Automatic Transmission Basics

PART TWO

Planetary Gears

The torque converter we studied last month might very well be described as a transmission itself. It provides torque multiplication when needed, and automatically changes to a direct drive coupling at road speed. But the torque converter isn't efficient enough to power the modern vehicle all by itself.

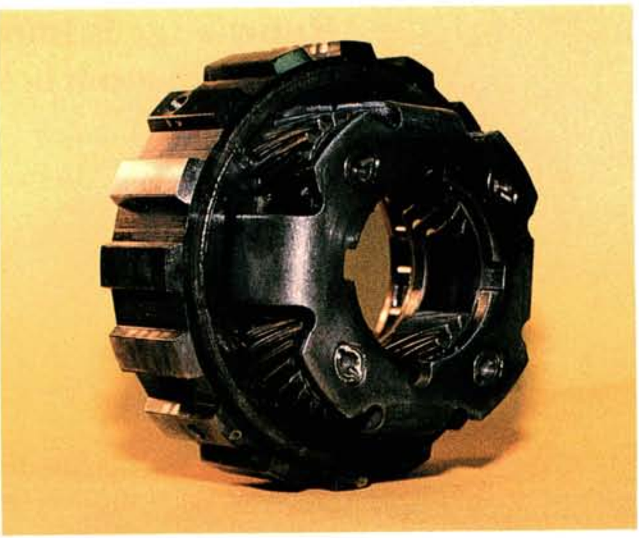
To really make things work properly, we need to add some gearing to our transmission to make it truly effective.

Planetary gears are used by the automatic transmission to provide different gear ratios needed to move the car in the desired direction at the correct speed. Planetary gears run in constant mesh and have the following components.

• **The Sun Gear** is found at the center of the planetary set, just as the sun is found at the center of our solar system. Hence the name.

• **Planet Gears** surround the sun gear, again, just like planets in our solar system. The number of planet gears, or pinions, can vary. These gears are mounted in a support member called a planet carrier and each gear spins on its own separate shaft. These gears are in constant mesh with the sun gear. They are also in constant mesh with the ring gear.

• **The Ring Gear** is the large outer gear. Since its gear teeth face inward toward the planet gears, it is sometimes referred to as the **Internal Gear**. Its gear teeth are in constant mesh with the planet gears. As we said, the planet gears are in constant mesh with both the sun and ring gears.



Planetary gearsets are very compact. The number of planet gears surrounding the sun gear will vary depending on the loads the transmission has to bear. Most planetary sets use helically cut gears. These are not as strong as square cut gears, but are a lot quieter. Therefore, if the transmission is in for some heavy-duty service, the number of planet pinions can be increased to better distribute the work load.

The unit shown in our photos has four drive pinions in the planet carrier.

Gear Ratios

Any of our three components can be a drive member or a driven member depending on which direction of rotation, or gear ratio, is needed. The planetary set can provide us with gear reduction or overdrive, direct drive or reverse, or no power transmission at all in neutral. And it does all this while the gears stay constantly meshed. There's no need to engage and disengage gear teeth like a manual transmission does.

Instead, clutches and bands are used to either hold or release different members of the planetary gearset to get the desired direction of rotation, proper gear ratio, or combination of rotation and ratio.

Let's stop and look at some photos that will show how different drive modes are engaged. We've taken the planetary set in our photos and glued some red arrows to the ring gear and the planet carrier. We've started by placing those arrows in the straight up, or 12 o'clock position, as a reference point.

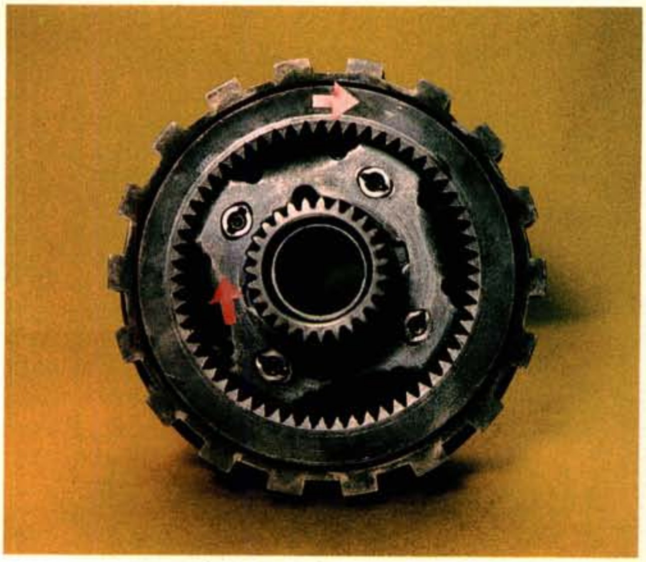
Reduction

Before we go any further, this simple equation may help clarify what we're doing.

DECREASED output gear speed = INCREASED torque

Let's start with this combination.
- Hold the sun gear so it can't turn.
- Turn the ring gear.
- The planetary gears will spin on their shafts in the planet gear carrier, but since the sun gear is held stationary, the spinning planet gears will crawl around the sun gear and carry the planet carrier with it.

Let's go back to our photo of the planetary set. This photo shows the gearset after the ring gear has made



one full revolution (remember, the sun gear is held stationary). As you can see, the ring gear has made one full revolution, with the arrow back in the 12 o'clock position. But the arrow on the planet carrier has only traveled about three-quarters of the way around, to the 9 o'clock position.

Since one complete revolution of the ring gear did not give us one complete revolution of the planet carrier, we can see that the planet carrier is turning more slowly, generating torque. Since the planet carrier is the output member in this mode, that additional torque is transmitted to the drive wheels.

In this Reduction Mode, the planet carrier moves in the same direction as the ring gear. Clockwise rotation of the ring gear causes the planet carrier to rotate in a clockwise direction, too.

Sun Gear Drive

Here's another possible combination that would yield reduction results if we do the following and reverse the roles of the ring and sun gears as follows:
- Hold the ring gear so it can't turn.
- Turn the sun gear.
- The planet carrier will rotate around the sun gear as it did in our other example, but will turn even more slowly than it did when the ring gear powered the planet carrier. This gives us even more reduction, and even greater torque.

Either way, when the planet carrier becomes the output member, the planetary set works in reduction and output torque increases.

Overdrive

Up to this point, the planet carrier has been the output member. We have alternately held the sun gear and driven the ring gear, or held the ring gear and driven the sun gear to make the planet carrier transmit additional torque in the reduction mode.

Now let's put the planet carrier to work as the driving member. He's the one generating the input force now. Let the other guys do some of the output work for a while.

Try the following combination:

- Hold the sun gear so it can't turn.
- Turn the planet gear carrier. As the planet carrier walks around the stationary sun gear, it will cause the ring gear to rotate.
- The ring gear will rotate around the planet carrier faster than the speed of the planet carrier.

In this mode, one complete revolution of the driving member (planet carrier) results in more than one complete revolution of the ring gear. As you can see in our photo, the planet carrier has made one complete revolution and returned to the 12 o'clock position. The ring gear, however, has returned to and then gone past the 12 o'clock position, clear down to the 4 o'clock position. Since the ring gear is turning faster than the planetary gear driving it, it generates more speed, less torque.

The ring gear is said to be operating in Overdrive in this mode. Faster rotation of the output gear means more output speed and less torque, just fine for low-load highway cruising.

INCREASED output gear speed = DECREASED torque

Direct Drive

If any two of the planetary gearset members rotate in the same direction at the same speed, the third member has no choice except to follow along. One input revolution equals one output revolution. It doesn't matter which two members of the planetary set we hold.

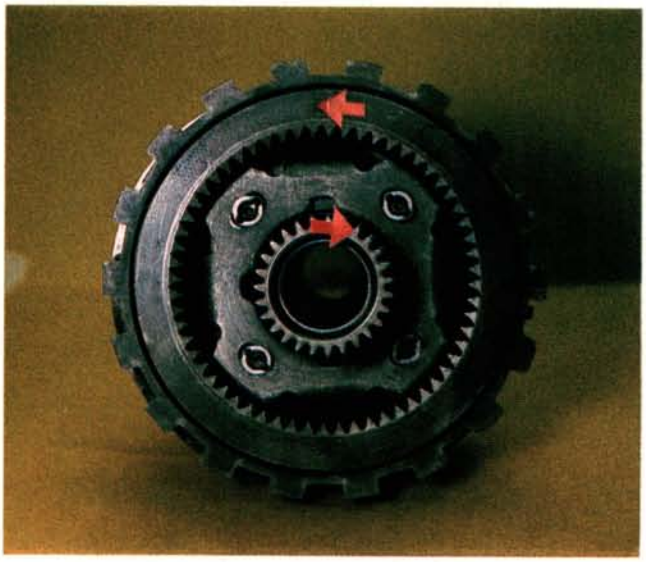
In this Direct Drive mode, the planet gears do not spin on their shafts. Instead they simply stand still and connect the teeth on the sun gear to the teeth on the ring gear without increasing or decreasing output

speed or torque.

In Direct Drive, input speed is equal to output speed, since the planetary gearset turns as a unit.

Reverse Gear

Until now, the planet carrier has either been the driving or the driven member. When the planet carrier is the output member, we have reduction. When it's the input member, driving either the sun gear or the ring gear, we have overdrive. Now, however, we're going to hold the planet gear stationary, so it can't turn.



While the planet carrier is held stationary, we can turn either the sun gear or the ring gear to get reverse. The planet gears will act like idler gears do in a manual transmission, and reverse the direction of the output rotation. We call them idler gears because they don't move along the face of an adjoining gear, they simply sit in one place and "idle" on their shafts.

For example, if we hold the planet carrier and turn the ring gear in a clockwise rotation, the sun gear will rotate in a counterclockwise direction. The idling planetary gears or pinions reverse the rotational direction of the output member—the sun gear in this case.

Since the sun gear is so much smaller, however, it will rotate more quickly than the ring gear, and won't generate as much torque as a result.

If our transmission had only one planetary gearset, this lack of low end torque wouldn't be of much use to us in a reverse gear. And since we don't drive at road speed in reverse, a combination of reverse gear and torque multiplication would be a lot more useful.

Reverse Reduction

Let's try this combination instead, to get reverse:

- Hold the planet carrier stationary.
- Turn the sun gear in a clockwise rotation.
- The ring gear will rotate in a counterclockwise direction.

And since the ring gear is so much larger than the sun gear, it will turn more slowly. As a result, we get reverse, and the additional benefit of having enough torque to back up that long hill in front of our house.

Compound Planetary Sets

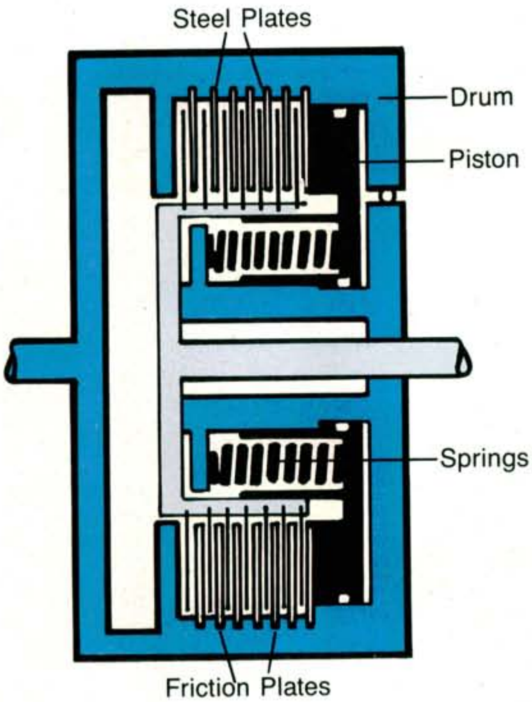
As versatile as a single planetary gearset can be, it does have a limited number of ratios. If we want a three or a four speed automatic, we can add gearsets, however. The average automatic transmission with three forward speeds is likely to have two planetary gearsets. When we have more than one planetary gearset, we refer to it as a Compound Planetary System.

Hold and Release

We'll look at the ways different members of a compound planetary system work a little later. But for now, we ought to stop and look at the components used to alternately hold and release the different members of the planetary set. After all, we've talked quite a bit about holding, releasing, and driving different parts of the planetary set to get different ratios.

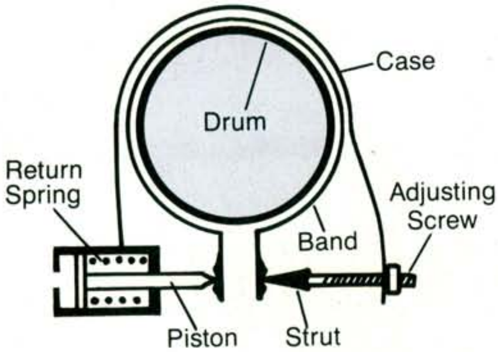
There are three commonly used components that allow us to choose which members of the planetary set will be held or released. Two of them are hydraulically activated, one is purely mechanical.

The Multiple Disc Clutch



The Multiple Disc Clutch is a bit like a multilayered sandwich. This clutch assembly is used to connect or disconnect, hold or release two moving components. It is made up of alternating friction discs and steel plates. Hydraulic pressure moves a piston to compress this sandwiched layer of discs and clutches to couple the discs. If this pressure is vented, return springs retract the piston, and the clutch member disengages.

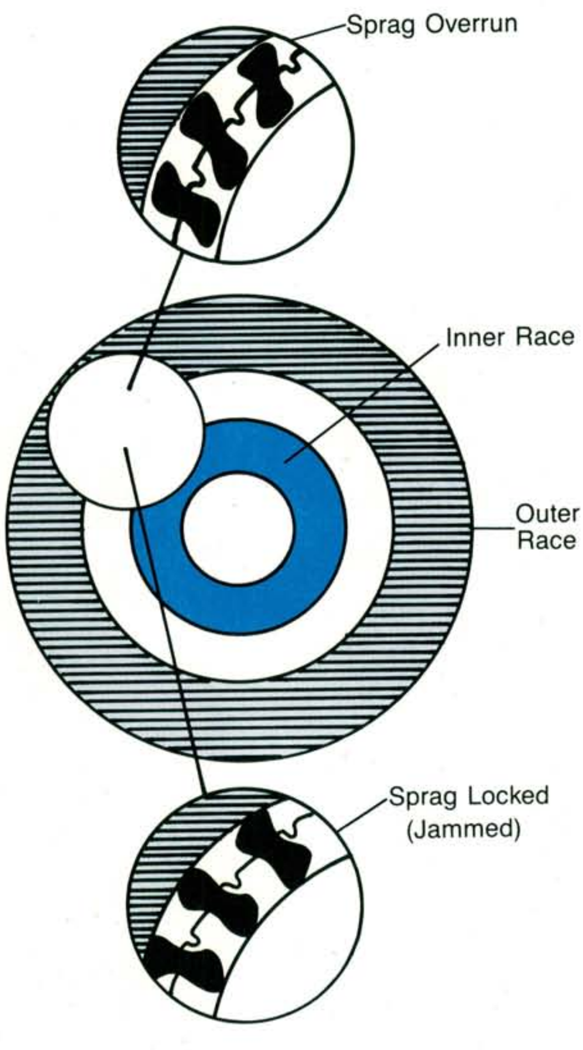
The Brake Band



A Brake Band is a steel strap with friction material on its face that can be tightened around a drum to stop its rotation. It is also hydraulically operated. Hydraulic pressure is sent to a piston in a cylinder called a Servo. The pressure moves the piston toward a lip on the band, causing it to compress the band around the drum, stopping the drum's rotation.

If pressure behind the piston is released, the piston relaxes and the drum is free to turn again.

One-Way Clutches



One-Way, or Overrunning clutches are holding devices. Like the one-way clutch found in the torque converter, these units are purely mechanical in their operation, and don't depend on hydraulic pressure to be activated. We showed you a roller-style clutch in the torque converter article. There's another kind of one-way clutch called a sprag-style clutch. It too has small springs, but instead of rollers, it uses elongated locks called sprags.

—By Ralph Birnbaum