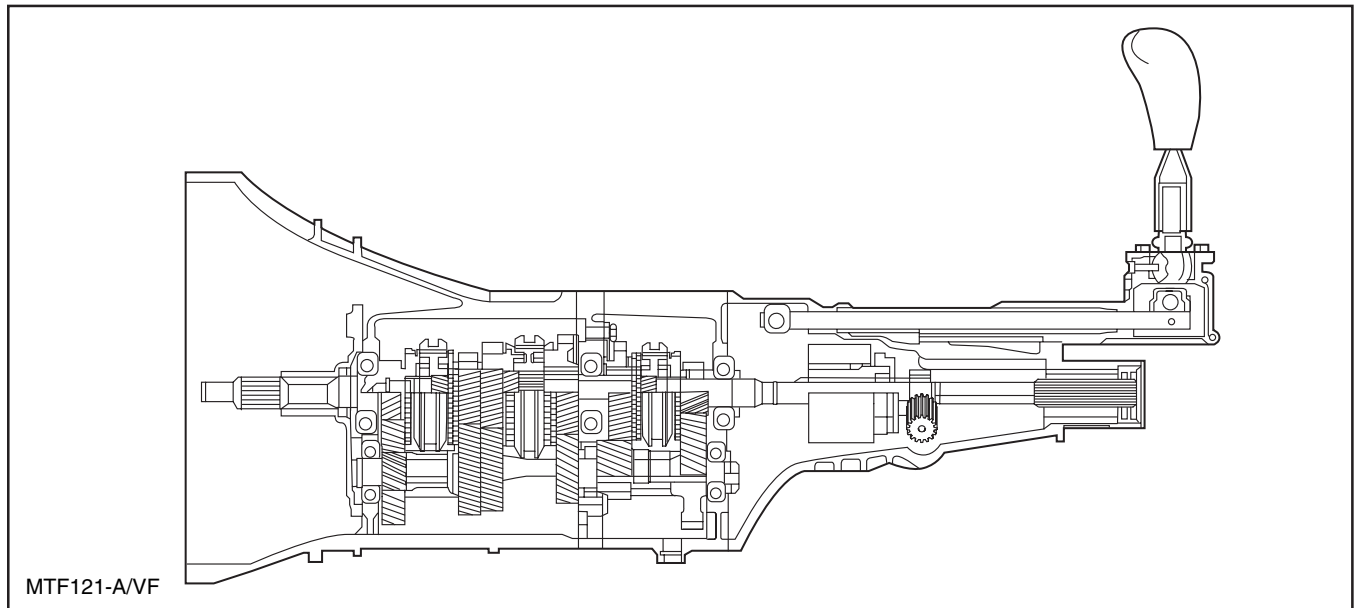
Clutch engaged

Objectives

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

- Explain the purpose and function of a manual transmission/transaxle.
- Describe a manual transmission/transaxle.
- Identify the components of a manual transmission/transaxle.
- Explain the theory and operation of a manual transmission/transaxle.

Manual transmissions and transaxles



Typical manual transmission

The manual transmission is a vital link in the drivetrain of many modern vehicles. The manual transmission uses different size gears to give the engine a mechanical advantage over the driving wheels. Without this mechanical advantage, an engine can generate only limited torque at low speeds. Without enough torque, moving a vehicle from a standing start would be impossible.

During normal operating conditions, power from the engine is transferred through the engaged clutch to the transmission input shaft. The input shaft transfers this power to gears in the transmission, which alter its torque and speed and then send it to the rest of the drivetrain.

Manual transmissions are used on rear-wheel and four-wheel drive vehicles. On front-wheel drive vehicles manual transaxles are used. Manual transaxles basically perform the same function as manual transmissions. However, transaxles also have one additional function: they contain the differential which provides final gear reduction and differential action for the wheels. The differential unit is mounted inside the transaxle housing. The differential receives torque directly from the output gear of the transmission components inside the transaxle. It then uses a gear ratio to multiply this torque and transmits it to the wheels via halfshafts.

Purpose of gears

The purpose of the gears inside a transmission or transaxle is to transmit rotating motion. Gears are normally mounted on a shaft and they transmit rotating motion from one shaft to another. Gears and shafts act upon each other in one of three ways:

- The shaft can drive the gear.
- The gear can drive the shaft.
- The gear can be free to turn on the shaft.

Sets of gears can be used to multiply torque and decrease speed, decrease torque and increase speed, transfer torque and leave the speed the same, or change the direction of torque.

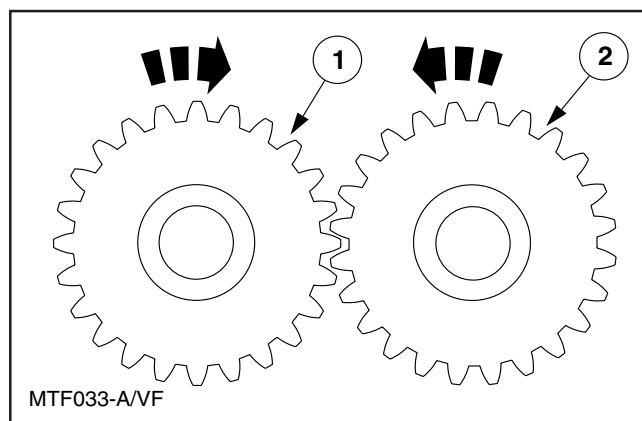
Gear rotation

Gear rotation inside a manual transmission or transaxle must be understood when performing diagnosis and repair.

A basic rule that applies to gears is that two external gears in mesh rotate in opposite directions.

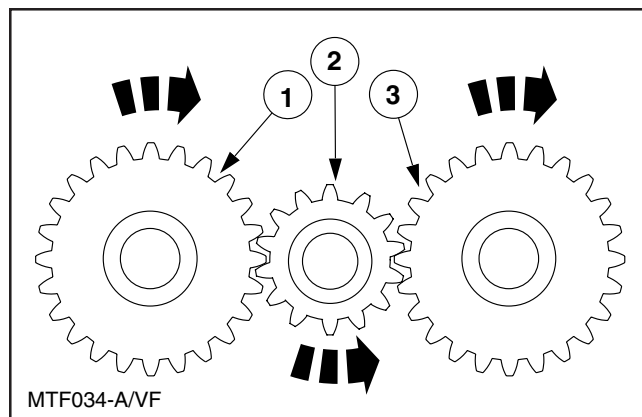
This means that an engine that is driving a gear clockwise will cause any gear in mesh with this gear to rotate counterclockwise. To get that driven gear to turn the wheels in a clockwise direction, a third gear must be added.

Another basic gear rule is that when the third gear is added, the output from the gearset is in the same direction as the input.



Gears in mesh 1:1 ratio

- 1 Clockwise rotating gear
- 2 Counterclockwise rotating gear



Two gears connected by an idler gear

- 1 Input gear rotating clockwise
- 2 Idler gear rotating counterclockwise
- 3 Output gear rotating clockwise

Gear design

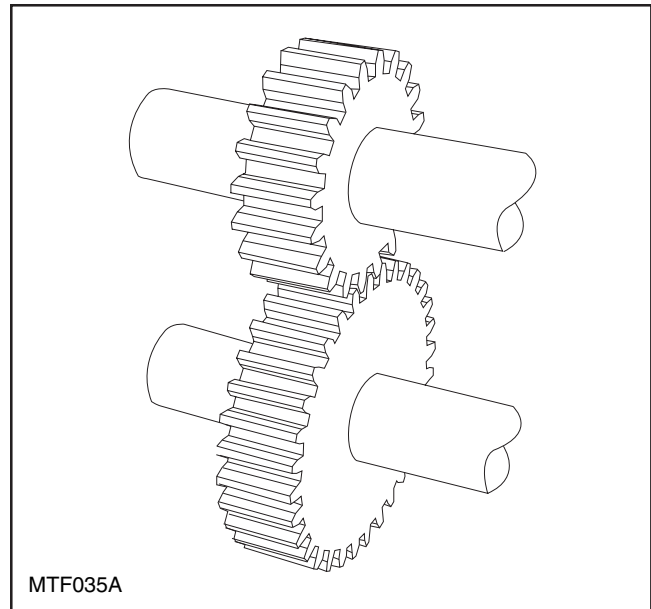
There are many types of gears, and each has its own operating characteristics. Common gears that are found in manual transmissions and transaxles include:

- Spur gears
- Helical gears
- Spur bevel gears

Spur gears

The spur gear is the simplest gear design used in manual transmission/transaxles.

- Its main advantage is that its teeth are cut straight so it can slide in and out of contact with other gears.
- Its main disadvantage is that it is noisy during operation. Spur gears whine at high speed.
- If a spur gear is found in a manual transmission/transaxle it is usually only used for reverse gear.



Basic spur gears

Helical Gears

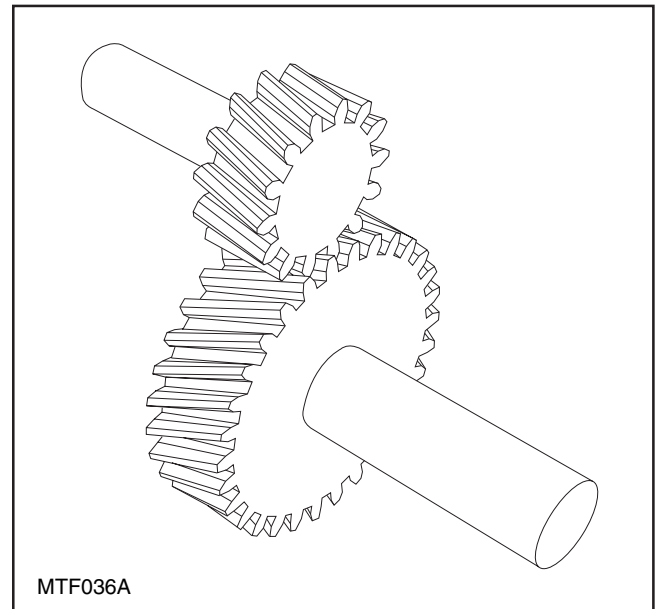
Helical gears are the most common types of gears used in manual transmission and transaxles. These gears are cut at an angle to the gear's axis of rotation. This allows two or more teeth to be in full contact at all times during operation.

- The main advantage of helical gears is that they operate much more quietly and are much stronger than spur gears.
- The main disadvantage of helical gears is that they cannot be slid into and out of contact with their adjoining gears. They must maintain contact at all times. Helical gears are sometimes referred to as constant mesh gears.
- Helical gears are used for all forward speed gears, and in some cases for reverse as well.

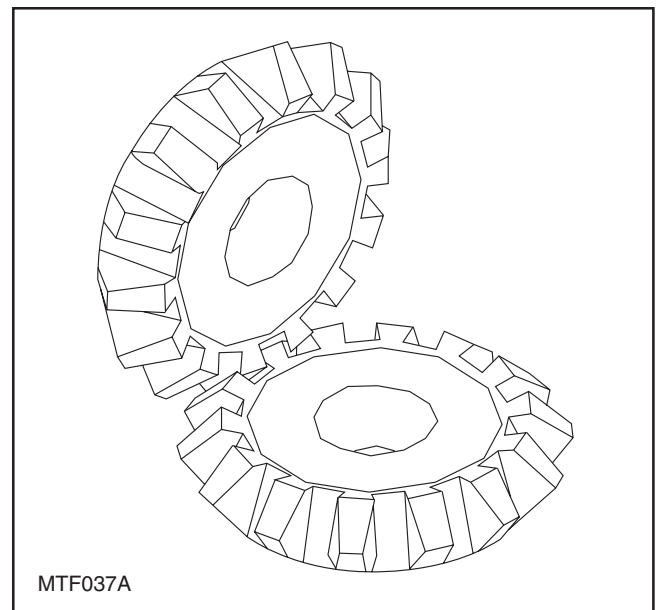
Spur bevel gears

Spur bevel gears allow a gear to rotate on an axis that is 90 degrees offset from the gear which it contacts.

- Spur bevel gears are only used as pinion gears and side gears in the differential assembly of a manual transaxle.



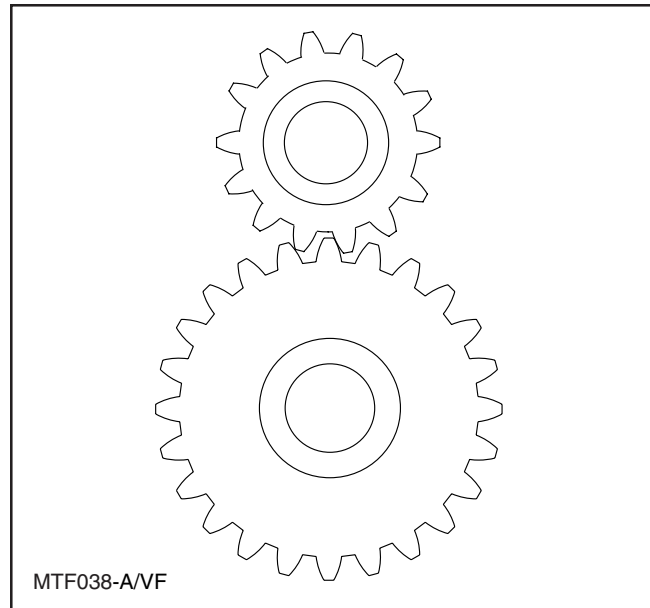
Basic helical gears



Basic spur bevel gears

Gear ratios

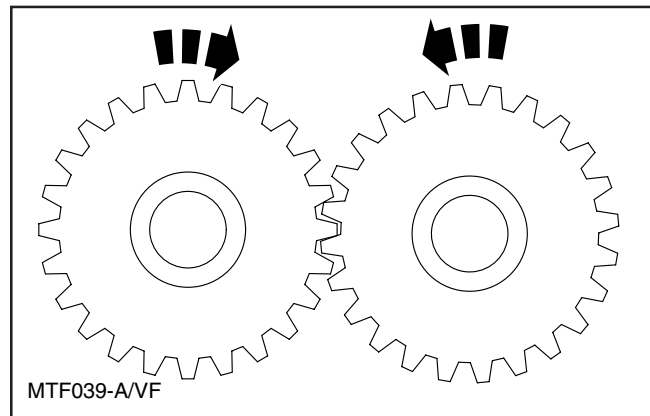
The ancient Greek engineer Archimedes once said, “Give me a lever long enough, and a place to put it and I can lift the world.” This statement refers to the ability of a lever to multiply force. Transmission gears are basically a set of levers arranged in a circle. Transmission gears multiply force by the differences in size and number of teeth in the gear. A gear ratio is a term that describes the differences in the number of teeth on the gears in mesh.



Circular levers (gears)

For example:

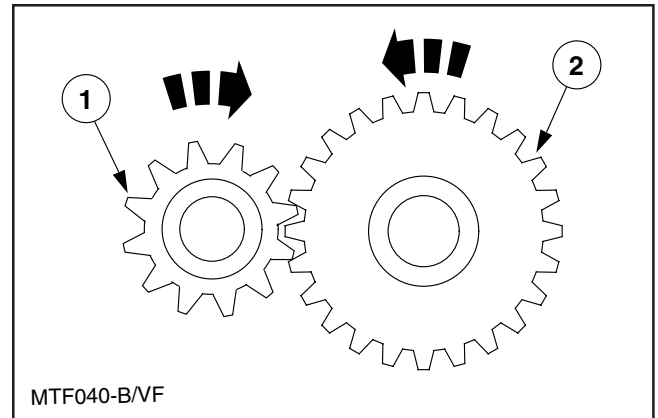
- Two gears are both the same size and have the same number of teeth.
- Each time the driving gear makes a complete rotation, so does the driven gear.
- Both gears are turning at the same speed, and because they are the same size and have the same number of teeth, they are turning with the same amount of torque.
- The only difference between the gears is that they are rotating in opposite directions.
- Gears the same size with the same number of teeth are considered a one to one gear ratio because the driving gear is rotating one time for each rotation of the driven gear.
- Gear ratios are usually written with a colon between them, so one to one would be written 1:1.



Reduction gear ratio

When the driving gear is smaller than the driven gear, the driven gear is turning slower than the driving gear, therefore the gears are in reduction. This is a reduction in the driven gear's speed, which multiplies torque.

- The smaller gear has 12 teeth and is driving the larger gear that has 24 teeth.
- The 12 tooth driving gear is turning with 10 pounds of torque. But the 12 tooth gear rotates twice for every rotation of the 24 tooth driven gear.
- This causes the driven gear to have twice as much torque in every rotation. The driven gear now turns with 20 pounds of torque.
- This is a reduction gear ratio of 2:1.

**Gears in reduction**

- 1 Driving gear
- 2 Driven gear

Gear ratios (continued)

An example of the gear ratios in a manual transmission would be:

- Reverse = 3.40:1
- 1st gear = 3.97:1
- 2nd gear = 2.34:1
- 3rd gear = 1.46:1
- 4th gear = 1:1
- 5th gear = .79:1

As you can see, Reverse and 1st through 3rd gears are reduction gears. 4th gear is 1:1 meaning that the driving and driven gears have the same number of teeth and are rotating at the same speed. This is called direct drive.

If an engine that produces 407 Nm (300 lb-ft) of torque is connected to a drivetrain that has a 10:1 gear ratio, the result is that 4,070 Nm (3,000 lb-ft) of torque is applied at the wheels, which is the amount of power needed to move the 1,360 kg (3,000 lb) vehicle.

However, there is a drawback to reduction gear ratios. The driving gear must turn many more times than the driven gear. So an engine that is operating at 6,000 revolutions per minute (rpm) will only turn a drivetrain with a 10:1 gear ratio at 600 rpm.

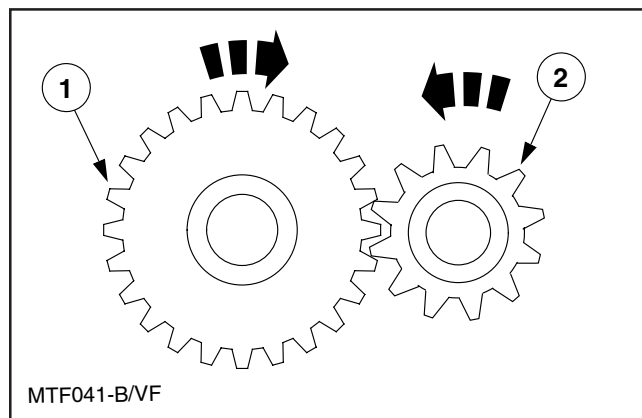
Because of centrifugal force, once a vehicle begins moving, it does not require as much power to maintain its speed as it did to get it moving. Because of this force gear ratios can be changed to allow increased rotation speed.

Overdrive gear ratio

Any time the driving gear is rotating slower than the driven gear it is called an overdrive gear ratio.

Overdrive ratios allow the drivetrain to actually turn faster than the engine because at high speed very little torque is needed to keep the vehicle moving. Since overdrive ratios allow the engine to operate at lower rpm they provide better fuel economy.

To determine the total gear ratio of the entire drivetrain, all that has to be done is to multiply the ratio of the specific transmission gear by the ratio of the differential. For example, assume you have a differential with a 3.78:1 ratio. To determine the actual gear ratio that is being used in any specific gear, just multiply that gear ratio by 3.78. If the transmission 1st gear has a 3.97:1 ratio, multiply it by the differential ratio of 3.78:1 and you find that the total gear reduction from the engine to the wheels is 15.01:1. So the torque of the engine is being multiplied 15.01 times by the drivetrain.



Gears in overdrive

- 1 Driving gear
- 2 Driven gear

Basic manual transmission operation

To understand how modern transmissions work, we should first look at the operation of a basic 3-speed transmission. In this section we will build up a simple set of gears to see how a basic 3-speed transmission works.

Powerflow

The path that power follows from the input shaft to the output shaft in a manual transmission is called powerflow. Understanding powerflow is essential for the diagnosis of manual transmission concerns.

Although the powerflow through some transmissions may be slightly different because of differences in parts, all manual transmission powerflow is very similar.

On the typical manual transmission, the input shaft is powered through the clutch and drives the countershaft (layshaft). The countershaft (layshaft) then transfers the power to the gear engaged to the output shaft by the synchronizer.

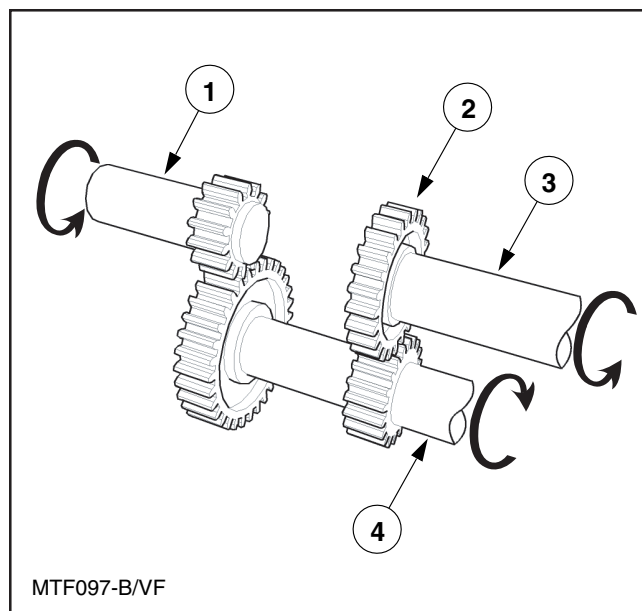
Gear reduction

To get a manual transmission into 1st gear takes the use of four gears and three shafts.

- A small gear on the input shaft from the engine drives a larger gear fastened to the transmission countershaft.
- Another smaller gear fastened to the countershaft drives a large gear on the third shaft, which is the output shaft.

Looking at the size of the gears you can see that there is gear reduction between the input shaft gear and the countershaft input gear. Additionally, there is more gear reduction between the countershaft 1st gear and the output shaft 1st speed gear.

Note that the input shaft and the output shaft are turning in the same direction because the countershaft acts as an idler gear between them.



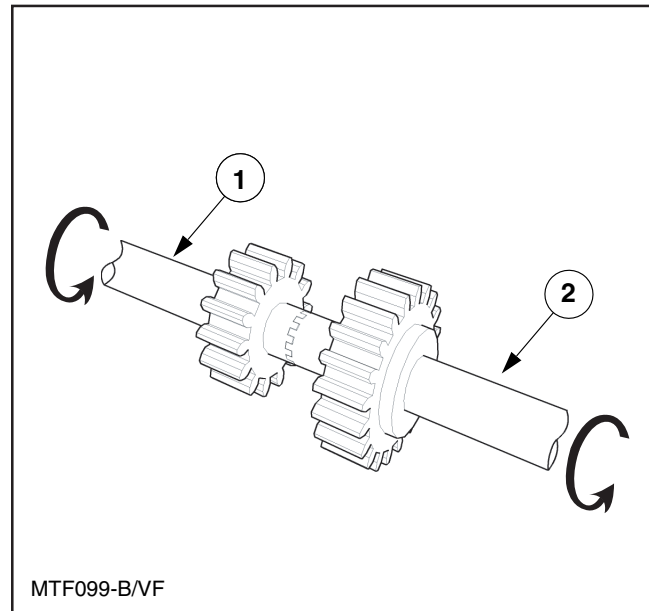
Basic transmission in first gear

- 1 Input shaft
- 2 1st speed gear
- 3 Output shaft
- 4 Countershaft

Powerflow (continued)**Direct drive**

3rd gear in our basic transmission is direct drive. In direct drive no gear reduction takes place.

- The input shaft is mechanically connected directly to the output shaft.
- Each rotation of input shaft results in a rotation of the output shaft, giving it a 1:1 ratio.



Basic transmission in third gear (direct drive)

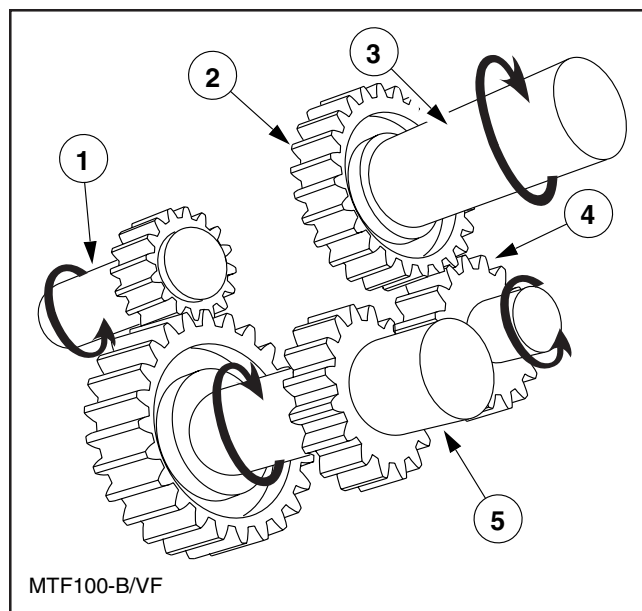
- 1 Input shaft
- 2 Output shaft

Reverse

To achieve reverse in a manual transmission requires the use of an additional gear and shaft. This gear is commonly known as the reverse idler gear. In some transmissions the reverse idler gear actually slides in and out of contact with its adjoining gears. In other transmissions it is a helical gear that is constantly in mesh.

- In reverse, power still enters the transmission through the input shaft and is transferred to the countershaft input gear.
- However, the countershaft reverse gear and the output shaft reverse gear are not in direct contact.
- In order for the countershaft reverse gear to transmit rotation to the output shaft reverse gear, the reverse idler gear meshes with the teeth on both gears.
- The normal rotation of the output shaft is reversed, allowing it to rotate in reverse.

Note that the countershaft reverse gear is smaller than the reverse speed gear on the output shaft, providing a reduction gear ratio to multiply power in reverse. This gear reduction is needed since reverse can only be engaged from a standing stop.



Basic transmission in reverse

- 1 Input shaft
- 2 Reverse speed gear
- 3 Output shaft
- 4 Reverse idler gear
- 5 Countershaft

Manual transmission components

Although the operation of a manual transmission is very straightforward, many different components are needed to make its operation practical.

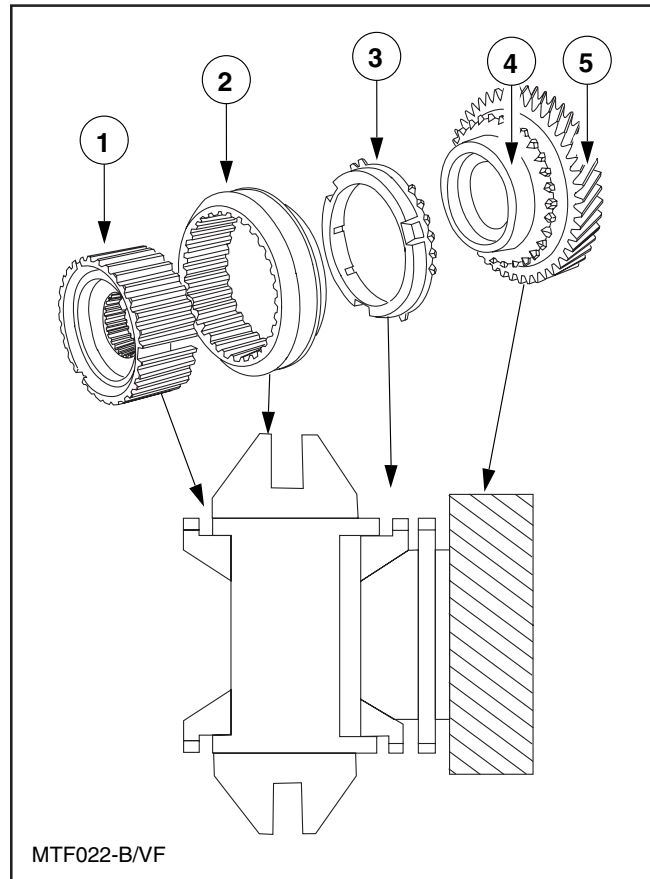
Synchronizers and speed gears

In a transmission, gears are named for the speed they are used with. For example, the gear that is used for 1st gear is called the 1st speed gear. All forward gears in modern transmissions are helical gears. Helical gears are quiet and have additional strength. However, because the teeth of helical gears are angled, they cannot be slid into and out of engagement with each other. For this reason, the speed gears are not directly splined to the shaft upon which they ride. The inner diameter of the speed gears is smooth, allowing them to rotate freely on the shaft. When the gear needs to be connected to the shaft, the synchronizer sleeve moves over and engages the clutching teeth on the side of the gear.

- The synchronizer sleeve is locked to the speed gear.
- The synchronizer sleeve inner diameter has internal teeth that slide along the external teeth of the synchronizer hub outer diameter.
- The synchronizer hub is splined to the shaft's inner diameter.

The speed gear is connected to the output shaft through the synchronizer, allowing the torque of the gear to be transmitted.

In most instances, each synchronizer works with two speed gears because its sleeve can slide both forward and rearward. For this reason, synchronizers will be named for the gears they control. For example, the 1-2 synchronizer works on both 1st and 2nd speed gears.



Basic synchronizer and speed gear

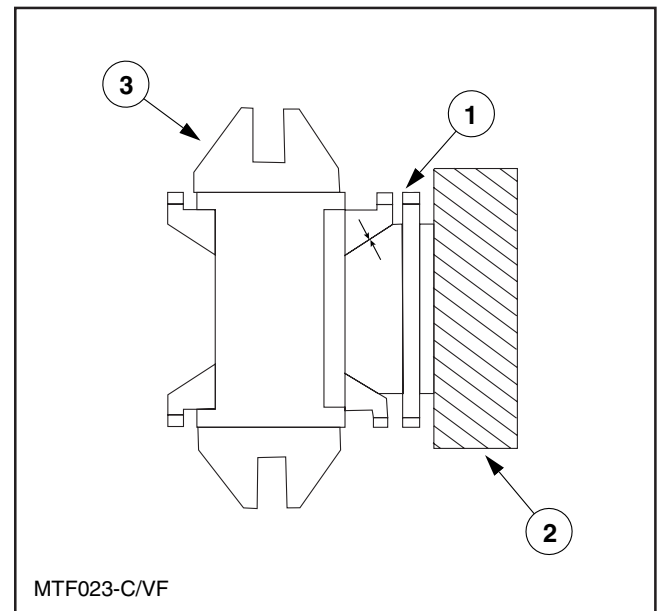
- 1 Synchronizer hub
- 2 Synchronizer sleeve
- 3 Blocking ring
- 4 Clutching teeth
- 5 Speed gear

Synchronizing gear and shaft speed

Another function of the synchronizer is to make the speed of the speed gears match that of their shaft, before the gear is locked to the shaft. The rotating speed of the gear is different than the speed of the shaft. If the speed of the gear and shaft isn't the same before the synchronizer sleeve engages the gear's clutching teeth, both the sleeve and the clutching teeth could be damaged.

When a gear is selected, the shift fork forces the synchronizer sleeve toward the speed gear.

- A blocking ring, which has a cone-shaped inner surface, is pushed into contact with the cone-shaped shoulder of the speed gear.
- As the synchronizer sleeve continues to move, it compresses the inserts against the retaining springs.
- As it moves further, the sleeve splines mate with teeth on the blocking ring.
- Friction between the blocking ring and gear shoulder causes the gear, which is rotating freely on the shaft, to speed up or slow down to the same speed as the synchronizer.



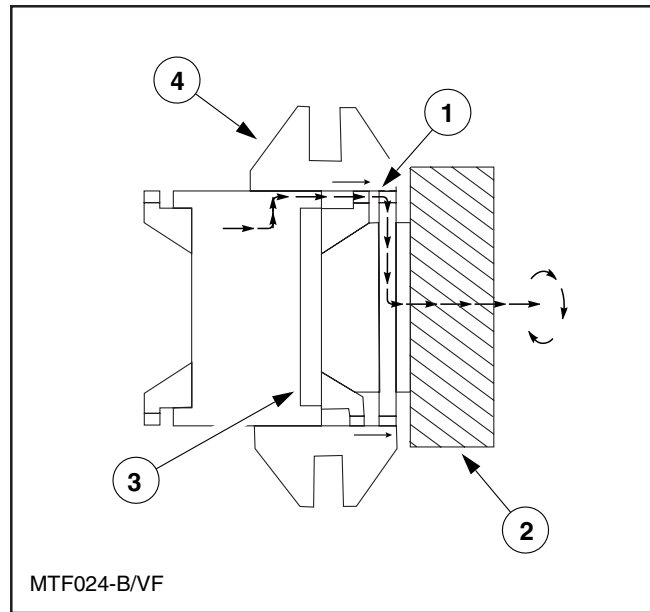
Synchronizer operation

- 1 Blocking ring
- 2 Driven gear
- 3 Synchronizer sleeve

Manual transmission components (continued)

Synchronizing gear and shaft speed (continued)

- The blocking ring prevents the sleeve’s splines from engaging the gear’s clutching teeth until they are all rotating at the same speed.
- When the blocking ring (which is connected to the synchronizer) and the speed gear teeth are lined up, the synchronizer sleeve can slide over the gear’s clutching teeth, locking the gear to the shaft.
- As this happens, the compressed inserts move into a notch on the inner diameter of the sleeve, helping to hold the sleeve in place.



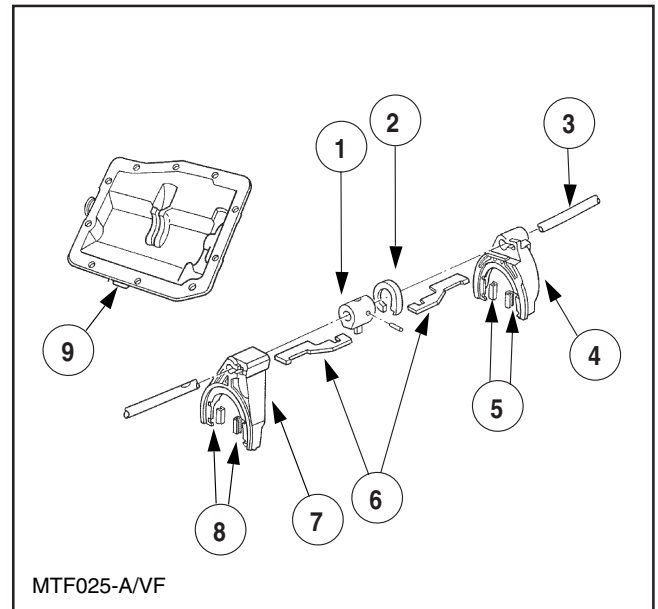
Synchronizer operation

- 1 Point where sleeve and gear mesh
- 2 Driven gear
- 3 Blocking ring
- 4 Synchronizer sleeve

Shift mechanisms

The transmission is shifted by means of shift mechanisms. Common components of the shift mechanisms include:

- Shift forks
- Shift rails
- Interlock plates
- Detents



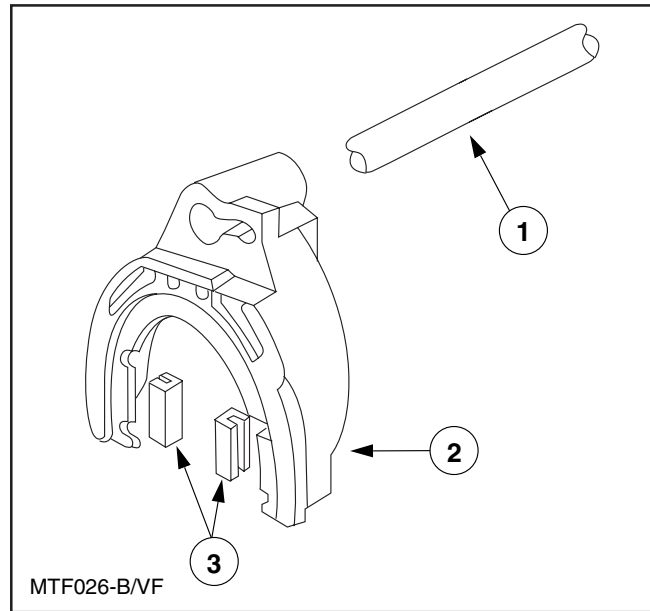
Typical shift mechanism – exploded view

- 1 Selector arm
- 2 Interlock plate
- 3 Shift rail
- 4 1-2 shift fork
- 5 Inserts
- 6 Selector arm plates
- 7 3-4 Shift fork
- 8 Inserts
- 9 Shift cover

Shift forks and shift rails

The transmission is shifted by means of shift forks that fit into a groove cut into the center of the synchronizer sleeve. The forks ride on shift rails that are moved by the driver using the gearshift. When the driver moves the gearshift, the selector shaft will move, causing the shift fork to move the synchronizer sleeve and engage the speed gear.

The shift forks usually have inserts on their tips that fit snugly into the synchronizer sleeve and prevent shift fork wear.

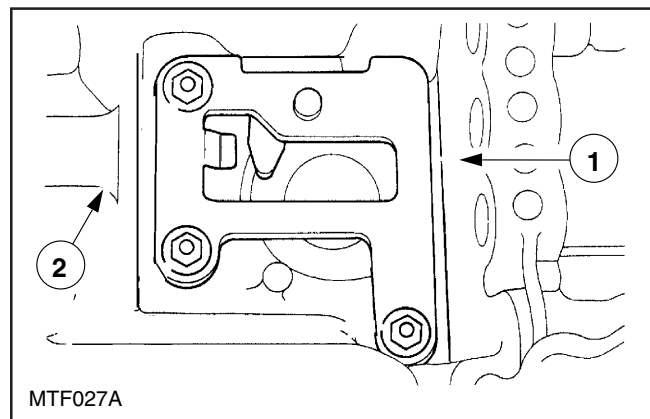


Shift fork and shift rail

- 1 Shift rail
- 2 Shift fork
- 3 Shift fork inserts

Interlocks and detents

To prevent transmission damage, the shift mechanism uses interlocks. These devices can be connected to the selector shafts or the shift cover. Interlocks are designed to prevent the transmission from being shifted into more than one gear at a time.

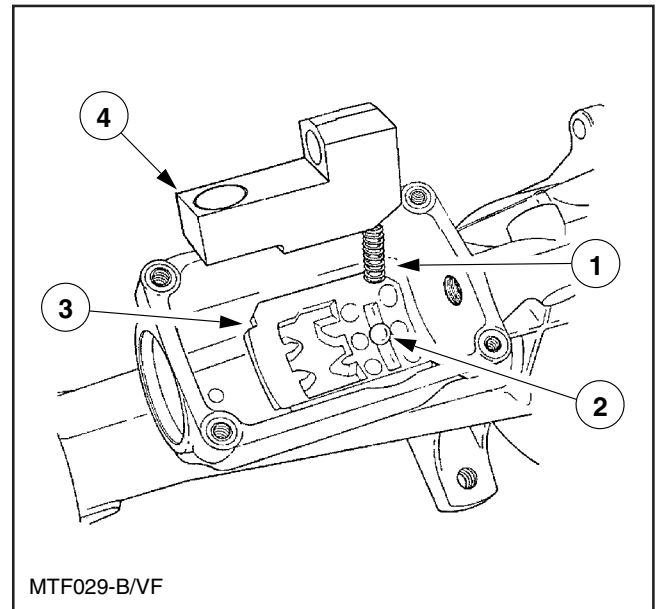


Interlock plate

- 1 Interlock plate
- 2 Shift cover

Detents

Detents are used to hold the shift forks in position once a gear has been selected. Detents are usually a ball and spring design and can either fit into notches on the selector shafts or in a lever called the offset lever. Once the shift fork is moved, the spring of the detent forces the ball into a notch on the selector lever or shift rail, locking the shift fork in position.

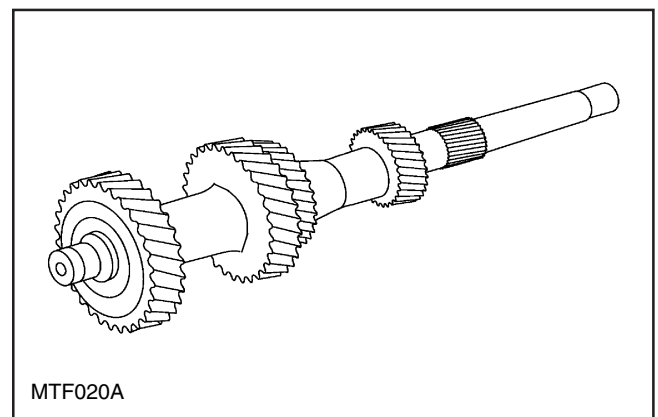


Typical detents

- 1 Detent spring
- 2 Detent ball
- 3 Detent plate
- 4 Offset lever

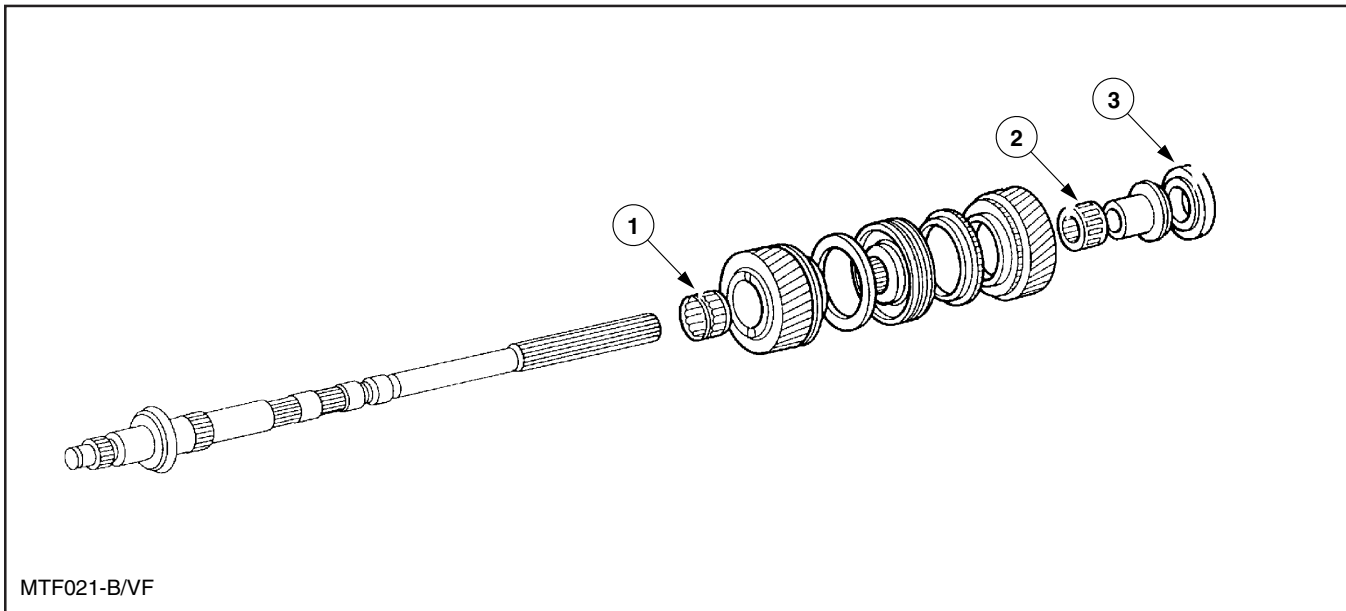
Countershaft

The countershaft is made up of a series of gears that can be machined from one piece of hardened steel or may have a series of individual gears that are splined to a single shaft. Some countershafts do have synchronizers and smooth inner diameter gears as well as splined gears.



Typical countershaft

Bearings



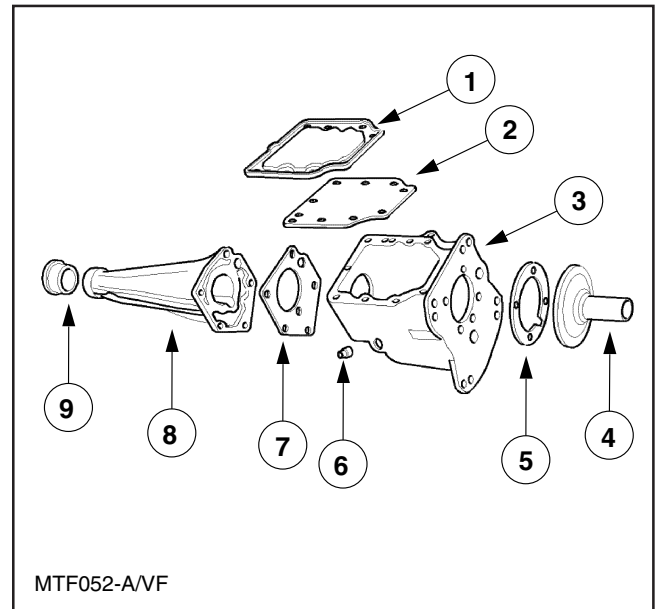
Typical transmission bearings

- 1 Gear bearing
- 2 Gear bearing
- 3 Output shaft support bearing

All transmission shafts and many of the gears ride on bearings. These can be caged needle bearings, ball bearings, or tapered roller bearings. These bearings are designed to allow free rotation while providing the support necessary for the component. Many of the bearings inside a transmission require special service tools for removal and installation.

Housing

The shafts and gears of the transmission are contained in a housing. The parts of the housing include the transmission case, the extension housing, and the top cover. The parts are bolted together with gaskets and seals, providing a leak-proof seal at all joints. The housing is filled with transmission fluid to provide constant lubrication and cooling for the spinning gears and shafts.

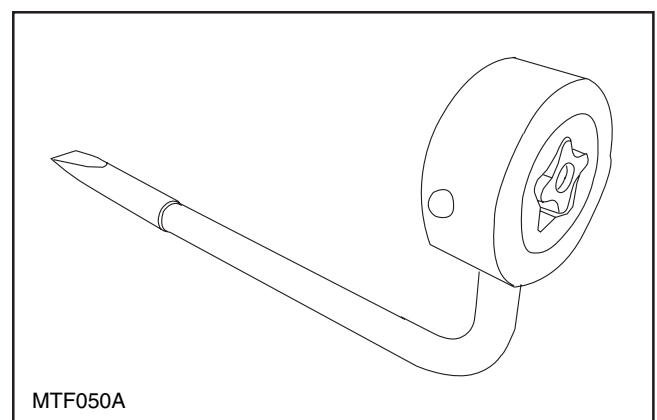


Typical transmission housing assembly

- 1 Cover gasket
- 2 Cover plate
- 3 Transmission case
- 4 Front bearing retainer
- 5 Gasket
- 6 Fill plug
- 7 Gasket
- 8 Extension housing
- 9 Extension housing seal

Pump

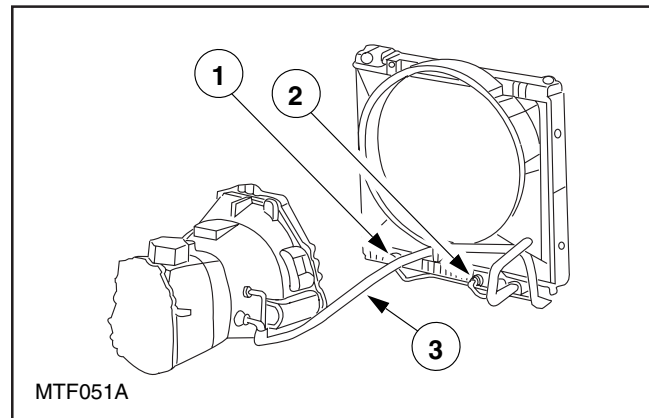
Some new manual transmissions use a pump to improve cooling and lubrication of the internal components. Most pumps used in the manual transmissions are gerotor type pumps and are driven by the countershaft.



Typical pump

Oil cooler

Another new system found on some vehicles is the oil cooler. This oil cooler is part of the radiator and uses the engine coolant to also cool the transmission oil. The transmission pump sends the hot oil to the cooler through oil tubes. In the radiator it is cooled using the engine coolant. The oil then returns to the transmission.

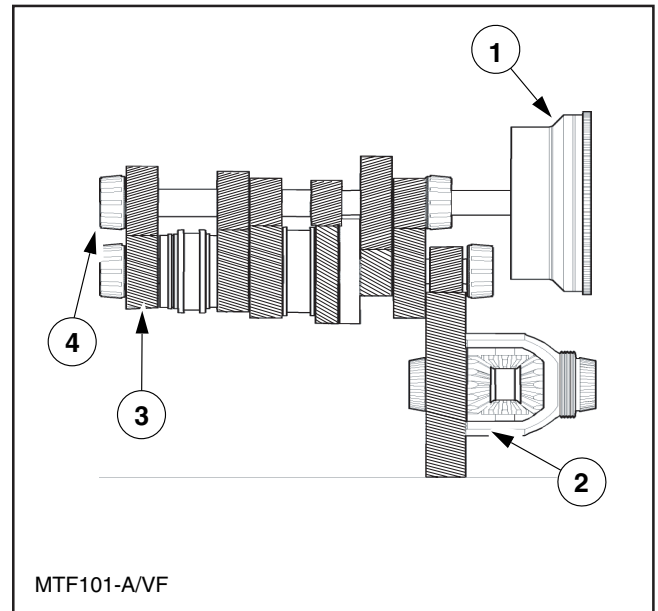


Typical oil cooler

- 1 Oil cooler inlet
- 2 Oil cooler outlet
- 3 Oil tubes

Manual transaxle operation

The manual transaxle can basically be divided into two sections: the transmission section and the differential section. The transmission section uses the same types of components as a manual transmission. Shift forks, synchronizers, and gears are basically the same design. But there is one major difference between a manual transaxle and a manual transmission: there is no countershaft. The countershaft is not needed because rotation from the input shaft and the main shaft (sometimes called the output shaft) is transferred to the differential, which then sends the torque to the wheels in the same direction of rotation as the input shaft (except when the vehicle is in reverse).



Manual transaxle

- 1 Clutch assembly
- 2 Differential assembly
- 3 Output shaft
- 4 Input shaft

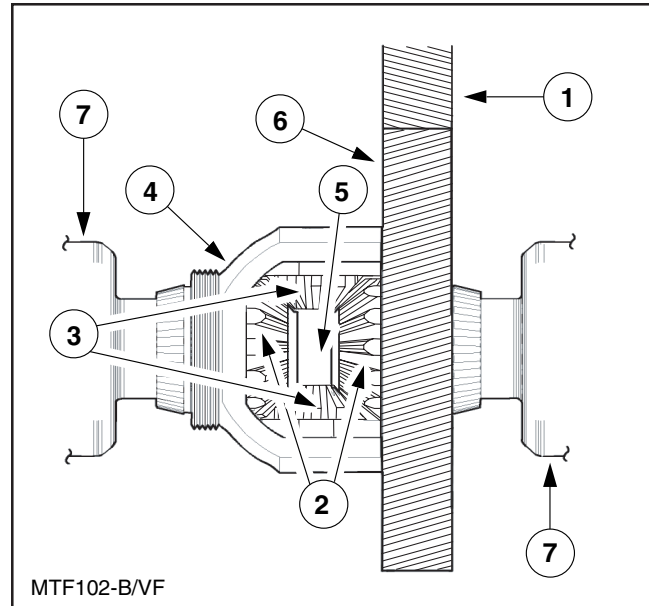
Manual transaxle components

Although the operation of a manual transaxle is similar to the transmission, many different components are needed to make it operate.

Differential

The differential of the transaxle transfers power to the wheels, provides a final gear ratio, and enables the wheels to rotate at different speeds during turns. This is done using four small gears mounted inside a carrier, which in turn is driven by the output shaft output gear through a ring gear.

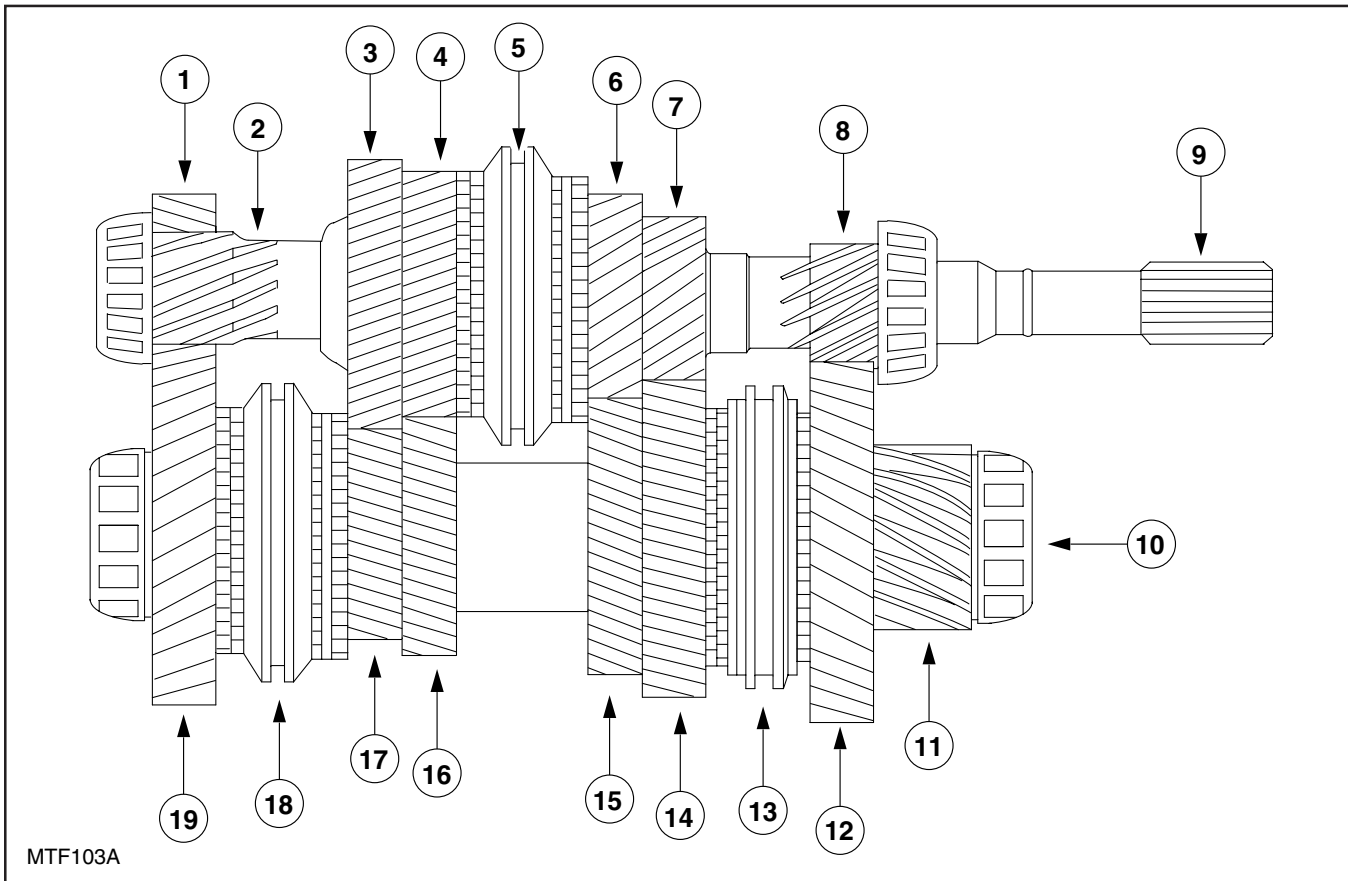
- Inside the carrier are two side gears. These gears are splined to the halfshafts.
- Between the side gears, and providing connections between them are two pinion gears, which ride on a shaft that is supported by the carrier.
- The side gears are only connected to the carrier through the pinion gears. Therefore it is the pinion gears that actually drive them.



Basic differential components

- 1 Output pinion
- 2 Side gears
- 3 Pinion gears
- 4 Carrier
- 5 Pinion shaft
- 6 Ring gear
- 7 Halfshafts

Input and output shaft assemblies



Typical manual transaxle input and output shaft

- | | |
|----------------------|------------------------------------|
| 1 Reverse gear idler | 11 Output pinion gear |
| 2 Reverse gear | 12 First speed gear |
| 3 Fifth gear | 13 1/2 synchronizer |
| 4 Fourth speed gear | 14 Second speed gear |
| 5 3/4 synchronizer | 15 Third gear |
| 6 Third speed gear | 16 Fourth gear |
| 7 Second gear | 17 Gear wheel (fifth speed gear) |
| 8 First gear | 18 Fifth/reverse gear synchronizer |
| 9 Input shaft | 19 Reverse speed gear |
| 10 Output shaft | |

Input Shaft

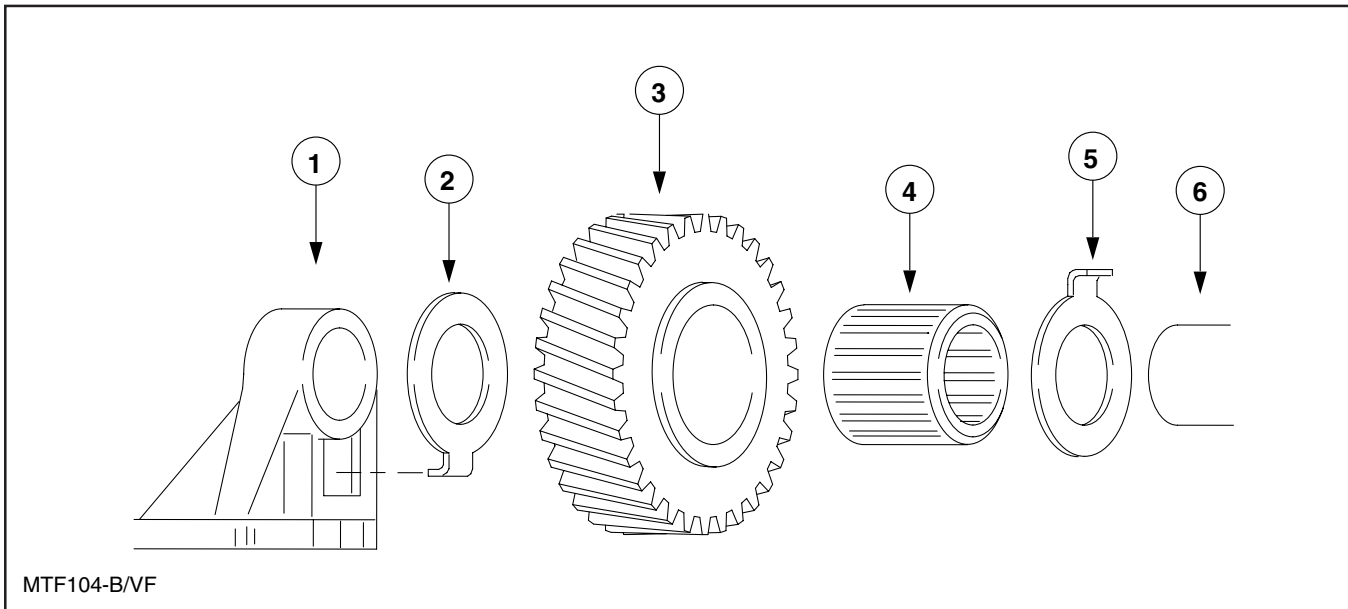
The input shaft of the transaxle transfers crankshaft rotation to the output shaft assembly. Along the input shaft length are the drive gears for all the different gear ratios. Some of these gears are cut directly from the input shaft. Other gears with synchronizers just ride on the input shaft the same way the speed gears of a manual transmission ride on the output shaft.

On the input shaft, 1st, 2nd and reverse gears are cut into the shaft itself. 3rd and 4th gears ride on the shaft and, during operation, must be locked to it through a synchronizer. 5th gear is a separate gear, but it is splined directly to the shaft.

Output shaft

The output shaft of the transaxle transfers power to the differential at the selected gear ratio. In the previous illustration of the output shaft, the 1st, 2nd, 5th and reverse driven gears ride on the shaft and are engaged through the first/second or fifth/reverse synchronizer respectively. 3rd and 4th driven gears are cut into the output shaft. Additionally, the differential output gear is a separate gear but it is splined directly to the shaft.

Reverse idler gear



Constant mesh reverse idler

- 1 Reverse gear idler shaft mount
- 2 Thrust washer
- 3 Reverse idler gear

- 4 Needle roller bearing
- 5 Thrust washer
- 6 Reverse idler shaft

There are two basic types of reverse idler gears used in transaxles: constant mesh and spur-cut. The constant mesh is basically the same as those in manual transmissions, while the spur-cut is a sliding type that is engaged by a shift fork.

Constant mesh

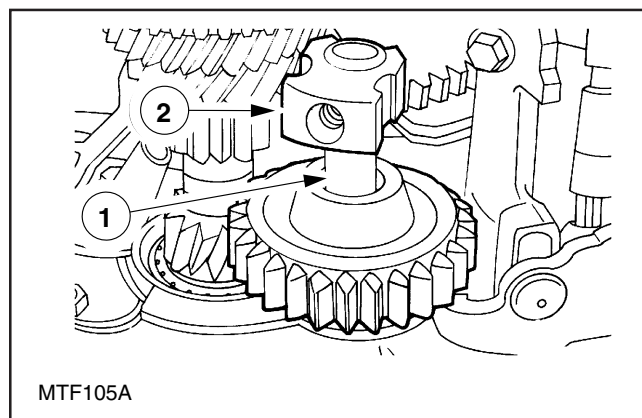
The constant mesh is a synchronized, helical-type reverse idler gear.

- It is in constant mesh with the both the reverse driving gear on the input shaft and the driven gear on the output shaft.
- Reverse is engaged when the fifth/reverse synchronizer engages the reverse driven gear with the output shaft.

Spur-cut

Some transaxles have a spur-cut reverse idler gear that is moved by a shift fork along its own shaft.

- When engaged, the idler gear meshes between the spur-cut reverse drive gear on the input shaft and the spur-cut reverse driven gear on the outside diameter of the first/second synchronizer sleeve.
- This action reverses rotation of the output shaft and differential and drives the vehicle in reverse.



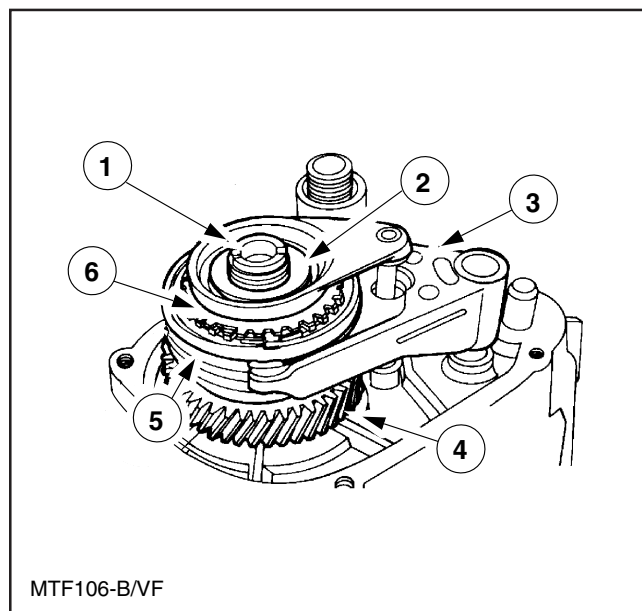
Reverse idler gear

- 1 Reverse idler gear
- 2 Reverse idler gear shaft

Reverse synchronizer

Reverse engagement is synchronized by the fifth/reverse synchronizer.

- When reverse is selected by the driver, the fifth gear synchronizer hub is pressed against the reverse blocking ring, which is pressed against the reverse blocking ring retainer.
- This retainer is connected to the input shaft.
- As the blocking ring cone surface engages the cone surface of the retainer, it stops rotation of the input shaft and allows the smooth meshing of the reverse idler gear and the reverse speed gear.



Typical reverse synchronizer

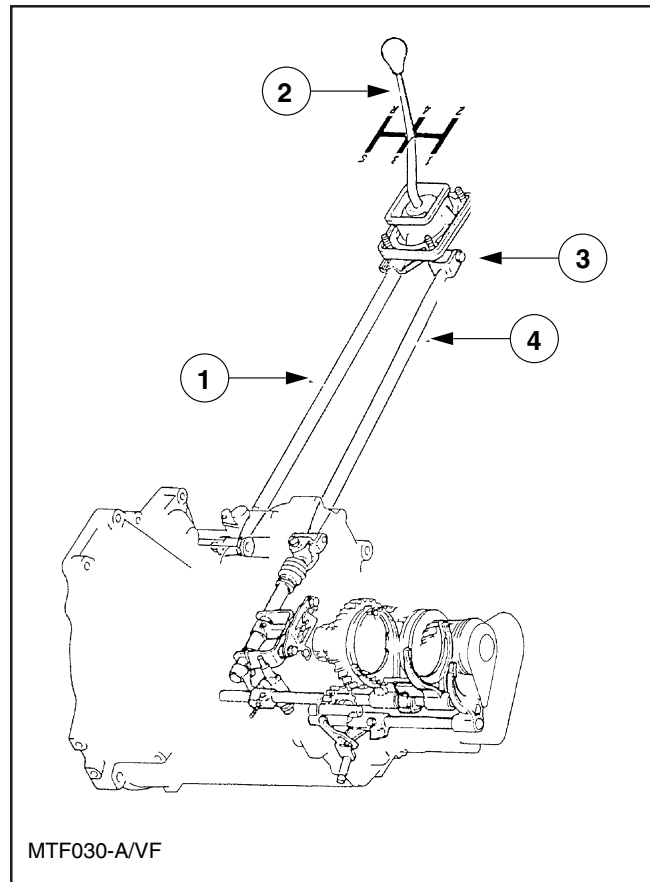
- 1 Input shaft
- 2 Blocking ring retainer
- 3 Shift fork, fifth/reverse
- 4 Fifth speed cluster gear
- 5 Fifth/reverse synchronizer
- 6 Reverse blocking ring

Shift linkages

Because of the location of the transaxle, a shift linkage must be used between the transaxle and the shift lever inside the vehicle. There are two basic types of linkages.

Rod and clevis linkage

Rod and clevis linkage uses a rod that connects to the shift rails inside the transaxle. This rod and clevis allows movement of the shift rails, which in turn moves the shift forks inside the transaxle. This type of linkage also uses a stabilizer bar between the gearshift assembly and transaxle. The rod connects to the shift lever through support bushings.

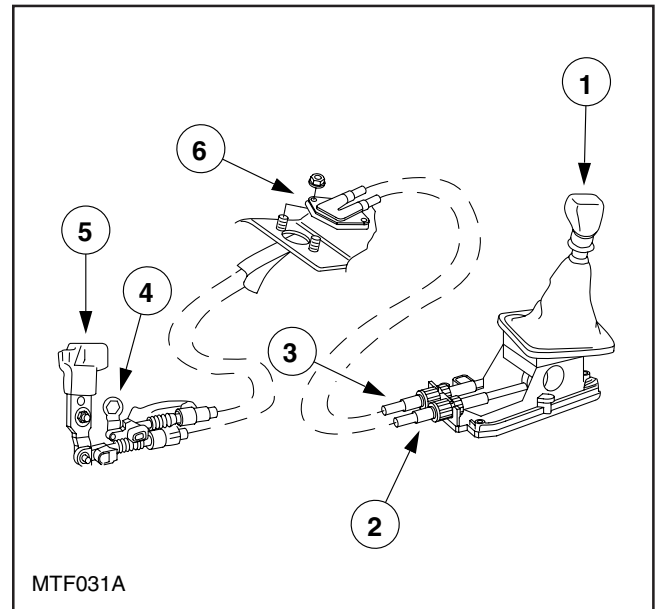


Rod and clevis linkage and transaxle

- 1 Stabilizer bar
- 2 Shifter
- 3 Rod support bushing
- 4 Gearshift rod and clevis

Cable linkage

Some transaxles are equipped with a cable gearshift linkage. Because they are jointly connected to the floor assembly, the selector and shift cables may only be replaced as a pair. The cables on this type of linkage are connected to a selector mechanism on the transaxle. These cables work in combination with each other to allow the driver to select gears.

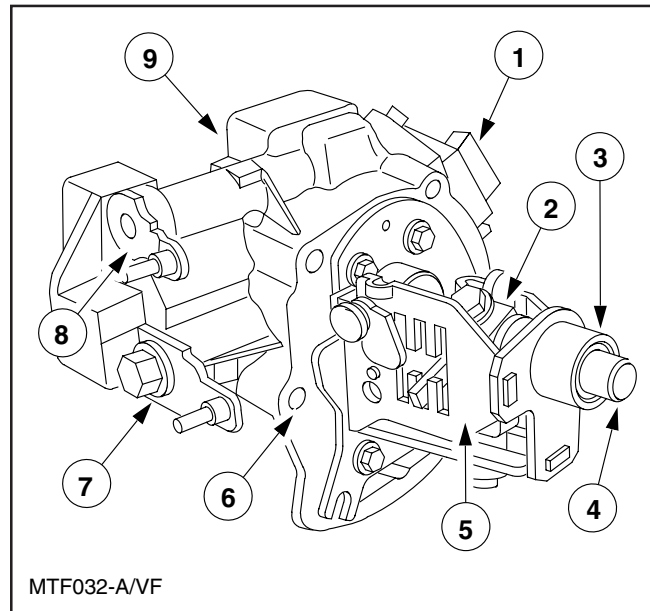
**Cables and shifter**

- 1 Gearshift lever
- 2 Shift cable
- 3 Selector cable
- 4 Gear selector lever on the transaxle
- 5 Gearshift lever on the transaxle
- 6 Cable guide

Shift linkages (continued)

Cable linkage selector mechanism

Cable linkage systems require the use of a selector mechanism. The selector and shift cables connect to this mechanism and movements of the mechanism's selector levers determine the transaxle gear.



Selector mechanism

- 1 Reversing lamp switch
- 2 Selector finger
- 3 Selector finger bracket
- 4 Selector shaft
- 5 Selector gate
- 6 Selector mechanism housing
- 7 Selector lever
- 8 Gearshift lever
- 9 Selector mechanism cover

Objectives

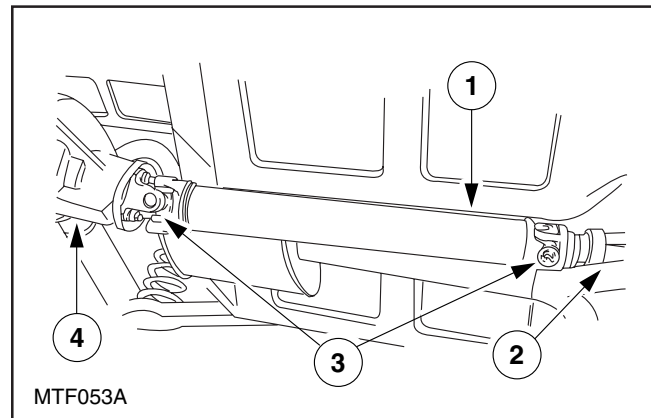
Upon completion of this lesson, you will be able to:

- Explain the purpose and function of a driveshaft.
- Describe a driveshaft and identify the types.
- Identify the components of a driveshaft.
- Explain the theory and operation of a driveshaft.

Driveshafts

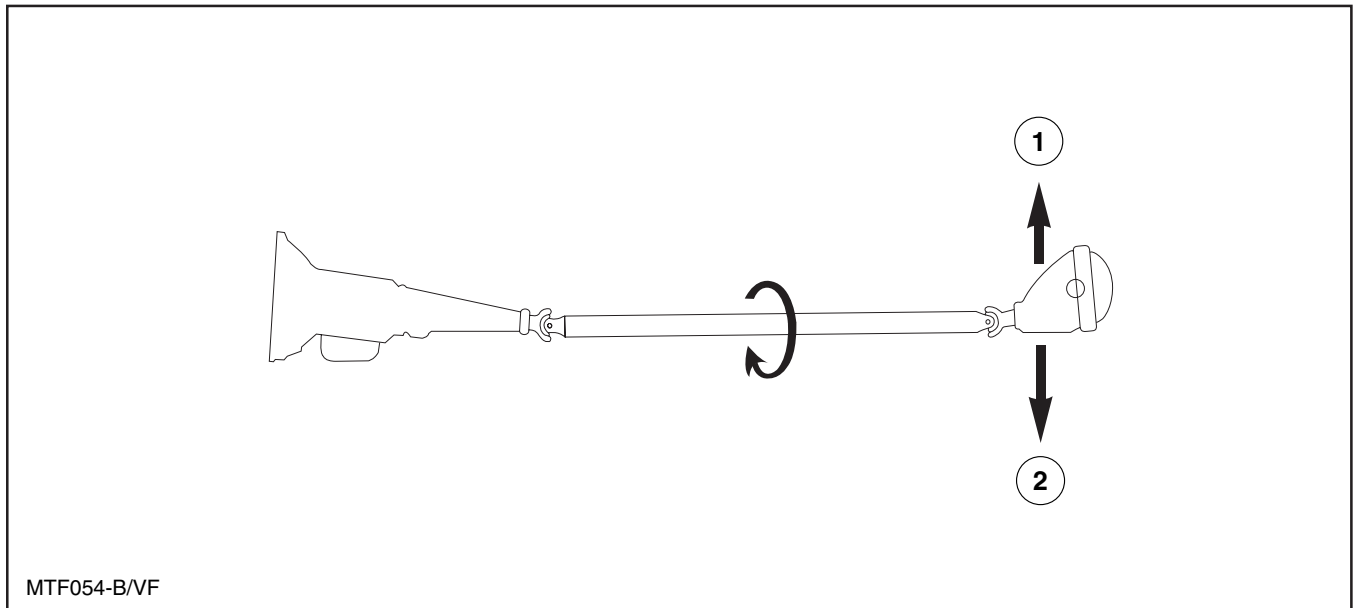
In order for a rear axle to be driven, a rear-wheel drive vehicle needs a driveshaft. The driveshaft transfers the rotation torque of the transmission output shaft to the differential, causing the rear wheels to turn.

Front-wheel drive vehicles and vehicles with independent front or rear suspension require unique driveshafts called halfshafts.



Typical rear-wheel drive driveshaft

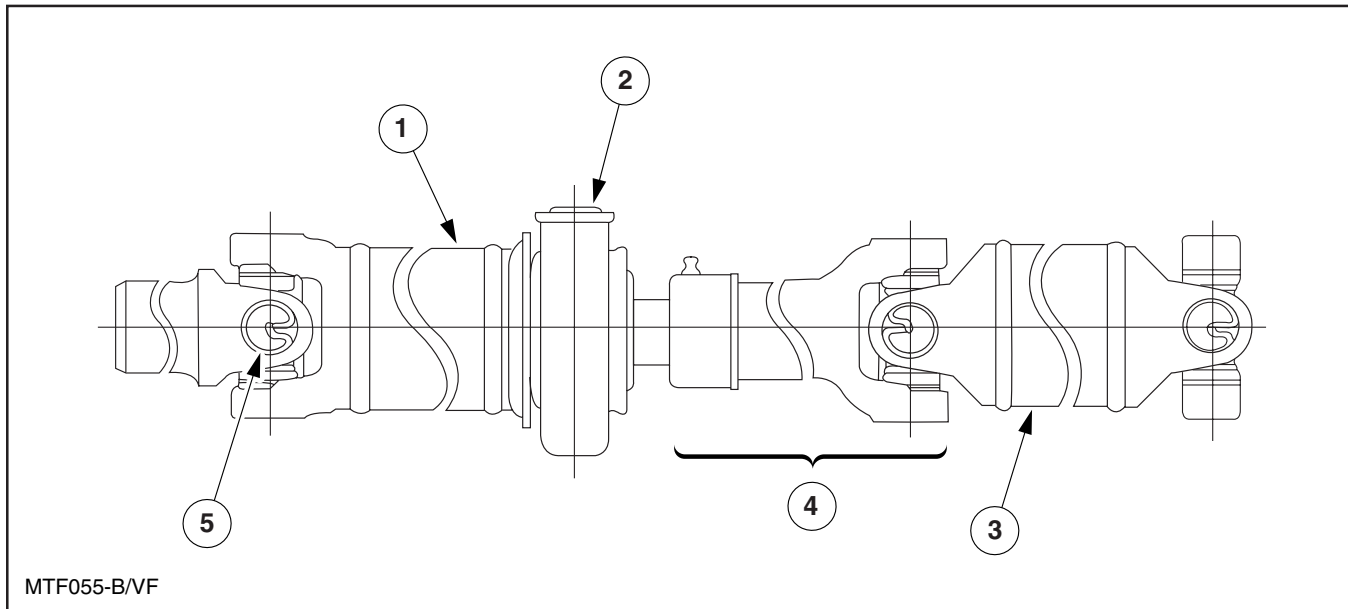
- 1 Driveshaft
- 2 Transmission tail shaft
- 3 Universal joints (U-joints)
- 4 Rear axle assembly

Drivetrain angles**Drivetrain side view and top view**

- 1 Acceleration
- 2 Deceleration

As a vehicle is driven, the angle of the drivetrain constantly changes due to the movement of the axle assembly. As the vehicle load changes, or the wheels hit bumps or holes in the road, the axle moves up and down in relation to the frame. When driving or braking torque is applied, the rear axle may also wind up or down on the suspension. The transmission, however, is fixed to the frame. Without flexibility, the driveshaft would bend and eventually break. U-joints and slip yokes provide the drivetrain with the flexibility needed. The driveshaft can smoothly transfer torque while rotating, changing length, and moving up and down.

Split driveshafts



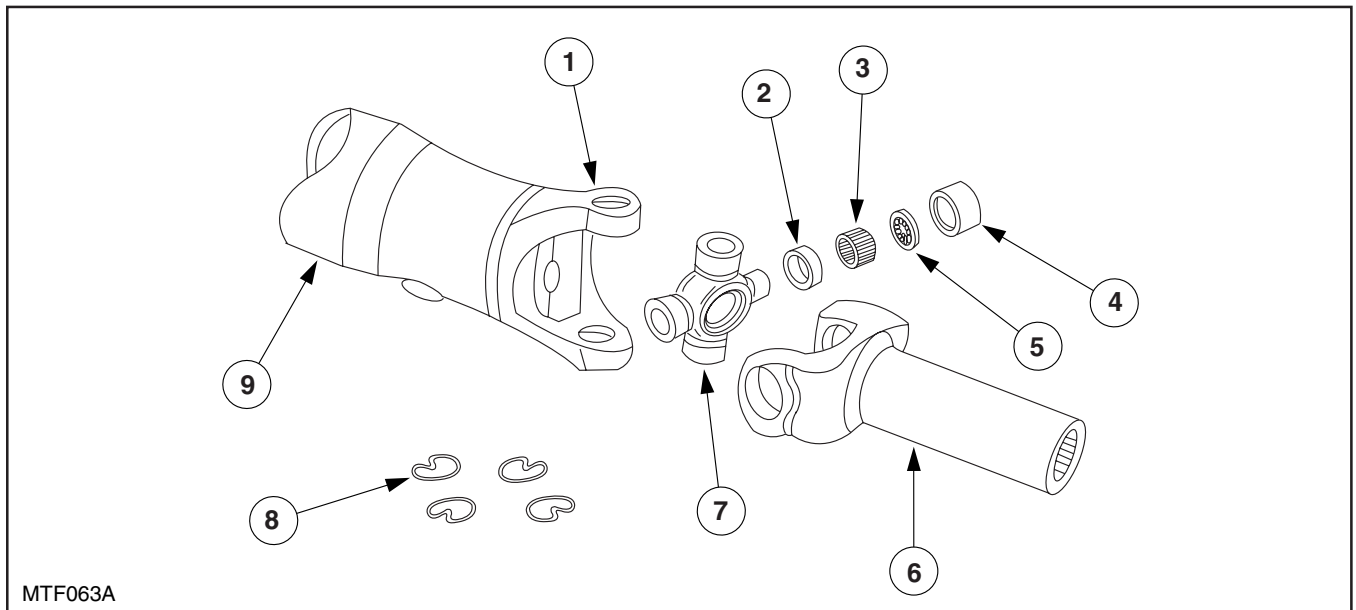
Split driveshaft components

- | | |
|------------------|-------------|
| 1 Driveshaft | 4 Slip yoke |
| 2 Center bearing | 5 U-joint |
| 3 Driveshaft | |

Some driveshaft assemblies are designed with more than one section. Multi-piece driveshafts use center support bearings, which serve to mount the multiple sections. Universal joints, or U-joints, constantly adjust to changes in the angle between the fixed transmission and the moving axle. Slip yokes accommodate length changes by permitting the driveshaft to slide in and out at the slip spline. Driveshafts differ in length, diameter, and the type of slip yoke used. This accommodates various wheelbase and powertrain combinations.

Driveshaft components

Universal joints

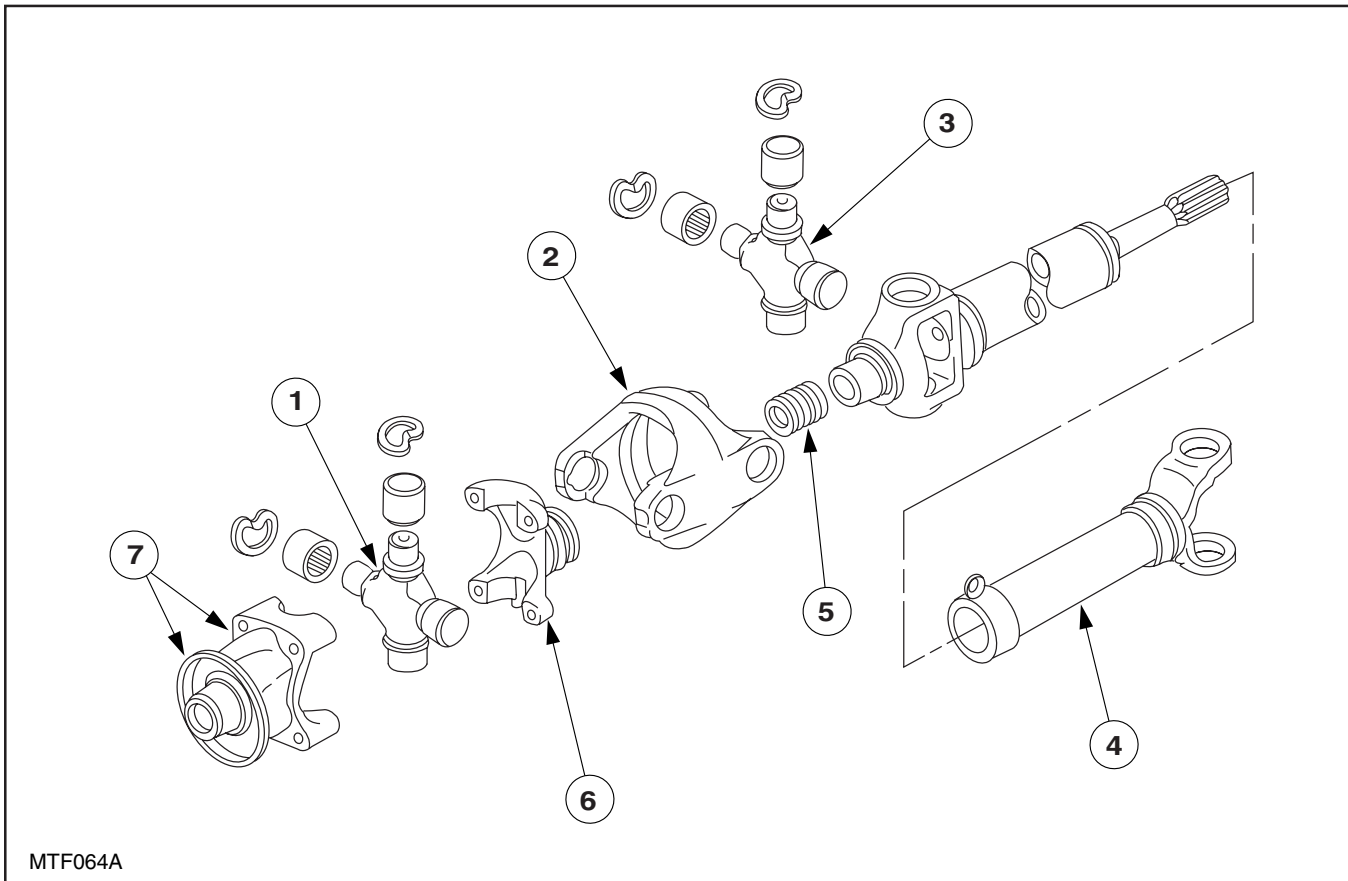


Single Cardan U-joints

- | | |
|------------------|------------------------|
| 1 End yoke | 6 Slip yoke |
| 2 Grease seal | 7 Cross shaft (spider) |
| 3 Needle rollers | 8 Snap rings |
| 4 Bearing cup | 9 Driveshaft |
| 5 Thrust washer | |

Single Cardan U-joints (named after the designer) consist of a center cross shaft assembly and two yokes. Each yoke can rotate around the axis made by mating ends of the cross shaft. Snap rings secure the bearing cup to the yoke, and may be internal or external. Original U-joints are lube-for-life. Some U-joints are equipped with a nylon thrust washer at the base of the bearing cup.

Driveshaft components (continued)



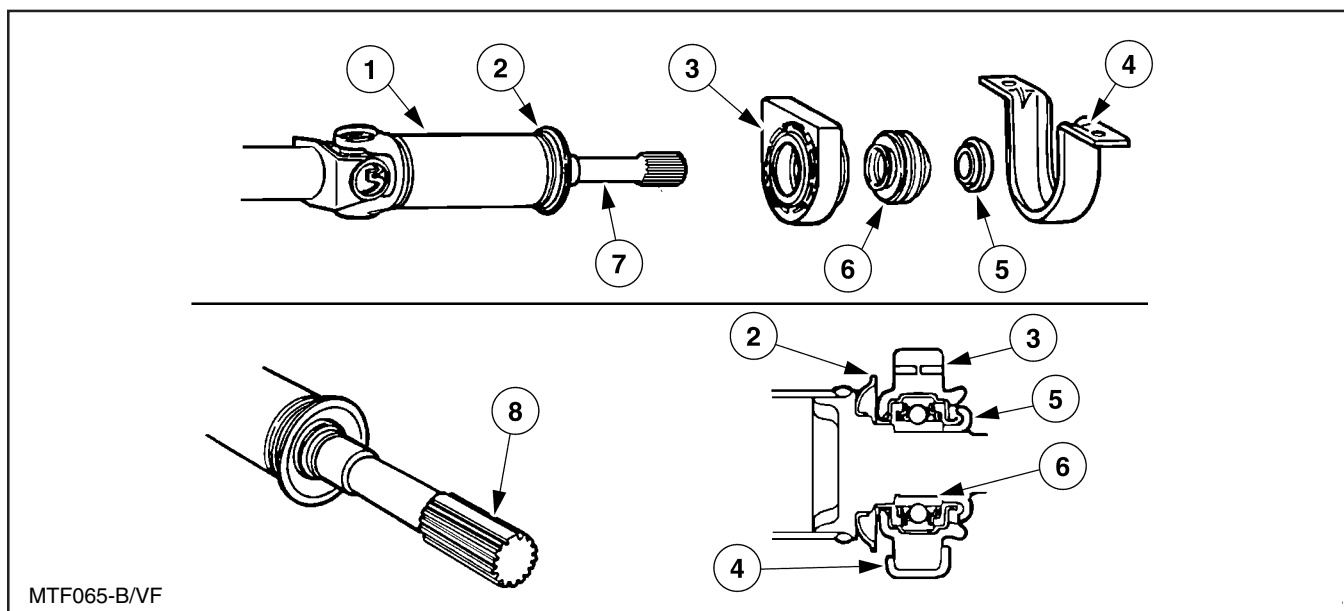
Double Cardan U-joint

- 1 Cross shaft assembly
- 2 Center yoke
- 3 Cross shaft assembly
- 4 Slip yoke
- 5 Centering spring
- 6 Socket yoke
- 7 Companion flange

Double Cardan U-joints are used when the operating angle is too large for a single joint to handle. The double Cardan U-joint consists of two individual Cardan U-joints closely connected by a center yoke and a socket yoke.

The center yoke, socket yoke, and centering spring keep both U-joints in line with each other. This assembly splits the angle of the two shafts between the two joints.

Driveshaft center bearing



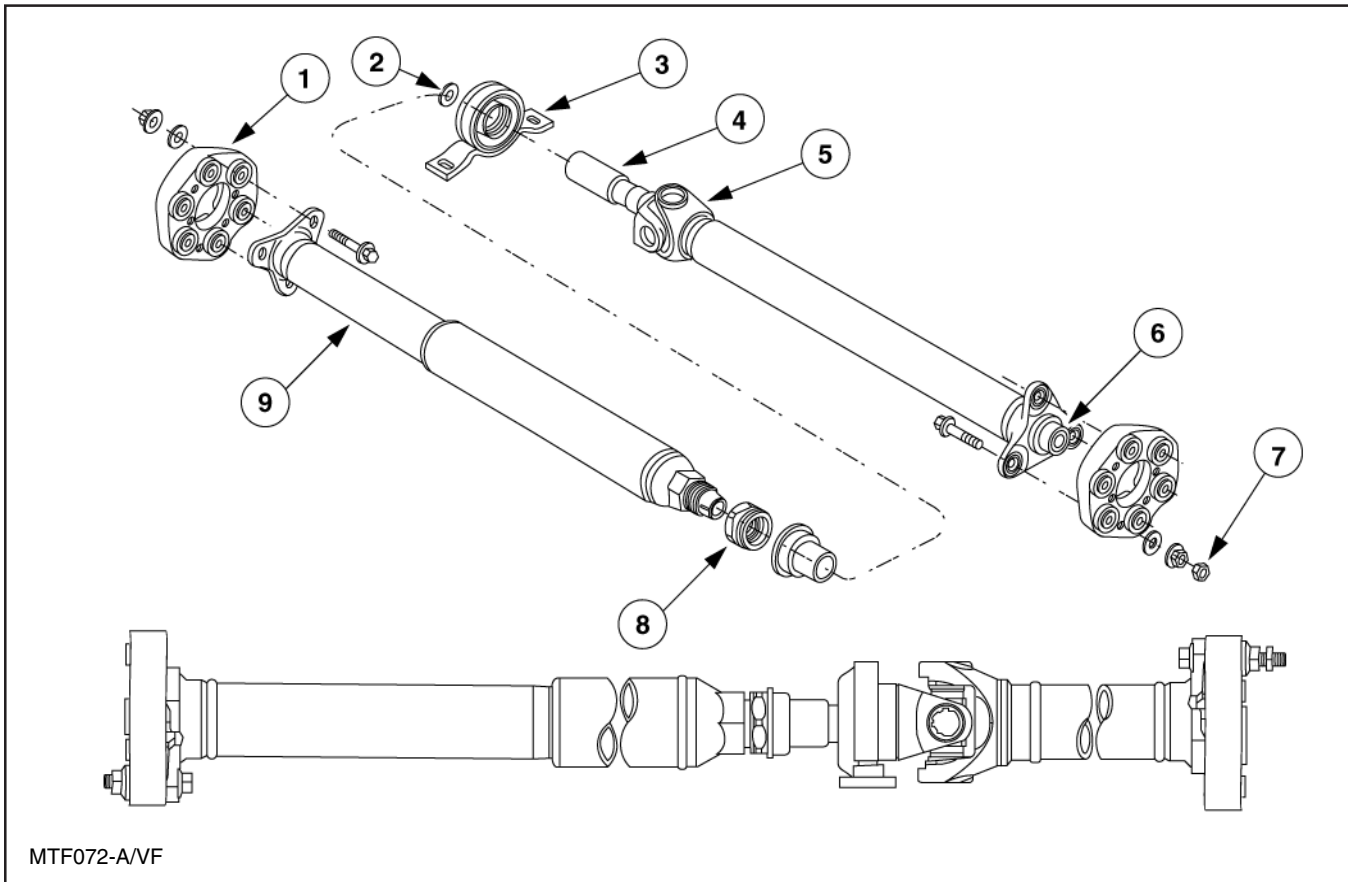
Typical center bearing

- | | |
|-------------------------------------|-----------------------------|
| 1 Driveshaft and coupling shaft | 5 Bearing shield (retainer) |
| 2 Dust slinger | 6 Center bearing |
| 3 Rubber insulator | 7 Splined stub shaft end |
| 4 Driveshaft center bearing bracket | 8 Blind spline |

The two-piece driveshaft used in some vehicles consists of two shafts, three U-joints, and a rubber-insulated, frame-mounted center bearing. The center bearing is needed to support the two-piece driveshaft assembly during operation and is pre-lubricated and sealed for life. The front U-joint is positioned almost straight so that it does not generate a speed fluctuation, and the other two joints are phased to prevent vibration.

Driveshaft components (continued)

Flex couplings



Typical flex coupling driveshaft assembly

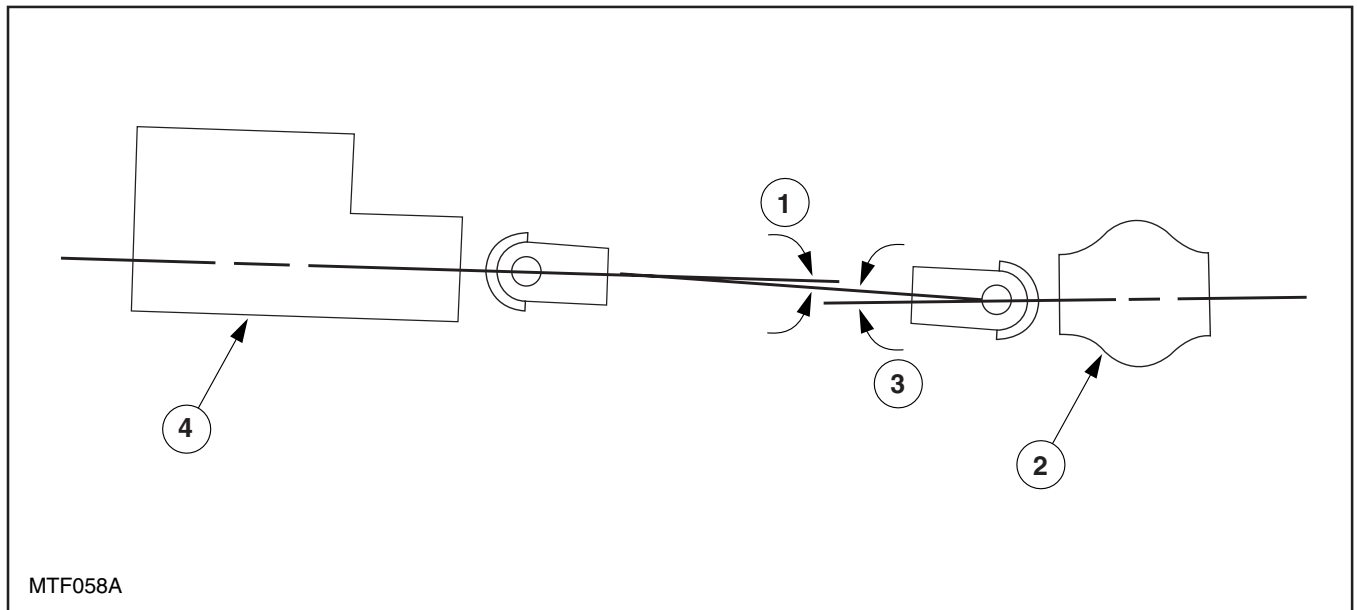
- | | |
|---------------------------------|------------------|
| 1 Flex coupling | 6 Pilot bearing |
| 2 Center bearing retaining ring | 7 Balance nut |
| 3 Center bearing | 8 Center locknut |
| 4 Slip yoke | 9 Driveshaft |
| 5 U-joint | |

Some vehicles use flex couplings in place of the U-joints. Flex couplings are made of rubber.

Flex coupling operating angles must be within one degree.

Driveshaft operation

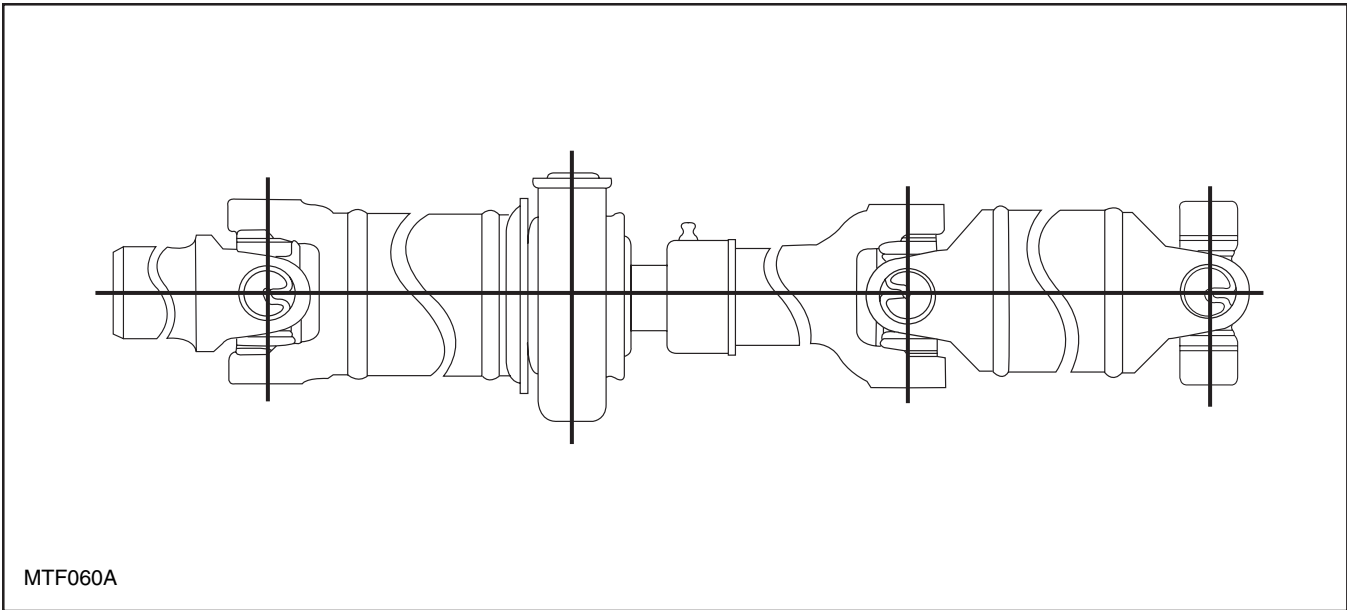
Operating angles and balance



Drivetrain operating angles

- | | |
|------------------------------------|----------------------------|
| 1 Transmission to driveshaft angle | 3 Driveshaft to axle angle |
| 2 Axle | 4 Transmission |

U-joints accommodate the changes in the operating angles at each end of the driveshaft. The slip yoke accommodates driveshaft motion by adjusting the length of the shaft. To operate properly, driveshafts must be balanced and sized. The range of the operating angles must also be matched. In a one-piece driveshaft system, there are two driveshaft operating angles. The first is the angle between the transmission, or transfer case output shaft and the driveshaft. The second is the angle between the driveshaft and the rear axle input shaft.

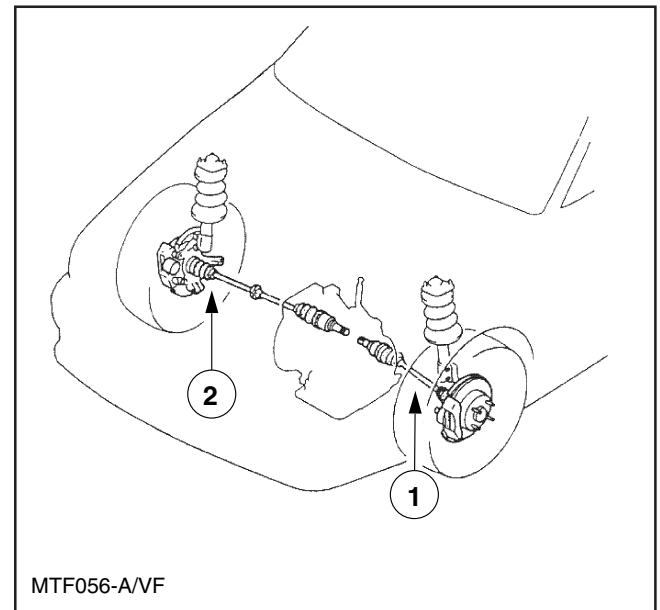
Driveshaft operation (continued)**Driveshaft phase****Each shaft must be assembled with yokes in the same plane**

The U-joints on each end of the driveshaft must also be in phase. Being in phase means that the driven yoke must have the same point of rotation, or the same plane, as the driving yoke. Phasing will allow each shaft to speed up and slow down at the same time during each rotation, which will minimize any vibrations during normal operations. If the shafts are not in phase, the slowing down and speeding up of the driveshaft will be transmitted to the axle even if the operating angles are parallel, resulting in damaging vibrations.

Halfshafts

Front-wheel drive vehicles require unique drive axles called halfshafts. The halfshafts transfer power from the differential in the transaxle to the wheels.

Halfshafts are connected between the side gears of the differential and the wheel hub. Halfshafts must be able to smoothly transmit torque during turns and to change length as the vehicle travels over bumps, or as vehicle load changes.

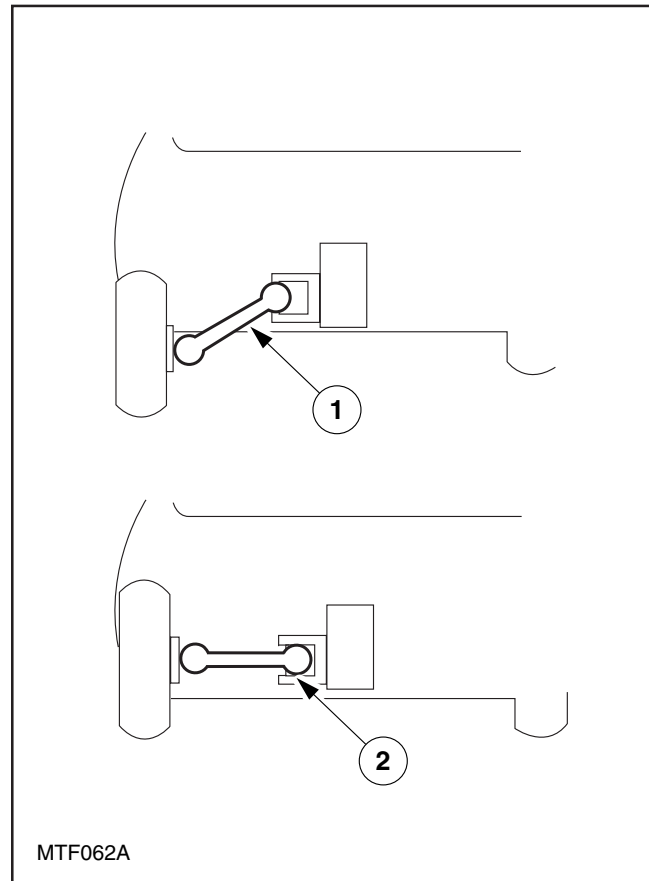


Typical halfshaft assembly

- 1 Left halfshaft assembly
- 2 Right halfshaft assembly

Halfshafts (continued)**Varying halfshaft length**

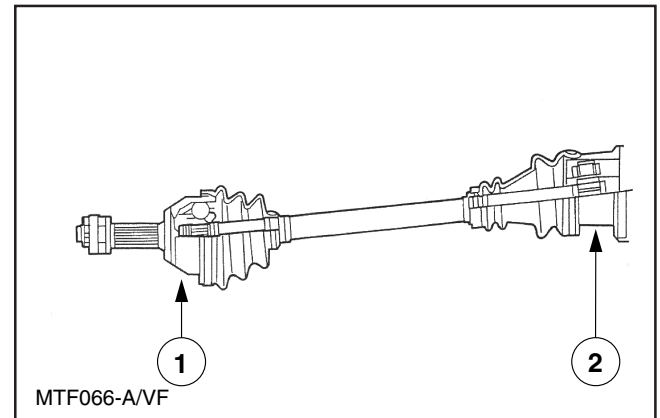
The halfshaft provides this smooth transfer of power because of the constant velocity (CV) joints located at each end of the shaft. CV joints are designed to allow a smooth transfer of torque while allowing for steering and front suspension movement. As the suspension moves, the CV joints allow the halfshafts to change length and operate smoothly through varying angles. The outer CV joints allow the steering system to turn the wheels, as well as allow for the up and down movement of the suspension. The inner CV joint allows for halfshaft length change (plunge) due to suspension movement.

**Halfshaft length change**

- 1 Halfshaft extended
- 2 Halfshaft compressed

Halfshaft operation

During vehicle operation the outer CV joint pivots, allowing the shaft to change angles quickly and smoothly. Power is transferred even when the vehicle is being turned sharply. At the same time the inner joint also allows pivoting, but it also can change length. Pivoting and length change is done because the components of the inner joint ride in a sleeve and can move in and out along its length as needed when the suspension is reacting to the contours of the road. This ability is called “plunge”.



Halfshaft assembly

- 1 Inner CV joint
- 2 Outer CV joint is fixed

Basic halfshaft components

Inner CV joint

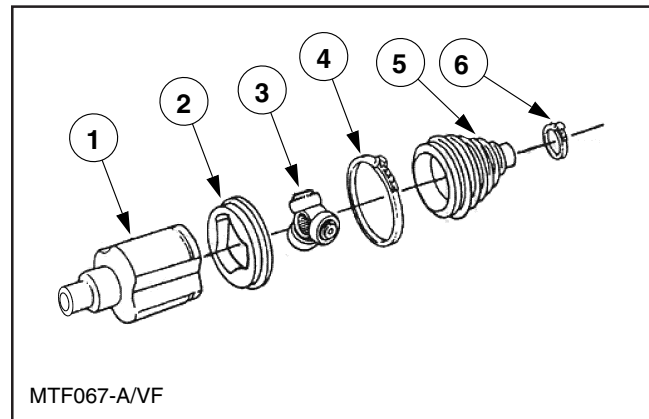
Common components found on all halfshafts include:

- CV joint boots
- Inner CV joint
- Shaft
- Outer CV joint

The inner CV joint is splined to the side gear of the differential. To prevent the inner CV joint from easily pulling out of the side gear, it is held in place using a spring steel circlip. There are two common types of inner CV joints.

The tripod-type joint shown above has three trunnions fitted with special rollers that ride on needle bearings.

- Tripod joint rides inside the sleeved race of the joint housing (sometimes called the tulip because of its appearance).
- Since the rollers are not fixed to the joint housing, they are free to move back and forth inside the joint housing.
- The movement of the rollers allows for angulation of the shaft as well as letting it change length for suspension action.

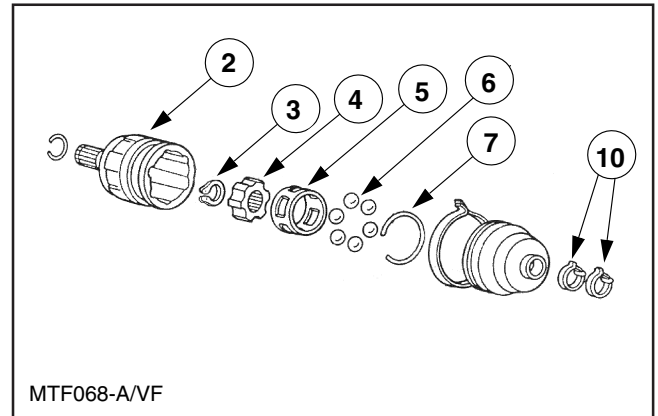


Inner tripod joint

- 1 Joint housing (tulip)
- 2 Inner sleeve insert
- 3 Tripod joint
- 4 Boot clamp
- 5 CV joint boot
- 6 Boot clamp

The plunging ball-type inner CV joint uses an outer race that has straight grooves machined into it.

- The inner race is connected to the shaft, and large caged ball bearings ride between the inner and outer races.
- As the shaft changes length, the inner race and caged ball bearings are free to move in and out along the grooves of the outer race, thus letting the shaft angulate and change length.



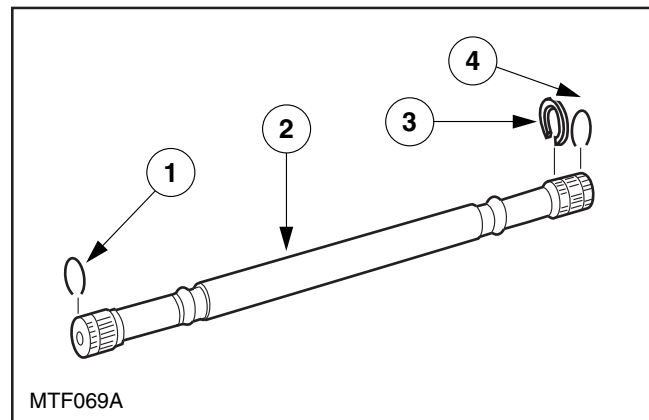
Plunging ball joint

- 1 Circlip
- 2 Housing/outer race
- 3 Snap ring
- 4 Inner race
- 5 Bearing cage
- 6 Ball bearings
- 7 Bearing retainer
- 8 Boot clamp
- 9 CV joint boot
- 10 Boot clamps

Basic halfshaft components (continued)**Shaft**

The shaft of the halfshaft assembly is splined at both ends to allow the CV joints to be fitted to it.

- Since the shaft rotates at only about 1/3 the speed of a rear wheel drive driveshaft, it does not need to be balanced.
- Some shafts use rubber dynamic dampeners to help eliminate small vibrations that may be generated during vehicle operation.
- Shorter shafts may be made of solid steel, while longer shafts are made of hollow tubing.
- The splines of the shaft have grooves cut into them to allow snap rings and/or circlips to be installed to retain the CV joints.

**Typical shaft**

- 1 Circlip
- 2 Shaft
- 3 Snap ring
- 4 Circlip

Intermediate shaft

Vehicles with larger engines may require the use of an intermediate shaft. An intermediate shaft is a shaft that connects from the transaxle to the halfshaft assembly and is supported by a hanger bearing that is bolted to the vehicle frame.

The intermediate shaft is needed on some vehicles because the farther from the center of the vehicle that the halfshafts are connected to the transaxle, the more torque steer is felt at the steering wheel. Torque steer can be very pronounced on vehicles with large engines whose transaxles are not located at the vehicle centerline.

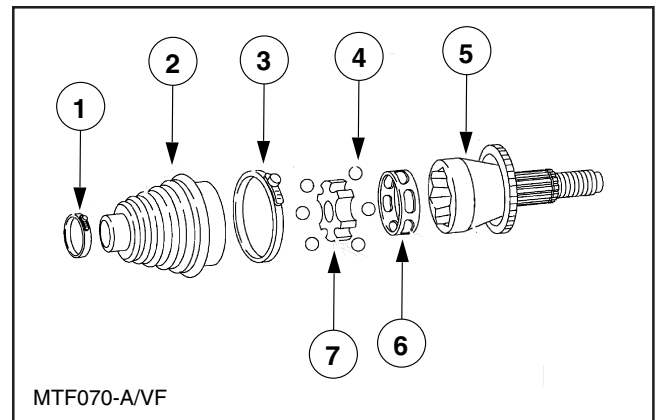
Outer CV joint

The outer CV joints used on many vehicles are Rzeppa-type joints (named for their inventor). These joints are fixed ball joints that consist of an inner ball race, a set of large ball bearings that are caged into position. These ball bearings move inside of races machined into the outer housing. When the wheels are turned for vehicle steering, the ball bearings allow the inner race, which is splined to the shaft, and the outer race, which is splined to the wheel, to operate at angles to each other.

The outer race of the CV joint is splined to the wheel hub using an interference fit. This interference fit eliminates backlash between the wheel hub and the halfshaft. However, because of the extremely tight fit of interference fit splines, a special service tool must be used when removing the CV joint from the wheel hub. Vehicles with anti-lock brake systems (ABS) will have the wheel speed sensor ring of the ABS around the outside of the outer CV joint housing.

CV joint boots

Both inner and outer CV joints have rubber or plastic boots that cover the opening of the joint where it connects to the shaft. These boots are held in place by special clamps. The boots are designed to keep contamination out of the CV joint, and to keep the special grease used to lubricate the joints from escaping. Any tear in the boot, or damage to the boot clamp that allows contamination into the joint requires either boot or joint replacement.



Rzeppa-type CV joint

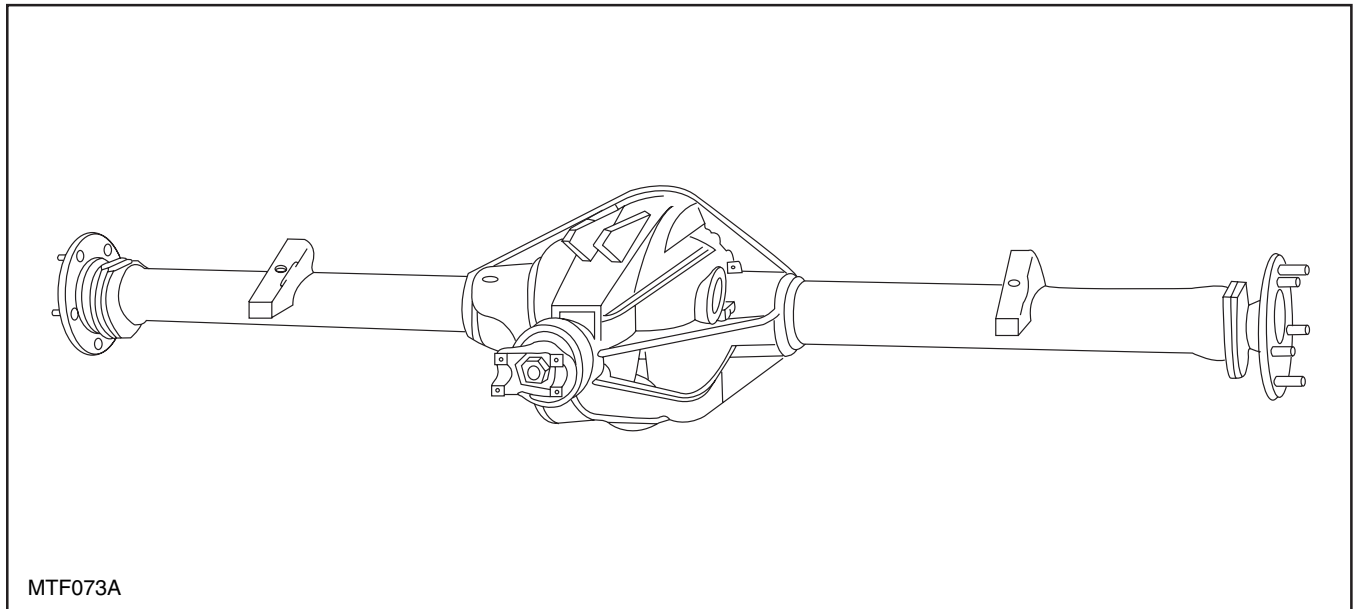
- 1 Boot clamp
- 2 CV joint boot
- 3 Boot clamp
- 4 Ball bearings
- 5 Outer housing
- 6 Bearing cage
- 7 Inner race

Objectives

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

- Explain the purpose and function of a rear axle and differential.
- Describe a rear axle and differential and identify the types.
- Identify the components of a rear axle and differential.
- Explain the theory and operation of a rear axle and differential.

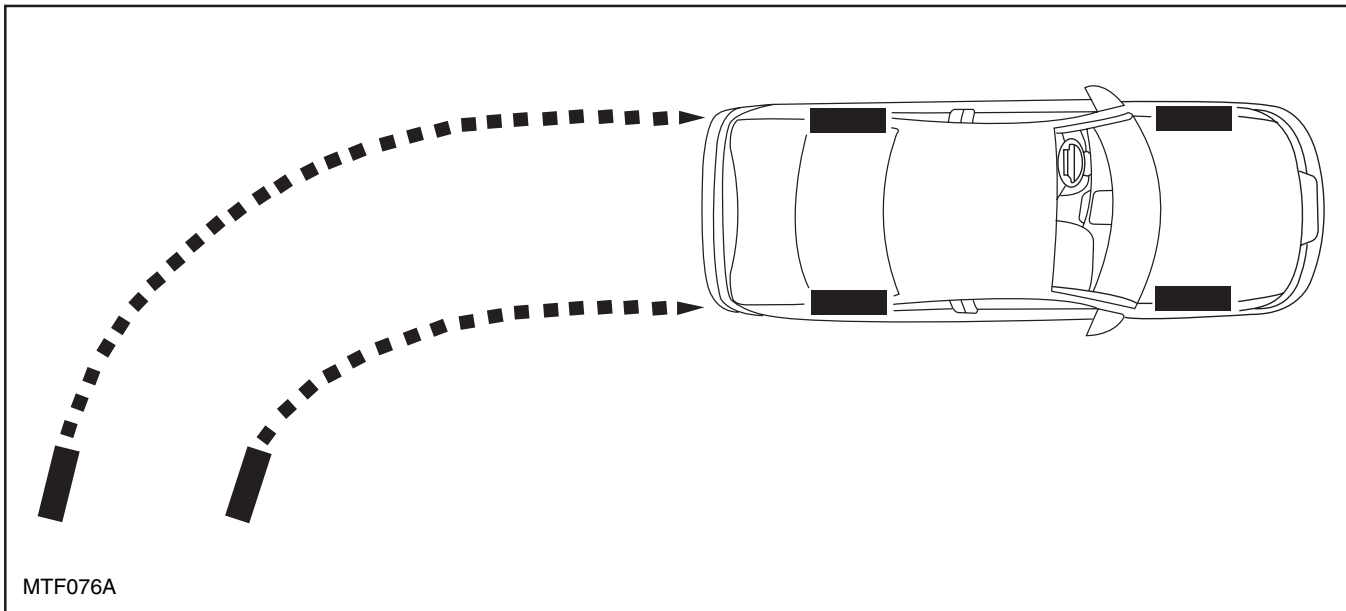
Rear axle and differential



Rear axle assembly

On rear-wheel drive vehicles, torque is transmitted from the transmission through a driveshaft to the rear axle and differential assembly. The rear axle serves many purposes. The housing serves as a mounting point for suspension components and supports the vehicle. Inside the housing is the ring and pinion gear set and differential assembly. The ring and pinion gear set and differential assembly transfer power from the driveshaft to the rear wheels via the axle shafts.

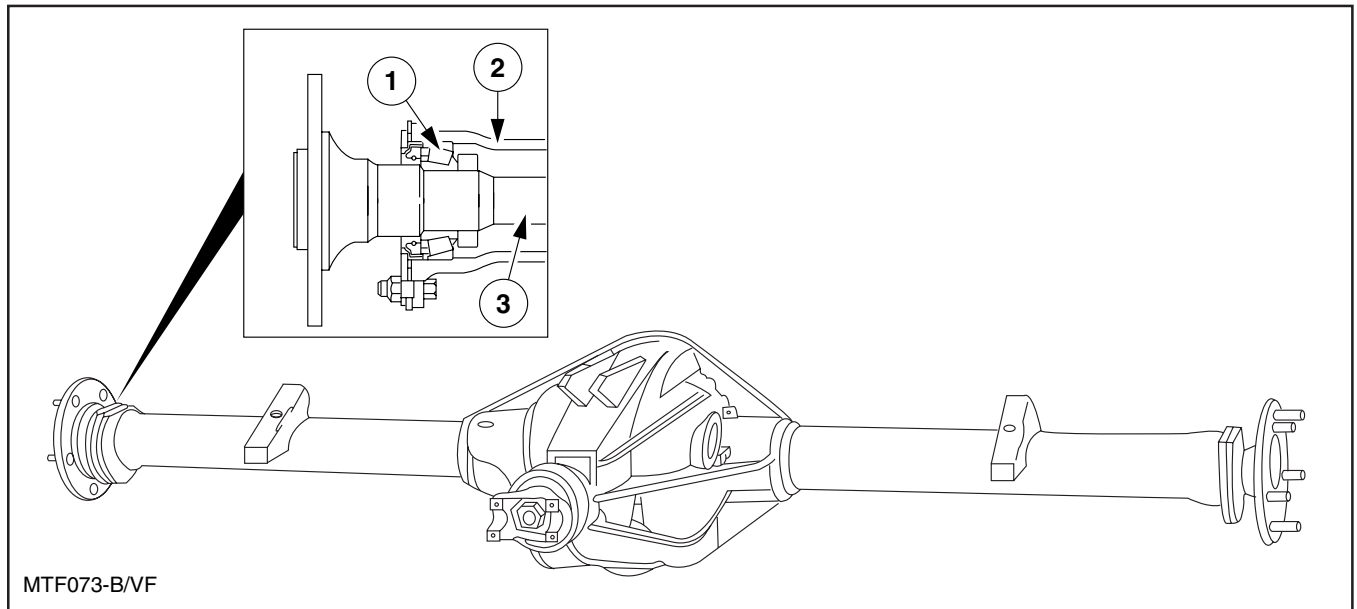
The ring and pinion gear set allows the torque to change direction 90 degrees from the driveshaft to the axle shafts. The ring and pinion gear set also provides a gear reduction since the pinion gear is much smaller than the ring gear. The relationship between the number of teeth on the ring and pinion gear is known as the gear ratio.

Rear axle and differential (continued)**Differential assembly**

The rear axle shafts must be able to turn at different speeds to compensate for the fact that the wheel on the outside of a turn must travel a greater distance and therefore, faster than the wheel on the inside of the turn. The rear axle assembly contains a differential.

The differential is a set of gears that transmits torque from the driveshaft to the rear axle shafts individually, as required. The result is the freedom of each axle and wheel to rotate at the correct speed independently of the other axle. There are basically two types of differentials: conventional (open/non-locking), and limited slip (locking).

Types of rear axle assemblies



Semi-floating axle assembly

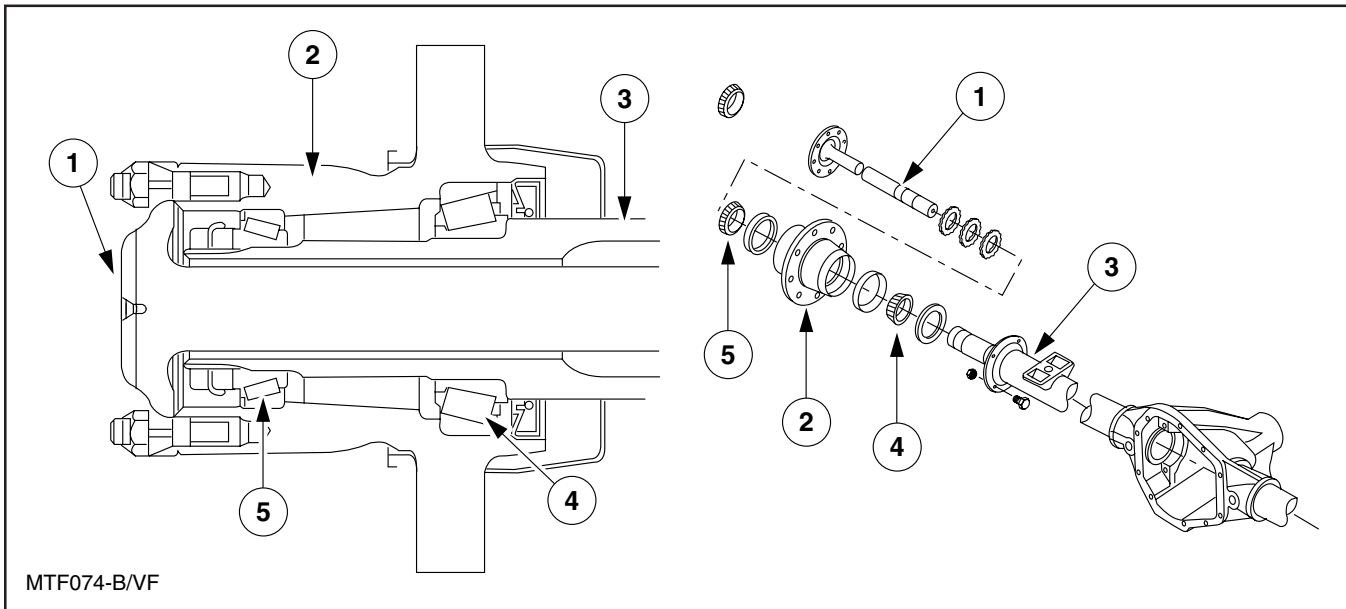
- 1 Bearing
- 2 Housing
- 3 Axle shaft

There are three basic types of rear axle assemblies, depending on how the axle shafts and wheels are supported:

- Semi-floating
- Full-floating
- Independent

The semi-floating rear axle uses shafts that are typically held in the housing by C-clips. These C-clips are positioned in a slot on the splined inboard end. The C-clips also fit into a machined recess in the differential side gears within the differential case. A semi-floating axle shaft rides on one straight roller bearing at the outboard end. The semi-floating axle shaft supports the weight of the vehicle, as well as providing driving torque.

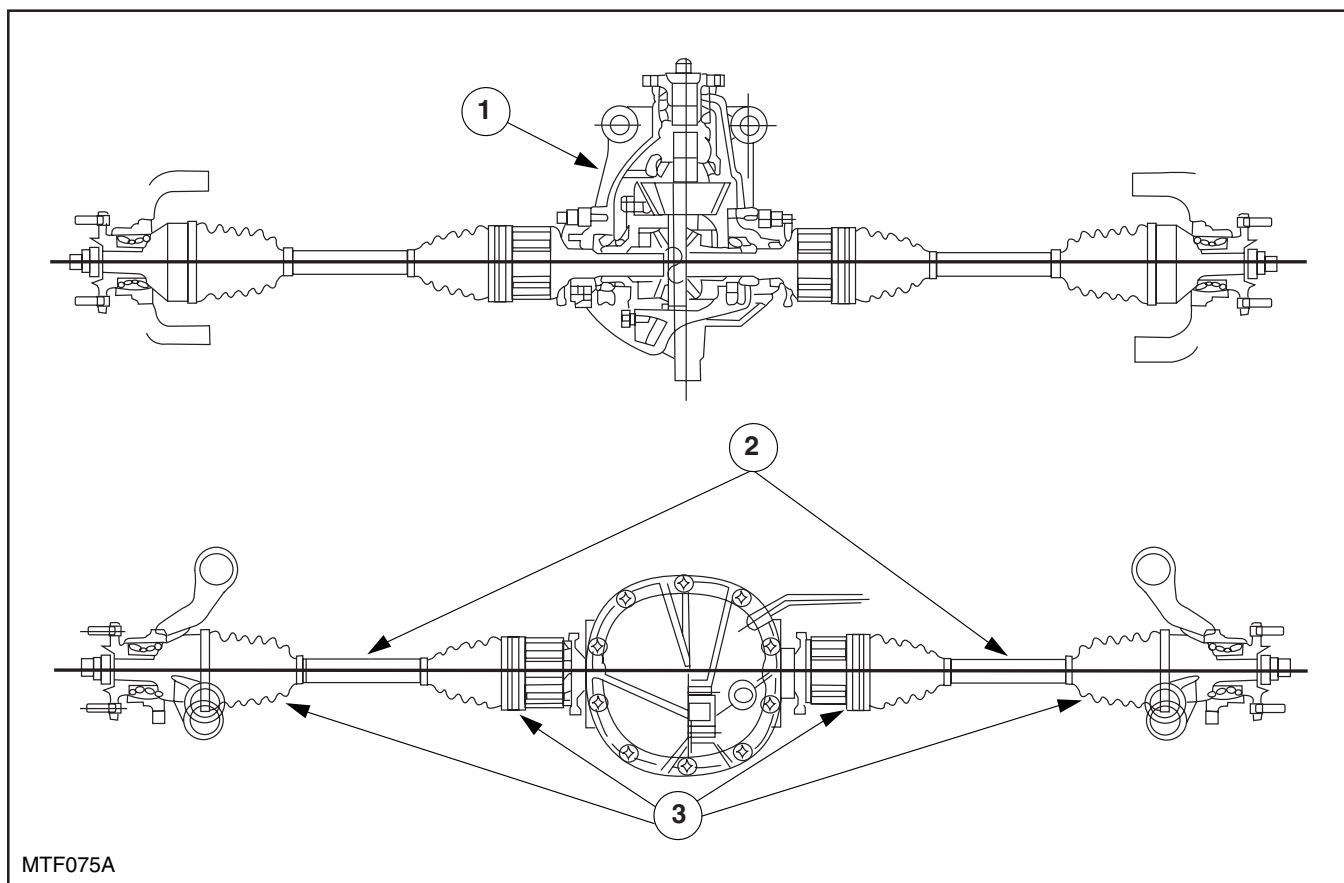
Types of rear axle assemblies (continued)



Full-floating axle assemblies

- | | |
|----------------|-----------------|
| 1 Axle shaft | 4 Inner bearing |
| 2 Hub | 5 Outer bearing |
| 3 Axle housing | |

The full-floating rear axle provides increased load carrying capability. The hub is supported, or “floats”, on the axle spindle, on two opposing tapered roller bearings. All of the vehicle’s rear weight is placed on the axle housing, and none on the axle shaft. The axle shaft merely drives the wheel. The hub is retained on the spindle by a ratcheting nut that is tabbed to a slot in the spindle.



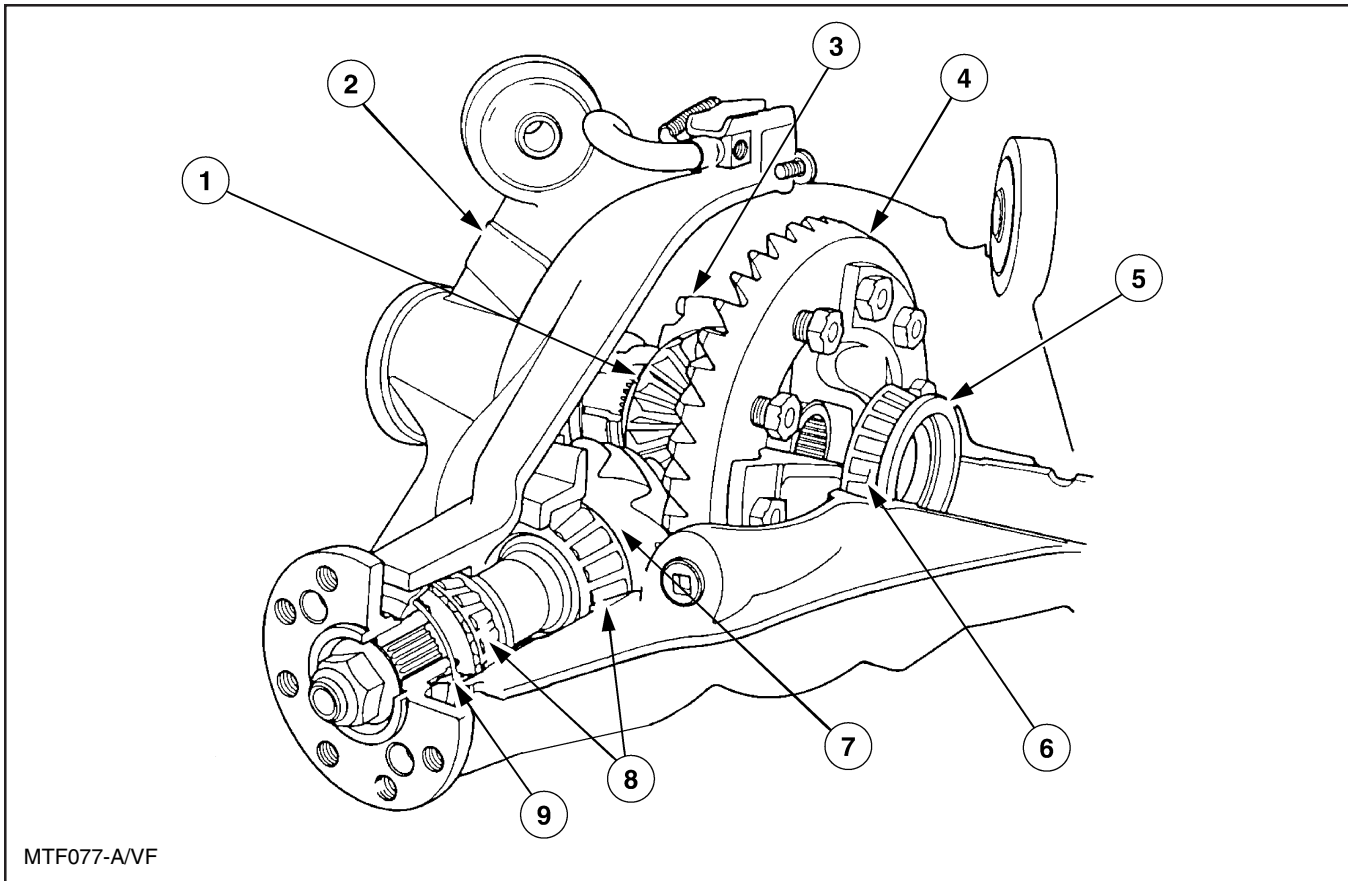
Independent rear suspension (IRS) rear axle

- 1 Differential assembly
- 2 Halfshafts
- 3 Constant velocity (CV) joints

The third type of rear axle used is the independent rear suspension (IRS) rear axle. This axle is similar to the other types, except that a separate suspension system and not the axle assembly carries all of the vehicle weight. No axle tubes are used. Instead of axle shafts, halfshafts are used like driveshafts to connect the axle housing to the drive wheels.

Constant velocity (CV) joints at both ends of the halfshafts are capable of operating at varying angles, and provide a way for the shaft length to change. The changing of the shaft length allows for wheel suspension and dynamic movement. The inboard CV joint stub shaft is held in the differential side gear by a circlip. The outboard shaft is pressed into the hub and secured with a rear axle wheel hub retainer.

Rear axle differential components



Conventional rear axle assembly

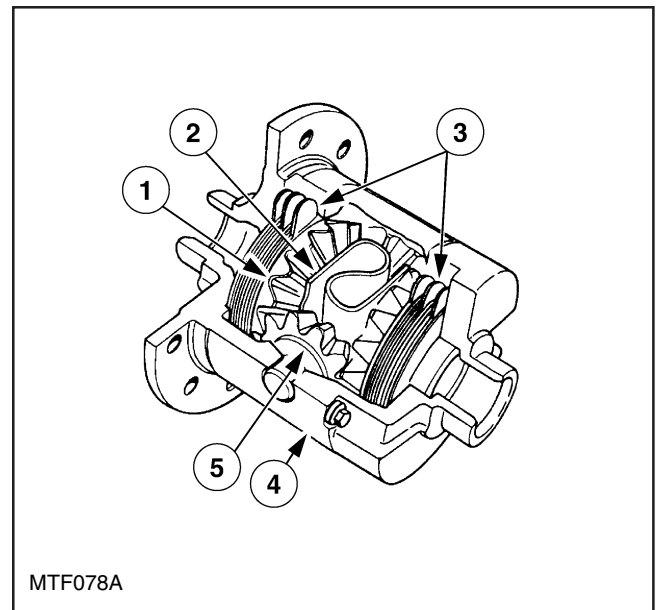
- | | |
|----------------------------------|-------------------------|
| 1 Differential side gear bearing | 6 Differential case |
| 2 Rear axle housing | 7 Drive pinion |
| 3 Differential case | 8 Drive pinion bearings |
| 4 Ring gear | 9 Pinion seal |
| 5 Shim | |

The typical conventional rear axle assembly consists of:

- rear axle housing
- drive pinion
- ring gear
- differential case
- differential side gears
- differential pinion gears
- differential case bearings
- drive pinion bearings
- shims and seals

Limited slip differentials

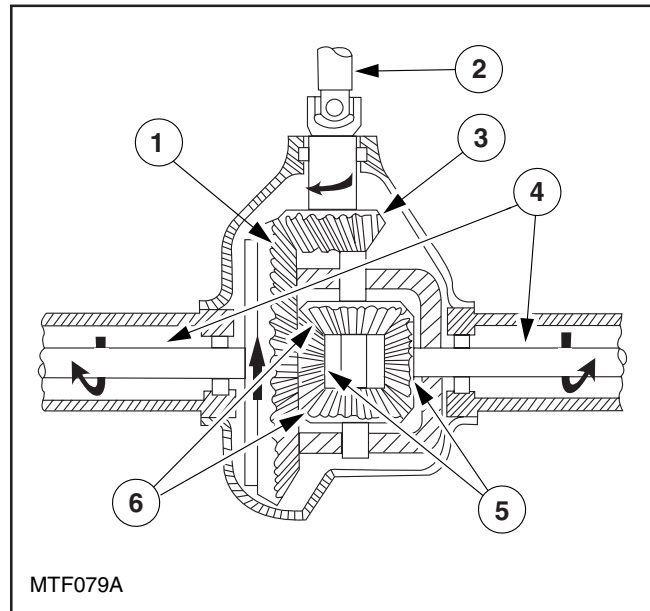
The typical limited slip rear axle assembly consists of basically the same components as the conventional axle assembly, with the exception of some clutches and springs added to the differential assembly.

**Limited slip unit**

- 1 Differential side gear
- 2 Differential clutch spring
- 3 Differential clutch pack
- 4 Differential case
- 5 Pinion gear

Rear axle/differential powerflow

The drive pinion, which engages the ring gear, receives engine power through the transmission and driveshaft. The drive pinion drives the ring gear, which is bolted to the differential case outer flange. The differential case then rotates. The drive pinion and ring gear multiply torque, and reduce speed according to the rear axle ratio. As the case turns, its internal gears are driven. The drive pinion and ring gear change the direction of powerflow from the driveshaft to the axle shafts. The differential case has two openings to allow for lubricant flow and repairability.



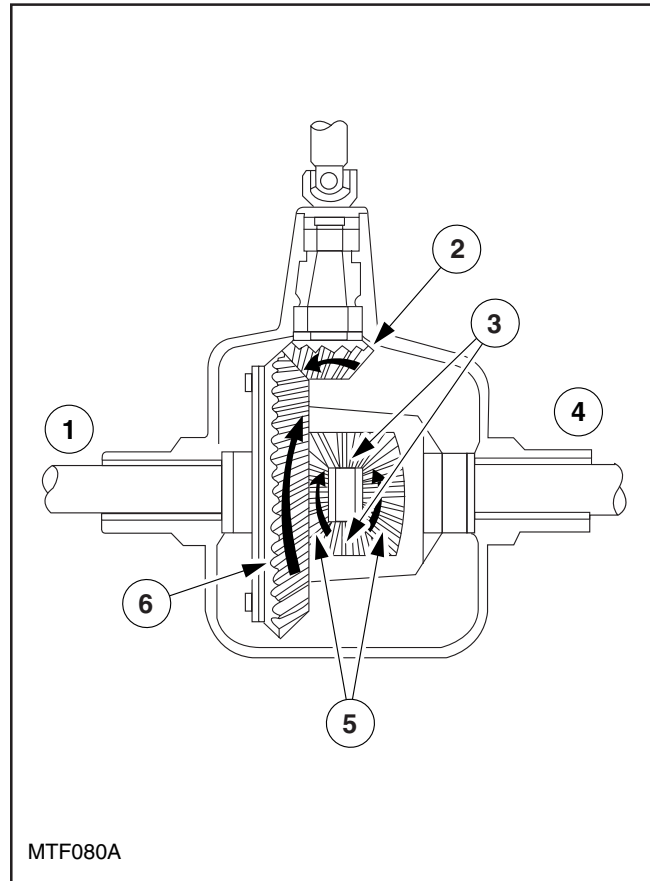
Differential assembly

- 1 Ring gear
- 2 Driveshaft
- 3 Drive pinion
- 4 Axle shafts
- 5 Side gears
- 6 Pinion gears

Rear axle/differential powerflow (continued)

Conventional differentials

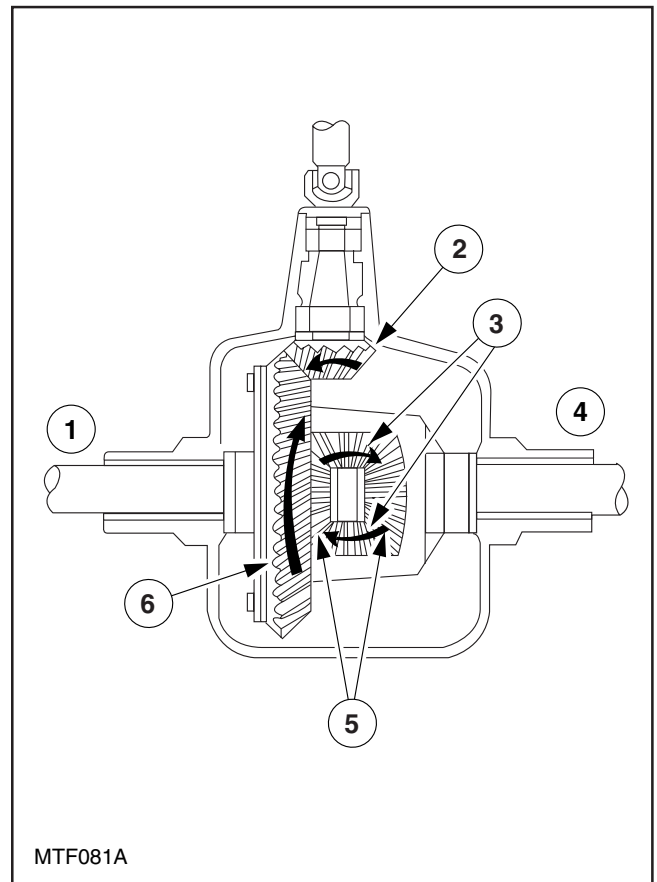
During straight-ahead driving, each wheel turns at the same speed. The differential side and pinion gears turn with the case, with no movement between the teeth of the pinion and side gears. The complete differential assembly rotates as a unit.



Differential assembly straight ahead driving

- 1 Inside axle – 100 rpm
- 2 Drive pinion
- 3 Pinion gears
- 4 Outside axle – 100 rpm
- 5 Side gears
- 6 Ring gear

During a turn, the outside axle shaft must rotate faster than the inside axle shaft. In this situation, the pinion gears “walk” forward on the side gear of the inside (slower) axle shaft, increasing the speed of the side gear on the outside (faster) axle shaft. As the pinion gears “walk” around the slower side gear, they drive the faster side gear at greater speed. The sharper the turn, the greater the speed difference.

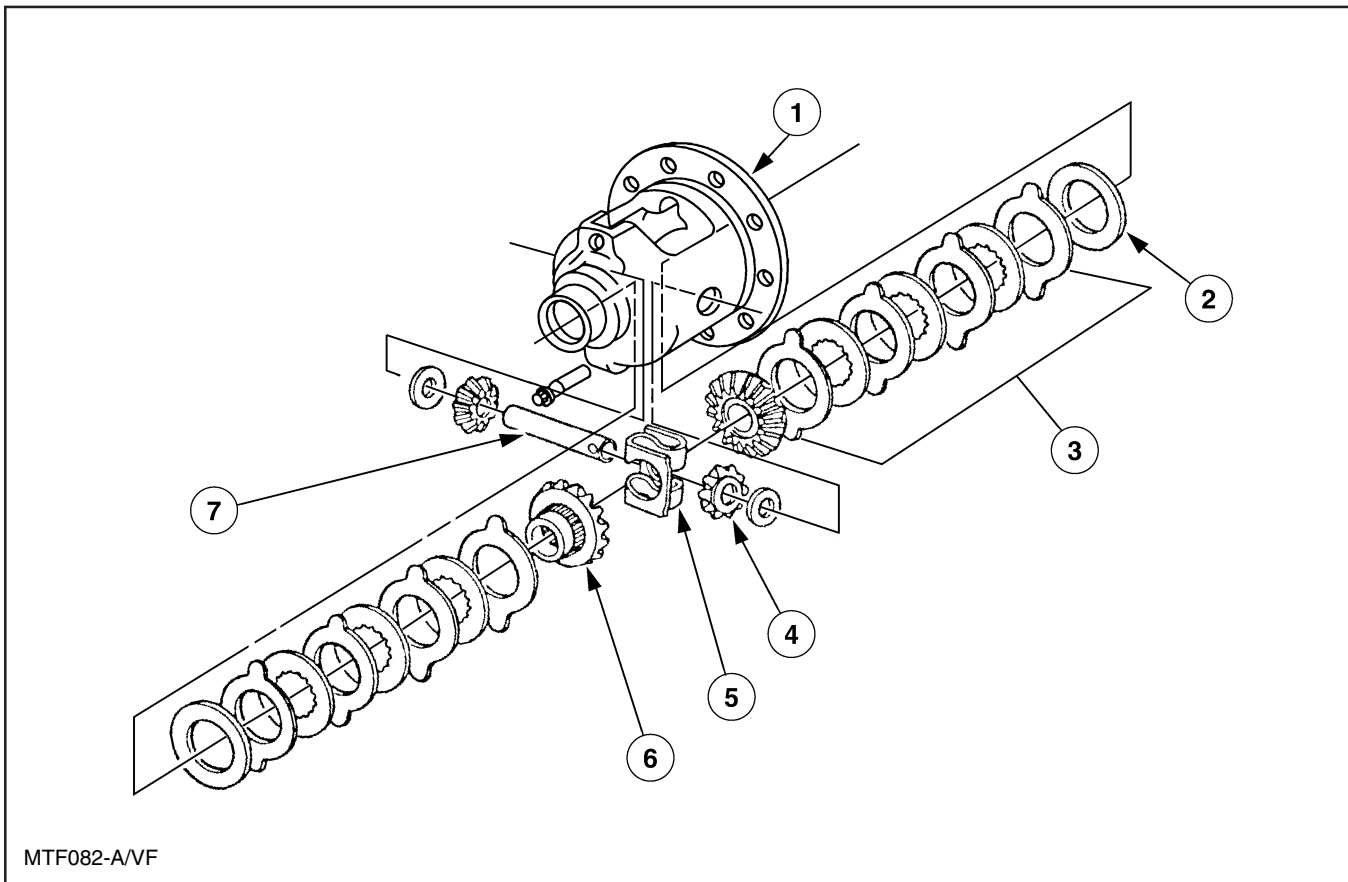


Differential assembly during left turn

- 1 Inside axle – 90 rpm
- 2 Drive pinion
- 3 Pinion gears
- 4 Outside axle – 110 rpm
- 5 Side gears
- 6 Ring gear

Rear axle/differential powerflow (continued)

Limited slip differentials



Typical limited slip differential

- 1 Differential case
- 2 Differential clutch pack shim
- 3 Differential clutch pack
- 4 Differential pinion gear
- 5 Preload spring
- 6 Differential side gear
- 7 Differential pinion shaft

There are many names for limited slip differentials; Traction-Lok, Trac-Lok and Power-Lok. The conventional or “open” differential can be a disadvantage in a limited traction situation. When a vehicle is stuck in the snow, one drive wheel spins and the other stays stationary. Increasing torque to the spinning wheel will not increase torque to the stationary wheel.

The limited slip differential is designed to increase the driving torque to the wheel with the greatest amount of traction. Friction is built into the system by adding a series of friction plates between the differential side gears and the differential case. Traditional differential action will only occur when enough torque is supplied to overcome the friction. If one drive wheel has no traction, the other wheel will always receive some torque.

Limited slip operation

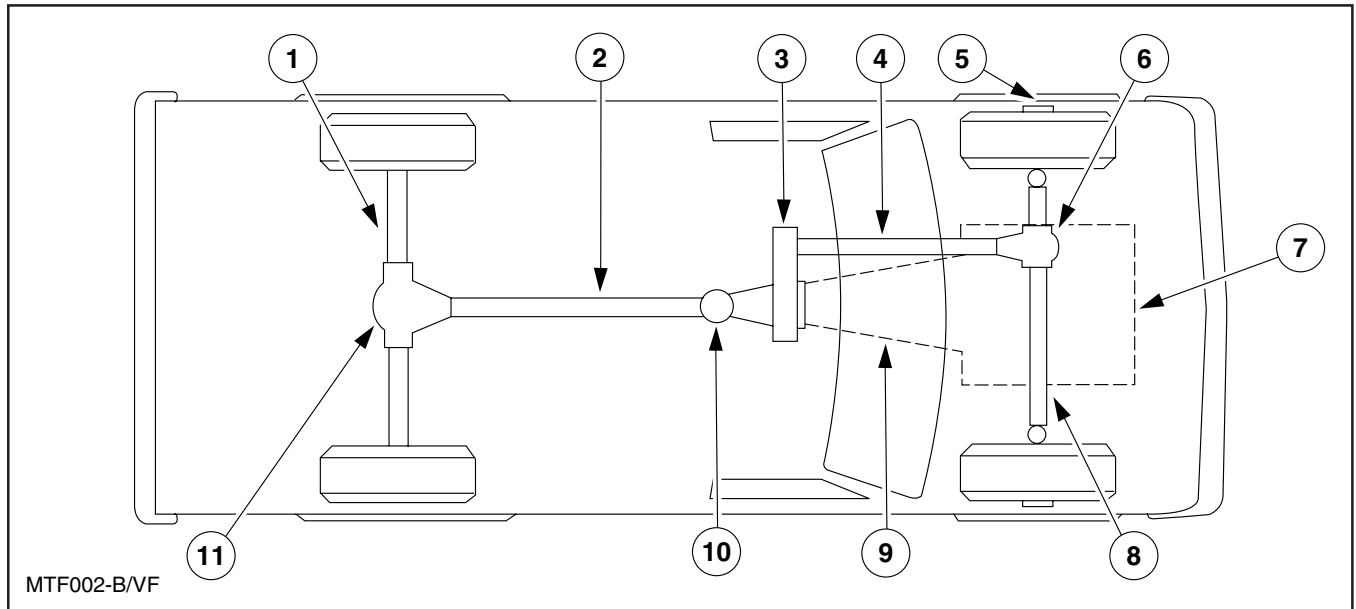
Within the differential case, the clutch plates are stacked on each side gear hub. A preload spring is located between the side gears. This spring applies preload force to the clutch packs by pushing against the side gears. As the clutch plates wear, the preload spring separates the pinion and side gears, which can increase total axle lash. Axle lash may be felt when shifting from forward and reverse.

The side gear thrust loads create additional force. These loads, from separating forces of the side and pinion gears, are caused by torque in the drivetrain. The steel plates are stacked in pairs between the friction plates, and are splined to the side gear hub. The side gear, in turn, is internally splined to the rear axle shafts. The friction plates thus engage notches in the differential case. The friction created by the plates creates torque capacity, which tries to prevent the side gears from rotating relative to the case. Available torque is a function of preload and added thrust load. In low traction, applying the brake and torquing the drivetrain, and then slowly releasing the brake and driving away can increase torque. This increases thrust load on the side gears.

Objectives

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

- Explain the purpose and function of a transfer case and 4x4 system.
- Describe a transfer case and 4x4 system.
- Identify the components of a transfer case and 4x4 system.
- Explain the theory and operation of a transfer case and 4x4 system.

4x4 drivetrain**4x4 drivetrain components**

- | | |
|----------------------|----------------------|
| 1 Rear axle | 7 Engine |
| 2 Rear driveshaft | 8 Front axle |
| 3 Transfer case | 9 Transmission |
| 4 Front driveshaft | 10 Slip yoke |
| 5 Locking hub | 11 Rear differential |
| 6 Front differential | |

The purpose of the 4WD system is provide torque to all four wheels of the vehicle rather than just two of the wheels.

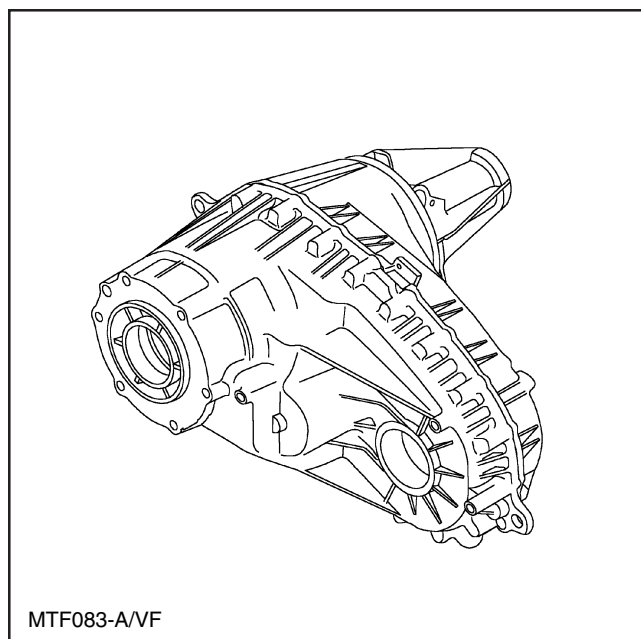
The 4x4 drivetrain includes all the same components as a rear-wheel drive drivetrain as well as a transfer case, a front driveshaft, and a front drive axle (with or without locking hubs).

Some vehicles use an AWD system. The AWD system is a system that uses all four wheels as drive wheels all the time. AWD systems can be made up of many different components. The AWD system has a transmission or transaxle, a transfer case, a front and rear differential.

Transfer case

Just as in a rear-wheel drive system, the engine supplies power to the transmission through the driveshaft and rear axle to the wheels. The transfer case is the gear assembly used to control powerflow to the front axle and somewhat to the rear axle. The transfer case transfers the power through one input shaft and two output shafts, one to each drive axle. The input shaft of the transfer case is connected to the transmission output shaft.

Many transfer cases include a gear reduction mechanism to provide a lower range, usually at a 2:1 ratio. Low range is limited to 4-wheel drive (4WD) operation because it doubles the torque to the drive axles, and this increased torque is often more than one axle is designed to handle.



Typical transfer case

Types of transfer cases

The two types of transfer cases are part-time 4-wheel drive and full-time 4-wheel drive.

Part-time transfer case

Part-time transfer case systems may be manually shifted, electronically shifted, or automatically shifted into 4WD. Vehicles with part-time transfer cases operate the same as 2-Wheel Drive (2WD) vehicles when 4WD is not engaged. The system is only operated in 4WD mode when commanded by the driver, or in the case of an Automatic 4-Wheel Drive (A4WD) system, commanded by the module.

Full-time transfer cases

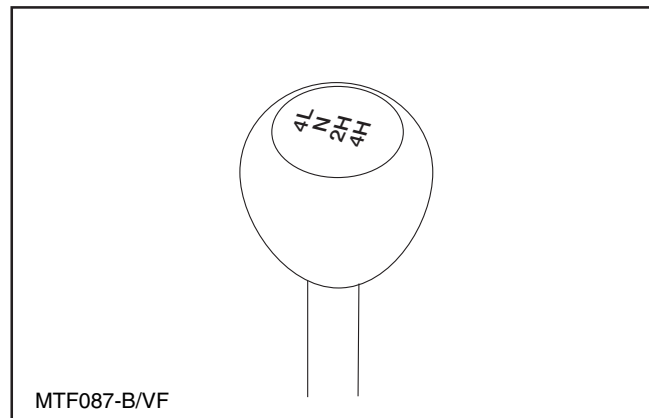
Full-time transfer case systems are always in the 4WD mode and cannot be controlled by the driver. The front drivetrain is always engaged and maintains constant power to both the front and rear axles. A vehicle with a full-time transfer case system will not perform like a 2WD vehicle.

4x4 controls

Manual shift lever

The manual shift transfer case allows the driver to manually shift the transfer case into N (Neutral – no power to either axle), 2WD, 4WD, or 4WD Low. A shift cam in the transfer case operates the forks, which move the reduction hub and 2W-4W lockup assembly into position.

To shift from N to 2WD or 4WD, the driver must place the transmission in the P (Park) position (automatic transmission) or depress the clutch pedal while the engine is idling (manual transmission) and move the transfer case shift lever to 2WD, 4WD, or 4WD Low.



Typical manual shift lever

Transfer case shift lever

Shifts from 2WD to 4WD can be made while the vehicle is moving in either direction at any speed, as long as the front wheel hubs are locked. Shifts from 4WD to 2WD can be made at any time. Shifts to 4WD Low must be made while at a complete stop. Vehicles with an automatic transmission require that the transmission be placed in the P position, pausing momentarily in the R (Reverse) position, then moving the transfer case shift lever to 4WD Low.

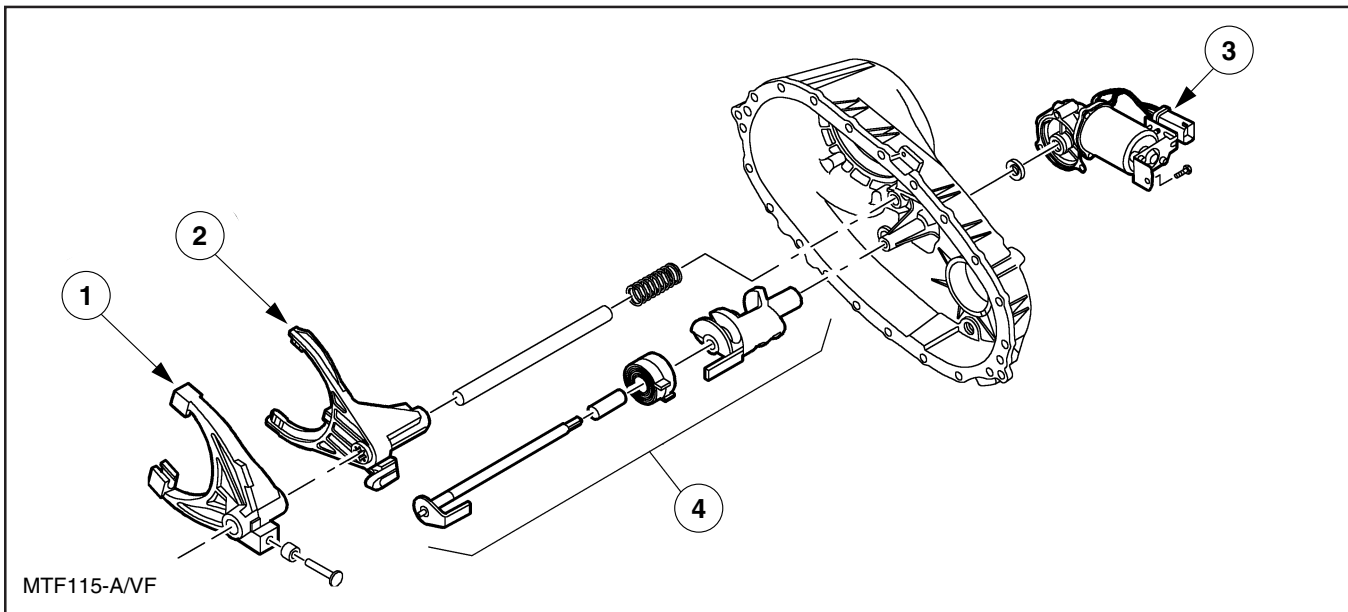
If the transfer case shift lever becomes difficult to shift due to drivetrain windup, move the vehicle in the opposite direction for a few feet to release the windup. If the transfer case shift lever is still difficult to shift, move the vehicle forward a few feet, shift the transmission to N, and while the vehicle is moving 3 mph or less, shift the transfer case to the desired position.

The shift range selector switch, located on the instrument panel, signals to the control module the driver's shift selection. The shift range selector switch and instrument panel indicator illuminate when the shift motor is moved to the 4WD High or 4WD Low position. While the shift motor may be in position with the indicator lamp on, the reduction hub or 2WD-4WD lockup assembly may not yet be engaged. This could occur if their splines are not aligned with those of the planetary carrier or clutch housing. Because the reduction hub and lockup assembly are spring loaded, they will move into position when conditions allow. Lamp illumination does not guarantee that the selected shift mode has been engaged.

Some vehicles use a three-position switch to control the system operation, while other vehicles use a four-position switch. The available switch positions are 2WD, A4WD, 4WD High, and 4WD Low.

Mechanical components

Shift forks



Typical shift fork assembly (electronic shift)

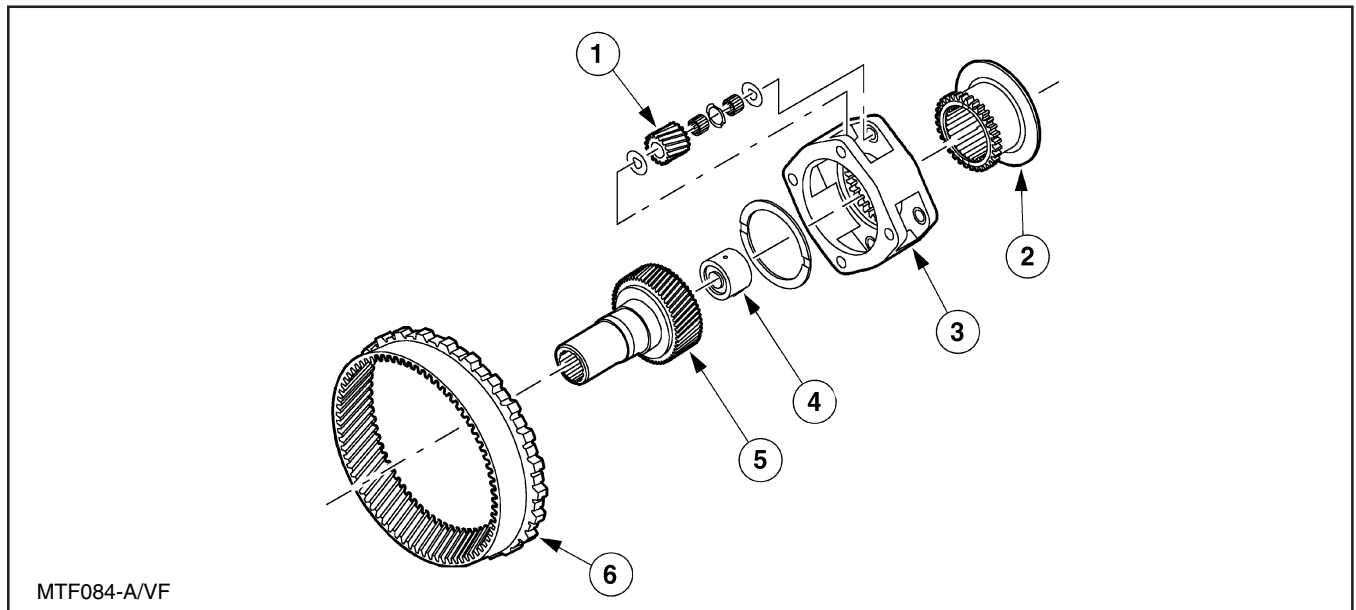
- | | |
|------------------------|----------------------|
| 1 Reduction shift fork | 3 Shift motor |
| 2 Lock-up shift fork | 4 Shift cam assembly |

Some transfer cases use a reduction shift fork to shift between low and high ranges. The reduction shift fork usually moves a component that engages the planetary gearset.

Most transfer cases use a shift lever or motor and shift cam assembly to shift the reduction shift fork and lock-up shift fork.

Some transfer cases use a lock-up shift fork to shift between 2WD and 4WD. The lock-up shift fork usually moves a component that engages the drive sprocket and chain.

Planetary gearsets



Typical planetary gearset

- | | |
|---------------------------|-------------|
| 1 Planetary pinion gears | 4 Bearing |
| 2 Reduction hub | 5 Sun gear |
| 3 Planet carrier assembly | 6 Ring gear |

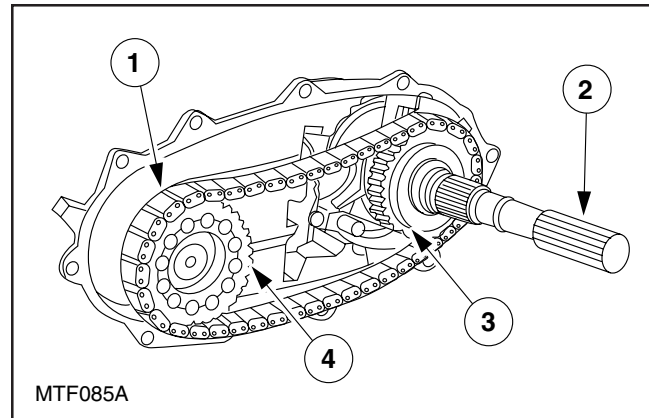
Some transfer cases use a simple planetary gearset for torque multiplication in 4WD Low. Planetary gearsets function in several ways. In part-time transfer cases, the planetary gears “walk” around the inside of the ring gear, which is held stationary in the case. The result is that the planetary gear carrier turns more slowly than the input shaft. Because the planetary gear carrier is attached directly to the output shaft through the reduction hub (high-low shift collar), the output shaft rotates at a lower speed than the input shaft. This action increases the engine torque available to the wheels. In all positions other than 4WD Low, the reduction hub joins the sun gear to the output shaft.

Mechanical components (continued)

Chain and sprockets

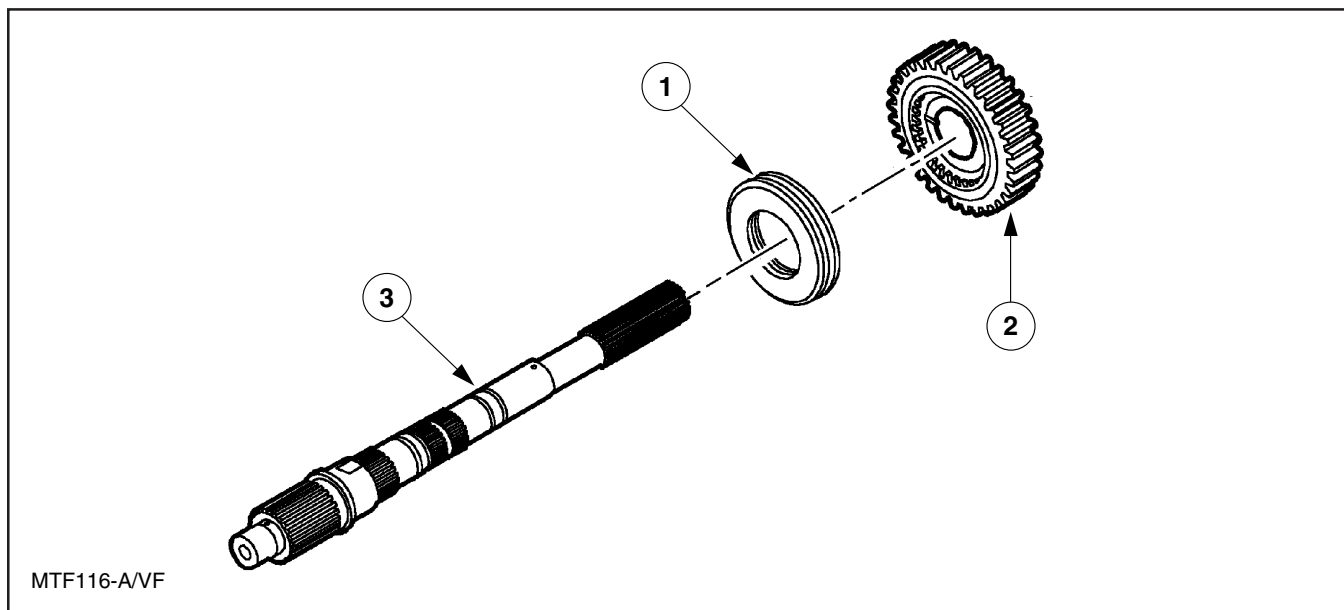
The transfer case contains a high-efficiency drive chain that provides power transfer to the front output shaft. The chain is driven by a drive sprocket on the rear output shaft and drives the driven sprocket on the front output shaft. On manual shift transfer cases, the 2WD to 4WD shift is accomplished when the 2W-4W shift fork moves the lock-up collar to engage the drive sprocket on the rear output shaft splines. The drive sprocket turns the chain, which turns the driven sprocket on the front output shaft.

On AWD transfer cases, the output from the planetary gearset enters the viscous coupling, which has one output to the rear output shaft and another to the sprocket of the drive chain for the front output shaft.



Drive Chain and Sprockets

- 1 Chain
- 2 Rear output shaft
- 3 Drive sprocket
- 4 Driven sprocket

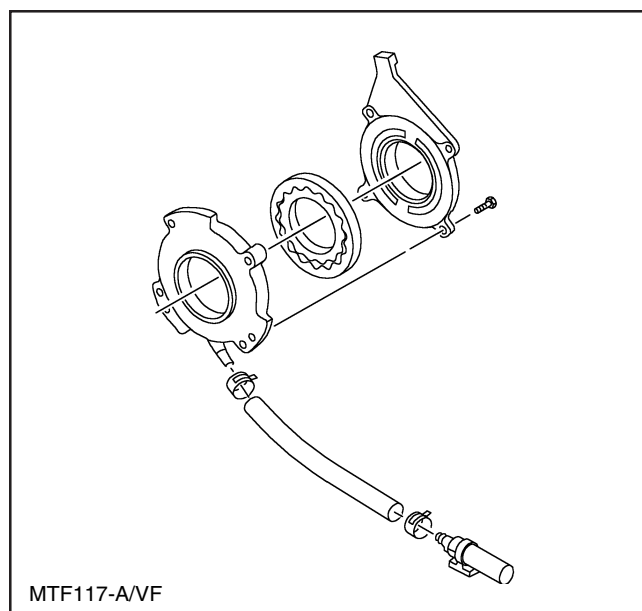
Lock-up collar**Lock-up collar assembly**

- 1 Lock-up collar
- 2 Drive sprocket
- 3 Rear output shaft

Some transfer cases use a lock-up collar assembly to mechanically lock the rear output shaft to the drive sprocket in 4WD High and 4WD Low. The lock-up collar is not applied in 2WD and A4WD.

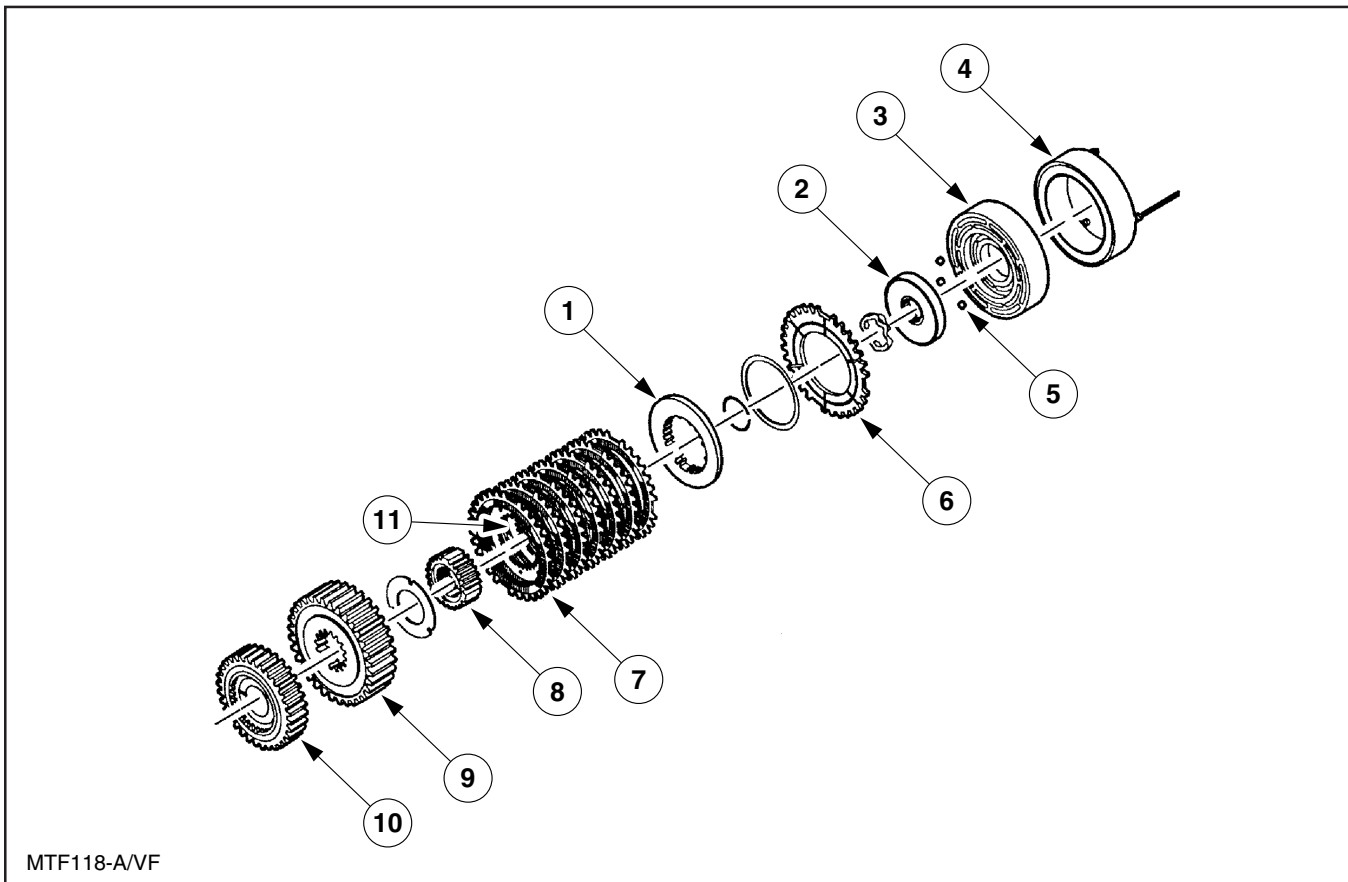
Pump

Most transfer cases use a fluid pump for lubrication. Fluid pumps are usually driven by the rear output shaft.

**Typical fluid pump**

Transfer case clutch types

Clutch pack and cam/coil housing assembly



MTF118-A/VF

Basic clutch pack and cam/coil housing assembly

- | | |
|-----------------------------|------------------------------------|
| 1 Pressure plate | 7 Externally splined clutch discs |
| 2 Cam | 8 Clutch hub |
| 3 Cam/coil housing assembly | 9 Clutch housing |
| 4 Clutch coil | 10 Drive sprocket |
| 5 Balls | 11 Internally splined clutch discs |
| 6 Armature | |

Some automatic transfer cases use a clutch pack and cam/coil housing assembly. The clutch pack and cam/coil housing assembly allows torque to be transferred to the front output shaft, as needed, to meet driving conditions. The clutch is module controlled through a relay, and applies when the module senses speed variances between the front and rear output shafts. In some vehicles, the clutch is used in place of a lock-up component to engage all four wheels.

The clutch hub is splined to the rear output shaft and to the internally splined clutch discs. The clutch hub rotates at rear output shaft speed.

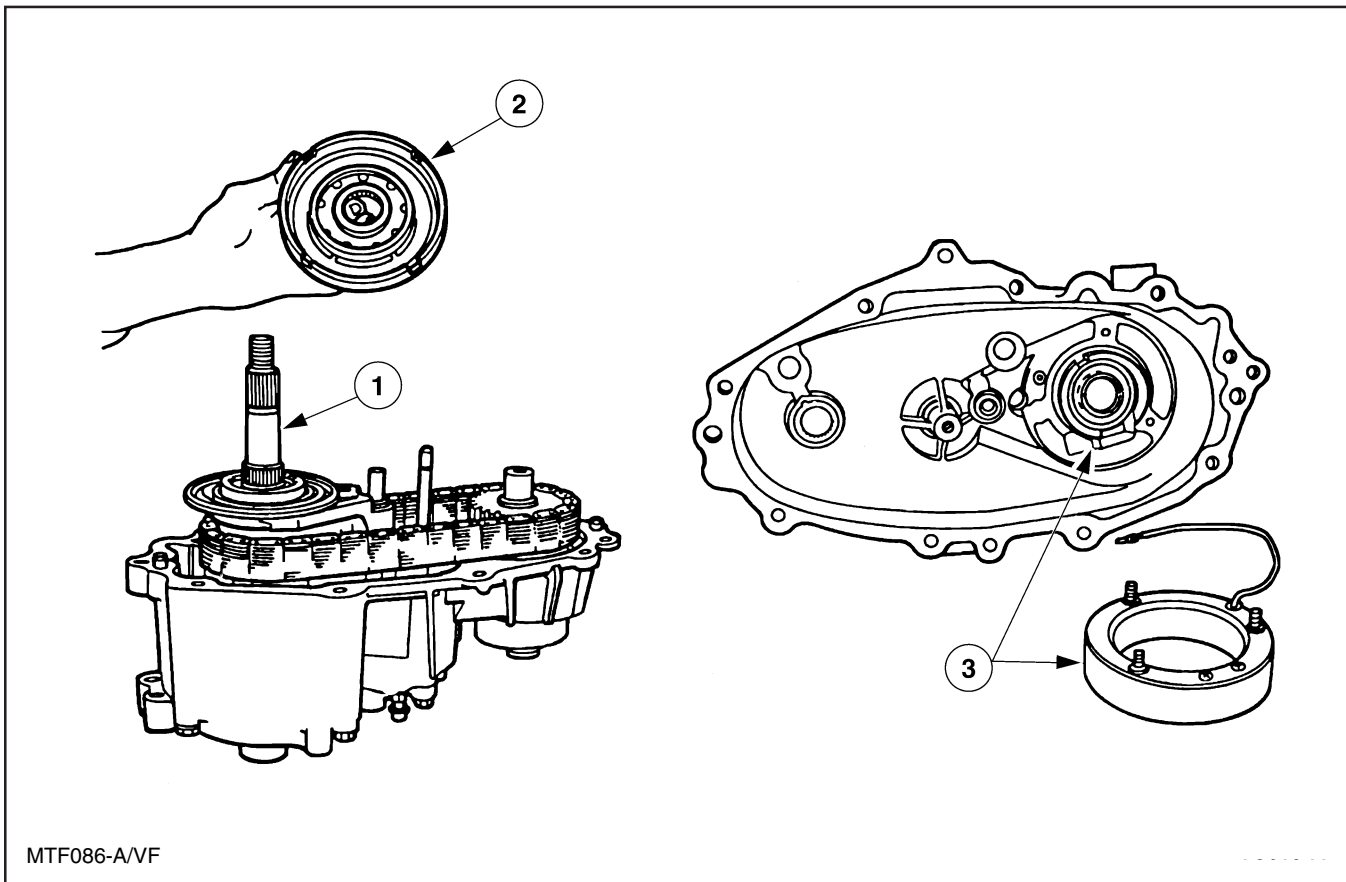
The clutch housing is splined to the drive sprocket and to the externally splined clutch discs. The clutch housing rotates at front output shaft speed.

When the module activates the relay, the relay provides battery power to the clutch coil. The clutch coil magnetically pulls the armature against the cam/coil housing assembly. Since the armature is splined to the clutch housing, it turns at the front output shaft speed and the cam/coil housing assembly starts to turn at the same speed.

On the inside of the cam/coil housing assembly is half of a ball and cam assembly. The other half of the ball and cam assembly is splined to the rear output shaft and the balls are seated between the two cams. Since the two cams are turning at different speeds, it causes the balls to “ramp up” on the cams. This ramp-up action pushes the cam against the pressure plate and squeezes the clutch pack. By squeezing the clutch pack together, the clutch hub is linked to the clutch housing and transfers torque to the front output shaft.

Transfer case clutch types (continued)

Magnetic clutch assembly

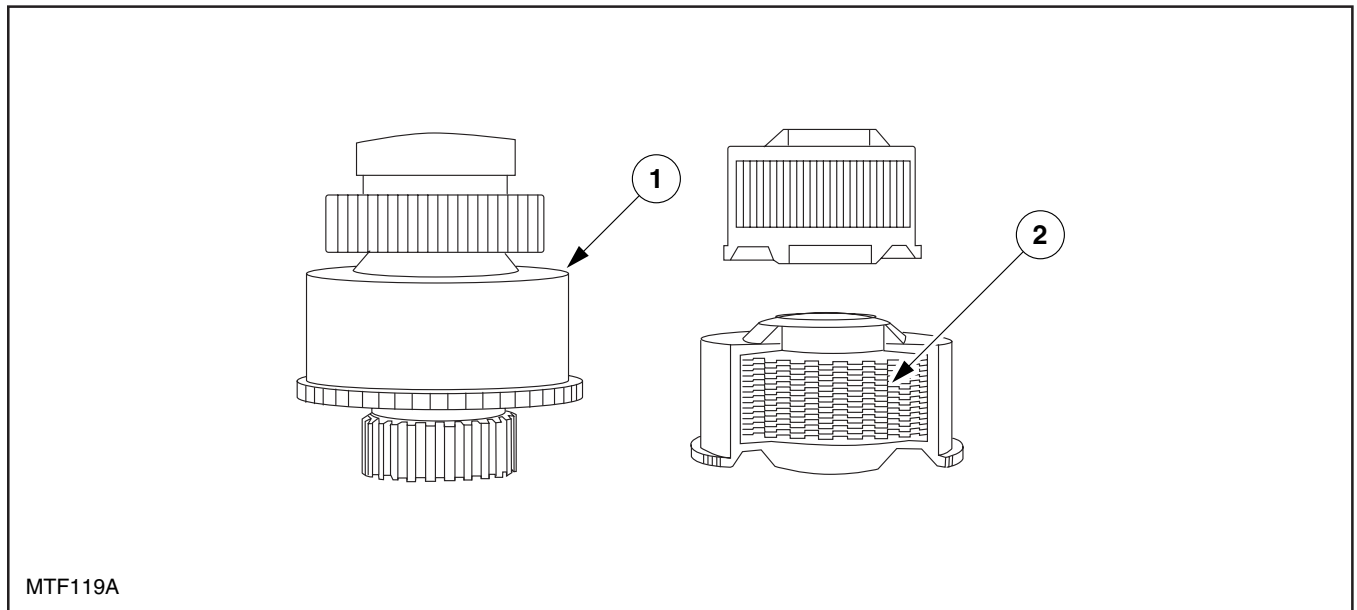


Typical magnetic clutch assembly

- 1 Output shaft
- 2 Clutch housing assembly
- 3 Clutch coil

Electronic shift transfer cases are equipped with a magnetic clutch, which is similar in operation to an air conditioning compressor clutch. The magnetic clutch allows the transfer case to be shifted into 4WD High at any safe speed. The clutch is controlled by a module through a solid state relay.

The clutch is used to spin up the front drive system from zero to vehicle speed in milliseconds. The spin-up engages the front locking hubs. After the hubs are locked, the control module allows the shift motor to execute the shift. When the transfer case rear and front output shafts reach synchronous speed, the spring-loaded synchronizer sleeve mechanically engages the mainshaft lockup hub to the chain-drive sprocket and the magnetic clutch is then deactivated.

Viscous coupling**Viscous coupling transfer case**

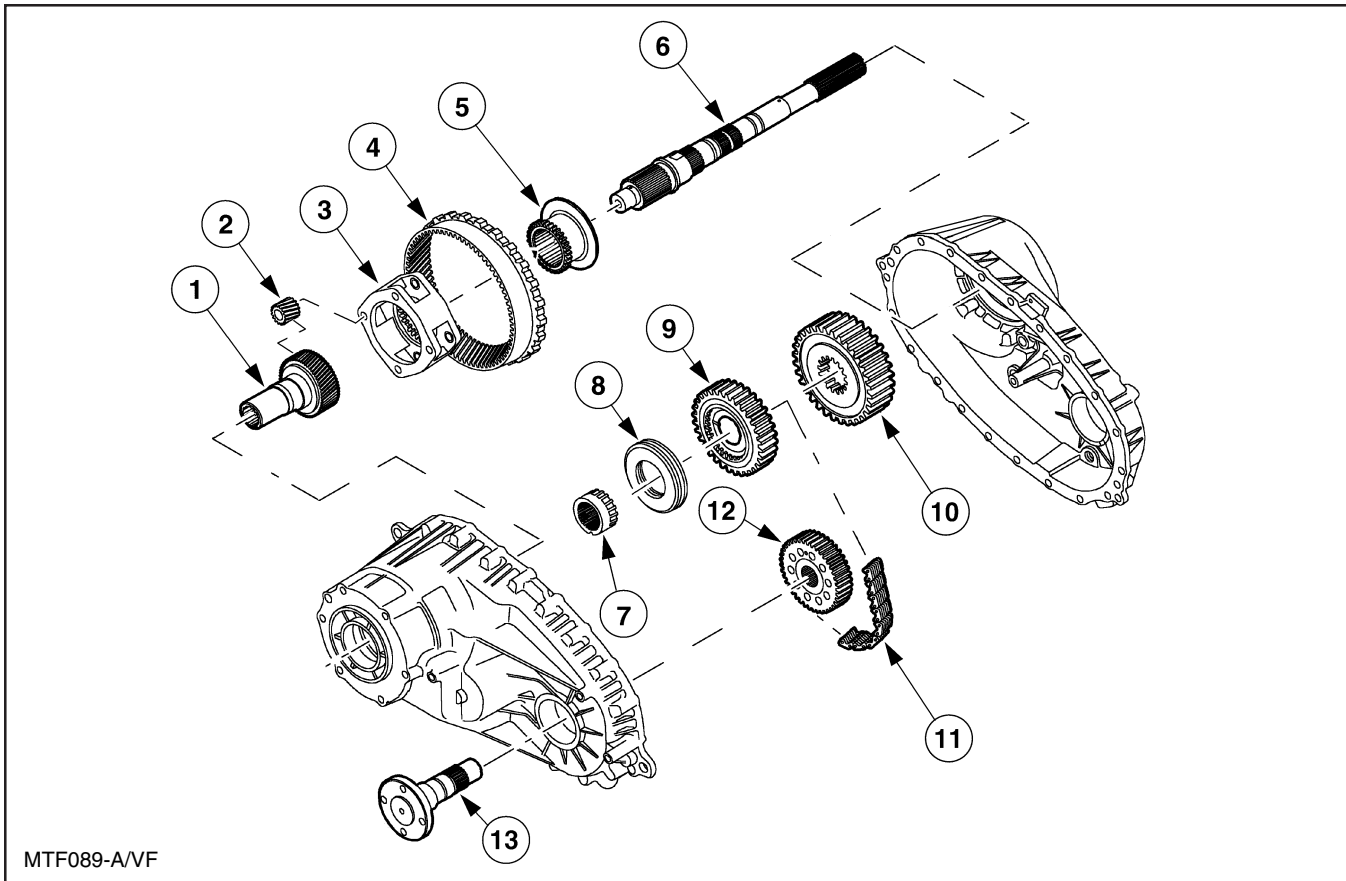
- 1 Housing
- 2 Clutch discs

The function of the viscous coupling is similar to that of a limited slip differential. The viscous coupling provides torque to the wheels regardless of the traction available to the tires. The viscous coupling automatically performs this function to improve vehicle traction when the rotation speed of the front and rear wheels varies.

The viscous coupling is similar to multi-disc clutches used in automatic transmissions. The viscous coupling has a sealed housing that contains two sets of discs. The discs have a ferric nitro-carburized coating. One set of discs is connected to the coupling housing and the other set is connected to the internal hub of the coupling.

The viscous coupling housing is a sealed unit and is filled with a combination of a special silicone based fluid (85%) and air (15%). The rotation of the housing is transmitted to the hub by the action of the fluid. As the housing (drive) plates rotate, they cut through, or “shear,” the fluid. The fluid quickly heats up and expands in the housing. As the fluid expands, it forces the air contained in the housing to press tightly against the hub (driven) plates and to rotate at the same speed as the drive plates. Torque is efficiently transferred between the drive and driven plates without direct contact between the drive and driven plates.

Basic transfer case powerflow



Part-time transfer case

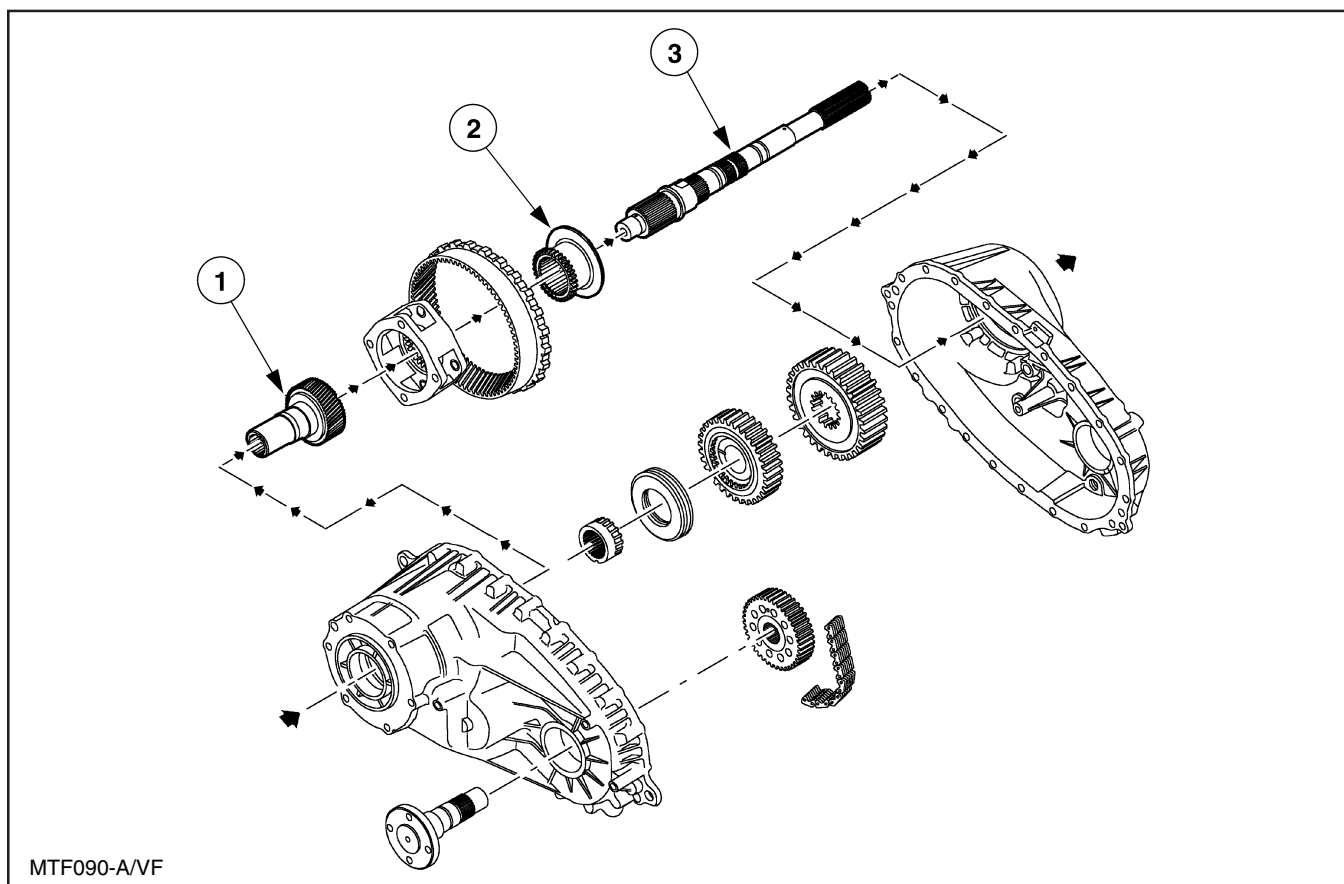
- | | |
|--------------------------|-----------------------|
| 1 Input shaft (sun gear) | 8 Lock-up collar |
| 2 Planetary pinion gears | 9 Drive sprocket |
| 3 Planetary carrier | 10 Clutch housing |
| 4 Ring gear | 11 Drive chain |
| 5 Reduction hub | 12 Driven sprocket |
| 6 Rear output shaft | 13 Front output shaft |
| 7 Inner lock-up hub | |

The transfer case uses a large chain to transfer power to the front output shaft. There are three ways for power to flow through this transfer case:

- 4x4 high
- 4x4 low
- 2-wheel drive

Low range is provided by a set of planetary gears. A lock-up collar is used to control the powerflow for 4WD to the drive chain sprocket.

The current transfer cases offer several advantages over systems used in the past, including ease of shifting, quiet operation, and reduced component wear. Unlike older systems, current transfer cases allow all internal 4WD components to be disengaged from the drivetrain when 2WD is selected. They create no additional drag and do not adversely affect fuel economy.

2WD high range**2H powerflow**

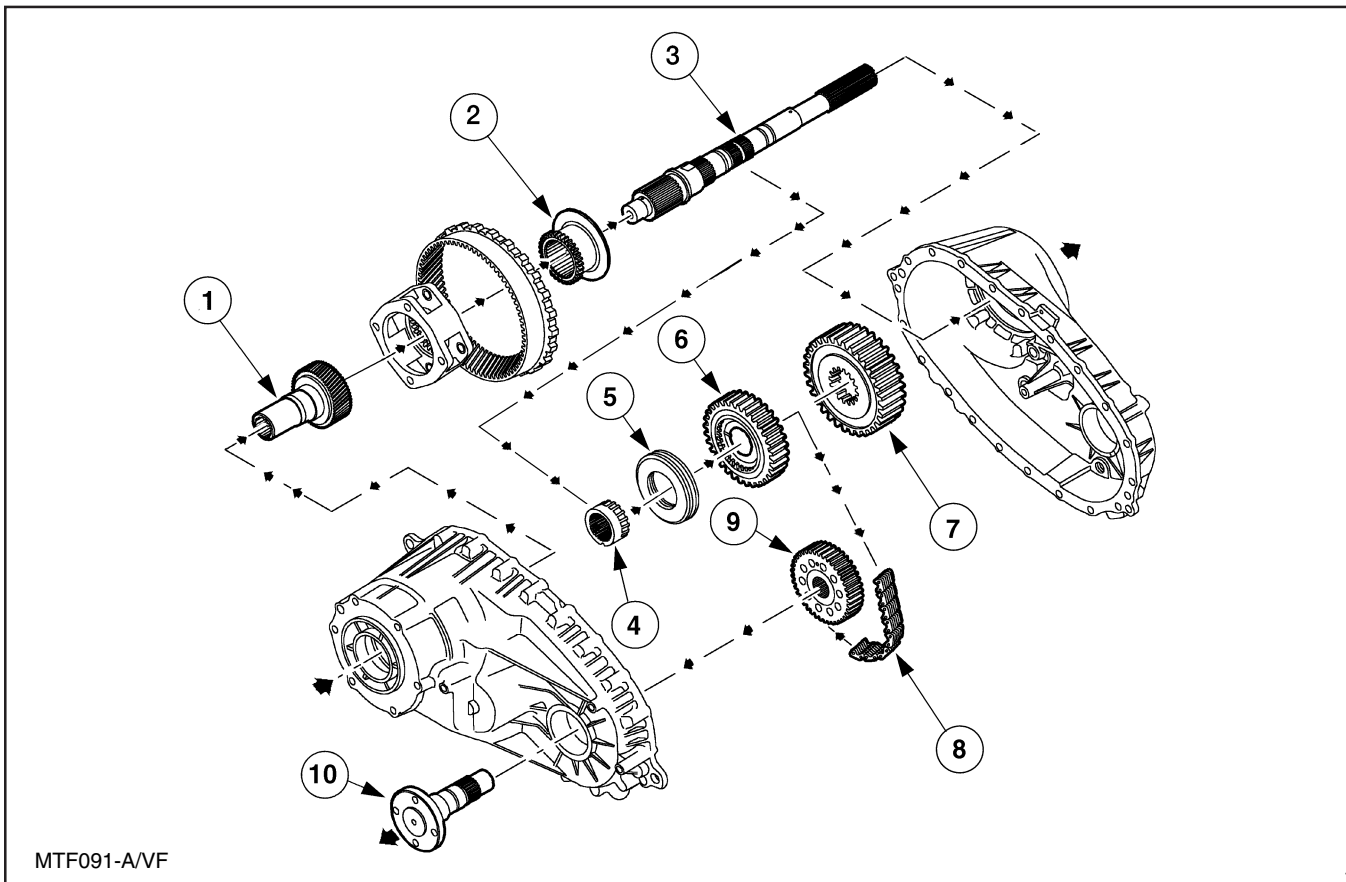
- 1 Input shaft (sun gear)
- 2 Reduction hub
- 3 Rear output shaft

When the vehicle is put into 2H, the reduction hub slides forward, engaging its internal splines with the external splines at the end of the input shaft. The input shaft locks to the rear output shaft and torque is transmitted to the rear differential. None of the 4WD components are engaged at this time.

Should the splines of the reduction hub and input shaft be butted (preventing engagement), the helical spring at the base of the shaft will maintain shift pressure, allowing the components to engage once the input shaft rotates.

Basic transfer case powerflow (continued)

4WD high range



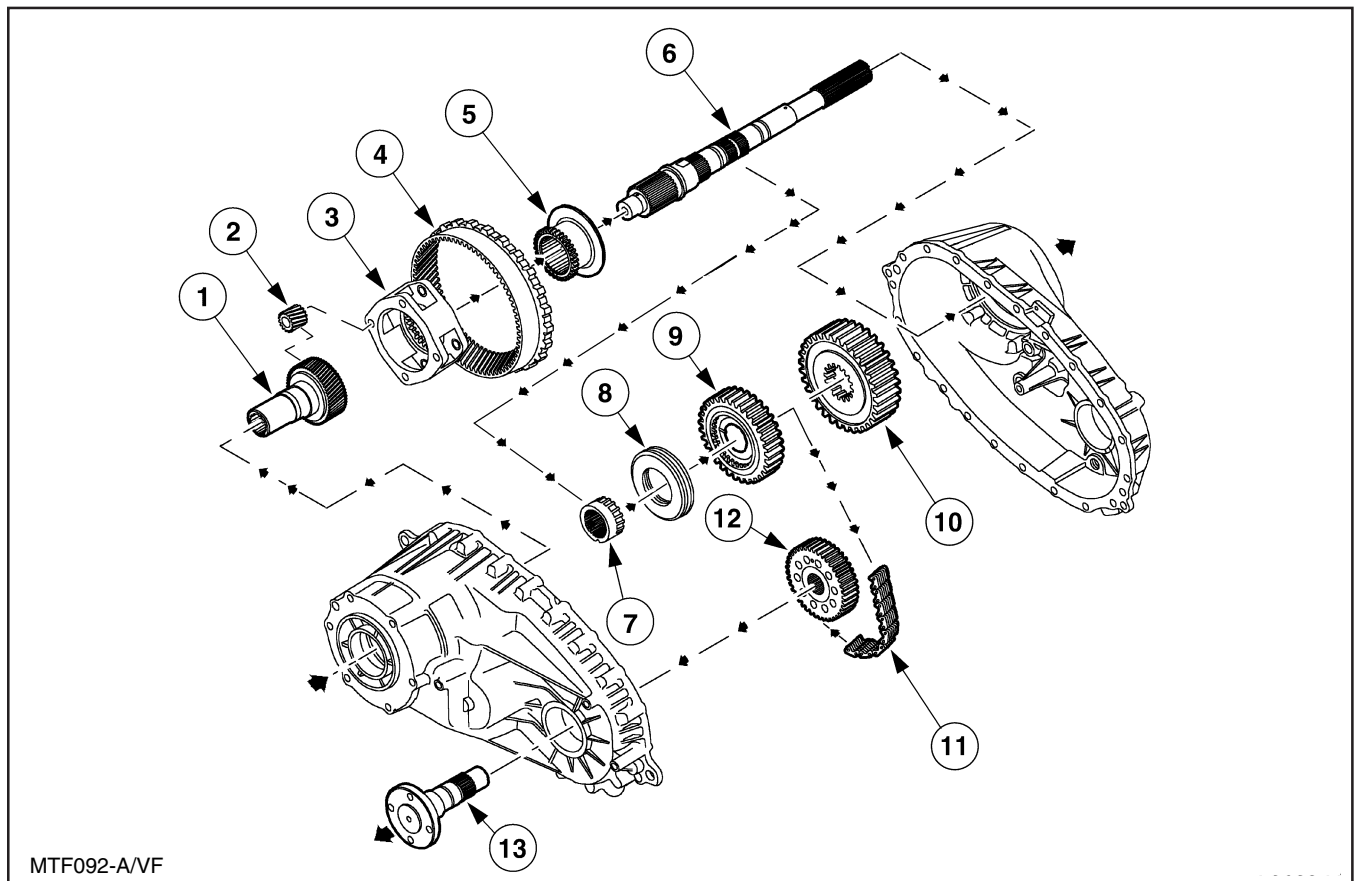
4H powerflow

- | | |
|--------------------------|-----------------------|
| 1 Input shaft (sun gear) | 6 Drive sprocket |
| 2 Reduction hub | 7 Clutch housing |
| 3 Rear output shaft | 8 Drive chain |
| 4 Inner lock-up hub | 9 Driven sprocket |
| 5 Lock-up collar | 10 Front output shaft |

When the vehicle is put into gear, torque is transmitted to the transfer case input shaft from the transmission output shaft. The reduction hub connects the input shaft to the rear output shaft, and torque is transmitted to the rear axle. When 4WD is selected, the lock-up collar moves and locks the inner lock-up hub to the drive sprocket.

With the inner lock-up hub locked to the drive sprocket, the drive sprocket is locked to the rear output shaft. With the rear output shaft locked to the drive sprocket, torque is also transmitted to the front axle through the drive chain, driven sprocket, and front output shaft.

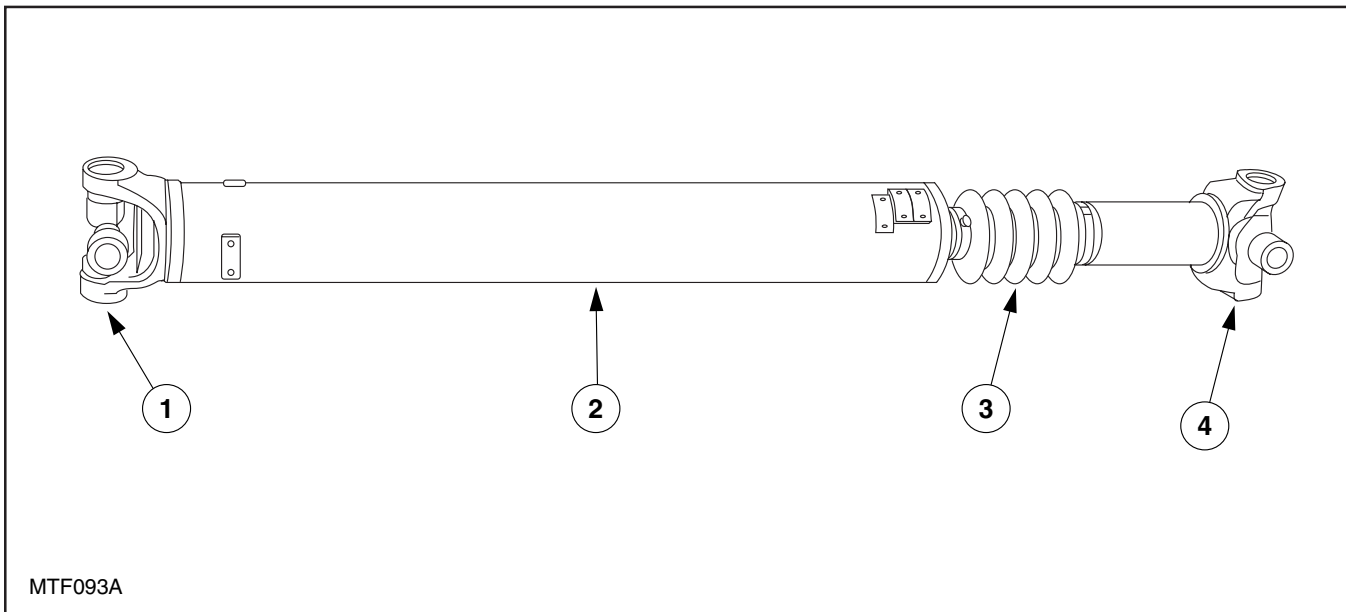
4WD low range

**4L powerflow**

- | | |
|--------------------------|-----------------------|
| 1 Input shaft (sun gear) | 8 Lock-up collar |
| 2 Planetary pinion gears | 9 Drive sprocket |
| 3 Planetary carrier | 10 Clutch housing |
| 4 Ring gear | 11 Drive chain |
| 5 Reduction hub | 12 Driven sprocket |
| 6 Rear output shaft | 13 Front output shaft |
| 7 Inner lock-up hub | |

When 4L is selected, the reduction hub moves onto the planetary carrier, locking the planetary carrier to the rear output shaft. When the vehicle is put into gear, torque is routed through the sun gear to the planetary pinion gears. The planetary pinion gears walk around the inside of the ring gear, which causes the planetary carrier and rear output shaft to rotate in reduction to the input shaft. More torque is now transferred through the transfer case.

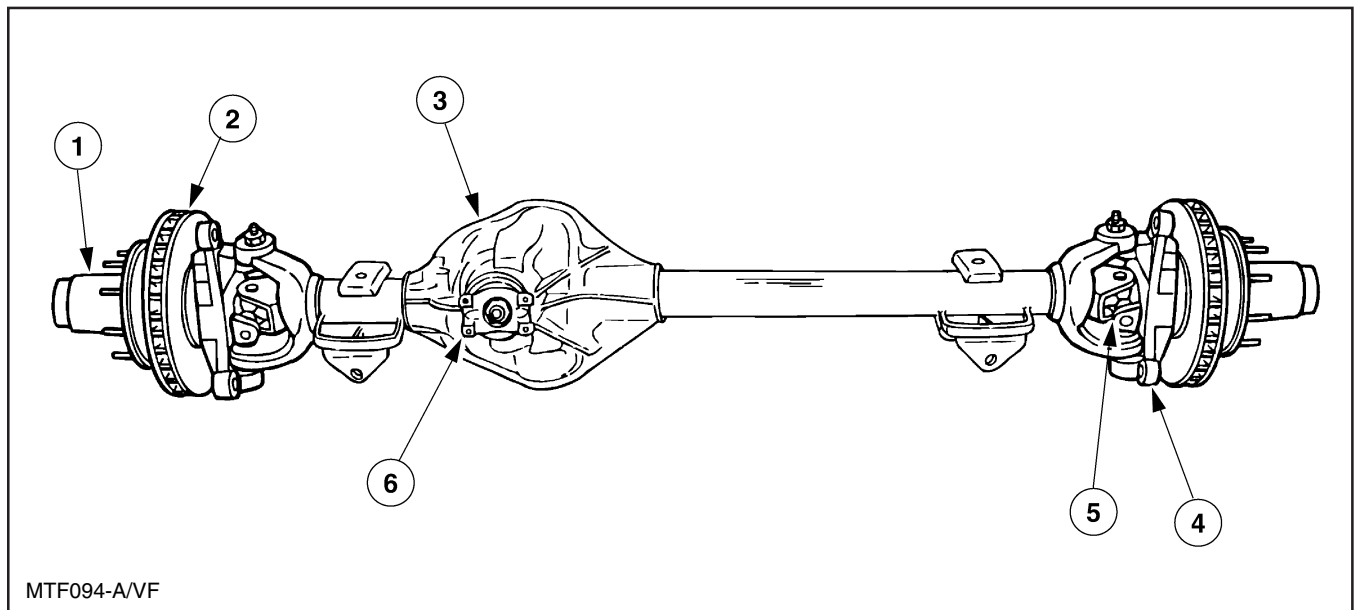
As in the 4H position, the inner lock-up hub remains locked to the drive sprocket. With the inner lock-up hub locked to the drive sprocket, torque is also transmitted to the front differential through the drive chain, driven sprocket, and front output shaft.

Front drivetrain components**Front driveshaft****Typical front driveshaft**

- | | |
|-----------------|----------------|
| 1 Front U-joint | 3 Boot |
| 2 Driveshaft | 4 Rear U-joint |

During 4WD operation, the front driveshaft delivers power to the front drive axle. A typical front driveshaft has a front single Cardan U-joint, a rear single or double Cardan U-joint, a rear slip yoke, and a boot (to cover the slip yoke splines).

Front axle



Monobeam front axle

- | | |
|---------------------|----------------------------|
| 1 Locking wheel hub | 4 Steering knuckle |
| 2 Brake rotor | 5 Shaft and joint assembly |
| 3 Axle housing | 6 Pinion yoke |

A front-drive axle is required to deliver power from the differential to the front wheels. The front-drive axle operates the same as a rear-wheel drive axle. The front-drive axle directs powerflow through the axle shafts to both front wheels when the system is in 4WD mode. Most axle shafts consist of two pieces, with an inner axle that connects to the axle gear in the differential, the U-joint, or CV joint, and an outer axle that connects to the wheel hub.

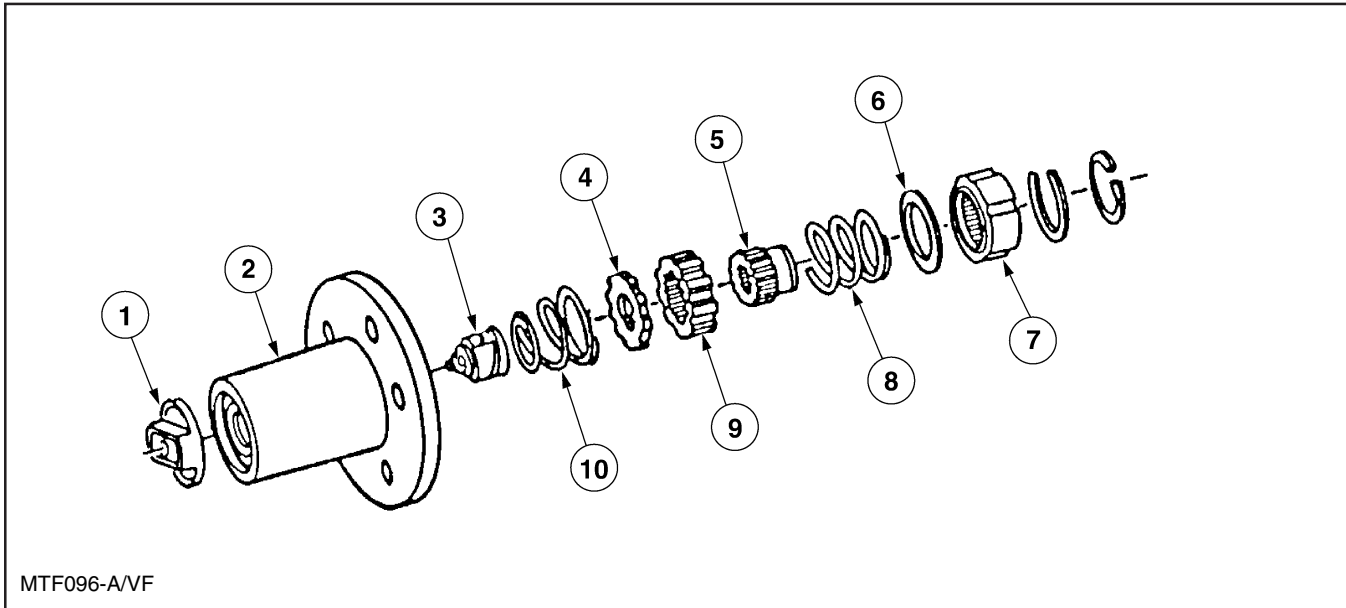
There are two types of front axles used on 4WD vehicles: Monobeam and Independent Front Suspension (IFS).

Monobeam axles have a one-piece design. Monobeam axles are used in applications where substantial amounts of weight are expected to be added to the front of the vehicle, such as winches, snow plows, etc.

IFS axles are designed to allow the front axle to become an integral part of the vehicle suspension. IFS axles use halfshafts with constant velocity (CV) joints to allow the axles to flex in relation to ground conditions and to the differential carrier, which is part of the axle housing.

Front drivetrain components (continued)

Locking wheel hubs



MTF096-A/VF

Manual locking hubs

- 1 Knob
- 2 Hub
- 3 Cam
- 4 Spring mount
- 5 Axle shaft sleeve ring

There are three types of locking hubs: manual, which require the driver to operate them; automatic, which engage based on axle shaft rotation; and vacuum, which are engaged by an externally supplied vacuum source. Manual hubs contain a clutch that is shifted by rotating a portion of the hub unit to manually engage the clutch (lock the hub), or disengage it. The hub engages when an internal cam moves a spline on the clutch hub into mesh with a spline in the wheel hub. Automatic hubs have a feature in which rotation of the axle causes the cam in the hub to operate. This feature allows the driver to engage 4WD without having to go to the hubs to lock them.

- 6 Spring mount
- 7 Bearing and retainer
- 8 Inner spring
- 9 Inner clutch ring
- 10 Outer spring

The pulse vacuum hub lock (PVH) system is a wheel-end disconnect front axle system that engages or disengages the hubs from the front axle halfshafts by means of vacuum from the engine manifold. When the driver makes a 4x4 engagement or disengagement, the electronic module energizes the PVH solenoid to apply one of two vacuum pressure levels downstream to the hub locks. The lower pressure level is regulated by the solenoid and acts to disengage each hub lock. The high level acts to engage the hub locks. If vacuum is lost, the system remains in whichever mode it is in at that time. The PVH system is designed in such a manner that there is no overlap between hub lock engagement/disengagement levels and solenoid engagement/disengagement levels. This ensures proper 4x4 function during shift-on-the-fly at all altitude and temperature extremes.

Objective

Upon completion of this lesson you will be able to:

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

Symptom-to-system-to-component-to-cause diagnostic procedure diagnosis

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.

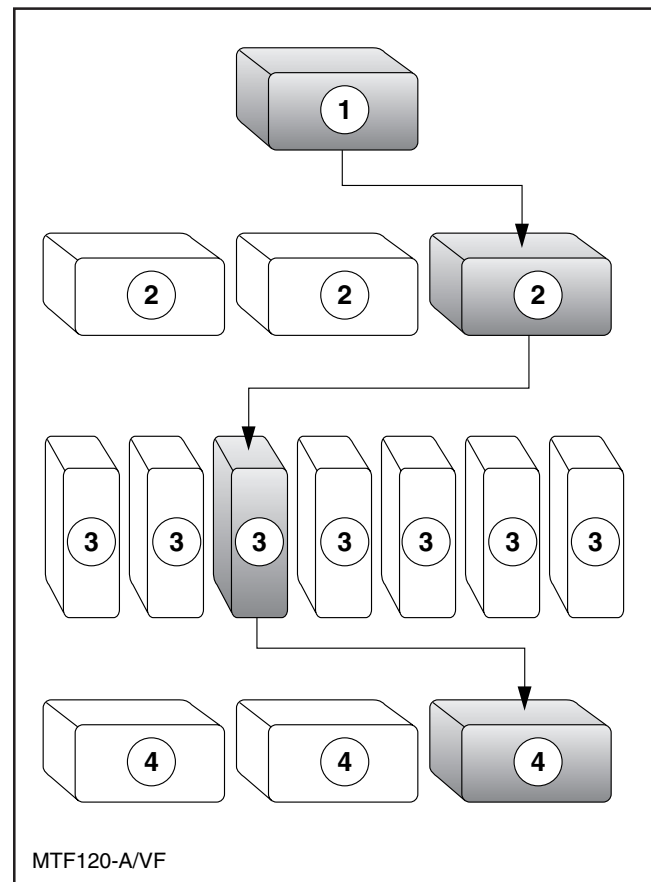
Symptom-to-system-to-component-to-cause diagnostic method

Using the Symptom-to-System-to-Component-to-Cause (SSCC) diagnostic routine 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 clutch is chattering because it is oil soaked, replacing the clutch assembly will correct the chattering problem. However, if the oil leak that caused the clutch failure is not corrected at the same time the clutch will certainly fail again.



SSCC Diagram

- 1 Symptom
- 2 Vehicle systems
- 3 Components
- 4 Causes

Workshop manual

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

The abbreviations conform to the standard SAE J1930 except those marked with an asterisk (*).

4WD*	Four-Wheel Drive	N*	Neutral
ABS*	Anti-lock Brake Systems	Nm*	Newton-Meters
AWD	All-Wheel Drive	P*	Park
Countershaft*	Layshaft	PTO*	Power Take-Off
CPP*	Clutch Pedal Position switch	PVH*	Pulse Vacuum Hub
CV*	Constant Velocity joints	R*	Reverse
FWD*	Front-Wheel Drive	RPM*	Revolutions Per Minute
IRS*	Independent Rear Suspension	RWD*	Rear-Wheel Drive
Kg*	Kilogram	SSCC	Symptom-to-System-to-Component-to-Cause
Layshaft*	Countershaft	U-Joint*	Universal Joint
Lb-Ft*	Foot-Pounds		