ASE 2 - Transmissions

Module 2
Gear Sets
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Introduction

The purpose of the Gear Sets module is to explain the operation of the gears involved with the production of different gear ratios in today’s General Motors transmissions and transaxles. These ratios are needed to allow a transfer of torque from the engine to the drive wheels. While other components are required to make this transition of power and torque occur, we will be focusing on the details related specifically to the gear sets involved.

You will be expected to not only identify the gear components but also describe and demonstrate how they can be utilized to provide the different gear ratios needed for proper transmission/transaxle operation. You will describe how different types of failures can occur within the gear set and the expected symptom from the failure.

The gear set is the heart of the transmission/transaxle. Every component within the transmission/transaxle assembly was designed with one goal in mind. That goal is to accurately and properly control the gear set components so the correct gear ratio is applied to meet the demands of the vehicle and driver.

Objectives

NATEF Area II.

Automatic Transmissions 17041.20

A -1. Identify and describe planetary gear set characteristics and operation

G -1. Identify the purpose of the final drive and differential assembly

G -2. Describe the components of the final drive and differential assembly

Upon completion of this module the student will be able to:

1. Identify the three primary parts of the simple planetary gear set.

2. Describe the difference between helical and spur cut gear sets including positive and negative characteristics.

3. Demonstrate the four modes of operation of the simple planetary gear set.

4. Perform the mathematical calculations necessary to determine the possible gear ratios of a given planetary assembly.
Lesson 1. Simple Planetary Gear Sets

Nearly all General Motors vehicles produced with automatic transmissions or transaxles use planetary gear sets to transfer power from the engine to the drive wheels. The only exception to this rule is some Saturn vehicles used the "manual transmission" style gear configuration, consisting of two externally toothed gears in mesh. Unlike a manual transmission however, the Saturn unit used clutch packs to lock a gear to the shaft instead of a synchronizer assembly.

We will first look at the simple planetary gear set and then proceed to the compound planetary gear set configurations. The reference to the simple planetary gear set is a reference to a single gear set consisting of an internal toothed gear, sun gear, and carrier assembly. The reference to the compound planetary gear set is a reference to a planetary gear assembly made up of more than one planetary gear set.

Terminology

**Internal gear** - (also known as ring gear): The outermost member of a gear set that has internal gear teeth in mesh with planetary pinion gears of the carrier assembly

**Sun Gear** - Externally toothed gear located in the center of the planetary gear set that has teeth in mesh with the pinions of the carrier assembly

**Carrier assembly** - A metal housing that supports smaller pinion gears in mesh with the sun gear and internal gear of a planetary gear set

![Figure 2-1](image)
Simple Planetary Gear Set Characteristics

1. Very strong
2. Compact
3. Versatile - provides different gear operation with only one gear set
   A. Gear reduction
   B. Overdrive
   C. Direct Drive
   D. Reverse

Most planetary gear sets have helical teeth. (teeth cut at an angle to the gears axis)

Helical cut teeth are usually found in cars and light duty trucks.

One advantage of the helical cut gear is it produces less noise during operation.

One disadvantage is that the angle cut gear generates a side thrust as load is applied. In the illustration above you can see the thrust washers between the gear and housing to allow gear movement while causing only minimal wear.

Helical cut teeth are not used in heavy-duty vehicles.
Vehicles with a higher gross vehicle weight rating (GVW) do not use helical cut gear teeth. Due to the side thrust generated from the helical cut gear the high load would cause the planetary gear set to have a short life because of a premature failure of the thrust washer. In this type of vehicle, heavy 1-ton p/u and larger, the planetary gears have spur cut teeth. The term "spur cut" teeth indicates that the teeth are cut parallel to the gears axis. They still require a washer on the side of the gear for wear but because the gear has straight cut teeth side thrust that causes wear is minimal.

One disadvantage of the spur cut gear is it is very noisy. The noisy condition is not usually a concern with high GVW vehicles.
Simple Planetary Gear Set Modes of Operation

We have already identified that a planetary gear set consists of a sun gear, internal gear, and a planetary carrier that supports (2 or more) pinion gears. Now it is time to look at what the planetary gear set can do for us and how it works.

First, the purpose of the gear set is to connect the engine to the drive wheels using the appropriate gear ratio. To accomplish this:

1. One of the three planetary gear set members must connect to the engine.
2. One of the planetary gear set members must connect to the drive wheels.
3. The third component of the gear set will attach to the case to prevent that component from turning.

Note: The only exception to this is direct drive, as you will see.

Think of it like this:
Any component connected to the engine is transmitting power into the gear set. We call this the input member or driving member.
Any component connected to the drive wheels or output shaft of the transmission is transmitting power out of the gear set. We call this the output member or driven member.
Any component connected to the transmission case will be prevented from turning. We call this the held member or reaction member.

In the following chart you can see there are two methods to get gear reduction, reverse, and overdrive. There are three methods to get direct drive.

<table>
<thead>
<tr>
<th>Operation - Method</th>
<th>Sun Gear</th>
<th>Internal Gear</th>
<th>Planetary Carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear Reduction - 1</td>
<td>Held</td>
<td>Input</td>
<td>Output</td>
</tr>
<tr>
<td>Reverse - 1</td>
<td>Input</td>
<td>Output</td>
<td>Held</td>
</tr>
<tr>
<td>Overdrive - 1</td>
<td>Held</td>
<td>Output</td>
<td>Input</td>
</tr>
<tr>
<td>Gear Reduction - 2</td>
<td>Input</td>
<td>Held</td>
<td>Output</td>
</tr>
<tr>
<td>Reverse - 2</td>
<td>Output</td>
<td>Input</td>
<td>Held</td>
</tr>
<tr>
<td>Overdrive - 2</td>
<td>Output</td>
<td>Held</td>
<td>Input</td>
</tr>
<tr>
<td>Direct Drive - 1</td>
<td>Input</td>
<td>Input</td>
<td>Output</td>
</tr>
<tr>
<td>Direct Drive - 2</td>
<td>Input</td>
<td>Output</td>
<td>Input</td>
</tr>
<tr>
<td>Direct Drive - 3</td>
<td>Output</td>
<td>Input</td>
<td>Input</td>
</tr>
</tbody>
</table>

Figure 2-4
Reverse - Example

Figure 2-6
Overdrive - Example

Figure 2-7
Direct Drive - Example

Figure 2-8

(664) DRIVING
Input Member

(662) DRIVEN
Output Member

(640) DRIVING
Input Member
If you study the previous chart (Figure 2-4) and pages of examples (Figures 2-5 thru 8) you will find a pattern that develops. The operation of the simple planetary gear set is dependent upon what is happening to the planetary carrier assembly. The sun gear and internal gear (ring gear) can exchange their responsibilities but as long as the planetary carrier role stays the same the type of operation produced stays the same.

Please note:
- If the planetary carrier is used as the output member the result is gear reduction
- If the planetary carrier is used as the input member the result is overdrive
- If the planetary carrier is used as the held member the result is reverse
  - Carrier*output / ring*input / sun*held = reduction
  - Carrier*output / ring*held / sun*input = reduction
  - Carrier*input / ring*output / sun*held = overdrive
  - Carrier*input / ring*held / sun*output = overdrive
  - Carrier*held / ring*output / sun*input = reverse
  - Carrier*held / ring*input / sun*output = reverse

For direct drive you simply drive two member of the gear set at the same speed, (connect two members to the engine), and the third member of the gear set must follow.

**Hands-on exercise**

It is now time to complete a hands-on portion of this module. Your instructor will provide you with a simple planetary gear set and you will become familiar with the operations we have just discussed. You will demonstrate each of the four modes of operation for your instructor, gear reduction, reverse, overdrive, and direct drive.
Simple Planetary Gear Set Ratio Calculations

In order to fully understand the simple planetary gear set you need at least some foundation into gear ratio calculation. It is more complicated than calculating the gear ratio of a standard transmission for example, but because it still uses simple mathematics it is a task you should easily master.

The following page contains illustrations and formulas for calculating the gear ratios for simple planetary gear sets.

The formula sheet information and contents:

I. The sheet contains six sets of rectangular boxes with three boxes in each set.
II. Each set of three boxes represents a simple planetary gear set.
   A. The top box represents the internal gear or ring gear.
   B. The middle box represents the planetary carrier assembly.
   C. The bottom box represents the sun gear.
III. Each set of boxes also represents a different type of operation.
   A. Two methods for gear reduction - numbers 1 & 2
   B. Two methods for overdrive - numbers 3 & 4
   C. Two methods for reverse - numbers 5 & 6
IV. Direct Drive is not shown because it is always a 1:1 ratio and no calculation is necessary.
V. Each box in the set also has an indicator attached to it.
   A. An arrow entering the box from the left indicates that component is used as the input/driving member.
   B. An arrow exiting from the box on the right indicates that component is used as the output/driven member.
   C. A large asterisk (✱) attached to the box indicates that component is used as the held/reaction member.
VI. Illustration numbers 1 thru 4 have two different formulas you can use to calculate the ratio and the answer will be the same no matter which one you choose.

Note: These formulas only work for calculating ratios for transmission gears that use a single planetary gear set. Example: The 4L60-E transmission utilizes only one gear set for 1st gear, 3rd gear, 4th gear, and reverse. The 4L60-E utilizes two gear sets for 2nd gear and will require additional mathematical formula calculations. See your instructor if you have interest in knowing more about these calculations.
**Simple Planetary Gear Set Ratio Calculations**

<table>
<thead>
<tr>
<th>Planetary Gear Set Representation</th>
<th>Formula #1</th>
<th>Formula #2</th>
<th>Example: R=70, S=34</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(R+S) + 1</td>
<td>(S+R) + S</td>
<td>(70 + 34) + 1 = 3.059 : 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(34+70) + 34 = 3.059 : 1</td>
</tr>
<tr>
<td>II</td>
<td>(S-R) + 1</td>
<td>(34 - 70) + 1 = 1.486 : 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(S+R) + S</td>
<td>(34+70) + 70 = 1.486 : 1</td>
</tr>
<tr>
<td>III</td>
<td>S / (S+R)</td>
<td>34 / (34+70) = 0.327 : 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 / [(R+S) + 1]</td>
<td>1 / [(70+34) + 1] = 0.327 : 1</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>R / (S+R)</td>
<td>70 / (34+70) = 0.673 : 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 / [(S+R) + 1]</td>
<td>1 / [(34+70) + 1] = 0.673 : 1</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>R + S</td>
<td>70 + 34 = 2.059 : 1</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>S - R</td>
<td>34 - 70 = 0.486 : 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S + R</td>
<td>34 + 70 = 0.486 : 1</td>
<td></td>
</tr>
</tbody>
</table>
**Simple Planetary Gear Set Ratio Exercise**

Given:
Sun Gear tooth count - 26 teeth
Internal Gear tooth count - 62 teeth

Calculate the gear ratio for this gear set in each of the following:
(note: gear reduction, reverse, and overdrive will have more than one ratio possible)

<table>
<thead>
<tr>
<th>Gear operation - Illustration #</th>
<th>Ratio produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse - 5</td>
<td></td>
</tr>
<tr>
<td>Reverse - 6</td>
<td></td>
</tr>
<tr>
<td>Overdrive - 3</td>
<td></td>
</tr>
<tr>
<td>Overdrive - 4</td>
<td></td>
</tr>
<tr>
<td>Gear reduction - 1</td>
<td></td>
</tr>
<tr>
<td>Gear reduction - 2</td>
<td></td>
</tr>
<tr>
<td>Direct drive</td>
<td></td>
</tr>
</tbody>
</table>
Planetary Gear Set used in FWD Final Drive

Most General Motors front wheel drive automatic transaxles use a planetary gear assembly within the final drive in order to acquire the needed gear reduction from the final drive assembly. Because of its compact size, strength, and physical configuration it is well suited for this task. The final drive also contains the differential assembly that has the same appearance and operation as in any rear wheel drive axle assembly. The responsibility of the differential assembly is to allow the drive wheels to smoothly rotate at different speed (such as during turns) while providing efficient torque transfer to the road surface.

The following picture is a final drive assembly from a 4T65-E transaxle.

The 4T65-E transaxle uses two planetary gear sets within the transmission portion of the unit and one planetary gear set in the final drive for a total of three planetary gear sets for the transaxle assembly.

Figure 2-9
Compound Planetary Gear Sets

Up to this point we have focused on simple planetary gear sets or a single planetary gear set. Today's transmissions and transaxles could not function if they only could rely on one planetary gear set to do the job. A planetary gear set may be able to provide different types of operation (gear reduction, direct drive, reverse, and overdrive), but it would be extremely difficult for one planetary gear set to provide all of these operations by itself. The reason is shown in the following example.

For a vehicle to take-off smoothly it needs to have a gear reduction mode of operation to increase engine torque. To achieve gear reduction the planetary carrier must be used as the output member (connected to the driving wheels).

For the same vehicle to have reverse would require that the planetary carrier be locked to the transmission case so it could be held from turning. The dilemma is not impossible to overcome but it is not practical with only one planetary gear set. The option is to incorporate multiple gear sets (usually two) to share the responsibilities for producing the different modes of operation. This configuration is referred to as a "compound planetary gear set".

General Motors has used different compound planetary configurations over the years.

They are as follows:

Simpson compound planetary gear set -
  A. uses two gear sets that have a common sun gear (sun gears for both sets are physically attached together)
  B. Used in the following: 3T40, 200, 2004R, 250, 325, 325-4L, 350, 375, 400, 425, 475, 4L80-E

Ravigneaux compound planetary gear set -
  A. Designed as though two carrier assemblies are combined into one housing
  B. Contains two separate sun gears but very often only one internal gear
  C. Not commonly used in GM Transmissions
  D. Used in the following: Aluminum Powerglide, 180, 3L30, 4L30-E, 4L40-E, 5L40-E

4L60-E / 4L65-E style compound planetary gear set -
  A. Input internal gear connected to the reaction carrier
  B. Input carrier and reaction internal gear connected to the output shaft
  C. Power flow through the gear set is the same as 4T40-E / 4T80-E

4T60-E / 4T65-E style compound planetary gear set -
  A. Input internal gear connected to the reaction carrier
  B. Input carrier connected to the reaction internal gear
Simpson Compound Planetary Gear Set

Figure 2-10
Ravigneaux Compound Planetary Gear Set

Figure 2-11
Figure 2-12

4L60-E/4L65-E Compound Planetary Gear Set
Figure 2-13
4T40-E/4T80-E Compound Planetary Gear Set

INPUT
SUN
GEAR
(533)
DRIVING

INPUT CARRIER
ASSEMBLY
(562)
DRIVEN

INPUT INTERNAL
GEAR
(560)
HELD

INPUT INTERNAL
GEAR FLANGE
(577)
HELD

Figure 2-14
Planetary Gear Set Wear

When rebuilding an automatic transmission you must always be on the lookout for damage from normal or abnormal wear. What do you look for? Condemning a good component can be costly but failing to find a worn component can be even more costly! We will look at some of the potential problem areas related to planetary gear set wear and failure in hopes that you will not be the technician who finds you are eating a comeback for dinner.

One of the most common points for wear to occur is the thrust washers on the side of the pinion gears supported within the planetary carrier assembly.

Figure 2-15
The proper way to measure for excessive thrust washer wear is with a feeler gauge as shown in the picture below. Always check the service information for the correct specification for your particular transmission. The specification for the 4L60-E is .008" - .024".

Note: These washers are replaceable on the planetary pinions found in General Motors FWD final drive assemblies, but all others require component replacement when washer wear specifications are exceeded.
If the thrust washer wear becomes severe enough catastrophic damage can result to the unit as you can see was about to occur with the unit in the picture shown below.

Figure 2-17
Often a splined area of a planetary assembly can become worn or strip. If this happens excessive noise, no vehicle movement or other malfunction can occur. Note the stripped splines in the picture below. In this vehicle the transmission only had reverse operation after the splines failed.

Figure 2-18
Any moving components such as planetary gear set members require constant lubrication to prevent overheating and failure. The following two pictures demonstrate some of the effects of lack of lube problems you can expect to see.

![Figure 2-19](image1)

At one time this was a normal planetary pinion gear. Notice the teeth are not stripped, only melted and rolled over.

Figure 2-19

More lube related problems

![Figure 2-20](image2)
The pinion gears supported within the planetary carrier assembly are under constant stress. There are a couple of places to watch for problems related to the pinion gears and their support structure.

First, watch for problems with the needle bearings and support pin that supports the pinion gear. A problem in this area will often go unnoticed because the pinion gear frequently will feel very smooth as you roll the gear. Sometimes an indicator of this problem is a discoloration of the support pin and the carrier housing around the support pin. Compare the appearance of the support pin to the other support pins in the carrier housing. If the indication is that there is a problem, drive the support pin out with a hammer and punch to view any damage (for your personal edification) and then replace the assembly. These problems can be easily overlooked, as you will see on the next page.
This planetary pinion support pin was removed from a 4L60-E reaction carrier assembly. The pinion on a carrier should roll "glass smooth" as many technicians would say. This technician noticed a "feel" that was less than perfect so he decided to investigate further and saved a comeback.

Note: The "high quality" technicians develop a "feel" for this type of thing. If it does not feel right it probably isn't. Take the time to make sure it is right. Strive to hone your skills at becoming a "high quality" technician and not just a parts replacer.
Planetary Gear Set Wear

Another example of pinion support pin problems due to stress and lack of lube.

Figure 2-23

Be aware that pitting or damage on the teeth of pinion gears, internal gear, and sun gear can also create noise. This damage, while not common, does occur and you should always be observant to this fact.

Figure 2-24
Because planetary gear sets will be turning in relation to other components there must be some measure taken to prevent wear at these points of contact. The devices commonly used are bearings, bushings, and thrust washers. It is extremely important that you look for wear on any of these components. Bushings normally control contact wear between components that deal with radial forces. They hold components in proper alignment as they spin on a shaft or other component. Thrust washers usually deal with longitudinal forces. If they wear endplay will become excessive. Bearings can be used in applications where they may deal with both types of forces. In any case it is imperative that you verify the proper condition of these components if you hope to complete quality transmission repairs.

The following pages show some of the components to inspect for wear or damage.

Pitting can occur in Torrington bearings and may not be very noticeable by “feel”. If you are careful, you can usually partially disassemble the bearing for inspection without damaging it using a pocketknife.

Note: This race should be as “smooth as glass”.

Figure 2-25
The bushing shown in the picture below is responsible for properly aligning the carrier assembly as it spins. If it is worn the pinion gears in the carrier will not mesh properly with the sun gear or the internal gear and normally will result in a noise. If the wear is severe enough a vibration could develop.

To check for bushing wear place the component, in this case the carrier assembly, over the shaft or other component it spins on and with great care and "feel" move the carrier side to side. There should be some movement but only a few thousandths of an inch. General Motors does not have a "field" measurement for bushing wear so this is something you will develop a "feel" for. If the movement is excessive replace the bushing or in some cases you may have to replace the component if the bushing is not serviced separately.

Figure 2-26
Thrust washers can be made of a metal or plastic type material. They will almost always have lube grooves designed into the contact surface of the washer to provide a "puddle and smear" action. As oil flows through the lube grooves the lube smears across the surface of the washer providing the constant layer of lubricant protection. Any scoring or otherwise visible damage is reason for replacement. This is a very inexpensive component and you should never take a chance if its quality is questionable.

Note: The two washers shown below are in perfect condition. The "witness marks" visible on the metal washer are normal and should not be considered a wear problem. "Witness mark" is a term to describe a non-destructive polishing process that takes place over time when two moving components touch. Think of it as a proper mating between the washer and the component it contacts and protects from wear.

![Figure 2-27](image)
Please note that what appears to be wear on the gear below is actually a normal machining process during manufacture. Do not condemn a gear for this condition.

Figure 2-28

Production machining markings
Planetary Gear Set Conclusion

When dealing with planetary gear sets, as with all other areas of the automatic transmission/transaxle field, attention to detail is imperative to produce a repair to be proud of and a satisfied customer.
Exercise 2-1
Select the best answer available for the following questions.

1. Which of the following is not a part of a planetary gear set?
   a. Planetary internal gear
   b. Planetary side gear
   c. Planetary pinion gear
   d. Planetary carrier

2. Which component of the planetary gear set do you look at to determine the operation of the gear set?
   a. Planetary carrier
   b. Planetary sun gear
   c. Planetary internal gear
   d. Planetary side gear

3. Which one of the following combinations of planetary gear set operation will produce reverse?
   a. Carrier as output / internal gear as input / side gear as held
   b. Pinion gear as input / internal gear as held / sun gear as output
   c. Internal gear as output / carrier as held / sun gear as input
   d. None of the above

4. You are given a planetary gear set with a sun gear tooth count of 22 teeth and an internal gear tooth count of 57 teeth. If the sun gear is the input member and the internal gear is the output member what gear ratio will be produced?
   Note: You can use the "Simple Planetary Gear Set Ratio Calculation sheet to aid in this question.
   a. 3.11 : 1
   b. 1.96 : 1
   c. 2.43 : 1
   d. 2.59 : 1

5. A planetary gear set has its sun gear connected to the engine and the internal gear connected to the transmission case. What type of operation will result?
   a. Gear reduction
   b. Reverse
   c. Overdrive
   d. Direct Drive