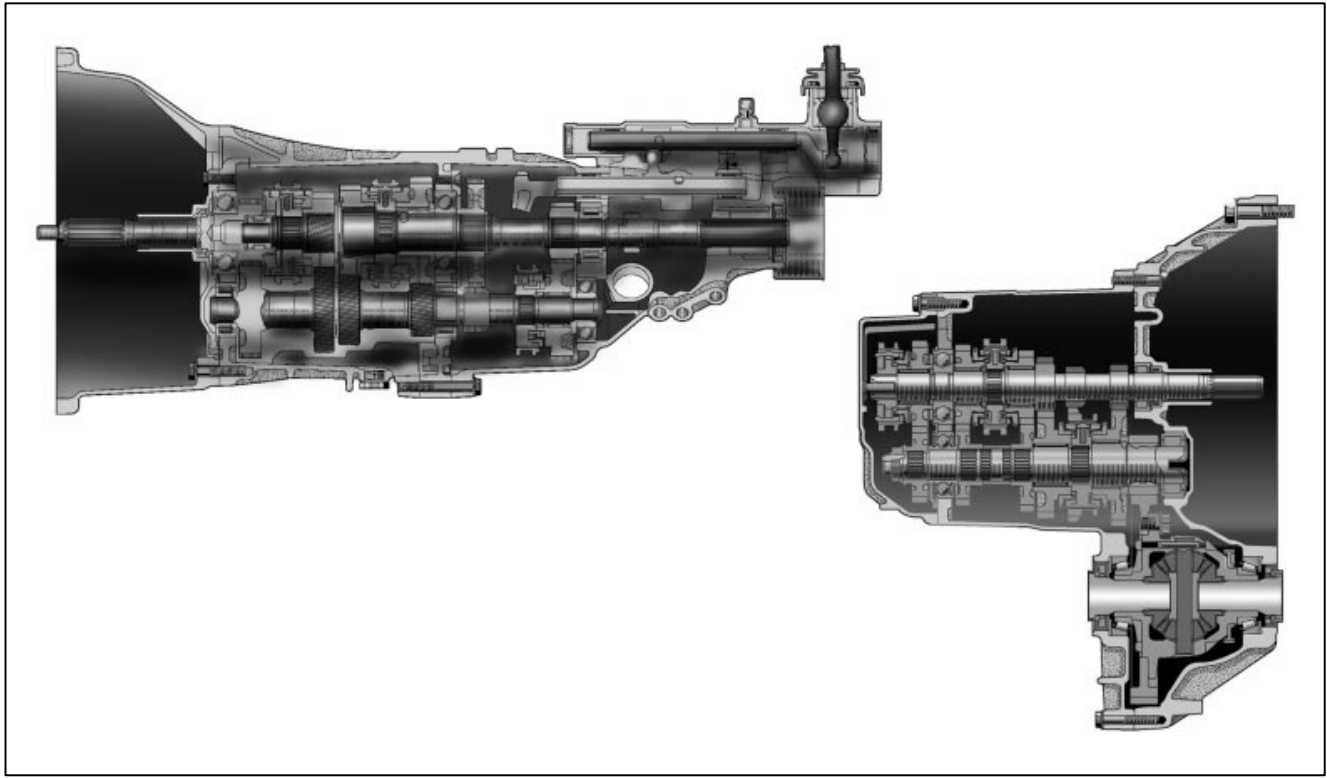


Section 1

Introduction to Manual Transmissions & Transaxles



- Learning Objectives:**
1. Identify the purpose and operation of transmissions.
 2. Describe torque and torque multiplication.
 3. Determine gear ratios.
 4. Identify spur and helical gears, and describe the difference between the two.

Introduction to Manual Transmissions & Transaxles

Drivetrain Energy produced in the engine is transmitted to the drive wheels through the drivetrain. The components that make up the drivetrain include: a clutch mechanism, transmission, propeller shaft, differential and axles. The drivetrain allows the driver to control power flow using engine torque and allows the vehicle to move from a stop to cruising speed while maintaining engine speed within its most efficient power band.

A drivetrain can transmit engine power to the rear wheels, front wheels or all four wheels. When the drivetrain delivers power to the rear wheels, it is referred to as **front engine rear drive (FR)**; when it delivers power to the front wheels, **front engine front drive (FF)**; and when it delivers power to all wheels, **four wheel drive (4WD)**.

Front Engine Rear Drive (FR) Drivetrain

A front engine rear drive (FR) drivetrain delivers power from a front mounted engine through the transmission and rear differential to the rear wheels.

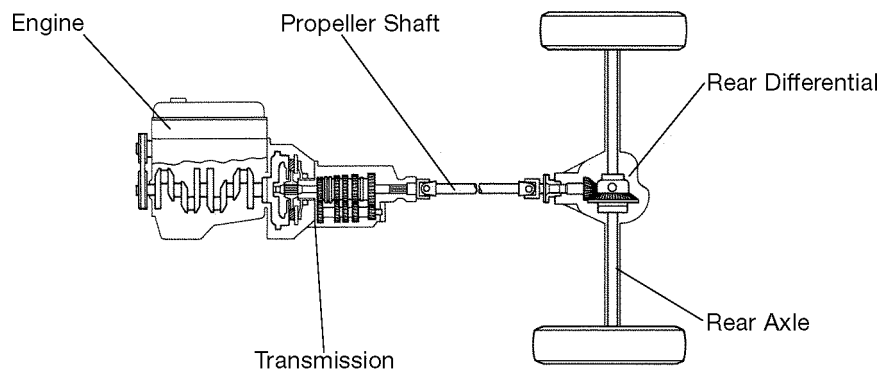


Fig. 1-1
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Front Engine Front Drive (FF) Drivetrain

A front engine front drive (FR) drivetrain delivers power from a front engine through the transaxle and differential to the front wheels. (This configuration is essentially the same for a rear mounted engine with rear wheel driver)

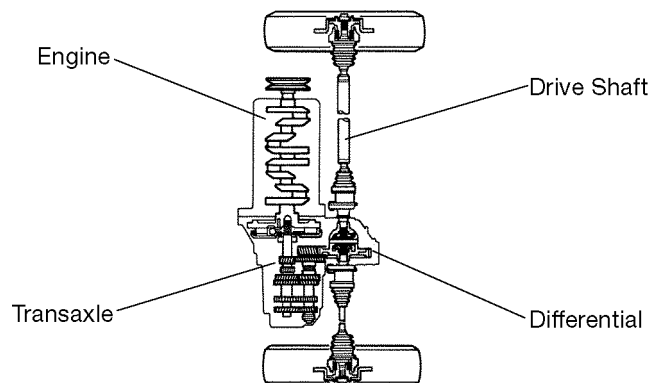


Fig. 1-2
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Four Wheel Drive (4WD) Drivetrain

A four wheel drive (4WD) drivetrain delivers power from a front mounted engine through either a transaxle to the front wheels and a transfer and a rear differential to the rear wheels; or through a transmission to the rear differential and rear wheels, and a transfer to a front differential and front wheels.

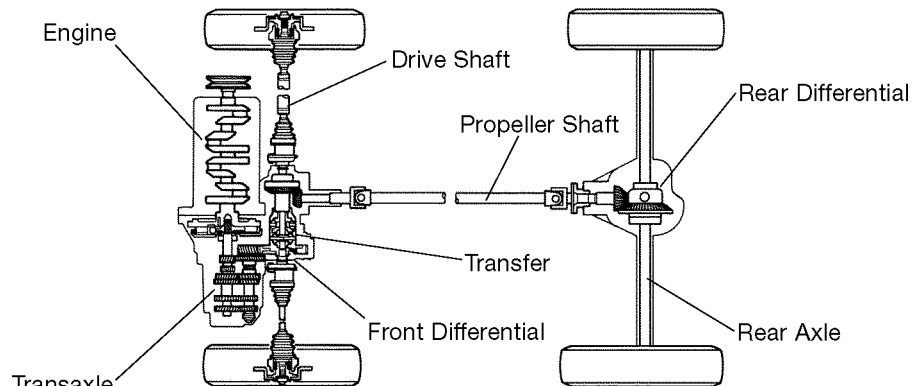


Fig. 1-3
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Torque Rotating mechanical power produced by the drivetrain is called torque. Torque is measured in foot-pounds of force (ft-lbf) or in Newton-meters (N•m). To enable an automobile to move, the drive axle applies torque to the wheels and tires to make them rotate. The transmission and drive axle gear ratios multiply engine torque so a vehicle can be moved forward or backward from a stop.

Engine Torque Torque, generated by the engine, is a twisting or turning force. Torque output increases proportionally with engine rpm to a certain point; This is a factor that greatly affects drivetrain design since very little torque is developed at engine speeds below 1000 rpm. A modern engine begins producing usable torque at about 1200 rpm and peak torque at about 2500 to 3000 rpm.

Torque

The transmission converts engine speed into the needed torque requirements to handle different driving situations.

When travelling on level ground at speed, engine torque is sufficient to drive the rear wheels at a constant speed. When at rest or travelling uphill, engine torque must be increased to the drive wheels to start the vehicle moving or maintain speed.

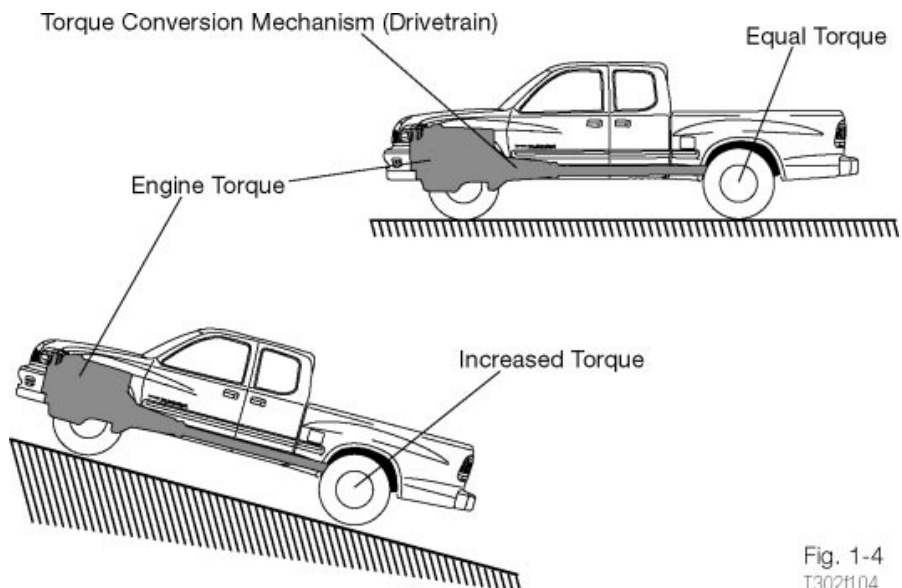


Fig. 1-4
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Torque Chart

Usable torque is produced beginning at about 1200 rpm and then increases proportionally with engine rpm to a certain point where it peaks around 2500 to 3000 rpm.

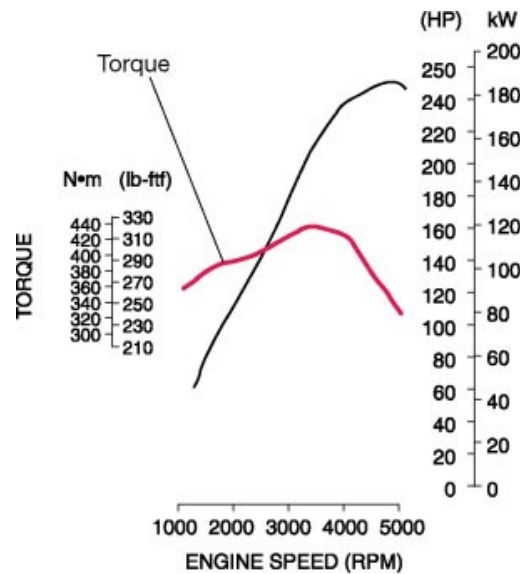


Fig. 1-5
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Torque Multiplication The transmission converts engine speed into the needed torque output required for different driving conditions.

High torque is needed to start off from a stop and engine torque must be greatly multiplied at low engine RPM. High torque for climbing hills is provided by increased engine RPM and torque multiplication. Less torque is required to keep the vehicle moving at intermediate or high speeds, allowing engine speed to be reduced.

Changing Speed or Torque Several devices, such as, gears, chains and sprockets can be used to change the speed or torque of a rotating output shaft. Gears with different teeth counts can be used to change the speed of a rotating shaft. Reducing the speed increases the torque proportionately; likewise, Increasing the speed reduces the torque.

The driven gear (output) always rotates in a direction opposite to the drive gear (input). If the drive gear and driven gear need to rotate in the same direction, the power can be routed through two gears sets, or through a combination of internal and external gears.

Changing the Speed or Torque of a Rotating Shaft

Gears with different teeth counts can be used to change the speed of a rotating shaft.

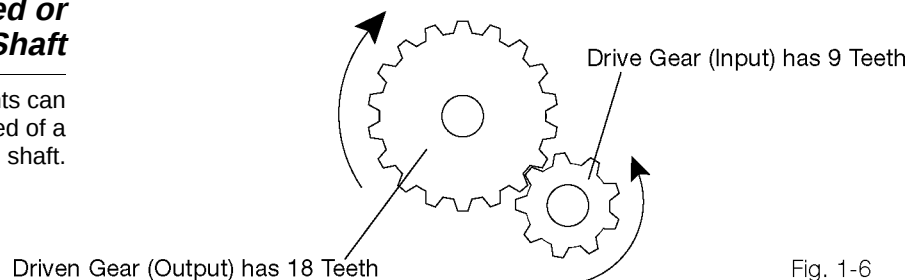


Fig. 1-6
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Gear Ratios Gear ratio is the ratio of the size of two or more gears acting on each other. Gear teeth are cut in proportion to their diameter; if you have a drive gear that has 9 teeth and a driven gear that is twice as large as the drive gear, the driven gear will have 18 teeth. (see figure 1-7) When the drive gear rotates one revolution, the driven gear will rotate 1/2 revolution—9 teeth of each gear will come into contact for each revolution of the drive gear.

Determining Gear Ratios Gear ratios are determined by dividing the number of teeth on the driven gear by the number of teeth on the drive gear. In the example in figure 1-7, $18 \div 9 = 2$, therefore the ratio is 2:1.

Gear Ratio

When two gears with a gear ratio of 2:1 rotate together, the smaller drive gear will rotate one revolution to produce one-half revolution of the larger driven gear.

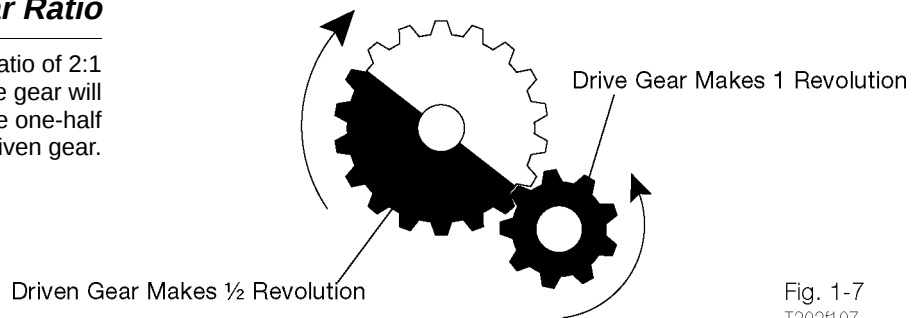


Fig. 1-7
T302f107

In this example, two revolutions of the drive gear will produce one revolution of the driven gear. This is called reduction—a reduction in speed, but an increase in torque. The higher the number of rotations on the drive gear, the lower the ratio.

If the drive gear has 9 teeth and the driven gear 6, there will be an increase in speed and a reduction in torque. This is referred to as overdrive. The ratio is determined as follows: $6 \div 9 = 0.6$ ($6/9 = 0.6$); so the ratio is 0.6:1. In this case, the drive gear turns 0.6 or three-fifths revolution for each turn of the driven gear. A gear ratio is always written so that the number 1 is to the right of the colon. This represents one turn of the output gear, while the number to the left represents the revolutions of the input.

Determining Gear Ratios

Most gear ratios are determined by dividing the number of teeth on the driven gear by the number of teeth on the drive gear.

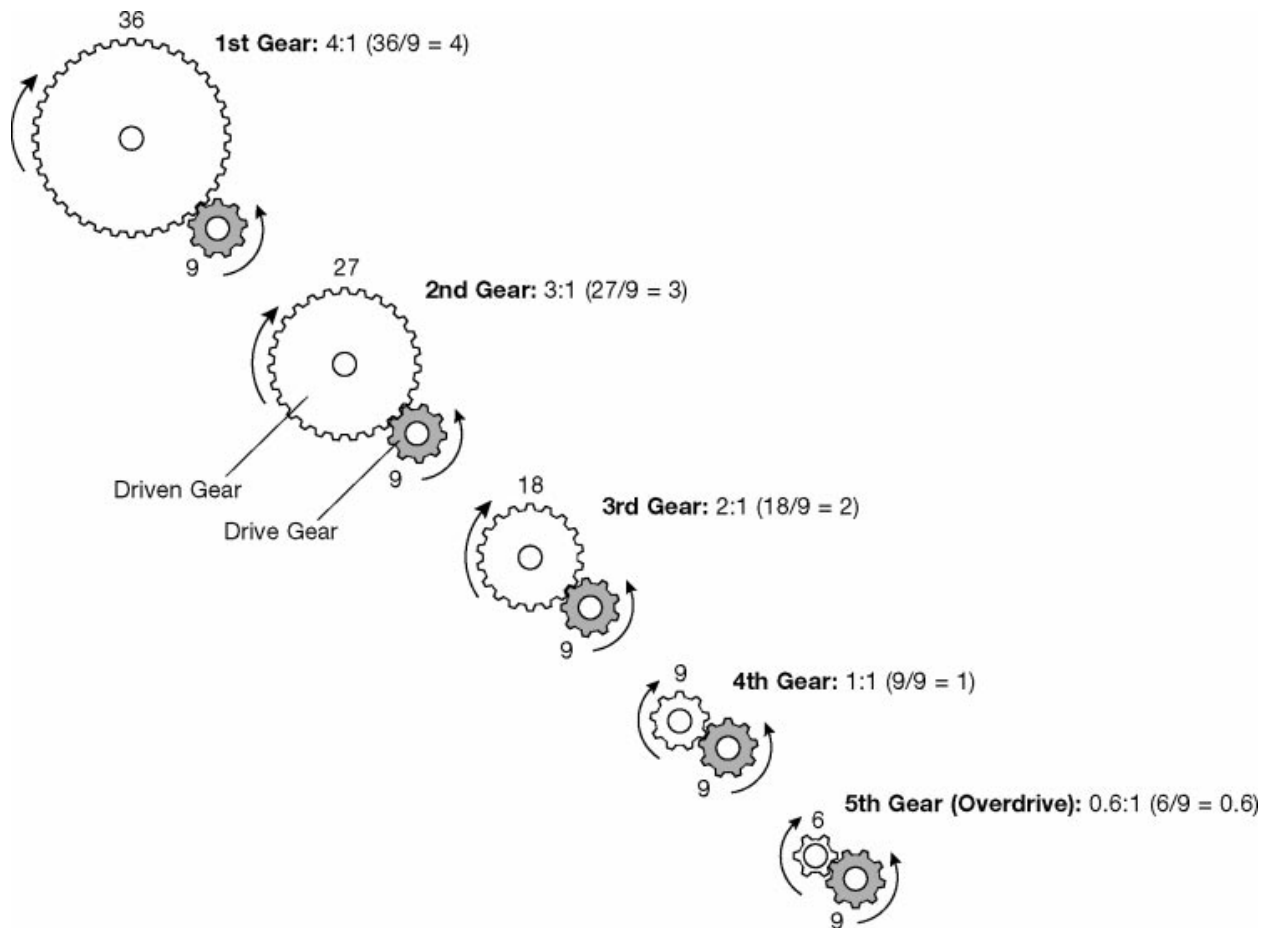


Fig. 1-8
T302f108

Simple Transmission

An example of a simple transmission would be one that consists of a drive gear and driven gear working to rotate a wheel (figure 1-9). Force is applied to a drive gear with 12 teeth to rotate a driven gear with 24 teeth, which in turn rotates a wheel; the gear ratio of this simple transmission would be: $24/12 = 2$ or 2:1. The speed of the drive gear is going to be twice the speed of the driven gear. This is determined by the ratio between the number of teeth on the drive gear and the driven gear. The gear ratio or reduction ratio also determines the amount of torque transmitted from the drive gear to the driven gear. Although the driven gear is turning at half the speed of the drive gear, the torque that the driven gear has is twice that of the drive gear.

Simple Transmission

This simple transmission demonstrates the use of gears to rotate a wheel. The drive gear in this example has 12 teeth and the driven gear has 24 teeth for a gear ratio of 2:1. The speed of the drive gear is twice that of the driven gear. Though the wheel rotates at a slower speed than the original force applied to the drive gear, it does so with more torque.

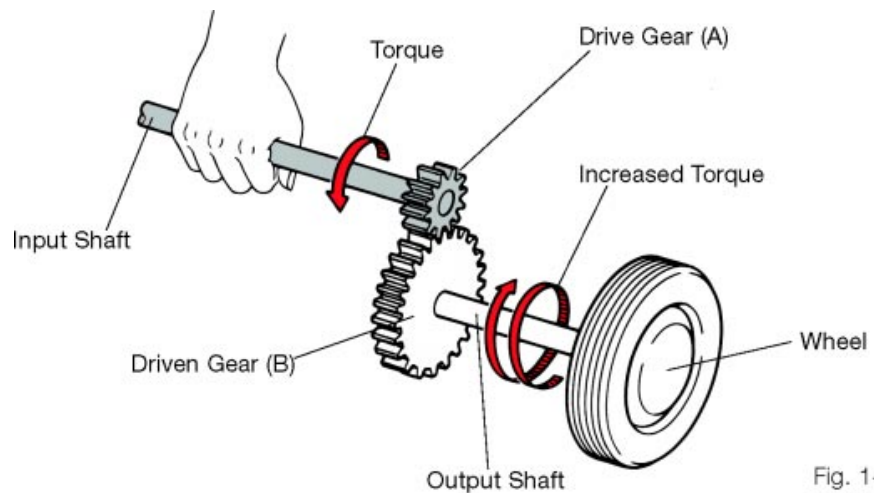


Fig. 1-9
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A simple formula using the input torque (the torque of the drive gear) and the gear ratio can be used to determine the torque applied to the wheel by the driven gear: The torque of the driven gear (B) equals the torque of the drive gear (A) multiplied by the gear ratio—the number of teeth on the driven gear divided by the number of teeth on the drive gear.

Formula to Determine Torque

The simple transmission in figure 1-9 has a gear ratio of 2:1; the drive gear (A) has a torque of 100 ft-lbf.

Use this formula to determine the torque of the driven gear (B) applied to the wheel.

$$\text{TORQUE GEAR B} = \text{TORQUE GEAR A} \times \frac{\# \text{ TEETH GEAR B}}{\# \text{ TEETH GEAR A}}$$

$$\text{TORQUE GEAR B} = 100 \text{ ft-lbf} \times \frac{24}{12}$$

$$\text{TORQUE GEAR B} = 100 \text{ ft-lbf} \times 2$$

$$\text{TORQUE GEAR B} = 200 \text{ ft-lbf}$$

Fig. 1-10

In a simple transmission as shown in figure 1-9, the direction of rotation of the drive gear is reversed to the driven gear as power is applied. Thus, the direction of rotation of the input shaft is reversed in the output shaft.

Direction of Rotation

When two gears are combined, the direction of rotation of the input shaft for the drive gear (A) is reversed in the output shaft for the driven gear (B).

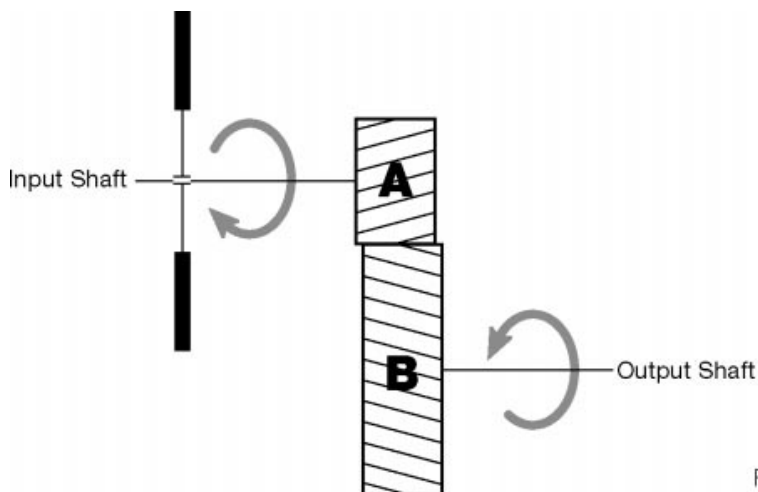


Fig. 1-11
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To maintain the same direction of rotation from the input shaft to the output shaft, two pairs of gears are used with a counter shaft connecting them. This allows the transmission to keep the direction of rotation the same between input and output shafts. Gears B and C can be called the counter shaft gears of the simple transmission diagram shown in figure 1-12.

Maintaining the same Direction of Rotation

If the direction of rotation of the output shaft needs to match that of the input shaft, a counter shaft is introduced into the gear set. The drive gear (A) drives the counter gear (B), rotating the counter shaft in the opposite direction of rotation; the counter shaft then rotates the counter gear (C), which then drives the driven gear (D) on the output shaft producing the same direction of rotation as the input shaft.

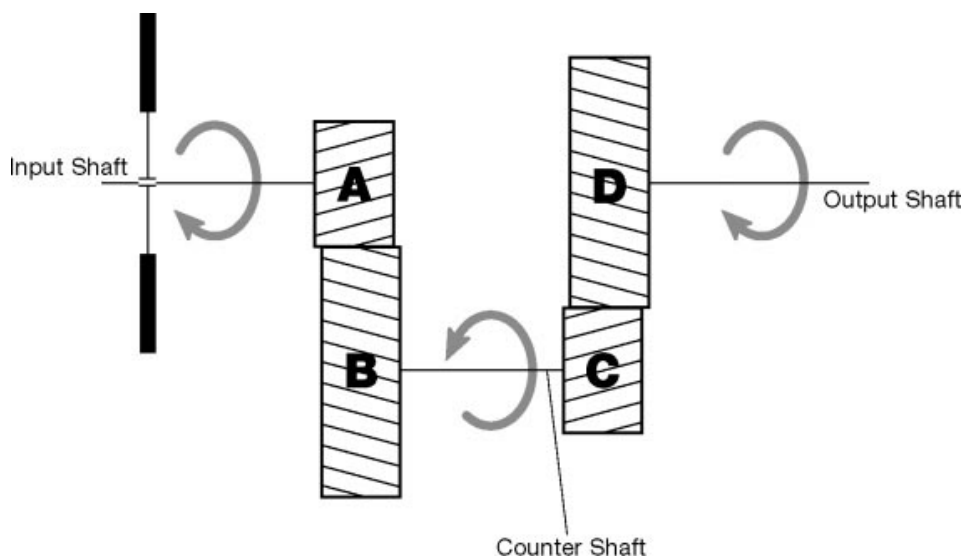


Fig. 1-12
T302112

Final Gear Ratio

When power goes through more than one gear set, two or more ratios are involved. Usually, the simplest way to handle this is to figure the ratio of each set and then multiply one ratio by the other(s). An example is a vehicle with a first gear ratio of 2.68:1 and a rear axle ratio of 3.45:1. The overall, or final gear ratio in first gear is 2.68×3.45 or 9.246:1. The engine rotates at a speed that is 9.246 times faster than the rear axle shafts.

Final Gear Ratio

The final gear ratio can be expressed with these equations.

$$\text{FINAL GEAR RATIO} = \frac{\text{OUTPUT GEAR B}}{\text{OUTPUT GEAR A}} \times \frac{\text{OUTPUT GEAR D}}{\text{OUTPUT GEAR C}}$$

OR

$$\text{FINAL GEAR RATIO} = \frac{\# \text{ TEETH GEAR B}}{\# \text{ TEETH GEAR A}} \times \frac{\# \text{ TEETH GEAR D}}{\# \text{ TEETH GEAR C}}$$

Fig. 1-13

Manual transmissions contain four or five forward pairs of gears and one set of gears for reverse. In reverse, an idler gear is used to change the direction of the output shaft for reverse.

Idler Gear

An idler gear is used to change the direction of the output shaft for reverse.

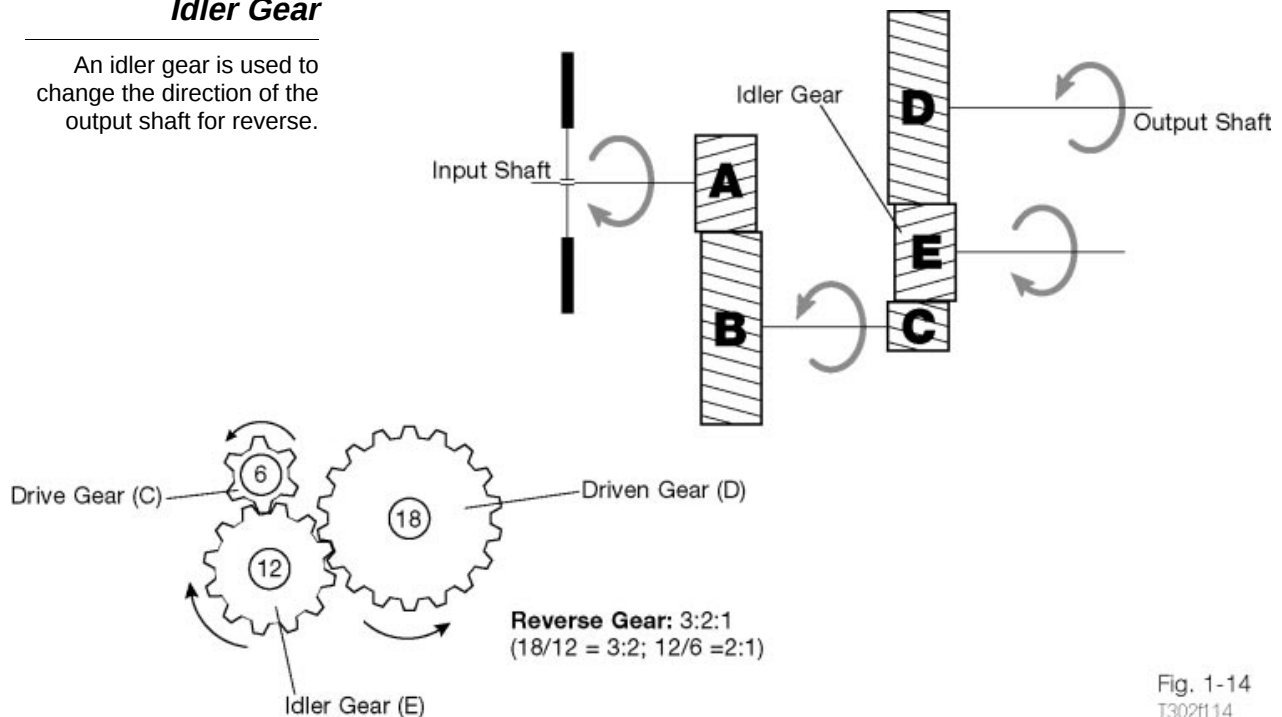


Fig. 1-14
T302114

Gear Types There are two types of gears: spur gears and helical gears.

Spur Gears Spur gears are cut perpendicular to the direction of travel. All thrust is transferred in the direction of rotation; but, spur gears are noisy. Spur gears are generally only used for reverse.

Helical Gears All other gears in Toyota transmissions are helical gears, which have the teeth cut in a spiral or helix shape. Helical gears operate more quietly than spur gears, but helical gears generate axial or end thrust under a load. Helical gears are also stronger than a comparable sized spur gear.

Helical Gears

The teeth on a helical gear are cut on a slant. This produces an axial or side thrust.

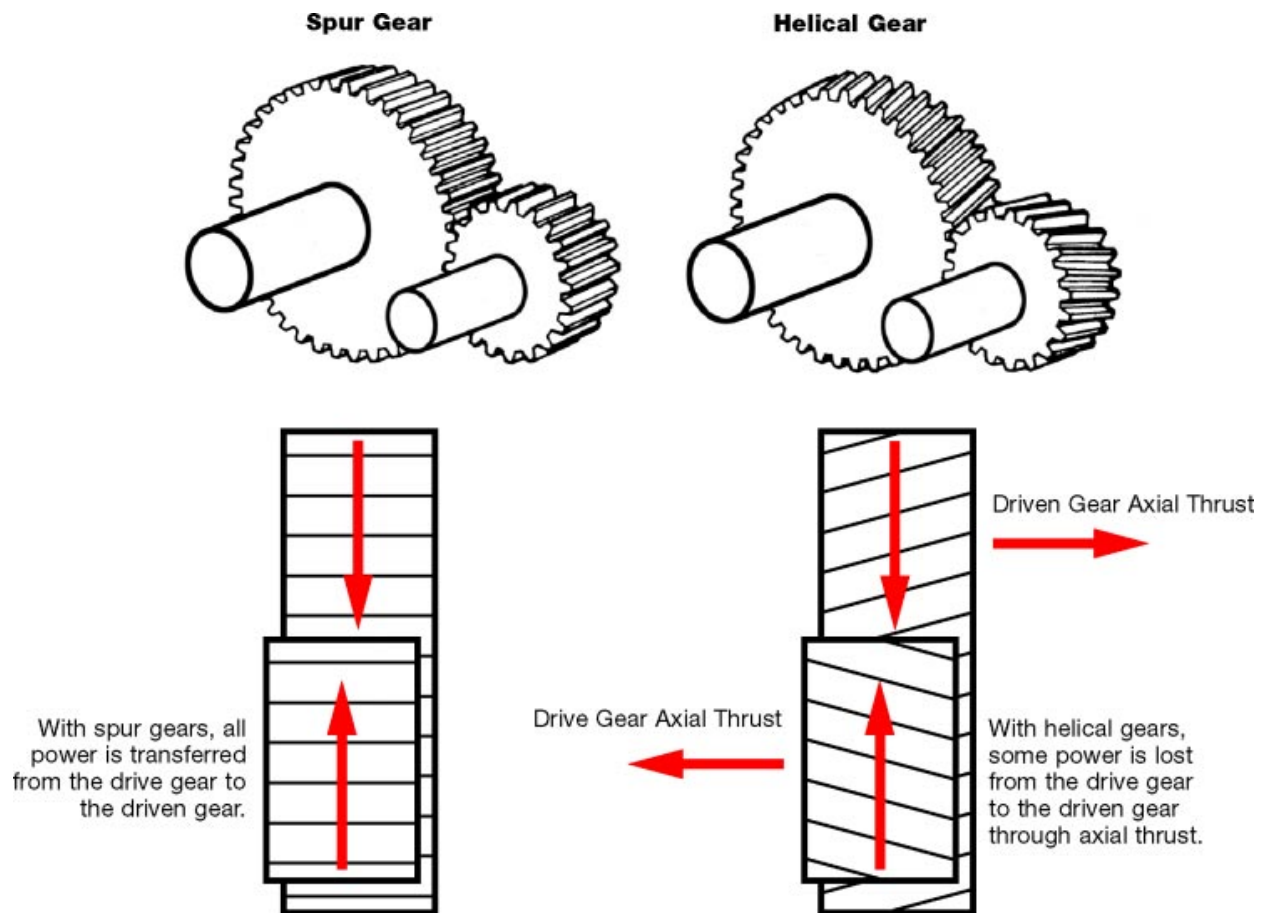


Fig. 1-15
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Notes