CHAPTER 6

TRANSMISSION THEORY

OBJECTIVES

After studying Chapter 6, the reader should be able to:

1. Identify the parts of a standard transmission.
2. Explain the purpose of each standard transmission part.
3. Trace the power flow for the various speeds.
4. Calculate the gear ratio for each gear speed.
5. Explain synchronizer operation.
6. Understand the requirements for good transmission operation.

KEY TERMS

Automated manual transmissions (AMT) (p. 136)
Ball bearing (p. 145)
Blocker rings (p. 126)
Bushing (p. 145)
Cam (p. 135)
Closed case (p. 145)
Cluster gear (p. 123)
Clutch shaft (p. 123)
Composite ring (p. 128)
Constant mesh (p. 124)
Detent (p. 132)
Dog clutch teeth (p. 126)
Dogs (p. 126)
Double cone (p. 128)
Hub (p. 126)
Idler gear (for reverse) (p. 125)
Input shaft (p. 123)
Insert plates (p. 126)
Interlock (p. 132)
Keys (p. 126)
Main drive gear (p. 123)
Mainshaft (p. 123)
Manual transmission fluid (MTF) (p. 140)
Mineral oil (p. 138)
Needle bearing (p. 145)
Oiling funnel (p. 141)
Open case (p. 145)
Output shaft (p. 123)
Overdrive (p. 131)
Pitch (p. 142)
Rail (p. 135)
Reverse idler shaft (p. 123)
Shift fork (p. 132)
Sleeve (p. 126)
Speed gears (p. 124)
Splines (p. 123)
Split case (p. 145)
Struts (p. 126)
Synchronizer assembly (p. 126)
Synchronizer rings (p. 126)
Synthetic oil (p. 138)
Tapered roller bearing (p. 145)
Trough (p. 141)
Tunnel case (p. 145)
Viscosity (p. 138)

INTRODUCTION

The purpose of the transmission or transaxle is to provide neutral, forward gear speeds or ranges and reverse. They must be able to provide a gear ratio that is low enough, when multiplied by the final drive ratio, to increase the engine's torque sufficiently to accelerate the vehicle at the desired rate. The highest gear ratio should allow the vehicle to cruise at an engine speed that is low enough to conserve fuel and decrease noise. There also needs to be intermediate ratios that are spaced so that the engine will not overrev before a shift or lug after a shift. Reverse must be roughly the same ratio as first since the vehicle will be starting from a stop in both cases.

A transmission or transaxle has several different paths through which power can flow (Figure 6-1). These paths provide the required forward gear ranges and a reverse. A RWD

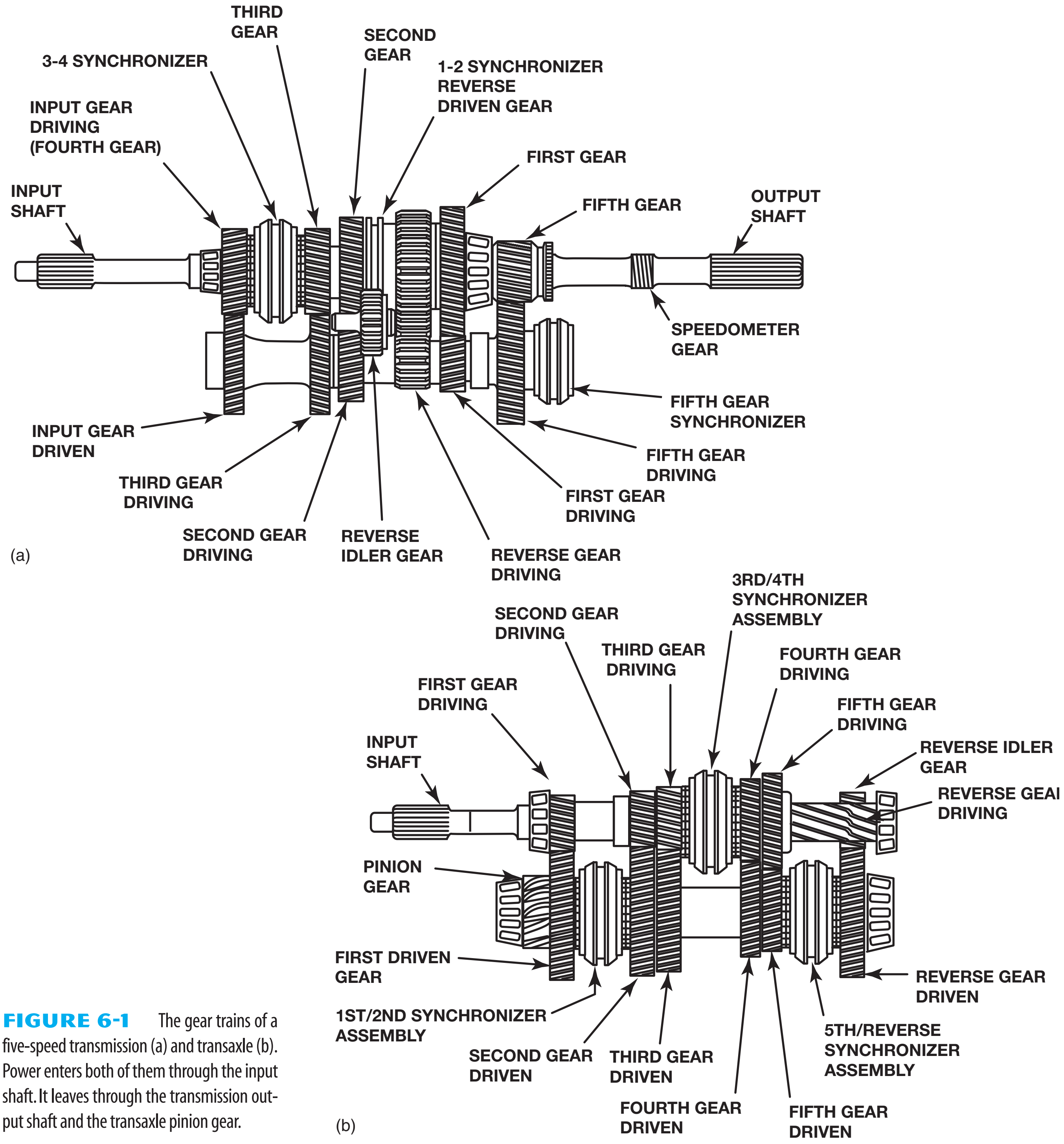


FIGURE 6-1 The gear trains of a five-speed transmission (a) and transaxle (b). Power enters both of them through the input shaft. It leaves through the transmission output shaft and the transaxle pinion gear.

transmission has the power entering the input shaft and passing through at least two gear sets before transferring to the mainshaft. The power will exit through the mainshaft and then on to the driveshaft. The transmission mainshaft output, shaft is directly in line with the input shaft.

The power enters the transaxle at the input shaft. It will pass through one gear set and then to the final drive gears. The power then will pass through the differential and out of the transaxle to the two axle shafts. Each of the available power paths through the transmission or transaxle represents a different gear ratio or transmission speed. Reverse is achieved in both the transmission and transaxle by having the power flow pass through an additional gear set.

Transaxles can be constructed in several ways, depending on whether the drivetrain is transverse or longitudinally mounted. Typically, the transaxle is mounted transverse. Transaxles have the input and output shafts parallel to one another. RWD drive transmissions will be discussed in this chapter, and transaxles in Chapter 7.

CONSTRUCTION

A RWD transmission has four shafts, one of which is nearly all gears and is commonly called a **cluster gear,** countershaft gear or *layshaft*. Besides the cluster gear, there is the **input shaft,** also called a **main drive gear** or **clutch shaft,** the **output shaft,** also called a **mainshaft,** and the **reverse idler shaft.** The mainshaft is piloted into the rear of the input shaft gear with a bearing. It is also supported at the rear of the transmission case by another large bearing, and by the universal joint spline, which in turn is supported by a bushing at the rear of the extension housing (Figure 6-2). The input shaft gear is supported by a bearing at the front of the transmission case and the pilot bearing in the end of the crankshaft. With most older transmissions, the cluster gear is supported by the countershaft with a bearing at each end. Many newer transmissions support the cluster gear directly by a bearing set; counter shafts are not used. Some transmissions with very long cluster gears and mainshaft gear groups use a support in the middle of the transmission with bearings for the cluster gear and mainshaft (see Figure 6-11).

There are two types of gear sets used in transmissions: Sliding gears and gears that are in constant mesh. Both types are used in modern transmissions. The forward gear ranges are all in constant mesh, with reverse typically being a sliding gear.

Sliding gears are engaged by sliding the gears into mesh. The gears have internal **splines** that match the external splines of the mainshaft (Figure 6-3). To shift gear, the sliding gear would be moved along the splines until it is meshed with its matching gear. The power would then be transfered from one gear to the other and then through the splines to the mainshaft. Sliding gears used for reverse are mounted on a smooth, unsplined shaft because they will be engaging two gears at the same time. The disadvantage of sliding gears is that it is difficult to shift gears with the vehicle moving.

Constant mesh gears are always engaged with their mating gear and are mounted so that one of them can freewheel on its shaft. The gears are shifted by connecting the freewheeling gear to its shaft. This is done through a synchronizer assembly. The synchronizer is splined to the shaft and has a sleeve that can be slid into place to engage the gear to the synchronizer. The power will then be able to flow from the gear to the synchronizer and then to the shaft. The advantage of constant mesh gears is that the synchronizer will allow shifts to be made while the vehicle is moving and without the driver needing to do any extra clutching (see Figure 6-6).

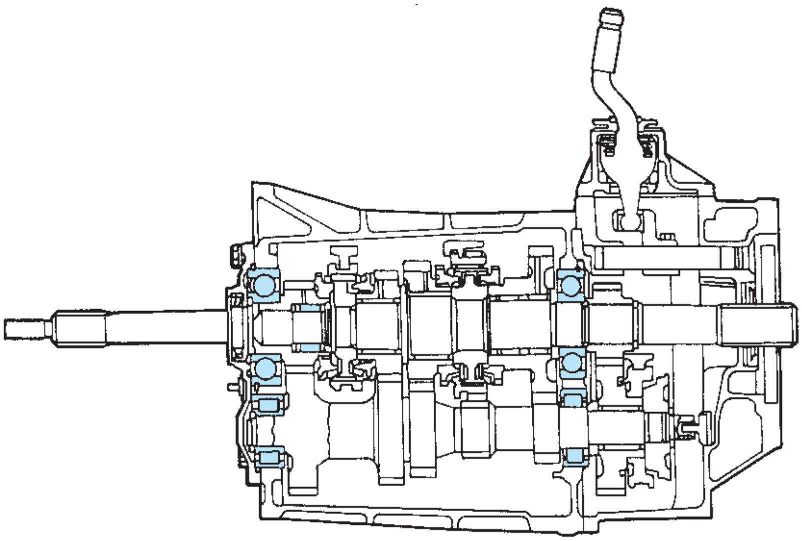


FIGURE 6-2 Bearings support the input shaft, countershaft, mainshaft, and speed gears (shaded). *(Courtesy of DaimlerChrysler Corporation)*

GEAR RATIOS

In all gear speeds but one, the power flows from the main drive gear (input) to the cluster gear and then from the cluster gear to the mainshaft (output) (Figure 6-3). The power passes through two gear sets. The exception is a 1:1 ratio, where the power flows directly from the main drive gear to the mainshaft. In older transmissions, this is high gear; in newer overdrive transmissions, this is third or fourth, one of the intermediate speeds.

All the forward gears are normally in **constant mesh** so they always rotate at their design speed relative to engine speed. The gears of the cluster gear rotate as an assembly. The output gears usually are mounted on the mainshaft so they float or rotate freely. These gears are called **speed gears**; they complete the ratio for each gear speed when they become coupled to the mainshaft. The mainshaft includes synchronizer assemblies for each pair of gear speeds and can lock the individual speed gears to the mainshaft. This is done for each shift.

The gear set for a simple sliding gear three-speed transmission is shown in Figure 6-4. In this gear set, there are essentially six gear ratios to be concerned with: the main drive gear to cluster gear, cluster gear to first gear, cluster gear to second gear, cluster gear to reverse idler gear, reverse idler gear to reverse gear, and main drive gear to output shaft. A four- or five-speed gear set is similar except that each additional speed requires a gear set consisting of one speed gear on the mainshaft and another on the cluster gear.

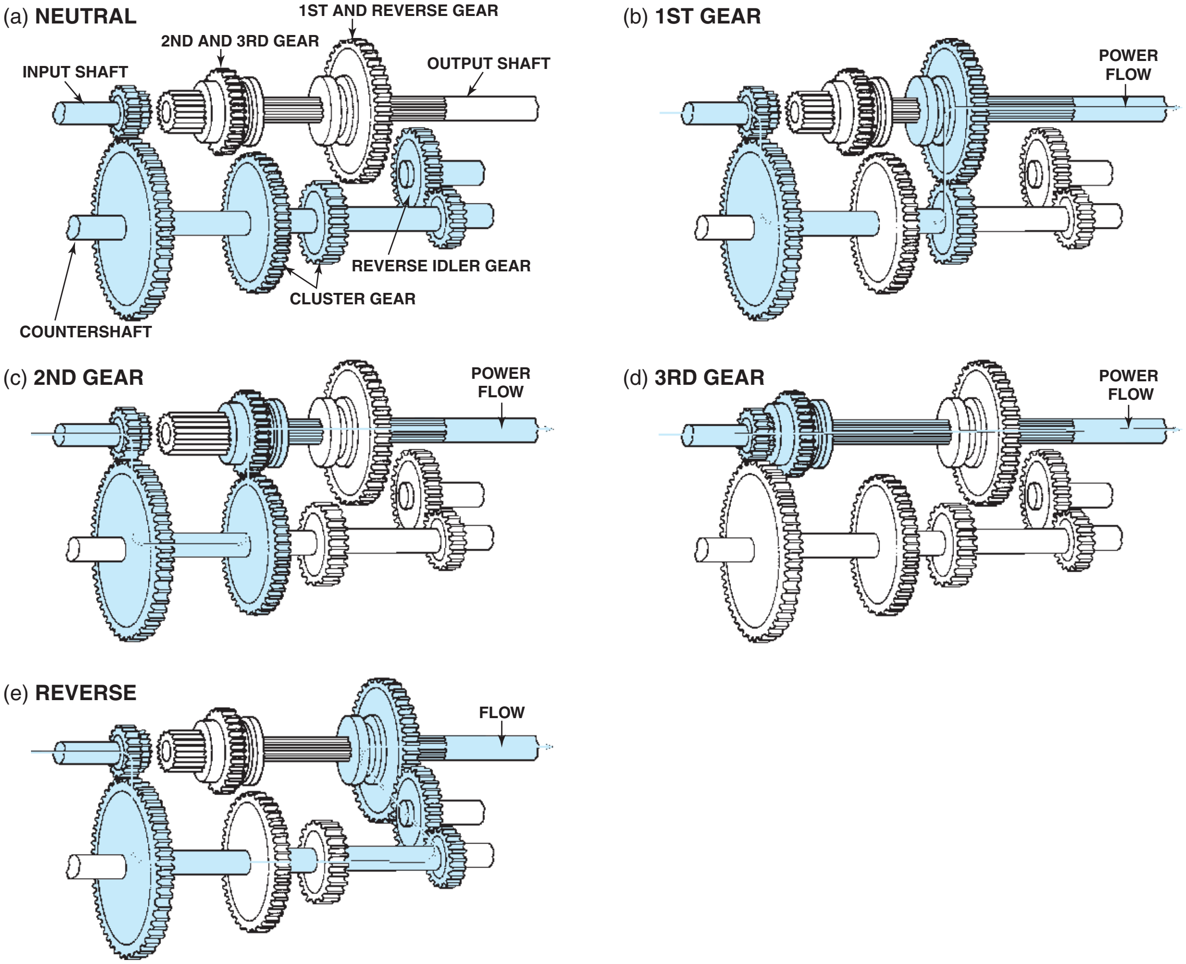


FIGURE 6-3 (a) Very simple transmission in neutral (no output gears in mesh); (b) first gear—the first–reverse gear is slid into mesh with the cluster gear; (c) second gear—the 2–3 sliding gear is in mesh with the cluster gear; (d) third gear—the 2–3 sliding gear is in mesh with the input shaft; and (e) reverse—the first–reverse gear is in mesh with the reverse idler gear.

To calculate the ratios for the transmission shown in Figure 6-4, start with the input ratio.

- In this gear set, the main drive gear has 20 teeth, and it is meshed with a 48-tooth gear at the front of the cluster. The ratio will be 48 (driven gear) ÷ 20 (driving gear), or 2.4:1. The engine will always rotate 2.4 times faster than the cluster gear (whenever the clutch is engaged).
- The cluster first gear has a 22-tooth gear, which drives the 40-tooth first and reverse gear. This ratio is 40 ÷ 20, or 1.82:1. The first-gear ratio will be 2.4 times 1.82, or 4.37:1.
- The cluster second gear has a 40-tooth gear, which drives the 30-tooth second gear; this ratio is 30 ÷ 40, or 0.75:1. The second-gear ratio will be 2.4 × 0.75, or 1.8:1.
- The third-gear power flow goes directly from the main drive gear to the output shaft, so the ratio is 1:1.
- The cluster reverse gear has a 20-tooth gear that drives the reverse idler gear, which drives the 40-tooth first and reverse gear; this ratio is 40 ÷ 20, or 2:1. The reverse-gear ratio will be 2.4 × 2, or 4.8:1. A simple idler gear, as shown, will have no effect on the gear ratio.

Because the gears in most transmissions are in constant mesh, they will always rotate at their gear ratio speed relative to the input shaft gear. In high gear, with a ratio of 1:1 (and first- and second-gear ratios of 2.07:1 and 1.46:1), you can drive down the road with an engine and mainshaft speed of 2000 rpm. The first-speed gear in this transmission will be turning at 966 rpm (2000 ÷ 2.07), and the second-speed gear will be turning at 1370 rpm (2000 ÷ 1.46).

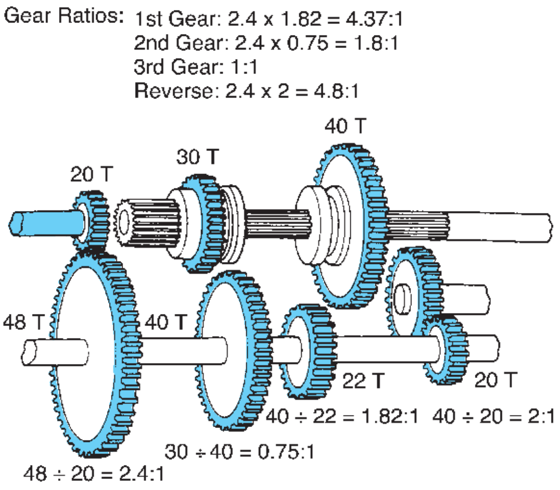


FIGURE 6-4 A transmission's gear ratios are computed by determining the ratios for each gear set and then multiplying the input gear set ratio by the ratio of the first, second, and reverse sets.

REVERSE

Reverse requires one more gear in the gear train. Remember that when one external gear drives another, they will rotate in opposite directions. In a transmission, the input shaft gear rotates in a clockwise direction (the same as the engine), the cluster gear rotates in a counterclockwise direction, the mainshaft rotates clockwise when driven either through the gear train or by the direct coupling (Figure 6-5a).

To make the vehicle back up, the mainshaft must rotate counterclockwise. To accomplish this, an **idler gear** is meshed between the cluster gear and the reverse gear on the mainshaft (Figure 6-5b). A simple idler will not change the ratio, but it will cause a reversal of rotation. The idler gears used in some transmissions are long, with a gear of one size meshed with the cluster gear and a different-sized gear to mesh with the reverse gear. This idler gear will affect the ratio such that the overall ratio becomes

> main drive gear to cluster gear ratio × cluster gear to idler gear ratio × idler gear to reverse gear ratio

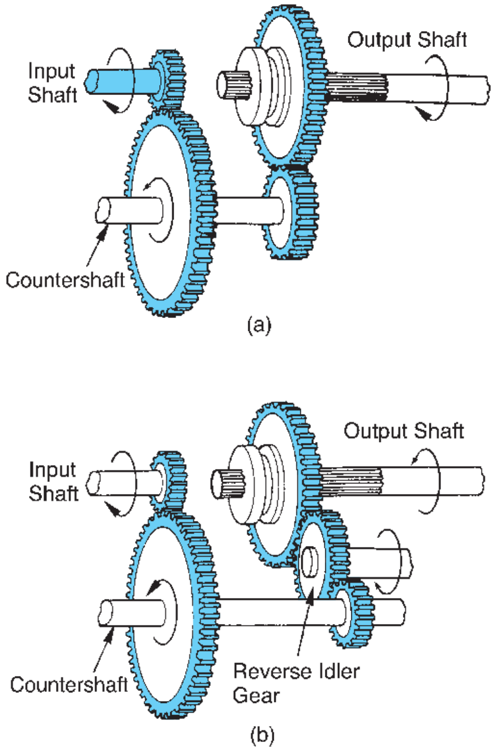
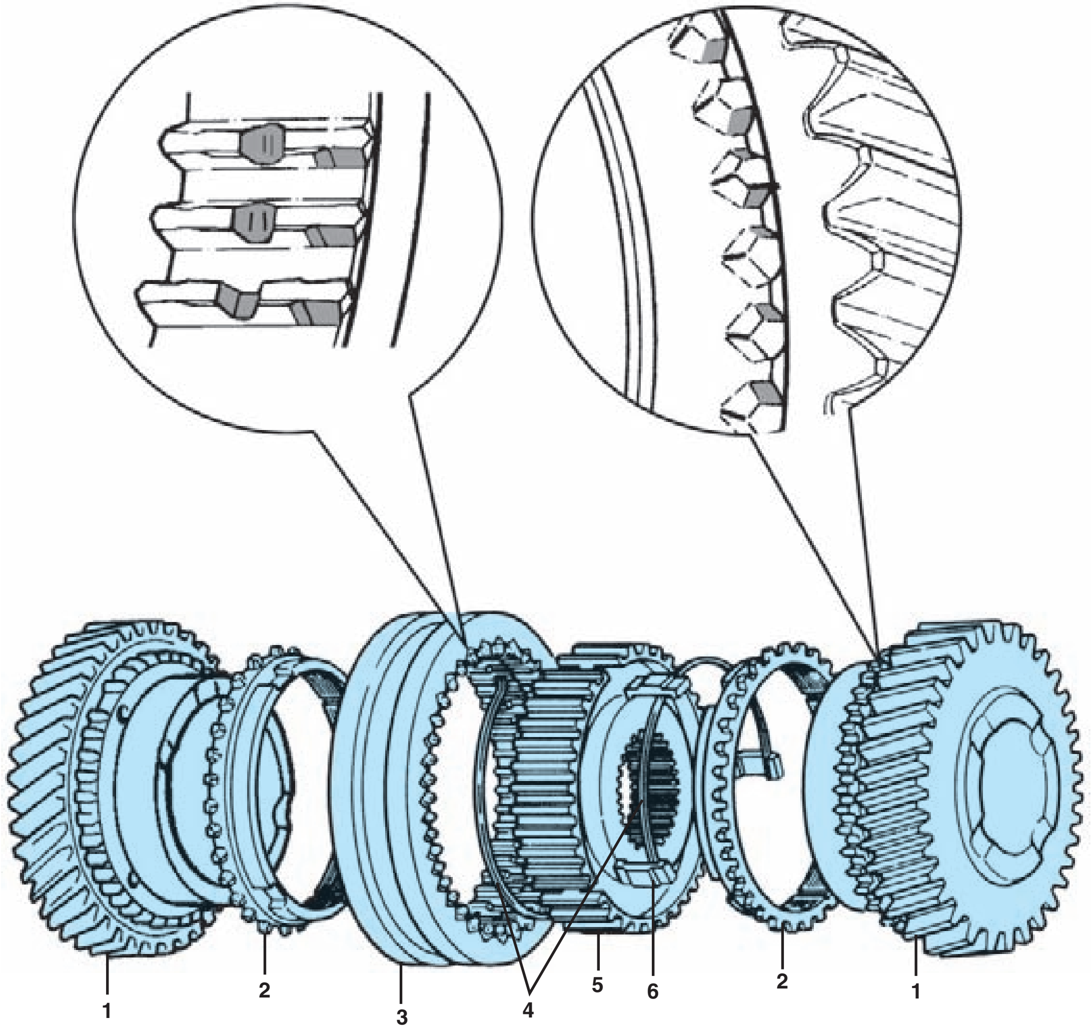


FIGURE 6-5 (a) The input shaft rotates in a clockwise direction; the countershaft rotates in a counterclockwise direction; and the first–reverse gear drives the output shaft in a clockwise direction. (b) When meshed with the idler gear, the first–reverse gear will be driven in a counterclockwise direction. A simple (single) idler is shown.

SYNCHRONIZERS

Most transmissions use synchronizer assemblies for all the shifts except reverse. A few transmissions, however, use a synchronizer for the reverse shift. A **synchronizer assembly** includes (Figure 6-6):

- A **hub,** which is secured to the mainshaft, has external splines to match the sleeve.
- A **sleeve** with internal splines, which is slid to one side or the other over the hub to make a shift.
- A pair of **blocker rings**, also called **synchronizer rings**, which have external teeth to match the sleeve and an internal cone clutch surface.
- A set of three spring-loaded **keys**, also called **struts**, **insert plates**, or **dogs**.
- A speed gear with a set of **dog clutch teeth** and a polished, external cone clutch surface on the speed gear. Typ-



1. SPEED GEAR
2. BLOCKER RING
3. SYNCHRONIZER SLEEVE
4. ENERGIZER SPRING
5. SYNCHRONIZER HUB
6. KEY

FIGURE 6-6 A synchronizer assembly that uses brass blocker rings. Note the shape of the speed gear clutch teeth and the sleeve's inner splines. *(Courtesy of Toyota Motor Sales USA, Inc.)*

ically there is a speed gear on each side of the hub and sleeve.

It is the synchronizer's job to lock a speed gear to the mainshaft without gear clashing. To do this, it must block the shift until the synchronizer sleeve and the gear are rotating at the same speed. This requires slowing the clutch disc, input shaft gear, clutch shaft, cluster gear, and the gear being shifted into, as well as the other speed gears.

Follow what occurs through a 1–2 shift. Assume that the first-gear ratio is 2:1, the second-gear ratio is 1.5:1, and the engine speed before the shift is 4000 rpm. At the time of the shift, the mainshaft will be revolving at 2000 rpm, one-half of the engine speed, and the second gear will be revolving at 3000 rpm (2000 × 1.5). The clutch disc speed will have to drop to 3000 rpm to bring the second gear to the same speed as the mainshaft (3000 ÷ 1.5 = 2000). When the clutch is released, the disc and related parts will begin slowing down, but not fast enough to avoid gear clash, especially if the shift is rushed.

To begin a shift with synchronized shift, the action follows this sequence (Figure 6-7):

1. When the shift lever begins moving, the sleeve moves toward the gear being engaged and the spring-loaded keys follow the sleeve and, in turn, push the synchronizer ring against the gear's cone clutch surface.
2. The synchronizer ring and gear cone clutches contact, the gear speed difference makes the synchronizer ring rotate, about one-half the width of a spline.
3. The rotation of the ring blocks further movement of the sleeve, but sleeve pressure causes the braking action of the cone clutch to slow the gear.
4. The engaging gear slows and reaches the same speed as the hub and sleeve. It will rotate slightly backward relative to the sleeve to stop blocking the shift.
5. The sleeve moves sideways over the clutching teeth (dog clutch) of the engaging gear, and the shift is completed.

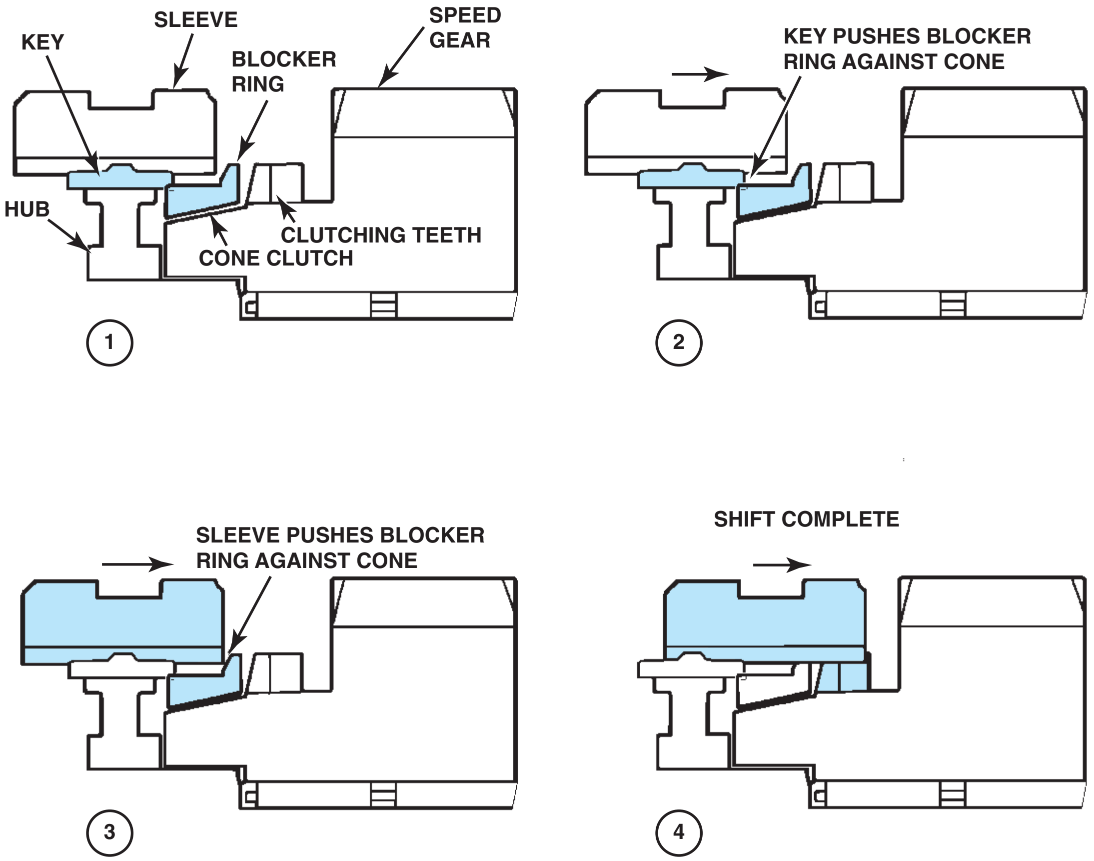


FIGURE 6-7 A synchronized shift begins as the shift fork moves the sleeve toward the speed gear (1). The keys push the blocker ring against the cone (2). The cone's rotation will rotate the ring out of alignment with the sleeve so the sleeve will force the ring against the cone (3). As the speed of the sleeve and cone become equal, the blocker ring rotates to align with the sleeve, and the sleeve will slide into mesh with the clutching teeth (4).

Synchronizer action occurs every time you make an upshift. A downshift is the same except that the synchronizing action must speed up the gear to be engaged. Occasionally, you can hear this occur when you make a downshift.

A synchronizer assembly has three positions: neutral in the middle plus two gear speeds. All three-speed transmissions have a 2–3 synchronizer; some also have a synchronized first gear. A four-speed transmission will normally have two synchronizer assemblies, a 1–2 and a 3–4. A five- or six-speed transmission will require an additional synchronizer. Other styles of synchronizers are used in a few transmissions, but they are uncommon and are not described in this book.

Traditionally, the synchronizer ring has been made from brass and has a series of sharp grooves on the internal cone surface (Figure 6-8). These grooves break through the lubricating film on the mating gear's cone clutch surface. The grooves also hold lubricant so that they will break free and not wedge in place. Many newer transmission use **composite rings** that are lined with carbon-, metal-, or paper-based composite material for improved shift feel or durability. Some of these materials are similar to those used to line automatic transmission clutch plates. Transmissions using paper-lined rings must use a special manual transmission fluid (MTF) or automatic transmission fluid (ATF) for lubricant. Some synchronizers use a **double cone**, with an outer cone and an inner cone along with the blocker ring. The multiple cones provide more surface area for better synchronization and longer service life.

Synchronizer sleeves have a slight back cut (taper) at the ends of the splines, which matches a similar back cut on the clutch teeth of the speed gears (Figure 6-9). This back cut tends to lock the gears in engagement to prevent the sleeve from jumping out of mesh. To slide out of mesh, the driven sleeve would have to speed up or the speed gear would have to slow down.

POWER FLOW

Shifting into a gear involves moving a synchronizer sleeve or a gear into mesh to make a connection between the mainshaft and that speed gear. The three-speed transmission has four possible power paths, and they are first (low), second, third (high), and reverse (Figure 6-10). As the power flows through each of these paths, the amount of torque and speed or the direction of rotation is altered by each gear set.

As more gear speeds are added, the major difference is that the transmission becomes longer and more complex. Each gear speed requires a driven speed gear, a driving gear on the cluster gear, and one-half of a synchronizer assembly. In some cases, the synchronizer assembly can be on the cluster gear to select which of the driving gears will transfer power (Figure 6-11). Another variation is the

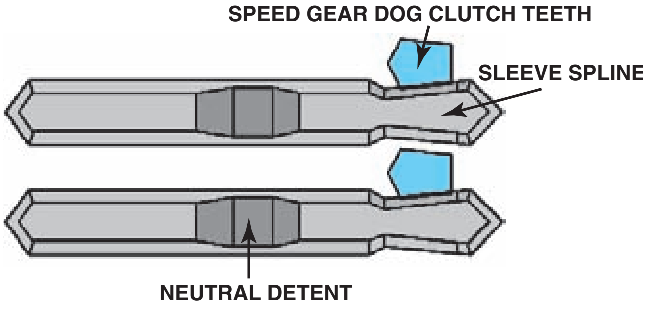


FIGURE 6-9 The splines in the sleeve and the dog clutch teeth have a slight back-taper or back-cut to hold them in mesh as the vehicle is driven. *(Courtesy of Toyota Motor Sales USA, Inc.)*

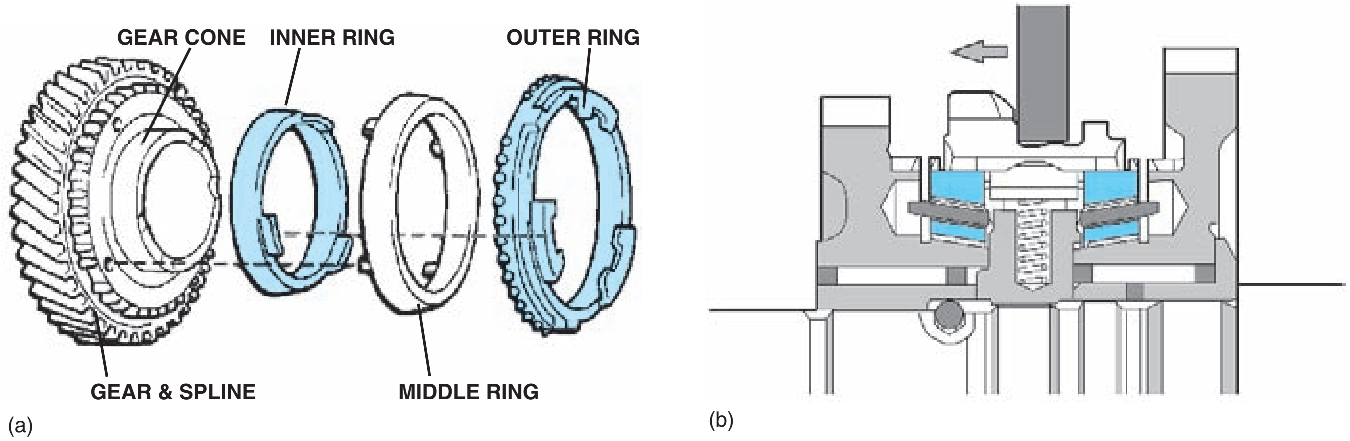


FIGURE 6-8 Exploded (a) and cutaway (b) views of a triple-cone synchronizer. The inner and outer rings rotate with the synchronizer sleeve while the middle ring rotates with the speed gear. *(Courtesy of Toyota Motor Sales USA, Inc.)*

power flow for reverse. Some transmissions mount the reverse driven gear on the 1–2 synchronizer sleeve, and the shift into reverse is made by sliding the reverse idler into mesh with the reverse cluster gear and the reverse driven gear. Some transmissions mount the reverse driven gear as a speed gear on the mainshaft and use a sliding-sleeve shift. Other transmissions use a synchronizer, just like they do for a forward gear.

FOUR-SPEED TRANSMISSIONS

A four-speed transmission requires an additional gear on the cluster gear, a matching gear on the mainshaft, and a synchronizer to connect this gear to the mainshaft. Note that in the transmission shown in Figure 6-12 the second cluster gear is

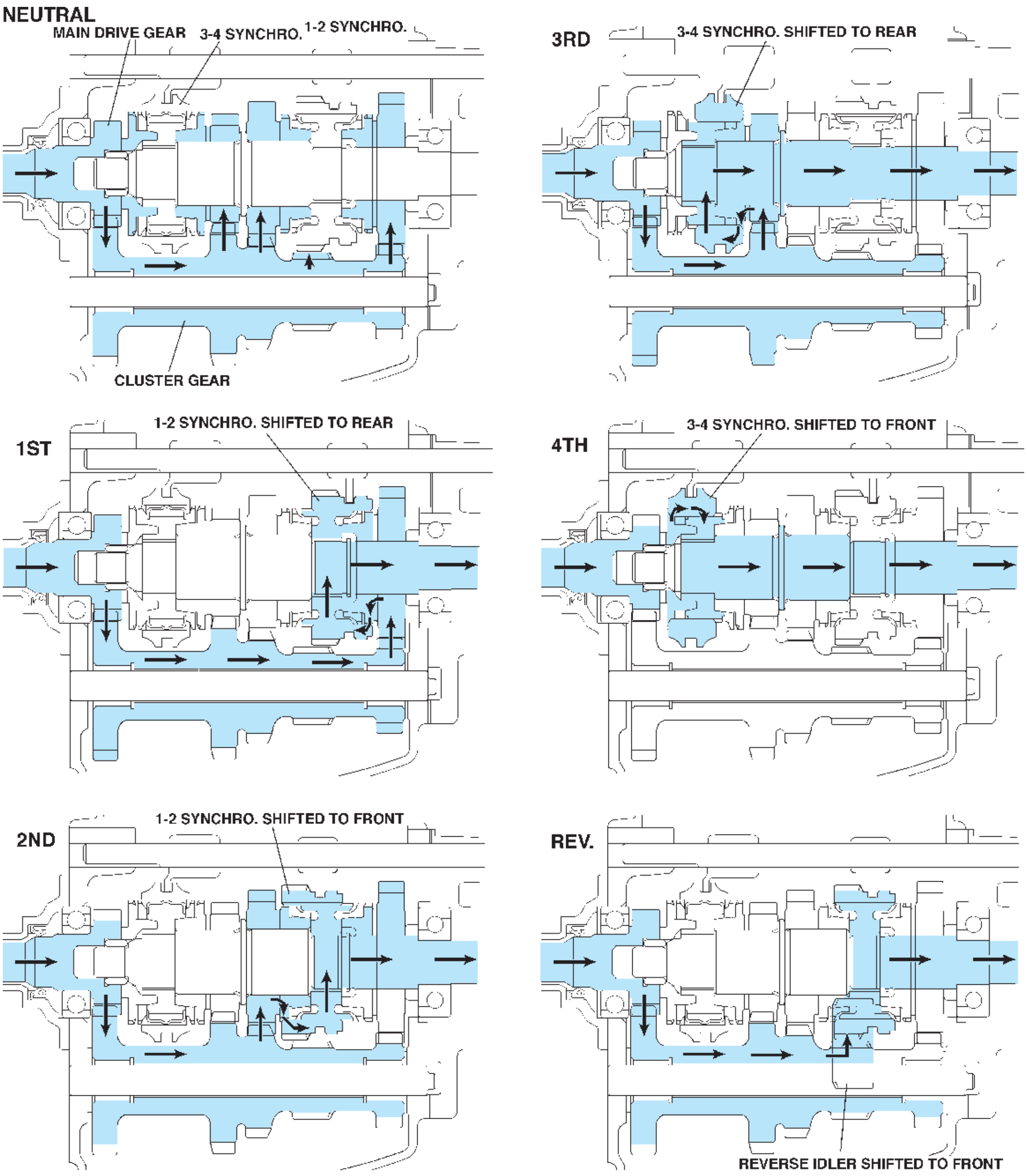


FIGURE 6-10 Power flows through a four-speed transmission. Note how the 1–2 and 3–4 synchronizer sleeves and the reverse idler gear are moved for the shifts.

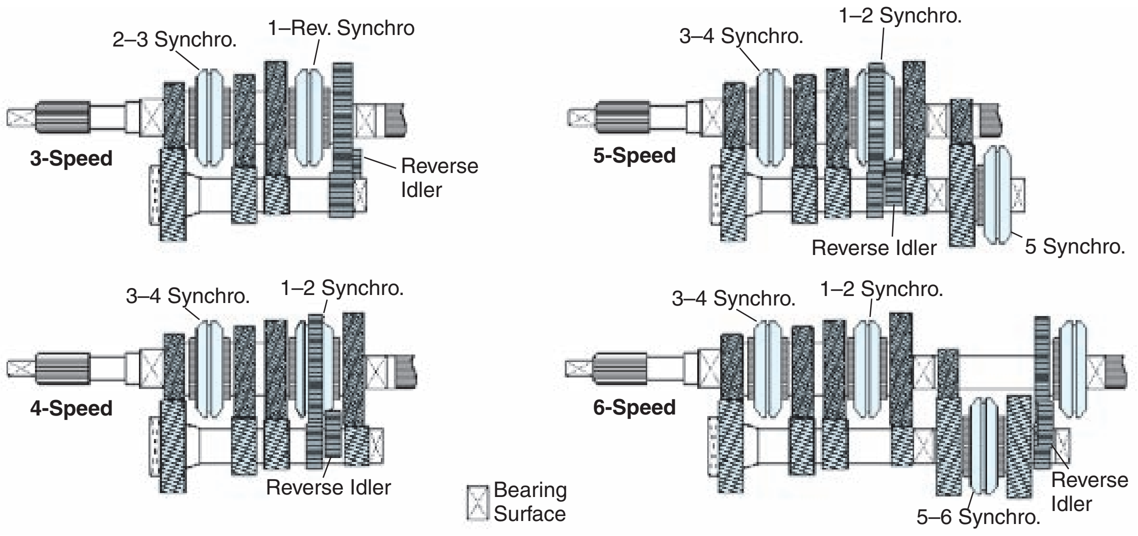


FIGURE 6-11 A comparison of three-, four-, five-, and six-speed transmissions shows the major differences to be the length of the unit and the number of synchronizer assemblies.

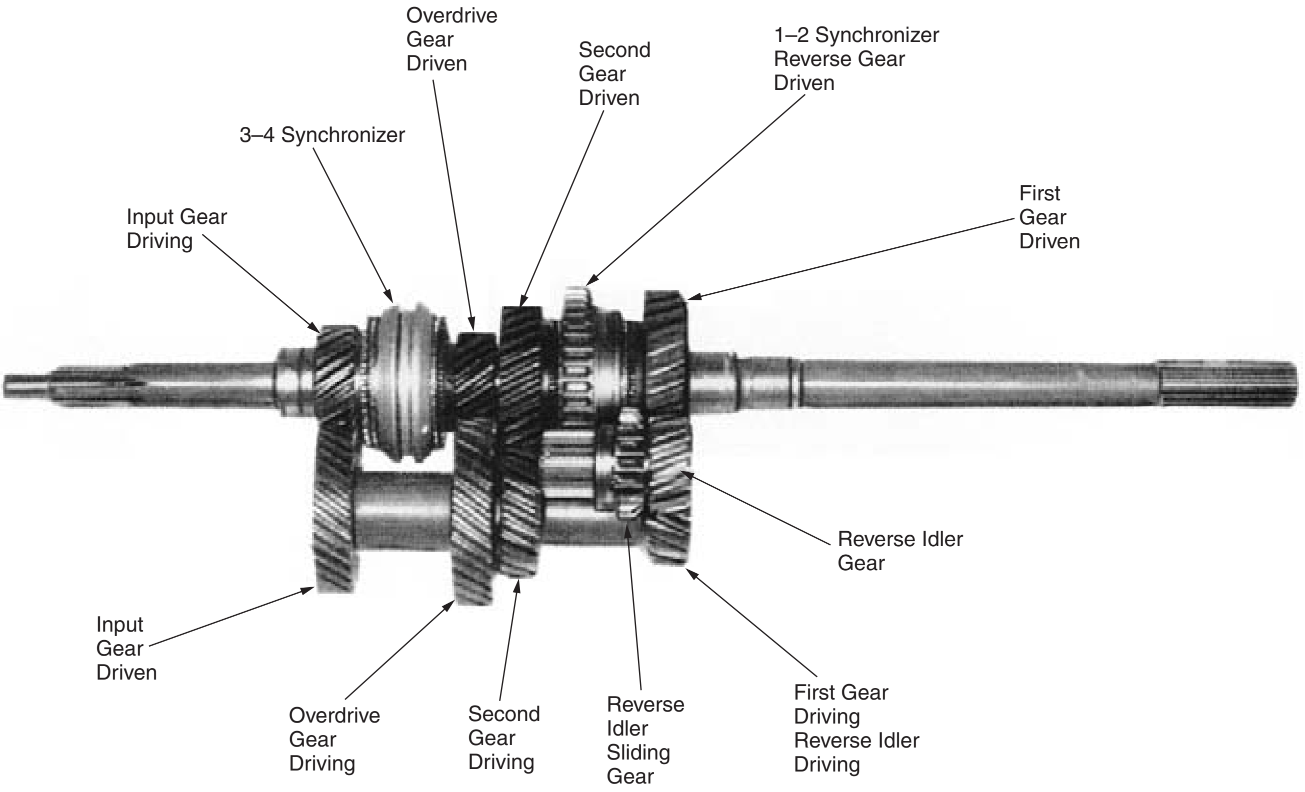


FIGURE 6-12 This four-speed transmission with an overdrive fourth gear. Note that the idler is shifted to engage reverse. *(Courtesy of Ford Motor Company)*

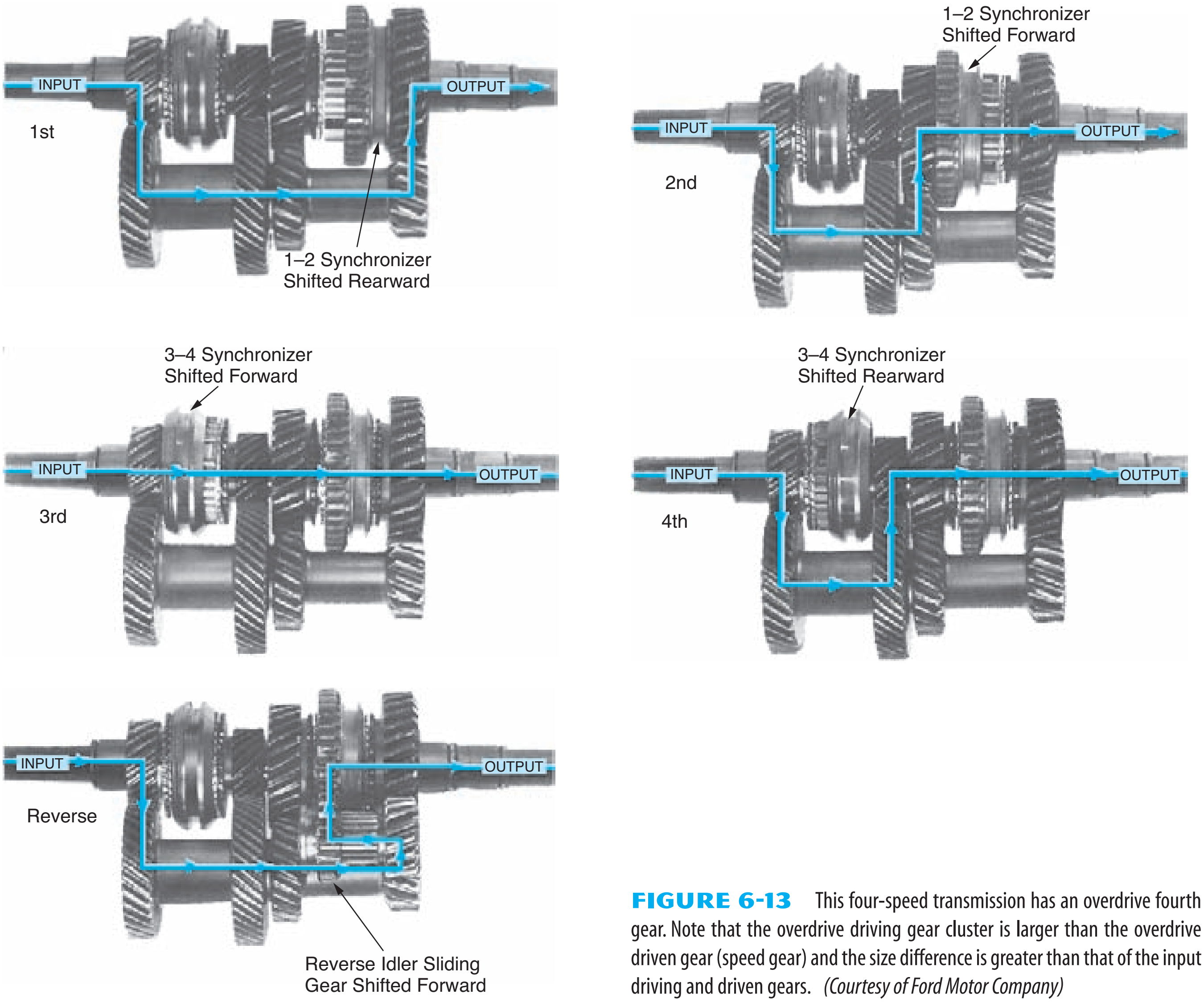


FIGURE 6-13 This four-speed transmission has an overdrive fourth gear. Note that the overdrive driving gear cluster is larger than the overdrive driven gear (speed gear) and the size difference is greater than that of the input driving and driven gears. *(Courtesy of Ford Motor Company)*

larger than the first cluster gear, and the main drive gear is also larger than the gear on the other side of the 3–4 synchronizer. In this transmission, third gear will have a 1:1 ratio, and fourth gear will be an **overdrive** (Figure 6-13). This fourth gear will not be as efficient as third, even though it will reduce engine speed and improve fuel mileage. Sending the power flow through the cluster gear produces a small amount of load on the bearings, which causes a slight power loss, making the transmission about 85 percent efficient. In a 1:1 ratio with the input connected to the main shaft, a transmission is about 90 to 92 percent efficient.

To shift into reverse, some four-speed transmissions place the reverse gear on the 1–2 synchronizer sleeve and slide the reverse idler into mesh with it and the cluster gear. Some transmissions locate the reverse gear in the extension housing.

The four-speed transmissions used in many pickups and older vehicles usually have a fourth-gear ratio of 1:1. The first-gear ratio in some pickups is very low, about 4:1 or 6:1, and this is often called a “granny gear.” Some passenger vehicles have “close ratio” four-speeds, where the first-gear ratio is about 2.2:1, the fourth-gear ratio is 1:1, and the second- and third-gear ratios are between these. Close ratios allow a shift between gears with a minimal loss of engine rpm. The wide-ratio four-speed transmissions have a first-gear ratio of about 2.8:1. In many cases, the physical difference between the wide- and close-ratio versions of a particular transmission will be the size of the main drive gear and the number 1 gear on the cluster gear, all the other gears will be the same (Figure 6-14). Remember that the ratio of the main drive gear to the cluster gear affects all the other ratios except the direct drive.

Typical Ratios	*Close Ratio*	*Wide Ratio*
1st	3.50:1	4.03:1
2nd	2.14:1	2.37:1
3rd	1.89:1	1.49:1
4th	1.00:1	1.00:1
Reverse	3.39:1	3.76:1

FIGURE 6-14 The T4 transmission is available in two different ratios, as shown here. The close-ratio version has a 3.50:1 first-gear ratio, and the wide-ratio version has a 4.03:1 first-gear ratio. *(Courtesy of BWD Automotive Corporation)*

FIVE-SPEED TRANSMISSIONS

A five-speed transmission requires an additional gear on the cluster gear and on the mainshaft, plus another synchronizer (Figure 6-15). The synchronizer can be on the mainshaft with the other gears or on the cluster gear. In most cases, a five-speed transmission will have three forward reduction ratios (first, second, and third gears), a 1:1 fourth-gear ratio, and an overdrive fifth gear.

Most transmissions are built with a variety of ratios for each gear to suit the particular vehicle. Engine size and vehicle weight are used to determine the best gear ratios for the vehicle (Figure 6-16). Heavy vehicles and small engines require lower first gears, with corresponding lower ratios in the other gear speeds.

Five-Speed Variation

The M5R4 transmission, used in later-model Ford Explorers, has a redesigned gear arrangement (Figure 6-17). The first, second, third, fifth, and reverse driving gears along with the 3–4 synchronizer are mounted on the longer-than-normal input shaft. The short mainshaft has the output shaft gear and the clutch teeth for fourth gear. The 1–2 and 5–R synchronizer assemblies are mounted on the countershaft.

SIX-SPEED TRANSMISSIONS

A six-speed transmission requires one more gear on the cluster, an additional speed gear, and one-half of a synchronizer assembly (Figure 6-18). This increases the weight, length, and cost of the unit. The additional gear is usually another overdrive ratio. Some six-speeds have low and high gear ratios similar to those of a five-speed, with the ratios closer together (see Figure 16-22). Six-speed transmissions are used in performance-oriented vehicles where the additional cost is less of a problem.

TRANSMISSION TORQUE CAPACITY

A transmission is designed to be strong enough to handle a certain amount of torque. High torque requires large input shafts, even larger output shafts, big wide gears, and large bearings. This increases the weight of the transmission and also increases the drag and power loss in the unit. Smaller transmissions improve fuel mileage, but they can break under load if they are too small. Exceeding the transmission's designed torque capacity will cause failure.

To get an idea of what higher torque load requires, compare the diameter of the input and output shafts of a transmission. The torque increase from first gear requires the larger output shaft.

SHIFT MECHANISMS

When the driver moves the gearshift lever, the shift mechanism moves one or two synchronizer sleeves or gears to engage the desired gear speed. The standard shift lever motion is in an H pattern for a three-speed with an extension for a four-speed or a double H pattern for a five-speed. As the lever is moved across the H, the transmission is in neutral and a shift lever is being selected. Moving the shifter into one of the arms of the H moves a shift fork to engage a gear (Figure 6-19). During an upshift or downshift, one synchronizer sleeve is moved to neutral before the sleeve of the desired gear is moved to engage the desired gear.

Many transmissions use internal linkage with everything mounted inside of the transmission case. With transmissions using external linkage, shift motion is transmitted from the shift lever to the transmission by a group of two or three metal rods (Figure 6-20).

A shift mechanism must include two features, an **interlock** system and a series of **detents** (Figure 6-21). Some transmissions also include a reverse lockout. The interlock prevents engagement of more than one gear at a time. It is impossible for the transmission to transmit power through two different ratios and have two different output shaft speeds at the same time. If two gears are engaged, the transmission will lock up, and both the input and output shafts will freeze and become stationary. A technician may do this intentionally at times during an overhaul if it is necessary to hold the input or output shaft from rotating.

The detents are used to locate the internal **shift forks** in one of their three positions. A detent is usually a spring-loaded ball or bullet-shaped rod that is pushed into one of a series of

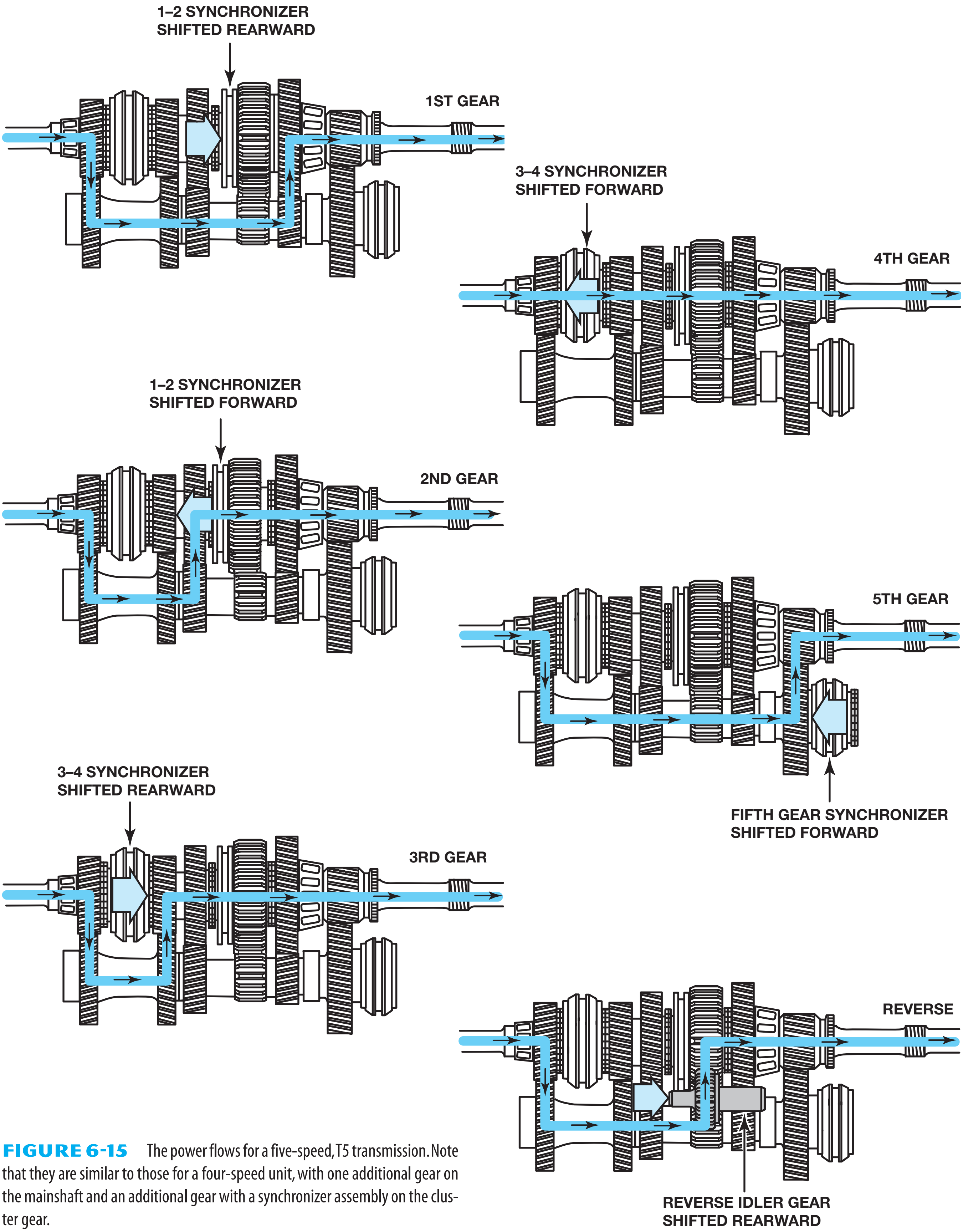


FIGURE 6-15 The power flows for a five-speed, T5 transmission. Note that they are similar to those for a four-speed unit, with one additional gear on the mainshaft and an additional gear with a synchronizer assembly on the cluster gear.

	Close Ratio		*Wide Ratio*
1st	2.95:1	3.35:1	3.97:1
2nd	1.94:1	1.99:1	2.34:1
3rd	1.34:1	1.33:1	1.46:1
4th	1.00:1	1.00:1	1.00:1
5th	.73:1	.68:1	.79:1
Rev.	2.76:1	3.15:1	3.70:1

FIGURE 6-16 Ratios for three versions of a T5 transmission. *(Courtesy of BWD Automotive Group)*

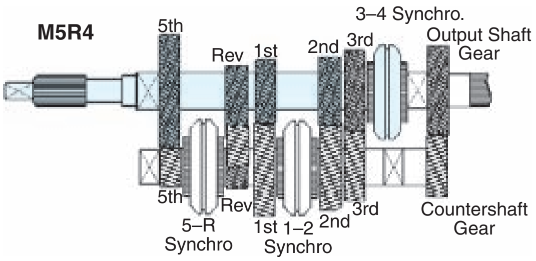


FIGURE 6-17 The M5R4 five-speed transmission has a long input shaft with four fixed gears, one speed gear, and the 3–4 synchronizer assembly. The countershaft has two fixed gears plus two synchronizer assemblies and four speed gears. The mainshaft has only one fixed gear and the dog clutch teeth for fourth gear (direct drive).

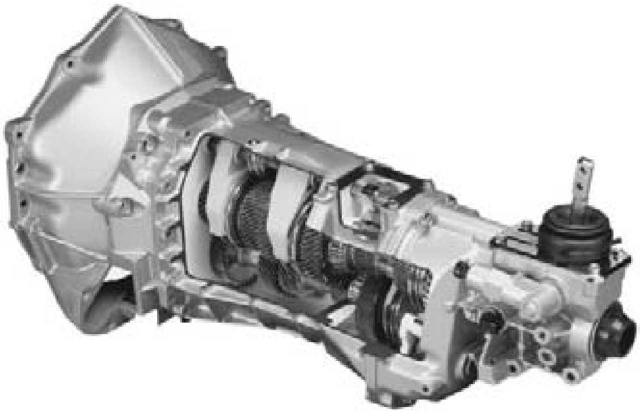


FIGURE 6-18 A T56, six-speed transmission. First through fourth gears are in the main case; fifth, sixth, and reverse gears are located in the extension housing. *(Courtesy of Transmission Technologies Corporation, TTC)*

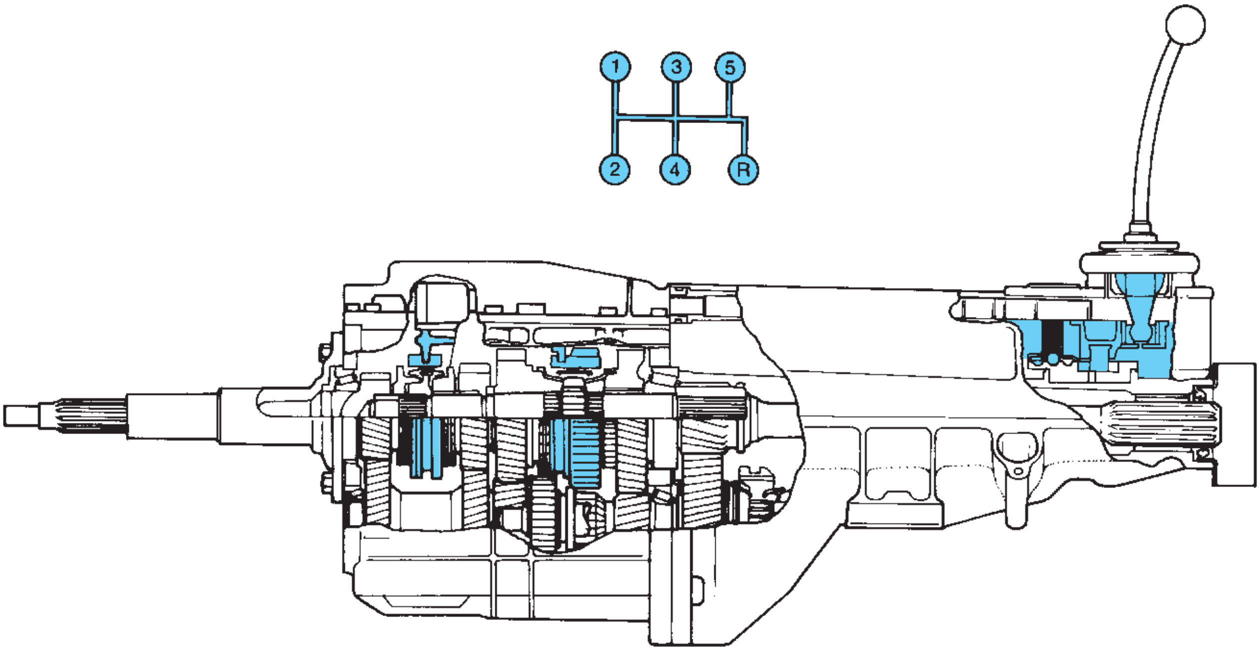


FIGURE 6-19 When the gearshift lever is moved, the internal linkage (shift rails) moves the shift fork and synchronizer sleeve to shift gear speeds. *(Courtesy of BWD Automotive Corporation)*

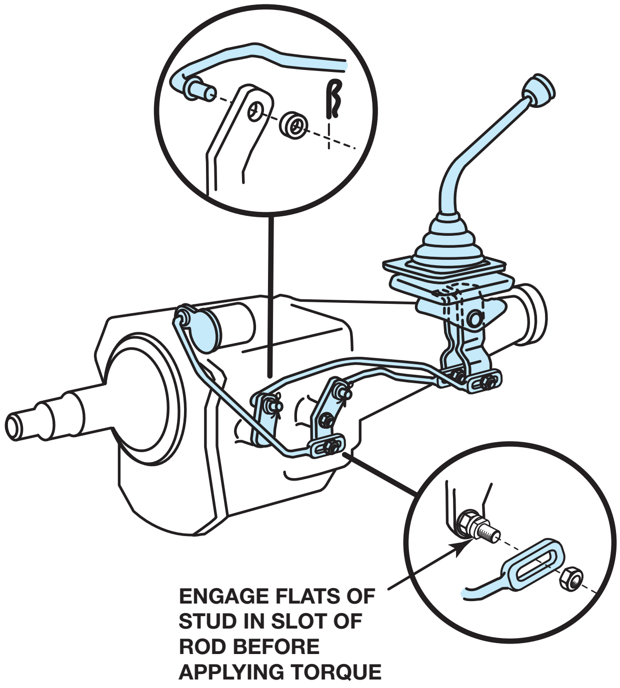


FIGURE 6-20 External linkage (shift rods) is used to transmit shift motions from the shift levers to the transmission levers.

three notches or a spring-loaded lever with three notches that drop over a cam (Figure 6-22). As you shift gears, you can feel the detents as they engage and disengage the shift rails or cams. Most synchronizers have three detent positions—neutral plus a gear to each side. The synchronizer sleeve is moved by a shift fork that is mounted on either a rail or a cam. A **rail** is a metal rod that slides lengthwise; a **cam** usually pivots on its shaft, which extends out the side of the case or side cover. Since it must contact and move the spinning synchronizer sleeve, the contact surfaces of the fork will be either hardened steel, bronze, or a low-friction plastic/nylon pad attached to the fork. After the sleeve/gear has been positioned, there should be little contact between the fork and the sleeve/gear. At this time, the fork is located by the detent. The sleeve is located by the synchronizer keys when in neutral and by the dog clutch teeth on the mating gear when it is shifted.

A reverse lockout mechanism is used to prevent accidental engagement of reverse while making an upshift. This mechanism requires the driver to perform an additional operation to shift into reverse. This might require that the shift lever be pushed downward or lifted up, or there may be an additional lever or button to be pushed. Some transmissions use a stronger shift lever centering spring so it takes extra effort to move the shifter to select the reverse shift rail.

The detents, shift rails, and forks are not designed to hold the gear or sleeve into mesh, only to position it completely into mesh. The cut of the sleeve or gear is what actually keeps it into mesh during the different driving situations. Holding a gear into mesh with the fork will cause rather rapid wear of the fork and fork groove.

External Linkage

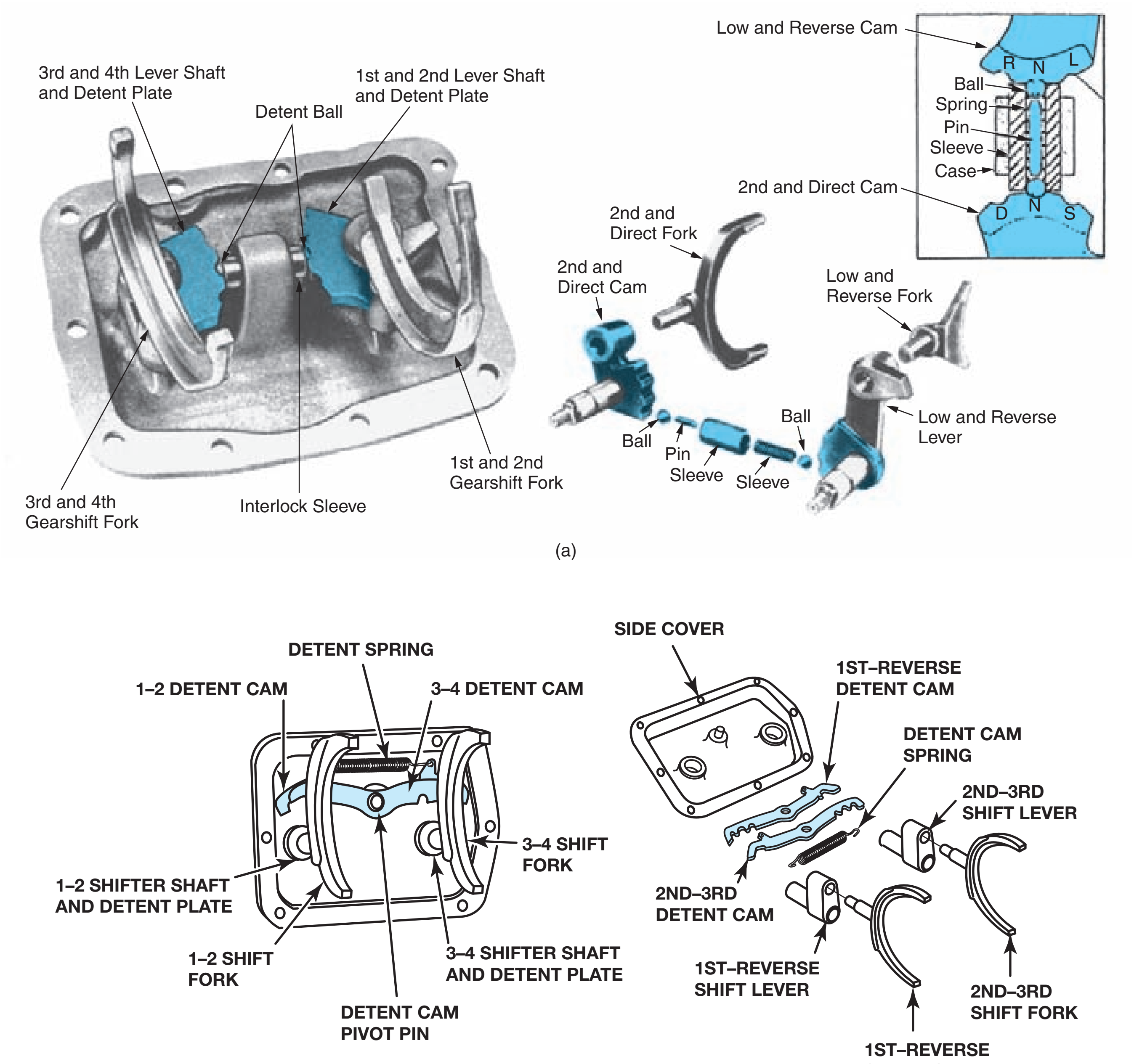
External shift linkage is normally attached to the transmission extension housing for floor shifts or is made as part of the steering column for column shifts. These assemblies have the gear selector arm mounted in such a way that it can swing and pivot to select the desired gear. The assemblies include a shift lever that is connected to each shift lever on the transmission by an adjustable rod. A four-speed transmission will have a 1–2 shift lever at both the shifter and the transmission connected by the 1–2 shift rod. There will also be a pair of 3–4 shift levers plus a 3–4 shift rod and a pair of reverse levers with a reverse shift rod.

When the gearshift/selector is moved laterally, across the car in a floor shift or parallel to the steering column in a column shift, a crossover blade at the end of the selector lever moves from one shift lever to the other to select a 1–2, 3–4, or reverse shift. Next, when the selector lever is moved lengthwise to the car (floor shift) or up or down (column shift), that shift lever is moved and, in turn, moves the corresponding lever at the transmission and the desired sleeve/gear inside the transmission.

Internal Linkage

In light-duty vehicle transmissions, the gearshift lever is normally mounted in the extension housing with one or more shift rails that transmit the shifting motions to the main case. In trucks and heavy duty vehicles, the shift assembly is built into the top cover of the transmission case (Figure 6-23). The selector lever with its pivot, the shift rails with the forks attached, and the detents and interlocks are all in this assembly.

A passenger vehicle transmission linkage is more complex, especially five-speeds and some four-speeds, where shift motions have to get to both the mainshaft and countershaft areas of the transmission. There are quite a number of methods to do this, but they all work in essentially the same manner. Sideways motion of the selector lever will cause the selector lever either to engage one of the shift rails or to rotate a single rail to engage one of several shift forks, plates, or rails (Figure 6-24). As the selected fork, plate, or rail is engaged, the interlock moves to lock the other rails to keep them from moving. Lengthwise motion of the shift lever will move the selected rail or plate, its fork, and the sleeve or gear into mesh.



(a)

(b)

FIGURE 6-21 Every shift linkage includes detents to position the shift forks and an interlock(s) to prevent movement of more than one fork at a time. The styles shown in both an assembled and exploded form include cams and spring-loaded balls with an interlock sleeve (a), spring-loaded lever-type detent (and interlock) cams (b), rails with interlock pins and spring-loaded detent balls (c), and rail with interlock plate and spring-loaded detent ball (d). *(a is courtesy of DaimlerChrysler Corporation; c is courtesy of Ford Motor Company; d is courtesy of BWD Automotive Corporation)*

Some modern six-speed transmissions include a reverse lockout to prevent shifting into reverse gear while the vehicle is moving forward. The six-speed shift pattern along with a synchronized reverse gear make a shift into reverse quite possible, and power train damage could easily occur. This mechanism uses an electric solenoid that is electronically controlled by the vehicle's electronic control module (ECM). The operation is described in Chapter 15.

Automated Manual Transmissions

Manual transmissions are considered more fuel-efficient than automatic transmissions, but many drivers prefer the driving ease of an automatic transmission. **Automated manual transmissions (AMT)**, also called *dual clutch transmissions (DCT)* or *direct shift gearbox (DSG)* provide easy shift control,

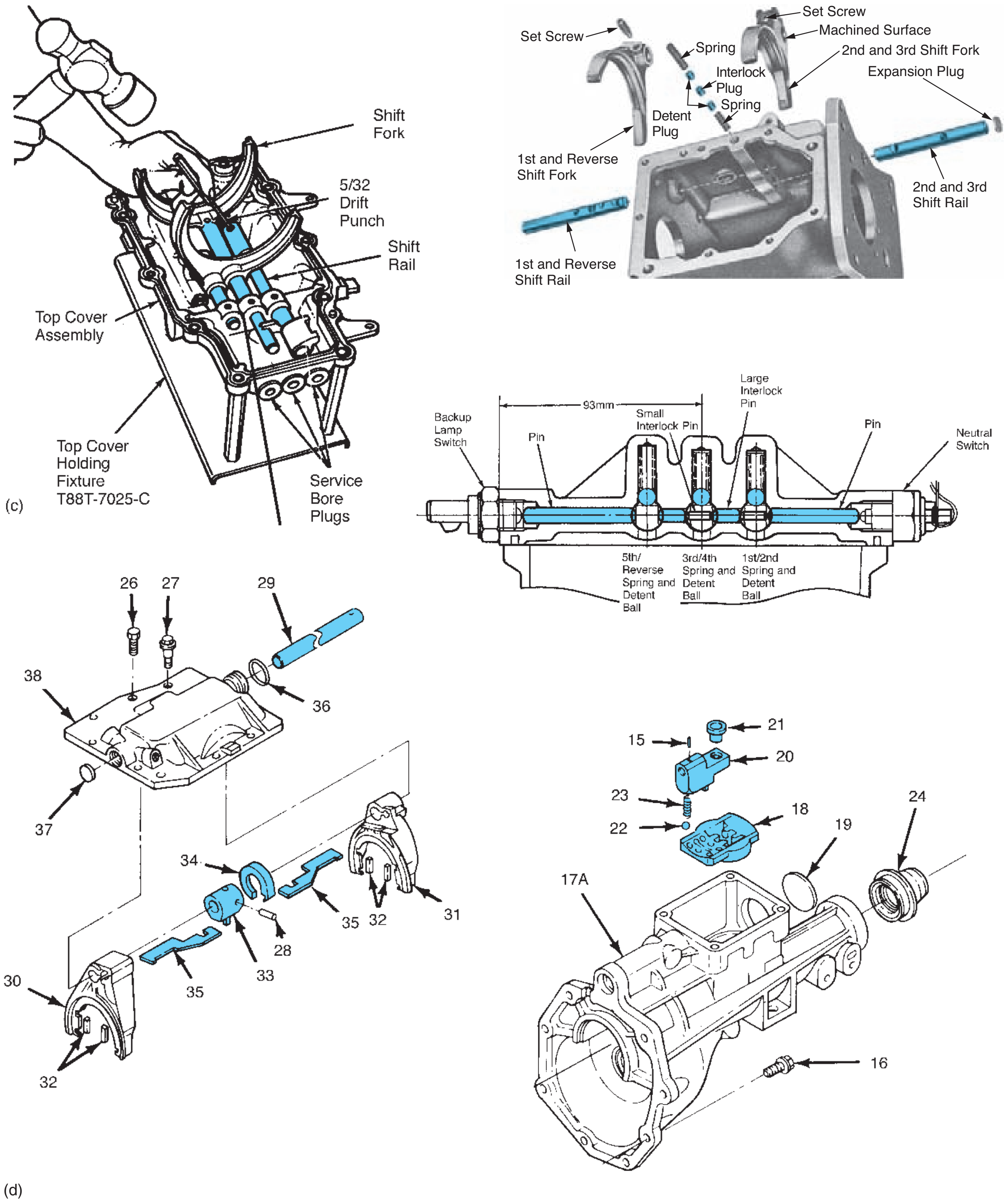


FIGURE 6-21 *(Continued)* *Key:* 15, roll pin; 16, bolt; 17, extension assy; 18, detent guide plate; 19, plug; 20, offset lever; 21, damper sleeve; 22, ball; 23, spring; 24, oil seal; 28, selector arm pin; 29, shifter shaft; 30, 3–4 shift fork; 31, 1–2 shift fork; 32, insert; 33, selector arm assy; 34, interlock plate; 35, selector plate; 36, O-ring; 37, plug; 38, case cover; 117, case assy.

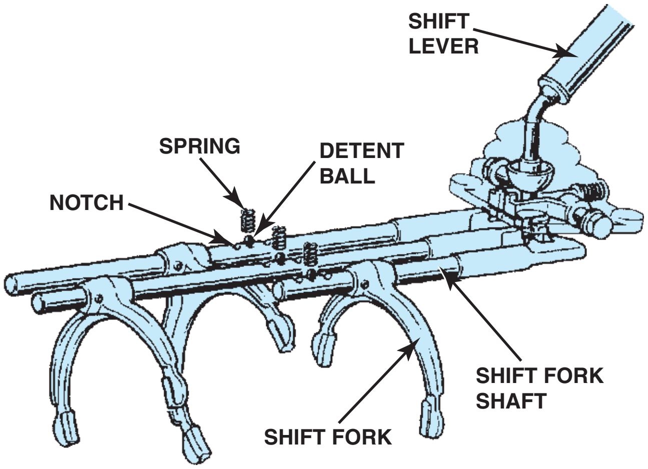


FIGURE 6-22 The detent notches in the shift shafts are designed to hold the shift shaft in one of the three positions. *(Courtesy of DaimlerChrysler Corporation)*

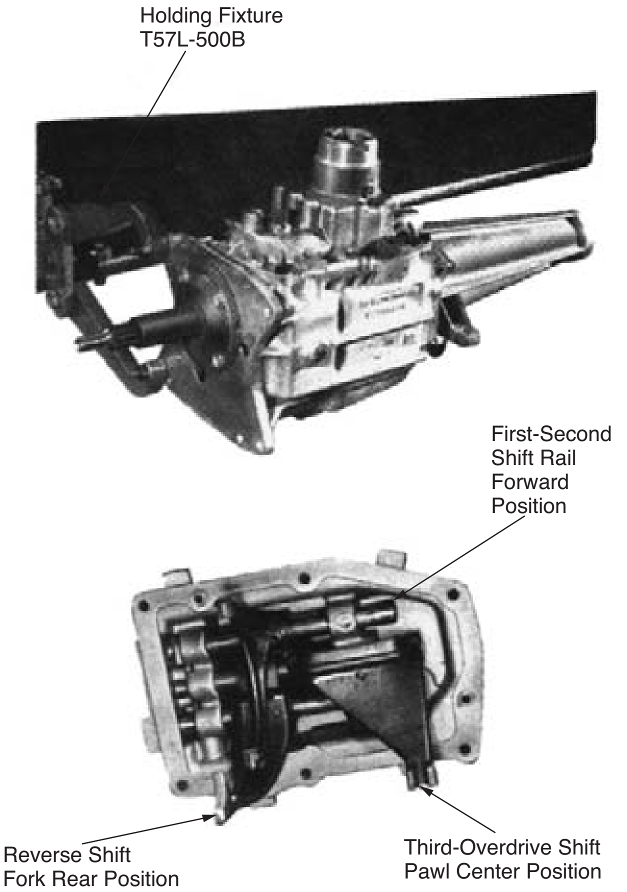


FIGURE 6-23 All of the shift linkage, including the shift forks, for this pickup or truck transmission is contained in the top cover. *(Courtesy of Ford Motor Company)*

very fast shifting, and good fuel economy. At this time, AMTs are used in a few expensive cars but are expected to become popular options in the near future.

An AMT is similar to the dual-clutch transaxle described in Chapter 7 (also see Figure 6-25). Two automated clutches are used, and they are applied alternately. One clutch drives the odd-numbered gears (1, 3, and 5) and the other drives the even-numbered gears (2, 4, and 6).

While the transmission is in first gear with one clutch driving, the 2–4 synchronizer is shifted into second gear. The 1–2 shift occurs when the first clutch is released and the second clutch is applied. After the second clutch applies, the 3–5 synchronizer is shifted into third gear. This procedure is repeated for each gear change. The synchronizers are shifted using electronic actuators that are controlled by a transmission control module (TCM). The TCM uses input from transmission speed sensors, engine management, and driver input to perform the shifts (Figure 6-26).

GEAR LUBRICATION

Manual transmissions, transfer cases, and drive axles must be lubricated to reduce heat and friction. Lubricants can be either refined *petroleum* or *synthetic* products. Refined natural products, also called **mineral oils**, are usually less expensive. **Synthetic oils** are man-made from petroleum or vegetable-oil stock. The lubricant's job is to:

- reduce friction
- transfer heat away from the gears and bearings
- reduce corrosion and rust
- flush dirt and wear particles away from the moving parts

Two rating systems help us select the proper lubricant for a particular usage. These are the Society of Automotive Engineers (SAE) viscosity rating and the American Petroleum Institute (API) Service Classification.

Viscosity is a measurement of fluid thickness. Viscosity is determined by how fast the fluid runs through a precisely sized orifice at a particular temperature. All oils are

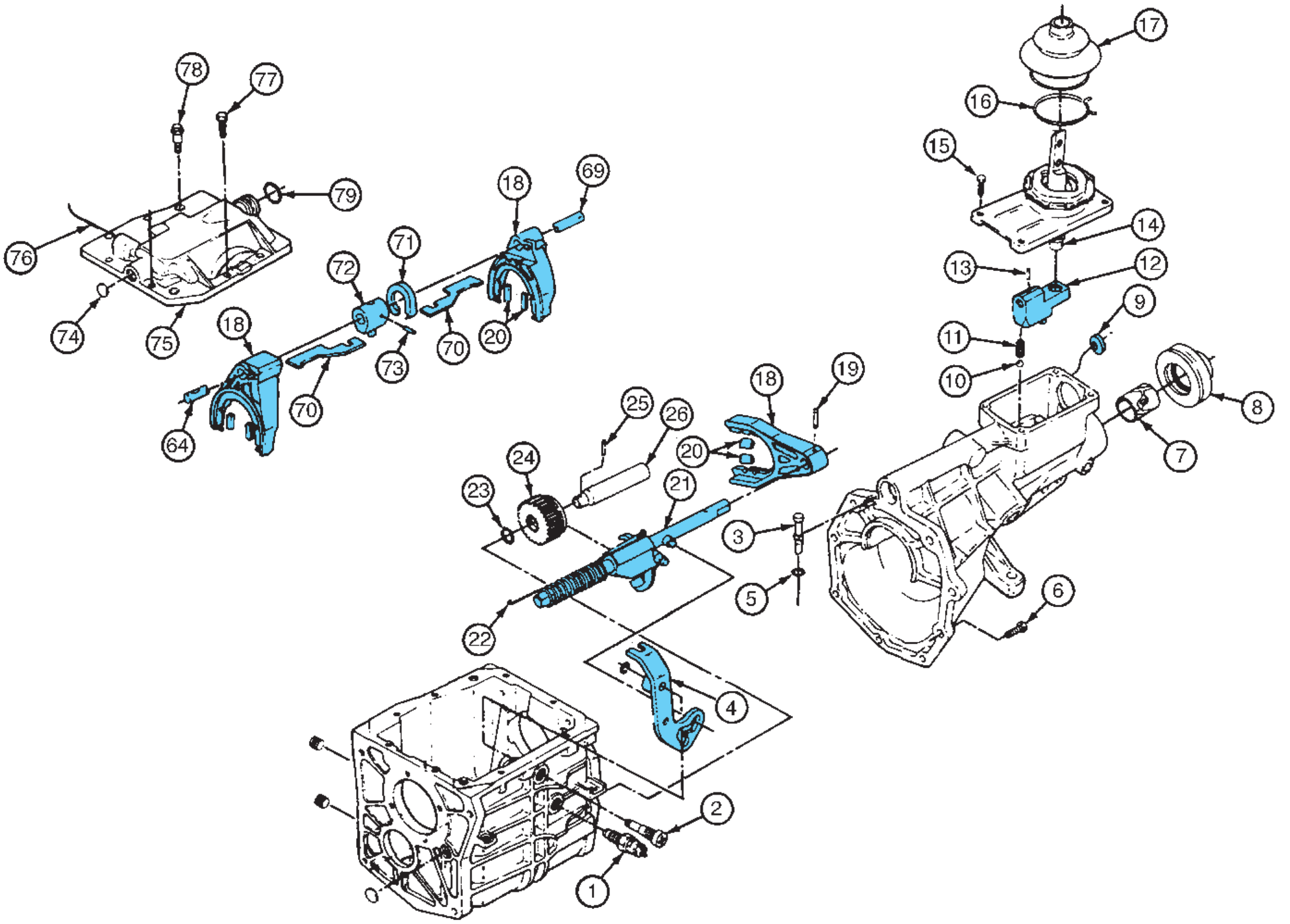


FIGURE 6-24 In this transmission, the shift lever is in the extension housing. A shift rail transmits motion to one of the four shift forks, and the detents and interlock plate are in the main case. *(Courtesy of Ford Motor Company)*

thicker and flow slower when cold and thinner; more fluid when hot. The *viscosity index (VI)* is an indication of the flow difference between hot and cold. In a gearbox, a lubricant that is too thick will deliver poor lubrication when cold because the thick fluid will not flow into smaller areas. A too-thick gear oil might *channel* (i.e., flow in a ropelike pattern). It also increases drag between parts so they do not turn as easily, and shift collars will not slide as easily. Synchronizer cones will not work very well because they cannot break through the thick oil film. This can cause hard shifting until the fluid warms. A too-thin lubricant will not provide the lubricating film under hot conditions. Thin fluids also cause more gear noise. The viscosity numbers (60 to 140) used for gear oils are larger than those for engine oils (10 to 50), but the oil's actual viscosity is similar. Gear oils normally become thinner over time.

The API gear oil classifications are:

GL-1: straight mineral oil; used in nonsynchromesh transmissions; might have some additives; not a satisfactory lubricant for modern passenger car transmissions.

GL-2: a designation for worm gear drives used mostly in industrial applications.

GL-3: contains mild EP additives; used in manual transmissions and transaxles with spiral bevel final drives.

GL-4: formulated for use in manual transmissions and transaxles with hypoid final drives; contains about half the additives used in GL-5.

GL-5: enough EP additive to lubricate hypoid gears in drive axles.

GL-6: an obsolete designation.

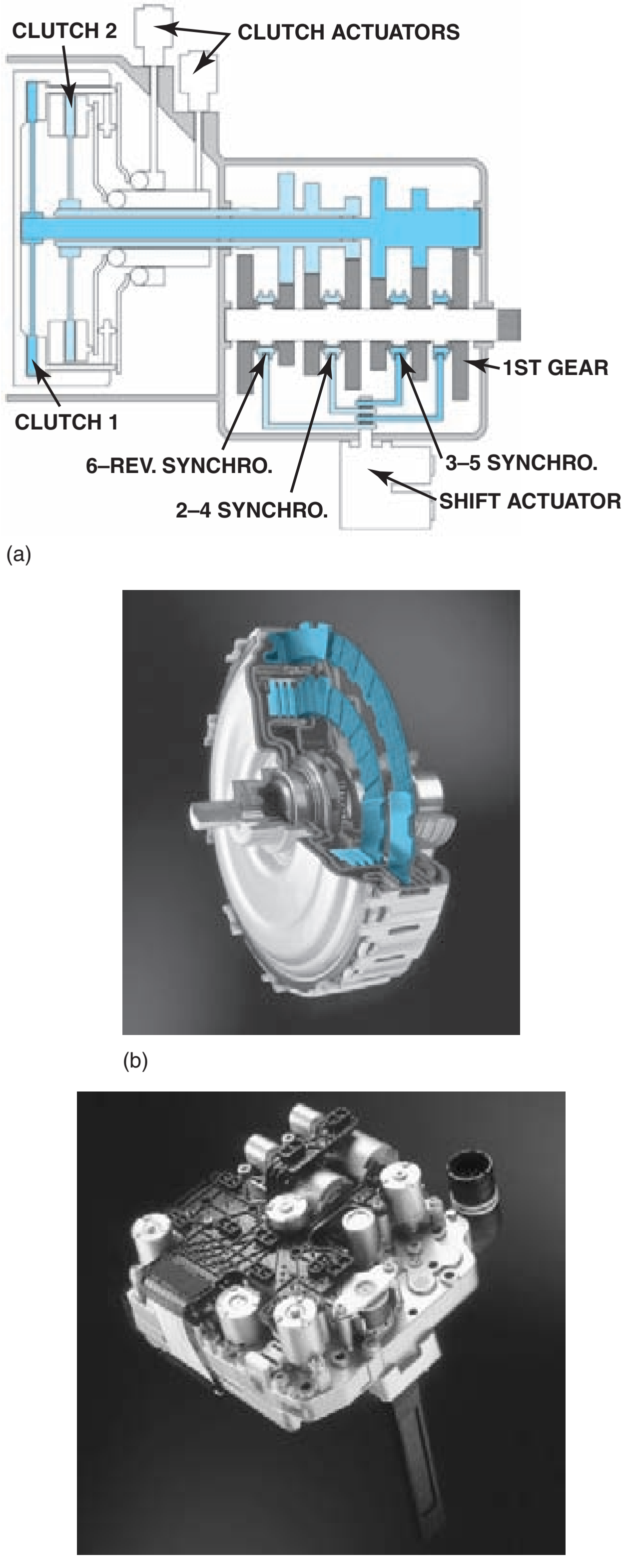


FIGURE 6-25 An automated manual transmission (AMT) uses two clutches (a). One of them drives the odd-numbered gears, and the other one drives the even numbered one (b). The actuators that apply the clutches and shift the synchronizers are operated by a control module (c).

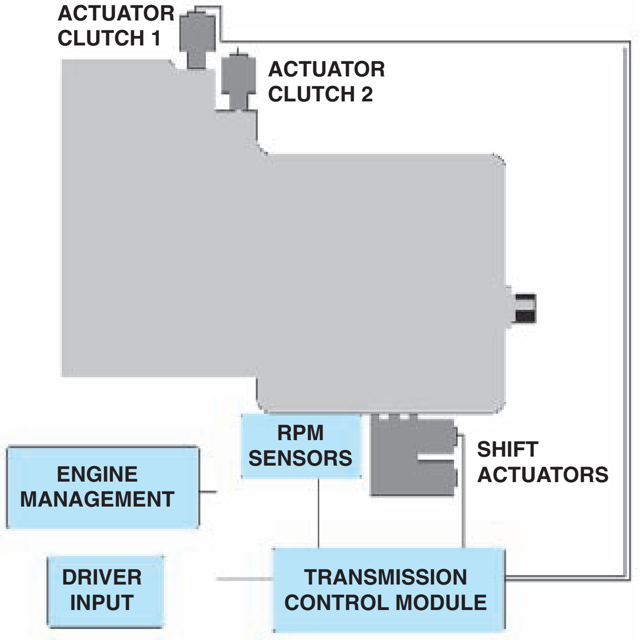


FIGURE 6-26 The electronic controls for an AMT include a control module that receives signals from the transmission rpm sensor(s), engine control module, and driver-operated switches.

An additional classification, GLS (Gear Lubricant Special), is sometimes used to indicate a proprietary set of specifications determined by the vehicle or gearbox manufacturer. **Manual transmission fluid (MTF)** usually is in this category. An MTF might contain a friction modifier to give proper synchronizer action and long life.

API classifications are an indication of the fluid's ability to maintain a lubricating film under the load and prevent metal-to-metal contact between the gear teeth. These classifications are also concerned with the oil's thermal stability, gear surface fatigue, and compatibility with oil seals, copper and brass, and other gear oils. Other concerns are foaming, corrosion resistance, and seal compatibility. Too much of one additive can have detrimental effects on other operating characteristics. For example, GL-5 can cause hard shifting problems in a transmission because the EP additive interferes with synchronizer operation.

Synthetic lubricants usually have a much better VI than conventional lubricants; the viscosity stays more stabile with temperature changes. Stable viscosity provides better lubrication; this, in turn, allows more efficiency, less cold-operation drag, and better high-temperature lubrication. A synthetic lubricant also offers better resistance to oxidation, so the fluid will normally have a longer life span.

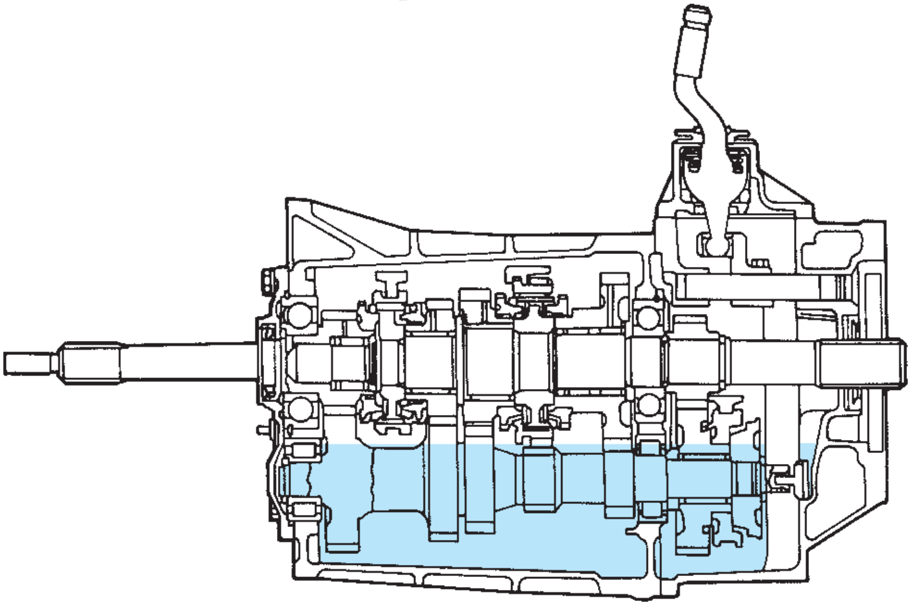


FIGURE 6-27 The fluid level of most transmissions is at the bottom of the fill plug opening, and the fluid is moved around inside the case when the gears rotate. *(Courtesy of DaimlerChrysler Corporation)*

TRANSMISSION LUBRICATION

The transmission cluster gears run in a bath of lubricant, and as they spin, their motion will throw the lubricant throughout the case. The lubricant can be gear oil, ATF, or manual transmission fluid, as determined by the manufacturer. The fluid level is normally at the bottom of the check/fill plug in the side of the case (Figure 6-27). This is usually at a level just below the rear bushing and seal.

The lubricant reduces friction so that the parts spin more easily and transfers heat away from the gear contact and rubbing parts. Poorly lubricated gears can get so hot that the metal becomes plastic and deforms (Figure 6-28). Floating gears on the mainshaft or cluster gear have special paths and provisions for getting the lubricant into their bearings, and some transmissions have **troughs** or **oiling funnels** to get lubricant into the critical areas (Figure 6-29).

Each transmission includes a vent, normally located at the top of the case. This relieves internal pressure that would occur as the gears and oil warm up while operating. If not relieved, the pressure would force the oil out past the input and output shaft seals. Many early transmissions used only a slinger—a large, flat washer—to stop the oil from flowing out at the front bearing.

A transmission is lubricated by oil thrown off the cluster gear. If a vehicle is towed in neutral, the cluster gear does not rotate and wear can occur between the rotating mainshaft and the stationary gears that float on it. A transmission with the synchronizer on the cluster gear will receive some lubrication through its gear action.

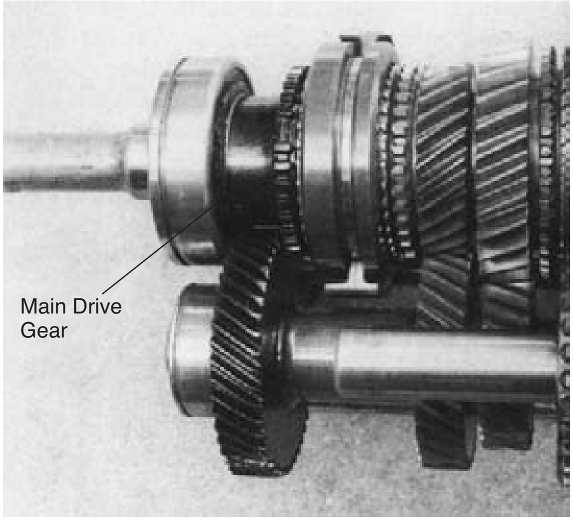
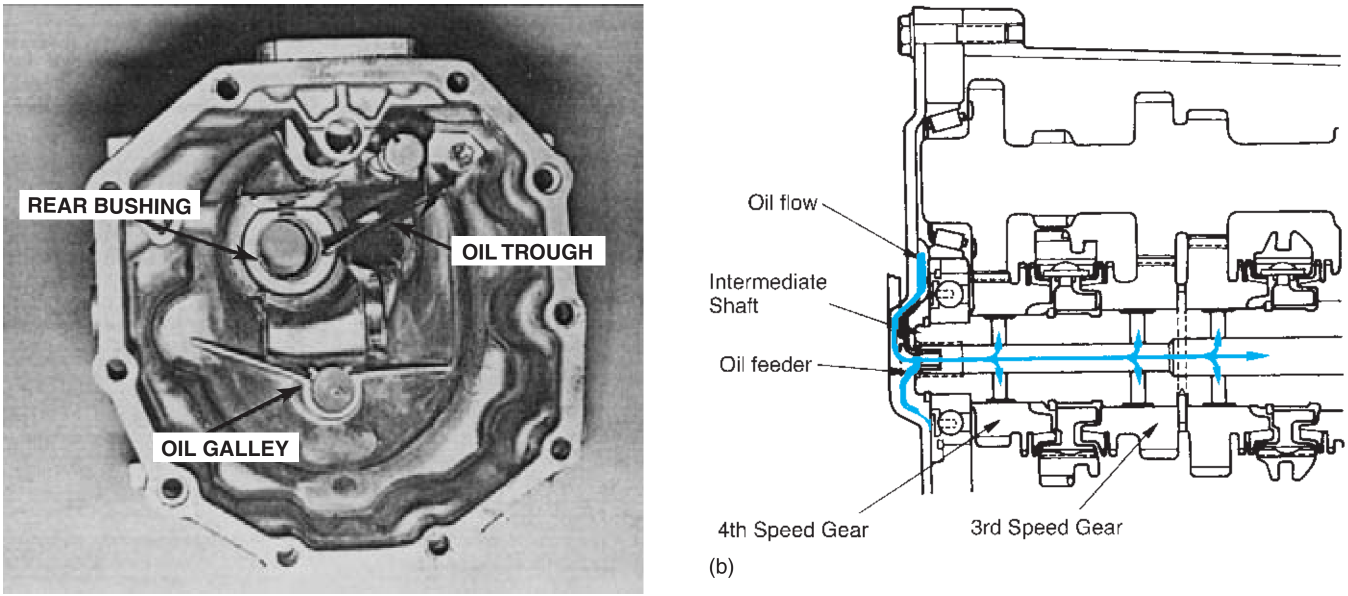


FIGURE 6-28 This transmission was operated without oil. Note the heat-darkened color and the lack of teeth on the main drive gear. The gear got so hot that the metal reached its plastic state, and the teeth were removed or reshaped.



(a)

(b)

FIGURE 6-29 This extension housing (a) includes a trough to deliver oil to the cluster gear bearing; and (b) delivers oil to the center of this shaft, where it will flow on to lubricate the speed gears. *(Courtesy of DaimlerChrysler Corporation)*

DESIGN FEATURES

Knowledge of certain design features will increase your understanding of transmission operation, make problem diagnosis easier and more accurate, and improve service and overhaul techniques.

Gears

All forward gears in a modern transmission are helical gears; spur gears are sometimes used for reverse. When you back up, you can often hear a whine or light growl from the transmission. Spur gears are used for reverse because they are less expensive, will shift into mesh more easily, and have no tendency to generate end thrust under load.

The end thrust created by a helical gear requires a thrust surface on the side of the gear. This is especially true at the side loaded during forward motion. During deceleration, the thrust direction will reverse, and a helical gear will thrust in the opposite direction. Gear side or end float should be limited to reduce noise or possible damage, especially in the gears used at cruising speeds where throttle change is normal (Figure 6-30).

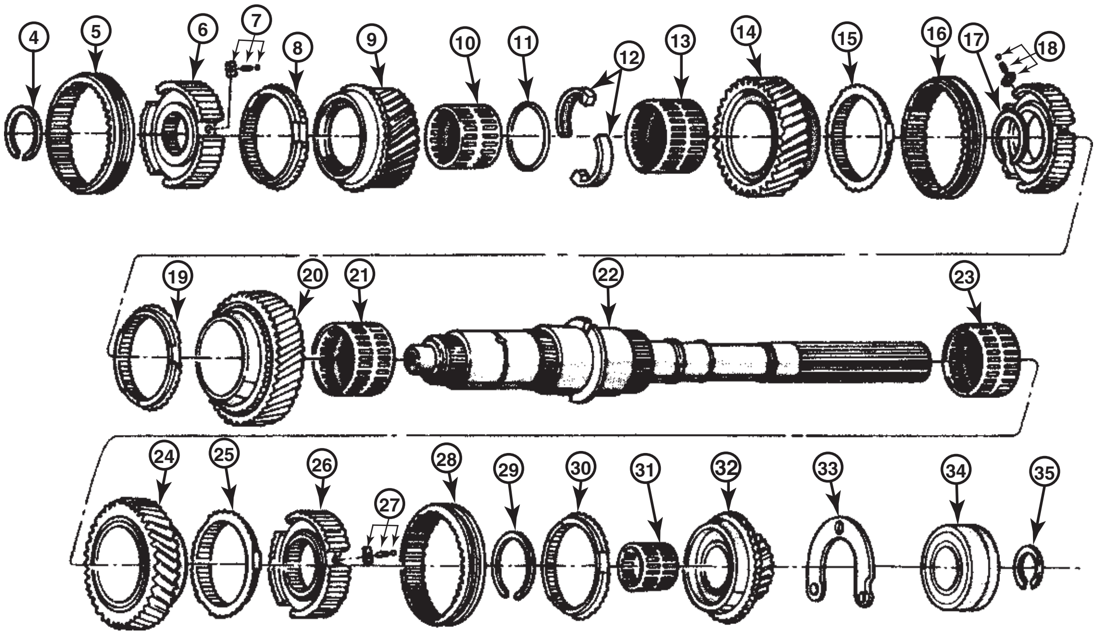
The **pitch**, which is the distance between teeth or the number of teeth for a particular gear diameter, is determined by the manufacturer. Finer pitch gears, which have more teeth for a particular diameter, operate quietly, but because the teeth are thinner, tooth breakage may occur under heavy loads.

A helical gear can also be made with the helix cut at different angles. As the angle is increased, the gear will run more quietly, but end thrust will increase. Some modern five-speeds use fine-pitched gears with a greater helix angle for the fifth gear (Figure 6-31). This produces quiet operation at cruising speeds where low torque loading is encountered.

A gear that is slid into mesh with another gear has the ends of its teeth beveled or cut at an angle (Figure 6-32). This allows the gear teeth to slide into mesh with each other much more easily, especially if they are not aligned exactly.

Mainshaft

Close inspection of a mainshaft reveals specific areas that serve specific purposes. The positioning of the snap ring grooves is very exacting to locate parts in precise locations (Figure 6-33). The snap rings may be available in different widths to adjust thrust clearance/gear end play. The mainshaft itself is located by the rear bearing, bearing surface, and retaining ring. Each synchronizer assembly has a set of splines so that torque can transfer to the shaft. Each gear location has a bearing surface, or journal, which often has a special provision for lubricating the floating speed gear. A mainshaft will have a surface for the pilot bearing to the main drive gear at the front and the splines to match the U-joint splines at the rear. Close to the rear of the shaft, there will be provision for mounting a speedometer drive gear or vehicle speed sensor (VSS) or the worm teeth for the speedometer drive gear will be cut into the shaft.



④ SNAP RING, 3–4 SYNCHRO HUB
⑤ SLEEVE, 3–4 SYNCHRO
⑥ HUB, 3–4 SYNCHRO
⑦ STRUT, SPRING, DETENT BALL (3 SETS), 3–4 SYNCHRO
⑧ THIRD SPEED SYNCHRO RING
⑨ THIRD GEAR
⑩ THIRD GEAR NEEDLE BEARING
⑪ RETAINING RING
⑫ THRUST WASHER (2-PIECE)
⑬ SECOND GEAR NEEDLE BEARING
⑭ SECOND GEAR
⑮ SECOND SPEED SYNCHRO RING
⑯ SLEEVE, 1–2 SYNCHRO
⑰ SNAP RING, 1–2 SYNCHRO HUB
⑱ STRUT, SPRING, DETENT BALL (3 SETS), 1–2 SYNCHRO
⑲ FIRST SPEED SYNCHRO RING
⑳ FIRST GEAR
㉑ FIRST GEAR NEEDLE BEARING
㉒ OUTPUT SHAFT
㉓ REVERSE GEAR NEEDLE BEARING
㉔ REVERSE GEAR
㉕ REVERSE SYNCHRO RING (SOLID BRASS)
㉖ FIFTH–REVERSE SYNCHRO HUB
㉗ STRUT, SPRING, DETENT BALL (3 SETS), FIFTH–REVERSE SYNCHRO
㉘ SLEEVE, FIFTH–REVERSE SYNCHRO
㉙ SNAP RING, FIFTH–REVERSE SYNCHRO HUB
㉚ FIFTH SPEED SYNCHRO RING
㉛ FIFTH GEAR NEEDLE BEARING
㉜ FIFTH GEAR
㉝ BEARING RETAINER (IN HOUSING)
㉞ OUTPUT SHAFT BEARING
㉟ SNAP RING, SHAFT BEARING

FIGURE 6-30 Speed gears float on their mainshaft journals and have thrust surfaces on each side to keep them properly positioned.

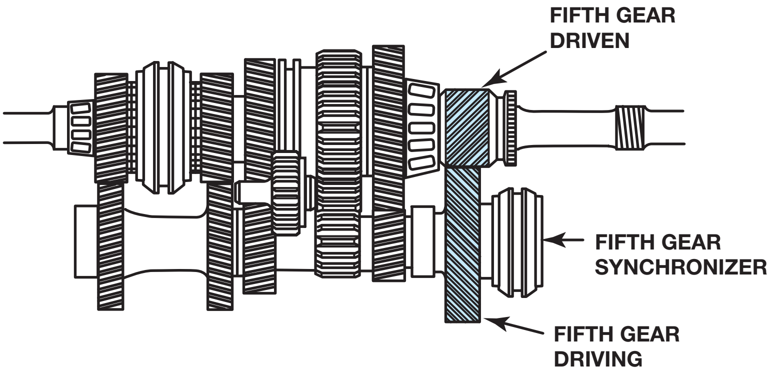


FIGURE 6-31 Notice the gear teeth in this transmission; those on the fifth gears have a finer pitch and a greater helix angle, to produce quieter operation while cruising.

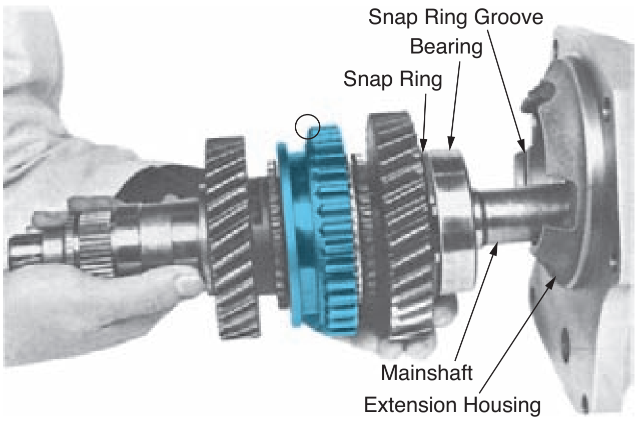


FIGURE 6-32 The left ends (circled) of the reverse gear teeth around this 1–2 synchronizer sleeve are beveled to allow easier engagement with the reverse idler during shifts into reverse. Constant mesh gears normally have teeth that are squared off at the ends. *(Courtesy of DaimlerChrysler Corporation)*

Countershaft and Cluster Gear

The cluster gear is supported by the rodlike countershaft with a set of needle bearings at each end in older transmissions (Figure 6-34). The countershaft has a press fit into the case. Units with high torque loading use a double set of needle bearings at each end to support the cluster gear. A thrust bushing is used between the gear and the case at each end to control end thrust. The thrust washer or a wear plate is keyed into the case so that it will not spin and wear into the case.

The fit between the countershaft and the case is tight enough to prevent lubricant leaks. At one end of the shaft, there is normally a locating device to prevent shaft rotation.

Some newer transmissions support the countershaft assembly, which includes the cluster gear, with a pair of tapered roller bearings (Figure 6-35). Tapered bearing design is capable of absorbing thrust loads along with the normal side loads. Tapered roller bearings are normally adjusted during installation to obtain free running with a very slight clearance.

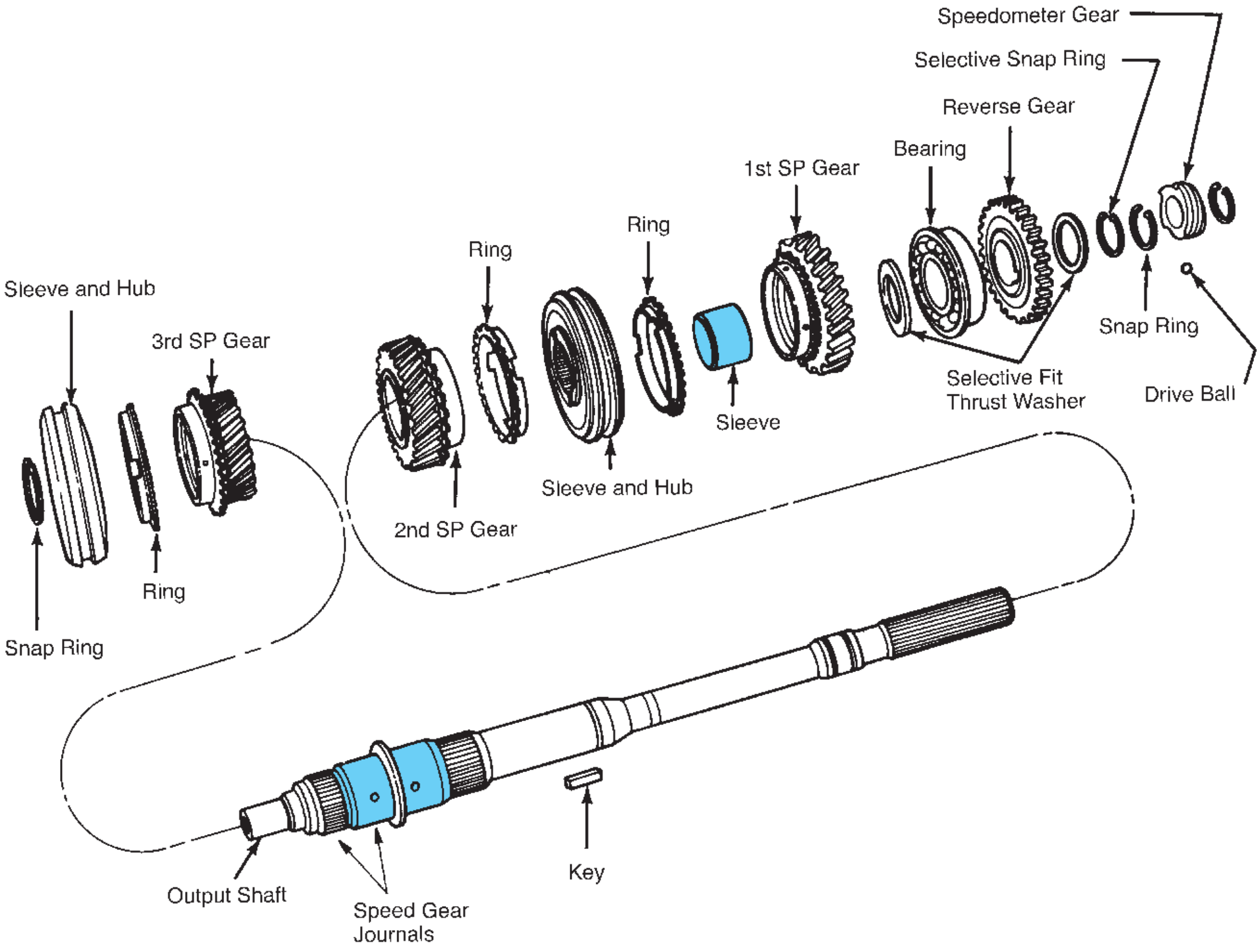


FIGURE 6-33 Most mainshafts have smooth journals for the speed gears and splined areas to connect to the synchronizer hubs. Some include grooves for fluid flow. Some include raised, washerlike thrust surfaces to keep the speed gears separated. *(Courtesy of Ford Motor Company)*

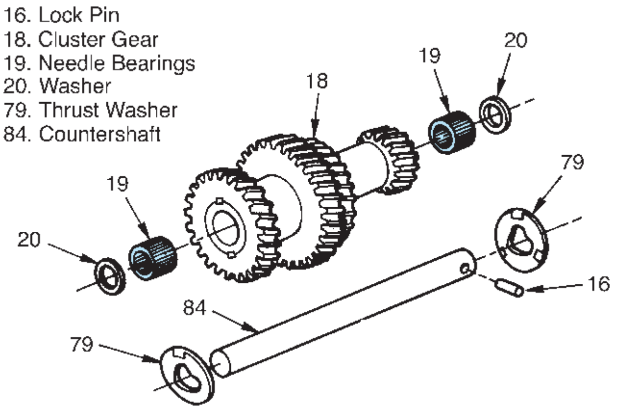


FIGURE 6-34 This cluster gear is mounted on two sets of needle bearings (19) on the countershaft (84) and uses two thrust washers (79) to absorb thrust loads. Note the lock pin (16), which keeps the countershaft in place and prevents rotation. *(Courtesy of Ford Motor Company)*

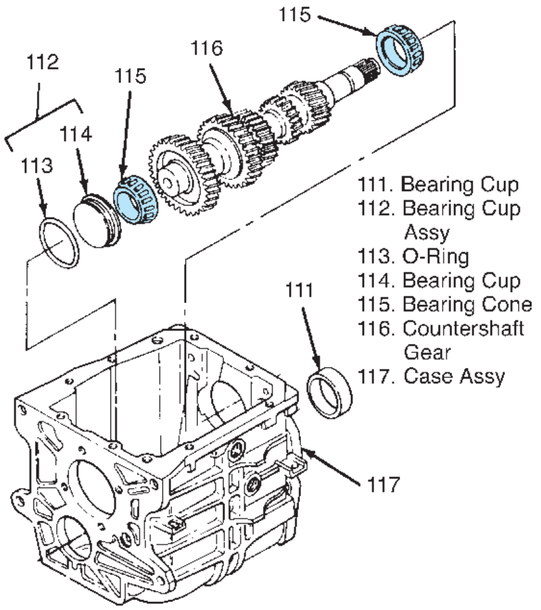


FIGURE 6-35 This countershaft gear is mounted on a pair of tapered roller bearings (115), which locate it in the case and allow it to rotate. *(Courtesy of BWD Automotive Corporation)*

Most cluster gears are one-piece units, and if one of the gears is damaged, the entire unit must be replaced. The cluster gear used in the Tremec TR-3550 transmission is a three-piece unit (Figure 6-36). The two gears at the front of the cluster gear have a press fit onto the main cluster gear. Woodruff keys help the assembly transfer torque. Another unusual cluster gear is used in the six-speed, T56 transmission. The cluster gear/countershaft fits in the main case and has the gears needed for first through fourth. A countershaft extension drives fifth, sixth, and reverse, and it fits in the extension housing. The back of the cluster gear and the front of the extension have matching splines to transfer torque (Figure 6-37).

Case

The main case and extension housing are usually made from aluminum castings. Older transmissions use cast iron cases. Most cases have openings for access to the gear train. The term **open case** is sometimes used for a case in which the side or top cover is removable and includes the shifting forks and other mechanisms (Figure 6-38a). A cover that includes the shift mechanism is normally located by dowel pins so that the shift motions do not cause movement of the cover, which could cause incomplete gear engagement. **Closed case** refers to a case that might have access openings, but the shift mechanism is located entirely within the case (Figure 6-38b). The Ford toploader is a closed case design. With a **tunnel case**, the gears and shafts are loaded from the end of the case (Figure 6-38c). In a **split case** design, the case has two halves that are bolted together (Figure 6-38d). Many five- and six-speed transmissions use a center plate design (see Figure 8-48). The center plate has bearings that support the mainshaft and cluster gear.

BEARINGS

Transmissions use a variety of bearings, depending on the particular design. The types used are **needle bearings**, **ball bearings**, **tapered roller bearings**, and plain **bushings**

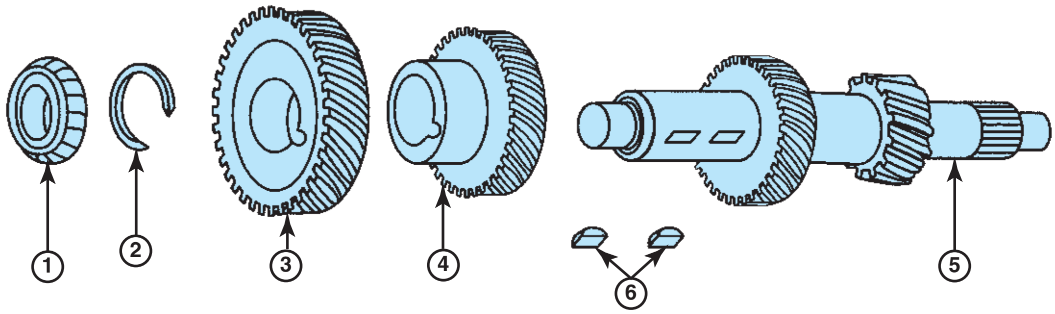


FIGURE 6-36 Two gears, the input (3) and third (4), are press fit onto the cluster gear for a TR-3550 transmission.

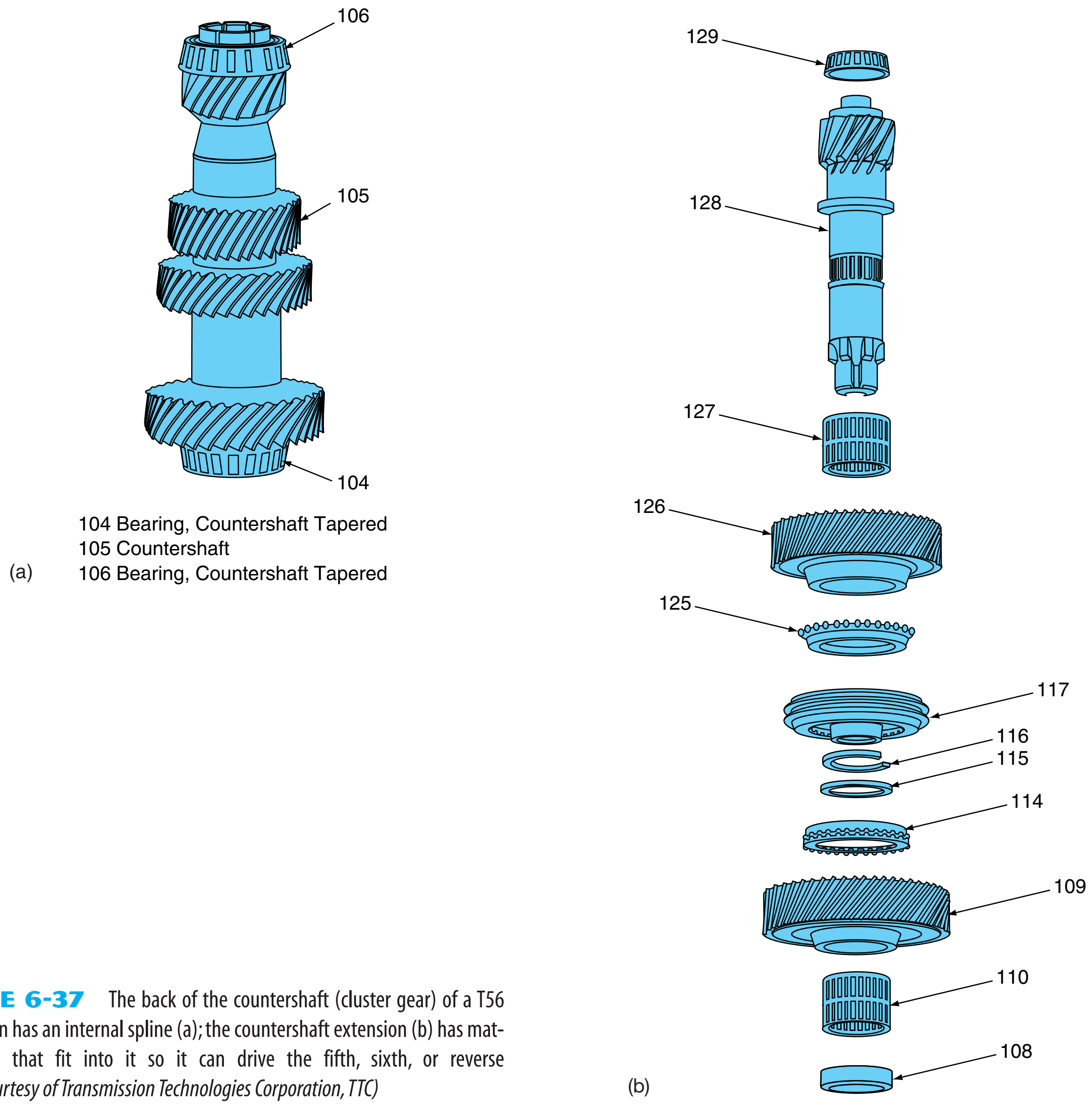


FIGURE 6-37 The back of the countershaft (cluster gear) of a T56 transmission has an internal spline (a); the countershaft extension (b) has mating splines that fit into it so it can drive the fifth, sixth, or reverse gears. *(Courtesy of Transmission Technologies Corporation, TTC)*

(Figure 6-39). To work properly, all types of bearings must have proper lubrication.

Needle bearings, either caged or free, can carry large side loads but are unable to control end thrust loads. Free needle bearings are used to support the cluster gear in most older transmissions.

Ball bearings can carry moderate to high side loads and thrust loads. Thus they are commonly used for the main drive gear and mainshaft in many transmissions. A "maxi" version of the ball bearing can carry even greater side loads. A maxi bearing can be identified by the increased number of balls as well as loading notches at one side of the inner and outer races. The speed gears in many modern transmissions are mounted over caged needle bearings (see Figure 6-37).

Tapered roller bearings can carry large side loads and thrust loads and are generally used in pairs with the cones and cups facing in opposite directions. This bearing is normally installed with a method (usually shims) for adjusting end play or, in a few cases, preload. In some newer transmissions, tapered roller bearings are used to support the main drive gear, the mainshaft, and the countershaft.

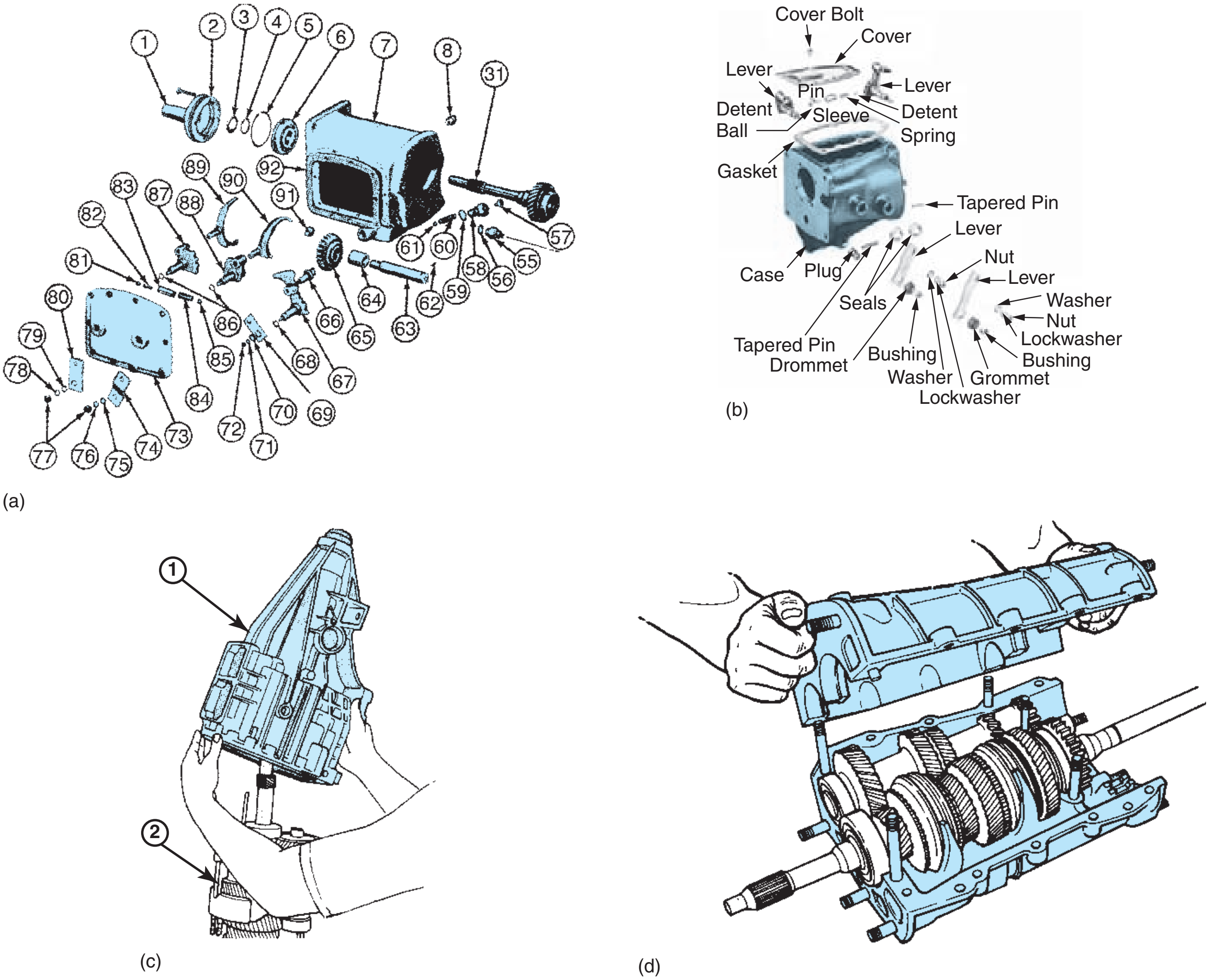


FIGURE 6-38 The major transmission case designs are the open case (a) with the shift linkage mounted in a cover; the closed case (b) the tunnel case (c), which is loaded from one end; and the split case (d). *(a, b, and c are courtesy of DaimlerChrysler Corporation; d is courtesy of Ford Motor Company)*

A plain bushing is used to support the driveshaft slip yoke in the extension housing. A bushing can support a large side load and allows free in-and-out movement.

OVERDRIVE UNITS

Two approaches are used with a standard transmission to get an overdrive ratio. One approach, described earlier, is commonly used in newer transmissions. The other approach is to attach an overdrive unit in place of the extension housing on an RWD transmission. From the mid-1930s to the early 1960s, each domestic vehicle manufacturer offered a manual transmission with an overdrive of this type. In most cases, the unit was manufactured by Borg Warner (Figure 6-40). In England and Europe, several vehicle manufacturers used an overdrive unit known as the Laycock de Normanville. In the mid-1980s, an overdrive unit manufactured by Doug Nash Industries was used with a version of the Borg Warner T10 transmission and installed in Corvettes. Each of these units provides two ratios: a 1:1 direct drive, sometimes called *underdrive* or *passing gear*, and an overdrive with a ratio somewhere between 0.8:1 and 0.6:1.

The Borg Warner and de Normanville units use true planetary gear sets with a sun gear that can rotate or be held

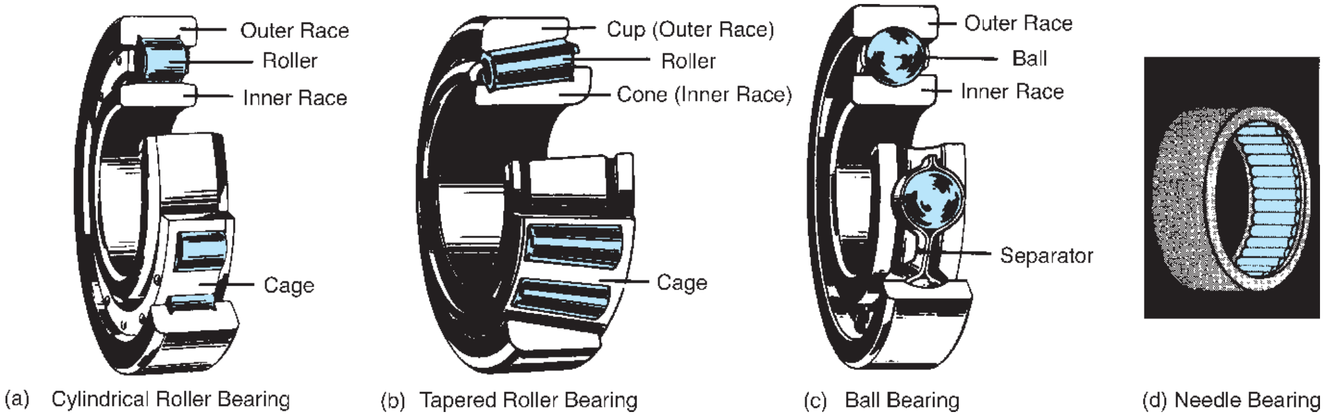


FIGURE 6-39 The types of frictionless bearings are cylindrical or straight roller bearings (a), tapered roller bearings (b), ball bearings (c), and needle bearings (d). *(Courtesy of CR Services)*

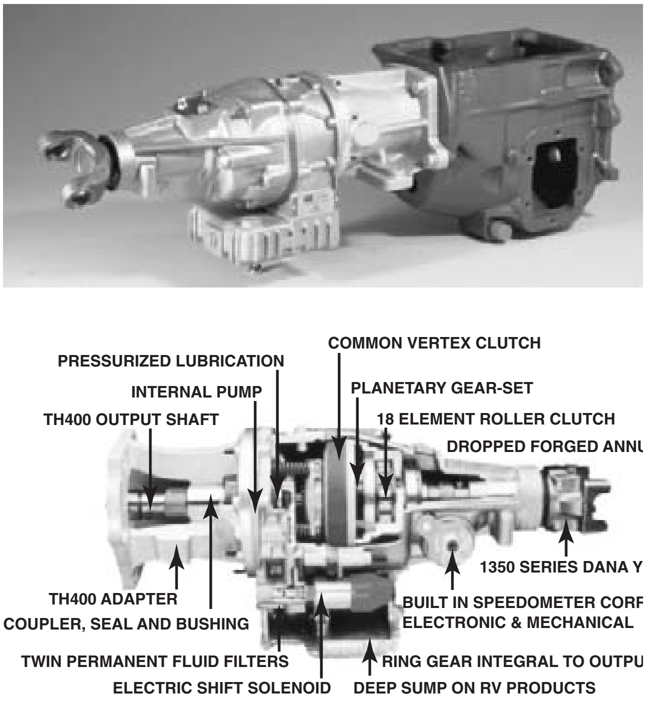


FIGURE 6-40 An aftermarket overdrive unit has replaced the standard transmission extension housing (a). It contains a planetary gearset and method of shifting between 1:1 and overdrive gear ratio (b). *(Courtesy of Gear Vendors Inc.)*

stationary. It uses a planet carrier that is driven by the transmission mainshaft, a ring gear that is connected to the output shaft, and a one-way clutch assembly that allows the carrier to drive the output shaft. Overdrive occurs when the sun gear is held stationary. When the carrier is driven, the planet pinion gears will be forced to "walk" (rotate on their axis) around the sun gear. This motion causes the outer teeth of the planet gears, the ones in mesh with the ring, to move faster than the carrier; as a result, they will drive the ring gear at an overdrive ratio (Figure 6-41).

In the Borg Warner unit, sun gear motion is controlled by a mechanical cable actuated by the driver from the dash control and an electric solenoid. When the dash control is pulled outward, the sun gear is shifted to mesh with both the planet gears and the carrier; this locks the gear set into a 1:1 ratio. Pushing the control inward moves the sun gear so that it is in mesh with the planet gears and the sun gear control plate; now the sun gear and the control plate are free to rotate. Power can pass from the carrier to the output shaft through the one-way clutch in underdrive, and an electric solenoid can complete the shift into overdrive by engaging and locking the sun gear control plate stationary.

The Laycock de Normanville unit uses a similar gear arrangement and power flows but a different shifting procedure. It uses a large double-cone clutch that is attached to the sun gear and operated by a hydraulic piston. In underdrive (the 1:1 ratio), the cone clutch is moved rearward, locking the sun gear to the ring gear, and the gear set rotates as a single unit with no internal motion (Figure 6-42). In overdrive, the cone clutch is moved forward, locking the sun gear to the case to produce the same planet gear operation described earlier. Hydraulic pressure to shift the cone clutch comes from a self-contained hydraulic system and is controlled by an electric solenoid.

The Doug Nash is not a true planetary gear set, but the operation is similar. In this unit, the transmission mainshaft is connected to one sun gear, another smaller sun gear is connected to the output shaft, and a carrier with a set of planet gears connects these two. Each of the planet gears has two sizes: The smaller end meshes with the front input sun gear, whereas the larger end meshes with the rear sun gear. Two clutch packs are used and arranged so that one is released while the other is applied. In underdrive, one of the clutch packs locks the carrier to the output shaft, locking up the gear set. In overdrive, the other clutch locks the carrier to the case, and the large sun gear drives the set of smaller pinions; these, in turn, drive the other sun gear, producing the overdrive ratio. To make the shifts, this system also uses a self-contained hydraulic system controlled by an electric solenoid.

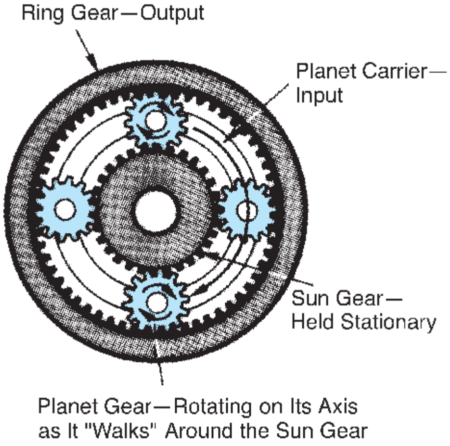


FIGURE 6-41 If the sun gear of a planetary gear set is held stationary while the planet carrier is rotated, the planet pinion gears will be forced to rotate on their axis and "walk" around the sun gear. This will force the ring gear to rotate at an overdrive ratio.

AUXILIARY TRANSMISSIONS

An auxiliary transmission, fitted between the main transmission and the drive axle, is used to provide an additional higher or lower gear or to reduce the size of the steps between the gear ratios of the main transmission. Heavy trucks commonly use auxiliary transmissions with "splitter" ratios. These provide a slight reduction, a 1:1 direct drive, and a slight overdrive (Figure 6-43). The gear changes go something like this: first–low, first–DD, first–OD, second–low, second–DD, second–OD, third–low, and so on. Note that between first–OD and second–low it is necessary to shift both the main and auxiliary transmissions.

Auxiliary transmissions are popular in the recreational vehicle (RV) and motor home (Figure 6-44). Aftermarket (produced for installation after the vehicle is constructed) units are available that are very similar to two-speed transmissions. These are usually two-speed units, one of the speeds being direct drive and the other speed being overdrive. But a unit may be constructed so it can be mounted either way. When mounted in the vehicle, it is positioned to produce the desired ratio. When positioned one way, it produces an overdrive, but if it is turned around and the input and output shafts are swapped, it produces an underdrive.

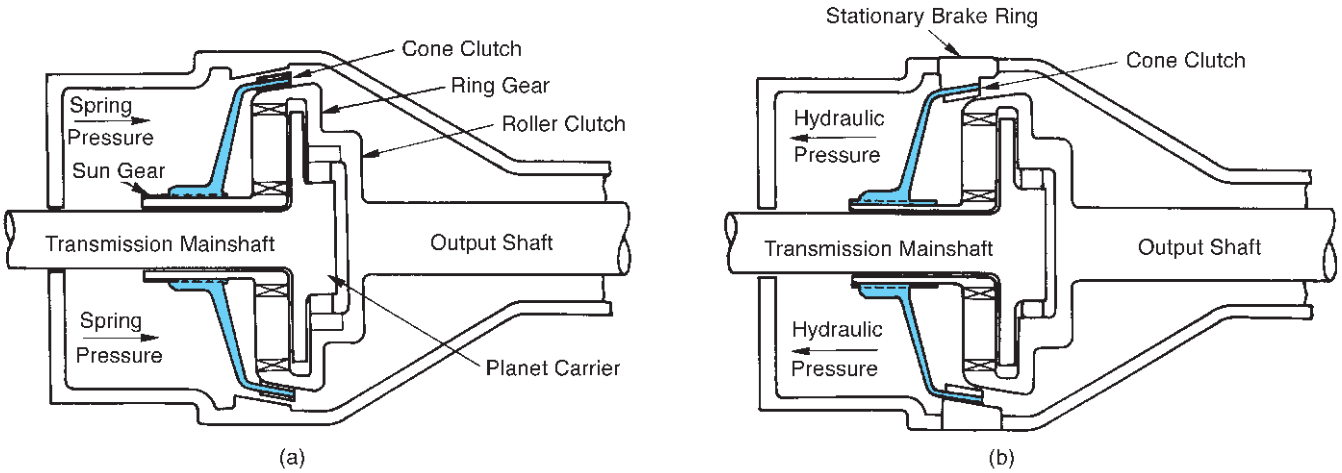


FIGURE 6-42 (a) Spring pressure forces the cone clutch to lock the sun gear and the ring gear together to provide a 1:1 ratio in this Laycock overdrive gear set. (b) Hydraulic pressure forces the cone clutch against the stationary brake ring, holding the sun gear stationary and causing an overdrive ratio.

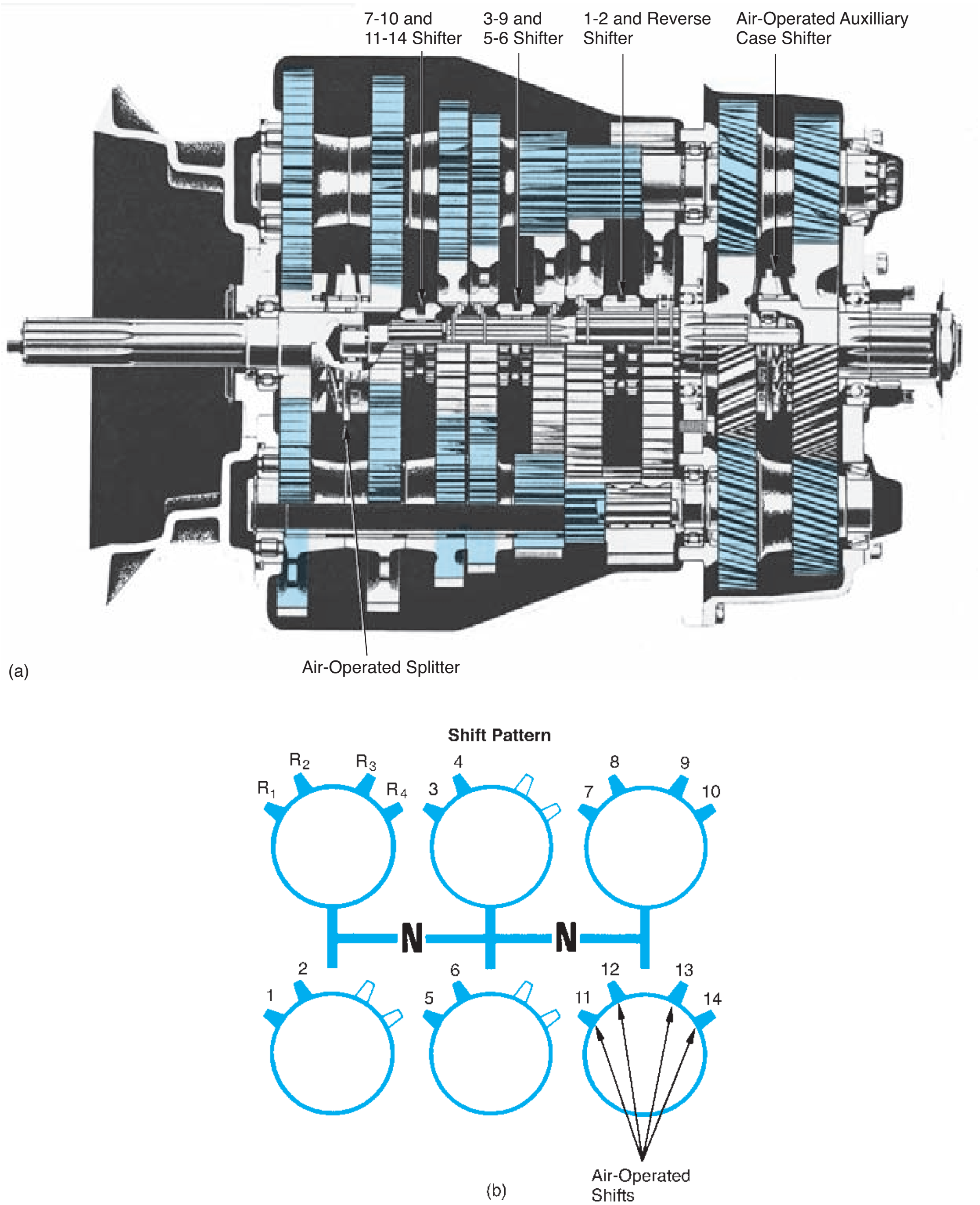


FIGURE 6-43 This 14-speed heavy truck transmission has five forward gear ratios in the main gear section plus two "splitter" ratios, one at the main drive gear and one in the auxiliary section. The splitter shifts are air operated with the switch control on the shift lever. Twin cluster gears increase the torque capacity of this transmission. *(Courtesy of Dana Corporation)*

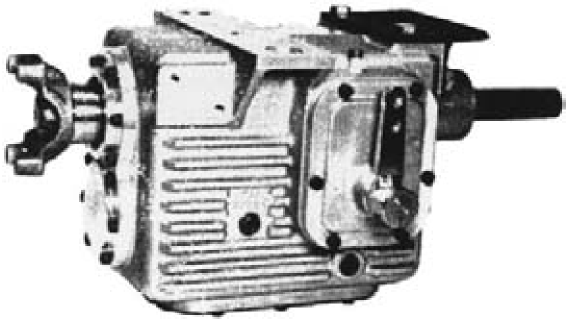


FIGURE 6-44 This auxiliary transmission is mounted between the transmission and drive axle. It provides a 1:1 ratio and either an overdrive or a reduction ratio.

SUMMARY

1. Transmissions and transaxles provide gearsets for forward speeds and reverse as well as neutral.
2. Transmissions normally have three shafts: input, output, and countershaft.
3. Synchronizer assemblies normally have a hub, sleeve, a set of keys, two blocker rings, and a speed gear on each side.
4. Early blocker rings were a single, brass ring; newer blocker rings are double, paper-lined rings.
5. Transmissions torque capacity is determined by the size of the gears and shafts.
6. Transmissions shifts use external or internal linkage that includes detents, interlocks, and shift forks.
7. Transmissions are lubricated with gear oil or manual transmission fluid (MTF).
8. Special transmission design features include gear tooth pitch and helix angle, cluster gear variations, case construction, and bearing type.
9. Overdrive units can be mated to a transmission to add an additional gear ratio.

REVIEW QUESTIONS

1. The are two types of gears sets used in standard transmissions. They are
   - **a.** ____________ ____________
   - **b.** ____________ ____________ ____________
2. ____________ ____________ gears are shifted by the use of a synchronizer.
3. The vehicle needs to be at rest when shifting ____________ ____________.
4. The synchronizer must be able to synchronize or match the ____________ of the gears.
5. The purpose of the ____________ on the inside of the synchronizer chronizer ring is to break through the lubricating film.
6. The power flow for second gear in a four-speed rear-wheel-drive transmission would be from the
   - **a.** ____________ drive gear to the
   - **b.** ____________ gear to the
   - **c.** second ____________ gear to the
   - **d.** second ____________ gear
7. The main difference between a four-, five-, or six-speed rear-wheel-drive transmission is the ____________ of gears and the ____________ of the transmission.
8. The ____________ mechanism prevents the engagement of more than one gear at a time.
9. The ____________ mechanisms are used to lock and hold the internal shift linkage in position.

10. All forward gears in modern transmissions use ____________ gears; reverse typically uses ____________ gears.

11. ____________ are used to locate parts on the mainshaft.

12. The bearings that are best suited to handle both side and thrust loads are ____________ bearings.

13. A bushing is used in the ____________ housing to support the driveshaft slip yoke.

14. Name four types of bearings.

a. ____________ ____________

b. ____________ ____________ ____________

c. ____________ ____________

d. ____________ ____________

15. ____________ transmissions can be added to increase the number of gear ratios.

CHAPTER QUIZ

1. A four-speed transmission is in third gear: A. The 1–2 synchronizer is in neutral; B. The 3–4 synchronizer is moved to engage third gear. Which is correct?
- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

2. A three-speed transmission is in third gear, so (A) there is a 1:1 gear ratio; (B) the 2–3 synchronizer has engaged the input shaft gear. Which is correct?
- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

3. The cluster gear is supported by (A) two sets of needle bearings around the countershaft; (B) roller bearings between the countershaft and the case. Which is correct?
- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

4. While discussing a four-speed cluster gear, Student A says that it is a combination of four or five gears. Student B says that it has six gears. Who is correct?
- **a.** Student A
- **b.** Student B
- **c.** Both A and B
- **d.** Neither A nor B

5. Two students are discussing synchronizer rings. Student A says they equalize the speeds of the synchronizer assembly and the speed gear being engaged. Student B says they block the synchronizer sleeve briefly during a shift. Who is correct?
- **a.** Student A
- **b.** Student B
- **c.** Both A and B
- **d.** Neither A nor B

6. During a normal upshift, the synchronizer must (A) speed up the mainshaft assembly; (B) slow down the clutch disc, main drive gear, cluster gear, and speed gears. Which is correct?
- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

7. The idler gear is used for which gear?
- **a.** First gear
- **b.** Second gear
- **c.** Third gear
- **d.** Reverse

8. A four-speed transmission is in second gear: (A) the power flow is from the input shaft gear to the cluster gear and then to the second speed gear on the mainshaft assembly; (B) The 1–2 synchronizer is moved so that the sleeve has engaged the clutching teeth of second gear. Which is correct?
- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

9. When one synchronizer is shifted into gear, the movement of the other shift forks is blocked by the (A) detents; (B) interlocks. Which is correct?

- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

10. The detent mechanism inside a transmission is used to

- **a.** locate the synchronizer sleeves in the correct position.
- **b.** prevent more than one shift fork from moving at one time.
- **c.** hold a gear into mesh.
- **d.** all of these.

11. A four-speed transmission with external linkage uses (A) two shift rods to connect the shifter to the transmission; (B) an interlock mechanism built into the shifter assembly. Which is correct?

- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

12. The speedometer gear is driven by the

- **a.** main drive gear.
- **b.** mainshaft.
- **c.** cluster gear.
- **d.** driveshaft.

13. A transmission is lubricated (A) by gear oil that is thrown around the case by gear rotation; (B) to remove excess heat from the gears. Which is correct?

- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

14. Two students are discussing a transmission that is noisy in first, second, third, and reverse but quiet in fourth gear. Student A says there is probably a bad input shaft gear. Student B says it probably has a faulty 1–2 synchronizer assembly because reverse is on the synchronizer sleeve. Who is correct?

- **a.** Student A
- **b.** Student B
- **c.** Both A and B
- **d.** Neither A nor B

15. A four-speed transmission makes a grinding noise only while shifting into second gear. This could be caused by a (A) damaged main drive gear; (B) faulty 1–2 synchronizer sleeve. Which is correct?

- **a.** A only
- **b.** B only
- **c.** Both A and B
- **d.** Neither A nor B

16. The main drive gear has 18 teeth that drive a 24-tooth gear at the front of the cluster gear. What is the ratio between these two?

17. Using the gear ratio from question 16, how fast will the cluster gear be turning with an engine speed of 2000 rpm?

18. First gear on the cluster has 18 teeth, and the first-speed gear has 28 teeth. What is the ratio?

19. If the input gear set is 18 and 24, what is the ratio for first gear?

20. Using the gear ratio from question 19, how fast will the mainshaft be turning with an engine speed of 2000 rpm?