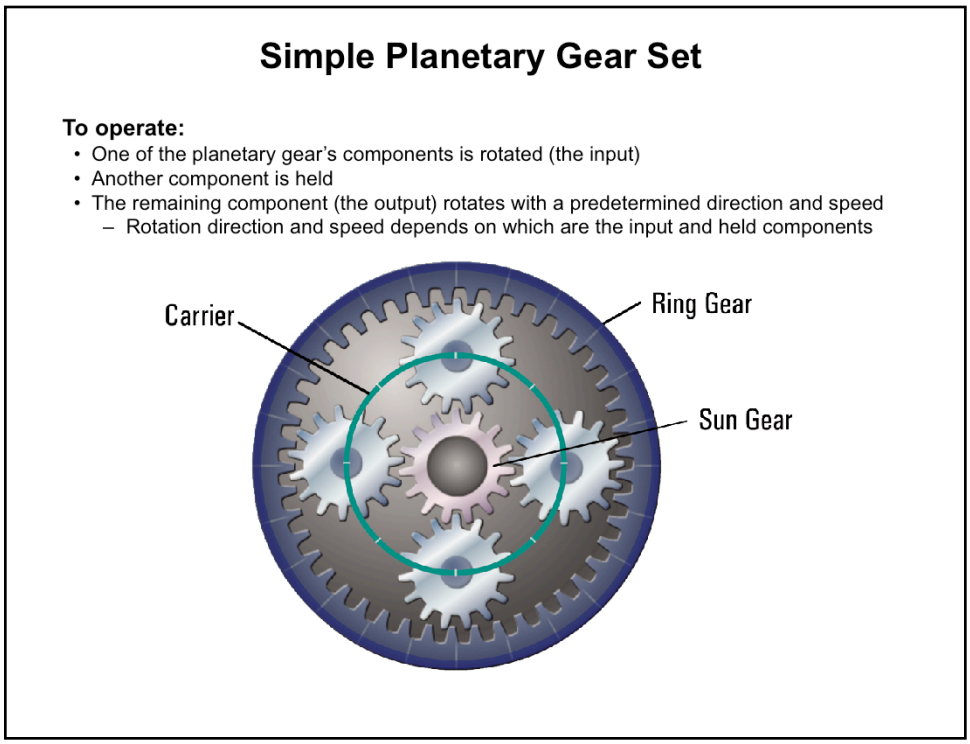
Section 4 Topics

Simple Planetary Gear Set

- Components
- Operation
- Holding Devices
- Multiplate Clutch
- Brake
- One-way Clutch

- Simple Planetary Gear Set and Holding Devices Worksheet



Simple Planetary Gear Set

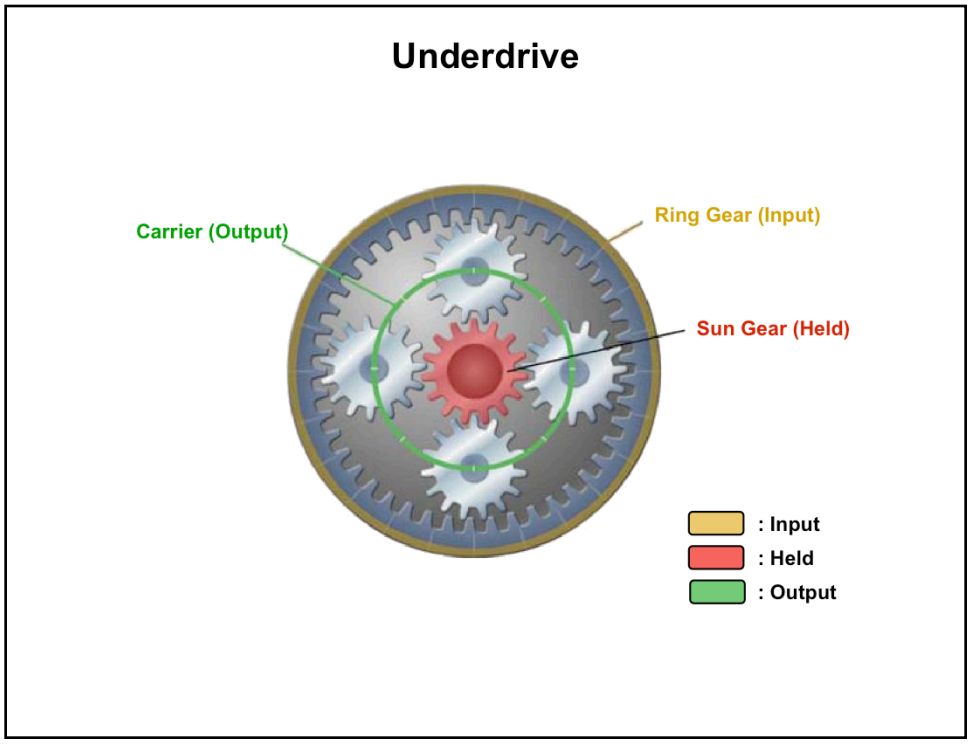
A simple, planetary gear set consists of:

- Ring gear
- Sun gear
- Carrier
  - Pinion gears are attached to the carrier
  - Pinion gears ride between sun and ring gears

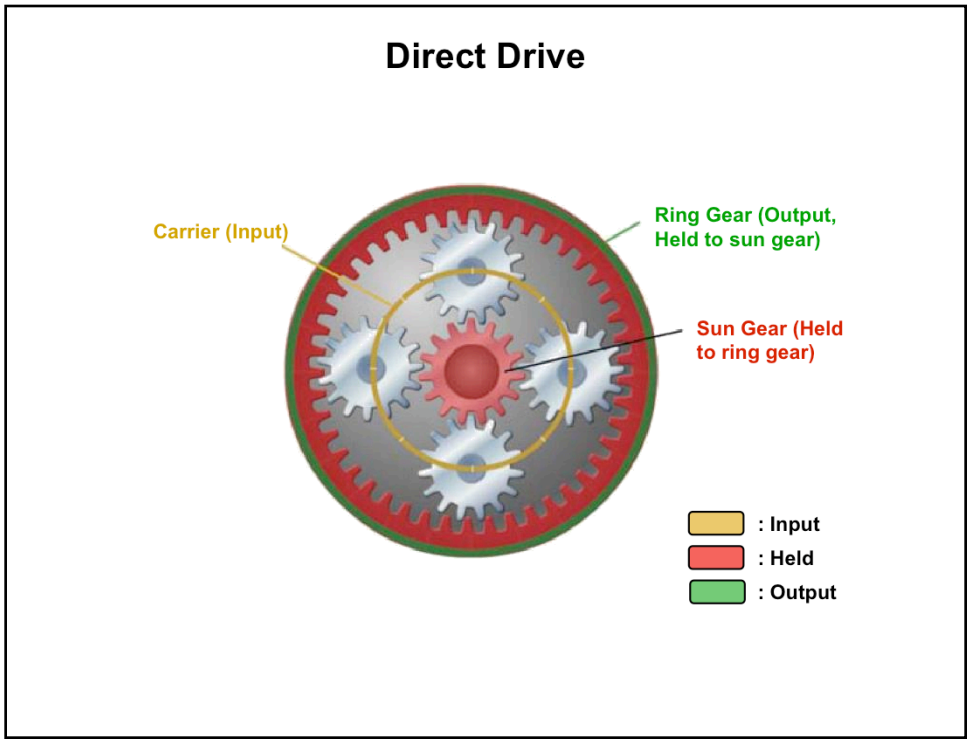
In the simple planetary gear set:

- Forward gear ratios are achieved by holding either the ring gear or sun gear. Input to the carrier results in overdrive. Output through the carrier results in underdrive.
- Reverse gear ratios are achieved by holding the carrier. Input to the ring gear results in overdrive. Input to the sun gear results in underdrive.

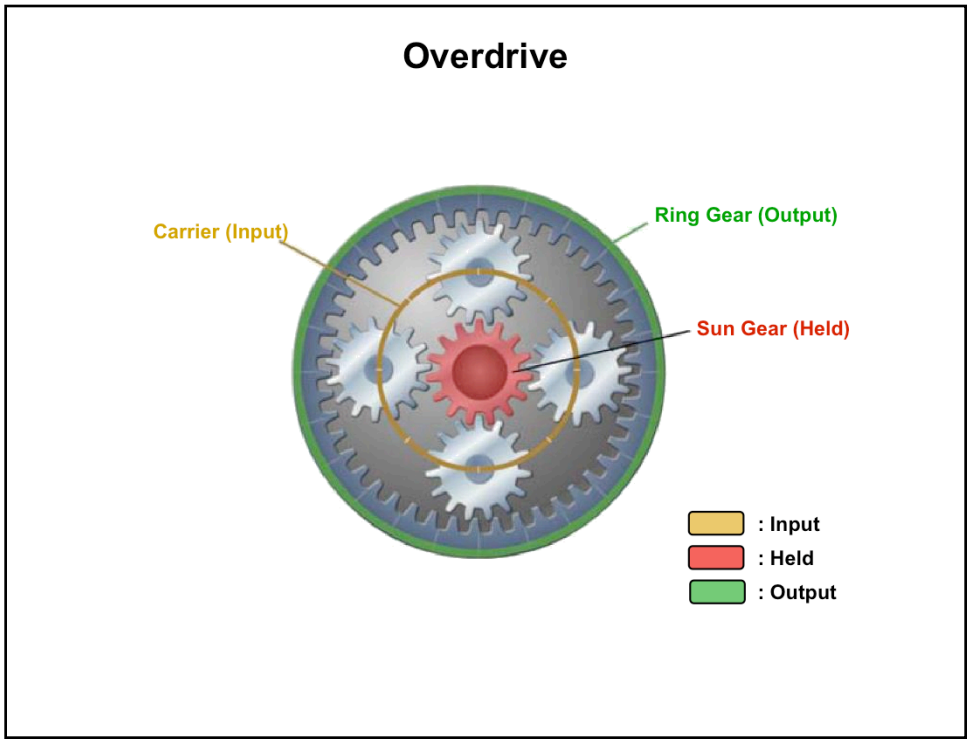
One purpose of the planetary gear set is to provide varying forward gear ratios, allowing the vehicle's engine to stay in its best power range throughout the range of vehicle operating conditions. The planetary gear set must also provide a reverse gear.



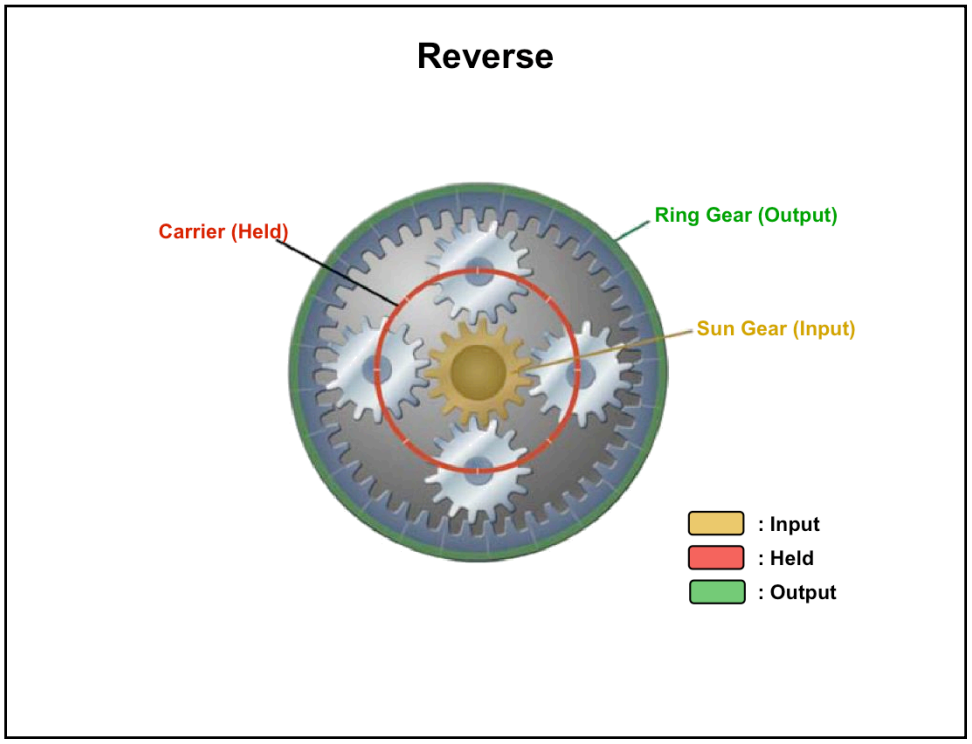
Underdrive When the internal teeth of the ring gear turn clockwise, the external teeth of the pinion gears walk around the fixed sun gear while rotating clockwise. This causes the carrier to rotate at a reduced speed.



Direct Drive When any two members are held together and another member provides the input turning force, the entire assembly turns at the same speed as the input member.



Overdrive When the carrier turns clockwise, the external toothed pinion gears walk around the external toothed sun gear while rotating clockwise. The pinion gears cause the internal toothed ring gear to accelerate to a speed greater than the carrier speed in a clockwise direction.



Reverse With the carrier held, when the external toothed sun gear turns clockwise, the external toothed pinion gears on the carrier idle in place and drive the internal toothed ring gear in the opposite direction.

Whenever the carrier is held and either of the other gears are input members, the output gear will rotate in the opposite direction.

Simple Planetary Gear Operation

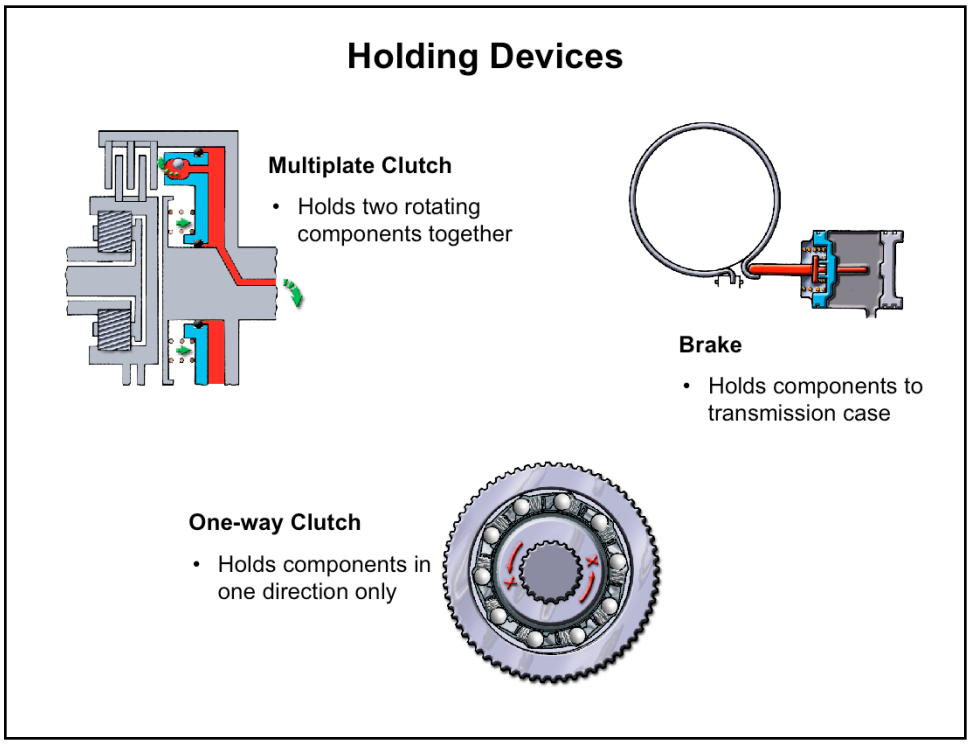
HELD	POWER INPUT	POWER OUTPUT	ROTATIONAL		ROTATIONAL DIRECTION
			SPEED	TORQUE	
Ring Gear	Sun Gear	Carrier	Reduced	Increased	Same direction as drive member
	Carrier	Sun Gear	Increased	Reduced	
Sun Gear	Ring Gear	Carrier	Reduced	Increased	Same direction as drive member
	Carrier	Ring Gear	Increased	Reduced	
Carrier	Sun Gear	Ring Gear	Reduced	Increased	Opposite direction from drive member
	Ring Gear	Sun Gear	Increased	Reduced	

Rotation Speed and Direction

The operation of a simple planetary gear set is summarized in the chart above. Different speeds and rotational directions can be obtained by holding one of the planetary members in a fixed position, providing input torque to another member, with a third member used as an output member.

Simple vs. Complex Gear Sets

There are a limited number of gear ratios available from a single planetary gear set. To take full advantage of the optimum torque curve of the engine, most automatic transmissions in production today use a combination of two or more planetary gear sets. Additional gears and shafts may also be needed to complete the flow of power through the transmission.



Holding Devices

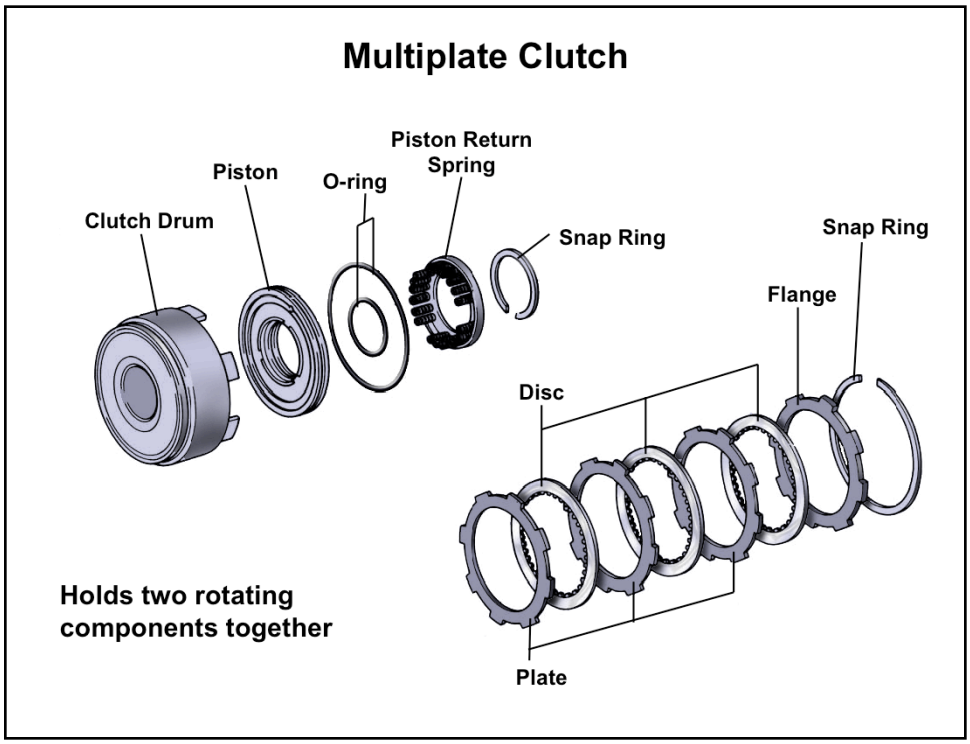
There are three types of holding devices used in the planetary gear set. Each type has its specific design advantage:

- **Multiplate clutch** — holds two rotating components together so that they turn in the same direction and at the same speed.
- **Brake (multiplate or band)** — holds planetary components to the transmission case so they cannot turn in either direction. Also used to hold one race of a one-way clutch to provide an additional state of one-way clutch operation.
- **One-way clutch (roller or sprag)** — holds planetary components locked in one rotational direction while allowing free rotation (“freewheel”) in the opposite direction.

The multiplate clutch and multiplate brake are the most common holding devices. They are versatile and, by removing or including more friction discs, designers can easily adapt the transmission to accommodate engines of different power output.

Brake bands are compact and have a large surface area to create strong holding force, but tend to wear more quickly and require periodic adjustment.

One-way clutches are small in size and, because they are mechanical rather than hydraulic devices, they release and apply quickly. This provides good response for upshifts and downshifts but can be more harsh than a hydraulic application.

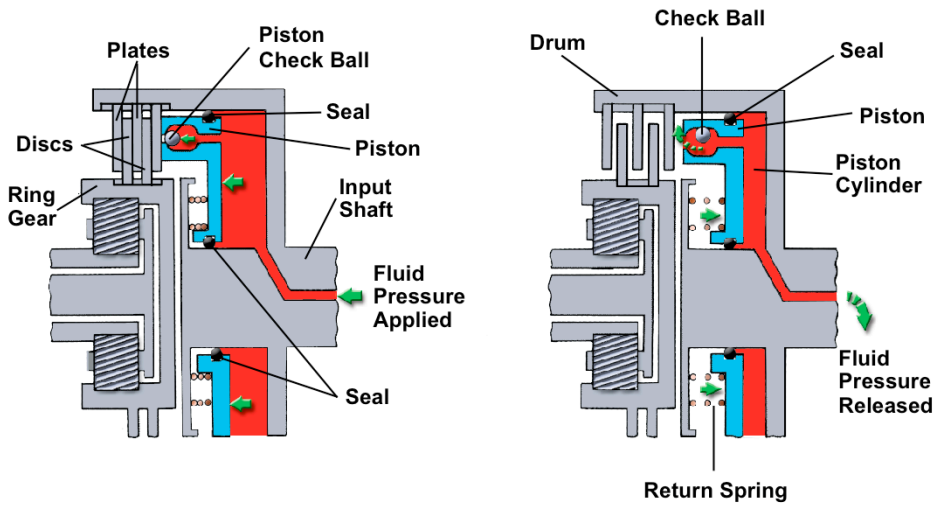


Multiplate Clutches

Multiplate clutches are made up of the following components:

- **Clutch drum:** provides the bore for the hydraulic apply piston. The drum is slotted on the inner diameter to engage the steel plates and transfer turning torque from the engine.
- **Piston:** houses hydraulic seals. May include a relief ball valve.
- **Return springs:** return the piston to its at-rest position in the clutch drum.
- **Friction discs:** steel plates with friction material bonded to both sides. Friction discs are always mounted between two steel plates. The friction disc inner diameter is slotted to fit over the splines of the clutch hub.
- **Steel plates:** provide a smooth surface for the friction discs to engage. Steel plates are slotted on the outer diameter to fit the slots of the clutch drum. Plates can be installed steel-to-steel to create a specific clearance for the clutch pack.
- **Clutch hub:** center of hub is splined to a shaft. The hub outer diameter is splined to engage the internal slots of friction discs, transferring torque from the shaft to the discs.

Multiplate Clutch Operation



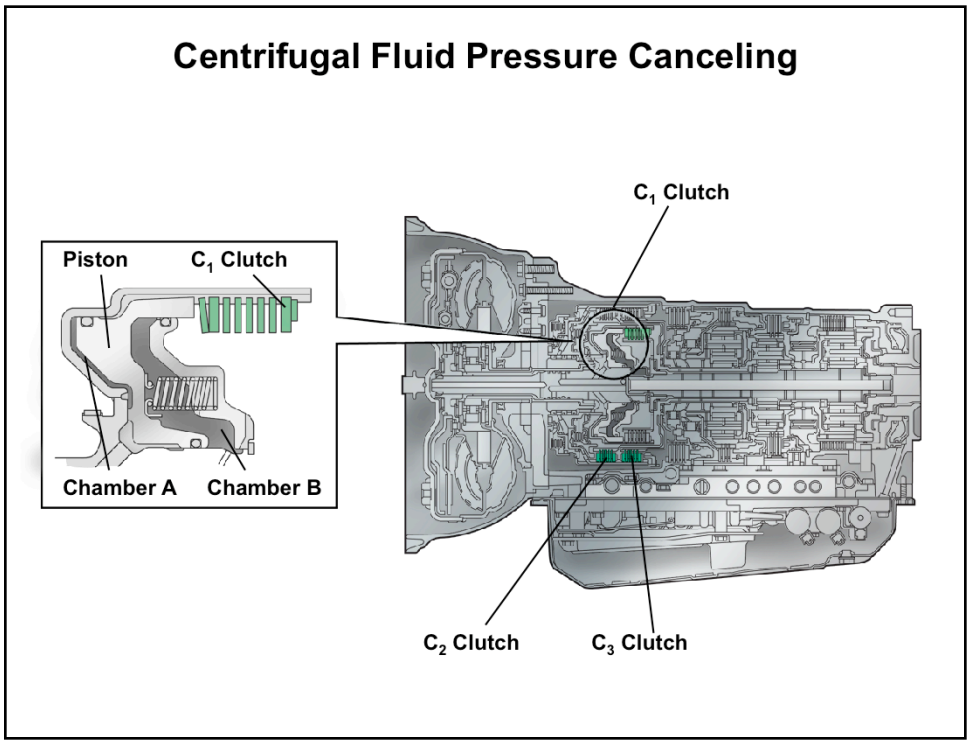
Operation

Multiplate clutches hold two rotating components together so that they act as an assembly.

To apply the clutch, hydraulic pressure is routed to the side of the piston opposite the return springs. When hydraulic pressure overcomes return spring pressure, the return springs compress and the piston squeezes the friction discs and steel plates together so that they rotate as a unit. When hydraulic pressure is released, the return springs push the piston back to its at-rest position, allowing the friction discs and steel plates to rotate independently of each other.

Because the clutch drum rotates while the vehicle is in motion, it presents a unique challenge to ensure that pressurized fluid reaches the clutch and holds the clutch engaged for many tens of thousands of miles of service. Oil seal rings seal the fluid passages between the piston, the clutch drum, and the center support.

Even when the clutch is not applied, some fluid remains behind the piston. As the drum rotates, centrifugal force moves this fluid to the outer diameter of the drum where it can create pressure on the piston. The pressure may not be enough to fully engage the clutch, but it may reduce the clearance between the friction discs and steel plates. The pressure can cause the clutch to disengage too slowly and/or not release completely, leading to erratic shifting, heat build-up, and excessive clutch plate wear.



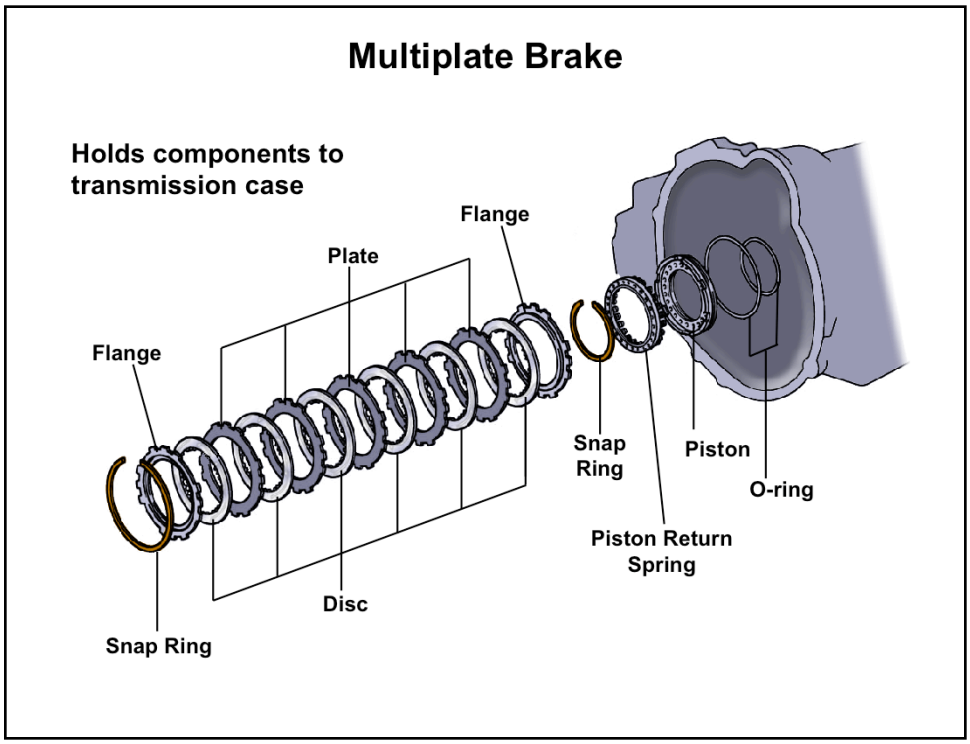
Centrifugal Fluid Pressure Cancelling

In older designs, a check ball valve allows fluid to escape when pressure is released from the clutch. As pressure drops, centrifugal force moves the ball away from the valve seat, allowing fluid to escape. The return springs can then fully seat the piston, maintaining proper clearance between the friction discs and steel plates.

There are two problems with this design:

- With only a small amount of fluid remaining in the chamber, additional time is required to fill the chamber for the next application cycle.
- Centrifugal force varies with rotational speed, so the check valve's operating characteristics can change as speed changes.

In newer designs, a centrifugal fluid pressure canceling mechanism does the same job without the need for a check valve. Instead, opposing fluid chambers apply equal amounts of centrifugal force to both sides of the piston. This cancels out the effects of centrifugal force on piston movement and leads to smoother shifts.

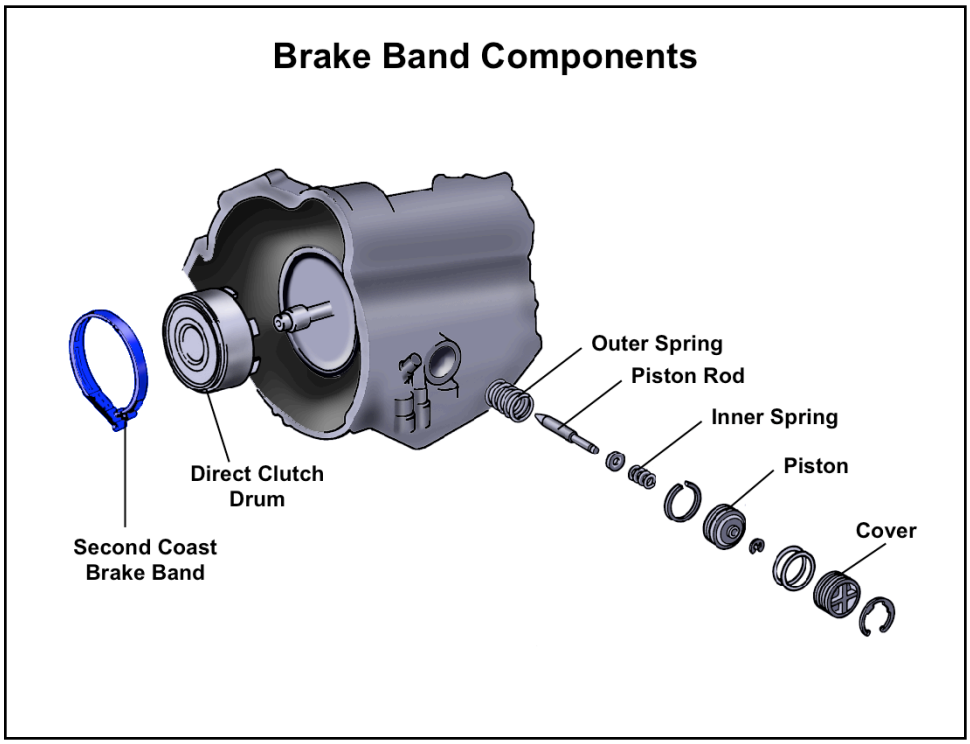


Multiplate Brake

A multiplate brake is similar to a multiplate clutch. Brakes can lock a gear set component to the transmission housing so that the component cannot rotate. They can also be used to lock one race of a one-way clutch, providing an additional state of one-way clutch operation. Multiplate brakes are made up of these components:

- **Transmission housing:** provides the cylinder bore for the brake piston. Splines in the housing engage outer slots in the steel plates, providing an anchor.
- **Piston:** houses hydraulic seals.
- **Return springs:** return the piston to its at-rest position.
- **Friction discs:** steel plates with friction material bonded to both sides. Friction discs are always mounted between two steel plates. The friction disc inner diameter is slotted to fit over splines in the rotating component.
- **Steel plates:** provide a smooth surface for the friction discs to engage. Steel plates are slotted on the outer diameter to fit slots in the transmission housing. Plates can be installed steel-to-steel to create a specific clearance for the clutch pack.

The multiplate brake has a piston, hydraulic seals, and return springs, like a multiplate clutch. But because the brake assembly does not rotate, there is no centrifugal force to affect hydraulic fluid pressure, so there is no need for check ball valves or other centrifugal fluid pressure canceling mechanisms.



Multiplate Brake Operation

To apply the brake, hydraulic pressure is routed to the side of the piston opposite the return springs. When hydraulic pressure overcomes spring pressure, the return springs compress and the piston squeezes the friction discs and steel plates together, locking the rotating component to the stationary transmission housing. When hydraulic pressure is released, the return springs push the piston back to its at-rest position, allowing the friction discs and steel plates to rotate independently of each other.

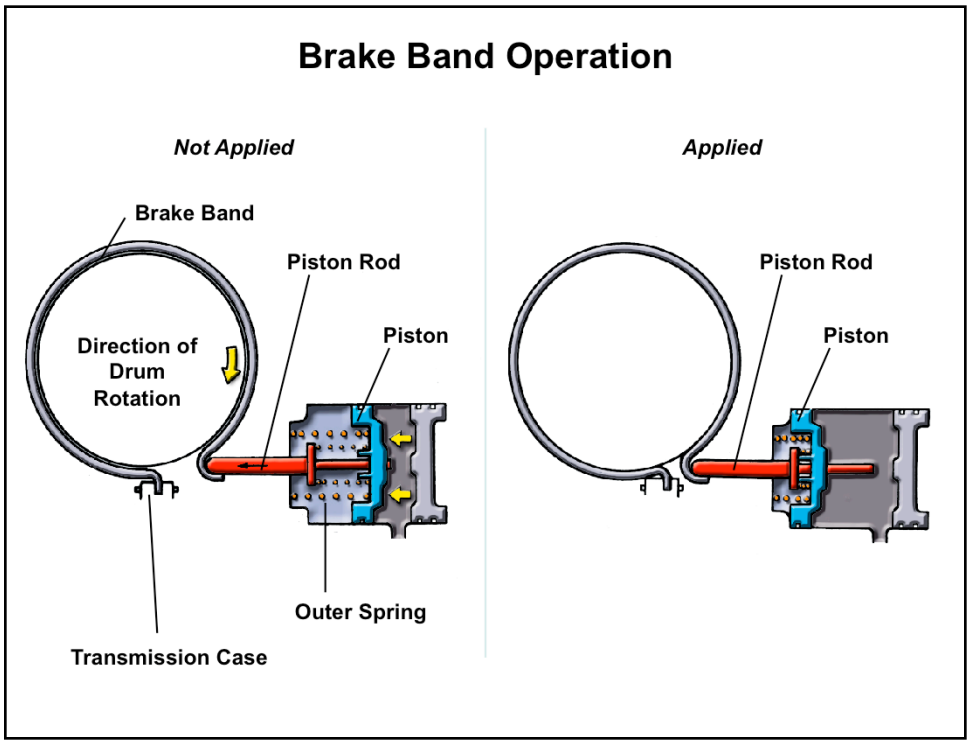
Brake Bands

The brake band is an older design feature not seen in current Toyota automatic transmissions.

Brake Band Components

The brake band is a metal band lined with friction material. There is a slight spring tension to the band, so it wants to expand. The band surrounds a clutch drum, with one end of the band anchored to the transmission housing. Additional components include:

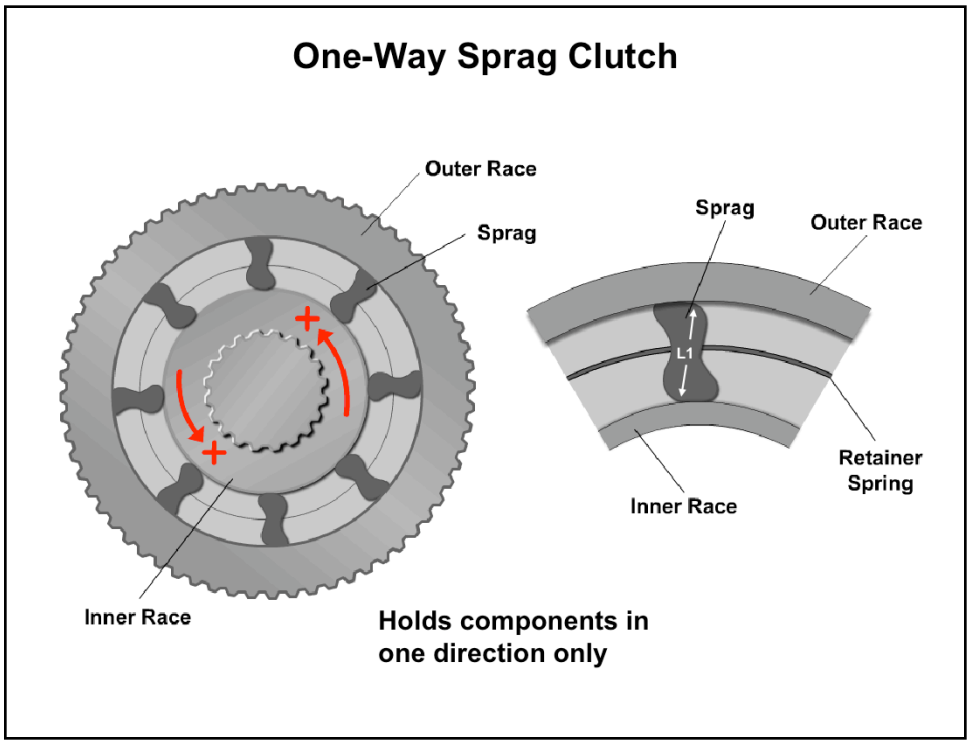
- A spring-loaded piston that pushes against a rod. The rod pushes against the unanchored end of brake band.
- The return spring that moves the piston to its at-rest position when hydraulic pressure is released.



Brake Band Operation

The brake band locks a multiplate clutch drum to the transmission case so that it cannot rotate. When hydraulic pressure is applied to the piston, it moves against spring pressure and pushes the rod. The rod pushes against the free end of the band, making the brake band clamp down on the clutch drum. This holds the drum and any related components to the stationary transmission housing.

When hydraulic pressure is released, the return spring pushes the rod and piston away from the free end of the brake band. The band's spring tension causes it to expand away from the clutch drum.



One-way Clutches

A one-way clutch is a mechanical holding device that does not require hydraulic pressure for application. In one direction of rotation, the clutch's inner race is locked to its outer race. In the other direction of rotation, the clutch races unlock. The inner and outer races can turn independently, and the unit "freewheels."

One-way clutches are typically used to prevent a planetary gear set component from rotating in one direction while allowing it to rotate freely in the opposite direction. They are designed to transmit torque during acceleration or cruising, then freewheel during deceleration (so that the vehicle slows without any engine braking effect).

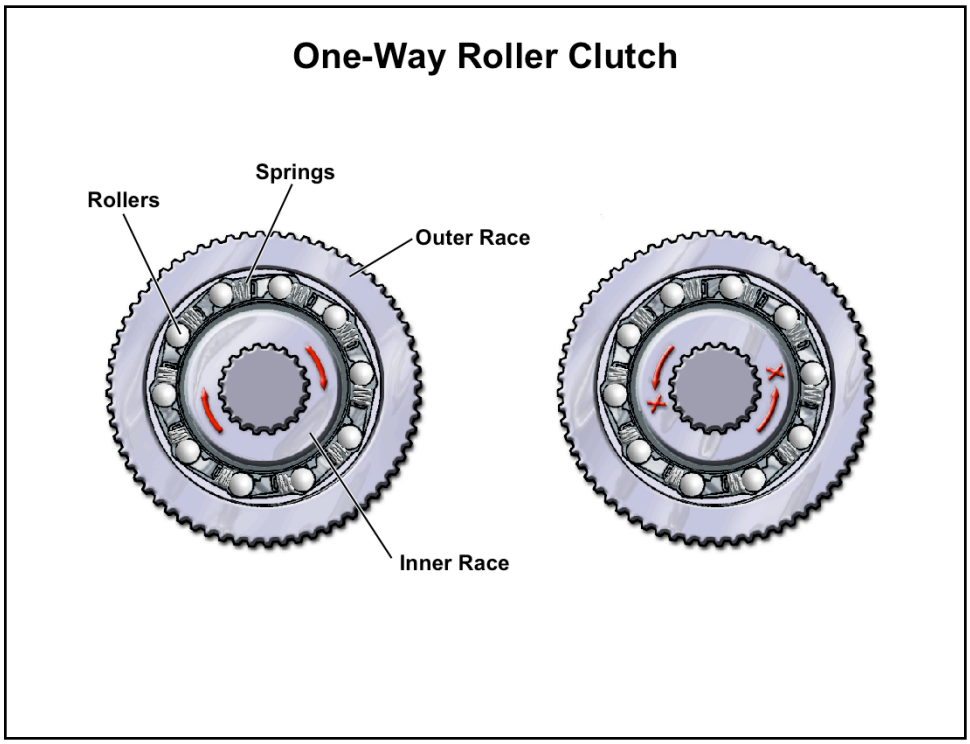
One-way clutches are either a roller or sprag design. Both designs rely on metal pieces that ride between the inner and outer races.

Sprag Clutch

The inner and outer races are separated by a number of sprags that have a "figure 8" cross-section. The sprags are separated by a retainer spring.

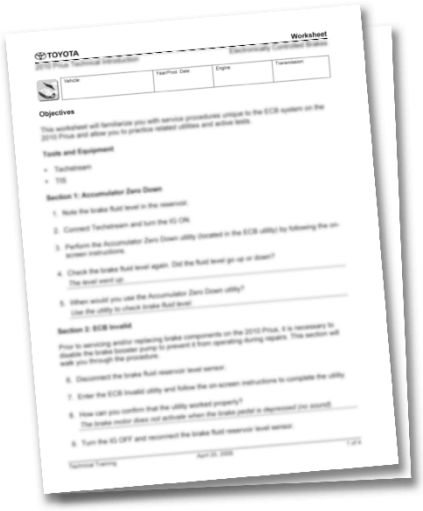
In the illustration, the side view of the sprag shows four lobes. The distance between the two lobes identified by L1 is shorter than the distance between the two races. The opposite lobes are longer than the distance between the races. As a result, when the inner race turns clockwise, it causes the sprag to tilt and the short distance allows the inner race to turn independently of the outer race.

When the inner race turns counterclockwise, it tries to move the sprag so that the long distance is wedged against the outer race. This causes the inner race and outer race to be locked together.



Roller Clutch In the roller clutch, the inner and outer race are separated by a number of barrel-shaped rollers. The outer race is cam-cut for each roller, with one narrow end and one wider end. Springs push each roller toward the narrow end of the cut. When the inner race rotates clockwise, the drag on each roller compresses the springs. The rollers move to the wider end of the wedge and the inner and outer races can turn independently. If the inner race is rotated counterclockwise, the rollers are forced into the narrow end of the wedge and the races are locked together.

Worksheet



Simple Planetary Gear Set and Holding Devices

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