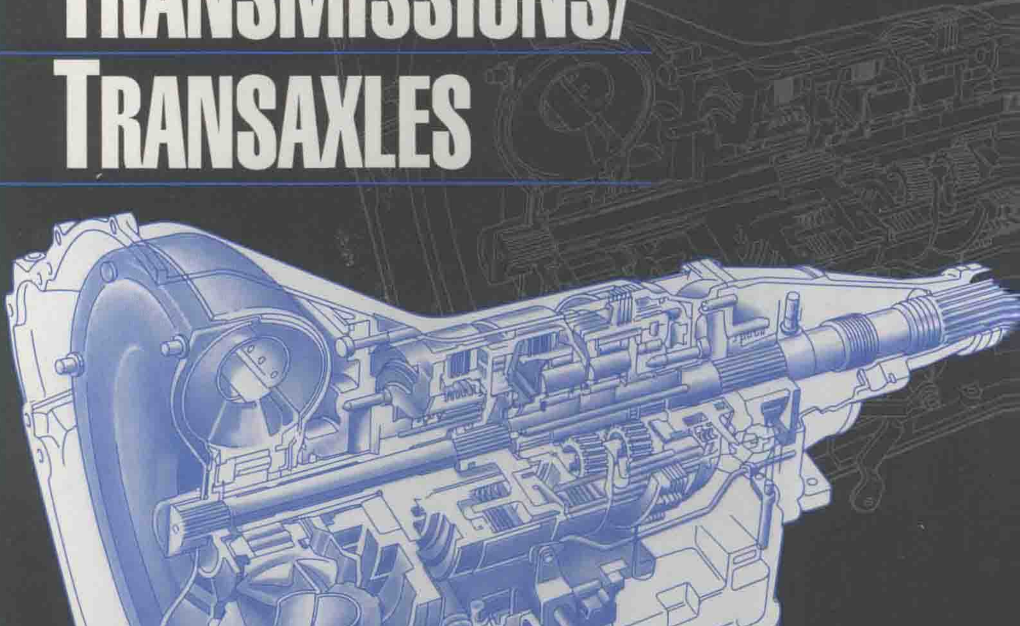
AUTOMATIC TRANSMISSIONS/ TRANSAXLES



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AUTOMATIC TRANSMISSIONS/ TRANSAXLES

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AUTOMATIC TRANSMISSIONS/TRANSAXLES

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PREFACE

Along with the modern automobile, the automatic transmission has evolved steadily and gradually. The somewhat bulky and cantankerous transmissions of the 1950s and 1960s have become the relatively lightweight electronically controlled transaxles of the 1990s.

This evolution has had an impact on the transmission repair industry. In the early years, apprentice mechanics could be trained to learn all necessary repair techniques with one of the half-dozen commonly used transmissions by working alongside an experienced mechanic. Today, not only do we have a larger variety of domestic transmissions and transaxles, but also these units are constantly upgraded to meet the demands of consumers, manufacturers, and government agencies. A substantial number and variety of units used in imported cars have also entered the scene. The major areas of change include the addition of final drives and differentials in the development of transaxles and the use of lockup torque converters, overdrive gears, and electronic shift controls. At one time, a mechanic could work on and memorize a particular transmission such as a Powerglide or C4 and be expert in repairing that transmission for a number of years.

The transmission technician of today, however, cannot memorize all the individual transmissions with their updates and electronic circuitry. The number of things that can fail and cause problems has increased dramatically. Problem diagnosis is no longer a process of checking the dipstick and driving around the block. It has become a systematic, many-stepped process involving the use of pressure gauges and electronic testing equipment. Repair has become a procedure that is carefully guided by service manuals with update bulletins.

This textbook explains the operating principles of gearsets, friction devices, hydraulic systems, and torque converters to enable the prospective technician to understand transmission operation. It also discusses the electronic control systems used in most modern transmissions and transaxles. Given this background, the technician will know what should occur for each gear range operation and upshift or downshift.

In-car maintenance and adjustment operations are described so that the student technician will learn what should be done to keep a transmission/transaxle operating correctly. A chapter on problem diagnosis procedures describes all the tests used to locate the cause of transmission/transaxle problems.

Service operations, both in-car and bench, are thoroughly described so that the future technician will know how and why they are performed and what tools and equipment are needed to perform them. The service operations are described in a generic manner because today's transmission technician must also use a service manual while working on a specific transmission/transaxle to ensure that all the required service operations are performed. In addition, a chapter describing various transmission modifications is included to acquaint the student technician with every aspect of transmission work.

The text covers all content areas of the ASE Transmission/Transaxle test. Along with class instruction, it should prepare students to pass this test and obtain certification.

I acknowledge and thank all the firms that granted use of illustrations used in this text; their names appear in the credit lines. Special thanks are in order to Dennis Zeiger, Chrysler Corporation; Wayne Ferrell, Sealed Power Technologies; and J. E. "Corky" Meyers, Torque Converter Rebuilding Systems.

Thomas W. Birch

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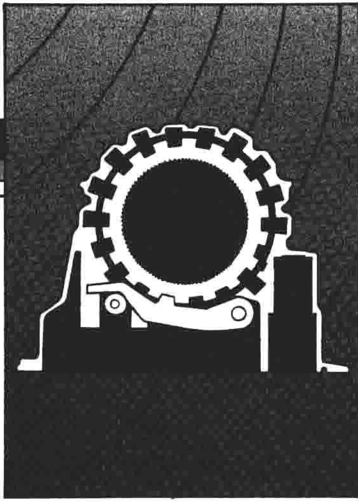

CHAPTER 1

INTRODUCTION TO TRANSMISSIONS

OBJECTIVES

After completing this chapter, you should:

- **Be able to identify the major components of an automatic transmission and transaxle.**
- **Have an understanding of how different gear ratios can be obtained in a planetary gearset.**
- **Have a basic understanding of the systems within an automatic transmission and how they relate to each other.**

1.1 TRANSMISSIONS: THEIR PURPOSE

Every driver is familiar with the gear shift lever that is moved to control a car's motion. We know that this lever determines gear selection in the transmission, and this determines the driving mode of the car. The transmission provides the various gear ratios for forward and reverse operation.

At one time, most cars mounted the transmission behind the engine and used a drive shaft to transfer power to the rear axle and driving wheels. This is called *rear-wheel drive* (*RWD*) (Fig. 1-1). Most modern cars drive the front wheels (*FWD*). In most cases, the engine is mounted in a *transverse* position, crosswise with the car, with the *transaxle*, a combination of the transmission and final drive axle, attached to it. Two short drive shafts are used to connect the transaxle to each front wheel (Fig. 1-2).

A car cannot operate very well without a transmission, which serves several purposes:

P Park gear in an automatic transmission locks the drive wheels to hold the car stationary.

R Reverse gears allow the car to go backward.

N Neutral allows us to run the engine without moving the car.

D High gears allow the car to go faster while the engine runs slower.

I Intermediate gear prevents high-gear operation.

L Low gears multiply the engine's torque so there will be enough power to move the car.

Before the 1940s every car used a clutch and standard, manual transmission. The first automatic transmission was the Hydra-Matic Drive introduced on the 1940 Oldsmobile; it was an option costing $57. By the 1960s, most of the domestic (produced in America) cars were equipped with automatic transmissions.

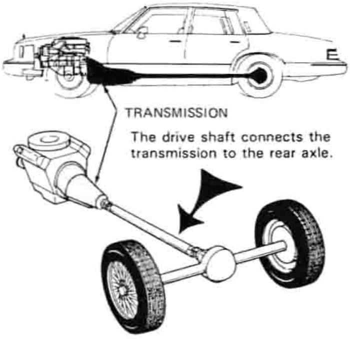

Fig. 1-1 The drive train of a RWD car consists of a clutch and transmission mounted to the rear of the engine, a drive shaft, and a rear-axle assembly. *(Copyrighted material reprinted with permission from Hydra-matic Div., GM Corp.)*

Both types of transmissions serve the same general purpose in providing the needed gear ratios. The difference is that the driver selects the gear and performs each shift while depressing the clutch pedal in a standard transmission. An automatic transmission does not require a manual clutch and can make automatic upshifts and downshifts. Each of these transmission types offer several advantages over the other. Several manufacturers have offered semiautomatic transmissions over the years. Chrysler Corporation's Fluid Drive and Volkswagen's Automatic Stick Shift are examples of semiautomatic transmissions that tried to combine the best fetures of standard and automatic transmissions. The driver had to perform each of the upshifts and downshifts but did not need to operate a clutch.

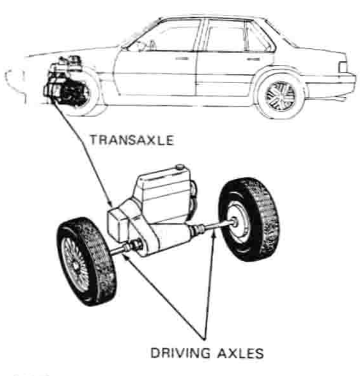

Fig. 1-2 The drive train of a FWD car consists of a transaxle assembly mounted to the engine and a pair of drive axles to the front wheels. *(Copyrighted material reprinted with permission from Hydra-matic Div., GM Corp.)*

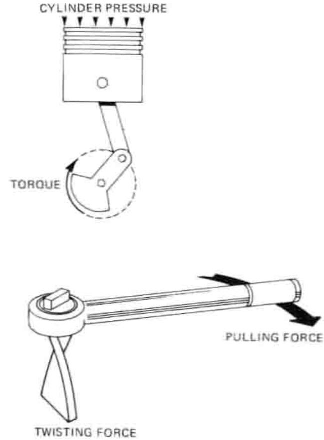

Fig. 1-3 Pressure in the cylinder forces the piston downward, which in turn forces the crankshaft to turn. This produces the rotating torque that turns the transmission gears, drive shaft, and drive wheels. When we pull on a wrench, we produce the torque needed to turn a nut or bolt.

1.2 TORQUE AND HORSEPOWER

Torque is a twisting force (Fig. 1-3). We exert torque on a nut or bolt as we tighten or loosen it. Torque must be exerted at the drive axle in order to turn the wheels and move the car (Fig. 1-4).

Torque is commonly measured in foot-pounds (ft-lb), inch-pounds (in.-lb), or Newton-meters (N-m). A foot-pound of torque is created when we exert a pound of force on a wrench that is one foot long. Force (in pounds) times the wrench length (in feet) equals the amount of torque in foot-pounds. One foot-pound of torque is equal to twelve inch-pounds, or 1.356 N-m.

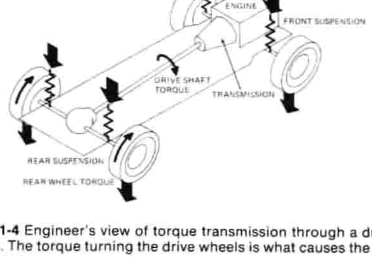

Fig. 1-4 Engineer's view of torque transmission through a drive train. The torque turning the drive wheels is what causes the car to move.

Torque is a form of mechanical energy and, like all other forms of energy, cannot be created or destroyed. It can and is transformed from one form of energy to another. A car's engine converts the potential heat energy of gasoline into torque that rotates the flywheel. The transmission receives the torque and increases or decreases it according to the gear selected. The torque at the drive wheels is transformed into the kinetic energy of the moving car.

Most of us are more familiar with the term *horsepower* than torque. Horsepower is a measurement of the amount of energy developed in the engine. It is a product of torque and engine speed. To determine horsepower, an engineer uses a dynamometer to measure the amount of torque that the engine can produce at various points through its operating range. Then the simple formula, torque times revolutions per minute (rpm) divided by 5252, is used to convert torque at a certain rpm into a horsepower reading. The various readings are then plotted into a curve, as shown in Fig. 1-5. A typical horsepower and torque curve shows us that an engine does not produce very much torque at low rpm, produces the most usable torque in the mid-rpm range, and has a reducing amount of torque with an increasing amount of horsepower at higher rpm.

The amount of torque from an engine can be increased or decreased through the use of gears, belts and pulleys, and chains and sprockets (Fig. 1-6). These are called ***simple machines***. Gears are commonly used in transmissions. Transmissions of the future will probably make greater use of a belt with variable-size pulleys; this will be described later in this chapter. Simple machines cannot increase the amount of horsepower or energy. They can modify it by changing the amount of torque or speed. A driver feels the torque increase when he or she steps on the gas, forcing the car to move. A large amount of torque produces faster motion.

The amount of torque that a transmission can handle is referred to as *torque capacity*. Larger engines and heavier cars require larger transmissions with greater torque capacity than lighter cars with smaller engines. A transmission's torque capacity is determined by the diameter of the shafts, the size of the clutch packs and bands, and the size of the gears.

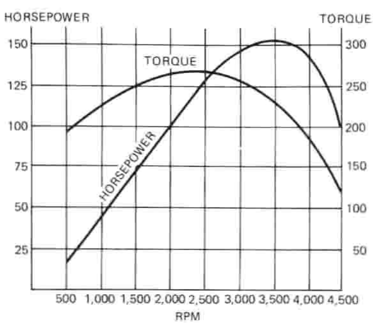

Fig. 1-5 Typical horsepower–torque chart for an automotive engine. Note that the maximum horsepower (155) occurs at about 3400 rpm and that maximum torque (262) occurs at between 2000 and 2500 rpm. This varies depending on the engine size and design.

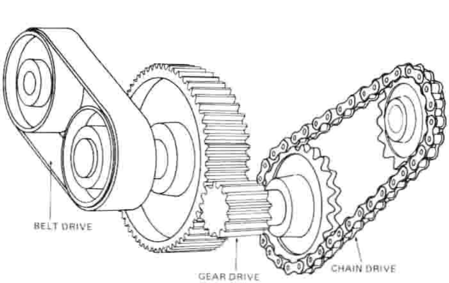

Fig. 1-6 The common methods of transmitting torque are belt, gear, and chain drives.

1.3 GEAR RATIOS

The term *gear ratio* refers to the relative size of two gears. The ratio can be determined using either the diameter or the number of teeth of the two gears. A pair of gears of different size will have different numbers of teeth on them, and the number of teeth is exactly relative to the diameter of the gears (Fig. 1-7). When the driving gear, where the power is put in, is smaller than the driven gear, the ratio between the two gears produces more torque but less speed at the output shaft; this is called *gear reduction*. When the driving gear is larger, an overdrive results. This increases the speed but reduces the torque.

If, for example, one gear has 15 teeth and the gear meshed with it has 30 teeth, the 30-tooth gear is exactly twice the diameter of the 15-tooth gear. If the 15-tooth gear is the input, driving gear, it has to rotate two revolutions for each revolution of the 30-tooth-driven gear.

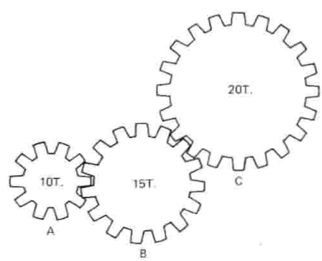

Fig. 1-7 In a matched set of gears, the number of teeth on each gear is related to the diameter. Gear C, which has twice the diameter as gear A, has twice the number of teeth. Gear B, with one and a half times the diameter of gear A, has one and a half times as many teeth.

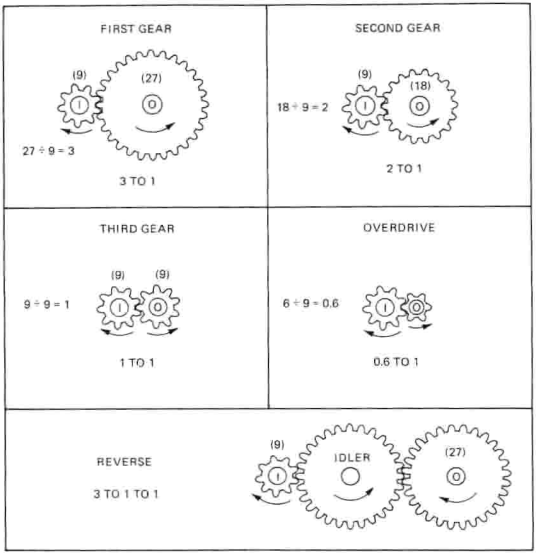

Fig. 1-8 The gear ratio is determined by dividing the number of teeth on the driven (output) gear by the number of teeth on the driving (input) gear.

This gear ratio is 2:1, and the output shaft has twice the torque and half the speed as the input shaft (Fig. 1-8).

When figuring gear ratios on simple gearsets, we always divide the number of teeth on the driven gear by the number of teeth on the driving gear. If the driving gear has 12 teeth and the driven gear 36 teeth, the ratio will be $\frac{36}{12}$, or 3:1—a reduction—and the input shaft will turn three revolutions for each output shaft revolution. If we turn that gearset around, the ratio would be $\frac{12}{36}$ or 0.3:1—an overdrive. In this case, the input shaft would turn 0.3 turns for each revolution of the output shaft.

When power travels through more than one gearset, the overall ratio is determined by multiplying one gear ratio by the next. An example of this is a modern RWD car with a five-speed transmission (shown in Fig. 1-9). A transmission first-gear ratio of 3.97:1 and a rear-axle ratio of 3.55:1 produces an overall ratio of 3.97 × 3.55, or 14.09:1, in first gear. The engine will revolve 14.09 turns for each revolution of the drive axle. An overdrive ratio in fifth gear in this transmission of 0.8:1 times the 3.55 rear-axle ratio produces an overall ratio of 2.84:1. In this gear, the engine will revolve 2.84 turns for each drive axle revolution. This car will have about one-fifth the torque it had in first gear but will be able to go about five times faster in fifth gear for each engine revolution.

Gear	Ratio	Final Drive Ratio	Overall Ratio	mph per 1000 rpm
I	3.97:1	3.55:1	14.09:1	5.4
II	2.34:1	3.55:1	8.31:1	9.2
III	1.46:1	3.55:1	5.18:1	14.7
IV	1:1	3.55:1	3.55:1	21.5
V	0.80:1	3.55:1	2.84:1	26.9

Fig. 1-9 The overall gear ratio can be determined by multiplying the transmission gear ratio by the final drive ratio. If a car has a final drive ratio of 3.55:1 and a first-gear ratio of 3.97:1, the overall ratio will be 14.09:1. All forward-gear ratios for a late-model car with a five-speed transmission are shown here. The mph per 1000 rpm indicates the relative speed for the different gears.

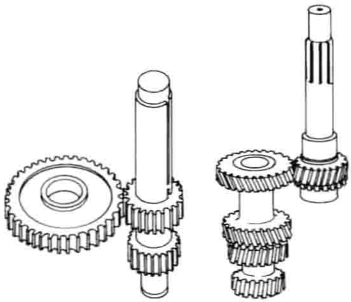

Fig. 1-10 The teeth of a spur gear (left) are cut so they are parallel to the shaft while the teeth of a helical gear (right) are cut at an angle to the shaft.

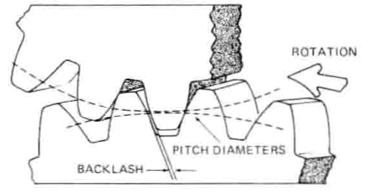

Fig. 1-11 The clearance on the nonloaded side of the gear teeth is called backlash.

Most gears have external teeth with the teeth cut around the outside of the gear. Some gears (e.g., the ring gear in a planetary set) have the teeth cut on the inside of the gear's rim. Most of the gears we will be studying are helical gears as compared to spur gears. The teeth of a spur gear are cut in a straight line, parallel to the axis of the gear and the shaft on which the gear is mounted. The teeth of a helical gear are cut on a spiral helix shape; they would spiral continuously if they were extended (Fig. 1-10). The other major gear type—a bevel gear—is used to transfer power between shafts that are not parallel, and they are made in both a spur bevel and spiral bevel form. A spur gear is less expensive to make, but it is noisier and not as strong as a helical gear. A helical gear tends to be quieter and stronger, but it has a tendency to slide sideways, out of mesh.

Some other important rules to learn about gearsets are:

- The driving gear will always rotate in the opposite direction as the driven gear unless one of them is an internal gear.
- Two gears transferring power push away from each other in an action called gear separation. The amount of gear separation force is proportional to the amount of torque being transferred.
- All gearsets have a certain amount of *backlash* to prevent binding (Fig. 1-11).
- The smaller gear(s) in a gearset is often called a pinion.

1.4 TRACTIVE FORCE

An engineer uses the term *tractive force* to describe the power in an automobile's drive train. It is a product of the engine's torque multiplied by the gear ratio and is plotted in the form shown in Fig. 1-12. Note that a curve is shown for each of the transmission's gears and that first gear produces the most torque and fifth gear the most speed, as we would expect. This curve (b) does not show engine rpm, but in each case in this particular curve, the left end is plotted for 500 rpm and the right end for 4500 rpm.

When discussing vehicle speed, it should be remembered that the tire diameter affects speed. The larger the tire, the faster the car will go at a particular axle rpm and vice versa (Fig. 1-13). You can use the following formula to determine the car speed at a particular engine rpm or vice versa:

$$\text{Engine rpm} = \frac{\text{mph} \times \text{gear ratio} \times 336}{\text{tire diameter}}$$

$$\text{mph} = \frac{\text{rpm} \times \text{tire diameter}}{\text{gear ratio} \times 336}$$

The amount of horsepower required to reach a certain speed is influenced by the weight and shape of the car and on how level the road is. Vehicle motion is resisted by two types of friction: rolling and aerodynamic. Rolling friction is produced by the tires, axles, and other rotating parts of the power train. A heavier car increases the rolling resistance because of the load at the tires and axles. This resistance increases at a constant rate as the car speeds up, and if we double the speed, it requires twice as much power to overcome rolling resistance. Aerodynamic friction or drag is created as we force the body of the car through air. A large, boxy car is much harder to push through air than a small, streamlined car. Aerodynamic drag increases at the square of the car's speed; if we go twice as fast, the aerodynamic drag increases about four times (Fig. 1-14). Combined, these two curves are referred to as *tractive resistance*.

When we place the curve for tractive force over the curve for tractive resistance, we can get an idea of the car's performance (Fig. 1-15). The top speed is where the two curves cross at the right side. We can also see that the lower gears produce much more force than needed to overcome the resistance. This excess force is used to accelerate the car; the greater the amount of excess, the greater the rate of acceleration.

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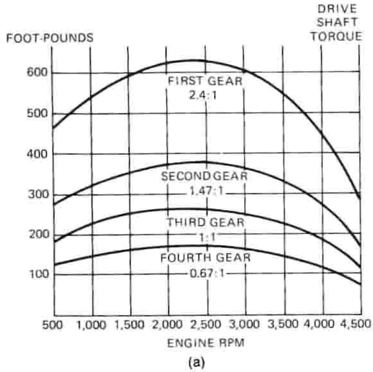
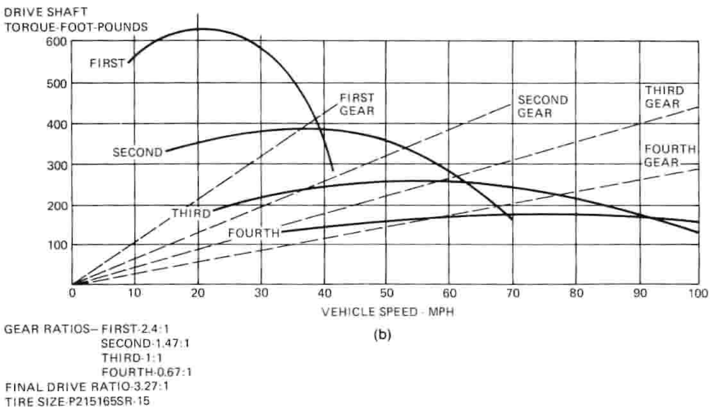


Fig. 1-12 Tractive force is determined by multiplying the engine's torque by the gear ratio, as shown in (a); note that this is the greatest in first gear. This plot is for a typical V8 engine of about 300 in.^{3} (5 L). (b) The same curves as in (a) in relationship with the vehicle speed.



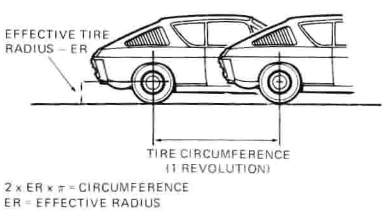


Fig. 1-13 The speed of a vehicle is determined by the diameter of the drive tire and how fast we turn that tire.

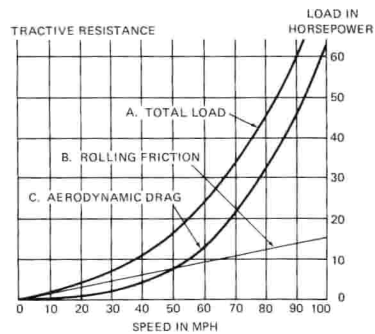


Fig. 1-14 (a) The load on a car increases as it goes faster. It is a combination of (b) the rolling friction, which increases at a constant rate, and (c) aerodynamic drag, which increases at a much more rapid rate. Plot shows the loads on a late-model, domestic coupe with good aerodynamic design.

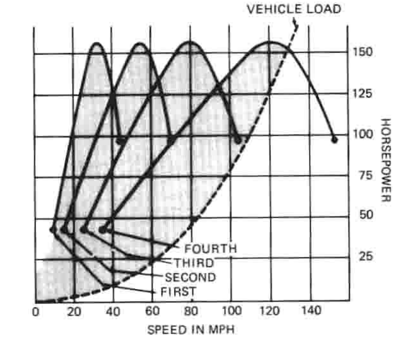


Fig. 1-15 Chart showing the vehicle's road load and the horsepower available. The point where the two intersect, about 128 mph, is the theoretical top speed. The shaded area to the left shows the excess horsepower, which is used for acceleration.

Excess force is also convenient when going up hills because the slope of the road increases the amount of tractive resistance.

1.5 STANDARD TRANSMISSION AND CLUTCH

A standard transmission provides several sets of gears to produce the necessary gear ratios (Fig. 1-16). When a driver selects a particular gear, the power must flow through a particular path as it goes from the input shaft to the output shaft—a 1:1 ratio. A gear reduction or overdrive is produced when the power flows from the main drive gear on the input shaft to the cluster gear and from the cluster gear to a driven gear on the output shaft (Fig. 1-17). The actual shift is made by moving a synchronizer sleeve to couple the desired driven gear to the synchronizer hub and the output shaft (Fig. 1-18).

In a standard transmission, this shift cannot be made while the power is flowing. The power flow must be interrupted or disengaged by depressing the clutch pedal (Fig. 1-19). This allows the gear to be engaged to slow down or speed up to the same speed as the synchronizer sleeve during the shift. This is sometimes called a nonpower shift. The clutch is also needed so the transmission input shaft can come to a stop so we can shift from neutral to low or reverse.

A FWD transaxle is slightly different from a RWD unit in that power is always transferred through three or more shafts that are parallel to each other (Fig. 1-20). The input comes from the clutch; the second shaft transfers power to the pinion gear of the final drive; and the third shaft is the ring gear of the final drive and the differential. The various transmission ratios are the different power paths between the first and second shafts. Like an RWD transmission, a synchronizer assembly is used to make the shifts.

1.6 PLANETARY GEARSETS

With only one exception (the HondaMatic), all automatic transmissions use *planetary gearsets* to provide the different gear ratios. A planetary gearset is a combination of a *sun gear*, two or more *planet gears*, a *planet carrier*, and a *ring gear*. The ring gear, also called an *annulus gear*, is an internal gear; all the other gears are common external gears. The carrier holds the planet gears (also called *pinions*) in position and allows each of these gears to rotate in the carrier (Fig. 1-21). When the gearset is assembled, the sun gear is in the center and meshed with the planet gears, which are around it, somewhat like the planets in our solar system. The ring gear is meshed with the outside of the planet gears.

The three major members of the planetary gearset—the sun gear, ring gear, and planet carrier—have two possible actions: they can rotate or stand still. Depending on what the other members are doing, the planet gears have three possible actions: they can stand still on their shafts and rotate with the carrier; they can rotate on their shafts in a stationary carrier and act like idler gears; or they can rotate on their shafts in a rotating carrier. This last condition is called "walking" (Fig. 1-22). The planet gears walk around the outside of a stationary sun or the inside of a ring gear. The rotating carrier forcing the planet gears around the stationary gear forces the planet gears to rotate on their shafts. This in turn forces the output shaft to rotate.

Planetary gearsets are arranged so power enters one of the members (the sun gear, ring gear, or carrier), leaves through one of the other members, and has the third member held stationary in reaction. One of the basic physical laws states that for every action, there is an equal and opposite reaction. In a gearset, the action is usually an increase in torque; the reaction is an equal amount of torque that tries to turn the gear box in a reverse direction. For example, watch a short-wheelbase truck-tractor pull a heavy trailer from a dead stop. The action needed is to turn the drive wheels and move the truck; the reaction is a lifting of the frame at the left front wheel. The front of the truck lifts in reaction to the drive axle torque, and the left side lifts in reaction to the drive shaft torque. Getting back to the planetary gearset, one of the three members has to be held stationary in reaction to obtain the torque or speed increase in the gear box. There cannot be a ratio change without a reaction member.

Planetary gearsets offer several advantages over conventional gearsets. Because of the multiple planet gears, there is more than one gear transferring power; the torque load is spread over several gear teeth. Because of this, planetary gearsets are quieter and stronger. Also any gear separation forces (as gears transfer power, they tend to push away from each other) are contained within the ring gear, and this load is not transmitted to the case. This allows the transmission case to be thinner and therefore lighter. Another advantage is the small relative size. Conventional gears are normally side by side, and for a 2:1 gear ratio, one gear has to be twice the size of the other. A planetary gearset can easily produce this same ratio in a smaller package. Also, planetary gearsets are in constant mesh; no coupling or uncoupling of mechanical gears is required.

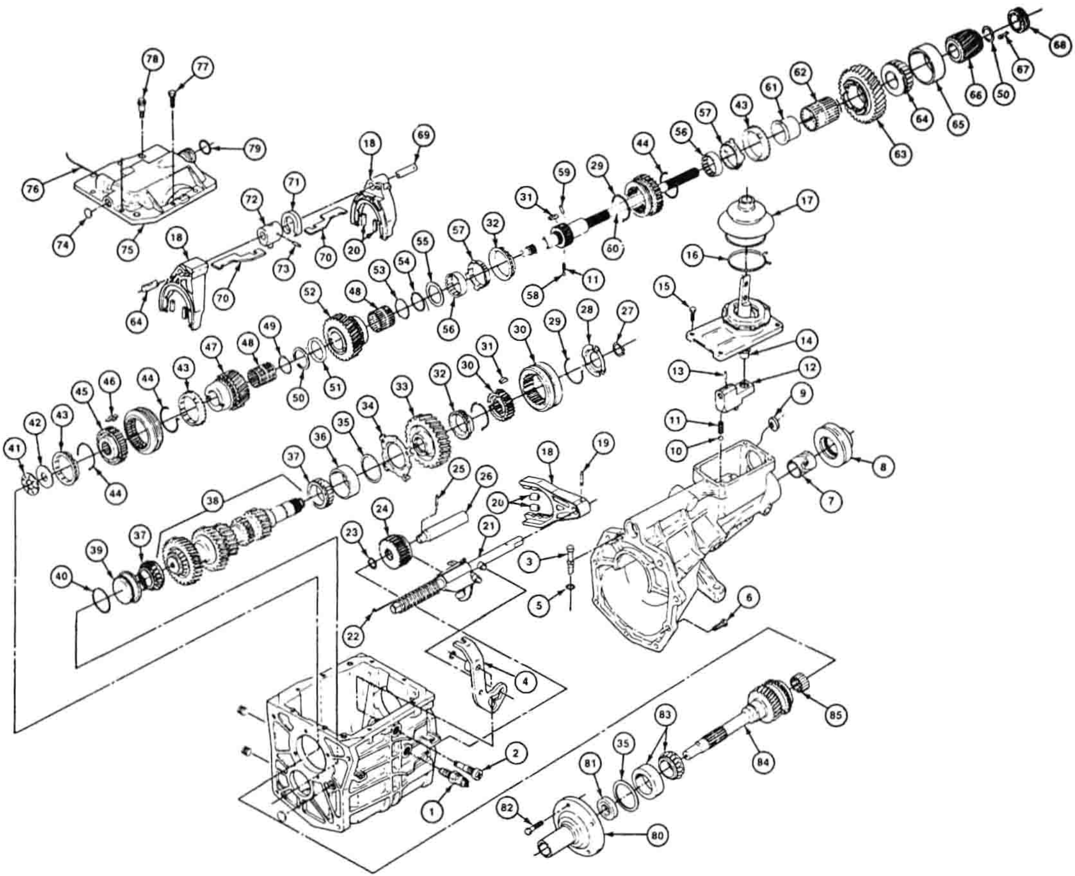


Fig. 1-16 (a) Standard transmission and (b) clutch. Note that a five-speed RWD transmission is shown in an exploded view. (*Courtesy of Ford Motor Company.*)

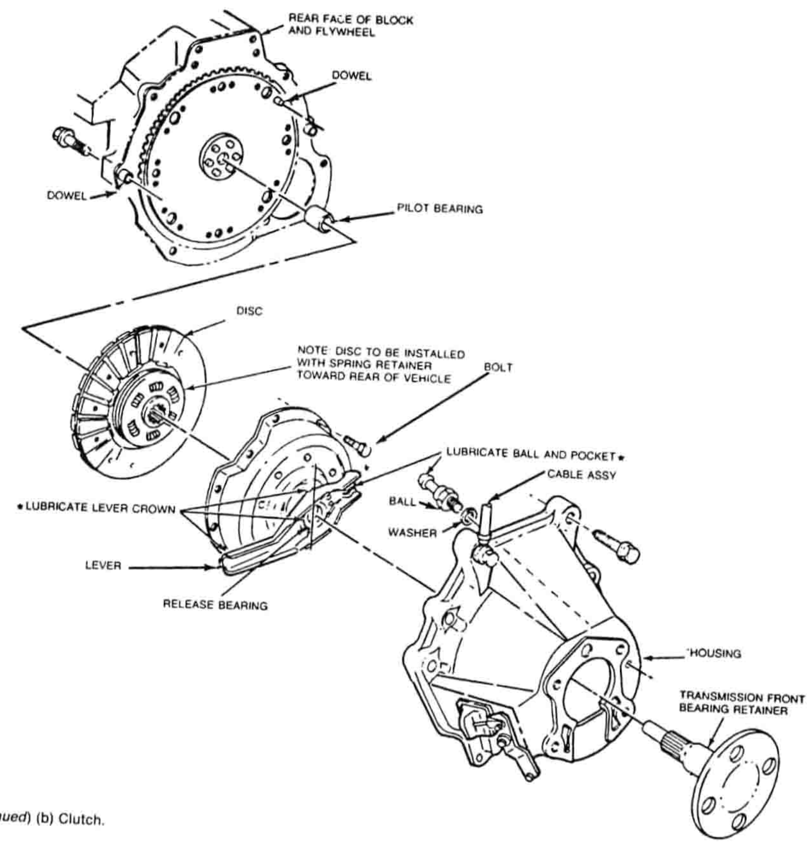


Fig. 1-16 (*Continued*) (b) Clutch.

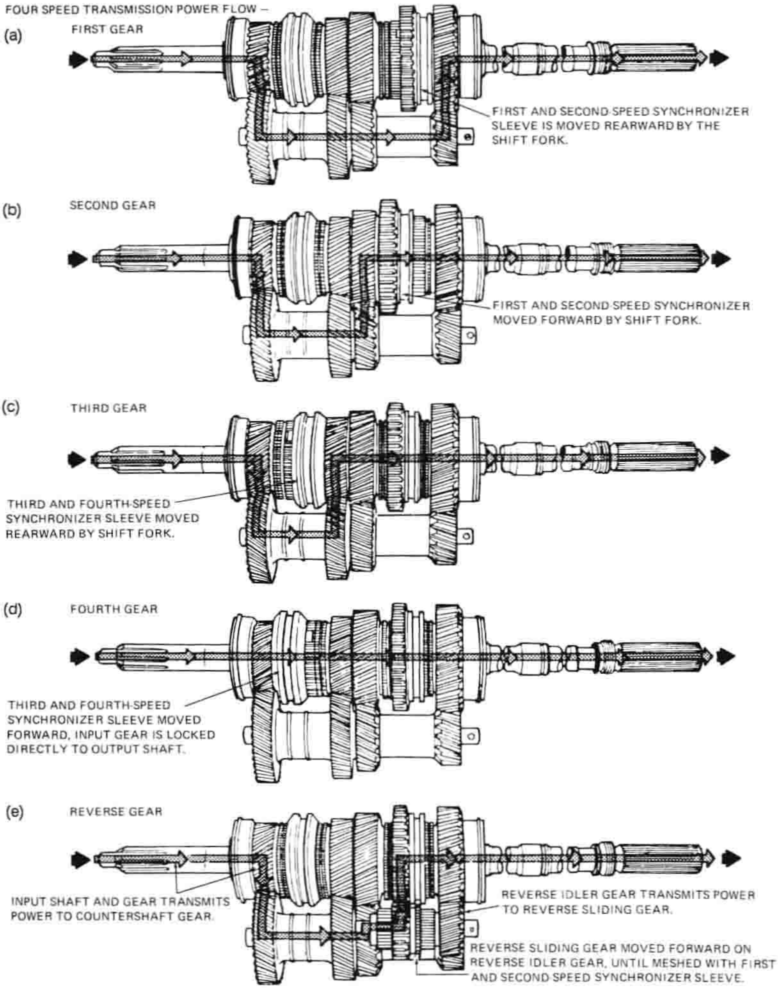


Fig. 1-17 Power flows for first gear of a four-speed standard transmission. The synchronizer sleeves are used to shift the power flow. (*Courtesy of Ford Motor Company.*)

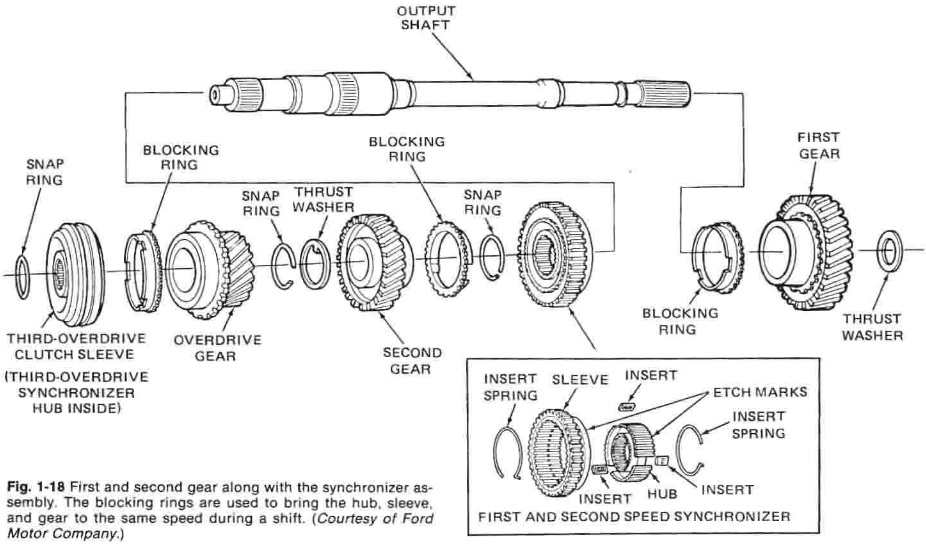


Fig. 1-18 First and second gear along with the synchronizer assembly. The blocking rings are used to bring the hub, sleeve, and gear to the same speed during a shift. (*Courtesy of Ford Motor Company.*)

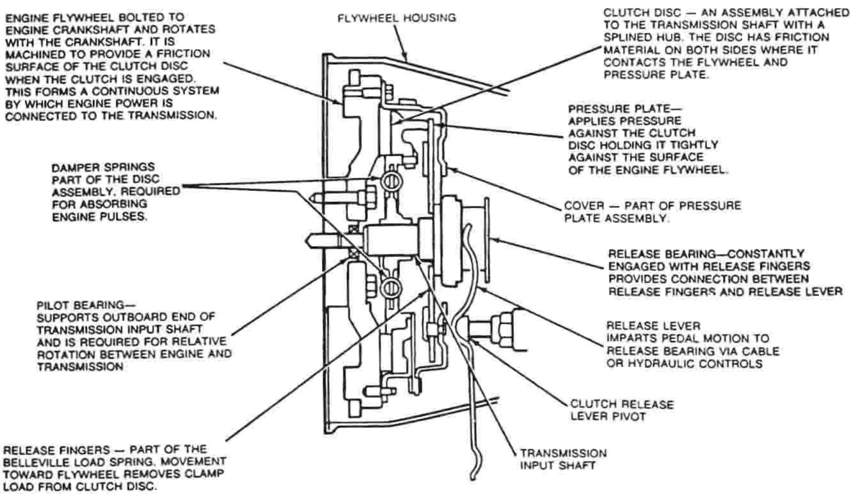


Fig. 1-19 When a clutch is engaged, the disc is held firmly between the flywheel and pressure plate. The pressure plate is moved to the right to release the clutch. (*Courtesy of Ford Motor Company.*)

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