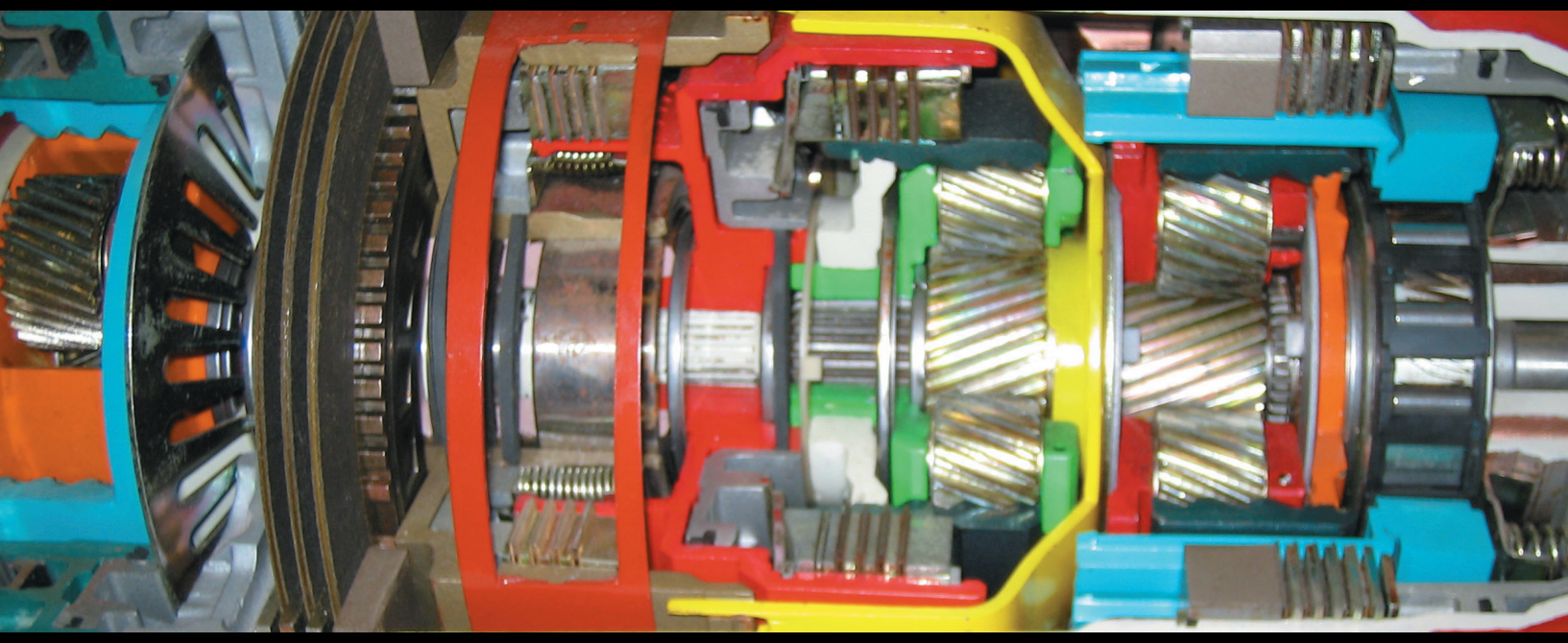
Automatic Transmissions and Transaxles

Seventh Edition

James D. Halderman



AUTOMATIC TRANSMISSIONS AND TRANSAXLES

SEVENTH EDITION

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James D. Halderman

Pearson

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PREFACE

PROFESSIONAL TECHNICIAN SERIES Part of the Pearson Automotive Professional Technician Series, the seventh edition of *Automatic Transmissions and Transaxles* represents the future of automotive textbooks. The series is a full-color, media-integrated solution for today's students and instructors. The series includes textbooks that cover all eight areas of ASE certification, plus additional titles covering common courses. The series is peer reviewed for technical accuracy.

UPDATES TO THE SEVENTH EDITION Based on conversations and recommendations from automotive instructors and reviewers, the following updates have been incorporated in the new seventh edition:

1. Automatic transmission/transaxle hydraulic systems has been greatly expanded and then split in to three chapters to make teaching and learning hydraulic systems easier:
   - **Automatic Transmission Fluid, Filters And Coolers**—Chapter 2
   - **Automatic Transmission/Transaxle Hydraulic System**—Chapter 3
   - **Hydraulic Control Valves And Solenoids**—Chapter 4
2. Updated throughout to match the latest ASE/NATEF tasks.
3. Over 50 new full color line drawings and photos make the subject come alive.
4. Case studies added to selected chapters that include the "three Cs" (Complaint, Cause and Correction).
5. Global electrical symbols added to Chapter 8.
6. All systems and components are described throughout with the following format to make learning complex systems easier:
   - Purpose and Function
   - Parts and Operation
   - Diagnosis and Service
7. All terms used adhere to the SAE J1930 standard.
8. Unlike other textbooks, this book is written so that the theory, construction, diagnosis, and service of a particular component or system is presented in one location. There is no need to search through the entire book for other references to the same topic.

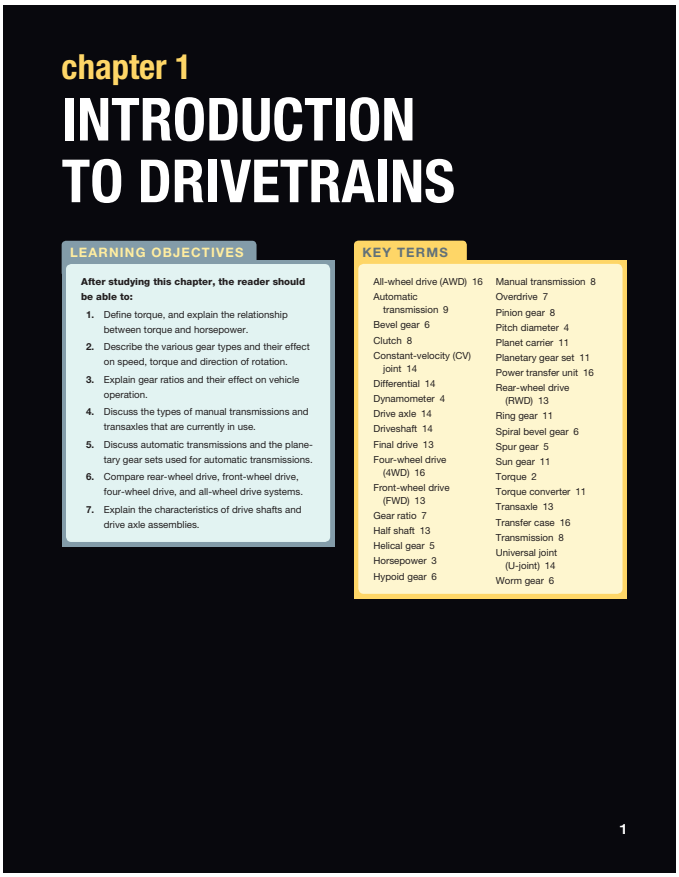
ASE AND NATEF CORRELATED NATEF-certified programs need to demonstrate that they use course material that covers NATEF and ASE tasks. All Professional Technician textbooks have been correlated to the appropriate ASE and NATEF task lists. These correlations can be found in the appendix.

A COMPLETE INSTRUCTOR AND STUDENT SUPPLEMENTS PACKAGE All Professional Technician textbooks are accompanied by a full set of instructor and student supplements. Please see page vi for a detailed list of supplements.

A FOCUS ON DIAGNOSIS AND PROBLEM SOLVING The Professional Technician Series has been developed to satisfy the need for a greater emphasis on problem diagnosis. Automotive instructors and service managers agree that students and beginning technicians need more training in diagnostic procedures and skill development. To meet this need and demonstrate how real-world problems are solved, "Real World Fix" features are included throughout and highlight how real-life problems are diagnosed and repaired.

The following pages highlight the unique core features that set the Professional Technician Series book apart from other automotive textbooks.

IN-TEXT FEATURES



chapter 1

INTRODUCTION TO DRIVETRAINS

LEARNING OBJECTIVES

After studying this chapter, the reader should be able to:

1. Define torque, and explain the relationship between torque and horsepower.
2. Describe the various gear types and their effect on speed, torque and direction of rotation.
3. Explain gear ratios and their effect on vehicle operation.
4. Discuss the types of manual transmissions and transaxles that are currently in use.
5. Discuss automatic transmissions and the planetary gear sets used for automatic transmissions.
6. Compare rear-wheel drive, front-wheel drive, four-wheel drive, and all-wheel drive systems.
7. Explain the characteristics of drive shafts and drive axle assemblies.

KEY TERMS

All-wheel drive (AWD) 16
Automatic transmission 9
Bevel gear 6
Clutch 8
Constant-velocity (CV) joint 14
Differential 14
Dynamometer 4
Drive axle 14
Driveshaft 14
Final drive 13
Four-wheel drive (4WD) 16
Front-wheel drive (FWD) 13
Gear ratio 7
Half shaft 13
Helical gear 5
Horsepower 3
Hypoid gear 6
Manual transmission 8
Overdrive 7
Pinion gear 8
Pitch diameter 4
Planet carrier 11
Planetary gear set 11
Power transfer unit 16
Rear-wheel drive (RWD) 13
Ring gear 11
Spiral bevel gear 6
Spur gear 5
Sun gear 11
Torque 2
Torque converter 11
Transaxle 13
Transfer case 16
Transmission 8
Universal joint (U-joint) 14
Worm gear 6

1

LEARNING OBJECTIVES AND KEY TERMS appear at the beginning of each chapter to help students and instructors focus on the most important material in each chapter. The chapter objectives are based on specific ASE and NATEF tasks.

TECH TIP

Solenoids Are Wear Items

Many technicians consider solenoids, especially PWM solenoids, to be "wear items" and automatically replace them if the transmission experiences problems after about 90,000 miles (150,000 km).

TECH TIPS feature real-world advice and "tricks of the trade" from ASE-certified master technicians.

Case Study

TSB to the Rescue

A Dodge Durango came in to the shop with a customer complaint of delayed engagement into reverse after sitting for a while. A check of a TSB (21-016-05) described filters with defective check valves. Replacement of the filter cured this problem.

SUMMARY:

Complaint—Customer complained of a delayed engagement into reverse after the vehicle sat for a while.

Cause—The original filter had a defective check valve.

Correction—A replacement filter fixed the concern.

CASE STUDY present students with actual automotive scenarios and show how these common (and sometimes uncommon) problems were diagnosed and repaired.

FREQUENTLY ASKED QUESTION

Is It Lb-Ft or Ft-Lb of Torque?

The unit for torque is expressed as a force times the distance (leverage) from the object. Therefore, the official unit for torque is lb-ft (pound-feet) or Newton-meters (a force times a distance). However, it is commonly expressed in ft-lb and most torque wrenches are labeled with this unit.

FREQUENTLY ASKED QUESTIONS are based on the author's own experience and provide answers to many of the most common questions asked by students and beginning service technicians.

NOTE: Most of these "locking nuts" are grouped together and are commonly referred to as *prevailing torque nuts*. This means that the nut will hold its tightness or torque and not loosen with movement or vibration.

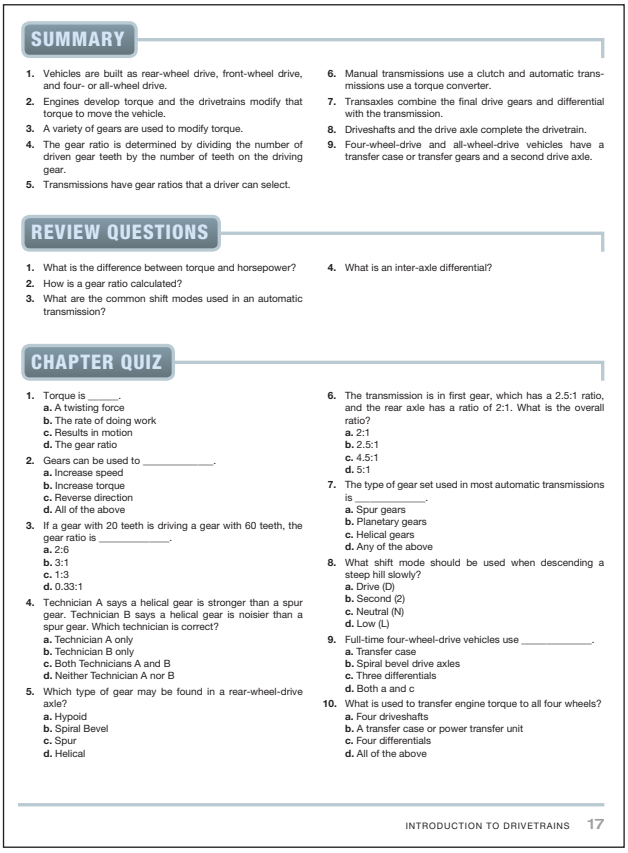
NOTES provide students with additional technical information to give them a greater understanding of a specific task or procedure.

CAUTION: Do not perform this quick check on a PWM solenoid because the lower coil resistance will allow excessive current flow that can damage the solenoid.

CAUTIONS alert students about potential damage to the vehicle that can occur during a specific task or service procedure.

WARNING

Use caution during servo cover removal because some servos use a strong piston spring. These require a special tool to hold the spring compressed during retainer ring removal and then allow the spring to be safely extended.



SUMMARY

1. Vehicles are built as rear-wheel drive, front-wheel drive, and four- or all-wheel drive.
2. Engines develop torque and the drivetrains modify that torque to move the vehicle.
3. A variety of gears are used to modify torque.
4. The gear ratio is determined by dividing the number of driven gear teeth by the number of teeth on the driving gear.
5. Transmissions have gear ratios that a driver can select.
6. Manual transmissions use a clutch and automatic transmissions use a torque converter.
7. Transaxles combine the final drive gears and differential with the transmission.
8. Driveshafts and the drive axle complete the drivetrain.
9. Four-wheel-drive and all-wheel-drive vehicles have a transfer case or transfer gears and a second drive axle.

REVIEW QUESTIONS

1. What is the difference between torque and horsepower?
2. How is a gear ratio calculated?
3. What are the common shift modes used in an automatic transmission?
4. What is an inter-axle differential?

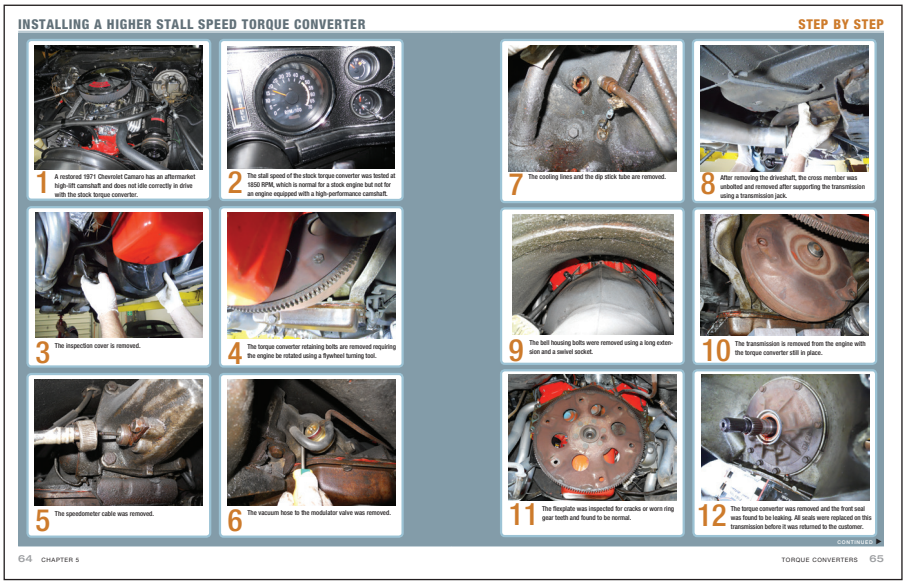
CHAPTER QUIZ

1. Torque is _____.
   a. A twisting force
   b. The rate of doing work
   c. Results in motion
   d. The gear ratio
2. Gears can be used to _____.
   a. Increase speed
   b. Increase torque
   c. Reverse direction
   d. All of the above
3. If a gear with 20 teeth is driving a gear with 60 teeth, the gear ratio is _____.
   a. 2:6
   b. 3:1
   c. 1:3
   d. 0.33:1
4. Technician A says a helical gear is stronger than a spur gear. Technician B says a helical gear is noisier than a spur gear. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
5. Which type of gear may be found in a rear-wheel-drive axle?
   a. Hypoid
   b. Spiral Bevel
   c. Spur
   d. Helical
6. The transmission is in first gear, which has a 2.5:1 ratio, and the rear axle has a ratio of 2:1. What is the overall ratio?
   a. 2:1
   b. 2.5:1
   c. 4.5:1
   d. 5:1
7. The type of gear set used in most automatic transmissions is _____.
   a. Spur gears
   b. Planetary gears
   c. Helical gears
   d. Any of the above
8. What shift mode should be used when descending a steep hill slowly?
   a. Drive (D)
   b. Second (2)
   c. Neutral (N)
   d. Low (L)
9. Full-time four-wheel-drive vehicles use _____.
   a. Transfer case
   b. Spiral bevel drive axles
   c. Three differentials
   d. Both a and c
10. What is used to transfer engine torque to all four wheels?
    a. Four driveshafts
    b. A transfer case or power transfer unit
    c. Four differentials
    d. All of the above

INTRODUCTION TO DRIVETRAINS 17

WARNINGS alert students to potential dangers to themselves during a specific task or service procedure.

THE SUMMARY, REVIEW QUESTIONS, AND CHAPTER QUIZ at the end of each chapter help students review the material presented in the chapter and test themselves to see how much they've learned.



STEP-BY-STEP photo sequences show in detail the steps involved in performing a specific task or service procedure.

SUPPLEMENTS

RESOURCES IN PRINT AND ONLINE

Automatic Transmissions and Transaxles

Name of Supplement	Print	Online	Audience	Description
Instructor Resource Manual 0-13-460626-4		✔	Instructors	NEW! The ultimate teaching aid: Chapter summaries, key terms, chapter learning objectives, lecture resources, discuss/ demonstrate classroom activities, and answers to the in-text review and quiz questions.
TestGen 0-13-461684-7		✔	Instructors	Test generation software and test bank for the text.
PowerPoint Presentation 0-13-461687-1		✔	Instructors	Slides include chapter learning objectives, lecture outline of the test, and graphics from the book.
Image Bank 0-13-461688-X		✔	Instructors	All of the images and graphs from the text-book to create customized lecture slides.
NATEF Correlated Task Sheets— for Instructors 0-13-460625-6		✔	Instructors	Downloadable NATEF task sheets for easy customization and development of unique task sheets.
NATEF Task Sheets— for Students 0-13-461692-8	✔		Students	Study activity manual that correlates NATEF Automobile Standards to chapters and page numbers in the text. Available to students at a discounted price when packaged with the text.
VitalSource eBook 0-13-461685-5		✔	Students	An alternative to purchasing the print text-book, students can subscribe to the same content online and save up to 50% off the suggested list price of the print text. Visit **www.vitalsource.com**

All online resources can be downloaded from the Instructor's Resource Center: **www.pearsonighered.com/irc**

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A large number of people and organizations have cooperated in providing the reference material and technical information used in this text.

A-1 Automatic Transmissions
Aceomatic Recon
AFM, Raytech Automotive Components Comp.
Alto Products Corp.
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ATEC Trans-Tool and Cleaning Systems
Autotrans
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BorgWarner, Morse TEC
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chapter 1

INTRODUCTION TO DRIVETRAINS

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4. Discuss the types of manual transmissions and transaxles that are currently in use.
5. Discuss automatic transmissions and the planetary gear sets used for automatic transmissions.
6. Compare rear-wheel drive, front-wheel drive, four-wheel drive, and all-wheel drive systems.
7. Explain the characteristics of drive shafts and drive axle assemblies.

KEY TERMS

All-wheel drive (AWD) 16
Automatic transmission 9
Bevel gear 6
Clutch 8
Constant-velocity (CV) joint 14
Differential 14
Dynamometer 4
Drive axle 14
Driveshaft 14
Final drive 13
Four-wheel drive (4WD) 16
Front-wheel drive (FWD) 13
Gear ratio 7
Half shaft 13
Helical gear 5
Horsepower 3
Hypoid gear 6
Manual transmission 8
Overdrive 7
Pinion gear 8
Pitch diameter 4
Planet carrier 11
Planetary gear set 11
Power transfer unit 16
Rear-wheel drive (RWD) 13
Ring gear 11
Spiral bevel gear 6
Spur gear 5
Sun gear 11
Torque 2
Torque converter 11
Transaxle 13
Transfer case 16
Transmission 8
Universal joint (U-joint) 14
Worm gear 6

DRIVETRAINS

PURPOSE AND FUNCTION The purpose of a vehicle drivetrain is to transfer power from the engine to the drive wheels. The drivetrain, also called a powertrain, serves the following functions:

- It allows the driver to control the power flow.
- It multiplies the engine torque.
- It controls the engine speed.

? FREQUENTLY ASKED QUESTION

Is It Lb-Ft or Ft-Lb of Torque?

The unit for torque is expressed as a force times the distance (leverage) from the object. Therefore, the official unit for torque is lb-ft (pound-feet) or Newton-meters (a force times a distance). However, it is commonly expressed in ft-lb and most torque wrenches are labeled with this unit.

TORQUE

DEFINITION **Torque** is a rotating or twisting force that may or may not result in motion. A vehicle moves because of the torque the drive axle exerts on the wheels and tires to make them rotate. Being a form of mechanical energy, torque cannot be created or destroyed—it is converted from one form of energy to another form of energy.

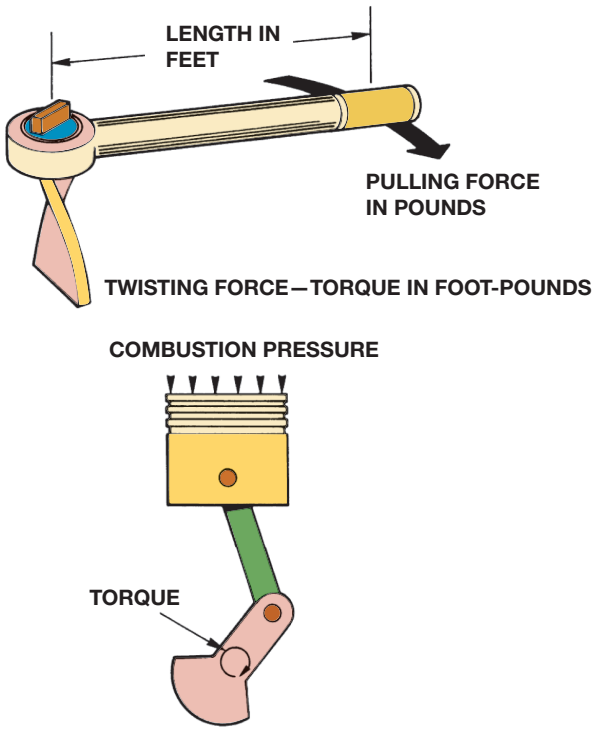


FIGURE 1–1 Torque, a twisting force, is produced when you pull on a wrench. An engine produces torque at the crankshaft as combustion pressure pushes the piston downward.

UNITS OF TORQUE Engine torque is developed when combustion pressure pushes a piston downward to rotate the crankshaft. ● **SEE FIGURE 1–1.**

The amount of torque produced will vary depending on the size and design of the engine and the throttle opening. Torque is measured in pounds-feet (lb-ft) or Newton-meters (N-m). One Newton-meter of torque is equal to 0.737 lb-ft. A factor that greatly affects drivetrain design is that very little or no torque is developed at engine speeds below 1000 RPM (revolutions per minute). An engine begins producing usable torque at about 1200 RPM and peak torque at about 2500 to 4000 RPM, with an upper usable speed limit of 5000 to 7000 RPM. The gear ratios in the transmission and drive axle are used to match the engine speed and torque output to the vehicle speed and torque requirements. ● **SEE FIGURE 1–2.**

DRIVE VS. DRIVEN GEARS The *drive* gear is the gear that is the source of the engine torque and rotation. The *driven* gear is the gear that is driven or rotated by the drive gear. Two gears meshed together are used to transmit torque and rotational motion. The driven gear can then rotate yet another gear. In this case, the second gear becomes the drive gear and the third gear is the driven gear.

TORQUE MULTIPLICATION The gear teeth are cut proportional to the diameter of the gear. If one of two mating gears was twice as large as the other, it would have twice as many teeth. For example, if the smaller gear has 10 teeth, a gear twice as large will have 20 teeth. If the teeth of these gears are intermeshed, 10 teeth of each gear will come into contact when the smaller gear rotates one revolution. This will require one revolution of the small gear and one-half revolution of the larger gear. It will take two revolutions of the small gear to produce one revolution of the larger gear. This is a gear ratio of 2:1, assuming that the small gear is the drive gear. To determine a gear ratio, divide the driven gear by the driving gear. ● **SEE FIGURE 1–3.**

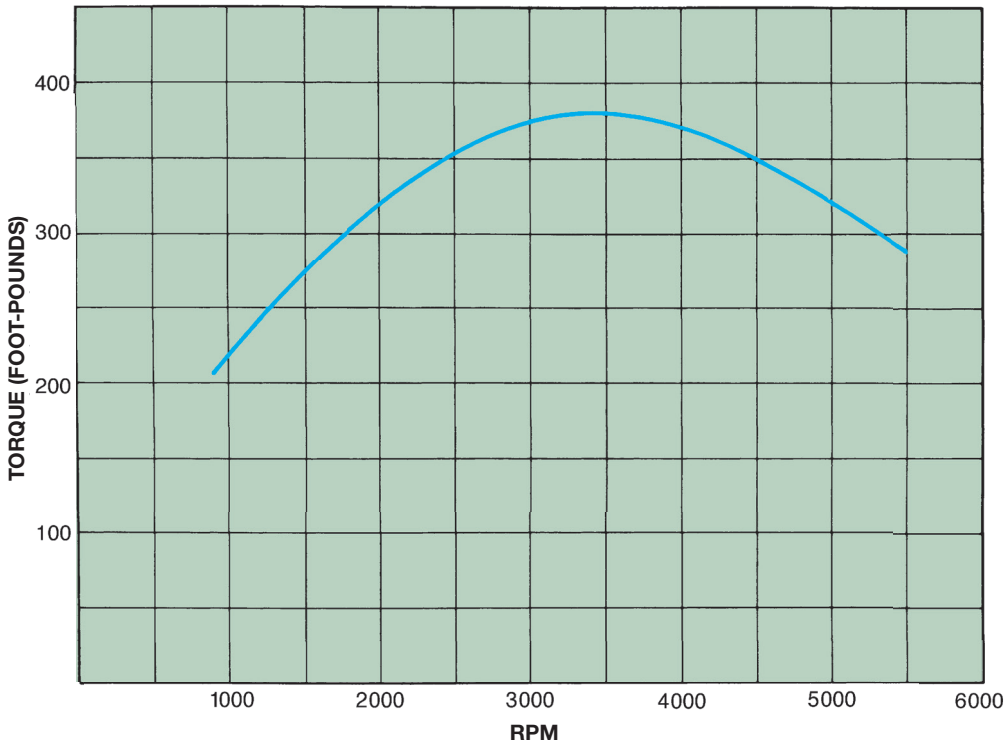


FIGURE 1–2 The torque produced by a 5.7 L engine as plotted on a graph. Note that the engine begins producing usable torque at 1000 to 1200 RPM and a maximum torque (381 ft-lb) at 3500 RPM. The torque produced by the engine decreases at higher RPM due to a decrease in volumetric efficiency.

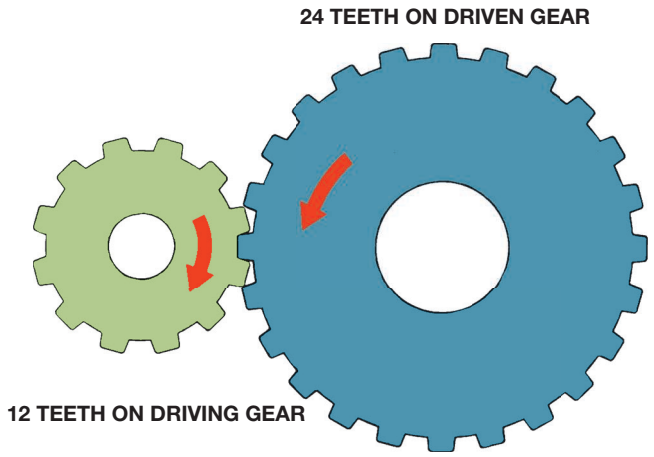


FIGURE 1–3 Gear ratio is determined by dividing the number of teeth of the driven (output) gear (24 teeth) by the number of teeth on the driving (input) gear (12 teeth). The ratio illustrated is 2:1.

GEARS ARE LEVERS Torque is increased because of the length of the gear lever, as measured from the center of the gear. Think of each tooth as a lever, with the fulcrum being the center of the gear. The lever lengths of the two gears can provide leverage much like that of a simple lever. Physics does not allow energy to become lost in a gear set, other than what is lost as heat in overcoming friction. Therefore, whatever power that comes in one shaft, goes out through another.

- If the speed is reduced, torque will increase by the same amount.
- If speed is increased, torque will decrease by the same amount.

For example, if the driving gear has 20 lb-ft (27 N-m) of torque at 500 RPM and the ratio is 2:1, the driven gear will have 40 lb-ft (54 N-m) of torque (twice as much) at 250 RPM (half the speed).

HORSEPOWER

DEFINITION The term power means the rate of doing work. Power equals work divided by time.

- Work is done when a certain amount of mass (weight) is moved a certain distance by a force. Whether the object is moved in 10 seconds or 10 minutes does not make a difference in the amount of work accomplished, but it does affect the amount of power needed. ● **SEE FIGURE 1–4.**
- Power is expressed in units of foot-pounds per minute. One **horsepower** is the power required to move 550 pounds one foot in one second, or 33,000 pounds one foot in one minute (550 lb × 60 sec = 33,000 lb). This

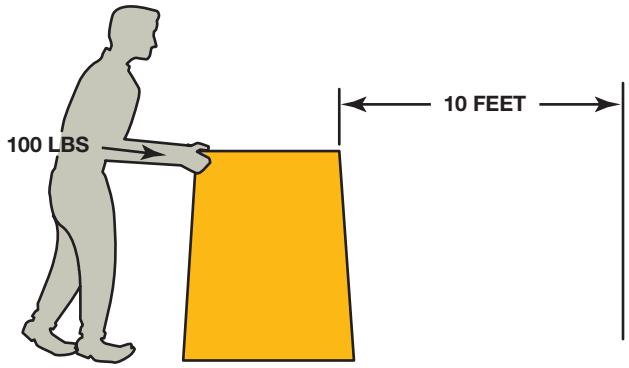


FIGURE 1–4 Work is calculated by multiplying force times distance. If you push 100 pounds 10 feet, you have done 1,000 foot-pounds of work.

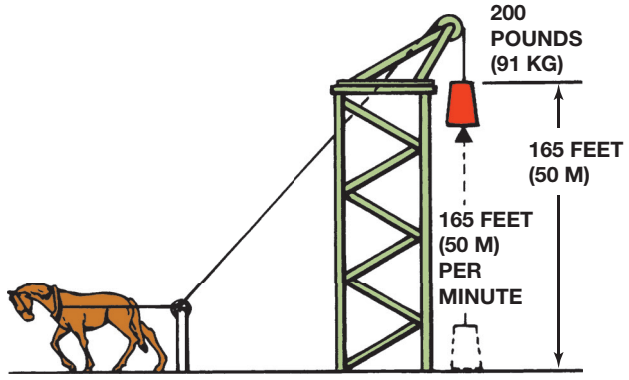


FIGURE 1–5 One horsepower is equal to 33,000 foot-pounds (200 lbs × 165 ft) of work per minute.

is expressed as 550 foot-pounds (ft-lb) per second or 33,000 foot-pounds per minute. ● **SEE FIGURE 1–5.**

HORSEPOWER AND TORQUE RELATIONSHIP To determine horsepower, a **dynamometer** is used to measure the amount of torque an engine can produce at various points through its operating range. The formula used to convert torque at a certain revolution per minute (RPM) into a horsepower reading is

Horsepower = Torque × RPM/5,252

NOTE: To determine how the constant "5,252" was derived, perform an Internet search to see an explanation.

The various readings are then plotted into a curve. A typical horsepower and torque curve shows us that an engine does not produce very much torque at low RPM. The most usable torque is produced in the mid-RPM range. Torque decreases with an increase in horsepower at a higher RPM.

The torque from an engine can be increased or decreased through the use of gears, belts, and chains. Gears, belts, or chains cannot increase horsepower; they can only modify its effect. A gear set can increase torque, but it will decrease speed by the same amount.

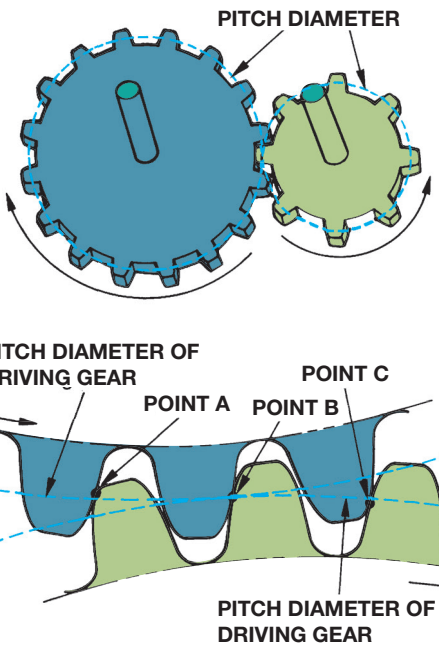


FIGURE 1–6 The pitch diameter is the effective diameter of the gear. Note how the contact points slide on the gear teeth as they move in and out of contact.

TECH TIP

How to Explain the Difference between Horsepower and Torque

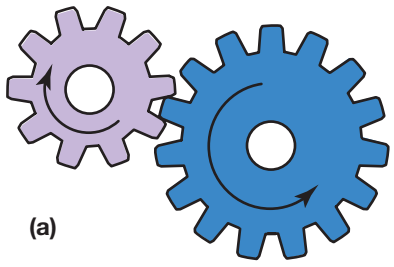
As Carroll Shelby, the well-known racer and business owner, said, "Horsepower sells cars, but torque wins races." Torque determines how fast the vehicle will accelerate, and horsepower determines how fast the vehicle will go.

GEARS

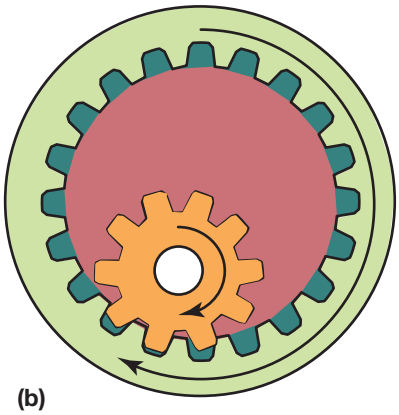
TERMINOLOGY The effective diameter of a gear is the **pitch diameter** (or *pitch line*). ● **SEE FIGURE 1–6.**

The pitch diameter is the diameter of the gear at the point where the teeth of the two gears meet and transfer power. The gear teeth are shaped to be able to slide in and out of mesh with a minimum amount of friction and wear. Major points include:

- Driven and driving gears will rotate in opposite directions.

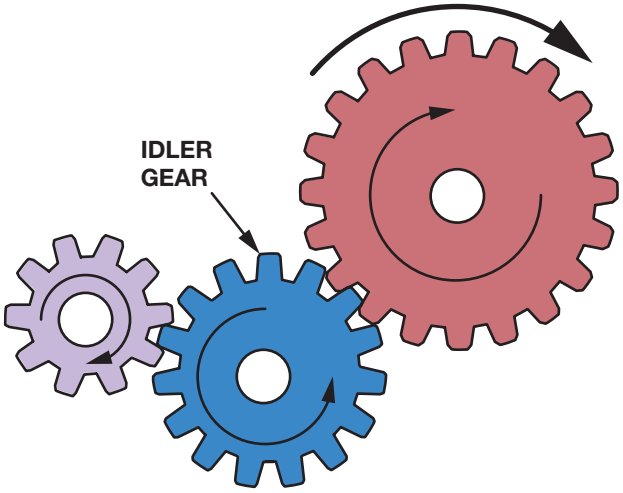


EXTERNAL GEARS



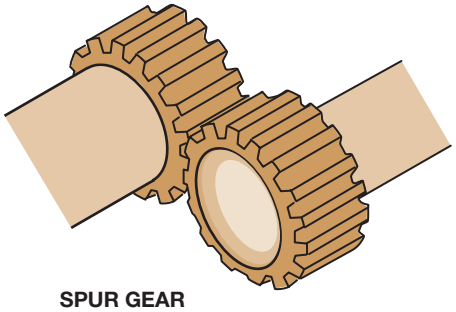
INTERNAL AND EXTERNAL GEARS

FIGURE 1–7 (a) When one external gear drives another, the direction of rotation is always reversed. (b) When an external gear drives an internal gear, the two gears will rotate in the same direction.



EXTERNAL GEARS

FIGURE 1–8 An idler gear reverses the direction of rotation so that the driving and driven gears rotate in the same direction.



SPUR GEAR

FIGURE 1–9 The teeth of a spur gear are cut parallel to the shaft, and this produces a straight pressure between the driving and the driven gear teeth.

- External gears will always reverse shaft motion.
- If same-direction motion is required, the power will be routed through two gear sets.
- When power goes through a series of gears, an even number of gears (2, 4, 6, and 8) will cause a reversal in direction and an odd number of gears (3, 5, 7, and 9) will produce same direction of rotation.

  ● **SEE FIGURE 1–7.**

REVERSING DIRECTION OF ROTATION

External gears reverse the direction of rotation when the drive gear transfers power to the driven gear. When it is necessary to change the ratio without changing the direction of power flow, an idler gear is added. An idler gear changes the rotational direction but does not affect the ratio. ● **SEE FIGURE 1–8.**

GEAR TYPES

Gears come in different types depending on the cut and relationship of the teeth to the shafts.

- **Spur gears**—Spur gears, the simplest gears, are on parallel shafts with teeth cut straight or parallel to the shaft. ● **SEE FIGURE 1–9.**
- **Helical gear**—Helical gears are the most used of all gears used in transmissions. These gears have teeth cut in a spiral or helix shape. ● **SEE FIGURE 1–10.**

Helical gears are quieter than spur gears, but generate axial or end thrust under a load. A helical gear is stronger than a comparable-sized spur gear and has an almost continuous power flow because of the angled teeth. ● **SEE FIGURE 1–10.**

NOTE: When discussing gears, a pinion gear is the smaller gear of a pair.

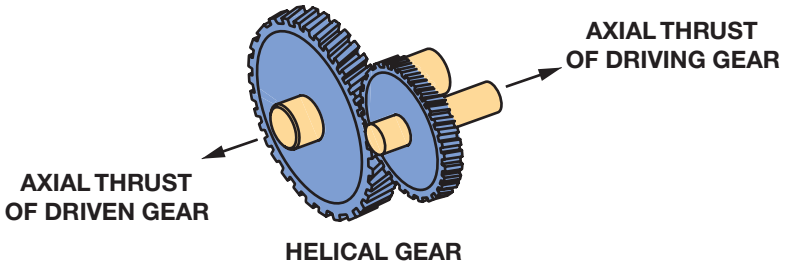


FIGURE 1–10 The teeth of a helical gear are cut on a slant, and this produces an axial or side thrust.

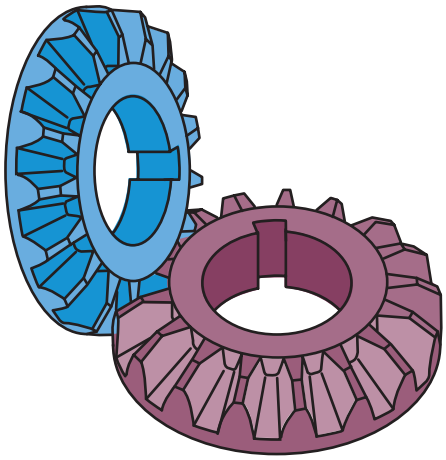


FIGURE 1–11 Bevel gears are commonly used in differentials.

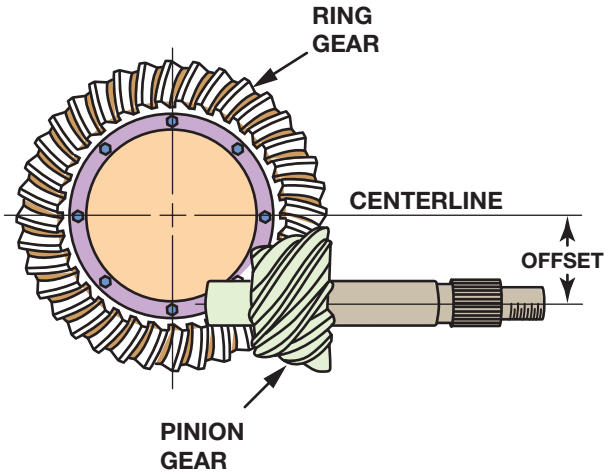


FIGURE 1–12 A hypoid gear set uses a pinion gear that is located below the centerline of the ring gear and is commonly used in drive axles.

- **Bevel gears**—Bevel gears are used on nonparallel shafts. The outer edge of the gear must be cut on the angle that bisects the angle of the two shafts. In other words, if the two shafts meet at an angle of 90° and the two gears are the same size, the outer edge of the gears will be cut at 45°. The simplest bevel gears have teeth cut straight and are called spur bevel gears. They are inexpensive but noisy. ● **SEE FIGURE 1–11.**
- **Spiral bevel gears**—Spiral bevel gears, like helical gears, have curved teeth for quieter operation.
- **Hypoid gear**—A variation of the spiral bevel gear is the hypoid gear, also called an *offset-bevel gear*. Hypoid gears are used in most drive axles and transaxles that have longitudinal mounted engines. The hypoid gear design places the drive pinion gear lower in the housing (below the centerline) of the ring gear and axle shafts. ● **SEE FIGURE 1–12.**
- **Worm gear**—A gear set used with shafts that cross each other but do not intersect is the worm gear. The worm gear or drive pinion is cut in a rather severe helix, much like a bolt thread, and the ring gear or wheel is cut almost like a spur gear. Worm gears are used in vehicle speed sensor drives. To determine the ratio of a worm gear, divide the number of teeth on the wheel by the pitch of the worm gear. For example, a single-pitch worm gear tooth driving a 20-tooth ring gear will have a ratio of 20:1, a very low ratio, and the wheel does not have to be 20 times larger than the worm gear. A 20:1 ratio in most gear sets requires the driven gear to be 20 times larger than the driving gear. ● **SEE FIGURE 1–13.**

? FREQUENTLY ASKED QUESTION

What Is a "Rock Crusher" Transmission?

A manual Muncie (M22) four-speed manual transmission in the muscle car era, was called the *rock crusher* because it used straight cut spur gears.

It was designed as a racing transmission because by using spur gears, the end thrust loads were reduced. However, spur gears are noisy and sounded like rocks being chewed up so therefore, the slang term "rock crusher" for this once popular transmission.

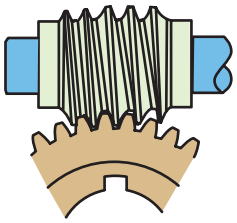


FIGURE 1–13 A worm gear set is also used to transmit power between angled shafts.

GEAR RATIOS

TERMINOLOGY **Gear ratios** are determined by the following methods:

- Dividing the number of teeth on the driven gear (output) by the number of teeth on the driving gear (input). Most of the time, this means dividing a larger number, such as 20, by a smaller number, such as 5. In this case, 20 ÷ 5 = 4, so the ratio will be 4:1.
- Gear ratio = driven gear/drive gear.
- The driving gear will turn four times for each revolution of the driven gear. This results in a speed reduction and a torque increase. The speed of the output will be 4 times slower than the input speed but, the output torque will be four times more than the input torque. The higher the ratio number, the lower the gear ratio. A 5:1 ratio is higher numerically, but, in terms of speed of the driven gear, it is a lower ratio than 4:1. **SEE FIGURE 1–14.**

Most of the time, the ratio will not end up as whole numbers. It will be something like an 11-tooth driving gear and a 19-tooth driven gear, which results in a ratio of 19 divided by 11, which equals 1.7272727 and can be rounded off to 1.73.

COMMONLY USED RATIOS The automotive industry commonly rounds off gear ratios to two decimal points. Drivetrain engineers usually do not use even ratios like 3:1 or 4:1 but instead use ratios that are at least 10 percent greater or less than even numbers. An even ratio, like 3:1, repeats the same gear tooth contacts every third revolution. If there is a damaged tooth, a noise will be repeated continuously, and most drivers will not like the noise. A gear set with a ratio such as 3.23:1 is called a hunting gear set, and a tooth of one gear contacts all of the other gear teeth, which produces quieter operation.

OVERDRIVE If the driving gear has more teeth (20) than the driven gear (5), there will be an increase in speed and a reduction in torque. This is called an **overdrive**. The ratio is computed by dividing 5 by 20, 5 ÷ 20 = 0.25, so the ratio would be expressed as 0.25:1. The driving gear will turn 0.25 or one-fourth of a revolution for each turn of the driven gear. Note that a gear ratio is always written with the number 1 to the right of the colon. This represents one turn of the output gear, while the number to the left represents the revolutions of the input gear.

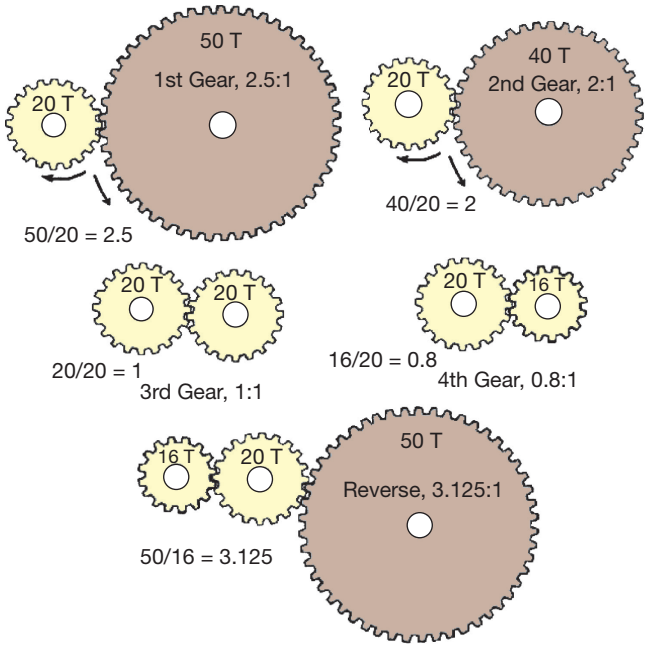


FIGURE 1–14 The gear ratio is determined by dividing the number of teeth on the driven (output) gear by the number of teeth on the driving (input) gear.

? **FREQUENTLY ASKED QUESTION**

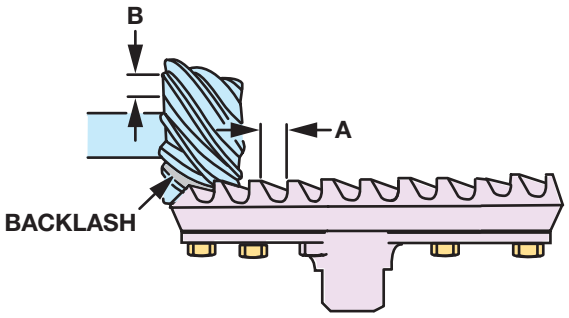
What Is the Relationship between Speed and Gear Ratio?

The following formulas can be used to determine the vehicle speed based on the gear ratio and engine speed, or the engine speed based on the gear ratio and MPH:

- MPH = (RPM × tire diameter) ÷ (gear ratio × 336)
- Engine RPM = (MPH × gear ratio × 336) ÷ tire diameter

NOTE: The constant 336 is used to convert the units from inches (tire diameter) to feet and MPH to feet per hour.

CALCULATING OVERALL RATIOS When power goes through more than one gear set, two or more ratios are involved. In most cases, the simplest way to handle this is to figure the ratio of each set and then multiply the ratios. An



A - B = BACKLASH

FIGURE 1–15 Backlash is the clearance between the teeth of two meshing gears. There has to be some clearance (backlash) to prevent the gears from getting into a bind condition when they are transmitting torque.

example of this is a vehicle with a first-gear ratio of 2.68:1 and a rear axle ratio of 3.45:1. The overall ratio in first gear is 2.68 × 3.45 or 9.246:1.

- At the same time there will be 9.246 times as much torque at the rear wheels than the engine produced.
- The engine will rotate at a speed that is 9.246 times faster than the rear axle shafts. The overall ratios for the other transmission gears would be figured in the same manner.

GEAR SET SUMMARY Typical rules about gear sets include the following:

- Two mated external gears will always rotate in opposite directions.
- Gear sets will multiply torque, but at a reduced speed.
- An idler gear allows the drive and driven gears to rotate in the same direction.
- To find the ratio, divide the driven gear by the drive gear.
- When power transfers through an even number (two or four) of gears, the input and output gears will rotate in opposite directions.
- When power transfers through an uneven number (one, three, or five) of gears, the input and output gears will rotate in the same direction.
- To find the overall ratio of multiple gear sets, multiply the ratios of the gear sets.
- Two gears transferring power push away from each other in an action called *gear separation*. The gear separation force (thrust) is proportional to the torque being transferred.
- The smaller gear(s) in a gear set may also be called a **pinion gear**.
- All gear sets *must* have backlash to prevent binding. **SEE FIGURE 1–15.**

TRANSMISSIONS

PURPOSE AND FUNCTION The purpose and function of gears in a **transmission** include the following:

- Low/first gear must provide enough torque to get the vehicle moving.
- High gear should provide an engine speed for fuel-efficient operation at highway speeds.
- The intermediate ratios should be spaced to provide adequate acceleration while minimizing the potential of overrevving the engine before the shift or lugging the engine after the shift.

TRENDS The majority of vehicles up to the 1970s used three-speed transmissions while some added an overdrive unit for a fourth gear ratio to lower engine RPM at cruise speeds. As the need to improve fuel economy and reduce exhaust emissions has improved, four-, five-, and six-speed transmissions have been introduced to provide lower first gears, overdrive, and/or smaller steps between gear ratios.

MANUAL TRANSMISSIONS

PURPOSE AND FUNCTION A **manual transmission**, also called a *standard transmission*, is constructed with a group of paths through which power can flow with each path used being a different gear ratio. **SEE FIGURE 1–16.**

Synchronizer assemblies or sliding gears and the shift linkage are used to control or engage the power paths.

CLUTCH Engine power must be stopped when making a shift in a manual transmission. The **clutch** is used to stop the power flow to allow the transmission to be shifted. It is also used to ease the engagement of the power flow when the vehicle starts from a standstill. The slight slippage as the clutch engages allows the engine speed to stay up where it produces usable torque as the vehicle begins moving.

Most vehicles use a foot-pedal-operated single-plate clutch assembly that is mounted on the engine flywheel. When the pedal is pushed down, the power flow is disengaged and

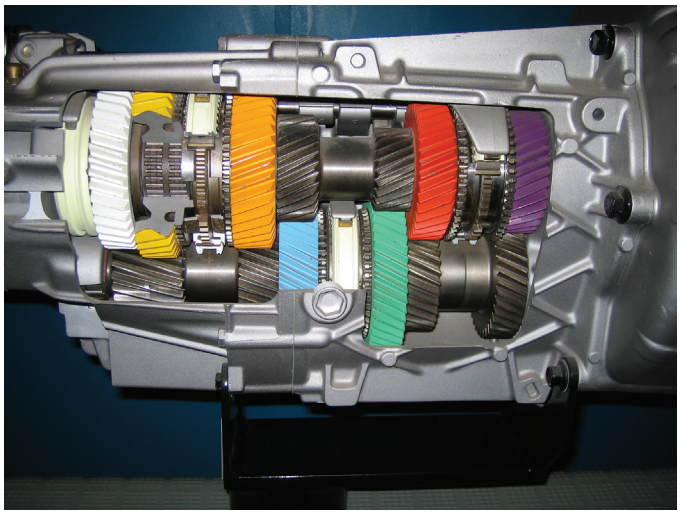


FIGURE 1–16 A manual transmission provides several gear ratios and a method to shift them.

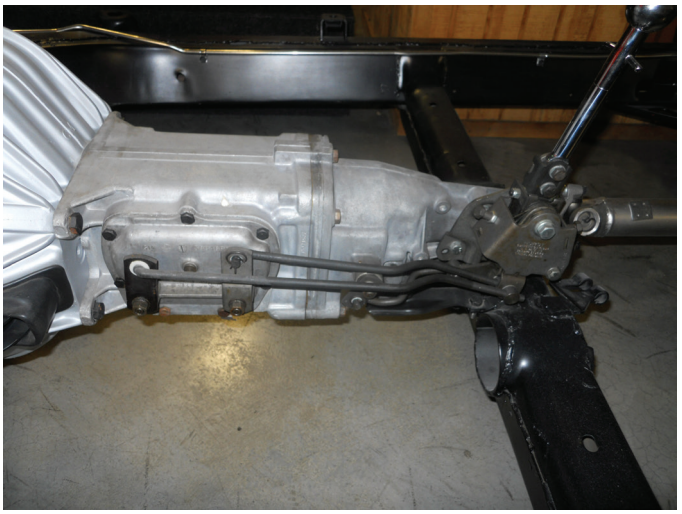


FIGURE 1–17 A Muncie four-speed manual transmission on a restored muscle car is an example of a close-ratio manual transmission.

FREQUENTLY ASKED QUESTION

What Is a "Close-Ratio" Transmission?

Gear ratio spread (GRS), is the difference between the lowest and highest ratios or, in other words, the overall range of the transmission gear ratios. In transmissions, it is fairly easy to visualize the difference between a 3.59:1 first gear and a 0.83:1 fifth gear. Gear ratio spread is determined by dividing the low gear ratio by the high gear ratio. The GRS for the gear transmission is 3.59 ÷ 0.83 = 4.33. RPM change/drop is fairly easy to determine:

- Subtract the higher ratio from the lower ratio and divide the product by the lower ratio.
- A close-ratio Muncie four-speed has ratios spaced fairly close together (25% or less), closer than the wide-ratio version. **SEE FIGURE 1–17.**

FREQUENTLY ASKED QUESTION

What Is an Automated Manual Transmission?

An automated manual transmission is a type of automatic transmission/transaxle that uses two clutches and a manual transmission-type gears and is shifted hydraulically by computer-controlled solenoids. This type of transmission is commonly called a *dual clutch* or an *electronically controlled manual transmission*.

when the pedal is released, power can flow from the engine to the transmission through the engaged clutch. **SEE FIGURE 1–18.**

AUTOMATIC TRANSMISSIONS

PURPOSE AND FUNCTION The purpose and function of an **automatic transmission** is to provide the forward and reverse gear ratios needed without requiring the driver to make the change in gearing as with a manual transmission. An automatic transmission has various gear ratios, but the paths of power flow are different from those of a manual transmission.

SHIFT MODES The transmission provides the various gear ratios for forward and reverse operations as well as two methods for the engine to run without moving the vehicle. Most automatic transmissions and transaxles include the following shift modes. **SEE FIGURE 1–19.**

- **Park.** In the park position, the output shaft is locked to the case of the transmission/transaxle which keeps the vehicle from moving. No power is transmitted through the unit so the engine can remain running while the vehicle is held stationary.

  In the park position

  1. The engine can be started by the driver.
  2. To move the shifter out of the park position on a late model vehicle, the brake pedal must be depressed to release the transmission shift interlock.

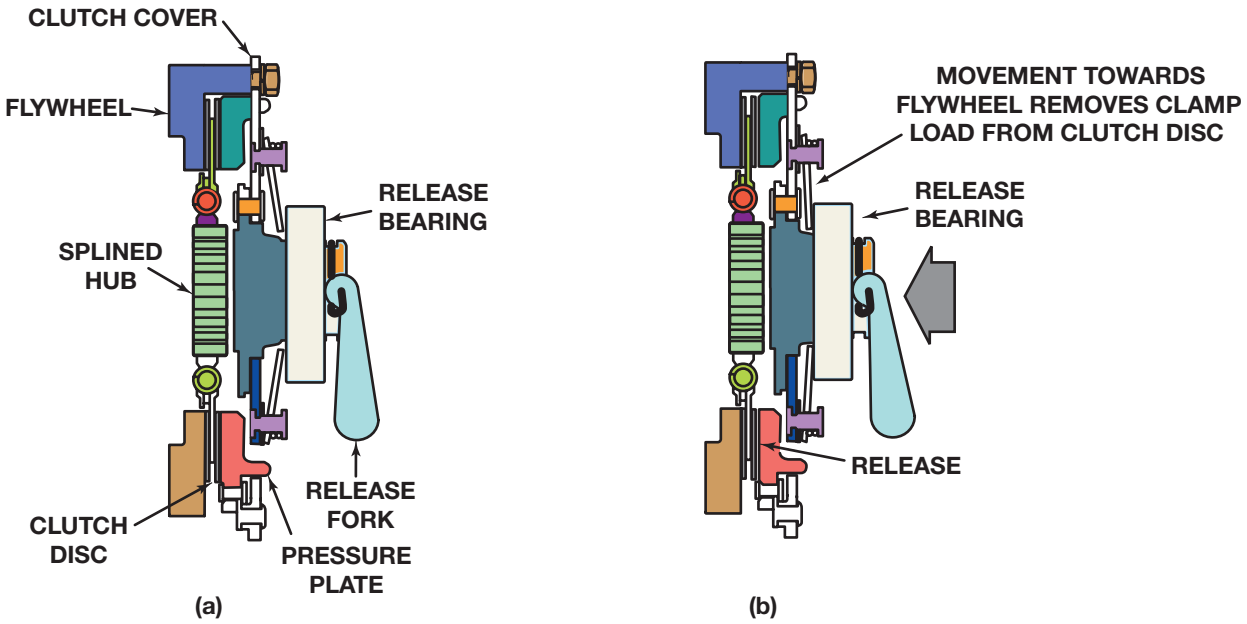


FIGURE 1–18 (a) A clutch cover (pressure plate assembly) is bolted onto the flywheel with the clutch disc between them. The release bearing and fork provide a method to release (disengage) the clutch. (b) When the clutch is engaged, the disc is squeezed against the flywheel by the pressure plate. Releasing the clutch separates the disc from the flywheel and pressure plate.

FIGURE 1–19 The gear selector is often called the "PRNDL," pronounced "prindle," regardless of the actual letters or numbers used.

- **Reverse.** The reverse gear selector position is used to move the vehicle in reverse. Reverse usually uses a gear ratio similar to first gear.
- **Neutral.** In the neutral position, no torque is being transmitted through the automatic transmission/transaxle. In this position the engine can be started by the driver.

CAUTION: The vehicle is free to roll when the gear selector is placed in the neutral position unless the brake pedal is depressed to prevent the vehicle from moving.

- **Overdrive (OD).** The OD is the normal position for the shift selector for most driving conditions. This position allows the transmission or transaxle to shift through all forward gears as needed for the best fuel economy and lowest exhaust emissions.

NOTE: The overdrive button used on many automatic transmissions is used to turn off overdrive and is used while towing or when driving in city traffic to prevent the transmission from shifting in and out of overdrive.

- **Drive (D).** The D position includes the overdrive ratios in most vehicles. If there is an overdrive shift mode, however, then D is used to provide all forward gears except overdrive. Use this position when driving on the highway.
- **Third (3).** In third position the transmission/transaxle will upshift normally to third gear, but will not upshift to a higher gear. When the third position is selected while driving in a higher gear, the transmission will downshift into third if the vehicle speed is low enough to prevent the engine from being overrevved. This gear selection is used for gentle grades at a moderate vehicle speed when engine braking is needed.
- **Second (2).** The second position is used for slowing the vehicle while descending long grades. In this gear selection, the vehicle speed is controlled and the engine speed is increased to provide engine braking. This gear selection is used for the gentle grades at a moderate vehicle speed.

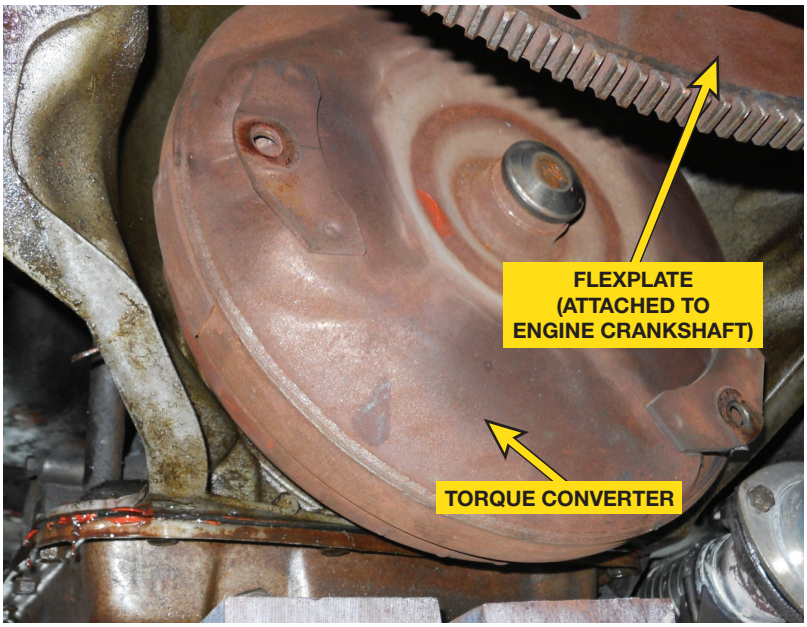


FIGURE 1–20 A torque converter is attached to the engine crankshaft and the other end is splined to the input shaft of the automatic transmission. The torque converter is used to transmit engine torque to the transmission, yet slip when the engine is at idle speed.

- **First (1 or Low).** The first (or low) position is used for slowing the vehicle while descending steep grades. In this gear selection, the vehicle speed is controlled and engine braking is used to slow the vehicle. This gear selection is used for the steepest grades at the lowest possible speed.

TORQUE CONVERTERS A **torque converter** replaces the manual transmission clutch. It is a type of fluid coupling that can release the power flow at slow engine speeds and also multiply the engine torque during acceleration. Torque converters in newer vehicles include a friction clutch that locks up to eliminate slippage at cruising speeds, improving fuel economy and reducing exhaust emissions. ● **SEE FIGURE 1–20.**

PLANETARY GEAR SETS Most automatic transmissions use **planetary gear sets**, which are a combination of gears. When the gear set is assembled, the sun gear is in the center and meshed with the planet gears, which are located around it, somewhat like the planets in our solar system. The ring gear is meshed around the outside of the planet gears. The three main members of the planetary gear set include the following:

1. **Sun gear**—It is the gear in the center.
2. **Ring gear**—It is also called an *annulus gear* or *internal gear.*
3. **Planet carrier**—It holds the planet gears (also called *pinions*) in position. ● **SEE FIGURE 1–21.**

Each of these gears can have two possible actions: They can rotate or stand still.

The planet gears/pinions have the following three possible actions.

1. They can rotate on their shafts in a stationary carrier and act like idler gears.
2. They can rotate on their shafts in a rotating carrier; the planet gears are walking.
3. They can stand still on their shafts and rotate with the carrier.

Planetary gear sets are used and combined in a complex manner so that transmissions with seven or eight speeds forward plus reverse are possible. Shifts are made by engaging or releasing one or more internal clutches that drive a gear set member, or by engaging or releasing other clutches or bands that hold a gear set member stationary. An automatic transmission might have as many as seven of these power control units (clutches or bands). One-way clutches are also used that self-release and overrun when the next gear is engaged. The control units can operate without the interruption of the power flow.

PLANETARY GEAR SET OPERATION Planetary gear sets are so arranged that power enters through one of the members and leaves through one of the other members while

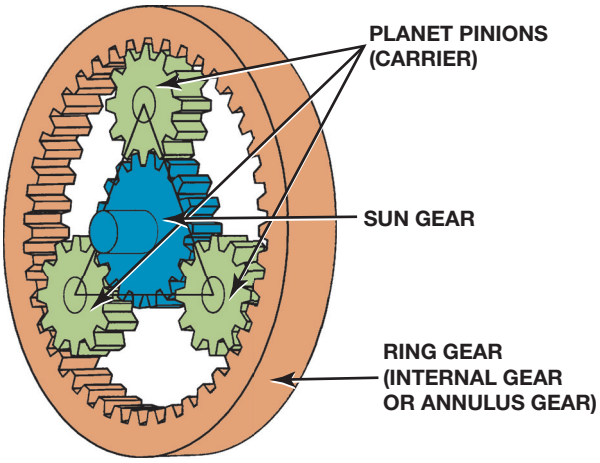


FIGURE 1–21 A typical planetary gear set showing the terms that are used to describe each member.

the third member is held stationary in reaction. Power flow through a planetary gear set is controlled by clutches, bands, and one-way clutches. One or more clutches will control the power coming to a planetary member and one or more reaction members can hold a gear set member stationary. The third planetary member will be the output. ● **SEE FIGURE 1–22.**

PLANETARY GEAR SET RATIOS

A simple planetary gear set can produce one of the following:

- A neutral if either the input clutch or reaction member is not applied
- Two reduction ratios
- Two overdrive ratios
- Two reverse ratios, one a reduction and one an overdrive
- The reduction, overdrive, and reverse ratios will require one driving member, one output member, and one reaction member in the gear set

NOTE: A 1:1, direct-drive ratio is achieved if two gear set members are driven.

ADVANTAGES OF PLANETARY GEAR SETS

Planetary gear sets offer several advantages over conventional gear sets.

1. Because there is more than one gear transferring power, the torque load is spread over several gear teeth.
2. Also, any gear separation forces (as gears transfer power, they tend to push away from each other) are contained within the planetary gear set, preventing this load from being transmitted to the transmission case.
3. Another advantage is the small relative size of the planetary gear set. 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 gear set can easily produce this same ratio in a smaller package.
4. Also, planetary gear sets are in constant mesh and no coupling or uncoupling of the gears is required.

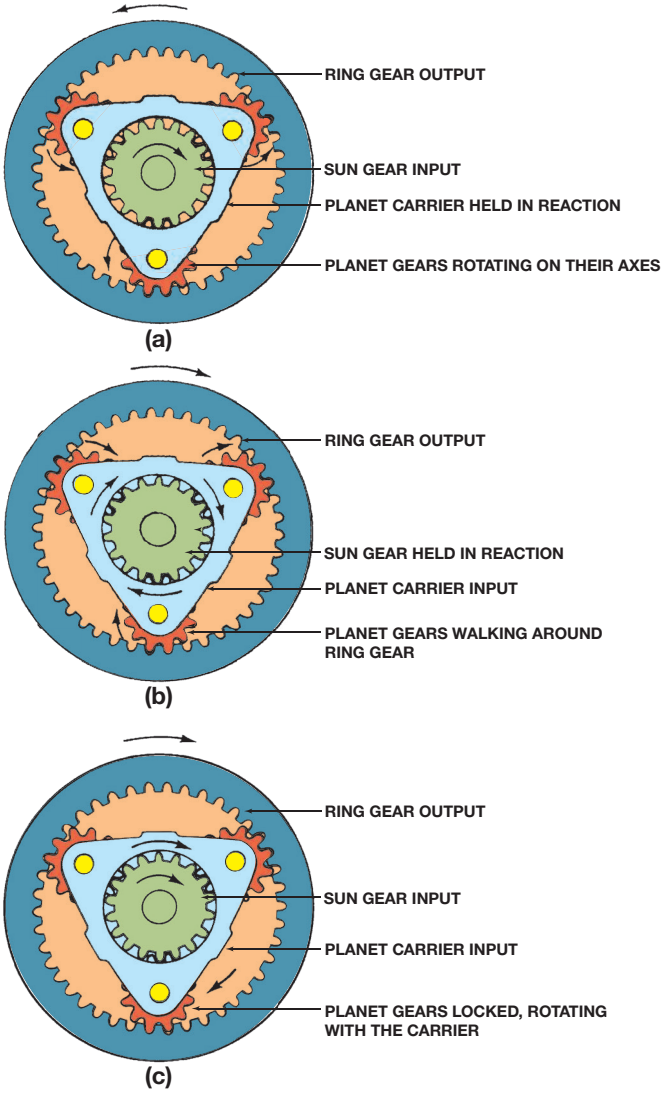


FIGURE 1–22 (a) If the planet carrier is held with the sun gear rotating, the planet gears simply rotate in the carrier and act as idler gears between the sun and ring gears. (b) If the sun or ring is held, the planet gears will walk around that stationary gear; they rotate on their shafts as the carrier rotates. (c) If two parts are driven and no parts are held, the planet gears are stationary on their shafts, and the whole assembly rotates as a unit.

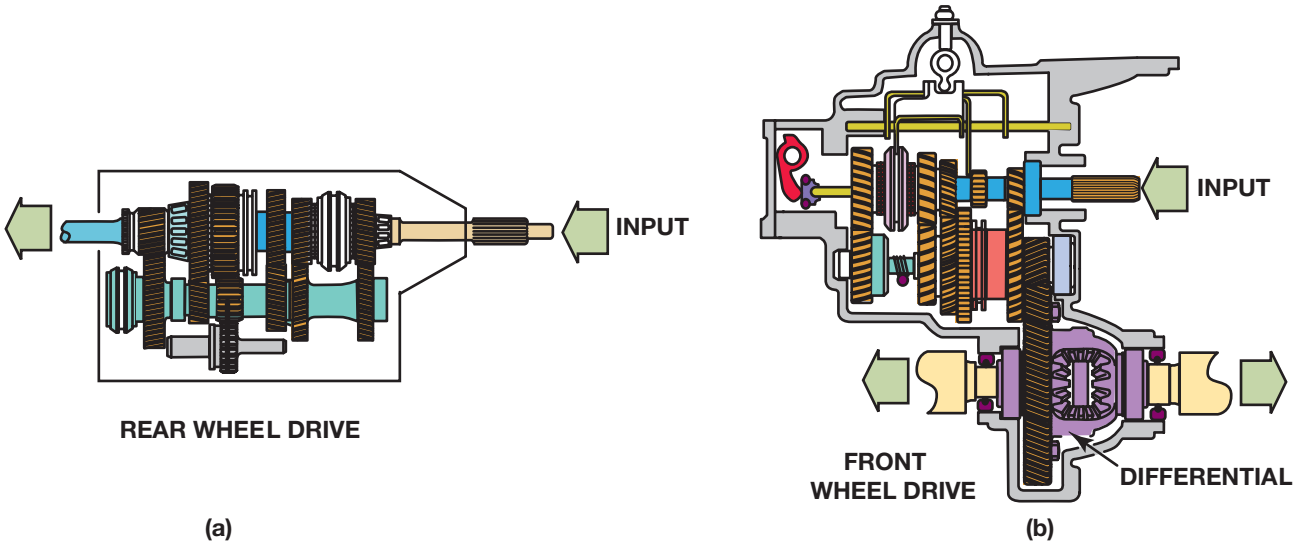


FIGURE 1–23 A RWD drivetrain uses a transmission to provide the necessary gear ratio and a single driveshaft to transfer power to the rear axle (a). A FWD drivetrain uses a transaxle that combines the transmission's final drive, and differential (b). A driveshaft is used for each front drive wheel.

? FREQUENTLY ASKED QUESTION

What Do All the Letters and Numbers Mean in Transmission Designations?

The numbers and letters usually mean the following:

- **Number of forward speeds.** The number of forward speeds may include four, five, or six such as the GM 4T60-E four-speed unit and the ZF 5HP24 five-speed unit.
- **Front-wheel drive or rear-wheel drive.** The letter **T** usually means *transverse* (front-wheel-drive transaxle) such as the Chrysler 41-TE; the **L** means *longitudinal* (rear-wheel-drive transmission) such as the General Motors 6L80; and the **R** means *rear-wheel drive* such as the Ford 5R55E.
- **Electronically controlled.** The letter **E** is often used to indicate that the unit is electronically controlled, and **M** or **H** is used to designate older mechanically (hydraulically) controlled units. Most automatic transmissions built since the early 1990s are electronically controlled and therefore the **E** is often included in the designation of newer designs of transmission or transaxles.
- **Torque rating.** The torque rating is usually designated by a number where the higher the number, the higher the amount of torque load the unit is designed to handle. In a GM 6L80-E, the torque rating is 80. Always check service information for the exact transmission designation for the vehicle being studied.

REAR-WHEEL DRIVE VS. FRONT-WHEEL DRIVE

At one time, most vehicles had the transmission mounted behind the engine and used a driveshaft to transfer power to the rear axle and driving wheels. This drivetrain is called **rear-wheel drive (RWD)**.

Many vehicles use a transaxle to drive the front wheels, called **front-wheel drive (FWD)**. Most FWD vehicles have the engine mounted in a transverse position, crosswise in the vehicle. Some are longitudinally mounted, in a lengthwise position as in RWD vehicles.

Two short driveshafts, called **half shafts**, are used to connect the transaxle to the front wheels. Driving only two wheels is adequate for most driving conditions. When the roads are slippery or driving off-road, driving all four wheels provides better vehicle control. ● **SEE FIGURE 1–23.**

TRANSAXLES

TERMINOLOGY A **transaxle** is a compact combination of a transmission, the **final drive** gear reduction, and the differential. It can be either a manual, automatic, or continuously variable transaxle. Transaxles are used in nearly all front-wheel-drive vehicles, some mid-engine vehicles, rear engine, and even a few rear-wheel-drive vehicles. ● **SEE FIGURE 1–24.**

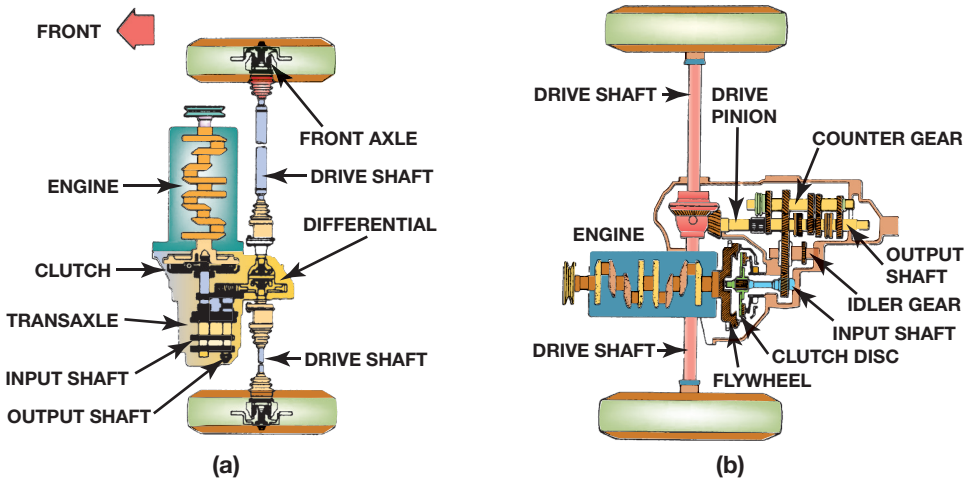


FIGURE 1–24 Transverse (a) and longitudinal (b) mounted front-wheel-drive (FWD) drivetrains.

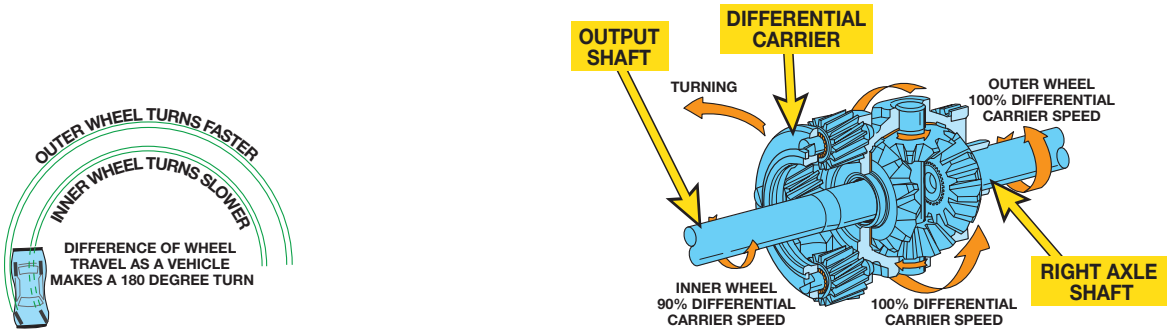


FIGURE 1–25 What happens when a vehicle makes a turn.

OPERATION A transmission normally has one output shaft that couples to the rear axle through the driveshaft. A transaxle has two output shafts that couple to the two front wheels through a pair of driveshafts. The **differential** used in transaxles or drive axles is a torque-splitting device that allows the two axle shafts to operate at different speeds so that a vehicle can turn corners. When a vehicle turns a corner, the wheel on the outer side of the turning radius must travel farther than the inner wheel, but it must do this in the same period of time. Therefore, it must rotate faster while turning. Most differentials are composed of a group of four or more gears. One gear is coupled to each axle and two are mounted on the differential pinion shaft. ● **SEE FIGURE 1–25.**

DRIVESHAFTS

TERMINOLOGY **Driveshafts**, also called a *propeller shaft* or *prop shaft*, transfer power from one component to another. Rear-wheel-drive vehicle driveshafts are usually made from steel tubing, and normally have either a **universal joint (U-joint)** or a **constant-velocity (CV) joint** at each end. Most front-wheel-drive vehicles use driveshafts that are a solid shaft or hollow steel tubing. A U-joint allows the shaft to change angle as the drive axle moves up and down when the wheels travel over bumps. Speed fluctuations occur in the driveshaft as the U-joints transfer power at an angle, but these fluctuations are canceled out or eliminated by the position of the U-joint at the other end of the driveshaft.

A front-wheel-drive vehicle driveshaft must use a CV joint at its ends because the front wheels must be steered at sharp angles. The short driveshafts used with transaxles and independent rear suspension drive axles are often called half shafts. ● **SEE FIGURE 1–26.**

DRIVE AXLE ASSEMBLIES

TERMINOLOGY Rear-wheel-drive vehicles use a drive axle assembly at the rear. A **drive axle** performs four functions:

1. It supports the weight of the rear of the vehicle.
2. It contains the final drive reduction gears.

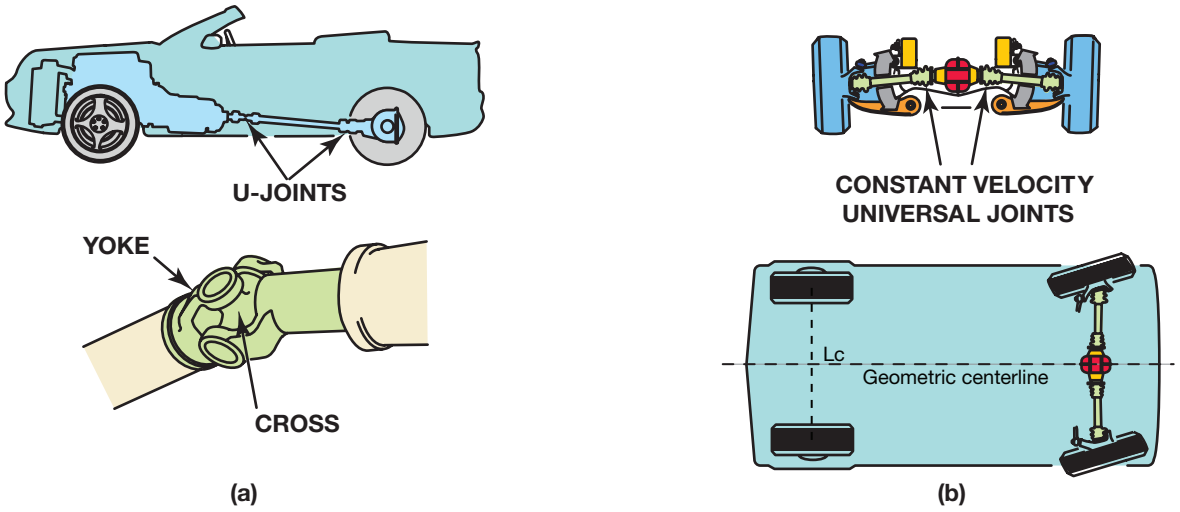


FIGURE 1–26 (a) A rear-wheel-drive (RWD) driveshaft uses a pair of universal joints to allow the rear axle to move up and down. (b) A front-wheel-drive (FWD) driveshaft uses a pair of constant-velocity joints to allow the front wheels to move up and down and steer.

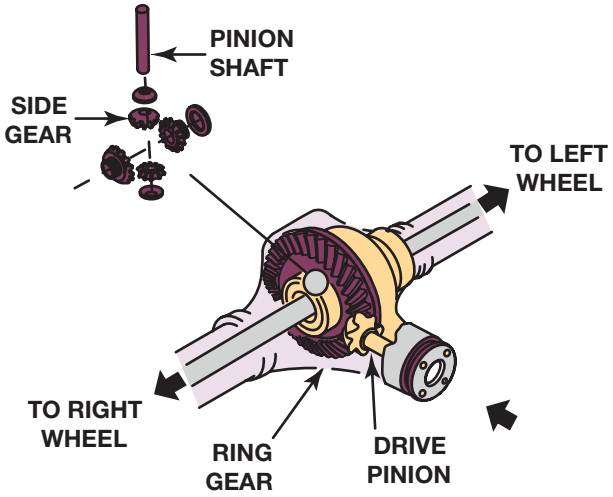


FIGURE 1–27 A drive axle includes a ring and pinion gear to produce a lower gear ratio. The drive axle also turns the power flow 90° and a differential (differential pinion and side gears) to allow the drive wheels to rotate at different speeds.

3. It contains the differential, which transfers torque to both drive wheels and allows the wheels to rotate at different speeds when cornering.
4. It allows the power to turn 90 degrees.

Most axle assemblies use strong axle shafts to transfer the torque from the differential gears to the wheels and tires. A bearing at the outer end of the axle housing serves to transfer vehicle weight to the axle and then to the wheels and tires while allowing the shaft to rotate.

The term final drive refers to the last set of reduction gears in a gear train. The torque that is applied to the drive wheels, and cruising speed engine RPM, is determined by the reduction gears and the drive wheel diameter. ● **SEE FIGURE 1–27.**

? **FREQUENTLY ASKED QUESTION**

What Must the Powertrain Overcome to Move the Vehicle?

To propel the vehicle, the engine and drivetrain must overcome the following:

- Rolling friction, which is the drag of the tires on the road, and bearing friction. These frictions increase at a constant rate, doubling as the speed is doubled.
- Aerodynamic drag, which is the wind resistance of air moving over the size and shape of the vehicle. It increases at a rapid rate, roughly four times as the speed is doubled (actually, velocity squared).
- Grade resistance, which is equal to 0.01 times the vehicle weight times the angle of the grade in percent.

TOWING CAPABILITY

DRIVETRAIN REQUIREMENTS Trucks are often used to tow trailers or heavy loads. In order for a vehicle to tow a heavy load, the vehicle must have the following features:

- An engine that can produce the needed torque and horsepower.
- A strong frame to withstand the forces involved.
- A strong trailer hitch properly installed and attached to the frame of the vehicle.

- A strong drivetrain (transmission, driveshaft, and drive axle(s)) that can transmit the engine torque to the drive wheels.
- Heavy-duty brakes so that the heavy load can be slowed and stopped safely.

SAE J2807 STANDARD Starting in 2013, the Society of Automotive Engineers (SAE) established a standardized test procedure to determine the tow rating for vehicles. The standard includes three vehicle performance standards including:

1. **Climbing test.** During the climbing test, the vehicle with the loaded trailer (at the specified rating that the vehicle manufacturer states is the capacity of the vehicle) has to climb a hill that rises 3,000 feet (900 m) over a length of 11.4 miles (18 km) without dropping below 40 MPH (64 km/h). This test is based on the Davis Dam grade, a stretch of road in Arizona southeast of Las Vegas.
2. **Acceleration test.** During this test, the vehicle with loaded trailer must accelerate from 0 to 30 MPH (48 km/h) in 12 seconds and less than 30 seconds to reach 60 MPH (100 km/h).
3. **Launching.** This test is used to test the vehicle and loaded trailer in both forward and reverse. The test places the vehicle at the base of a long hill with a 12% grade. The vehicle must be able to climb the grade 16 feet (5 m) from a stop five times within five minutes.

These tests not only test the power of the vehicle but also that the engine and transmission can be kept at the proper temperature, meaning that the engine and transmission (if automatic) be equipped with a cooler.

NOTE: Not all vehicle manufactures adhere to the SAE standard when reporting their recommended tow rating, because while standardized, the use of the SAE J2807 is voluntary.

FOUR-WHEEL DRIVE

TERMINOLOGY **Four-wheel drive (4WD)** is often designated as "4 × 4" and refers to a vehicle that has four driven wheels.

- The first 4 indicates that the vehicle has four wheels.
- The second 4 indicates that all four wheels are driven.

A vehicle will have more pulling power and traction if all of its wheels are driven. This requires a drive axle at each end of the vehicle, another driveshaft, and a **transfer case** or **power transfer unit** to drive the additional driveshaft and drive axle. The transfer case is normally attached to the rear of the transmission. It has a single input shaft from the transmission and two output shafts, one to the front drive axle and one to the rear drive axle. Some transfer cases are two-speed and include a set of reduction gears for lower-speed, higher-torque operation.

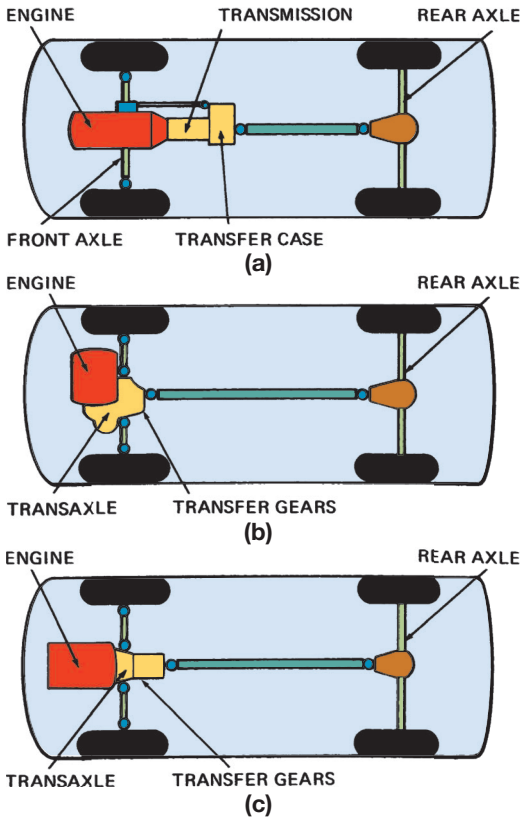


FIGURE 1–28 Three major 4WD configurations. The traditional form (a) uses a transfer case to split the torque for the front and rear drive axles. Both (b) and (c) are typical AWD configurations.

Four-wheel drive can be built into

- A front-engine rear-wheel drive
- A front-engine front-wheel drive
- A rear-engine rear-wheel drive

SEE FIGURE 1–28.

ALL-WHEEL DRIVE **All-wheel-drive (AWD)**, also called full-time four-wheel drive, vehicles are four-wheel-drive vehicles equipped with a center (inner-axle) differential so they can be operated on pavement in four-wheel drive. Full-time four-wheel drive is another name for all-wheel drive. All-wheel-drive vehicles are designed for improved on-road handling. There will be one differential in each drive axle assembly plus a differential between the two drive axles. The inter-axle differential allows the front-to-rear wheel speed differential. Because all wheels are driven, these vehicles are excellent for use in rain and snow where added control is needed.

SUMMARY

1. Vehicles are built as rear-wheel drive, front-wheel drive, and four- or all-wheel drive.
2. Engines develop torque and the drivetrains modify that torque to move the vehicle.
3. A variety of gears are used to modify torque.
4. The gear ratio is determined by dividing the number of driven gear teeth by the number of teeth on the driving gear.
5. Transmissions have gear ratios that a driver can select.
6. Manual transmissions use a clutch and automatic transmissions use a torque converter.
7. Transaxles combine the final drive gears and differential with the transmission.
8. Driveshafts and the drive axle complete the drivetrain.
9. Four-wheel-drive and all-wheel-drive vehicles have a transfer case or transfer gears and a second drive axle.

REVIEW QUESTIONS

1. What is the difference between torque and horsepower?
2. How is a gear ratio calculated?
3. What are the common shift modes used in an automatic transmission?
4. What is an inter-axle differential?

CHAPTER QUIZ

1. Torque is _____.
   a. A twisting force
   b. The rate of doing work
   c. Results in motion
   d. The gear ratio
2. Gears can be used to _____.
   a. Increase speed
   b. Increase torque
   c. Reverse direction
   d. All of the above
3. If a gear with 20 teeth is driving a gear with 60 teeth, the gear ratio is _____.
   a. 2:6
   b. 3:1
   c. 1:3
   d. 0.33:1
4. Technician A says a helical gear is stronger than a spur gear. Technician B says a helical gear is noisier than a spur gear. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
5. Which type of gear may be found in a rear-wheel-drive axle?
   a. Hypoid
   b. Spiral Bevel
   c. Spur
   d. Helical
6. The transmission is in first gear, which has a 2.5:1 ratio, and the rear axle has a ratio of 2:1. What is the overall ratio?
   a. 2:1
   b. 2.5:1
   c. 4.5:1
   d. 5:1
7. The type of gear set used in most automatic transmissions is _____.
   a. Spur gears
   b. Planetary gears
   c. Helical gears
   d. Any of the above
8. What shift mode should be used when descending a steep hill slowly?
   a. Drive (D)
   b. Second (2)
   c. Neutral (N)
   d. Low (L)
9. Full-time four-wheel-drive vehicles use _____.
   a. Transfer case
   b. Spiral bevel drive axles
   c. Three differentials
   d. Both a and c
10. What is used to transfer engine torque to all four wheels?
    a. Four driveshafts
    b. A transfer case or power transfer unit
    c. Four differentials
    d. All of the above

chapter 2

AUTOMATIC TRANSMISSION FLUID, FILTERS AND COOLERS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Discuss the specifications and types of automatic transmission fluids (ATF).
3. Discuss ATF filters, heaters, and coolers.

KEY TERMS

Automatic transmission fluid (ATF) 19
Depth filter 23
Micron 22
Surface filter 22
Turbulator 24

AUTOMATIC TRANSMISSION FLUID

PURPOSE AND FUNCTION

Automatic transmission fluid (ATF) is highly refined oil with a viscosity similar to SAE 20W-20 oil, and is specially designed for use in automatic transmissions. Recent ATFs are lower in viscosity and are similar to SAE 0W-10 oil.

The purpose and function of ATF includes the following:

- Transfers power in torque converters
- Provides hydraulic pressure in clutches and band servos
- Lubricates bearings, bushings, and gears
- Transfers heat to cool transmission parts
- Provides the correct friction for clutch and band application
- Acts as the medium to control transmission shifting by traveling through passageways, acting on valves, and being directed by solenoids

BACKGROUND

Early automatic transmissions used engine oil for a transmission fluid. Since the internal operating conditions in engines and automatic transmissions are significantly different from each other, a special transmission fluid was developed in the late 1940s. At first, the ATF was simply a mineral oil similar to engine oil, but dyed red.

ADDITIVES

Transmission fluid is formulated with various additives to produce favorable operating characteristics. Automatic transmission fluid contains about 10% to 15% additives. These additives are chemical compounds, and the reasons for their use are as follows:

- **Detergents-dispersants.** Keep the transmission clean and the valves free from sticking by keeping foreign items in suspension until they are removed by the filter or by draining.
- **Oxidation inhibitors.** Reduce oxidation and decomposition of the fluid, which can produce varnish and sludge.
- **Viscosity index improvers.** Changes the fluid viscosity with change in temperature so that fluid thickness and shift characteristics remain stable during a range of changing temperatures.
- **Friction modifiers.** Changes the fluid's coefficient of friction.

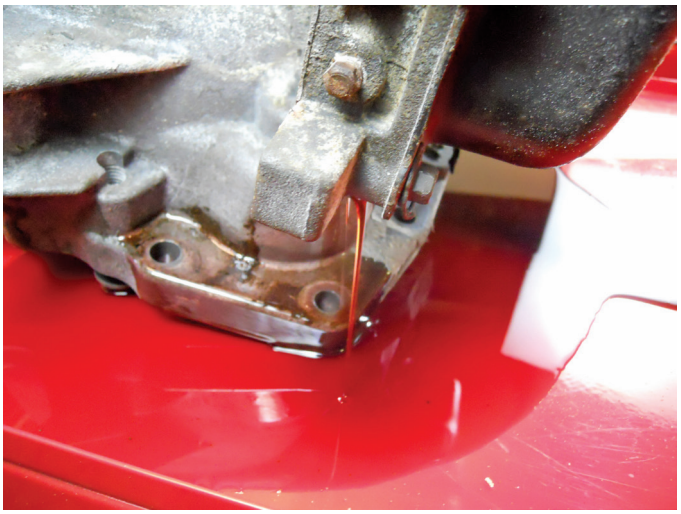


FIGURE 2–1 ATF being drained from a recycling center automatic transaxle still looks bright red in this unit being used for training.

- **Foam inhibitors.** Prevent formation of air bubbles and foam in the fluid.
- **Seal swelling agents.** Produce a slight swelling of the elastomers (seals) to compensate for any wear that occurs.
- **Anti-wear agents.** Reduce friction and prevent scoring and seizure of metal parts against each other.
- **Rust inhibitors.** Prevent rust from forming on the iron and steel parts.
- **Corrosion inhibitors.** Prevent corrosion of the nonferrous parts.
- **Metal deactivators.** Form a protective film to inhibit oxidation of metal surfaces.
- **Dye.** Dye is added to make ATF red. **SEE FIGURE 2–1.**

TYPES

The three basic types of ATF include:

1. **Non-friction modified.** The first ATF did not have friction reducing additives. This type of fluid was used in early band-type automatics. Type F ATF is an example of a non-friction-modified ATF.
2. **Friction modified.** Friction-modified ATF types include Dexron.
3. **Highly friction modified.** All current original equipment manufacturers use automatic transmission fluids that are highly friction modified. These include Dexron VI, Mercon V, ATF +4, and ATF WS.

SYNTHETIC ATF

Synthetic oils have been available for years for military, commercial, and general public use. The

term *synthetic* means that it is a manufactured product and not refined from a naturally occurring substance, like engine oil (petroleum base) which is refined from crude oil. Synthetic oil is processed from several different base stocks using several different methods. According to the American Petroleum Institute, oils are classified into the following groups:

- **Group I**—Solvent refined mineral oil with few, if any, additives. Not used in current formulations of ATF.
- **Group II**—Mineral oil with quality additive packages; which includes most friction-modified automatic transmission fluids.
- **Group III**—Hydrogenated (hydroisomerized) synthetic compounds, commonly referred to as hydrowaxes or hydrocracked oil and is considered to be synthetic. Most "fill-for life" ATF is made from Group III base stock.
- **Group IV**—Synthetic oils made from monomolecular oil are called polyalpholefin (POA) and include Mobil 1 ATF.
- **Group V**—Synthetic oils made from non-mineral sources such as alcohol from corn, called diesters or polyolesters and includes Red Line and Royal Purple ATF.

Groups III, IV, and V are considered to be *synthetic* because the molecular structure of the finished product does not occur naturally, but is man-made through chemical processes.

- The major advantage of using synthetic ATF is its ability to remain fluid at very low temperatures, which results in consistent transmission operation regardless of operating temperature.
- The major disadvantage is cost. The cost of synthetic automatic transmission fluid can be four to five times the cost of petroleum-based fluids. A synthetic blend indicates that some synthetic fluid is mixed with petroleum base oil, but the percentage of synthetic used in the blend is unknown.

ATF EXAMPLES

GENERAL MOTORS The first transmission fluid was developed by General Motors and was labeled *Type A* transmission fluid. As transmission fluid was improved, Type A was replaced with *Type A, Suffix A; Dexron;* and then *Dexron II, Dexron IIE,* and *Dexron III.* These Dexron fluids are compatible, and Dexron III can be used in older transmissions that specify one of the older fluid types. General Motors introduced Dexron® VI in 2005 for use in the then new six-speed transmissions/transaxles. It is superior to the older versions of Dexron and is the recommended fluid for all General Motors automatic transmissions/transaxles. It has a more consistent viscosity to produce more consistent shift performance during extreme conditions and less degradation over time. This fluid has more than twice the durability and stability in tests compared to previous ATFs.

FORD Ford Motor Company has also developed fluids for use in its vehicles. *Types F, CJ, Mercon,* and *Mercon V* and Mercon LV (low viscosity) are required for various Ford transmission models. Mercon can be used in place of older Ford fluids, but Mercon V should be used only in transmissions that specify its use. Ford introduced Mercon SP fluid, which has the same characteristics as Dexron® VI and Toyota WS, and although these fluids are similar, they are *not* interchangeable.

TOYOTA Toyota uses world standard (WS) fluid. It is formulated to provide lower viscosity at normal operating temperatures, which helps improve fuel economy. At higher temperatures, this ATF provides greater durability.

FIAT/CHRYSLER Fiat Chrysler Automobiles has discontinued MOPAR ATF+3 and recommends ATF+4 for most applications. ATF+4 use Group III as base oil with additives that are said to allow up to 100,000 miles before service is needed.

TYPICAL ATF APPLICATIONS Automatic transmission fluid is formulated to work in specific transmissions. Using the specified fluid is the key to proper operation. ● **SEE CHART 2–1** for examples of the types and applications of selected vehicles and fluids.

ATF OPTIONS The shop has three options when filling or replacing automatic transmission fluid:

Option 1. Use the exact specified fluid as recommended by the vehicle manufacturer for the particular transmission/transaxle. This is the preferred option because it has been recommended by the vehicle manufacturer. The major disadvantage of this option is that some fluids are hard to find at local parts suppliers and may have to be purchased from a dealer. ● **SEE FIGURE 2–2.**

Option 2. Use a multi-vehicle fluid, also called *universal ATF*, which is designed to meet the specifications of several different makes. This is commonly used by many shops and can be successfully used if the fluid is within the specified viscosity and the fluid manufacturer states that it meets the original equipment (OE) requirement for friction coefficient. ● **SEE FIGURE 2–3.**

GENERAL MOTORS	DESCRIPTION
Type A	1949
Type A, Suffix A	1957 (friction modified)
Dexron	1967 (lower viscosity)
Dexron II	1978 (lower viscosity)
Dexron II-E	1990 (improved low temperature fluidity)
Dexron III	1993–2005 (improved low temperature fluidity)
Dexron VI	2005 (improved viscosity stability)

FORD/JAGUAR	DESCRIPTION
Type F	1967 (non-friction modified; designed for older band-type automatic transmissions)
Mercon	1987 (friction modified)
Mercon V	1997 (highly friction modified)
Mercon SP	Used in the Ford six speeds such as the 6R60 6HP 26 and also the 2003 and up Torque Shift
Idemitsu K-17	Jaguar X-type

CHRYSLER	DESCRIPTION
Chrysler 7176	Designed for front-wheel-drive transaxles
ATF + 2	1997 (improved cold temperature flow)
ATF + 3	1997 (designed for four-speed automatics)
ATF + 4	Used in most 2000 and newer Chrysler vehicles

HONDA/TOYOTA	DESCRIPTION
Honda Z-1	For use in all Honda automatic transaxles
Toyota Type III	Specific vehicles and years
Toyota Type IV	Specific vehicles and years
Toyota WS	Lower viscosity than Type IV; used in specific vehicles and years

MAZDA/NISSAN/SUBARU	DESCRIPTION
Mazda ATF-III	Specific vehicles and years
Mazda ATF-MV	Specific vehicles and years
Nissan Matic D	Specific vehicles and years
Nissan Matic J	Specific vehicles and years
Nissan Matic K	Specific vehicles and years
Subaru ATF	Specific vehicles and years
Subaru ATF-HP	Specific vehicles and years

AUDI/BMW/ MERCEDES/VOLVO	DESCRIPTION
Audi G-052-025-A2	Specific vehicles and years
Audi G-052-162-A1	Specific vehicles and years
BMW LA2634	Specific vehicles and years
BMW LT1141	Lifetime fill (BMW warns to not use any other type of fluid)
Mercedes 236.1	Specific vehicles and years
Mercedes 236.2	Specific vehicles and years
Mercedes 236.5	Specific vehicles and years
Mercedes 236.6	Specific vehicles and years
Mercedes 236.7	Specific vehicles and years
Mercedes 236.9	Specific vehicles and years
Mercedes 236.10	Specific vehicles and years
Volvo 97340	Specific vehicles and years
Volvo JWS 3309	Specific vehicles and years

MITSUBISHI/ HYUNDAI/KIA	DESCRIPTION
Diamond SP II	Specific vehicles and years
Diamond SP III	Specific vehicles and years

CHART 2–1

Selected samples of automatic transmission fluid and some applications. Always check service information for proper specified fluid when servicing automatic transmissions/transaxles.

Option 3. Use a standard ATF with a "top treatment" additive to meet the friction characteristics of the OE fluid. This option is popular with shops that do not want to stock more than a few types of fluids. A bottle of additive can change the coefficient of friction of the fluid but it cannot make the viscosity of the fluid lower (thinner). If using a top treatment additive, always follow the instructions on the bottle and do not exceed the specified amount. For additional information on top treatments, visit these websites:

http://www.lubegard.com

http://www.lifeautomotive.com ● **SEE FIGURE 2–4.**

ATF FILTERS

PURPOSE AND FUNCTION A filter is located at the pump inlet to trap dirt, metal, and other foreign particles that might cause wear in the pump, bearings, bushings, and gear train or cause sticking of the various valves.

FIGURE 2–2 The use of the factory-specific fluid is the recommend fluid to insure the best possible shifting and transmission operation.

FIGURE 2–3 Multi-vehicle, or universal fluid, is designed to meet the specifications of many types of fluids, making it popular with independent shops that service many makes and models of vehicles.

FIGURE 2–4 Aftermarket additives are available that can convert friction-modified ATF into highly friction-modified ATF.

TYPES OF FILTERS

- **Surface filter**—a surface filter traps the foreign particles at the outer surface. ● **SEE FIGURE 2–5.**
- This filter can be a woven screen of metal or synthetic material such as dacron or polyester. Some sources consider a paper filter to be a surface filter. With a metal or synthetic screen, the size of the openings varies from large to very fine, in the range of 50 to 100 microns (or micrometers). A **micron** is 1 millionth of a meter or 39 millionths of an inch. The symbol for micron is μm. The disadvantage of a surface filter is its limited surface area, which in turn limits its capacity. The mesh openings are the usable area. A large portion of a filter's surface is the

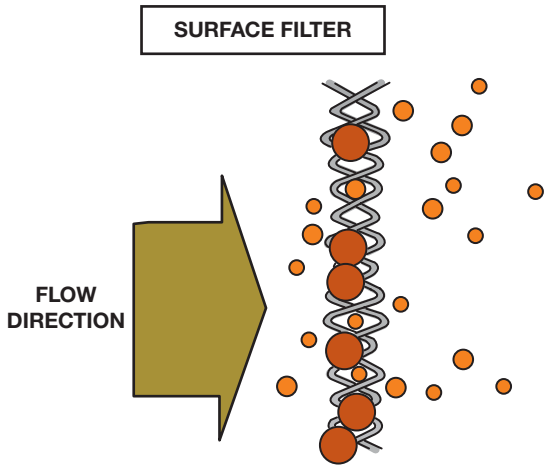


FIGURE 2–5 A surface filter traps particles that are too big to pass through the openings in the screen.

fiber or wire that makes up the filter, with the remainder being the openings. ● **SEE FIGURE 2–6.**

- **Depth filter**—a depth filter traps particles as they try to pass through the filter material. Depth filters are made of felt or a synthetic material of various thicknesses. The thickness of the material allows room to trap particles as well as room for fluid flow. It also has the ability to trap smaller particles, has more capacity to trap particles, and can function for a longer period of time. ● **SEE FIGURE 2–7.**

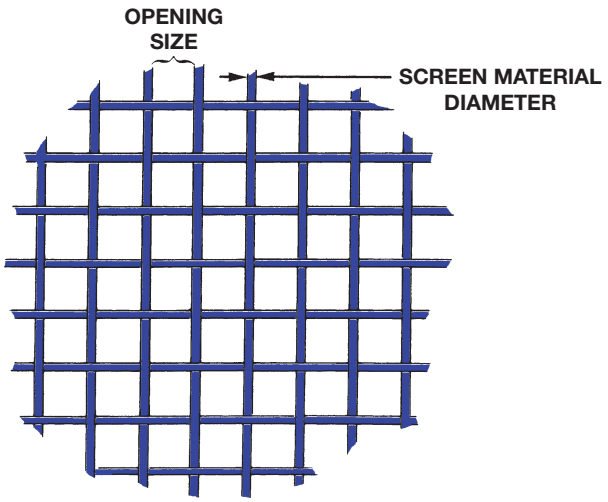


FIGURE 2–6 The surface area of a surface filter is reduced somewhat by the material that makes up the screen. The size of the screen openings determines how small of a particle can be filtered.

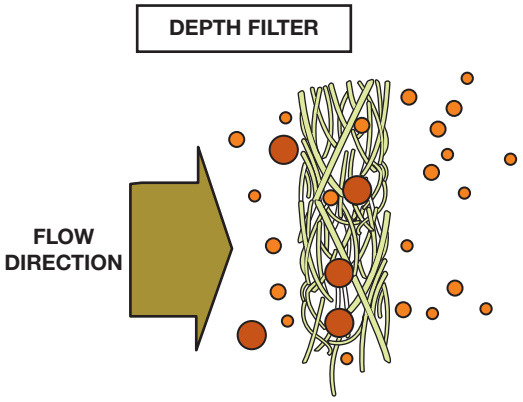


FIGURE 2–7 A depth filter is a group of woven fibers of a certain thickness. Foreign particles are trapped at different levels as they try to flow through.

ATF HEATERS AND COOLERS

TEMPERATURES Transmissions are expected to perform over a wide range of temperatures. Cold fluids are much thicker than hot fluids. On a cold day, the first shifts tend to be sluggish because the fluid moves slowly through the orifices and small openings. The best fluid operating temperature for an automatic transmission is in the range of 170°F to 180°F (77°C to 82°C). This produces good fluid viscosity without excessive fluid degradation. Some transmissions use fluid heaters to improve cold operation. ● **SEE FIGURE 2–8.**

Probably the greatest problem for transmission fluid is heat. Excess heat significantly shortens the life of ATF. Excess temperatures cause the fluid to break down and form gum or varnish. This can cause valve sticking or reduce the fluid flow in certain circuits. All transmissions use a cooler to help remove excess heat. The fluid should be changed more frequently than normal if the vehicle is driven under conditions such as towing that could result in fluid temperatures above 180°F (82°C). Adverse driving conditions that produce higher fluid temperatures are trailer towing, driving on hills, and stop-and-go driving. The torque converter is the primary source of heat in an automatic transmission. For example,

- A temperature of 195°F (90°C) will double the rate of fluid oxidation and cut the fluid life to half or about 50,000 miles (80,000 km).
- A transmission operating at 235°F (113°C) will reduce fluid life to about 25,000 miles (40,000 km).
- The same transmission operating at a temperature of 255°F (124°C) will reduce fluid life to less than 12,000 miles (19,000 km). ● **SEE FIGURE 2–9.**

OIL COOLER CIRCUITS The transmission oil flow begins as soon as the pump begins to rotate. The oil flow then exits

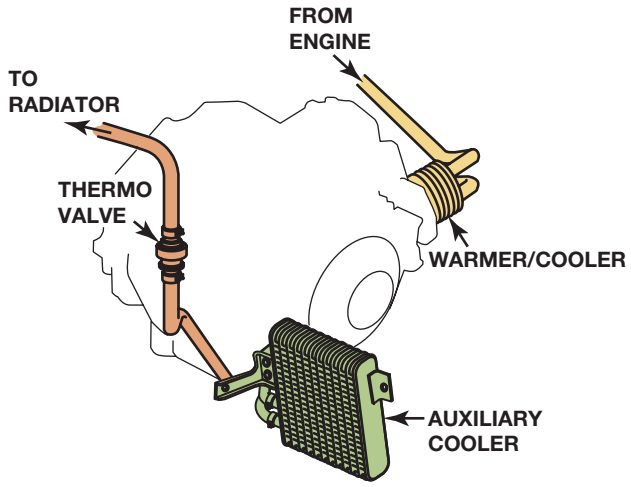


FIGURE 2–8 Engine coolant from the engine block flows through the passages in the warmer/cooler, and then out through the thermostatic valve to the upper radiator tank. The thermostatic valve uses a wax element–type valve to control the flow of engine coolant through the case-mounted cooler/warmer. The thermostatic valve improves the ATF warm-up times and maintains ATF temperature within the optimum operating range between 170°F and 180°F (77°C and 82°C).

APPROXIMATELY MILEAGE TO TRANSMISSION FAILURE AT AVERAGE TEMPERATURE

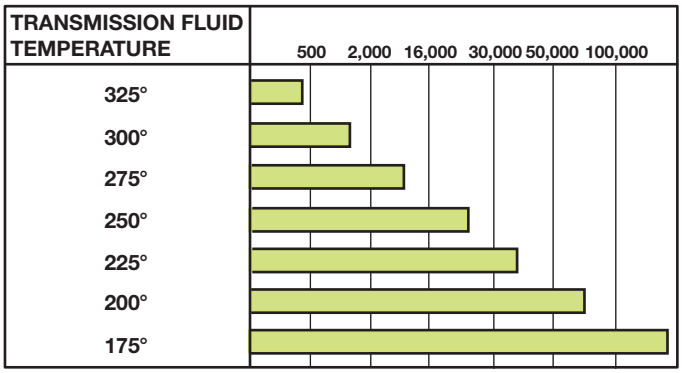


FIGURE 2–9 The life of automatic transmission fluid drops drastically when the temperature increases above normal.

the pump and enters the torque converter. As soon as the supply circuit begins to develop pressure, the regulator valve moves slightly and opens a passage to the torque converter. This fluid flow serves several purposes including the following:

- It ensures that the torque converter is filled so it can transmit engine torque to the transmission input shaft.
- It removes excess heat and helps control converter fluid temperature.
- It provides lubrication to the moving parts inside the transmission.

COOLER FLOW

The fluid leaving the torque converter is routed out of the transmission case and through a steel line to the transmission cooler. The cooler is positioned in the colder (outlet) tank of the radiator. Another steel line is used to return the fluid to the transmission. A cooler is often called a *heat exchanger* because it moves heat from one location to another. Heat from the transmission fluid is transferred to the engine coolant. ● **SEE FIGURE 2–10.**

SUPPLEMENTARY COOLERS

Supplementary coolers are aftermarket units that can be placed in series with the original equipment manufacturer (OEM) cooler to ensure adequate cooling. These are fluid-to-air coolers, whereas the original cooler is normally a fluid-to-coolant cooler. The heat in the fluid flows directly to the air passing through the cooler. The supplementary cooler is normally positioned where there is an adequate airflow, which is often in front of the radiator or air-conditioning condenser. There are two options when installing a supplemental cooler:

Option 1 The hot fluid from the transmission is routed through the supplementary cooler first, then through the original cooler and back to the transmission. When operating in very cold temperatures, the original cooler reduces the chance of overcooling the fluid by warming the fluid before returning it to the transmission.

Option 2 Many aftermarket auxiliary cooler manufacturers recommend installing their cooler after the fluid passes through the stock radiator cooler. Always follow the instructions that come with any auxiliary automatic transmission fluid cooler. ● **SEE FIGURE 2–12.**

? FREQUENTLY ASKED QUESTION

What Is a "Turbulator"?

A plain-tube cooler is not very effective for cooling fluid because fluid tends to increase its viscosity and slow down as it cools. The cooler oil then tends to become stationary on the outer, cooler areas of the cooler while the hotter, thinner-viscosity fluid flows through the center. The **turbulator** in well-designed oil coolers continuously mixes the fluid. The ATF in contact with the outer part of the cooler tubes is in contact with the relatively cool coolant in the radiator tank. The screen-like turbulator causes turbulence in the fluid flow to ensure constant mixing and thorough cooling of all the fluid. ● **SEE FIGURE 2–11.**

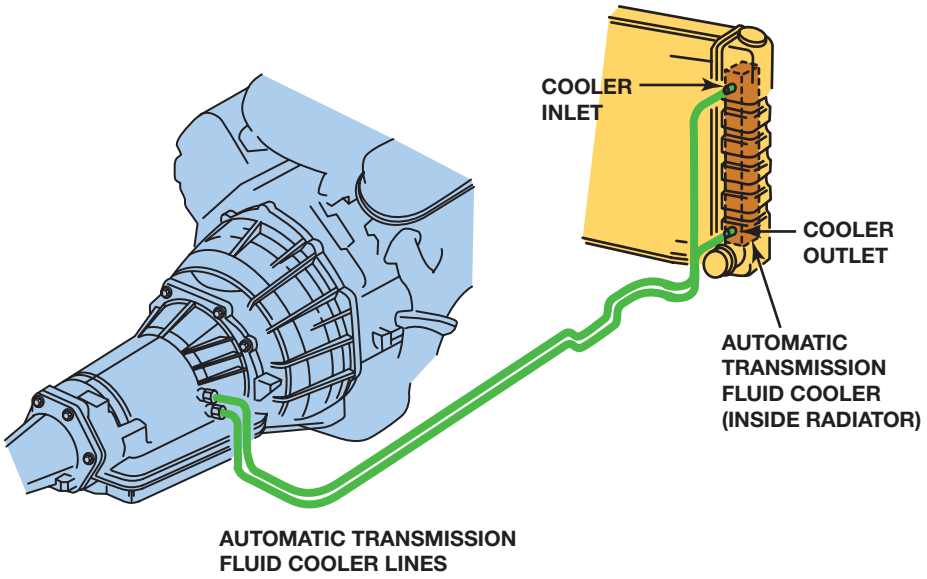


FIGURE 2–10 Automatic transmission fluid is routed from the torque converter, where most of the heat is generated, to the radiator where it is cooled. The fluid then returns to the transmission/transaxle to lubricate the bearings and bushings.

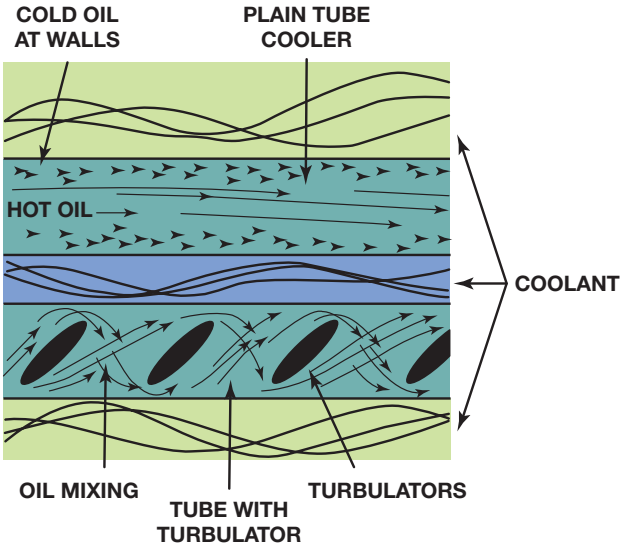


FIGURE 2–11 Cold fluid tends to stick to the walls of a plain tube cooler (top). The turbulator causes fluid turbulence to promote mixing so all of the fluid cools (bottom).

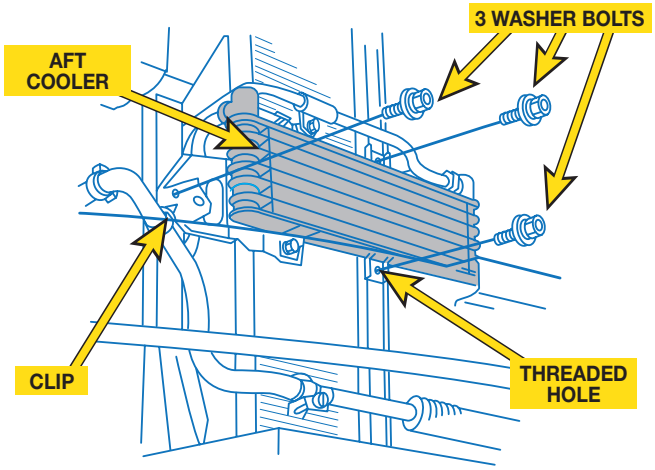


FIGURE 2–12 If the vehicle is being used for towing and it is not equipped with a supplemental cooler, an aftermarket cooler can be installed.

AUXILIARY FILTERS The transmission cooler tends to trap foreign particles and can become plugged, especially when the fluid is extremely dirty, contains metal particles, or there is a torque converter clutch mechanical failure. At least one aftermarket manufacturer markets a filter that can be installed in the transmission-to-cooler line. This filter provides added protection by removing foreign particles from the fluid and preventing cooler blockage. Many filters contain a magnet to remove iron particles. If the filter gets plugged, fluid flow will be restricted or blocked completely, which then shuts off transmission lubrication. To prevent this from happening, many supplementary filters include a bypass valve to maintain fluid flow when the filter becomes plugged. ● **SEE FIGURE 2–13.**

LUBRICATION FLOW In most transmissions, the fluid returning from the torque converter and cooler lubricates the transmission. The fluid from the cooler enters the lubrication passages at the case. It flows through holes drilled in the case to the main shaft bushings, where it passes into holes drilled in the input or output shaft. From there, it flows through the

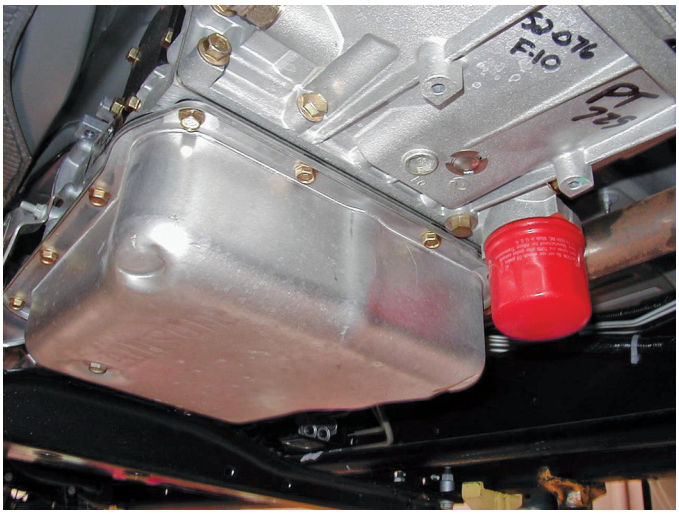


FIGURE 2–13 While most automatic transmissions use an internal filter only, this Allison transmission uses a spin-on-type filter that is designed to be replaced as part of routine service. There is another filter inside that is designed to be replaced only if the unit is overhauled or repaired.

TECH TIP

Don't Tow a Vehicle with the Drive Wheels on the Ground

A vehicle with an automatic transmission should not be towed or pushed very far because there will be no lubricating fluid flow when the engine is not running. The gear sets and bushings will run dry, wear, and overheat or burn out without a constant flow of lubricating oil. Most manufacturers recommend towing only when absolutely necessary. They caution that towing should be limited to a few miles with a maximum speed of 20 to 25 mph (32 to 40 km/h).

If possible, the drive wheels should be lifted off the ground or the driveshaft removed from a rear-wheel-drive (RWD) vehicle. Special cautions also should be taken when towing an all-wheel-drive (AWD) vehicle. ● **SEE FIGURE 2–14.**

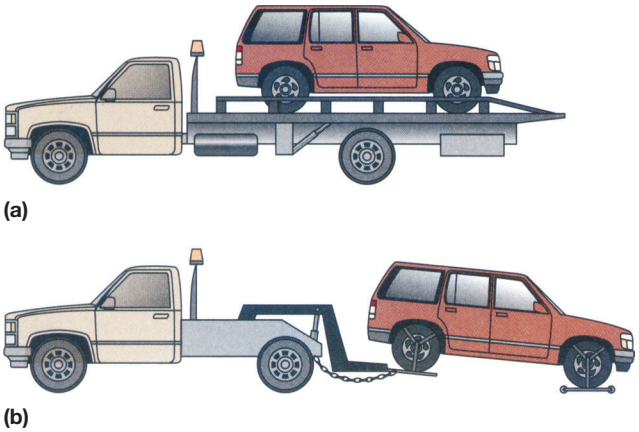


FIGURE 2–14 If an all-wheel-drive vehicle must be towed, it should be either on (a) a flatbed truck or (b) a dolly.

shaft to side holes that align with support bushings, thrust washers, planetary gear sets, clutch drum bushings, and clutch packs. Most transaxle final drive gears and differentials are also lubricated by this circuit.

SUMMARY

1. Automatic transmission fluid (ATF) performs the following functions:
   - Transfers power in torque converters
   - Provides hydraulic pressure in clutches and band servos
   - Lubricates bearings, bushings, and gears
   - Transfers heat to cool transmission parts
   - Provides the correct friction for clutch and band application
   - Acts as the medium to control transmission shifting by traveling through passageways, acting on valves, and being directed by solenoids
2. Types of ATF include:
   - Non-friction modified
   - Friction modified
   - Highly friction modified
3. Synthetic ATF is made from API groups III, IV or V
4. Technicians can select one of three possible fluids when servicing an automatic transmission/transaxles:
   - The original equipment fluid (preferred)
   - A multiple vehicle (universal) fluid
   - Use a top treatment in commonly used fluid
5. The best operating temperature for an automatic transmission is in the range of 170°F to 180°F (77°C to 82°C). This produces good fluid viscosity without excessive fluid degradation.
6. A filter is located at the pump inlet to trap dirt, metal, and other foreign particles that might cause wear in the pump, bearings, bushings, and gear train or cause sticking of the various valves.
7. Supplementary coolers are aftermarket units that can be placed in series with the original equipment manufacturer (OEM) cooler to ensure adequate cooling.
8. In most transmissions, the fluid returning from the torque converter and cooler lubricates the transmission.

REVIEW QUESTIONS

1. What are the functions of ATF?
2. What are the three options that a technician or shop can use when selecting the ATF for a vehicle?
3. How does a filter trap particles?
4. Why do some vehicles use a transmission fluid heater and a cooler?

CHAPTER QUIZ

1. Which fluid is highly-friction modified?
   a. Type A
   b. Type F
   c. ATF + 4
   d. Dexron
2. What is the color of ATF?
   a. Red
   b. Yellow
   c. Blue
   d. Green
3. Using an additive to convert friction-modified ATF into highly friction-modified ATF is often called _____.
   a. ATF +
   b. Top treatment
   c. Friction treatment
   d. Conversion fluid
4. Most “fill for life” automatic transmissions/transaxles use what type of ATF?
   a. API Group I
   b. API Group II
   c. API Group III
   d. API Group IV
5. Most vehicle manufactures recommend what type of ATF is used during service or replacement?
   a. Type A, suffice A
   b. Dexron
   c. Mercon
   d. The ATF recommended for the specific transmission/transaxle
6. The two types of automatic transmission filters are _____ and _____.
   a. Micron and paper
   b. Surface and depth
   c. Paper and cloth
   d. Nylon and rayon
7. Why is an ATF cooler used in an automatic transmission/transaxle?
   a. Excess temperatures cause the fluid to break down
   b. Hot AFT can form gum or varnish
   c. Excess heat significantly shortens the life of ATF
   d. All of the above

8. A turbulator is used to _____.
   a. Speed up the flow of ATF through the cooler
   b. Causes turbulence in the cooler to more adequately mix the cooler and warmer ATF in the cooler fluid sticking to surfaces of cooler
   c. Increase the pressure inside an ATF cooler
   d. Purge the ATF of bubbles
9. Normal automatic transmission fluid temperature is _____.
   a. Between 170°F and 180°F (77°C and 82°C)
   b. 195°F (90°C)
   c. 235°F (113°C)
   d. 255°F (124°C)
10. Why should a vehicle be towed with the drive wheels off the ground?
   a. To reduce the number of miles registered on the odometer
   b. To prevent transmission damage due to a lack of lubrication
   c. To help keep the temperature of the ATF from increasing to dangerous levels
   d. To reduce driveline (U-Joints and CV joint) wear

chapter 3

AUTOMATIC TRANSMISSION/ TRANSAXLE HYDRAULIC SYSTEM

LEARNING OBJECTIVES

After studying Chapter 3, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Discuss hydraulic principles and Pascal's Law.
3. Describe the types and operation of automatic transmission/transaxle pumps.
4. Explain the different methods for controlling fluid flow and regulating pressure.
5. Identify the types of hydraulic seals.

KEY TERMS

Control pressure
Dynamic seal 39
Exhaust 36
Fluid power 30
Hydraulics 30
Land
Line pressure 32
Mainline pressure 32
Manual valve
Mechatronic 36
Pressure regulator valve 36
Pressure relief valve 36
Regulator valve 35
Rooster comb 37
Servo valve 35
Spool valve 33
Static seal 39
Switch valve 35

THE HYDRAULIC SYSTEM

PURPOSE AND FUNCTION The automatic transmission's hydraulic system has several important purposes and functions including:

- Applies the clutches and bands and therefore control the transmission's power flow
- Transmits sufficient force and motion to completely apply the control units to prevent slippage
- Maintains fluid flow through the torque converter for its proper operation
- Maintains fluid flow to lubricate and cool the moving parts of the gear train

DEFINITION **Hydraulics**, often called **fluid power**, is a method of transmitting motion and/or force using a fluid. Hydraulics is based on the principle that liquids can flow easily through complicated paths, but they cannot be compressed. All the components in a hydraulic system are interconnected so that fluid pressure can be transmitted to all parts to work as designed.

HYDRAULIC PRINCIPLES

PASCAL'S LAW DEFINITION Pascal's law, formulated by Blaise Pascal (1623–1662), a French mathematician, states: "When force is applied to a liquid confined in a container or an enclosure, the pressure is transmitted equally and undiminished in every direction."

To help understand this principle, assume that a force of 10 lbs is exerted on a piston with a surface area of 1 square inch (sq. in.). Since this force, measured in lb or Newton (N), is applied to a piston with an area measured in square inches (sq. in.), the pressure is the force divided by the area, that is, "10 pounds per square inch (PSI)." It is this "pressure" that is transmitted, without loss, throughout the hydraulic system. ● **SEE FIGURE 3–1.**

PASCAL'S LAW FORMULA

F = P × A (force is equal to pressure multiplied by area)

P = F/A (pressure is equal to force divided by area)

A = F/P (area is equal to force divided by pressure)

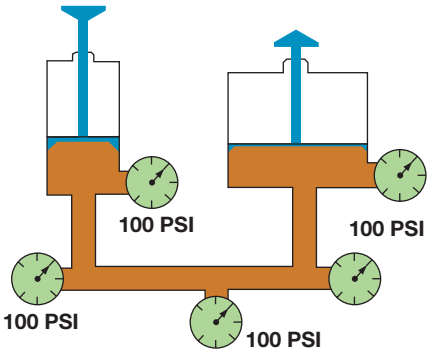


FIGURE 3–1 Fluid pressure is transmitted undiminished in all directions. Note that the pressure is equal throughout the system.

where

F = force (lb) or (N)

P = pressure in pounds per sq. in. or (kPa)

A = area in sq. in. or (sq. cm)

When fluid pressure or force is computed, use the area of the piston and not its diameter. The area of a piston or any circle can be determined using the following formula

$$a = \pi r^2$$

where

a = area

π = 3.1416

r = one-half the diameter

The pressure in a hydraulic system becomes a force to produce work, and the amount of force can be determined by multiplying the area of the output piston by the system pressure. A force of 100 pounds pushing on a piston that has an area of two square inches produces a force of 200 lb. (200 × 1). ● **SEE FIGURE 3–2.**

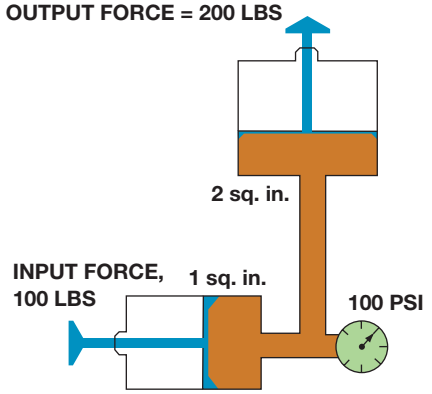


FIGURE 3–2 A 100 lb force applied on an input piston that has an area of 1 sq. in. will produce a fluid pressure of 100 PSI.

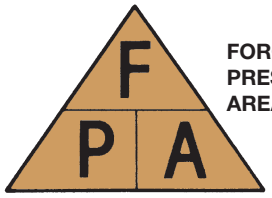


FIGURE 3–3 A simple memory triangle can be used to help remember the commonly used hydraulic formulas.

Application force is multiplied whenever the output piston is larger than the input piston. The pistons that apply clutches and bands are designed to be the correct size that develops adequate force to prevent slippage. Automatic transmissions contain valves that are moved based on which valve has the largest diameter, and therefore, the greater area. Force will decrease if the input piston is larger than the output piston. A simple memory triangle can be used as an aid to determine area, force, or pressure. ● **SEE FIGURE 3–3.**

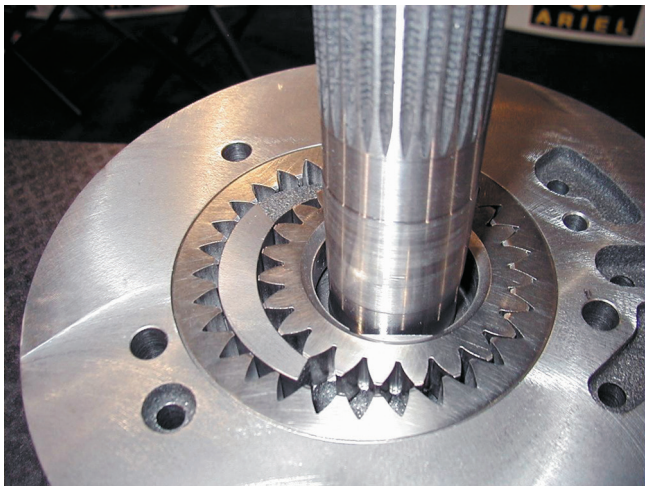
PUMPS

PURPOSE AND FUNCTION Every hydraulic system requires a pump to maintain fluid flow and to pressurize the fluid in the system. However, the pump itself does not develop pressure but instead pressure occurs when there is a resistance to flow. Initially, fluid flows freely when a hydraulic circuit is empty or partially filled. Once the circuit is completely full, there is a resistance to further flow. At this point, pressure begins to build up in the circuit as the pump continues the fluid flow.

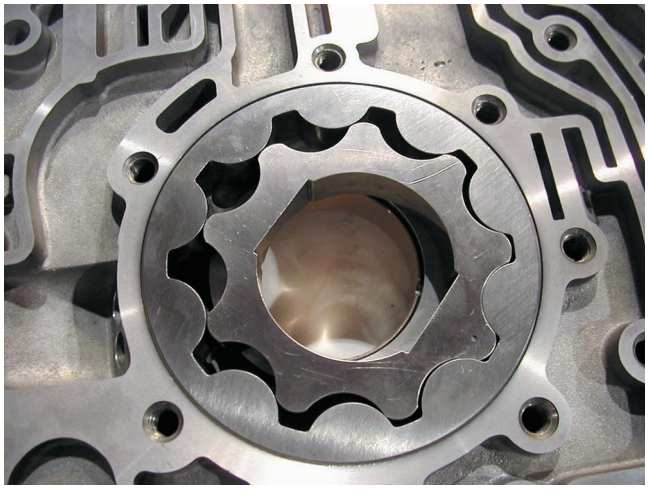
PARTS AND OPERATION The torque converter housing is bolted to the engine flexplate and rotates whenever the engine is running. The torque converter hub is keyed to the pump by tangs located inside the inner pumping member, located in the pump housing of the transmission. Three common types of rotary pumps are used to produce the fluid flow and resulting pressure in an automatic transmission. They include:

1. The internal–external gears with crescent (or gear) pump
2. The Gerotor (rotor) pump
3. The vane pump

● **SEE FIGURE 3–4.**



(a)



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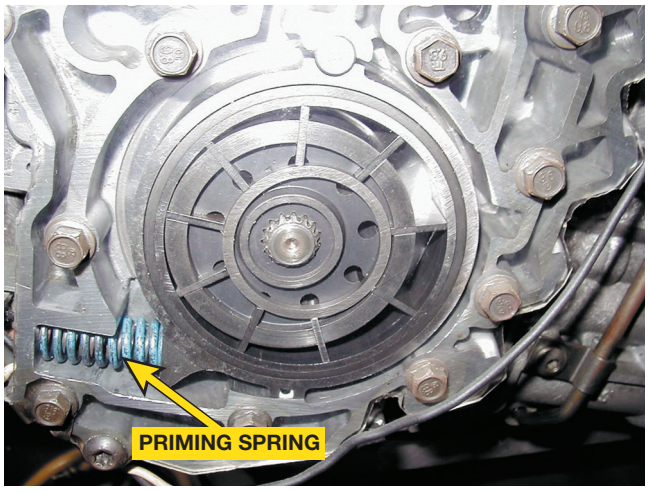


(c)

FIGURE 3–4 (a) Gear-type pump. (b) Gerotor-type pump. (c) Vane-type pump.

The pumping action in each of these pump types is essentially the same.

- The inner pumping member (external gear or inner rotor) is driven by the torque converter hub or a driveshaft, and the outer pumping member (the internal gear, outer rotor, or vane housing) is offset or eccentric relative to the inner gear or rotor.

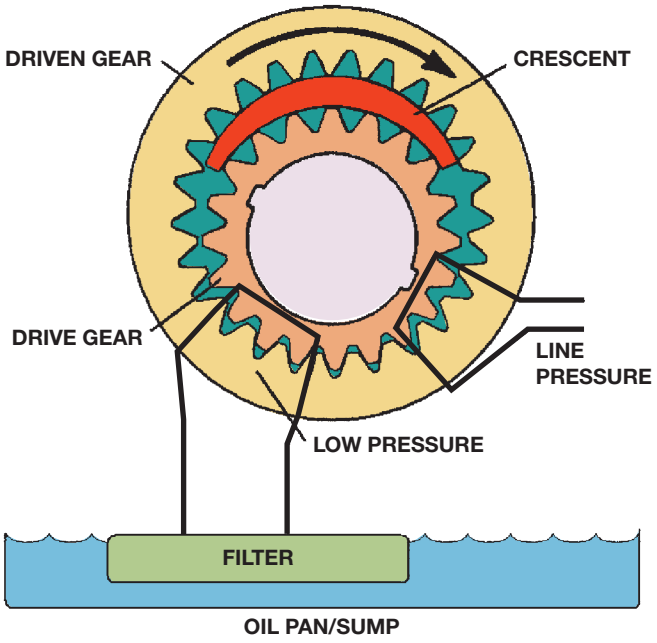


FIGURE 3–5 As a pump rotates, a low pressure (vacuum) is created as the pumping members move apart in one area, and atmospheric pressure will force fluid into this area. Pressure is created where the pumping members move together.

- As the inner member rotates, a series of chambers (between the gear teeth, the rotor lobes, or vanes) increase in volume in one area and decrease in another.
- A low-pressure area is created in the void area where the chamber volume increases. This area is connected to a passage leading to the filter that is submerged in fluid near the bottom of the sump.
- Atmospheric pressure inside the transmission pushes fluid into the filter, through the intake passage, and into the pump inlet. ● **SEE FIGURE 3–5.**

As the pump rotates, fluid fills the chambers just as fast as they enlarge. On the other side of the pump, the chambers get smaller and the outlet port of the pump is positioned in this area. Here the fluid is forced out of the pump and into the passage leading to the pressure control valve and the rest of the hydraulic system. The parts in a pump must fit together with very little clearance to prevent the fluid from leaking across the pump from the high-pressure area to areas of lower pressure. The fit provides just enough clearance for the parts to move without excess drag. The pressure-regulated fluid is often called **mainline pressure**, *line pressure* or *supply pressure*.

FIXED DISPLACEMENT PUMPS Many automatic transmissions use a fixed-size positive displacement pump. Every revolution of the pump will move the same volume of fluid. The faster the pump turns, the more fluid will be pumped during a given time period. Both the gear pump and the rotor pump are positive displacement pumps.

FREQUENTLY ASKED QUESTION

What Is a Front Pump?

The pumps used in automatic transmissions are driven by the torque converter and are located at the front of the transmissions. In the early days of automatic transmissions, manufacturers equipped the transmission with a pump that was driven from the output shaft and was called the rear pump. The purpose of this pump was to supply fluid under pressure to the governor and the fluid circuit when the vehicle was coasting down a hill with the engine at idle speed. It also made it possible to push start the vehicle. When a unit was equipped with a rear pump, it was common terminology to refer to the pump at the front as the "front pump." This term is still heard today long after the rear pump has been deleted from automatic transmissions.

VARIABLE DISPLACEMENT PUMPS Variable displacement pumps are also positive displacement in that they will pump a certain volume on each revolution, but the displacement, and therefore the fluid volume, can be changed. This is done by moving the vane housing to reduce the size of the pumping chambers. ● **SEE FIGURE 3–6.**

Variable displacement pumps allow a large output to produce the fluid volume needed for shifts and lubrication and a reduced output when it is not needed. A pressure sensing valve sends fluid to move the pump slide, and this reduces the offset between the rotor and the pump displacement.

DUAL-STAGE PUMPS Some transmissions use a dual-stage gear pump, which is a combination of two positive displacement pumps. Both pumps supply fluid when demands are high. The output of the second stage pump is released or vented when the primary stage can supply the needed flow and pressure. This system provides the volume of a large displacement pump at low speeds plus the economy of a small displacement pump at higher, cruising speeds. ● **SEE FIGURE 3–7.**

CHAIN-DRIVEN PUMPS Some automatic transaxles, such as the GM 6T75 and the Ford 6F50/6F55 units use a chain-driven pump. The purpose of using a chain-driven

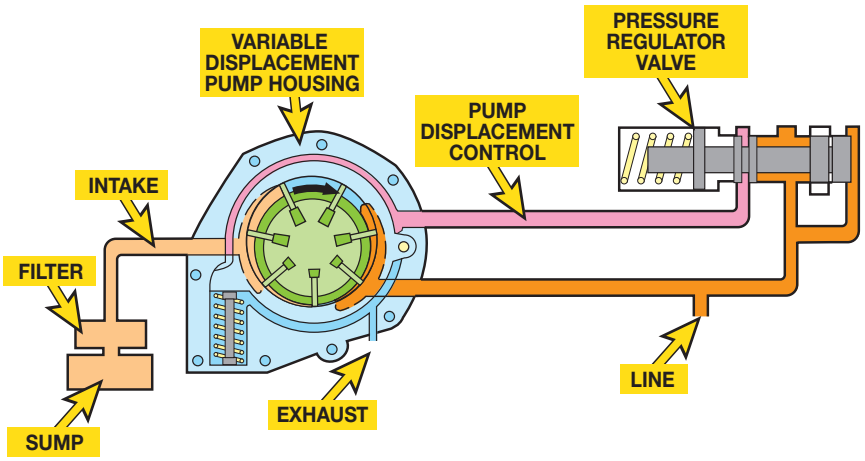


FIGURE 3–6 A variable displacement vane-type pump. The slide is moved to the high output position by a spring and decreased pressure comes from the pressure regulator valve.

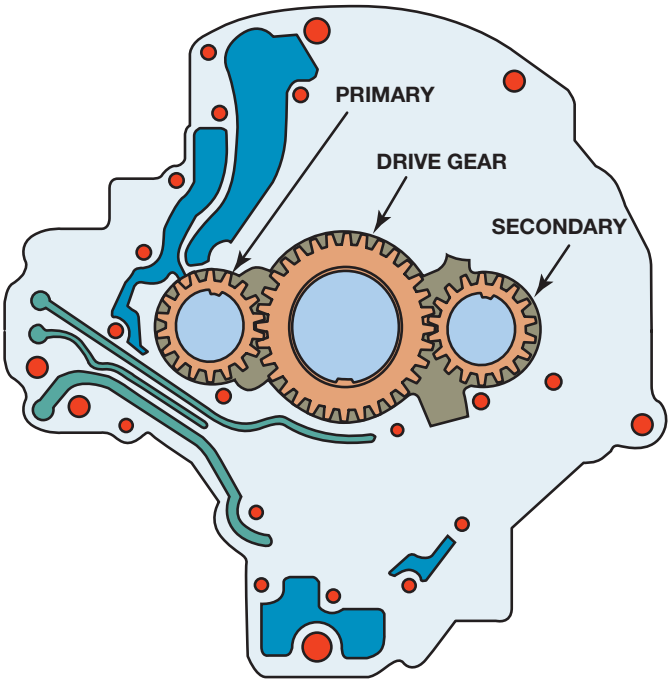


FIGURE 3–7 A dual-stage, external gear pump. Both stages are used at low engine speeds to produce enough fluid for the transmission's needs. At higher engine speeds, the output of the secondary stage is vented.

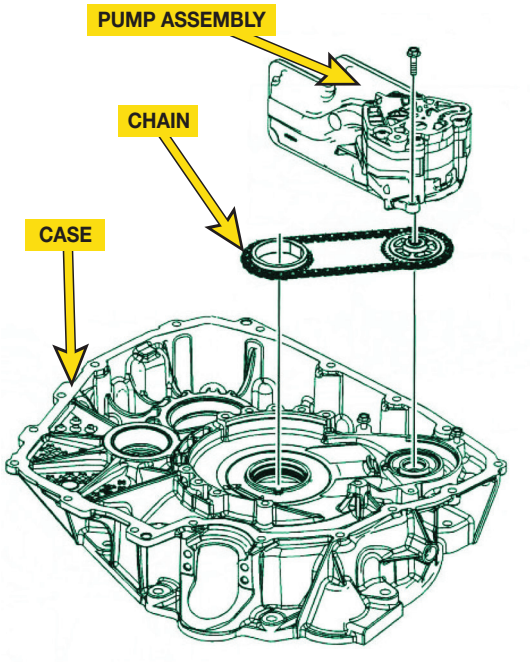


FIGURE 3–8 A chain-driven pump allows the transaxle to be shorter compared to a conventional pump that is driven by the torque converter.

pump is to reduce the overall length of the transaxle. Instead of the pump being driven by the torque converter, the pump is located beside the torque converter and driven by a chain. ● **SEE FIGURE 3–8.**

HYDRAULIC VALVES

SPOOL VALVES Most of the valves used in an automatic transmission are spool valves sliding in a round bore are used to control fluid flow. A **spool valve** gets its name because it looks similar to the spool that holds sewing thread. ● **SEE FIGURE 3–9.**

A spool valve can have two or more lands that fit the valve bore tightly enough so that fluid cannot escape past the valve land but also loosely enough so that the valve can slide freely in the bore. ● **SEE FIGURE 3–10.**

VALVE CONSTRUCTION Many valves are made from steel and some from aluminum, which are anodized, a type of coating used on aluminum parts to reduce wear. The annular grooves (valleys) between the lands are where the fluid flows through the valve. Typically, the valve-to-bore clearance is about 0.003

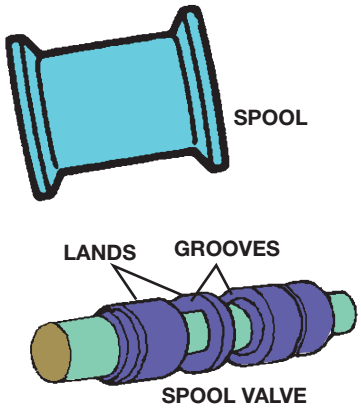


FIGURE 3–9 A spool valve resembles a spool for thread (top).

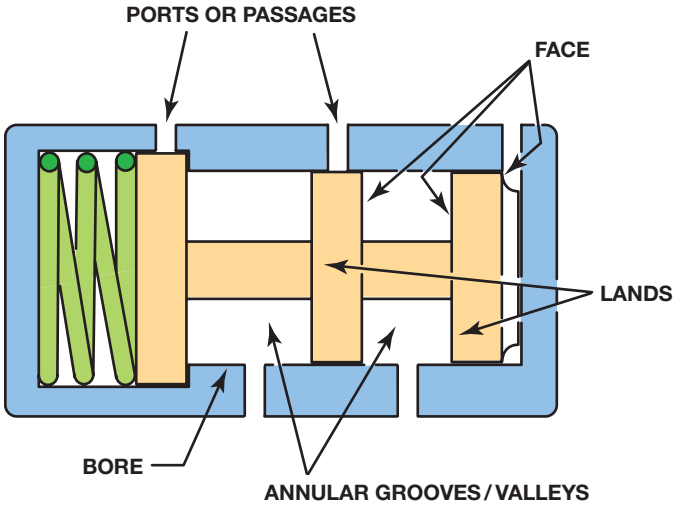


FIGURE 3–10 A spool valve and its bore. Note the names of the various parts.

to 0.004 inch (0.8 to 0.10 mm). The close fit requires the valve to expand and contract at the same rate as the valve body. This prevents the valve from sticking or having excessive leakage.

- The outer edges of the lands have sharp corners to help prevent debris from wedging between the land and the valve bore. The valleys or grooves between the lands serve as fluid passages.
- The faces serve as pressure surfaces, called *reaction surfaces*, to produce valve movement. Some valves are relatively long with a series of lands and grooves so fluid flow through two or more passages is controlled at the same time.
- The lands of a spool valve often have different diameters in order to provide different size reaction areas. A spool valve bore has fluid passages entering from the sides, which connect to the grooves (valleys) that extend clear around the valve. This is done to produce the same pressure entirely around the valve. As a spool valve is slid along the bore, the lands open up or close off the side passages and block or allow fluid flow from one place to another or to the sump to allow pressure to be exhausted.

VALVE HYDRAULIC FORCES Think of a valve as a hydraulic actuator. The hydraulic force exerted by a valve is simply the valve land area multiplied by fluid pressure. The valve area is determined using the formula for the area of a circle, πr^2.

For example, if a valve with a 2-lb (0.9-kg) spring pressing on one end and a 0.5-in. (12.7-mm) diameter land at the other end. ● **SEE FIGURE 3–11.**

- The area of the 0.5-in. land is 0.25 × 0.25 × 3.1416 = 0.196 sq. in. (1.26 cc).
- A fluid pressure of 10.2 PSI (70.33 kPa) acting on an area of 0.196 sq. in. (1.26 cc) generates a force of 2 lbs.

Fluid pressure greater than 10.2 PSI will cause the valve to move and compress the spring.

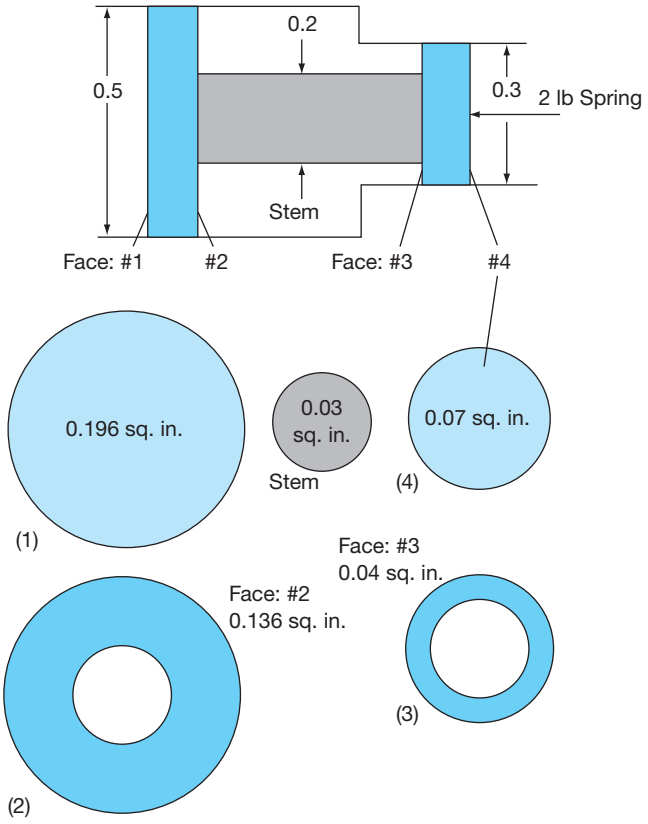


FIGURE 3–11 This valve spool has four possible hydraulic reaction faces. The areas are calculated like those of any other circular surface using the formula πr^2.

In some cases, pressure is exerted between two different-size land faces; fluid pressure acting on a larger face develops a greater force that will move the valve in that direction. If the diameter of one land is 0.5 in., the other land is 0.3 in. (7 mm), and the stem or shank of the valve is 0.2 in. (5.1 mm). There are three diameters and two important areas, as follows:

- Face 1: 0.5-in. diameter has an area of 0.196 sq. in.
- Stem: 0.2-in. diameter has an area of 0.1 × 0.1 × 3.1416 = 0.031 sq. in.
- Face 2: has an area of 0.196 – 0.030 = 0.166 sq. in.
- Face 3: has an area of 0.070 – 0.030 = 0.040 sq. in.
- Face 4: 0.3 diameter has an area of 0.15 × 0.15 × 3.1416 = 0.070 sq. in.
- Area difference between face 2 and face 3: 0.136 – 0.040 = 0.096 sq. in.
- A fluid pressure of 10 PSI (69 kPa) will develop a force of 0.96 lb (0.75 kg) pushing in the direction of face 2, the larger land.

VALVE CATEGORIES Most of the valves are controlled by fluid pressure. Some valves, like the manual valve, are operated mechanically. Valves can be divided into three categories:

1. **Switch valve**—A switch valve controls fluid flow into the different circuits and is also called a *flow control valve*.
2. **Servo valve**—A servo valve is used to move another valve. Some servo valves operate switch valves, and some help control pressure regulator valves.
3. **Regulator valve**—Used to control fluid pressure.

VALVE BODY

PURPOSE AND FUNCTION The valve body enables an automatic transmission/transaxle to operate automatically and is often referred to as the "brain" of the transmission. It supplies the hydraulic force to apply the clutches, bands, and the valves that control pressure and direct the fluid for automatic shifts. A valve body is where most of the hydraulic valves in a transmission/transaxle are located, and is attached to the case with bolts. Valve bodies can be made of either cast aluminum or cast iron.

LOCATION OF VALVE BODIES The valve body in most rear-wheel-drive transmissions is located inside the transmission oil pan at the bottom of the case. A transaxle valve body may be at the bottom of the case, on the backside of the torque converter housing, or on the top or side of the transaxle housing depending on the specific application. **SEE FIGURE 3–12.**

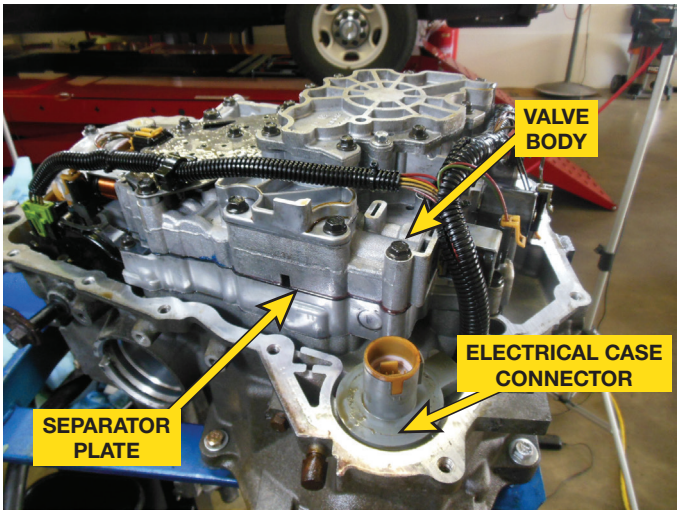


FIGURE 3–12 A typical valve body as installed on a GM 4T65-E transaxle.

FUNCTIONS OF A VALVE BODY The basic functions of the valve body assembly include:

- Control fluid pressures
- Schedule shifts to optimize engine performance
- Safely shift into reverse when requested
- Provide driver control of the operating ranges
- Provide for proper shift timing
- Provide engine braking to help control vehicle speed on downgrades
- Lock or unlock the torque converter clutch

VALVE BODY PARTS Valve bodies have many fluid passages for the various transmission hydraulic circuits cast into them. These are sometimes called worm tracks or *worm holes*. **SEE FIGURE 3–13.**

Some of these passages may be widened to form pockets that contain steel, nylon, or rubber check balls. Most valve bodies consist of two cast sections that bolt together with a flat metal separator plate between them.

- The upper section of the valve body is usually part of the transmission case and is often called the *case side*.
- The separator plate, also called a *transfer plate*, *restrictor plate,* or *spacer plate,* is located between the case side and the valve body side of the valve body assembly. It

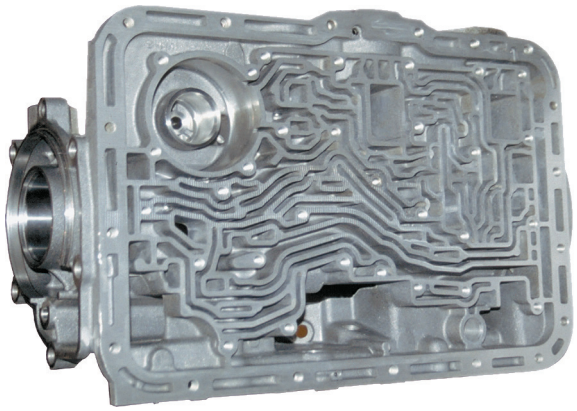


FIGURE 3–13 A typical upper valve body showing the fluid passages ("worm holes").

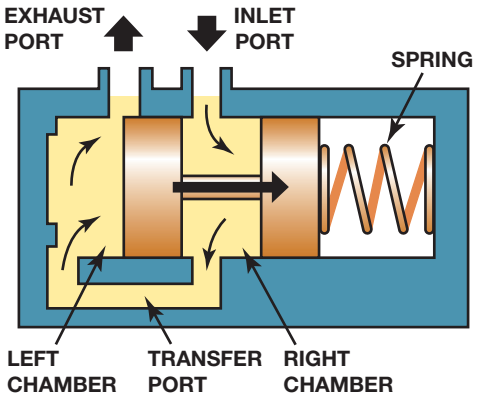


FIGURE 3–14 When pressure on the face of the pressure regulator valve overcomes spring force, the valve moves to open the exhaust port.

provides rigidity and contains calibrated drilled holes and openings that help manage fluid flow.

- The lower part of the valve body is located in the valve body itself and is often called the valve body side.
- Valve bodies contain specialized valves and circuits that are particular to a specific transmission.

Electronic solenoids are used in place of some valves on electronically controlled transmissions/transaxles. Some transmissions/transaxles incorporate the transmission control module (TCM) right on the valve body. This eliminates the wiring harness between the TCM and the solenoids, which in turn eliminates connector problems. Units that include the TCM within the transmission/transaxle are commonly called a **mechatronic** unit which is a word that combines mechanical with electronic components in one unit.

PRESSURE REGULATION

PRESSURE REGULATOR VALVE

As soon as the engine starts, the torque converter hub drives the transmission pump to produce fluid flow. Pressure is created by resistance to fluid flow. Transmission oil pumps are capable of creating an excessive amount of pressure quickly and therefore, every transmission uses a **pressure regulator valve**, or *pressure control valve,* to control hydraulic pressure. This is usually a spool valve and spring combination. This regulated pressure, commonly known as *mainline pressure, line,* or *control pressure*, is the working pressure for the entire hydraulic system. Most pressure regulator valves balance pump pressure on one side of the valve against a preset spring force acting on the other side of the valve. When hydraulic pressure is greater than the spring force, the valve moves in its bore far enough to uncover an exhaust port. ● **SEE FIGURE 3–14.**

The term **exhaust** refers to fluid flow back to the pan to empty or drain a circuit. The exhaust port provides a low-pressure path to the transmission oil pan (sump) where excess ATF is stored. Excess pressurized fluid flowing through this port reduces system pressure. When hydraulic pressure drops below spring pressure, the regulator valve closes the port and pressure begins to build up again. In operation, the opening and closing of the exhaust port occurs many times per second. This sequence of events achieves a steady pressure as the valve balances both the spring pressure and the hydraulic pressure. Because of this action, this type of valve is sometimes called a *balance valve*.

In addition to the pressure regulator, some transmissions use a **pressure relief valve** to release excess pressure that might occur under certain operating conditions. ● **SEE FIGURE 3–15.**

TYPICAL PRESSURES

Line pressure is controlled by the powertrain control module (PCM) or the transmission control module (TCM) to provide the specific pressure needed by the system based on input from the sensors, such as vehicle speed and engine load. For example, line pressure may be reduced to improve fuel economy because lowering the pressure reduces draw on the engine that is driving the pump.

Typical line pressures include:

- Normal line pressure—60 to 120 PSI (414 to 830 kPa)
- The accelerator pedal pressed to wide open throttle (WOT)—90 to 150 PSI (620 to 1,034 kPa)
- The gear selector in reverse or manual low (1)—150 to 300 PSI (1,034 to 2,068 kPa)

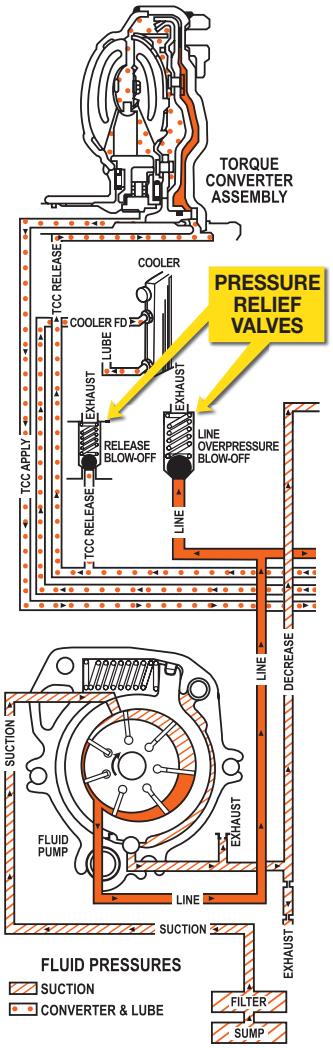


FIGURE 3–15 Typical pressure relief valves as found in the pump circuit.

MANUAL VALVE

PURPOSE AND FUNCTION The manual valve is the only hydraulic valve in the transmission that is "manually" controlled by the driver, and therefore, it is called a "manual valve" or sometimes *selector valve*. It receives the fluid from the pump and redirects the fluid to the shift valves, clutches or bands, wherever it is needed for that gear/speed. This valve is connected to the shift lever in the driver's compartment.

OPERATION The manual valve is moved by mechanical linkage when the driver moves the shift lever. The valve is held in position by the detent cam at the valve body. This detent is a spring-loaded roller or ball that drops into notches in the cam to position the manual valve properly in its bore. The detent cam is commonly called a **rooster comb**. ● **SEE FIGURE 3–17.**

? FREQUENTLY ASKED QUESTION

How is Pressure Maintained in the Automatic Transmission During Stop-Start Operation?

Many newer non-hybrid vehicles are equipped with a stop-start system. In these vehicles, the engine stops running when the vehicle is stopped and restarts when the driver releases the brake. Most of these vehicles use a an enhanced starter motor that is engineered to provide over 50,000 starts compared to a normal starter motor that is designed to provide only 5,000 engine starts during its life. When the engine stops, the hydraulic pump inside the transmission/transaxle also stops and pressure would drop preventing the clutches from holding. Some non-hybrid automatic transmissions/transaxles, such as the GM 4T45-E use an auxiliary electric driven pump to maintain line pressure when the engine stops during a stop-start event. ● **SEE FIGURE 3–16.**

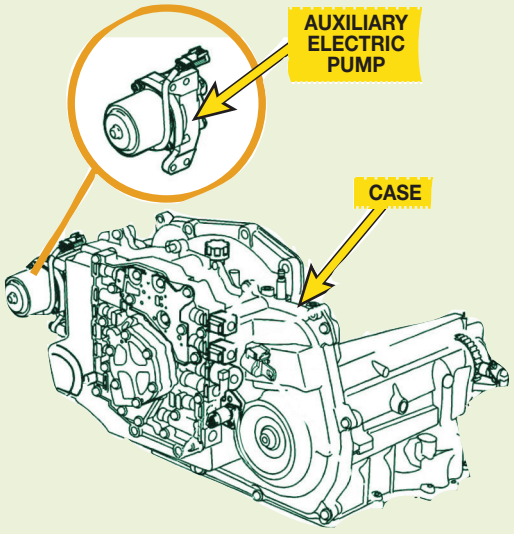


FIGURE 3–16 A GM 4T45-E uses an auxiliary electric pump to maintain hydraulic pressure when the engine stops during a stop-start event.

When the gear selector is in neutral or park, fluid flow through the manual valve is blocked by a land or trapped between two lands. In the other gear selector positions, the valve is moved to allow fluid flow through the valve to various valves and friction-apply circuits. Nearly all transmissions also have one *shift valve* for each automatic upshift. ● **SEE FIGURE 3–18.**

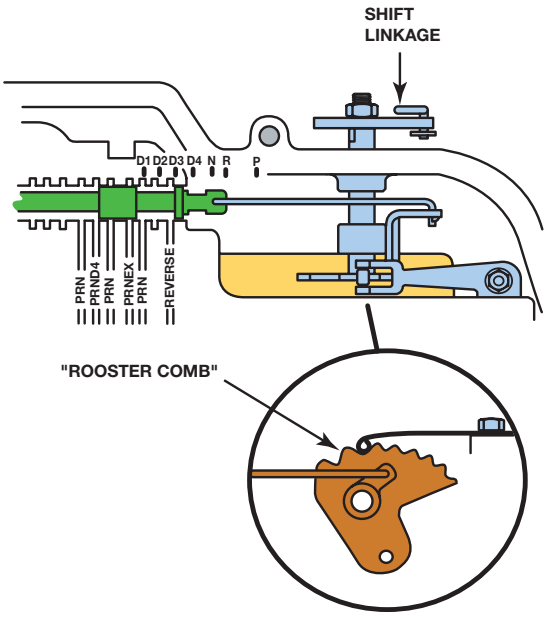


FIGURE 3–17 A rooster comb is the detent that helps retain the manual valve in the various positions in the valve body.

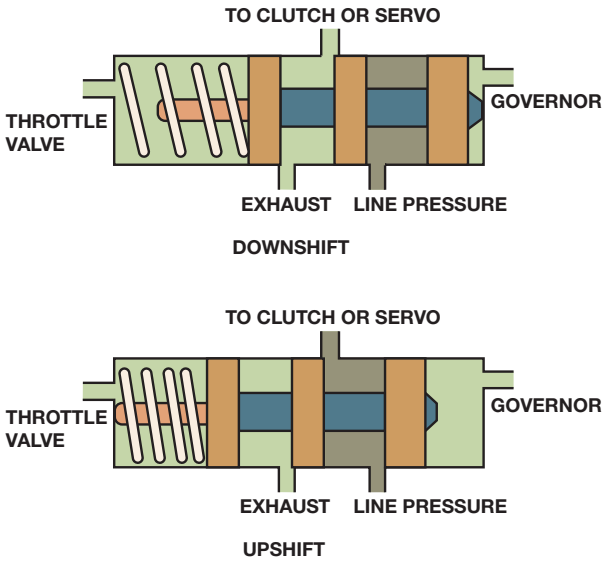


FIGURE 3–18 A typical shift valve has a spring to move the valve to a downshift position where the throttle pressure works with this spring. When governor pressure gets high enough, the valve will move to an upshift position.

FREQUENTLY ASKED QUESTION

What is a Shift-By-Wire System?

Many newer vehicles now use an electronic shifter that controls the manual valve using an electronic actuator or by using an electric motor to drive gears to rotate the manual valve instead of a lever control with mechanical linkage to the transmission. ● **SEE FIGURE 3–19.**

This design allows for effortless shifting between drive, park, neutral and reverse, and completely eliminates any wear-and-tear that used to occur in the mechanical connection between the shifter and transmission. The control uses one of the following to control the shifter:

- Push buttons
- Rotary knob ● **SEE FIGURE 3–20.**
- Smaller than normal (mini) shifter

An electric knob or dial and an electronic controller are used to control an actuator in or on the transmission/transaxle. The knob-control electronic module is about the size of a fist rather than the shoe-box-size space required for a lever control assembly. This space saving allows room for more storage space in the interior console.

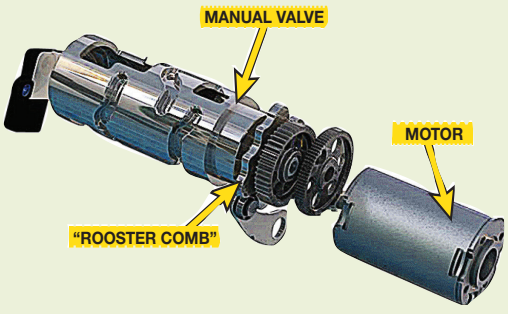


FIGURE 3–19 Some automatic transmissions, such as this VW/Audi unit use an electric motor to move the manual valve inside the transaxles itself. Other vehicles use an external actuator to move the manual valve. Check service information for the exact method used on the vehicle being serviced.

FIGURE 3–20 A rotary knob type electronic shifter used on a Chrysler 200.

HYDRAULIC SEALS

TYPES OF SEALS Gaskets and seals are used to keep the pressure from escaping where fluid flows between parts. Seals are of two types:

1. Static—A **static seal** is used to seal the space between two parts that are stationary relative to each other. Static seals include gaskets and O-rings that are placed between the two parts and squeezed tightly as the parts are fastened together. A static seal must provide enough compression to fill any possible voids between the two surfaces. ● **SEE FIGURE 3–21.**
2. Dynamic—A **dynamic seal** has a more difficult job because one of the surfaces to be sealed is moving relative to the seal. The movement can be rotating, such as when the torque converter enters the front of the transmission or the fluid flows from the pump housing into a clutch assembly, or sliding. At each end of the transmission, a rotating shaft enters or leaves the transmission, and the opening through which the shaft runs must be sealed to keep the fluid in and the dirt and water out. In both cases, a metal-clad lip seal is used. A lip seal has a flexible rubber sealing lip that rubs against the revolving shaft with enough pressure so fluid cannot flow between the shaft and the seal lip. A garter spring is often used to increase this sealing pressure. ● **SEE FIGURE 3–22.**

SEALING RINGS Another type of seal are sealing rings used to seal the fluid passages where fluid leaves a stationary member and transfers to a rotating member. ● **SEE FIGURE 3–23.**

FIGURE 3–21 A new O-ring seal being installed on a cover.

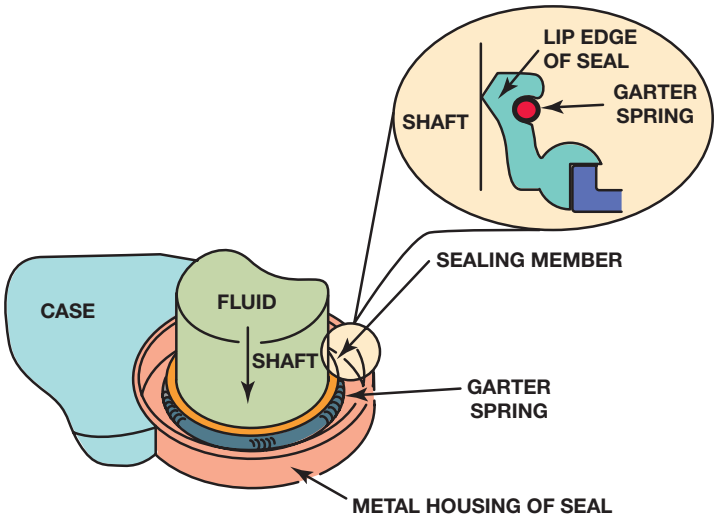


FIGURE 3–22 The sealing member of a metal-clad lip seal makes a dynamic seal with the rotating shaft while the metal case forms a static seal with the transmission case.

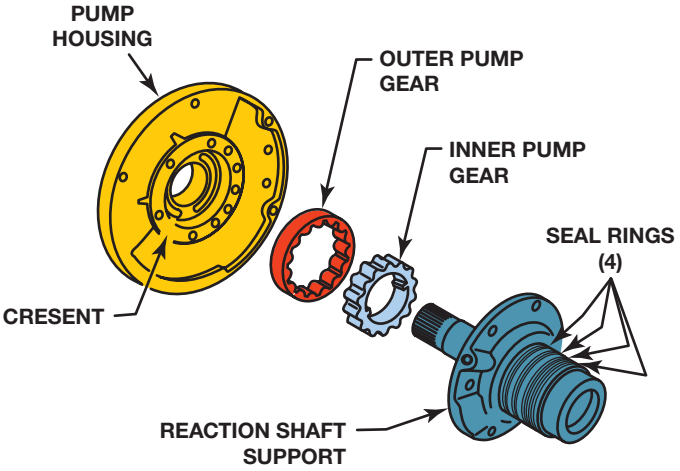


FIGURE 3–23 Sealing rings are used to seal the passages between stationary and rotating members. For example, the seal rings at the right keep the fluid flow from the pump to the front clutch from escaping.

This seal is a metal, plastic, or Teflon ring that fits tight in its bore to make a seal while the side seals against the side of its groove. ● **SEE FIGURE 3–24.**

A seal with a small leak is sometimes desirable to lubricate a bearing area close to the sealing ring. Metal and plastic sealing rings can be a *full-circle, hook ring,* or a *butt-cut ring* with a small gap. Teflon rings can be *scarf cut* (have the ends cut at an angle so they overlap), *butt cut,* or *uncut.* ● **SEE FIGURE 3–25.**

Teflon seals can change size. When a Teflon ring is stretched over a shaft, it must be resized to fit into the groove

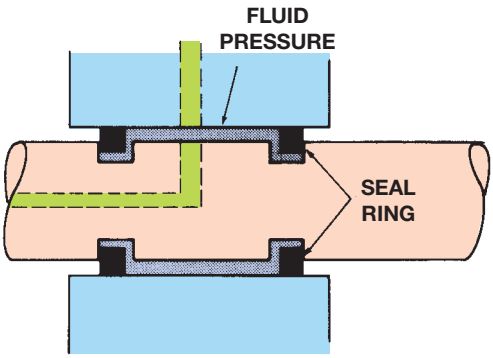


FIGURE 3–24 Fluid pressure forces a sealing ring outward in both directions to make firm contact with the side of the groove and outer diameter of the bore.

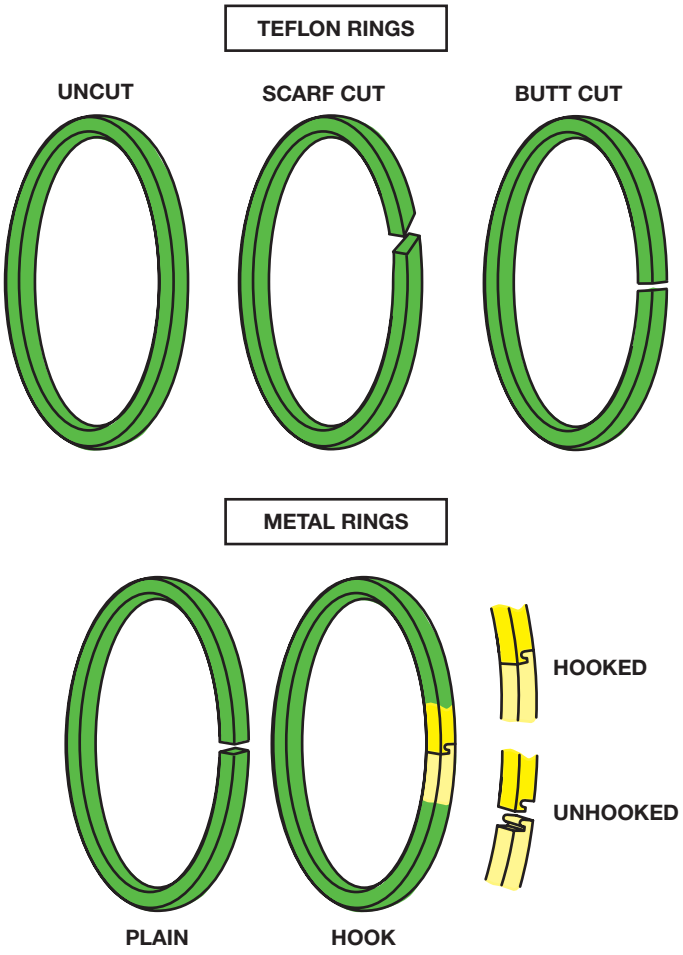


FIGURE 3–25 Metal seal rings (bottom) have plain or hooked ends. Teflon rings (top) are either uncut, scarf cut, or butt cut.

and bore. Special installing and resizing tools are recommended when installing Teflon sealing rings. The sliding seals for the clutch and band servo pistons are made of rubber in an O-ring, D-ring, lathe-cut seal, or lip seal shape. An O-ring is a rubber ring with a round cross section. A D-ring is rounded on the sealing side and square on the side where it is retained; the square portion prevents the seal from rotating. A lathe-cut seal, also called a *square-cut seal,* is a rubber ring with a square cross section. ● **SEE FIGURE 3–26.**

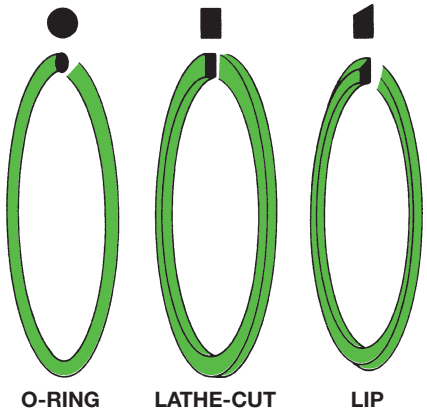


FIGURE 3–26 Clutch and servo piston seals are usually O-rings, lathe-cut rings, or lip seals.

SUMMARY

1. The hydraulic system applies the band and clutches, transmits force and motion, maintains fluid flow to the torque converter, and provides lubrication and cooling to the moving parts of the transmission.
2. Pumps produce the fluid flow in a transmission and the restriction to the flow results in the system pressure.
3. The three types of transmission fluid pumps include: The internal–external gears with crescent (or gear) pump, Gerotor (rotor) pump, and vane pump.
4. The mainline pressure is controlled by a variable pressure regulator.
5. Typical line pressures include:
   - Normal line pressure—60 to 120 PSI (414 to 830 kPa)
   - The accelerator pedal pressed to wide open throttle (WOT)—90 to 150 PSI (620 to 1,034 kPa)
   - The gear selector in reverse or manual low (1)—150 to 300 PSI (1,034 to 2,068 kPa)
6. The manual valve is the only hydraulic valve in the transmission that is controlled by the driver.
7. Electronically-controlled automatic transmission and transaxles rely on the correct operation of the sensors and solenoids, as well as software used by the PCM/TCM for proper shift quality.
8. Seals are used to confine the fluid to the appropriate passages.

REVIEW QUESTIONS

1. What does Pascal's law state?
2. How does a variable displacement pump work?
3. What is meant by mechatronic unit?
4. Where is the valve body located?

CHAPTER QUIZ

1. A force is expressed in what units?
   a. PSI **c.** Newton
   b. Lbs **d.** Either b or c
2. Fluid pressure is measured in what unit?
   a. Pounds
   b. Pounds per square inch (PSI)
   c. Newton
   d. Inches
3. If 100 lbs. of force is applied to 1 sq. in. of area, how much fluid pressure is created?
   a. 10 PSI
   b. 100 PSI
   c. 1 PSI
   d. 100 lbs
4. A chain-driven pump is used to _____.
   a. Increase the speed of the pump
   b. Reduce the length of the transaxle
   c. Decrease the number of parts needed
   d. Increase the distance between the torque converter and the pump
5. "Worm holes" are a term used to describe the opening in the _____.
   a. Dual stage pump
   b. Variable displacement pump
   c. Valve body
   d. Gerotor pump
6. The term _____refers to fluid flow back to the pan to empty or drain a circuit.
   a. Discharge **c.** Pressure drop
   b. Exhaust **d.** Dump
7. Using a spool valve to control fluid flow, where is the fluid blocked?
   a. At the lands
   b. At the grooves
   c. At the valleys
   d. At the spool
8. O-rings are a type of _____ seal.
   a. Dynamic **c.** Lip
   b. Static **d.** Inside
9. Fluid pressure is maintained in a transmission that uses a stop-start system using _____.
   a. A chain driven pump
   b. An electric pump
   c. An electric shifter
   d. A rear pump assembly
10. A shift-by-wire systems uses_____ and _____ to control the operation of the automatic transmission/transaxle.
    a. Wires and cables
    b. Electronic shifter and actuator
    c. Solenoids and relays
    d. Push buttons and dials

chapter 4

HYDRAULIC CONTROL VALVES AND SOLENOIDS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Describe the types and operation of automatic transmission/transaxle valves.
3. Discuss accumulators and orifices as used in an automatic transmission/transaxle hydraulic system.
4. Explain the operation of automatic transmission solenoids.
5. Describe how a pressure control solenoid (PCS) controls fluid pressure.

KEY TERMS

Accumulator 45
Governor 43
Linear solenoids 49
Orifice 46
Pressure control solenoids (PCS) 49
Pulse-width modulated (PWM) solenoids 48
Slide-bump shift 45
Solenoid 47
Throttle valve (TV) 43
Vacuum modulator 43

HYDRAULICALLY-CONTROLLED TRANSMISSIONS

BACKGROUND Non-computerized hydraulically-controlled transmissions, until the late 1980s used the hydraulic system components to determine when to shift. These components included:

1. A governor to detect vehicle speed.
2. A throttle cable and valve or a vacuum modulator to determine the load on the engine.

GOVERNOR The **governor** is connected to the output shaft and regulates hydraulic pressure based on vehicle speed. As the vehicle speed (output shaft) increases, centrifugal forces a pair of weights against pull-back springs. As the weights pull further out against the springs, more oil pressure is allowed past the governor to act on the shift valves that are in the valve body which then signal the appropriate shifts. ● **SEE FIGURE 4–1.**

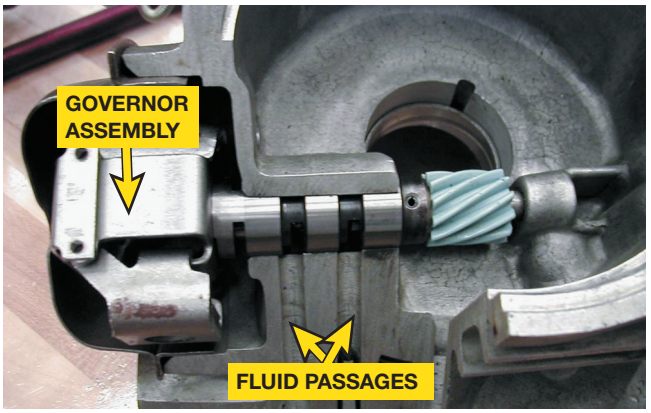


FIGURE 4–1 A governor assembly is used on older hydraulically controlled automatic transmissions/transaxles to control shift points based on vehicle speed.

ENGINE LOAD INPUT The higher the load on the engine, the longer the transmission will hold a gear before shifting to the next one. There are two types of devices that serve the purpose of monitoring the engine load and just one of the following is used, not both:

1. **Throttle Valve**—The **throttle valve (TV)** monitors the position of the gas pedal through a cable or rod that runs from the gas pedal to the throttle valve in the valve body. TV pressure is very low at idle speed and very high at wide-open throttle (WOT). A detent valve is used in some circuits to increase TV pressure and force downshifts at WOT. The maximum pressure that a governor or a throttle valve can produce is line pressure. ● **SEE FIGURE 4–2.**
2. **Vacuum Modulator**—The **vacuum modulator** monitors engine vacuum by a rubber vacuum hose, which is connected to the engine intake manifold. Engine vacuum reacts very accurately to engine load with high vacuum produced when the engine is under light load and diminishing down to zero vacuum when the engine is under a heavy load. The vacuum modulator has a spring that is always pushing against the hydraulic valve in the valve body, and the engine manifold vacuum reduces the power of the spring. The modulator is attached to the outside of the transmission case and has a shaft which passes through the case and attaches to the throttle valve in the valve body. When an engine is under a light load or no load, high vacuum acts on the modulator which moves the throttle valve in one direction to allow the transmission to shift early and soft. As the engine load increases, vacuum is diminished which moves the valve. ● **SEE FIGURE 4–3.**

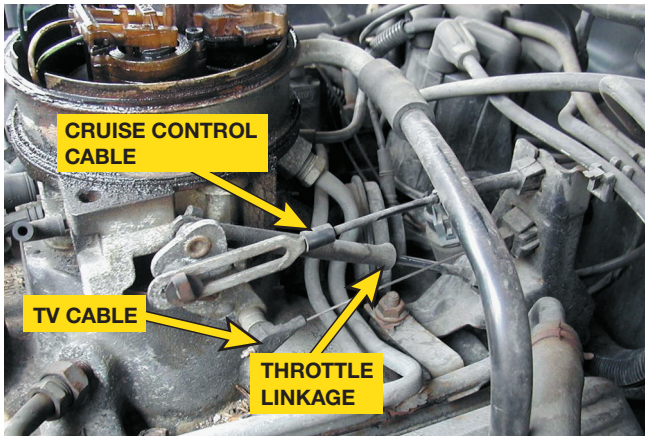


FIGURE 4–2 The throttle valve (TV) cable on a 4L60 transmission.

NOTE: Electronically-controlled automatic transmission and transaxles rely on the correct operation of the sensors and solenoids and software used by the PCM/TCM for proper shift quality.

SHIFT VALVES

PURPOSE AND FUNCTION An upshift or downshift occurs when the shift valves move. Shift valves are placed in one of two positions and are moved to the desired position by an increase or decrease of fluid pressure at one end.

- At rest or very slow speeds, the spring moves the valve to the downshift position. A typical shift valve has a land connected to the governor or shift solenoid area at one

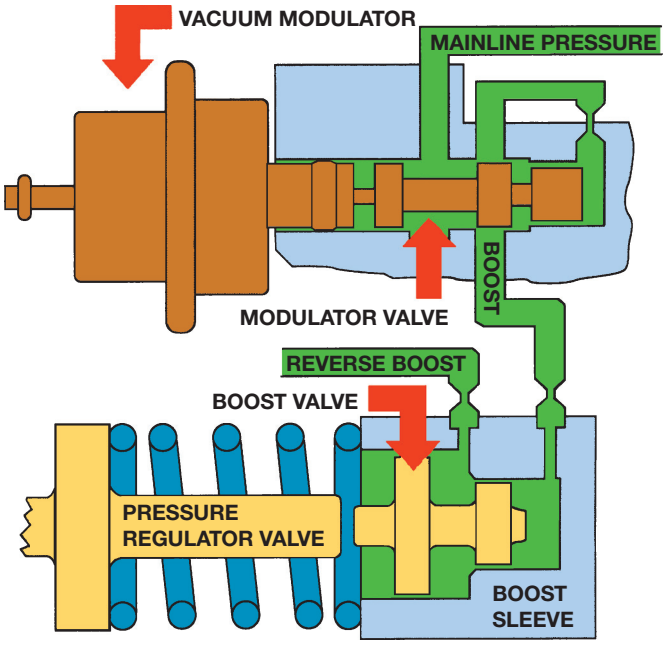


FIGURE 4–3 A vacuum modulator moves the modulator valve depending on the vacuum of the engine. A heavy load on the engine causes the vacuum to be lower than when the engine is operating under a light load. The spool valve applies mainline pressure to the boost sleeve of the pressure regulator valve, which causes the mainline pressure to increase.

end and a spring at the other. The controlled flow to the next gear's apply device also enters from the side and is blocked by a land or a closed valley while the passage to the apply device is open to exhaust.

- In a non-electronic transmission, governor pressure acts against the spring and throttle valve pressure to move the shift valve to upshift to second. In an electronic-controlled transmission, the PCM or TCM energizes the shift solenoid to make the shift to second based on inputs from the engine sensors and the vehicle speed sensor. ● **SEE FIGURE 4–4.**

SHIFT QUALITY

SHIFT OVERLAP To shift from one gear range to another, transmissions apply and release clutches or bands. Some transmissions are designed to apply a clutch or a band without having to release another one. These are called *nonsynchronous* or *asynchronous* transmissions. Synchronous transmissions require a clutch or band to release during the clutch or band apply for the next gear range, and these must be carefully synchronized.

NEED FOR SHIFT MODIFIERS Many automatic transmissions contain valves to adjust the quality (speed and firmness) of the shift.

- A light-throttle shift, made while the engine is not producing much torque, can be fairly slow and at a light pressure.
- At heavy throttle, the engine is producing more torque so higher pressures are needed for the shift in order to lock the band or clutch being applied and prevent excessive slippage.
- Too slow of a shift at pressures that are too low will cause slippage and burning of the friction material.
- Too fast of a shift at pressures that are too high produces an aggressive, harsh shift that can cause mechanical damage to the drive train. Several methods are used to tailor a shift to the throttle opening or speed of the vehicle.

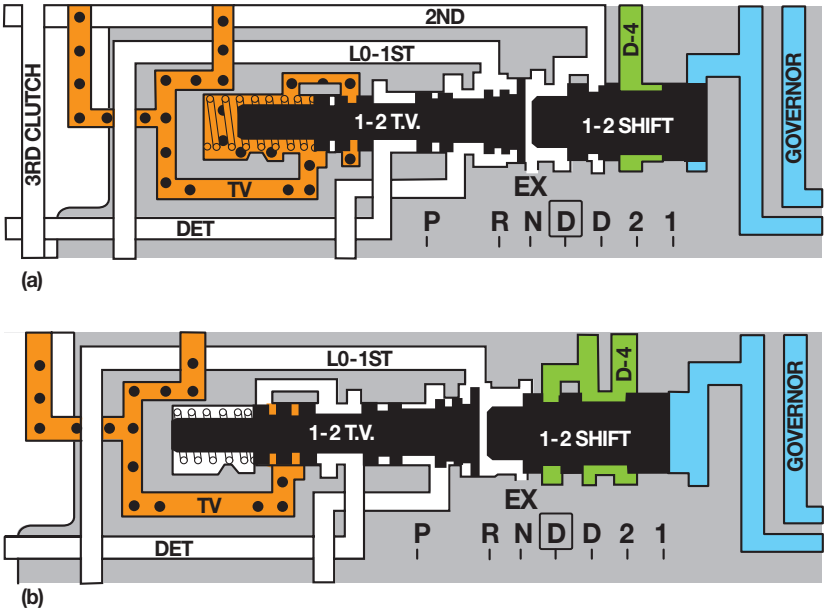


FIGURE 4–4 (a) As the speed increases, governor pressure increases and is applied to the 1–2 shift valve. (b) When the 1–2 shift valve moves, the fluid is directed to 2nd clutch and the shift is completed.

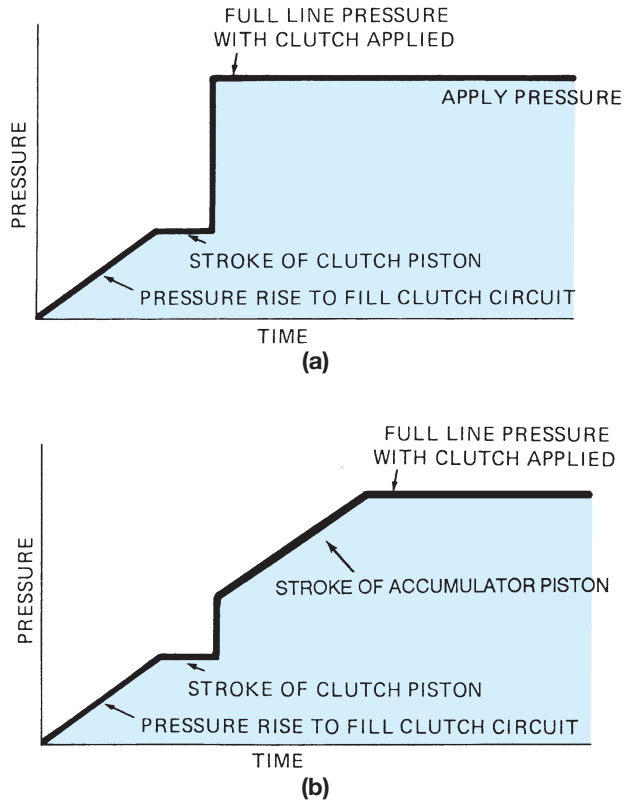


FIGURE 4–5 (a) When a clutch applies, fluid pressure rises gradually until the circuit is filled and the piston strokes to take up the clearance; then there is a rapid increase to line pressure. (b) An accumulator can be placed into the circuit to slow this pressure rise and soften clutch application.

ACCUMULATORS An **accumulator** is tied hydraulically to a clutch or band servo, and absorbs fluid during the pressure build-up stage when a clutch or band applies. This has the effect of slowing the pressure increase and lengthening the time it takes for the friction device to complete the shift. ● **SEE FIGURE 4–5.**

As clutch or band apply pressure is entering the apply side of the accumulator, fluid must leave the opposite, exhaust side of the accumulator piston. The pressure on the apply side and rate of stroke can be controlled by how easily the fluid leaves the exhaust side. If the accumulator piston bottoms out before the shift is complete, there will be a sudden pressure increase that will cause a **slide-bump shift**. This is a shift with poor quality that starts smooth, but ends harsh.

CONTROLLING FLUID FLOW

CHECK BALLS A check ball is the simplest device for controlling fluid flow. A *one-way check valve* resembles a steel bearing or plastic ball located over a hole in the separator plate. ● **SEE FIGURE 4–6.**

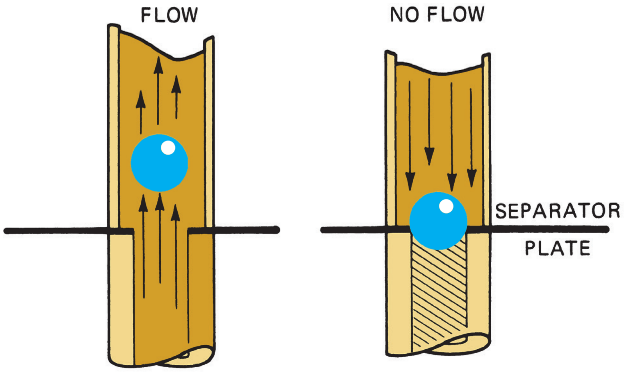


FIGURE 4–6 A check valve is opened by fluid flow in one direction (left) and closes when the fluid tries to flow in the reverse direction.

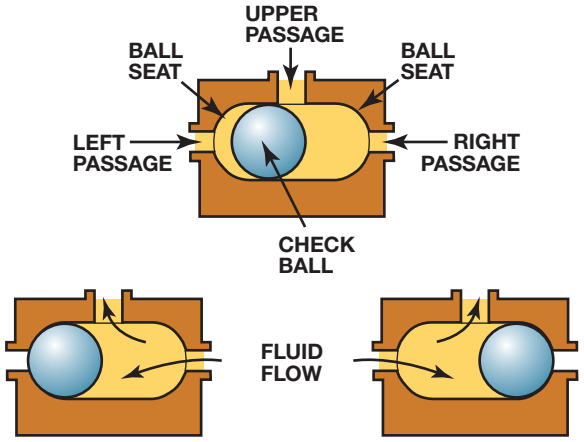


FIGURE 4–7 Check balls are used in the valve body to allow hydraulic circuits to share a common passage.

An upward fluid flow moves the ball aside and fluid flows around it. A downward fluid flow forces the ball against the hole and stops the flow. The flow of fluid is possible in only one direction, upward. Often there are check balls in both the case side and valve body side of the valve body assembly. ● **SEE FIGURE 4–7.**

Check balls are usually made from steel, but they can be made of nylon, rubber, or some composite material as well. The type of material used depends on the manufacturer and application.

Steel balls generally hold up better, but cause greater seat wear because of their hardness. The softer composite balls are easier on seats and they cannot be magnetized. Some transmissions use a *two-way check valve,* also called a *shuttle valve*. The ball is positioned above two side-by-side holes with another flow passage extending upward or to the side. Upward flow through one of the holes in the plate causes the ball to move over and seal the other hole. Fluid flow upward through the second hole causes the ball to move over and seal the first hole. ● **SEE FIGURE 4–8.**

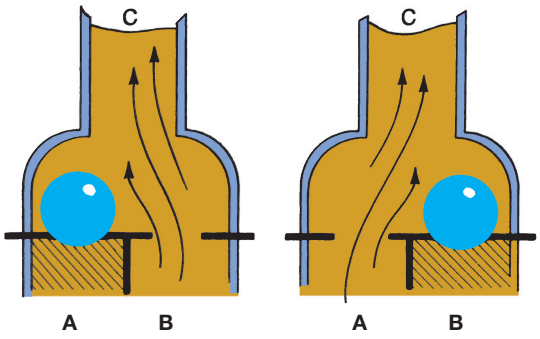


FIGURE 4–8 When fluid flows through this shuttle valve from port B to port C, the check ball moves over to close port A (left). Fluid flow from port A will close port B (right).

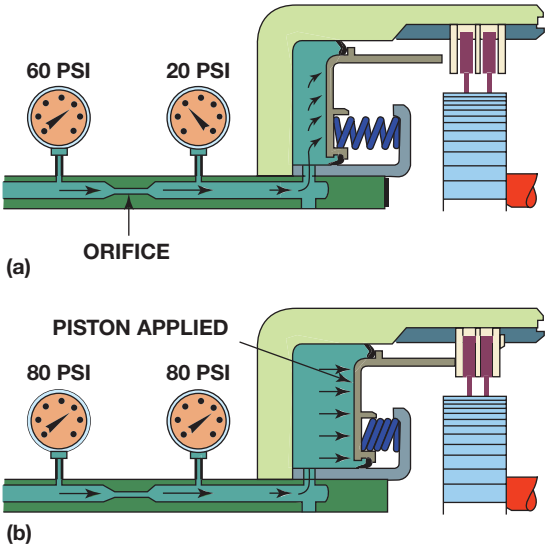


FIGURE 4–9 (a) An orifice will cause a pressure drop as fluid flows through; (b) when the flow stops, the pressure on both sides of the orifice will be the same.

ORIFICES

An orifice is simply a small hole, usually in the separator plate. An orifice produces a resistance to fluid flow and therefore causes a pressure drop as long as fluid is flowing through it.

- The amount of pressure drop is relative to the size of the orifice and the flow volume.
- The smaller the orifice size, the greater resistance to flow and the larger the drop in fluid pressure.
- As soon as the flow stops, the orifice no longer has an effect on the flow, and the pressure on both sides becomes equal.
- An orifice is also used to dampen fluid flow to the control valves. There is usually one in the passage between the pump and reaction land of the pressure regulator valve and this orifice helps soften pressure pulses from the pump that can cause the valve to overreact. **SEE FIGURE 4–9.**

See **CHART 4–1** for the hydraulic variables and how they are controlled in a hydraulically-controlled automatic transmission.

HYDRAULIC SUB-CIRCUITS

The hydraulic system is easier to understand if it is divided into sub-circuits. A flow control valve is the dividing point as supply pressure enters the different circuits. Also note that each circuit serves a particular purpose. **SEE CHART 4–2.**

VARIABLE	CHANGE	EFFECT
Line pressure	Increase	Firmer shift
Flow rate	Increase	Firmer shift
Orifice size	Increase	Faster flow rate
Accumulator rate	Increase	Firmer shift
Accumulator spring	Softer	Faster accumulator rate
Accumulator back pressure	Reduce	Faster accumulator rate

CHART 4–1

The firmness of a shift is controlled by the orifice size and the accumulator. In electronically-controlled automatic transmissions and transaxles, all of this is controlled by software.

NAME OF CIRCUIT	PURPOSE
Supply	Provides fluid to pressure regulator valve and transmission.
Main control pressure	Supplies fluid at a controlled pressure to transmission and converter when the engine is running.
Converter and cooler	Regulates converter pressure; provides gear train lubrication and cooling of the fluid.
Drive	Applies forward clutch and supplies control systems in forward-gear ranges.
Reverse	Increases control pressure.
Governor	Provides a pressure proportional to road speed for upshifts.
Throttle valve (TV)	Provides a pressure proportional to engine load and vacuum for shift timing and quality.
Accumulator	Cushions shift by softening clutch or band apply.

CHART 4–2

Each hydraulic circuit has its own purpose and function.

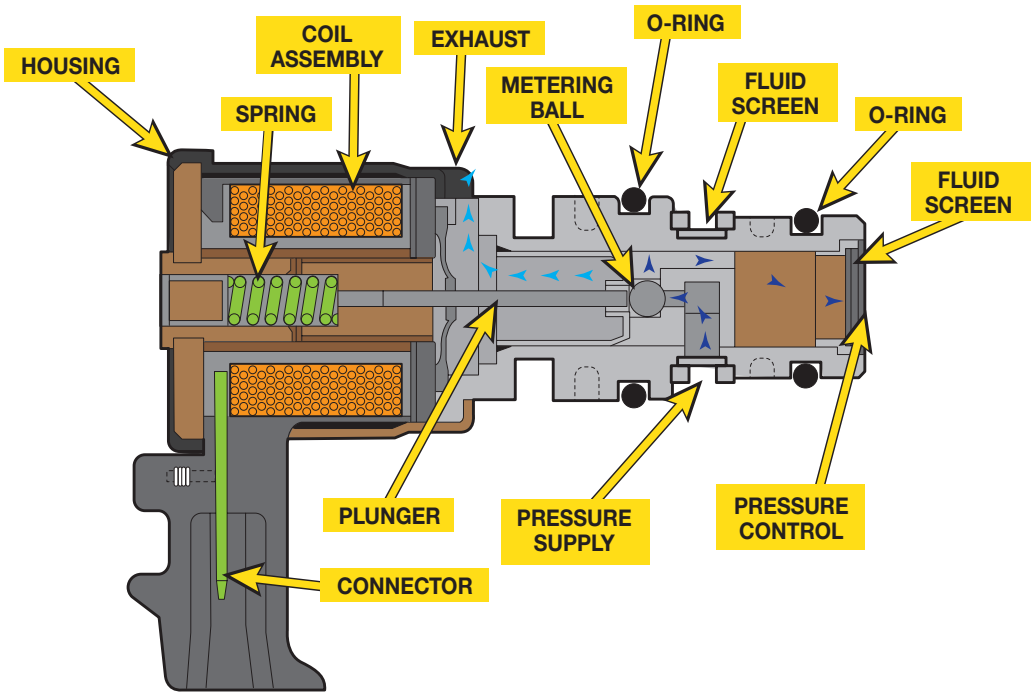


FIGURE 4–10 A typical automatic transmission solenoid showing the coil assembly where the magnetic field and the metering ball and plunger that works against the force of the spring.

TRANSMISSION SOLENOIDS

ELECTROMAGNETISM Scientists did not discover that current carrying conductors also are surrounded by a magnetic field until 1820. These fields may be made many times stronger than those surrounding conventional magnets. Also, the magnetic field strength around a conductor may be controlled by changing the current.

- As current increases, more flux lines are created and the magnetic field expands.
- As current decreases, the magnetic field contracts. The magnetic field collapses when the current is shut off.
- The interaction and relationship between magnetism and electricity is known as electromagnetism.

CREATING AN ELECTROMAGNET An easy way to create an electromagnet is to wrap a nail with 20 turns of insulated wire and connect the ends to the terminals of a 1.5 volt dry cell battery. When energized, the nail will become a magnet and will be able to pick up tacks or other small steel objects.

SOLENOID OPERATION A **solenoid** is a type of an electromagnetic switch that uses a movable core. In automatic transmissions, the movable core is used to control the flow of automatic transmission fluid through hydraulic circuits. When the electrical circuit to the solenoid is closed, the following occurs.

1. Current travels from the battery through a coil, creating an electromagnet.
2. The magnetic field created by the current attracts the core which then moves against the force of a spring. ● **SEE FIGURE 4–10.**

When the control circuit is opened, the following occurs.

1. The electromagnet loses its magnetism when the current is shut off.
2. Spring force moves the movable core back to its normally open (N.O.) position.

ON-OFF SOLENOIDS An electronic transmission controls the shift points by turning a solenoid(s) on and off. The solenoids in turn control the hydraulic pressure that moves the shift valves or operates the torque converter clutch. Solenoids used in electronically controlled automatic transmissions/transaxles are as follows:

- These can be normally open (N.O.) to allow fluid flow or normally closed (N.C.) to block fluid flow. ● **SEE FIGURE 4–11.**
- Shift solenoids have two states depending on application:
  1. **Apply**—Applies fluid pressure to a shift valve when energized/de-energized.

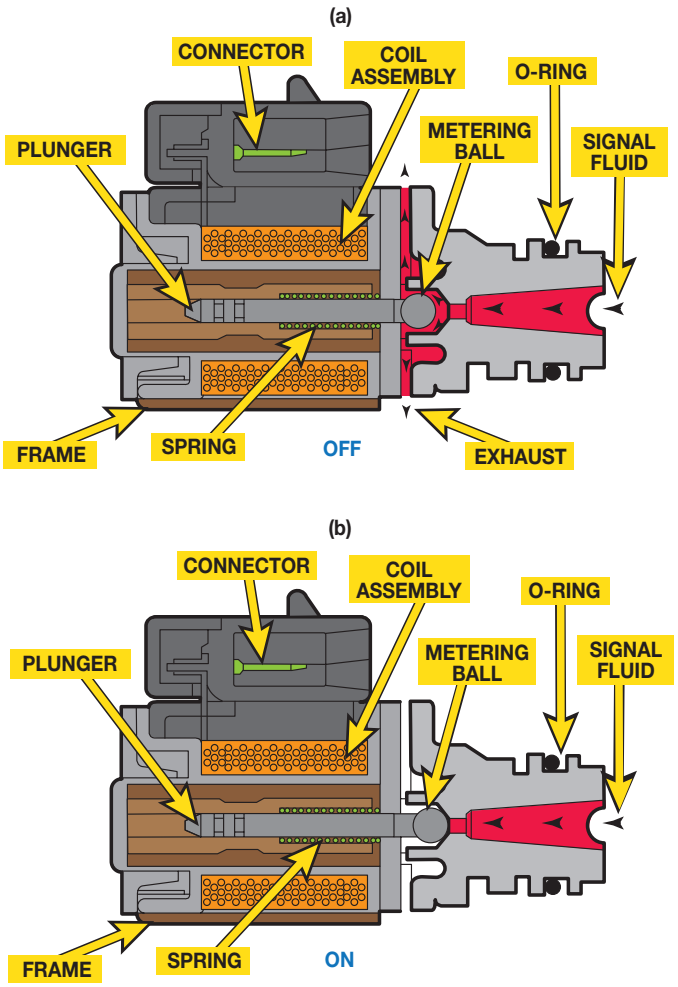


FIGURE 4–11 (a) In this example, the solenoid is commanded off, metering ball is off its seat and allows fluid to flow. (b) When the solenoid is on, the metering ball is seated preventing fluid flow.

2. **Venting**—Vents fluid pressure when energized/de-energized.

- Shift solenoids control the pressure force which in turn controls the position of the shift valve. ● **SEE FIGURE 4–12.**
- They are commanded on or off by the PCM/TCM.
- The resistance of most on–off type shift solenoids is 10 to 15 ohms.

PULSE-WIDTH MODULATED SOLENOIDS Some automatic transmission solenoids are **pulse-width modulated (PWM)**, which means that they are energized at a fixed rate (frequency) the amount of time it is "on" is controlled by the PCM/TCM. The ratio of on/off time is called the duty cycle and ranges from 0% (completely de-energized) to 100% (fully energized). A typical application of PWM solenoids is the torque converter clutch-apply circuit such as in the GM 4T60-E.

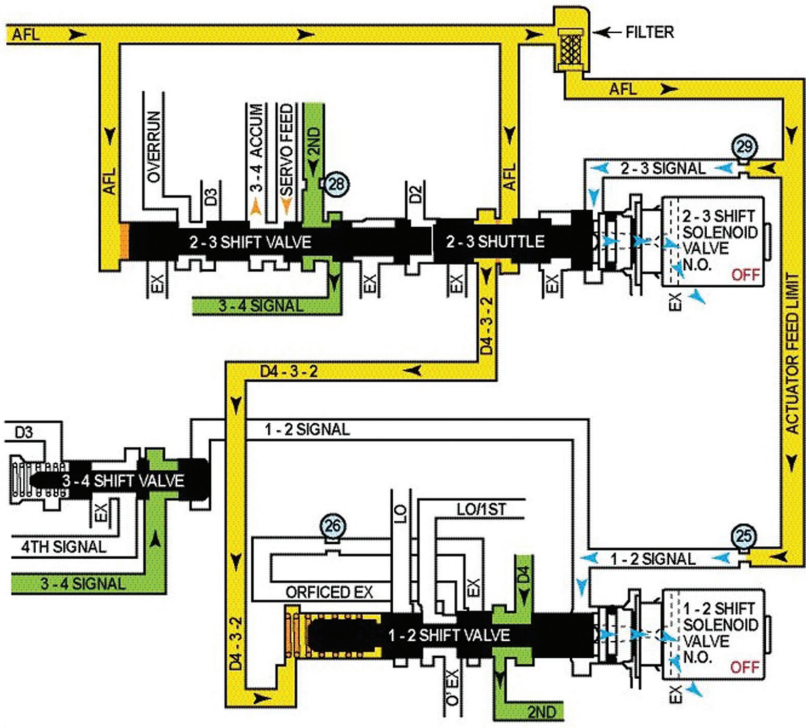


FIGURE 4–12 Shift solenoids are commanded on and off by the PCM/TCM as needed to make a shift.

FREQUENTLY ASKED QUESTION

What is a "pintle hump"?

Observing the operation of an on-off type shift solenoid using a digital storage oscilloscope, (DSO), there usually appears to be dip in the waveform about half or two thirds of the way up the ramp as current is flowing through the windings of the solenoid. This "hump" is created by the action of the plunger (pintle) inside the solenoid as it moves and provides the service technician proof that the solenoid did, in fact, move. **SEE FIGURE 4–13.**

Some experienced automatic transmission diagnostic technician use a DSO to check all of the solenoids while the transmission/transaxle is still in the vehicle using the following:

- A scan tool to command the solenoids on.
- An inductive amp clamp connected to the feed wire to the solenoid or around the wire being controlled by the PCM/TCM.
- A digital storage oscilloscope (DSO).

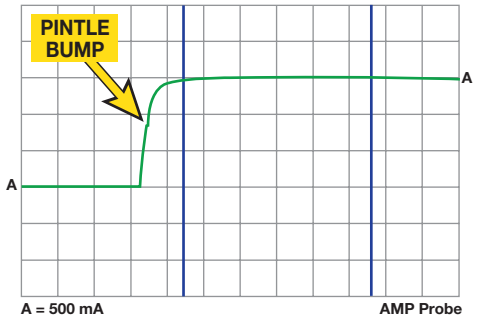


FIGURE 4–13 A scope waveform showing the opening of a solenoid using a current clamp around the solenoid feed wire. The hump is created when the core of the solenoid moves which creates a slight counter electromotive force (EMF) causing the slight hump in the current waveform.

- When the pulse width is high, the apply pressure to the TCC is at a minimum.
- When the pulse width is low, full line pressure flows through the solenoid to allow maximum converter apply pressure.
- PWM solenoids have a low resistance, usually 4–6 ohms.

LINEAR SOLENOIDS

Linear solenoids operate using a PWM control to cause the plunger inside the solenoid to move in or out depending on the amount of the applied current. The typical operation of a linear solenoid includes:

TECH TIP

Look for PUN or TUN

In GM automatic transmission/transaxles, the part numbers identify the solenoid performance characteristic data which is stored in the TCM. If a solenoid is replaced, not only should the correct solenoid be used, but its unique performance characteristic must be programmed into the TCM. These unique part numbers are called:

- PUN—Part unique number
- TUN—Transmission unique number

The PUN or TUN is printed on the solenoid. The vehicle then needs to be connected to a scan tool, which is connected the Internet so that the TCM can be updated with the new PUN/TUN.

Check service information for the exact procedures to follow for the unit being serviced.

- The PCM/TCM sends a pulse-width modulated signal at a fixed frequency with a varying duty cycle (on-off time).
- Current through the coil of the solenoid creates an electromagnetic force that is applied to the internal plunger which moves against a spool valve and spring force in the snout part of the solenoid.
- The higher the pulse-width of the signal applied from the PCM/TCM, the greater the movement of the plunger.
- Linear solenoids have a low resistance, usually 4–6 ohms. **SEE FIGURE 4–14.**

SEE CHART 4–3 for a comparison of the resistance of the various types of solenoids.

ELECTRONIC PRESSURE REGULATION

Electronic automatic transmissions/transaxles regulate hydraulic system pressure using a **pressure control solenoid (PCS)** that may also be called any of the following:

TYPE OF SOLENOID	TYPICAL RESISTANCE
On-off type shift solenoids	10–15 Ohms
Pulse-width modulated (PWM) shift or TCC solenoids	4–6 Ohms
Linear (PWM) solenoids	4–6 Ohms

CHART 4–3

Typical automatic transmission/transaxles solenoid coil winding resistance. Always check service information for the exact resistance specifications for the unit being serviced.

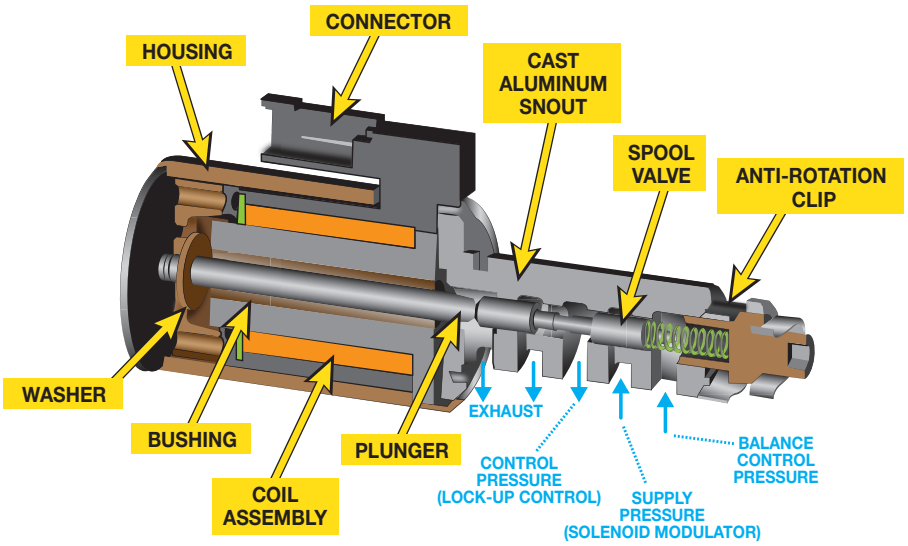


FIGURE 4–14 A linear solenoid is pulse-width modulated plus the spool valve moves in proportion to the pulse-width signal form the PCM/TCM.

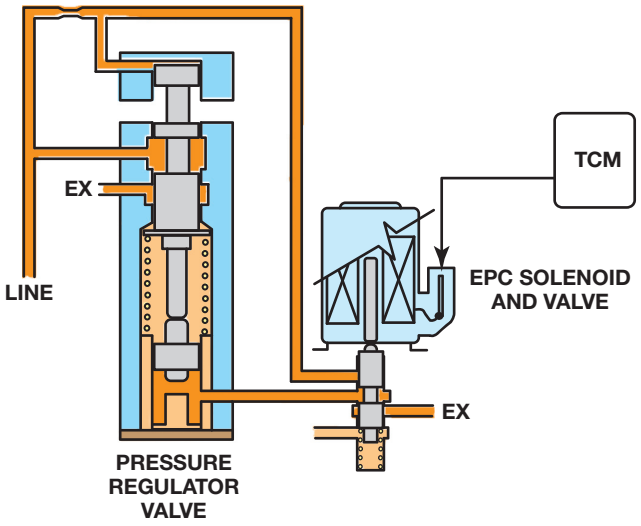


FIGURE 4–15 The TCM controls the EPC solenoid to change the pressure regulator valve to adjust line pressure.

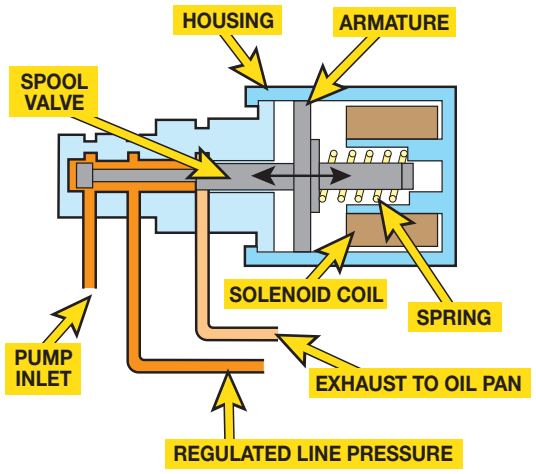


FIGURE 4–16 The pressure control solenoid controls the mainline pressure, which is in turn controlled by the powertrain control module (PCM) or the transmission control module (TCM), by applying pressure to the spring side of the pressure regulator valve.

- *Electronic pressure control (EPC)*
- *Pressure control (PC)*
- *Variable force solenoid (VFS)*
- *Force motor*

The powertrain control module (PCM) or the transmission control module (TCM) switches the solenoids on and off very quickly using pulse-width modulation (PWM). ● **SEE FIGURE 4–15.**

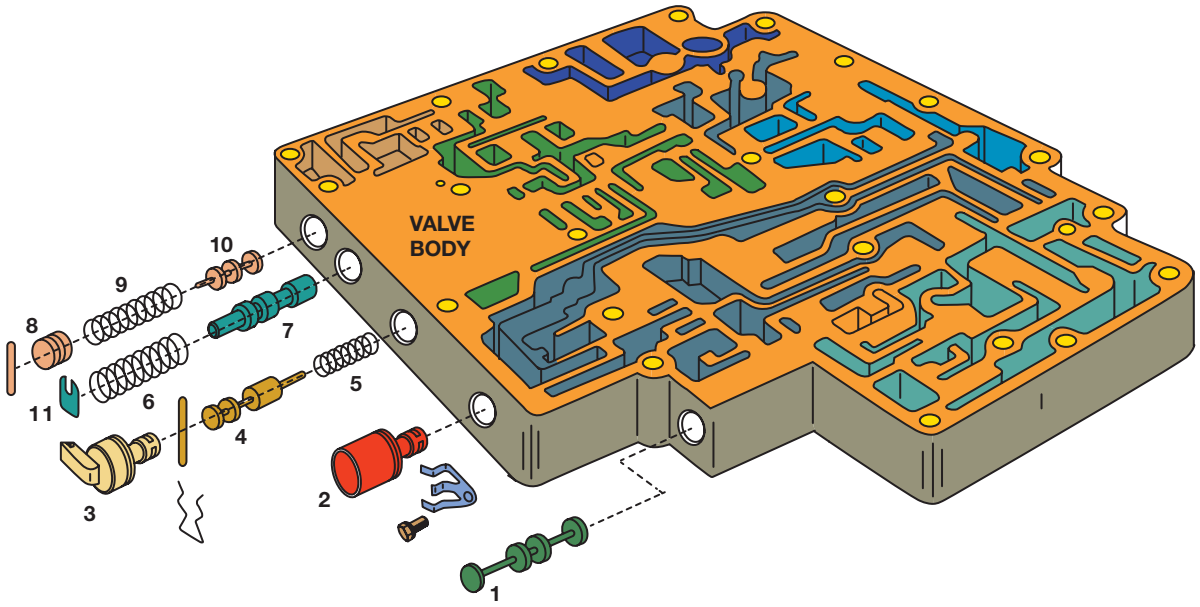
These pressure control solenoids usually have a low resistance of one to four ohms and operate at high frequency with varying duty cycles. Most electronic pressure control solenoids draw 1–2 amperes which has an inverse relationship to the fluid pressure:

- Higher amperage = lower fluid pressure
- Lower amperage = higher fluid pressure

By using the inverse relation in amperage and fluid pressure, if there is a fault in the system, the default setting if the EPC failed would be high pressure which would cause harsh shifts but would not likely cause internal transmission damage.

The solenoid pushes against an internal valve which opens and closes the hydraulic circuit it regulates. Electronic pressure control allows precise hydraulic system pressure regulation and can also be used to modify the timing and feel of transmission shifting. ● **SEE FIGURE 4–16.**

SOLENOID LOCATION Most solenoids are located or attached to the valve body. The exact type and location can vary according to make, model and year so it is important to check service information for the exact description and color of solenoids for the vehicle being serviced. ● **SEE FIGURE 4–17.**



1 VALVE, MANUAL
2 VALVE ASSEMBLY, PRESSURE CONTROL SOLENOID
3 VALVE ASSEMBLY, TCC PWM SOLENOID
4 VALVE, TCC REGULATOR APPLY
5 SPRING, TCC REGULATOR APPLY VALVE
6 SPRING, ACTUATOR FEED LIMIT VALVE
7 VALVE, ACTUATOR FEED LIMIT
8 PLUG, ACCUMULATOR VALVE BORE
9 SPRING, ACCUMULATOR VALVE
10 VALVE, ACCUMULATOR
11 RETAINER, ACCUMULATOR FEED LIMIT VALVE SPRING

FIGURE 4–17 A typical valve body showing some of the valves and solenoids as well as the clips and pins used to retain the parts in the valve body.

SUMMARY

1. Non-computerized hydraulically-controlled transmissions, until the mid to late 1980s used the hydraulic system components to determine when to shift. These components included:
   - A governor to detect vehicle speed.
   - A throttle cable and valve or a vacuum modulator to determine the load on the engine.
2. The vacuum modulator monitors engine vacuum by a rubber vacuum hose which is connected to the engine intake manifold. Engine vacuum reacts very accurately to engine load with high vacuum produced when the engine is under light load and diminishing down to zero vacuum when the engine is under a heavy load.
3. An accumulator is connected hydraulically to the clutch or band servo, and absorbs fluid during the pressure build-up stage when a clutch or band applies. This has the effect of slowing the pressure increase and lengthening the time it takes for the friction device to complete the shift.
4. A solenoid is a type of an electromagnetic switch that uses a movable core. In an automatic transmission, the movable core is used to control the flow of ATF through hydraulic circuits.
5. Solenoids used in electronically controlled automatic transmissions/transaxles are as follows:
   - These can be normally open (N.O.) to allow fluid flow or normally closed (N.C.) to block fluid flow.
   - Shift solenoids control the pressure force which in turn controls the position of the shift valve. They are commanded on or off by the PCM/TCM and include on-off, pulse-width modulated (PWM) as well as linear designs.
6. Electronic automatic transmissions/transaxle regulates hydraulic system pressure using computer-controlled solenoids called by any of the following names:
   - Pressure control solenoid (PCS)
   - Electronic pressure control (EPC)
   - Pressure control (PC)
   - Variable force solenoid (VFS)
   - Force motor

REVIEW QUESTIONS

1. What is used to measure vehicle speed in a hydraulically controlled automatic transmission?
2. What is used to measure engine load in a hydraulically controlled automatic transmission?
3. What is the difference between a nonsynchronous and an asynchronous transmission?
4. What is the purpose of an accumulator?
5. What is a pulse-width modulated solenoid?
6. What are the component names used that control mainline pressure in an electronically-controlled automatic transmission/transaxle?

CHAPTER QUIZ

1. On a hydraulically-controlled automatic transmission, what is used to measure vehicle speed?
   a. Governor
   b. Throttle valve (TV)
   c. Shift valve
   d. Pulse-width modulated solenoid
2. On a hydraulically-controlled automatic transmission, what is used to measure engine load?
   a. Governor
   b. Throttle valve (TV)
   c. Vacuum modulator
   d. Either b or c
3. Some transmissions are designed to apply a clutch or a band without having to release another one. This type of transmission is called _____.
   a. Nonsynchronous
   b. Asynchronous
   c. Synchronous
   d. Either a or b
4. A (An) _____ is connected hydraulically to the clutch or band servo, and absorbs fluid during the pressure build-up stage when a clutch or band applies.
   a. Orifice
   b. Accumulator
   c. Check valve
   d. Shift solenoid
5. Technician A said that pulse width modulated solenoids have a lower electrical resistance than a simple on-off-type solenoid. Technician B says that linear solenoids are pulse-width modulated. Which technician is correct?
   a. Technician A only
   b. Technician A only
   c. Both technicians A and B
   d. Neither technician A nor B
6. A linear solenoid _____.
   a. Is a type of on-off solenoid
   b. Is pulse-width modulated
   c. Uses a fixed duty cycle
   d. Operates using a variable frequency
7. A pressure control solenoid controls fluid pressure by using a _____.
   a. Fixed frequency
   b. Variable frequency
   c. Variable current flow
   d. Fixed voltage
8. Technician A says that a slide-bump shift can be caused by a defective throttle valve (TV). Technician B says that this type of shift can be caused by the accumulator piston bottoms out before the shift is complete. Which technician is correct?
   a. Technician A only
   b. Technician A only
   c. Both technicians A and B
   d. Neither technician A nor B
9. A duty cycle of 100% means _____.
   a. The solenoid is completely off
   b. The solenoid is fully energized on
   c. Can be either on or off depending on application
   d. The solenoid is not being controlled
10. Pulse-width modulated solenoids usually have _____.
    a. Low resistance
    b. High resistance
    c. Can have high or low resistance depending on application
    d. High resistance if normally open

chapter 5

TORQUE CONVERTERS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Identify and describe the components of a torque converter.
3. Explain torque converter operation.
4. Discuss the parts and operation of torque converter clutches.
5. Describe the purpose and procedure of a stall test.
6. Discuss the service of torque converters.

KEY TERMS

Coupling phase 57
Creep 57
Damper assembly 58
Flexplate 54
Impeller 54
Rotary flow 56
Stall speed 57
Stator 55
Torque converter clutch (TCC) 57
Torsional vibrations 58
Turbine 54
Vortex flow 56

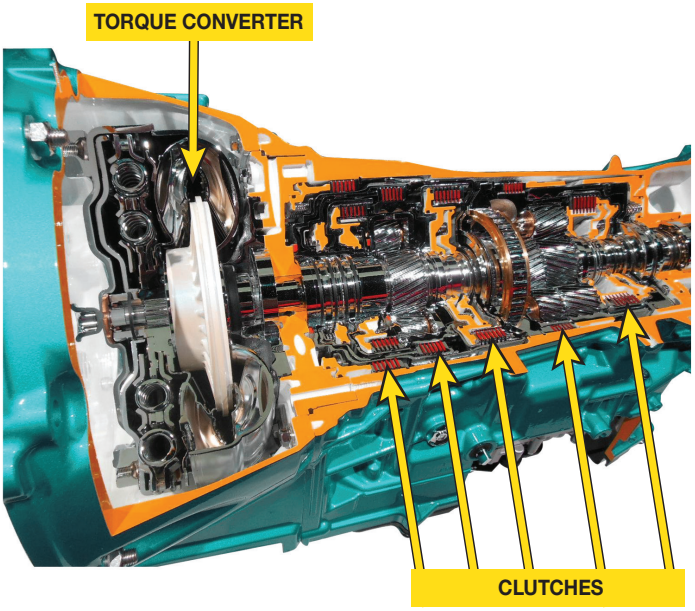


FIGURE 5–1 A cutaway of an eight speed automatic transmission showing the torque converter and the clutches needed to engage all eight forward speeds, plus reverse.

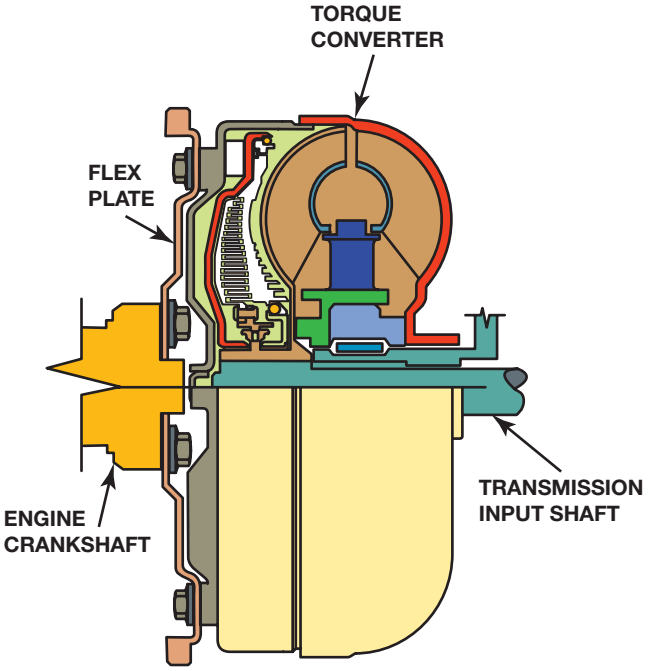


FIGURE 5–2 The torque converter bolts to the flexplate which is attached to the engine crankshaft and rotates at engine speed.

TORQUE CONVERTER TERMINOLOGY

PURPOSE AND FUNCTION The torque converter is located between the engine and the transmission/transaxle and performs the following functions.

1. Transmits and multiplies engine torque
2. Acts as a clutch between the engine and the transmission/transaxle
3. Allows slippage, which makes it possible for the transmission to be engaged even when the vehicle and wheels are stopped ● **SEE FIGURE 5–1.**

LOCATION The torque converter is bolted to a thin metal disc called a **flexplate**. The center of the flexplate often has a pilot indentation for the nose of the converter, and the flexplate itself is bolted to the rear flange of the engine crankshaft.

The flexplate replaces the heavy flywheel used with a manual transmission. An important function of a flywheel is to smooth out engine pulsations and dampen vibrations. An automatic transmission does not require a conventional flywheel because the weight of the torque converter provides enough mass to dampen engine vibrations. An external ring gear generally attaches to the outer rim of the flexplate, while on some applications the ring gear may be welded to the outside of the torque converter cover. This ring gear engages the starter motor pinion gear to turn the engine during starting. ● **SEE FIGURE 5–2.**

ELEMENTS The three major parts of the torque converter include:

- **Impeller.** The impeller is the driving member and rotates with the engine, and is located on the transmission side of the converter. When the engine is running, the flexplate and converter rotate with the crankshaft. The flexplate is flexible enough to allow the front of the converter to move forward or backward if the converter expands or contracts slightly from heat or pressure. The impeller inside the torque converter is also called the pump (not to be confused with the pump used to supply fluid under pressure to the entire transmission/transaxle). The impeller is the input to the converter. The vanes/fins inside the converter are attached to the rear of the impeller, transmission end, of the converter housing or cover. ● **SEE FIGURE 5–3.**
- **Turbine.** The turbine is located on the engine side of the converter. The impeller vanes pick up fluid in the converter housing and direct it toward the turbine. Fluid flow drives the turbine, and when the flow between the impeller and the turbine is adequate, the turbine rotates and turns the transmission input shaft. The turbine is the converter's output member. The center hub of the turbine is splined to the transmission input shaft. The turbine is positioned in the front, engine end, of the converter housing so the turbine vanes face the impeller vanes. ● **SEE FIGURE 5–4.**

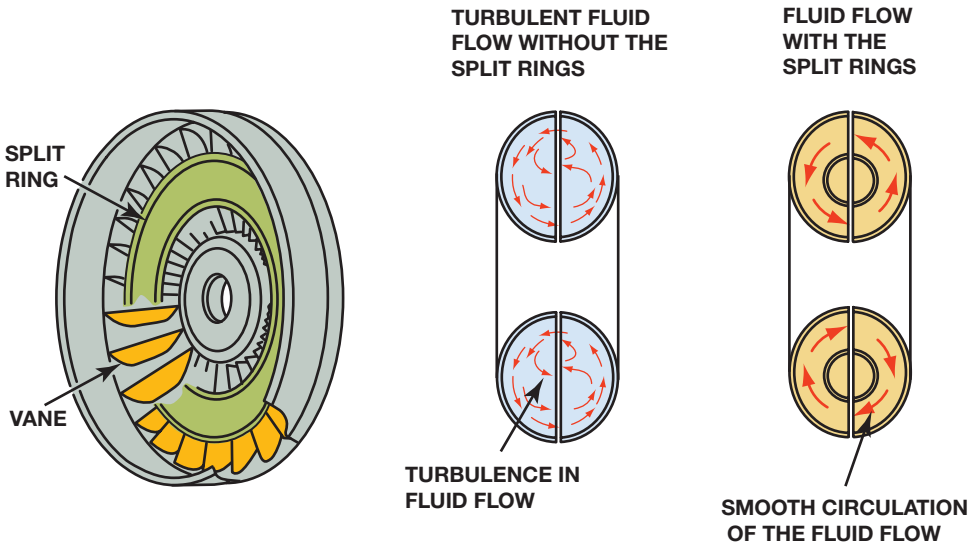


FIGURE 5–3 The split rings in the impeller and turbine help to direct the flow of fluid and improve the efficiency of the torque converter by reducing turbulence.

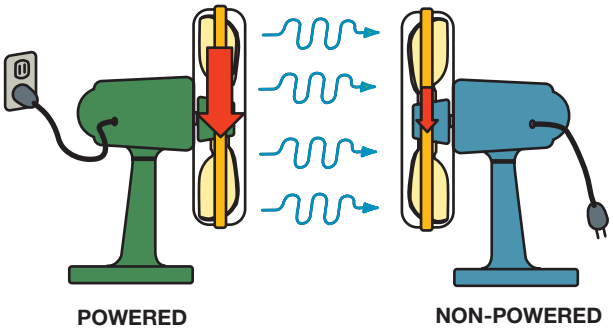


FIGURE 5–4 Two fans can be used to show how fluid, or air in the case of fans instead of automatic transmission fluid, can be used to transfer energy. If one fan is operating, which represents the impeller, the blades of a second fan (turbine) will be rotated by the flow of air past the fan that is unplugged, causing the blades to rotate.

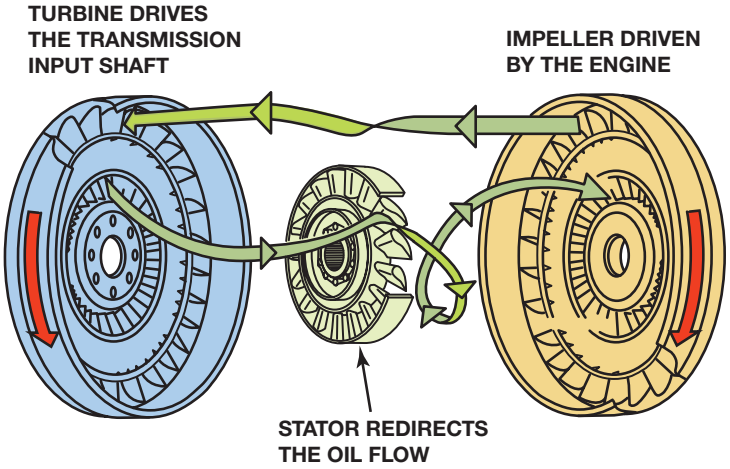


FIGURE 5–5 A torque converter is made from three parts: The impeller is located at the transmission end, attached to the housing, and is driven by the engine. The turbine is located at the engine side and is driven by the fluid flow from the impeller and drives the input shaft of the transmission. The stator redirects the flow to improve efficiency and multiply torque.

- **Stator.** A torque converter also contains the stator, or reactor, which is mounted on a one-way clutch. The stator is the reaction member of the torque converter. The stator assembly is about one-half the diameter of the impeller or turbine. The outer edge of the stator vanes forms the inner edge of the three-piece fluid guide ring that is also part of the impeller and turbine vanes. The stator is mounted on a one-way clutch that is attached to the stationary reaction shaft splines. The reaction shaft is made as part of the transmission front pump housing and is fixed and does not rotate. The one-way clutch allows the stator to rotate clockwise but blocks counterclockwise rotation. ● **SEE FIGURE 5–5.**

TORQUE CONVERTER OPERATION

TORQUE TRANSFER A torque converter is a *hydrodynamic* unit because it transfers power through the dynamic motion of the fluid. Most other hydraulic units transfer power through the static pressure of the fluid. When the engine is running, the converter impeller acts as a centrifugal pump. Fluid is thrown from the outer edge of the impeller vanes, and because of the curved shape of the converter cover, the fluid is thrown

FREQUENTLY ASKED QUESTION

What Is an Air-Cooled Torque Converter?

Some early torque converters used with smaller engines were air cooled. They had a shroud with fins attached to the rear of the converter cover, to force cooling airflow past the converter. Torque converters must be cooled because of the heat they generate during torque multiplication.

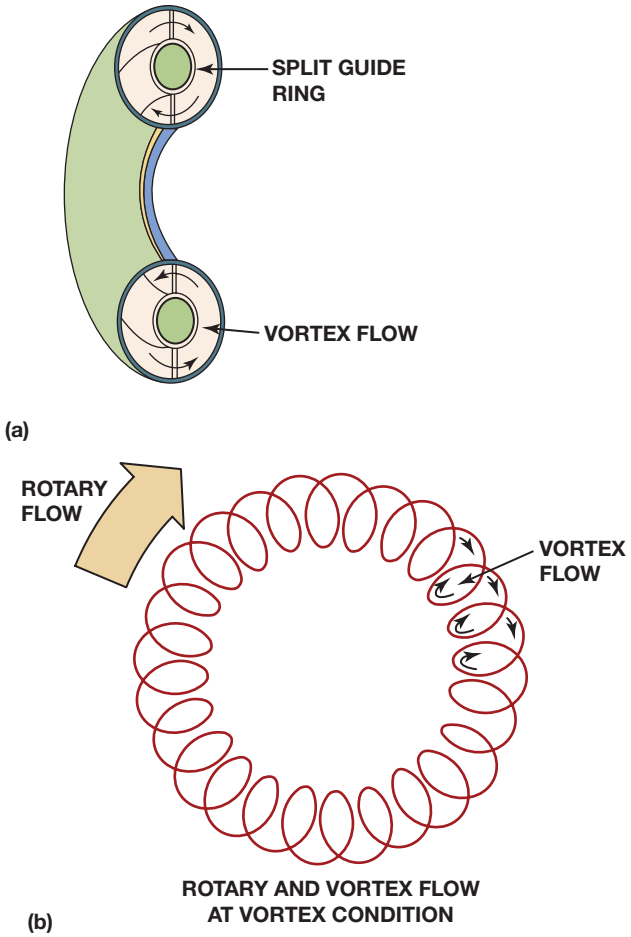


FIGURE 5–6 (a) The fluid flowing around the guide ring is called vortex flow. (b) The fluid flow around the converter is called rotary flow.

forward into the turbine. The impeller is turning in a clockwise direction, and the fluid also rotates in a clockwise direction as it leaves the impeller vanes. The mechanical power entering the converter is transformed in the fluid as fluid motion.

VORTEX FLOW The rotating fluid in the impeller tries to turn the turbine in a clockwise direction. If the turbine is stationary or turning at a speed substantially slower than the impeller, only part of the energy leaves the fluid to drive the turbine.

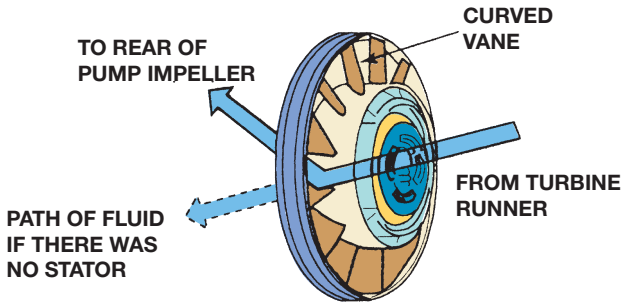


FIGURE 5–7 The fluid flow from the turbine is turned in the same direction as the impeller by the stator vanes.

Most of the fluid energy is lost as the fluid bounces off the turbine vanes. The fluid moves toward the center of the turbine, driven there by the continuous flow of fluid from the impeller. As energy leaves the fluid, the flow slows down and returns to the center of the impeller vanes, where the impeller will pick it up and keep it circulating. This flow is called a **vortex flow**. The vortex flow is a continuous circulation of fluid outward from the impeller, around the guide ring, inward into the turbine, through the stator, and back into the impeller. The guide ring directs the vortex flow, creating a smooth, turbulence-free flow. The clockwise flow of fluid leaving the impeller, in the direction of engine rotation, is called **rotary flow**.

When the impeller is rotating substantially faster than the turbine, the fluid tends to bounce off the turbine vanes and change the rotary flow to counterclockwise direction. The fluid flow still has quite a bit of energy. It can be compared with a tennis ball thrown against a wall. The ball bounces back and travels in a different direction, but it still has most of its energy of motion. A strong counterclockwise fluid flow from the turbine would tend to work against the clockwise rotation of the impeller. ● **SEE FIGURE 5–6.**

TORQUE MULTIPLICATION The stator redirects the fluid flow in the torque converter. It returns the fluid from the turbine back to the impeller in a clockwise direction. This action helps recover any energy remaining in the fluid. The curved shape of the stator vanes and a one-way clutch make this possible. Fluid leaving the turbine in a counterclockwise direction tries to turn the stator counterclockwise. This causes the stator one-way clutch to lock up and hold the stator stationary. The smooth, curved shape of the stator vanes redirects the fluid flow in a clockwise direction. ● **SEE FIGURE 5–7.**

Torque multiplication occurs because the stator redirects the fluid flow. This occurs only when the impeller is rotating faster than the turbine. As the turbine speed increases, the direction of flow becomes more rotary. The stator clutch overruns and the converter becomes more of a coupling, transferring power from the engine to the transmission. ● **SEE FIGURE 5–8.**

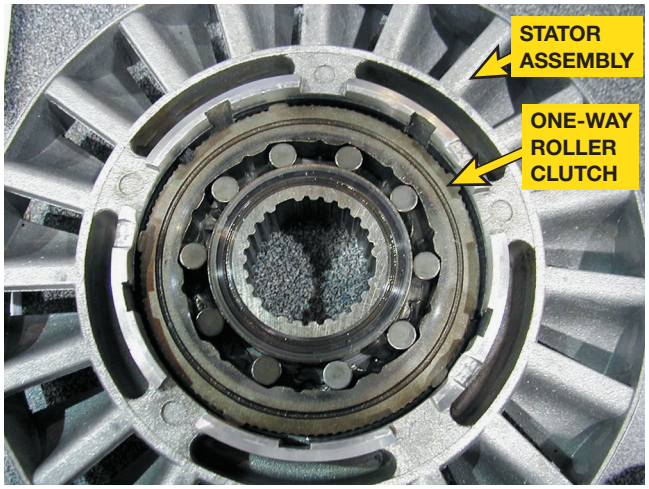


FIGURE 5–8 A stator contains a one-way roller clutch which locks it from rotating in one direction and allows it to rotate freely in the opposite direction.

An engineering term used for torque converters is the *stall torque ratio (STR),* which is the torque converter's ability to multiply torque. Most passenger vehicle torque converters have a STR between 1.68:1 and 2.1:1. For most converters, this means that the torque converter is able to double the torque of the engine at the stall speed of the converter.

COUPLING PHASE When the turbine speed reaches 90% to 95% of impeller speed, *coupling* occurs. The **coupling phase** occurs when the speeds of the impeller and turbine are nearly equal. Centrifugal force acting on the fluid in the spinning turbine is high enough to stop the vortex flow. At this point, there is no torque multiplication. It should be noted that this coupling speed is a relative point between the speeds of the impeller and turbine. Therefore, the coupling phase occurs at various vehicle speeds depending on throttle position and speed.

Some slippage occurs during the coupling phase. If power and load demands require, the converter can return to the torque multiplication phase. In a nonlock-up converter, the turbine almost never turns at the same speed as the engine and impeller, a condition commonly referred to as *converter slippage*. The converter's efficiency steadily improves during torque multiplication and the coupling phases to about 90% to 95%.

STALL SPEED **Stall speed** is the fastest RPM that an engine can reach while the turbine is held stationary. Stall is when the turbine is held stationary while the converter housing and impeller are spinning. This is done by shifting the transmission into gear and applying the brakes to hold the drive wheels stationary. The importance of stall speed is that an engine must be able to reach an RPM where enough torque is available to accelerate the vehicle, but not running so fast that there is poor fuel economy and excessive noise. Stall occurs to some degree each time a vehicle starts moving, either forward or backward, and each time a vehicle stops at a stop sign.

FREQUENTLY ASKED QUESTION

Did the ATX Transaxle Use a Different Torque Converter?

In some versions of the Ford ATX, a split-torque converter is used that has an internal planetary gear set. Here is how it works:

- The ring gear of the planetary gear set is connected to the front of the torque converter through a damper assembly so it will be driven at engine speed
- The input sun gear is connected to the turbine shaft
- The carrier is connected to the intermediate shaft
- The intermediate shaft (in transaxles using this torque converter) drives the intermediate clutch in the main gear assembly

This arrangement produces a partial mechanical input of 38% in second gear and 94% in third gear, which reduces torque converter slippage and improves operating efficiency and fuel mileage.

CREEP When the transmission selector is moved from park (P) or neutral (N) into a drive gear, some engine torque is transferred to the input shaft of the transmission or transaxle. The vehicle will move slightly if the brakes are released. This slight movement of the vehicle when the engine is at idle speed and the brakes are released, is called **creep**. Therefore, a slight movement is normal for a vehicle equipped with an automatic transmission.

NOTE: Vehicle creep is more noticeable when the engine is cold due to the higher idle speed.

TORQUE CONVERTER CLUTCHES

PURPOSE AND FUNCTION The **torque converter clutch (TCC)** is applied to eliminate the slippage during the coupling phase, which improves fuel economy. When the TCC applies, the converter locks up, connecting the transmission input shaft directly to the engine, much like a vehicle with a manual transmission and clutch.

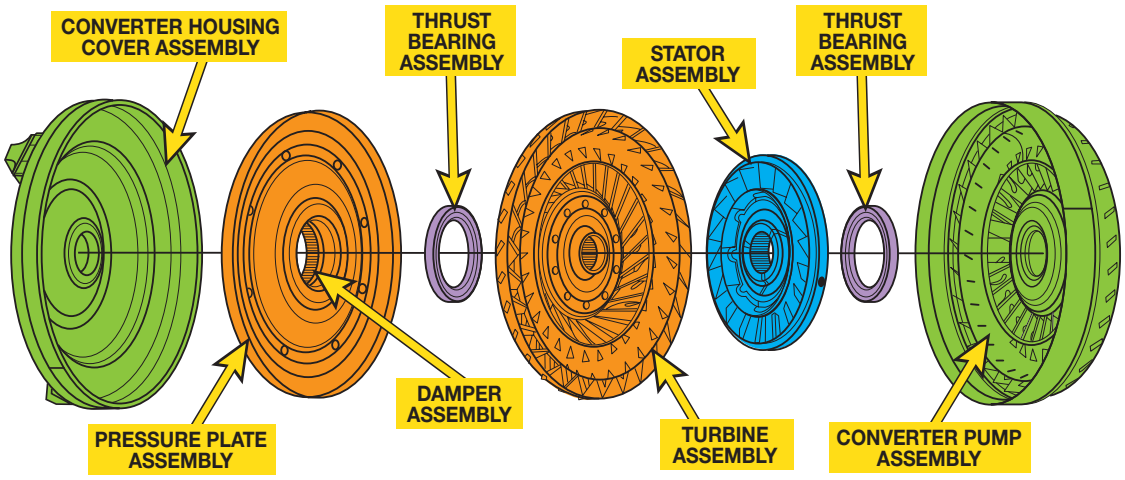


FIGURE 5–9 An expanded view of a typical torque converter assembly showing the torque converter clutch (TCC).

PARTS AND OPERATION

The converter clutch is a large clutch disc called a *pressure plate* or *clutch disc*. It has friction material and a damper assembly attached to it and it is splined to the turbine. When the friction material is forced against the torque converter cover, the turbine is driven mechanically by the engine. ● **SEE FIGURE 5–9.**

The torque converter clutch is controlled by a solenoid which is controlled by the powertrain control module (PCM) or the transmission control module (TCM). The TCC is applied and released when the fluid entering the converter changes from the rear or front.

- Normal torque converter action occurs when the TCC is released, and the fluid flows from the front to the rear, past the clutch plate.
- TCC lockup occurs when the fluid enters the rear of the torque converter and forces the clutch plate against the front cover.
- TCC apply forces the fluid in front of the clutch outward, and this fluid acts like an accumulator to soften clutch application.
- When fluid is flowing into the back (turbine) side of the torque converter, pressure is applied to the back side of the clutch piston, which forces it to come in contact with the torque converter cover. This locks the turbine to the cover and all the elements of the torque converter rotate as one unit.
- In order to release the TCC, the flow of fluid in the torque converter housing is reversed. This causes the clutch piston to move away from the torque converter cover and the turbine is released. ● **SEE FIGURE 5–10.**

TCC fluid flow is controlled by a TCC control valve that is in turn controlled by a solenoid. TCC apply blocks the flow of fluid through the torque converter and cooler. The torque converter does not generate heat when TCC is applied, but some heat is generated by the rest of the transmission. Some fluid will be directed past the TCC control valve to provide cool fluid for transmission lubrication.

FRICTION MATERIALS USED

Most TCCs use paper friction material. It can be secured to the front of the clutch disc, to the inside of the converter cover, or left free between the two. Some vehicles use a modulated or pulsed TCC apply pressure to smooth out TCC apply. This produces a lot of slipping that can wear out paper clutch lining fairly rapidly. These converters use synthetic materials for greater endurance under more severe operating conditions. ● **SEE FIGURE 5–11.**

TCC DAMPER ASSEMBLY

Clutch discs include a **damper assembly** that transfers the power through a group of coil springs. In most converters, the damper springs are grouped at the center; in others they are grouped around the outer edge. These springs are used to dampen **torsional vibrations** from the engine. All automotive engines produce torsional vibration at some operating speed. Torsional vibrations are small speed increases and slowdowns as the crankshaft revolves between engine cylinder firing pulses. These vibrations can produce gear noise in the transmission and drivetrain as well as a noticeable vibration and harshness in the vehicle. ● **SEE FIGURE 5–12.**

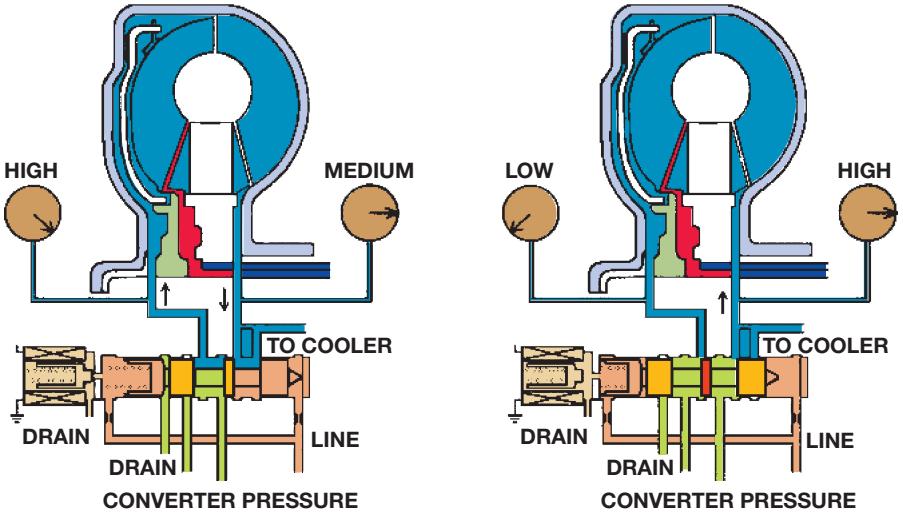


FIGURE 5–10 TCC releases fluid flows through the center of the turbine shaft to the front of the clutch disc (left). Pressure to apply the clutch enters between the converter hub and the stator support (right).

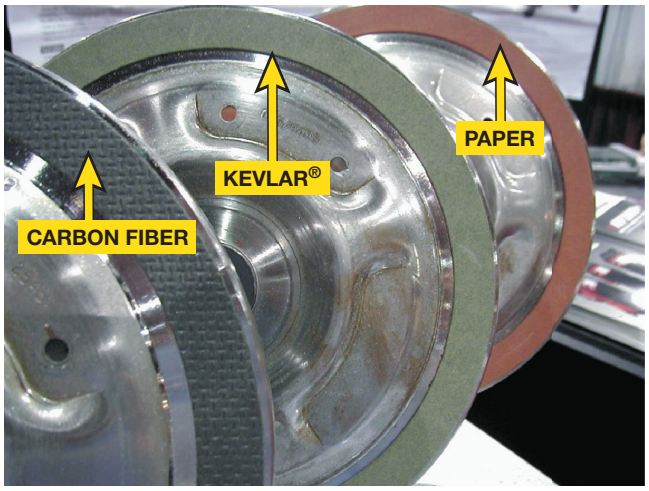


FIGURE 5–11 Torque converter clutch friction material is determined by the vehicle manufacturer to provide the needed coefficient of friction. For example, many older units use a paper-type friction material because they are fully applied or released, whereas most newer units use a synthetic material such as Kevlar® or carbon fiber because the torque converter clutch is pulsed on and off, therefore requiring a more robust material for long service life.

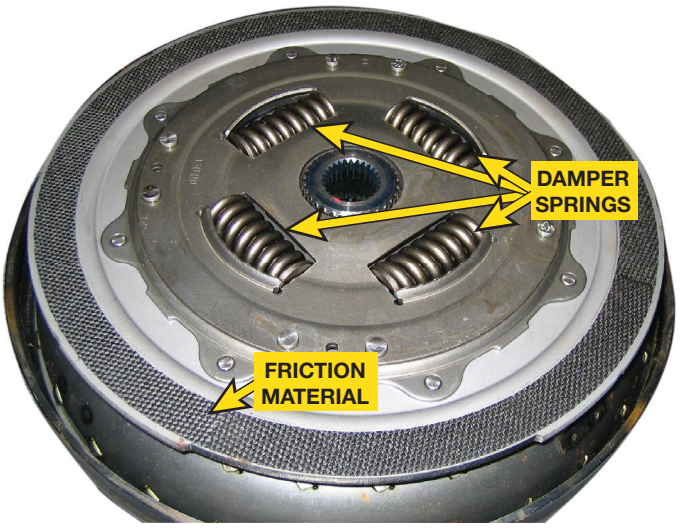


FIGURE 5–12 The damper springs used in many torque converter clutches are similar to the damper springs used in clutch discs used with a manual transmission.

STALL TEST

PURPOSE OF THE TEST A stall test is used to check the stator one-way clutch inside the torque converter and the strength of the apply devices inside the transmission/transaxle. A stall test measures stall speed of the torque converter in each of the gear positions. It is an important diagnostic test to determine transmission and torque converter condition. This test should be performed with caution because it operates the vehicle in a potentially dangerous situation: The vehicle is in gear with the throttle wide open. It is recommended that both the parking brake and the service brake be firmly applied, the wheels blocked, and the throttle be held open for a maximum of 5 seconds.

A stall test can severely damage the transmission if done incorrectly. During a stall test, the dynamic fluid pressure inside a converter becomes very high, because there is a lot of turbulence. Fluid temperature also becomes very high. All of the power the engine is producing is going into the converter, and no mechanical power is being delivered to the transmission. The natural law of energy conservation states that energy can neither be created nor destroyed. The energy going into

FREQUENTLY ASKED QUESTION

What Is a "Squashed Converter"?

The cross-sectional area of the impeller, turbine, and stator of most torque converters is round to give an efficient flow. The converter used with many newer transaxles has an elliptical cross-sectional shape that reduces the width of the converter. A shorter, low-profile converter, often called a *squashed converter*, makes the engine and transaxle shorter and easier to fit transversely in a vehicle. ● **SEE FIGURE 5–13.**

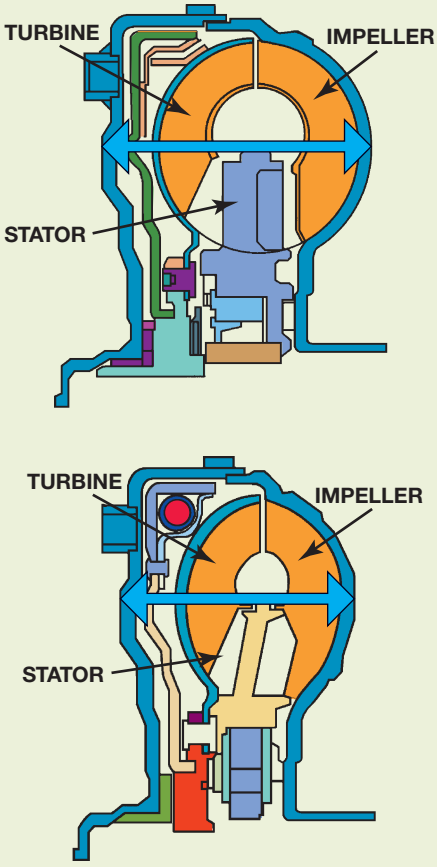


FIGURE 5–13 Most torque converters have a round cross section (top). Some new transmissions use a shorter, elliptical, squashed converter (bottom) that is about 13% shorter than a round style.

the converter must go somewhere and it is converted to heat. Because so much heat is generated, stall tests should not be conducted for more than 5 seconds, followed by a cooling period.

CAUTION: Exercise caution when performing a stall test for several reasons: personal safety, and the chance of possible damage to the vehicle and transmission.

FIGURE 5–14 This 4-cylinder General Motors vehicle has a stall speed of about 2350 RPM. Notice that the gear selector is in drive and the speedometer is reading zero.

STALL TEST PROCEDURE

To conduct a stall test, perform the following steps:

STEP 1 Connect a scan tool to monitor engine speed (RPM).

STEP 2 Position the vehicle with all four wheels firmly on the ground and place blocks at the front and back of the drive wheels.

STEP 3 Start the engine and note the RPM reading. ● **SEE FIGURE 5–14.**

STEP 4 Apply the brakes firmly, move the gear selector to reverse, move the throttle to wide open, and watch the tachometer. The speed should increase to somewhere between 1500 and 3000 RPM. As soon as the speed stops increasing or goes higher than 3500 RPM, quickly note the reading and close the throttle. Record the speed.

STEP 5 Shift to neutral, and run the engine at fast idle for 30 to 60 seconds to cool the converter.

STEP 6 Repeat steps 4 and 5 with the gear selector in drive.

STEP 7 Repeat steps 4 and 5 with the gear selector in low.

WARNING

Direct any bystanders away from the front or rear of the vehicle.

INTERPRETING STALL TEST READINGS

- **If all of the stall speeds were within the specification range.** The apply devices for the three gear ranges are all sound and in good shape. The apply devices for some gear(s) cannot be applied with the vehicle at rest so they cannot be stall tested.
- **If all of the stall speeds were equal but low.** The engine is weak, out of tune, or the stator one-way clutch is slipping. Checking engine performance should indicate which is at fault.

FREQUENTLY ASKED QUESTION

What Is a High-Stall Speed Converter?

A high-stall speed converter is called a *loose converter*. A low-stall speed converter is called a *tight converter*. When a vehicle is standing still, the turbine is not rotating. As the vehicle accelerates, the engine RPM increases quickly to the torque capacity of the converter (stall speed) and then it stabilizes. As the turbine speed increases, the engine speed also increases. A loose converter allows a higher engine RPM relative to the turbine RPM.

The actual stall speed of a torque converter is determined by the following factors.

- Amount of engine torque
- Diameter of the converter
- Angle of the impeller vanes
- Angle of the stator vanes

A high-torque engine has the ability to turn the impeller faster against a stalled turbine than a small or weak engine. A low-torque engine is normally equipped with a looser converter.

- If the converter is too tight, the engine RPM cannot increase to the point of usable power and the vehicle would lose acceleration and overall performance.
- A converter that is too loose will cause the engine to operate at excessive speed. The result will be poor fuel economy, excessive noise, and reduced performance because of the excessive slippage.

In production, the torque converter capacity/stall speed is matched to the engine size and vehicle weight to produce the best vehicle performance and fuel economy. Depending on the engine, different converters are used with a transmission model. One manufacturer uses eight different converters with one transmission model. The technician must ensure that the correct replacement converter is used.

- **If the stall speeds are normal, but the vehicle has normal acceleration and has reduced performance at higher speeds.** The stator one-way clutch could be seized in a locked-up condition.
- **If the stall speed is high in one or two of the gear ranges.** One or more of the apply devices is slipping. Consult a clutch and band application chart to determine which apply devices are at fault.

TORQUE CONVERTER SERVICE

REPLACEMENT A torque converter is considered to be part of the transmission and should be serviced or replaced when a transmission is overhauled. A torque converter is always replaced with a new or rebuilt unit if it has an internal failure. Most shops do not rebuild torque converters. There are companies that specialize in torque converter overhaul.

Torque converters tend to collect the metal, dirt, and other debris that enter with the fluid. It is impossible to thoroughly check a torque converter without cutting it open. The internal shape and the centrifugal force inside a torque converter can pack dirt and debris around the outer diameter. Foreign material can also lodge in the clutch lining of a lock-up torque converter. Some shops flush and check the torque converter during every transmission overhaul. Other shops install a rebuilt torque converter as standard practice. High-mileage transmissions, ones that show a lot of metal wear, and units with lock-up torque converters are candidates for replacement.

TORQUE CONVERTER CHECKS The torque converter should be checked to make sure it is in usable condition when the transmission is removed. These checks include:

1. **Visual inspection.** It includes the following steps:
   - Check the outer side (especially at the welds) for wetness, which might indicate a leak.
   - Check the mounting drive studs or threaded holes and lugs for physical damage.
   - Check the pilot area for damage.
   - Check the hub for signs of seal or bushing area wear.
   - Check the pump drive tangs or lugs for wear or damage. **SEE FIGURE 5–15.**
   - Check the starter ring gear, if used, for wear or damage.
2. **Stator one-way clutch operation.** It includes the following steps:
   - Place the converter flat on a bench.
   - Reach into the hub so one finger contacts the splines. **SEE FIGURE 5–16.**
   - Rotate the splines in a clockwise direction. If they rotate, the clutch is probably locked.
   - Try to rotate the splines counterclockwise. If they rotate, the clutch is slipping.

FIGURE 5–15 Visually check the pump drive notches or tangs for damage and the hub sealing surface for wear.

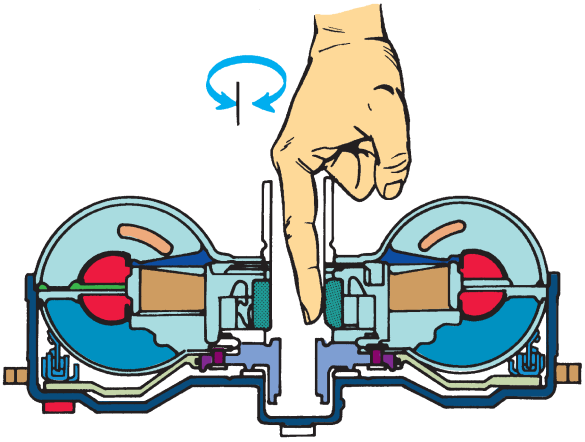


FIGURE 5–16 A stator clutch can be checked by reaching into the hub so a finger contacts the splines. The splines should rotate in one direction but not in the other.

NOTE: A commercial stator-holding tool may be used to check a one-way clutch. This tool can be inserted into a groove in the thrust washer on some stators to keep it and the stator from rotating. Next, a special one-way clutch-tool is inserted into the stator splines, and a torque wrench is used to apply torque to the tool and one-way clutch inner race. The one-way clutch should turn freely in a clockwise direction, and it should lock and hold at least 10 foot pounds (14 N-m) of torque in a counterclockwise direction. Do not apply any more torque than this because the special tool can break. A torque converter with a faulty one-way clutch must be replaced.

3. **Turbine end play.** End play is normally measured using a dial indicator. Two styles of dial indicator fixtures are commonly used to measure end play.

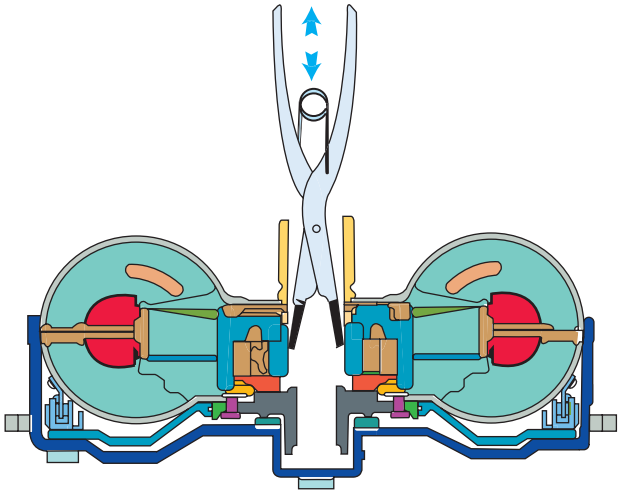


FIGURE 5–17 A quick end-play check can be made by gripping the turbine or stator splines and trying to move the turbine or stator in and out.

- One fixture uses an expandable stem that fits into the turbine splines and is expanded to lock into the splines. The dial indicator is positioned and adjusted so the measuring stylus is against the fixture and the dial reads zero. The fixture and turbine are lifted as far as they will go. The travel (end play) is read on the dial indicator.
- Another fixture for checking end play is designed so the torque converter sits on top of it. The measuring stem is moved upward to contact the turbine splines, and the dial indicator is adjusted to zero. Then the turbine is lifted as far as possible. The end play is read on the dial indicator.

The end-play can be felt as the turbine or stator is lifted and then lowered. Some manufacturers publish torque converter end-play specifications. If no specifications are available, use the rule of thumb that 0.030 inch (0.8 mm) is normal and 0.050 inch (1.3 mm) is the maximum allowable end play. A torque converter with excess end play (more than 0.050 inch) should be rebuilt or replaced. ● **SEE FIGURE 5–17.**

4. **Internal interference.** Torque converter interference should be checked twice, first with the turbine and stator toward the front and a second time with these toward the rear. To check a converter for internal interference, perform the following steps:
   - Set the torque converter on a bench with the hub up. Gravity will move the turbine and stator toward the front of the torque converter.
   - Insert the transmission pump stator support into the torque converter so the support splines engage the stator clutch splines.
   - Insert the transmission input shaft into the torque converter so its splines enter the turbine splines.

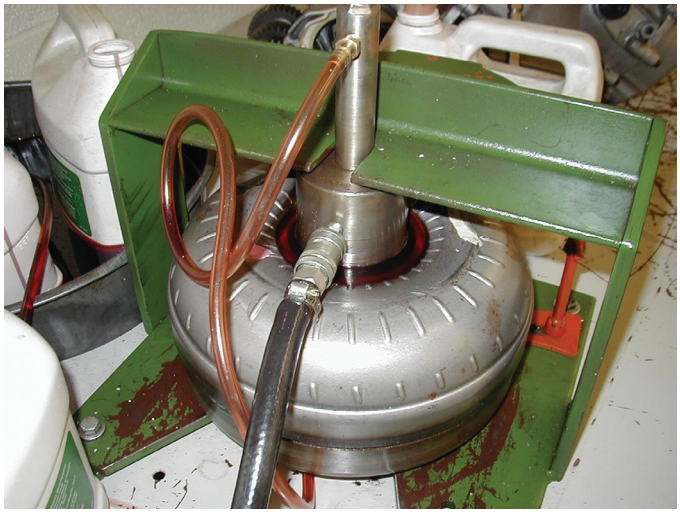


FIGURE 5–18 A leak-test fixture has been placed on the torque converter. It will be filled with ATF and then inspected for leaks.

- Rotate the pump and input shaft in both clockwise and counterclockwise directions, one at a time and together. If there is any sign of contact or rubbing, either a rubbing or grating sound or rough feel, the torque converter needs to be replaced.
- Turn the whole assembly over so the turbine and stator move toward the rear of the torque converter.
- Repeat step 4. Again, any sign of internal contact indicates a torque converter that should be rebuilt or replaced.

5. **Lock-up clutch operation.** Two styles of testers are available for checking torque converter clutches.
   - One type uses adapters that replace the turbine shaft and allow a vacuum to be exerted on the front side of the clutch plate assembly. If this chamber can hold a vacuum, the center seal and the clutch lining (which forms the outer seal) are good.
   - The second tester style uses adapters that attach to the turbine, using air pressure to apply the clutch. With the clutch applied, torque is exerted to try to turn the turbine. A good torque converter clutch locks the turbine and prevents it from turning.
6. **External leakage.** The torque converter must be pressurized to test for a leak. A special tool with an expandable plug that fits into the hub and a device to keep the plug in place is used. The plug is equipped with an air chuck to allow pressure to be added. ● **SEE FIGURE 5–18.**

A torque converter that passes inspection is reusable. One that fails one or more of the checks should be replaced with a new or rebuilt unit. A torque converter that has turned blue from overheating has failed internally and should be replaced.

Case Study

The Case of the Blue Torque Converter

An Acura (85,000 mi) runs good in park and neutral, but the engine dies as soon as it is shifted into gear. Tests reveal no problems outside of the transaxle.

When the transaxle was removed, the torque converter was found to be blue from overheating and seized up internally. It had also sent metal particles throughout the transaxle. The root cause of the problem was never discovered but rebuilding the transaxle along with a replacement torque converter fixed this transaxle.

SUMMARY:

Complaint—Vehicle owner complained that engine would die as soon as it was shifted into gear.

Cause—Root cause is unknown but an internal transaxle failure had occurred.

Correction—A new torque and rebuilding the transaxle fixed the customer concern.

TECH TIP

Converter Drain-Back Test

If the fluid leaves the torque converter when the engine is off, the vehicle will not move when the engine is restarted until the torque converter is refilled by the pump, which causes a delay. If torque converter drain back is suspected, operate the vehicle until it is at normal operating temperature, and drive the vehicle through several full-shift cycles. Check and adjust the fluid level if it is low, and shut off the engine. Allow the vehicle to sit for 30 to 60 minutes, then recheck the fluid level and mark it on the dipstick. Allow the vehicle to sit for 24 hours and then recheck the fluid level. If the level has risen by 1 inch (25 mm) or more, converter drain back has occurred. This means that the sealing rings around the torque converter are not able to seal properly and this means that the transmission or transaxle has to be removed to correct this condition.

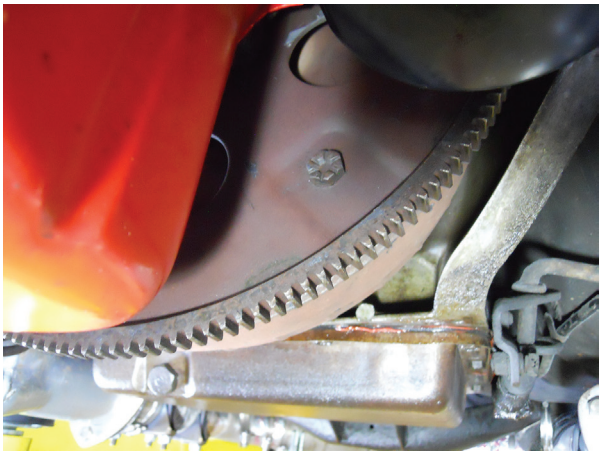
NOTE: All torque converters are balanced but a service technician is not able to verify that it is balanced. To avoid possible balance issues, purchase torque converters from a known company that checks the balance of all converters before they are packaged and sent out for sale.

INSTALLING A HIGHER STALL SPEED TORQUE CONVERTER

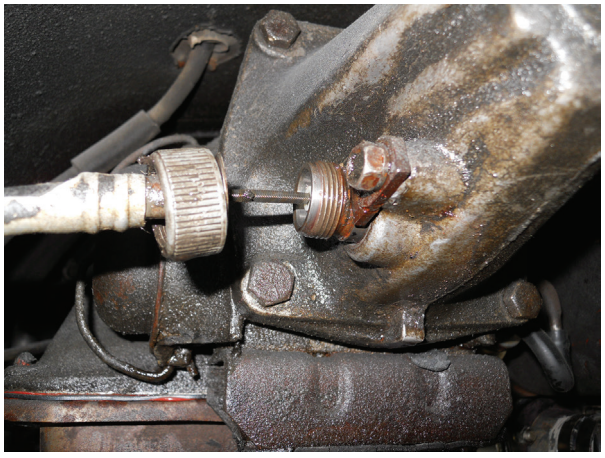
1 A restored 1971 Chevrolet Camaro has an aftermarket high-lift camshaft and does not idle correctly in drive with the stock torque converter.

2 The stall speed of the stock torque converter was tested at 1850 RPM, which is normal for a stock engine but not for an engine equipped with a high-performance camshaft.

3 The inspection cover is removed.



4 The torque converter retaining bolts are removed requiring the engine be rotated using a flywheel turning tool.



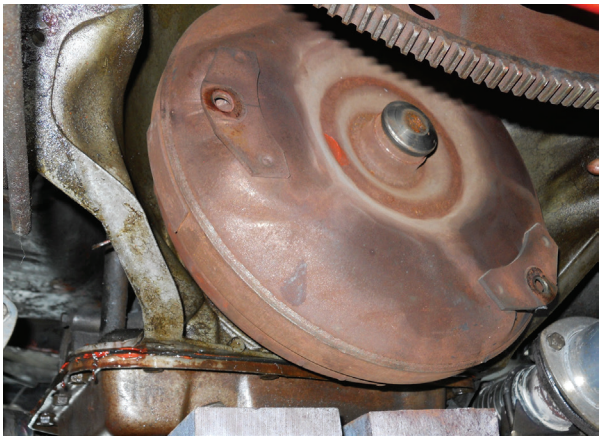
5 The speedometer cable was removed.

6 The vacuum hose to the modulator valve was removed.

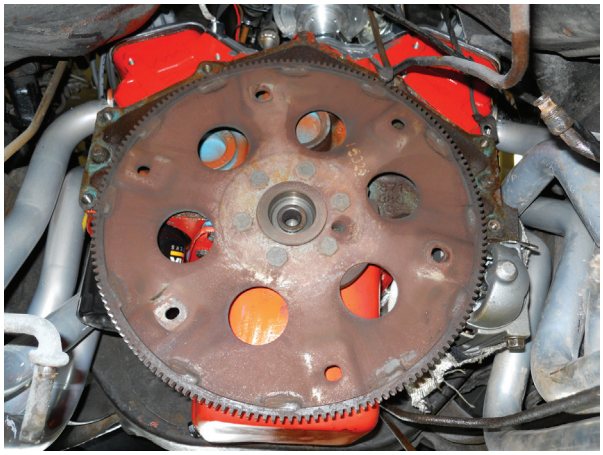
7 The cooling lines and the dip stick tube are removed.

8 After removing the driveshaft, the cross member was unbolted and removed after supporting the transmission using a transmission jack.

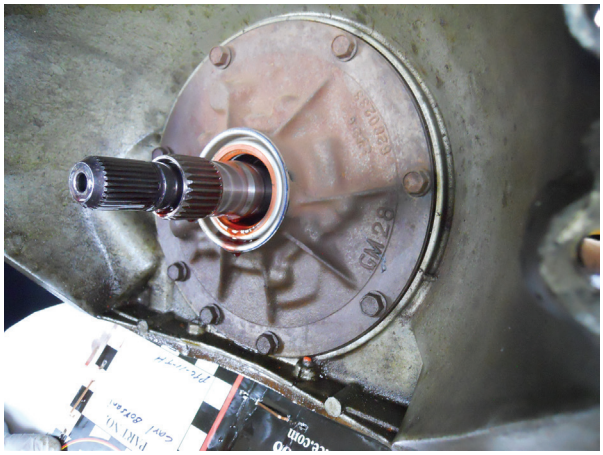
9 The bell housing bolts were removed using a long extension and a swivel socket.



10 The transmission is removed from the engine with the torque converter still in place.



11 The flexplate was inspected for cracks or worn ring gear teeth and found to be normal.



12 The torque converter was removed and the front seal was found to be leaking. All seals were replaced on this transmission before it was returned to the customer.

CONTINUED ▶

13 The new replacement higher stall speed converter is on the left, which is noticeably smaller in diameter than the stock converter.

14 The new torque converter is filled with ATF before being installed.

15 The torque converter is wiggled back and forth to ensure that all of the splines are engaged.

16 The holes in the flexplate were enlarged so that the new larger torque converter bolts would fit.

17 The transmission was installed and all parts reconnected, then the transmission was filled to the proper level with the specified ATF.

18 The stall speed was retested and the new converter is 2350 RPM, which worked well for this engine. The customer was very happy with the results.

SUMMARY

1. The torque converter is located between the engine and the transmission/transaxle and performs the following functions:
   - **a.** Transmits and multiplies engine torque
   - **b.** Acts as a clutch between the engine and the transmission/transaxle
   - **c.** Allows slippage, which makes it possible for the transmission to be engaged in gear even when the vehicle and wheels are stopped
2. The three major parts of the torque converter are the turbine, impeller, and stator.
3. A torque converter is a hydrodynamic unit because it transfers power through the dynamic motion of the fluid.
4. The flow of fluid inside a torque converter is both rotary and vortex flow.
5. When the turbine speed reaches 90% to 95% of impeller speed, coupling occurs.
6. Stall speed is the fastest RPM that an engine can reach while the turbine is held stationary.
7. The torque converter clutch is applied to eliminate slippage, thereby improving fuel economy.
8. A stall test is used to check the stator one-way clutch and the strength of the apply devices inside the transmission/transaxle.
9. A torque converter is considered to be part of the transmission and should be serviced or replaced when a transmission is overhauled.

REVIEW QUESTIONS

1. What are the three elements inside a torque converter?
2. What is the difference between rotary flow and vortex flow?
3. What is the purpose and function of a torque converter?
4. How much torque is a torque converter able to multiply?
5. What precautions are needed to be adhered to when performing a stall test?

CHAPTER QUIZ

1. The parts of a torque converter include _____.
   - **a.** Flexplate, housing, and turbine
   - **b.** Turbine, impeller, and stator
   - **c.** Impeller, flexplate, and housing
   - **d.** Stator, turbine, and housing
2. When the impeller and turbine are rotating at about the same speed, this is called _____.
   - **a.** Coupling
   - **b.** Stall speed
   - **c.** Torque multiplication
   - **d.** Vortex flow
3. Creep _____.
   - **a.** Is normal operation
   - **b.** Is caused by slippage inside the torque converter
   - **c.** Causes the vehicle to move slightly when the engine is at idle speed and the transmission is in drive gear
   - **d.** All of the above
4. A stall test is used to check the _____.
   - **a.** Stator
   - **b.** Impeller
   - **c.** Turbine
   - **d.** Torque converter clutch
5. A modified engine may need a torque converter that is _____.
   - **a.** Looser
   - **b.** Smaller in diameter
   - **c.** Has a higher stall speed
   - **d.** All of the above
6. The torque converter clutch circuit is controlled by the _____.
   - **a.** Driver
   - **b.** Fluid temperature
   - **c.** Command from the PCM/TCM
   - **d.** Fluid pressure

7. A torque converter should be checked by a technician for all of the following *except* _____.
   a. Leaks
   b. Proper balance
   c. Stator one-way clutch operation
   d. Turbine end play
8. If the stall speed is lower than specified, what could be the cause?
   a. Incorrect ATF was used in the automatic transmission/transaxle
   b. A slipping stator clutch
   c. Defective turbine
   d. Slipping torque converter clutch
9. A torque converter can multiply engine torque at the stall speed by about _____.
   a. Double
   b. Three times
   c. 10 times
   d. 100 times
10. A vehicle creeps faster than normal when the engine is cold. What is the most likely cause?
   a. Normal operation
   b. A TCC stuck in the applied position
   c. A defective stator one-way clutch
   d. Incorrect ATF

chapter 6

POWER FLOW THROUGH TRANSMISSION GEAR SETS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Explain how power can be transferred through planetary gear sets to produce the various ratios.
3. Discuss the Simpson gear set and identify the different types of Simpson gear trains.
4. Discuss the Ravigneaux gear set.
5. Explain the operation of the LePelletier gear train.

KEY TERMS

High-reverse clutch 78
LePelletier gear train 71
Nonsynchronous 76
Planet carrier 70
Ravigneaux gear set 71
Ring gear 70
Simpson gear train 71
Sun gear 70
Synchronous 76

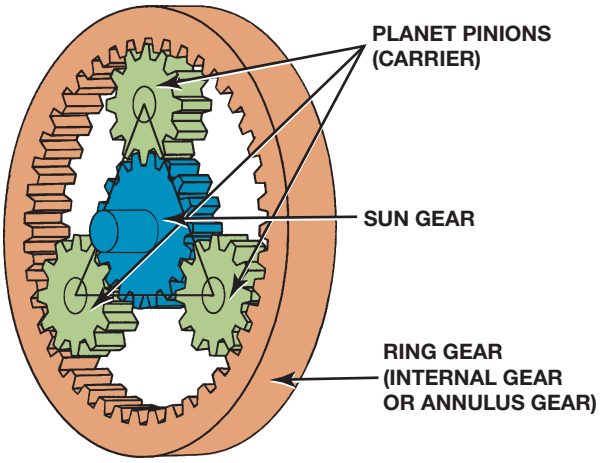


FIGURE 6–1 A typical planetary gear set showing the terms that are used to describe each member.

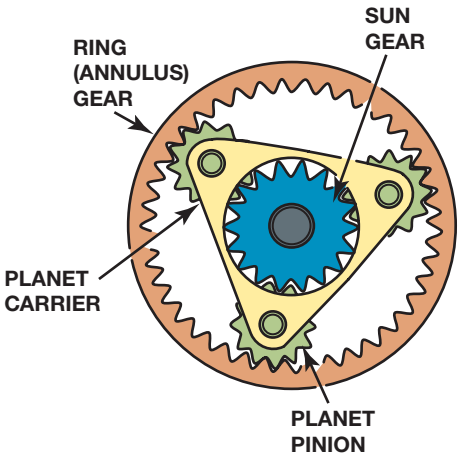


FIGURE 6–2 A typical planetary gear set showing the planet carrier which supports all of the pinion gears (also called planet pinion gears).

PLANETARY GEAR SETS

RATIOS Planetary gear sets are able to provide the following conditions:

- Neutral
- One or more gear reductions
- Direct-drive ratio (1:1)
- Reverse
- Overdrive

The exact ratio for reduction and overdrive are achieved by varying the number of teeth on the sun and ring gears.

SIMPLE PLANETARY GEAR SET A simple planetary gear set consists of three primary components.

- Sun gear
- Planet carrier (including planet pinion gears)
- Ring (annulus) gear

The **sun gear** gets its name from its position at the center of the gear set. The **planet carrier** holds the pinion gears, also known as planet gears, which revolve around the sun gear. The planet carrier assembly is commonly referred to simply as "the carrier." The outermost member of the gear set is the **ring gear**, an internal gear with teeth on the inside. The ring gear is sometimes called an annulus or internal gear. The pinion gears are in constant mesh with both the sun gear and the ring gear. ● **SEE FIGURE 6–1.**

The pinion gears are free to rotate on pins that are part of the carrier, and the entire assembly rotates to direct torque flow. Most transmission gear sets use three, four, or even five planet pinions. The pinions are fully meshed with both the sun gear and internal ring gear *at all times.*

The planetary gears never disengage to change gear ratios but torque is redirected. Both input and output torque flow through a planetary gear set occurs along a single axis.

PLANETARY GEAR SET TORQUE FLOW In a planetary gear set, the following operations are executed in order to achieve the various gear ratios and reverse.

- One of the members is being driven (input).
- One of the members is being held (reaction member).
- One of the members is the output.

Therefore, driving one element will cause all of the other gears to rotate as well. This allows the gear set to provide different gear ratios, depending upon how torque is transmitted through the assembly. ● **SEE FIGURE 6–2.**

Each member of a planetary gear set can play any one of these three roles (drive, held, or driven) to transmit torque. The various combinations of drive, held, and driven members result in the number of gear ratios available and change the direction of rotation as well for reverse.

NOTE: The held member can also be allowed to move in one direction or another as it is being held and does not necessarily need to be held to zero RPM to create a variable gear ratio. This is done in hybrid electric vehicle transmissions.

NEUTRAL, FORWARD, OR REVERSE	REDUCTION, OVERDRIVE, OR DIRECT DRIVE	PLANETARY GEAR ACTION
Neutral		When there is no driving member or reaction member, neutral results.
Forward	Direct drive, 1:1	When there are two driving members, direct drive occurs.
Forward	Reduction	When the carrier is the output, a forward reduction occurs.
Forward	Overdrive	When the carrier is the input, an overdrive occurs.
Reverse	Reduction or OD	When the carrier is the reaction member, a reverse occurs.
F or R	OD	When the sun gear is the output, an overdrive occurs.
F or R	Reduction	When the sun gear is the input, a reduction occurs.
Reverse	Reduction or OD	When one external gear drives another, reverse rotation occurs.
Forward	Any	When an external gear drives an internal gear or vice versa, same-direction rotation occurs.

CHART 6–1

Planetary gear set fundamentals.

Torque flows through a planetary gear set in several steps to get from the drive action of the first member to the driven action of the last member.

- The terms "*drive*" and "*driven*" describe how any two gears work together.
- When three or more gears are involved, the second gear is a *driven* gear in relation to the first, but it becomes a *drive* gear in relation to the third gear. ● **SEE CHART 6–1 AND FIGURE 6–3.**

? **FREQUENTLY ASKED QUESTION**

Which Companies Build Automatic Transmissions?

Many larger automobile manufacturers make their own automatic transmissions, including General Motors, Ford, Chrysler, and Honda. However, several companies manufacture automatic transmissions and transaxles that are used in a variety of vehicles. These include:

- **ZF Friedrichshafen AG.** This German company manufactures manual and automatic transmissions and transaxles for many vehicle manufacturers, including Mercedes, BMW, Volvo, VW, Audi, Jaguar, Chrysler, Bentley, and Maserati.
- **Aisin AW.** This Japanese company makes automatic transmissions for many vehicle manufacturers, including Ford, Toyota, Nissan, Mazda, Mitsubishi, Subaru, Kia, and VW.
- **JATCO (Japan Automatic Transmission Company).** This is a Japanese manufacturer of automatic transmissions and transaxles for many vehicle manufacturers, including Nissan, Mazda, Infiniti, VW, Mitsubishi, and Suzuki.

COMPOUND GEAR SETS

There are several different designs of planetary gear sets. The most popular compound planetary design is the **Simpson gear set.** This gear set was named for its inventor, Howard Woodworth Simpson (1892–1963), who was an American automotive engineer. ● **SEE FIGURE 6–4.**

- **Simpson gear set.** Combines one sun gear with two carriers with planet gears and two ring gears. A simple planetary gear set and a Simpson gear set can be combined to provide four- and five-speed transmissions.
- **Ravigneaux gear set.** Combines one carrier that has two sets of planet gears with two sun gears, and one ring gear. ● **SEE FIGURE 6–5.**
- **LePelletier gear set.** A Ravigneaux gear set and a simple planetary gear set can be combined to get six, seven, and eight speeds and is known as the **LePelletier gear set** (pronounced "la-plet-e-ay").

CALCULATING GEAR RATIOS

A simple planetary gear set can produce seven different gear ratios, plus neutral. The gear ratio is changed by changing the input (driving) and the

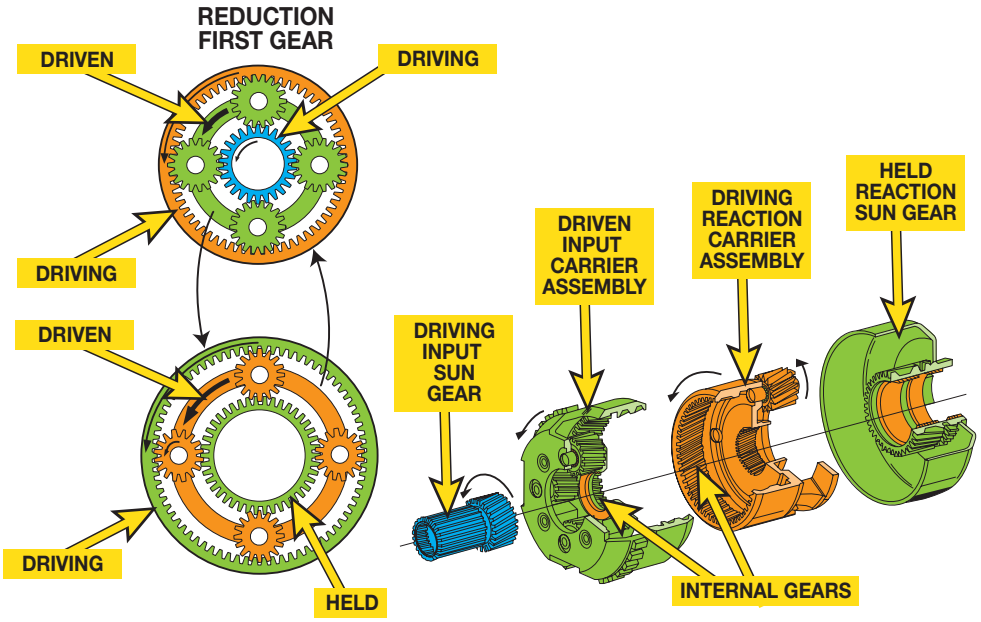


FIGURE 6–3 A typical planetary gear set showing the components and the action/reaction that occurs.

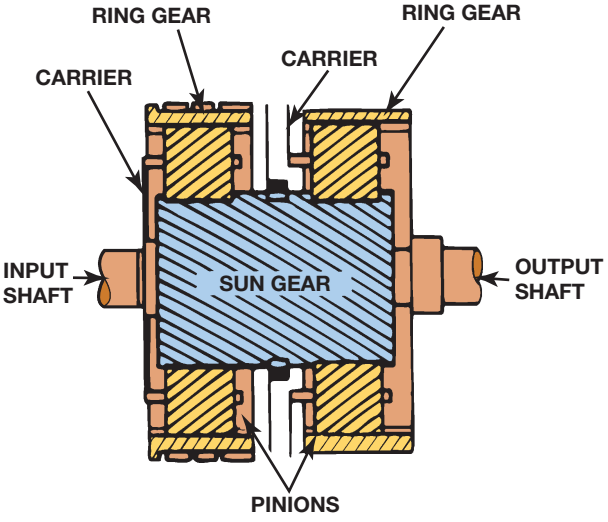


FIGURE 6–4 A Simpson planet gear set is composed of two ring gears and two planet carrier assemblies that share one sun gear.

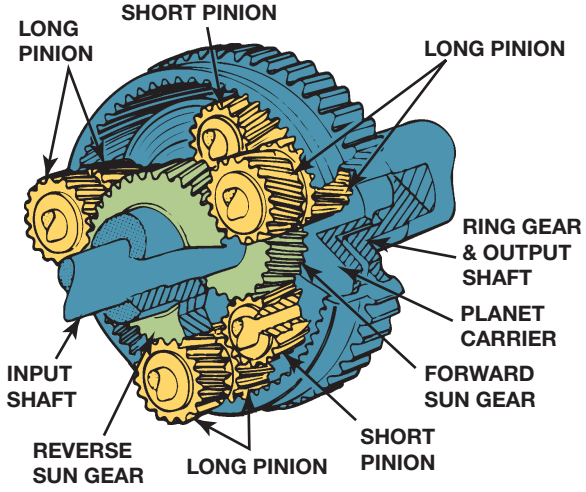


FIGURE 6–5 A Ravigneaux gear set is composed of two sun gears, one planet carrier that supports two sets of pinion gears, and a single ring gear.

reaction (held) members. The various conditions that can be achieved are as follows:

A. If the ring gear is held and the sun gear is driven, the planet gears are forced to rotate as they move around inside the ring gear. The result is an increase in torque and a decrease in speed. The formula for calculating the gear ratio is (sun + ring) ÷ sun.

B. If the ring gear is held and the carrier is driven, the planet gears are forced to rotate as they move around inside the ring gear. This is the reciprocal, or inverse (opposite), of A. The opposite of a reduction ratio is an overdrive ratio. The formula for calculating the gear ratio is sun ÷ (sun + ring).

C. If the sun gear is held in reaction and the ring gear is driven, the planet gears are forced to rotate as they move around the sun gear. The result is an increase in torque and decrease in speed. The formula for calculating the gear ratio is (sun + ring) ÷ ring.

D. If the sun gear is held and the carrier is driven, the planet gears are forced to rotate as they move around the sun gear. The result is an increase in speed and a decrease in

torque. The formula for calculating the gear ratio is ring ÷ (sun + ring). This ratio is the reciprocal of C.

E. If the carrier is held and the sun gear is driven, the planet gears will rotate and act as idlers and the planet gears drive the ring gear in a direction opposite to the sun gear. The result is a reverse with an increase in torque and a decrease in speed. The formula for calculating the gear ratio is ring ÷ sun.

F. If the carrier is held and the ring gear is driven, the planet gears will rotate and act as idlers, driving the sun gear in a direction opposite to the ring. The result is a reverse with an increase in speed and a decrease in torque. The formula for calculating the gear ratio is sun ÷ ring. This ratio is the reciprocal of "E" above.

NOTE: A technician rarely needs to calculate planetary gear set ratios. The gear ratio formulas are shown here for those who are interested or for reference. ● **SEE FIGURE 6–6.** ● **SEE CHART 6–2.**

Manufacturers usually provide clutch and band application charts for their transmissions, and these charts show which apply devices are used for each gear range. Each apply device drives a particular gear set member or holds it in reaction. Clutch and band charts are very helpful in understanding the power flow through a transmission. They are also very helpful when diagnosing transmission failures.

PARK POSITION

PURPOSE AND FUNCTION

Every automatic transmission and transaxle includes a park position. A shift into park prevents the transmission's output shaft from turning, thus holding the vehicle stationary. The parking gear has large gear-like teeth and is mounted on the output shaft of the transmission. The **park pawl** (sometimes called a lever) moves on a pivot pin in the case. ● **SEE FIGURE 6–7.**

OPERATION

In all gear positions except park, the park pawl is held away from the park gear teeth by a spring. When the gear selector is moved to park, a circular cam on the end of the park actuating rod pushes the pawl to mesh with the gear teeth. This holds the gear and output shaft stationary. The actuating cam is spring loaded. If the gear teeth and pawl are not aligned, the gear selector lever can still be shifted into the park position but the vehicle will not be held until the output shaft rotates slightly, then the spring moves the cam, which in turn moves the pawl into engagement.

The shift into park is a mechanical connection that should be made with the driveshaft stopped. ● **SEE FIGURE 6–8.**

TRANSMISSION SCHEMATICS

DESCRIPTION

Transmission parts and their operations are often illustrated using pictures and cutaway drawings. They show the bare essentials of the transmission gear train in the simplest way possible. When viewing a typical cutaway view of a gear train, the transmission is usually split lengthwise through the middle. This shows the relationship of the parts, but in many cases, it is difficult to tell where one part stops and another begins, making it difficult to trace the path of the power flow. Many exploded views of the internal parts show the front or back of a clutch, carrier, or gear, but it is difficult to tell what the backside connects to unless a separate view is given. Exploded views are typically used by parts personnel to identify parts.

SUN GEAR	PLANET CARRIER	RING GEAR	SPEED	TORQUE	DIRECTION
Input (Drive)	Output (Driven)	Held	Maximum reduction	Increase	Same as input
Held	Output (Driven)	Input (Drive)	Minimum reduction	Increase	Same as input
Output (Driven)	Input (Drive)	Held	Maximum Increase	Reduction	Same as input
Held	Input (Drive)	Output (Driven)	Minimum Increase	Reduction	Same as input
Input (Drive)	Held	Output (Driven)	Reduction	Increase	Reverse of input
Output (Driven)	Held	Input (Drive)	Increase	Reduction	Reverse of input

CHART 6–2

If any two members are locked together, then the resulting output is 1:1 ratio in the same direction as the input. If no member is held (locked), then there is no output (neutral).

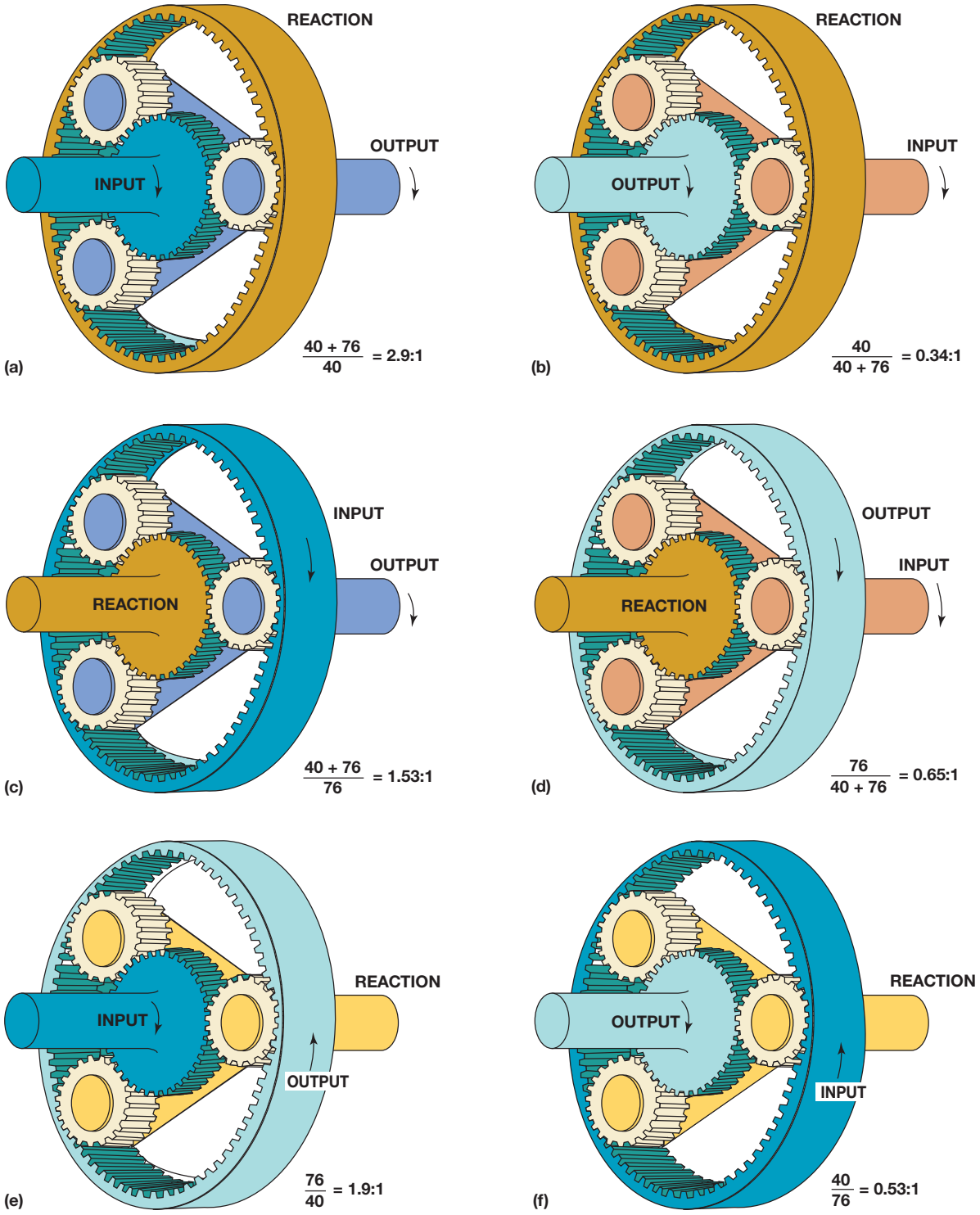


FIGURE 6–6 The gear ratio through a planetary gear set depends on which part is driven, which part is held, and which part is the output. The formula used to calculate the ratio is included with each illustration. Each gear set uses a 40-tooth sun gear and a 77-tooth ring gear.

READING SCHEMATICS An easier way to view transmission operation is by using schematics. Transmission schematics resemble stick drawings. Schematics use symbols for the parts and a line shows the link between the parts. Similar to electrical schematics, the major objective is to simplify the transmission as much as possible. A schematic is most useful when tracing the power flow. At present, there is no industry-wide standard for automatic transmission symbols and manufactures can use different formats for their transmission schematics. ● **SEE FIGURE 6–9.**

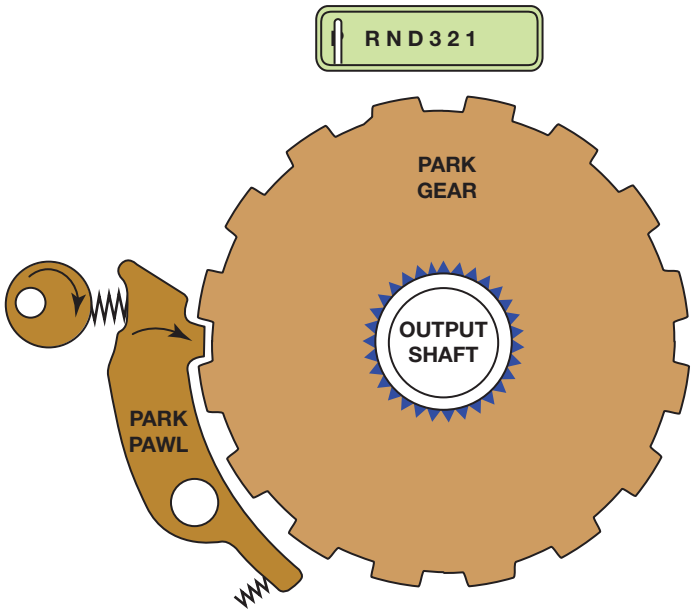


FIGURE 6–7 The parking pawl engages and locks the output shaft to the transmission case.

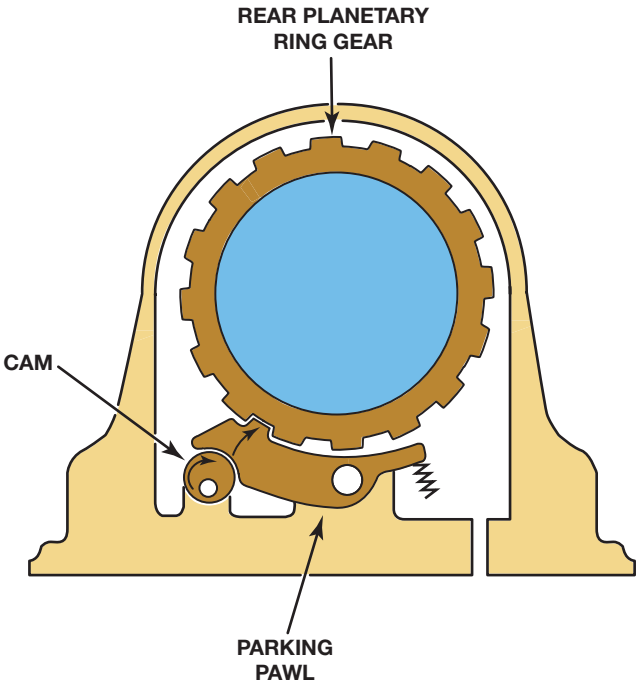


FIGURE 6–8 When the control rod is moved, the locking cam pushes the pawl into engagement with the parking gear.

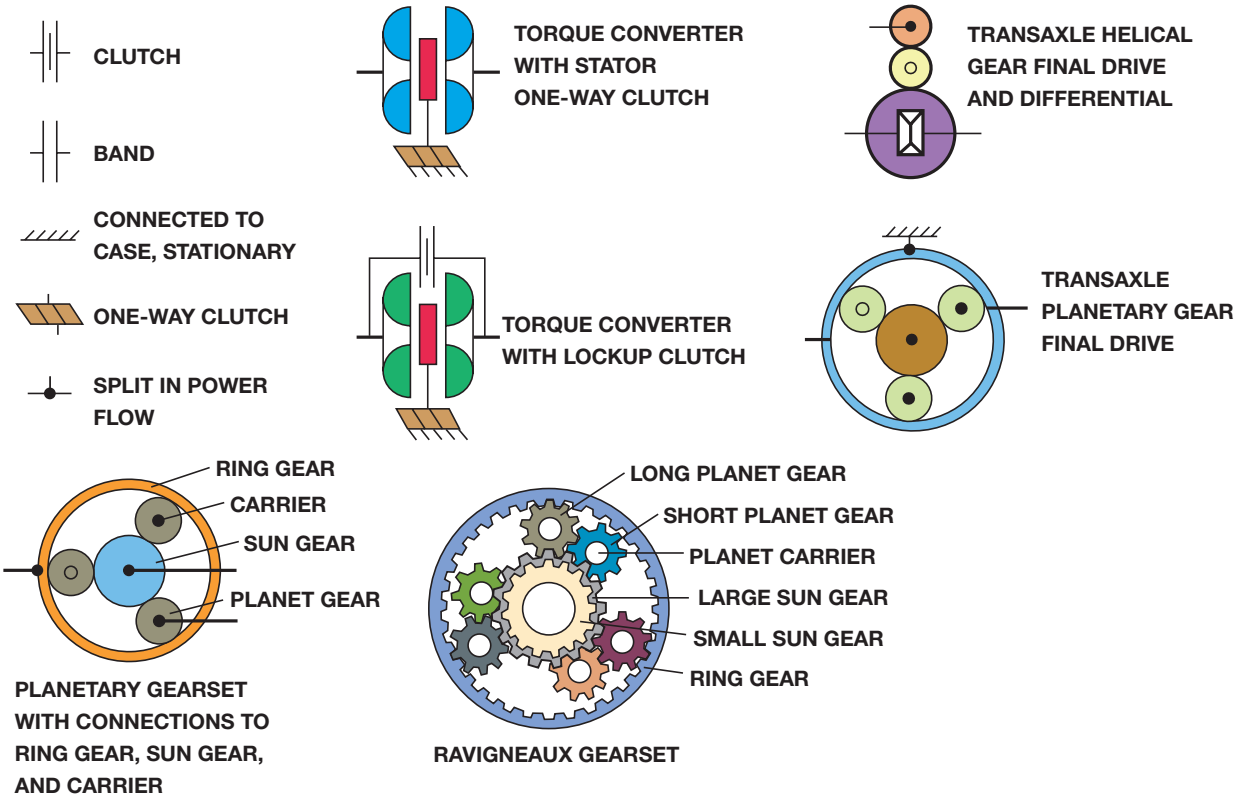


FIGURE 6–9 Common symbols used in the transmission schematics to illustrate the various parts.

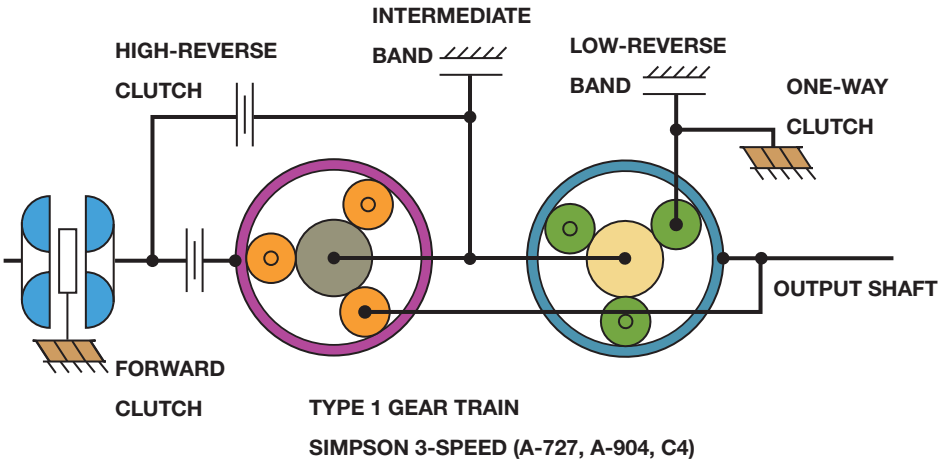


FIGURE 6–10 Type 1 gear set is a three-speed Simpson gear train that uses bands to hold the sun gear and reaction carrier. Note that the reaction carrier can also be held by a one-way clutch.

SIMPSON GEAR TRAIN TYPES

BACKGROUND The Simpson gear set consists of a double sun gear that is meshed with the planet gears of the two carriers and is a compound gear set commonly used in many three-speed transmissions/transaxles. Most of the automatic transmissions used in domestic vehicles during the 1960s and 1970s used this gear train. The better-known Simpson gear train transmissions are as follows:

Aisin-Warner: Three-speed models

Chrysler Corporation: 36 and 37 RH (Torqueflite A-727 and A-904) transmissions and the 31TH (A-404, A-413, A-415, and A470) transaxles

Ford Motor Company: Cruisomatic C3, C4, C5, and C6 and JATCO transmissions

General Motors: The 3L80 (THM 400), THM 200, 250, 350, 375, and 425 transmissions and 3T40 (THM 125) and THM 325 transaxles

JATCO: Three-speed models

Toyota: A40, A41, A130, A131, and A132

Although transmissions using a Simpson gear train are similar, they are not identical. The power flow through the gear set is essentially the same. They all have two input or driving clutches and a one-way reaction clutch, but the reaction members vary.

GEAR SET TYPES 1, 2, 3, AND 4 The major difference between these transmissions is the type of reaction member. A multiple-disc clutch can handle more torque than a band. It has a much larger friction area and multiple case connections. A clutch is more complex than a band and requires more space. To help understand these different arrangements, they are grouped into similar types, as follows:

- **Type 1**—transmissions use a band for both reaction members. ● **SEE FIGURE 6–10.**
- **Type 2**—transmissions use a multiple-disc clutch for the reaction carrier and a band to hold the sun gear.
- **Type 3**—transmissions use a multiple-disc clutch, a one-way clutch, and an overrun band for the sun gear reaction member and a multiple-disc clutch to hold the reaction carrier. (When a one-way clutch is used for a reaction member, an overrun band or clutch is applied to hold the reaction member during deceleration.)
- **Type 4**—transmissions use a multiple-disc clutch, a one-way clutch, and an overrun band for the sun gear reaction member and a band to hold the reaction carrier.

NONSYNCHRONOUS AND SYNCHRONOUS DESIGNS Type 3 and 4 units are **nonsynchronous** (asynchronous) designs. A nonsynchronous transmission is a unit that uses a one-way clutch to allow an upshift that requires only the application of the next driving or reaction member. All four types use a nonsynchronous 1–2 shift in drive. The 2–3 upshift timing is less critical because the disc clutch is used with a one-way clutch and the clutch stays applied while the one-way clutch simply overruns as the upshift occurs. A **synchronous** design transmission means that during an upshift, the new driving or reaction member must be timed or synchronized with the release of a driving or reaction member. The band used

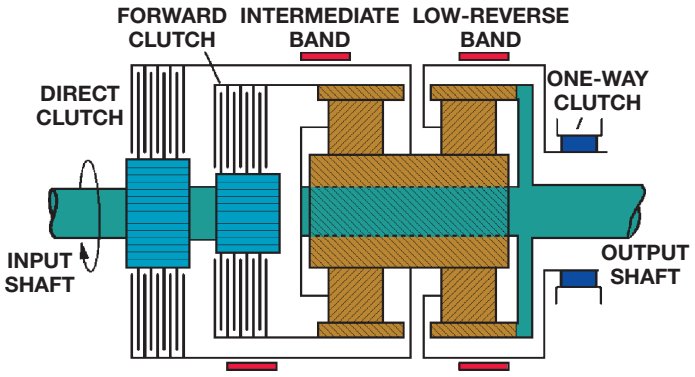


FIGURE 6–11 The one-way clutch of this type 1 gear set serves as the reaction member in first gear with the gear selector in Drive (D1). The low-reverse band is applied in manual first (M1) to allow engine compression braking.

in synchronous designs must be released at an exact time for the upshift, and it must reapply at the exact time during a downshift. ● **SEE FIGURE 6–11.**

The nonsynchronous arrangement is great for upshifts, but is ineffective during deceleration. Similar to the one-way clutch in first gear, the one-way clutch overruns during deceleration.

NEUTRAL Neutral is achieved by not applying the input clutches. Power enters the transmission from the torque converter but travels only as far as the released clutches. When shifted into neutral, some transmissions apply one of the clutches needed for first or reverse to prevent a harsh engagement when the vehicle is shifted into gear.

FIRST GEAR The Simpson gear set has two slightly different first gears—drive-1 and manual-1—the difference being in how the reaction carrier is held. In both gear ranges, power flows through the gear set when the front ring gear is driven and the reaction carrier is held. All Simpson gear sets use a clutch to drive the front (input) ring gear. Transmission types 1 and 4 use a one-way clutch and a band and types 2 and 3 use a one-way clutch and a holding clutch to hold the reaction carrier. In drive-1, the one-way clutch is used and it provides self-application and release. In manual-1, a band or holding clutch is applied to provide engine compression braking during deceleration. ● **SEE FIGURE 6–12.**

When manual-1 (low) is selected, the one-way clutch is assisted by either a band (types 1 and 4) or a multiple-disc clutch (types 2 and 3). The band is called the *low and reverse* or **low-reverse band**. The multiple-disc clutch is called a **low-reverse clutch**. The power flow is exactly the same as in drive-1 except that power can be transmitted from the drive shaft to the engine during deceleration. This provides engine (compression)

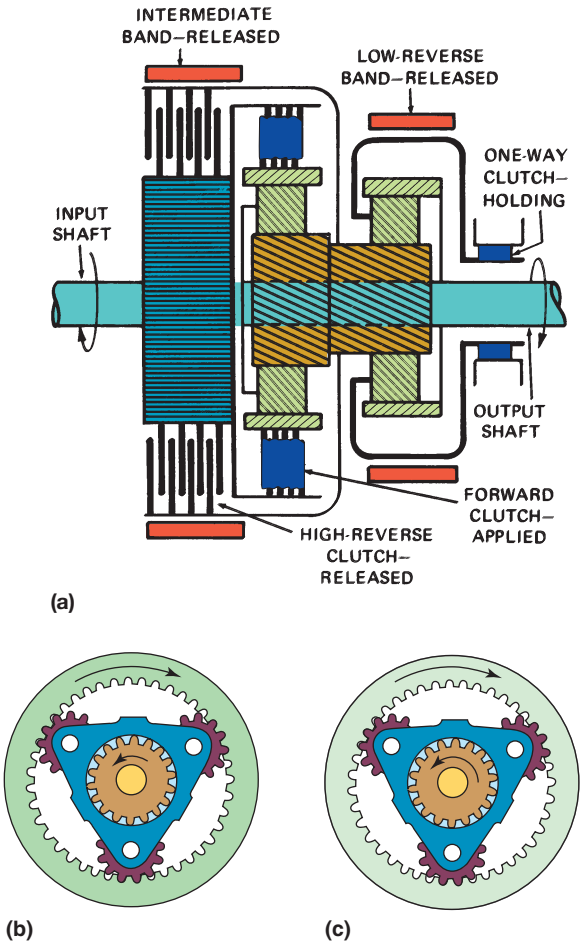
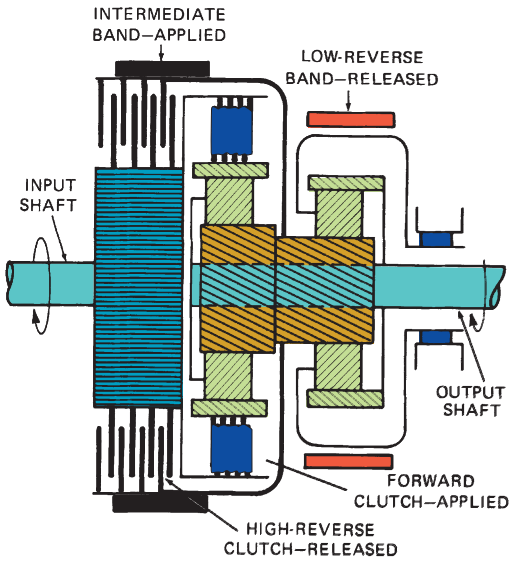


FIGURE 6–12 (a) In drive low (D1), the front ring gear is driven while the rear carrier is held by the one-way clutch. A reverse reduction occurs in both (b) the front unit and (c) the rear unit.

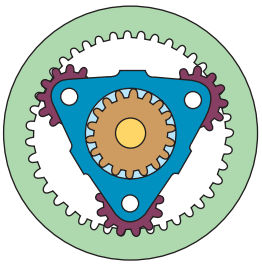
braking as the vehicle slows. Engine braking is easily noticed by comparing the deceleration of a vehicle in drive-1 and manual-1. For simplicity, this holding member will be called either a low-reverse band or a low-reverse clutch in this text.

In drive-1 (low), the following occur.

- The **forward clutch** is applied to drive the input ring gear in a clockwise direction.
- The output/front carrier will not rotate because it is connected to the driveshaft.
- The front planet gears are driven clockwise.
- The sun gear is driven in the reverse direction (counterclockwise) at a reduced speed.
- The reaction carrier is held from turning counterclockwise by the one-way clutch (or the low-reverse band or clutch in manual-1).
- The rear planet gears are driven clockwise.



(a) side view



(b) front view

FIGURE 6–13 In second gear, the ring gear is driven while the sun gear is held, and the planet gears walk around the sun gear and force the carrier to revolve at a reduced speed.

- The rear ring gear is driven clockwise at a reduced speed.
- The output shaft and driveshaft are driven clockwise at a reduced speed.

The gear set is producing two reverse reduction ratios, and the result is a forward (clockwise) rotation of the driveshaft. The overall ratio will be about 2.45:1 to 2.74:1 depending on the size of the gears used in a specific transmission.

SECOND GEAR The sun gear must be held stationary in second gear. This is done by a band in type 1 and 2 transmissions or a multiple-disc clutch plus a one-way clutch in type 3 and 4 transmissions. Type 3 and 4 transmissions use an **intermediate clutch** and an *intermediate one-way clutch*. When the intermediate clutch is applied, it holds the outer race of the intermediate roller clutch stationary. The one-way clutch locks, holding the sun gear from rotating counterclockwise. Because the one-way clutch will only hold in one direction, these units have two slightly different power flows in second gear: **drive-2** and **manual-2**. Manual-2 applies an intermediate overrun band to provide engine compression braking during deceleration. This reaction member is called an intermediate band or intermediate clutch.

In drive-2 (intermediate), the following occur.

- The forward clutch stays applied to drive the input ring gear clockwise. ● **SEE FIGURE 6–13.**
- The intermediate band or clutch applies to hold the sun gear stationary (reaction member).
- The front planet gears are driven clockwise and walk around the sun gear.
- The front carrier is driven clockwise.
- The front carrier drives the output shaft clockwise at about a 1.5:1 ratio.

THIRD GEAR Third gear in this gear set is direct drive with a 1:1 ratio. It is produced by applying both driving clutches (forward and high-reverse) and either releasing the intermediate band in synchronous transmissions (types 1 and 2) or allowing the intermediate roller clutch to overrun in nonsynchronous transmissions (types 3 and 4). The gear set locks up because the ring gear is trying to turn the planet pinions clockwise while the sun gear is trying to turn them counterclockwise.

In drive-3 (high), the following occur.

- The forward clutch stays applied to drive the input ring gear clockwise.
- The **high-reverse clutch** applies to drive the sun gear clockwise.
- The front planet gears become locked in the carrier.
- The front carrier is driven clockwise at the same speed as the ring and sun gears.
- The front carrier drives the output shaft clockwise at a 1:1 ratio. ● **SEE FIGURE 6–14.**

REVERSE Reverse in a Simpson gear train occurs when the high-reverse clutch and the low-reverse band or clutch are applied. The high-reverse clutch drives the sun gear (input member) while the carrier (reaction member) in the rear gear set is held stationary by the low-reverse band or clutch. The planet gears act as idlers, reversing the power flow as they transfer power from the smaller sun gear to the larger ring gear. A

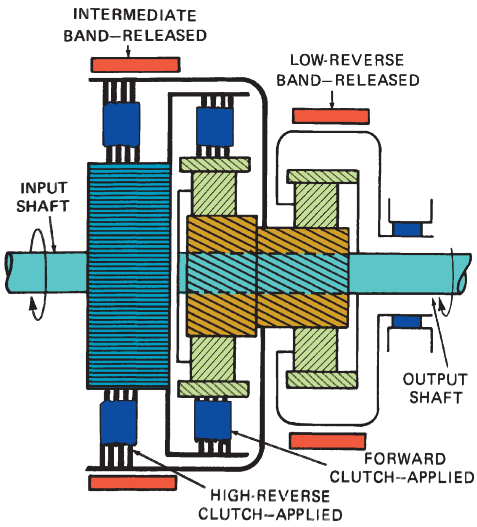


FIGURE 6–14 In third gear, both driving clutches are applied so two members (the ring and sun gears) of the same gear set are driven. This locks the gears and produces a 1:1 gear ratio.

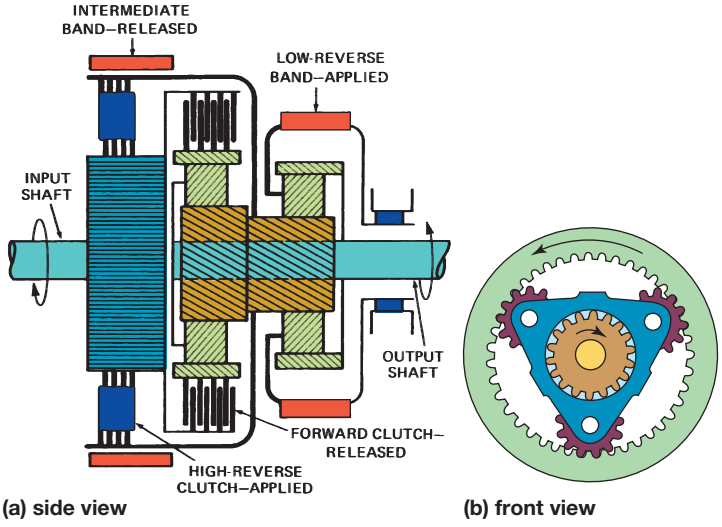


FIGURE 6–15 In reverse, the sun gear is driven while the carrier is held. The planet gears act as idlers and cause the ring gear to revolve in a reverse direction at a reduced speed.

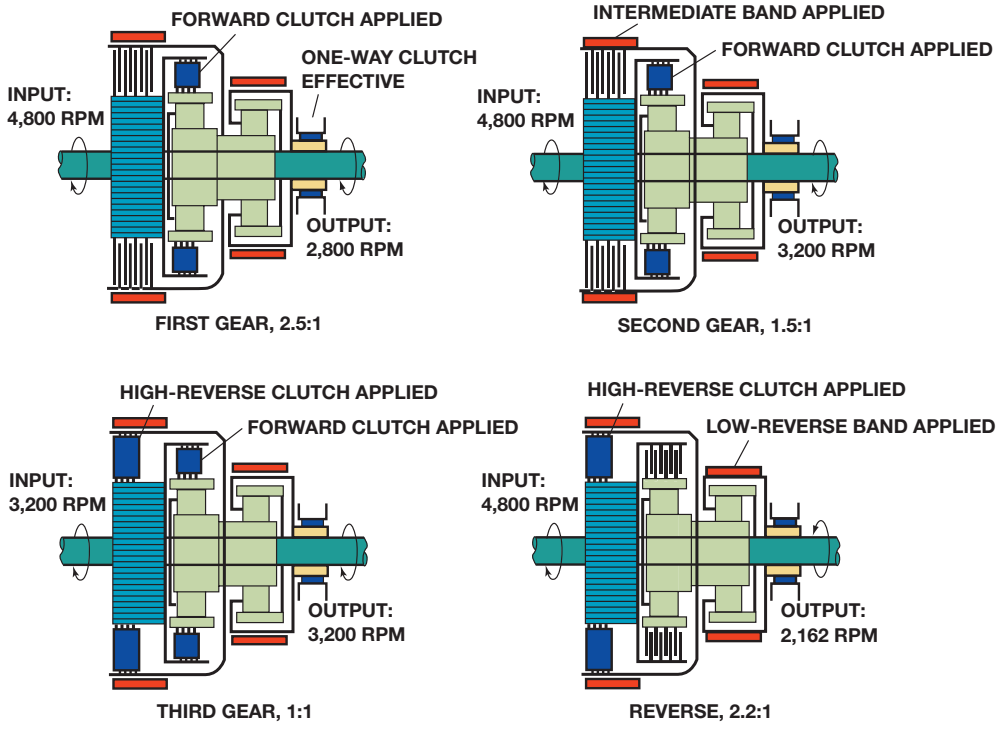


FIGURE 6–16 The full-throttle shift sequence for a type 1 transmission showing the apply devices and the output shaft speed at the 1–2 and 2–3 upshifts. Reverse is also shown.

reverse reduction is produced at the output ring gear of about 2.07:1 to 2.22:1. ● **SEE FIGURE 6–15.**

SHIFT TIMING EXAMPLE As a vehicle accelerates from a stop to cruising speed, the driving and reaction members have to apply and release in an exact operating sequence. When they apply, they must come on at a precise rate. Here is what happens during hard acceleration with shift points occurring at 4,800 RPM:

In first gear, the ratio will be 2.5:1, so the vehicle driveshaft will be revolving at 1920 RPM (4800 ÷ 2.5) when the 1–2 upshift occurs. Second gear has a ratio of 1.5:1, so the engine speed will drop from 4800 to 2800 RPM (1920 × 1.5) during the shift. ● **SEE FIGURE 6–16.**

FOURTH GEAR MADE POSSIBLE The Simpson gear train with an additional simple planetary gear set is used to produce a four-speed overdrive transmission or transaxle. The overdrive planetary gear set provides two speeds: direct 1:1 and overdrive. When the overdrive planetary gear set is in direct drive, it turns the Simpson planetary gear set input at engine speed. When the overdrive gear train is in direct drive 1:1, the Simpson gear train will shift from first to second and then to third. If the overdrive planetary gear set is in overdrive, it will turn the Simpson planetary gear set input faster than engine speed. The three-speed Simpson gear train will operate as described earlier. To get overdrive, the overdrive planetary gear set will be in overdrive and the Simpson gear set will be in direct 1:1. To get reverse, the overdrive gear set will be in direct and the Simpson will be in reverse. The more common transmissions using this gear set are as follows:

- Chrysler 42RH (A-500), 46RH (A-518)
- Ford 4R44E (A4LD), 5R55E, and E4OD
- GM 4T80-E, THM-200-4R, and 325–4L
- Jeep AW-4
- Nissan E4N7IB
- Toyota A40 and A340 series

OVERDRIVE In most of these transmissions, the overdrive gear set is built into the area at the front of the case between the torque converter and the main gear set. The input shaft from the torque converter is connected to the carrier of the overdrive gear set, and the ring gear of the overdrive gear set is arranged so it becomes the input of the main gear set. The Chrysler 42RH and 46RH have the overdrive gear set built into the transmission extension housing to cause a speed increase between the main gear set and the output shaft.

GEAR SET TYPES 5, 6, 7, AND 8 For examples of types 5, 6, 7, and 8 that use the Simpson gear train. ● **SEE FIGURE 6–17.**

The Chrysler 42RH and 46RH are a little unusual in that one hydraulic piston and return spring is used for both the direct clutch and the overdrive clutch (type 5 gear train). The very strong return spring is used to release the overdrive clutch and apply the direct clutch. Hydraulic pressure at the piston releases the direct clutch and then almost immediately applies the overdrive clutch. With this arrangement, the gear set is locked in either direct drive or overdrive with the overrunning clutch transferring power while the upshift or downshift is made.

In the 4R44E/5R55E (type 6), the power is transferred directly from the carrier to the ring gear. In the GM 200-4R (type 7), the gear set is locked because the one-way clutch does not allow the sun gear to overrun the carrier. The type 8 gear train describes the power flow through a Jeep AW-4 transmission.

Like other power flows using a one-way clutch, these gear sets overrun during deceleration and do not produce engine (compression) braking. To prevent this in manual-1, M2, or M3, the overdrive clutch in the Ford 4R44E/5R55E, overrun clutch in the 200-4R, or the O/D direct clutch in the AW-4 are applied. This locks the overdrive gear assembly so it operates in direct drive in both acceleration and deceleration. ● **SEE FIGURE 6–18.**

RAVIGNEAUX GEAR SETS

DESCRIPTION The Ravigneaux gear set uses:

- a single carrier that has two sets of intermeshed planet gears,
- two sun gears, and
- a single ring gear.

The planet gears are different lengths. The two sun gears have different diameters and are independent of each other. On one side of the Ravigneaux gear set, the sun gear meshes with the short pinion gears, which in turn mesh with the longer pinion gears, which are meshed with one of the ring gears. On the other side of the gear set, the long pinion gears mesh with the other ring gear and sun gear. In some transmissions, the ring gear is in mesh with the short pinions.

EXAMPLES The Ravigneaux gear set is used in the following.

- **Two-speed transmissions**—Chrysler Powerflite, the Ford two-speed, and the General Motors Powerglide, and THM 300
- **Three-speed transmissions**—Ford FMX and General Motors 3L30 (THM 180)
- **Three-speed transaxles**—Ford ATX, KM 171 to 175 versions
- **Four-speed transmission**—Ford 4R70W (AOD)
- **Four-speed transaxles**—Ford 4EAT, KM 175 to 177, and ZF-4

The exact arrangement of the gear set varies depending on the usage. ● **SEE FIGURE 6–19.**

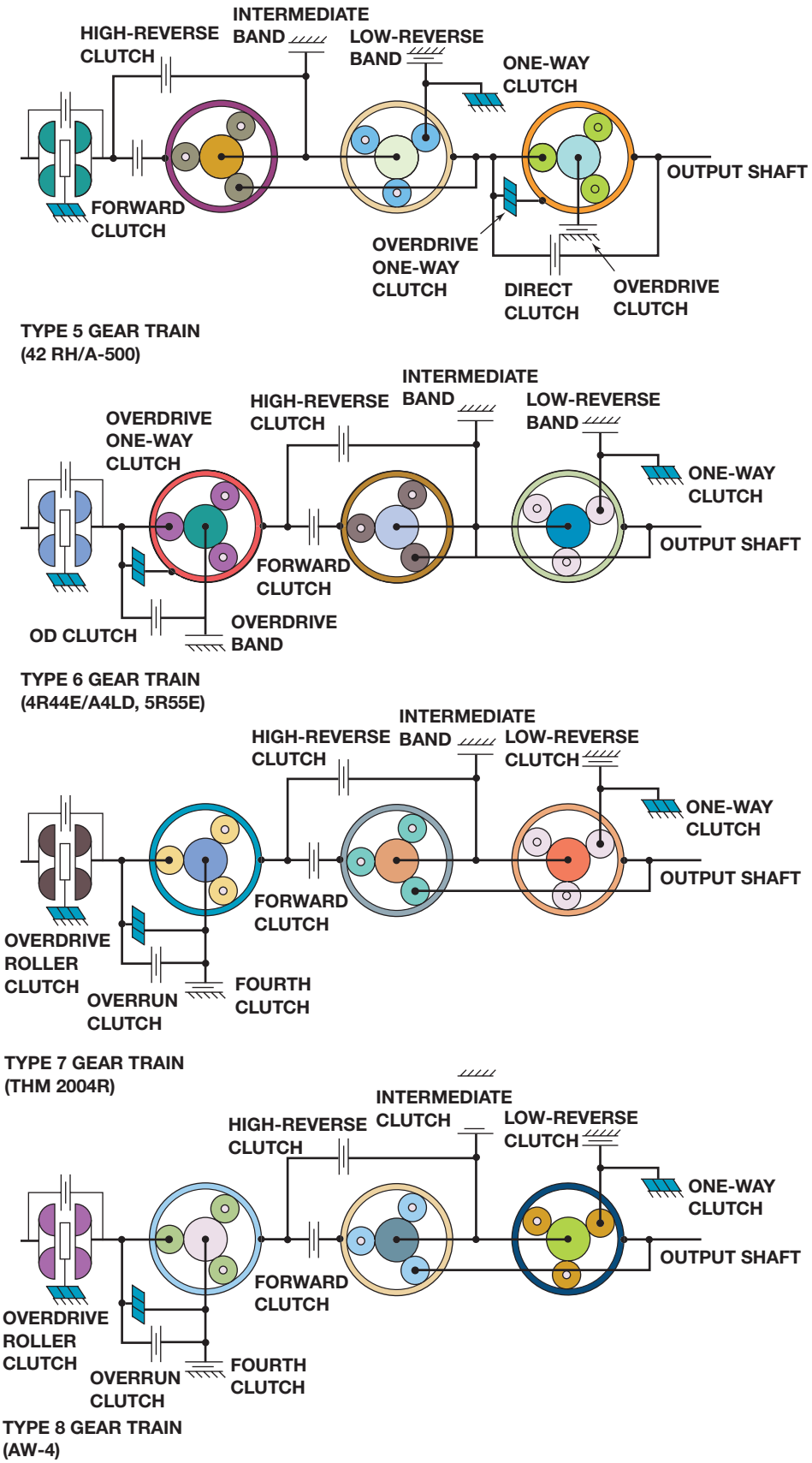


FIGURE 6–17 Types 5, 6, 7, and 8 gear sets illustrate the different four-speed gear train arrangements that combine a Simpson three-speed gear set with an overdrive unit.

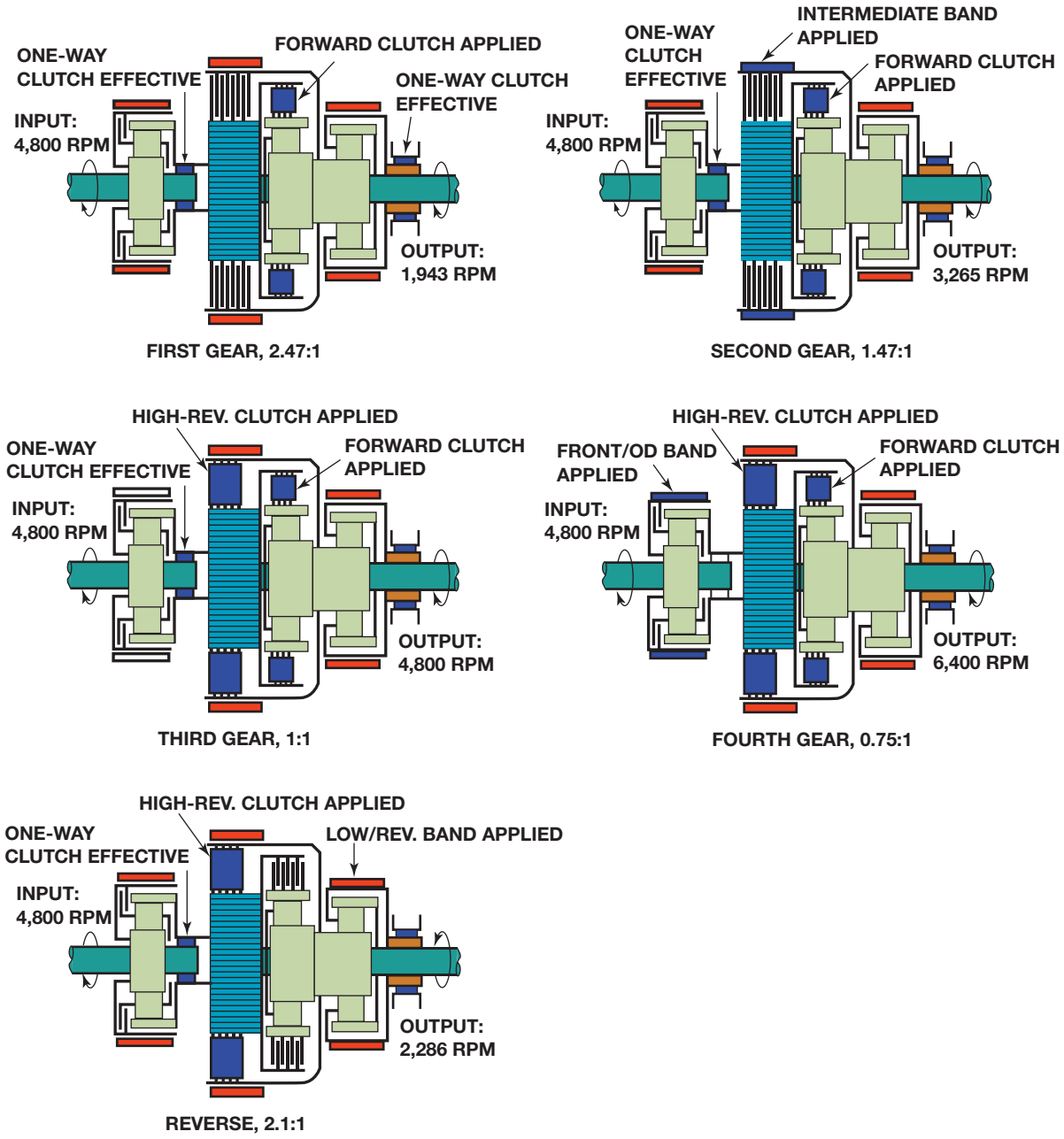


FIGURE 6–18 The full-throttle shift sequence for a type 6 transmission showing the apply devices and the output shaft speed at the 1–2, 2–3, and 3–4 upshifts, plus reverse.

FOUR-SPEED RAVIGNEAUX ARRANGEMENT AND OPERATION

The Ford 4R70W (AOD) (type 12 gear set) uses a four-speed version of the Ravigneaux gear train. The first version of this transmission, the AOD, has an additional input shaft (the direct driveshaft) and an additional clutch (the direct clutch). These are arranged so the carrier can be an input member in third and fourth gears as well as a reaction member in first and reverse. The direct driveshaft is driven by a damper assembly at the front of the torque converter so it is a purely mechanical input into the gear set. Newer versions use a more conventional torque converter with a converter clutch and connect the direct clutch to the forward clutch by a short stub shaft.

The first-, second-, and reverse-gear power flows in the 4R70W are the same as those in the old FMX unit used by Ford, with the exception that the intermediate clutch is used to hold the carrier for a reaction member in second gear. In third gear, the direct-drive clutch is applied to drive the carrier while the forward clutch remains applied to drive the small, forward sun gear. This locks the planet gears and drives the ring gear in direct drive. The intermediate clutch remains applied, but it

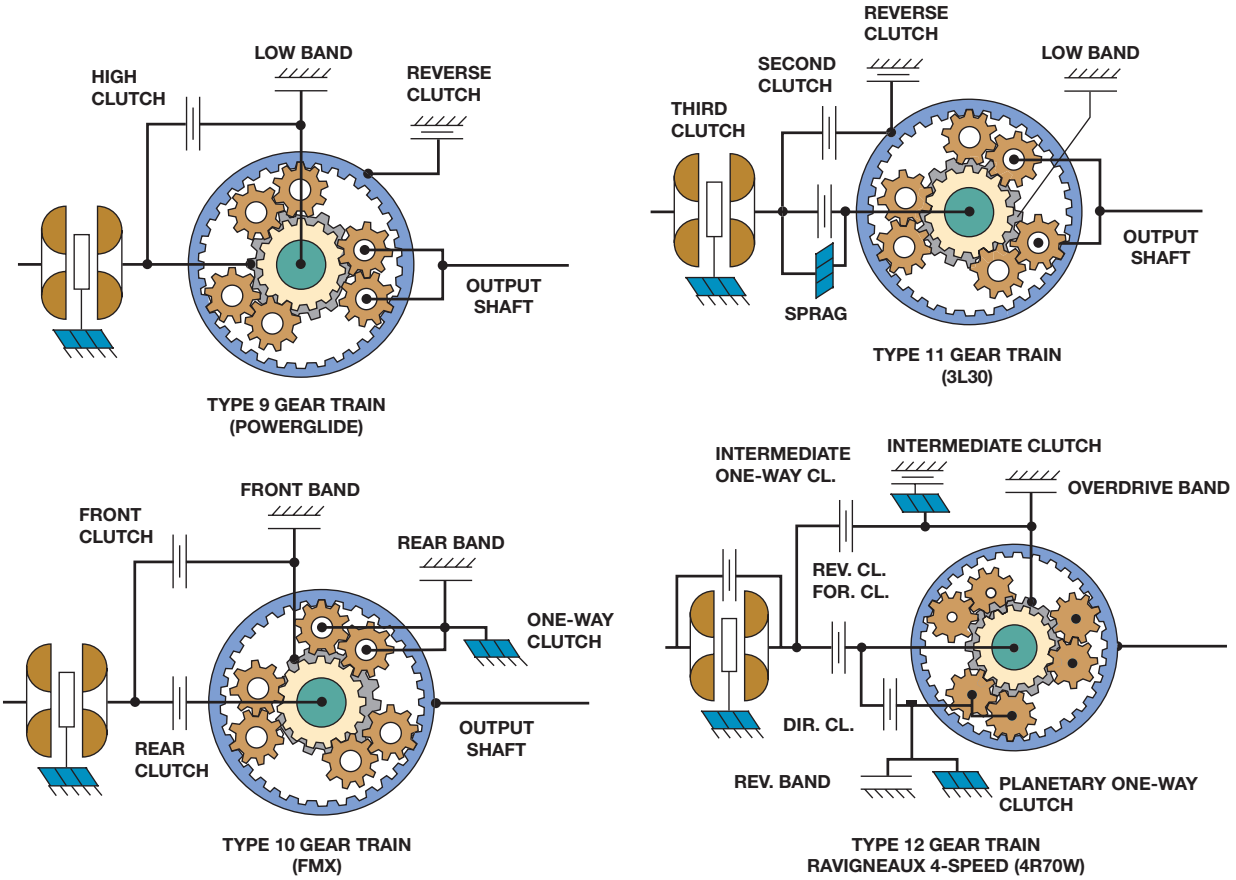


FIGURE 6–19 Types 9, 10, 11, and 12 gear sets illustrate the different three- and four-speed gear train arrangements that use a single Ravigneaux gear set.

FREQUENTLY ASKED QUESTION

How Was the Powerglide Different?

Two-speed transmissions were used in the 1950s and 1960s and are still a popular transmission used in racing. They are no longer in production, but so many were produced that they are still encountered. The most common was the Chevrolet Powerglide (type 9 gear set).

In two-speed Ravigneaux transmissions, the small **primary sun gear** is attached to the input shaft so it is always an input. The large sun gear, called the **secondary sun gear,** is either a reaction member or an input member. The carrier is the output member, and the ring gear can be a reaction member. A driving clutch is placed on the input shaft so the secondary sun gear can be driven, and a band, is placed around the clutch drum so the secondary sun gear can be held in reaction. The clutch is often called the *high clutch*, and the band is called a *low band*. The ring gear is held by either a band (first version) or a multiple-disc clutch (second version), called either a *reverse clutch* or a *reverse band*. ● **SEE FIGURE 6–20.**

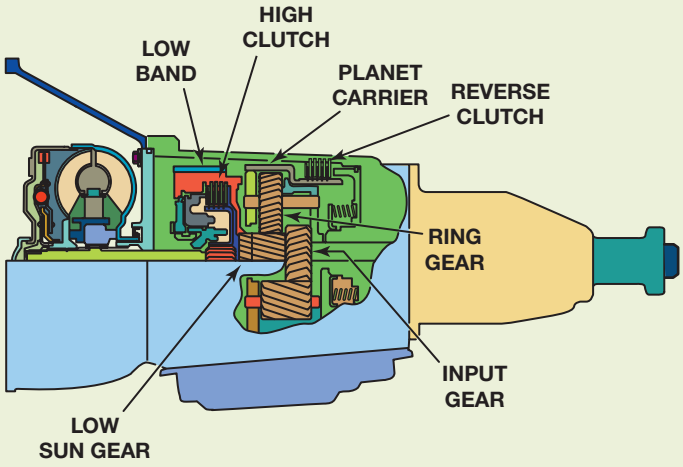


FIGURE 6–20 When a Powerglide is in low gear, the low band is applied to hold the low sun gear stationary. At this time, the long pinions will be driven by the input sun gear and walk around the low sun gear to drive the carrier.

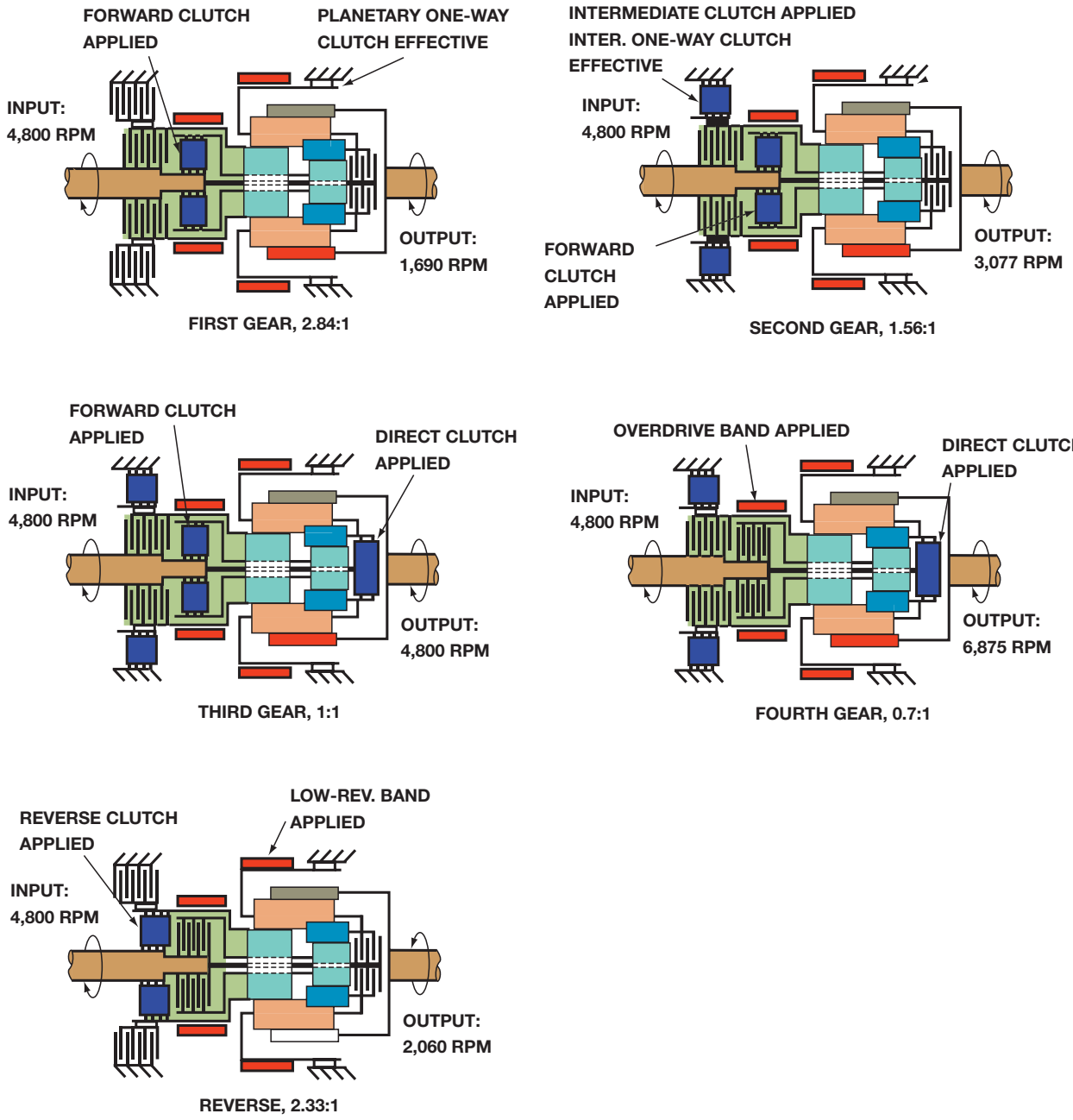


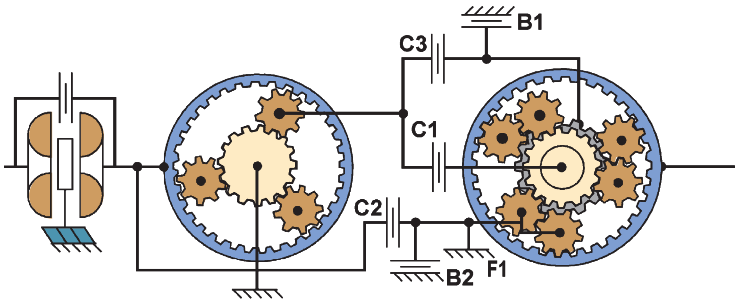
FIGURE 6–21 The full-throttle shift sequence for a type 12 transmission showing the apply devices and the output shaft speed at the 1–2, 2–3, and 3–4 upshifts and reverse.

becomes ineffective because the intermediate one-way clutch overruns. ● **SEE FIGURE 6–21.**

LEPELLETIER GEAR TRAIN

OPERATION The LePelletier gear train combines a simple planetary gear set with a Ravigneaux gear set providing six forward speeds. The combination is fairly simple, using only five multiplate clutches and, in some transmissions, a one-way clutch. Three of the clutches are driving members and the other two are used in reaction. This gear set is used in the Ford 6R60 and 6R80 and General Motors 6L80E transmissions, and transmissions produced by Aisin and ZF. ● **SEE FIGURE 6–22.**

Because the ring gear is always an input and the sun gear is always a reaction member (it is splined to the back of the pump), the simple gear set is always in reduction. The C1 and C3 clutches can provide a reduced speed input to the



TYPE 13 GEAR TRAIN
LEPELLETIER PRINCIPLE

(a)

Lepelletier Gear Ranges							
Range	C1	C2	C3	B1	B2	F1	Ratio
1	X					X	4.15:1
Manual 1	X				X		4.15:1
2	X			X			2.37:1
3	X		X				1.56:1
4	X	X					1.15:1
5		X	X				0.86:1
6		X		X			0.69:1
Reverse			X		X		3.39:1

(b)

FIGURE 6–22 (a) A schematic view of a type 13, LePelletier six-speed gear set (b) and a clutch application chart.

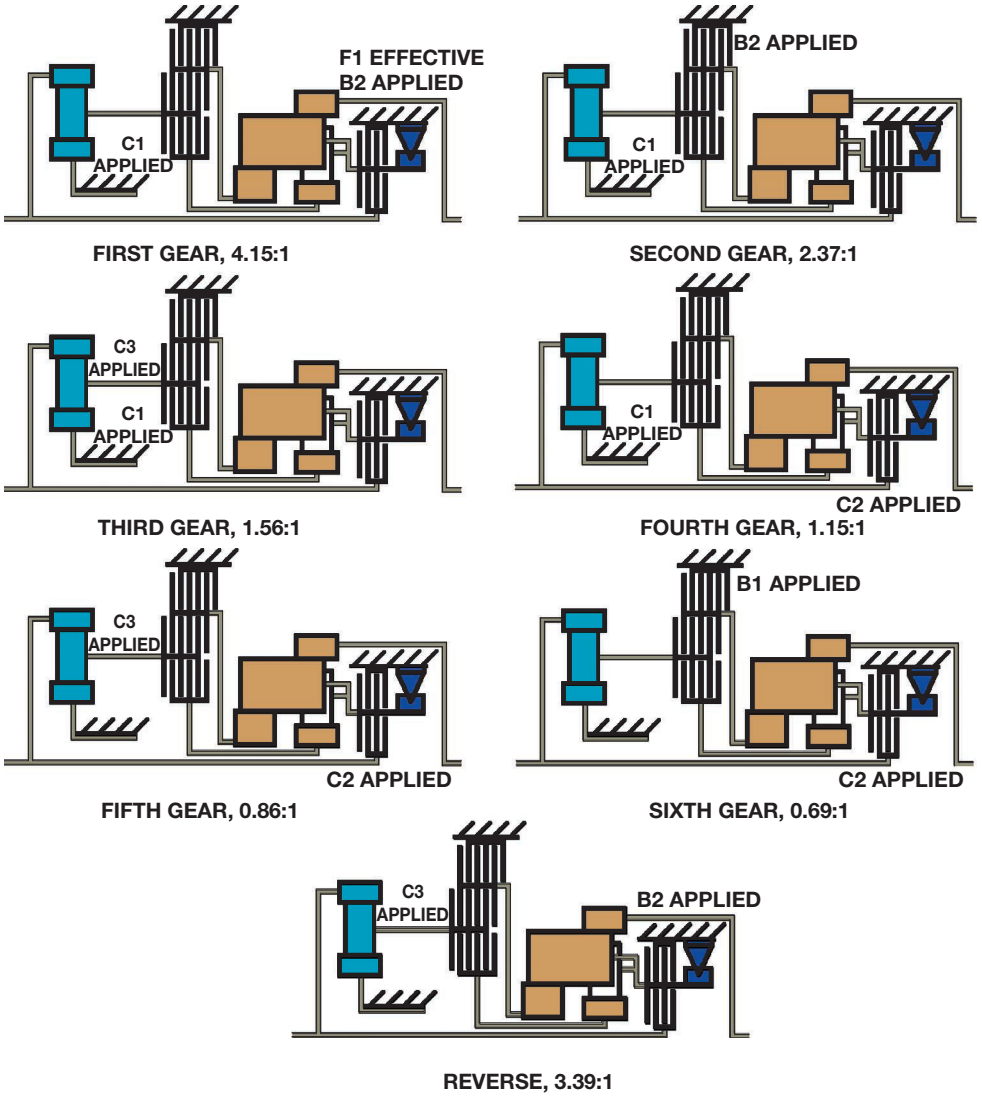


FIGURE 6–23 A type 13 shift sequence.

Ravigneaux gear set. The Ravigneaux gear set is arranged like a type 12 gear set, with three possible inputs and two reaction members.

This gear set has four reduction ratios and two overdrive ratios, with a gear ratio spread of over 6:1. Compared to current five-speed transmissions, these six-speed transmissions have fewer control devices and weigh about 13% less. Because of the close gear ratios and lighter weight, they also promise fuel mileage increases of 5% to 7%, and provide faster acceleration. ● **SEE FIGURE 6–23.**

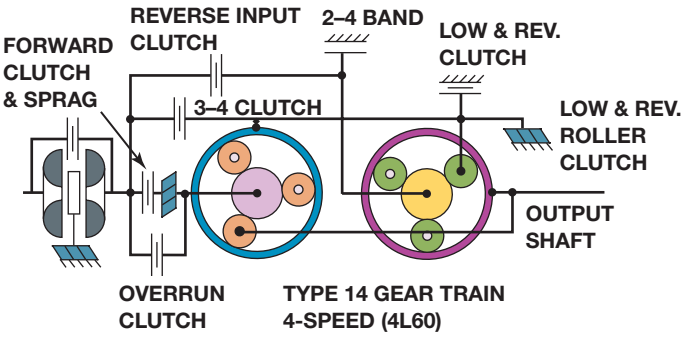


FIGURE 6–24 A schematic view of a type 14, GM 4L60-E four-speed gear set.

GM 4L60-E AND OTHERS

A four-speed gear set was developed by General Motors and introduced in the 4L60-E (THM 700-R4) rear-wheel-drive transmission. It has two simple planetary gear sets that have the ring gears interconnected with the carriers of the other set. A second version of this gear set is used in the following units:

- Chrysler 41TE (A-604) (front-wheel-drive unit) and 42LE (rear-wheel-drive unit)
- Ford AX4N, AX4S (AXOD), and CD4E units.
- General Motors uses this type of gear set in the 4T60-E, 4T65-E, and 4T80-E transaxles.

The 4L60-E (THM 7004R) rear-wheel-drive unit is a type 14 gear train and uses four multiple-disc clutches plus a one-way clutch as driving members and one multiple-disc clutch, a one-way clutch, and a band for holding members. ● **SEE FIGURE 6–24.**

The driving clutches are arranged so they can drive the sun gear and ring gear in the front gear set, called the **input gear set**, and the sun gear and carrier in the rear gear set, called the **reaction gear set**. The input housing contains three of the driving clutches and the hub for the fourth. There are two ways that the front sun gear can be driven. One way is through the *forward clutch* and forward one-way clutch, called a **forward sprag**, and the other way is through the *overrun clutch*. The overrun clutch is used in manual first (M1), M2, and M3 to provide engine braking during deceleration.

The rear carrier (and front ring gear) can be held by the one-way clutch, *low-roller clutch*, or the multiple-disc *low and reverse clutch*. The rear sun gear can be held by the *2–4 band* to serve as a reaction member as well as a driving member.

In neutral, all clutches are released so the power flows no farther than the input housing. ● **FIGURE 6–25.**

41TE/42LE The 41TE (A-604) and 42LE (Type 15) use a similar gear set to the 4L60 (THM 700R4), with different input and output members and a reversal of the gear set so the front ring gear and the rear carrier are the output members. This produces slightly different power flows.

NOTE: The 41TE transmission is also unique in that no bands or one-way clutches are used. This type of transmission/transaxle is called a *clutch-to-clutch* transmission.

Three of the multiple-disc clutches used in the 41TE are driving members and the other two clutches are holding members. The driving clutches are arranged so they can drive the front sun gear (closest to the engine), the front carrier, or the rear sun gear. Driving the carrier in the front gear set also drives the ring gear in the rear gear set. The holding clutches are arranged so one clutch can hold the sun gear in the front gear set. The other clutch can hold the ring gear in the rear gear set as well as the carrier in the front set.

Clutch application is controlled by the manual valve and four solenoid valves. The solenoid valves are controlled by the transaxle electronic control module, and they are opened and closed to produce the automatic upshifts and downshifts. They are also operated at the exact rate to produce the proper clutch application and release for good shift quality. In neutral, the three driving clutches are released. The low-reverse clutch is applied to hold the reaction member as soon as the transmission is shifted into first or reverse gear. ● **SEE FIGURE 6–26.**

A clutch and band chart is shown in ● **CHART 6–3.**

4T60/AX4N

The General Motors 4T60-E (THM 440), 4T65-E, and 4T80-E and the Ford AX4N (AXOD), AX4S, and CD4E transaxles use gear sets that are very similar to the arrangement in the 41TE. These transaxles have the front carrier and the rear ring gears combined and are the output members. The rear carrier and the front ring gear can be a driving member, a reaction, or neither. The rear sun gear can only be a reaction

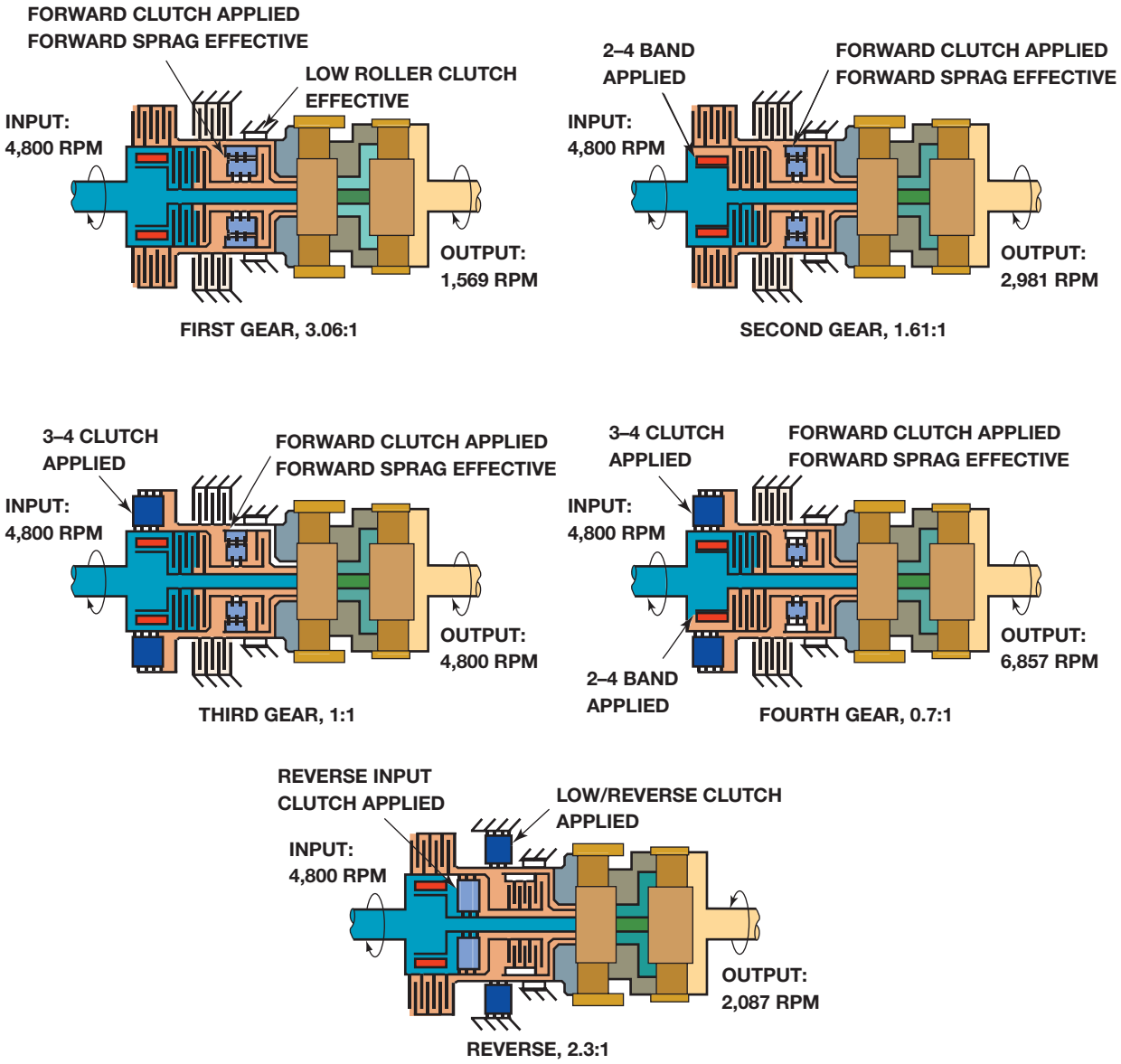


FIGURE 6–25 The full-throttle shift sequence for a type 14, 4L60 transmission showing the apply devices and the output shaft speed at the 1–2, 2–3, and 3–4 upshifts and reverse.

GEAR	UNDERDRIVE CLUTCH	LOW-REV. CLUTCH	2–4 CLUTCH	OVERDRIVE CLUTCH	REVERSE CLUTCH
D1	Applied	Applied			
D2	Applied		Applied		
D3	Applied			Applied	
D4			Applied	Applied	
R		Applied			Applied
Planetary Member	Drives Rear Sun	Holds Front Carrier & Rear Ring	Holds Front Sun	Drives Front Carrier & Rear Ring	Drives Front Sun

CHART 6–3

Four-Speed Gear Train Band and Clutch Application, Type 15.

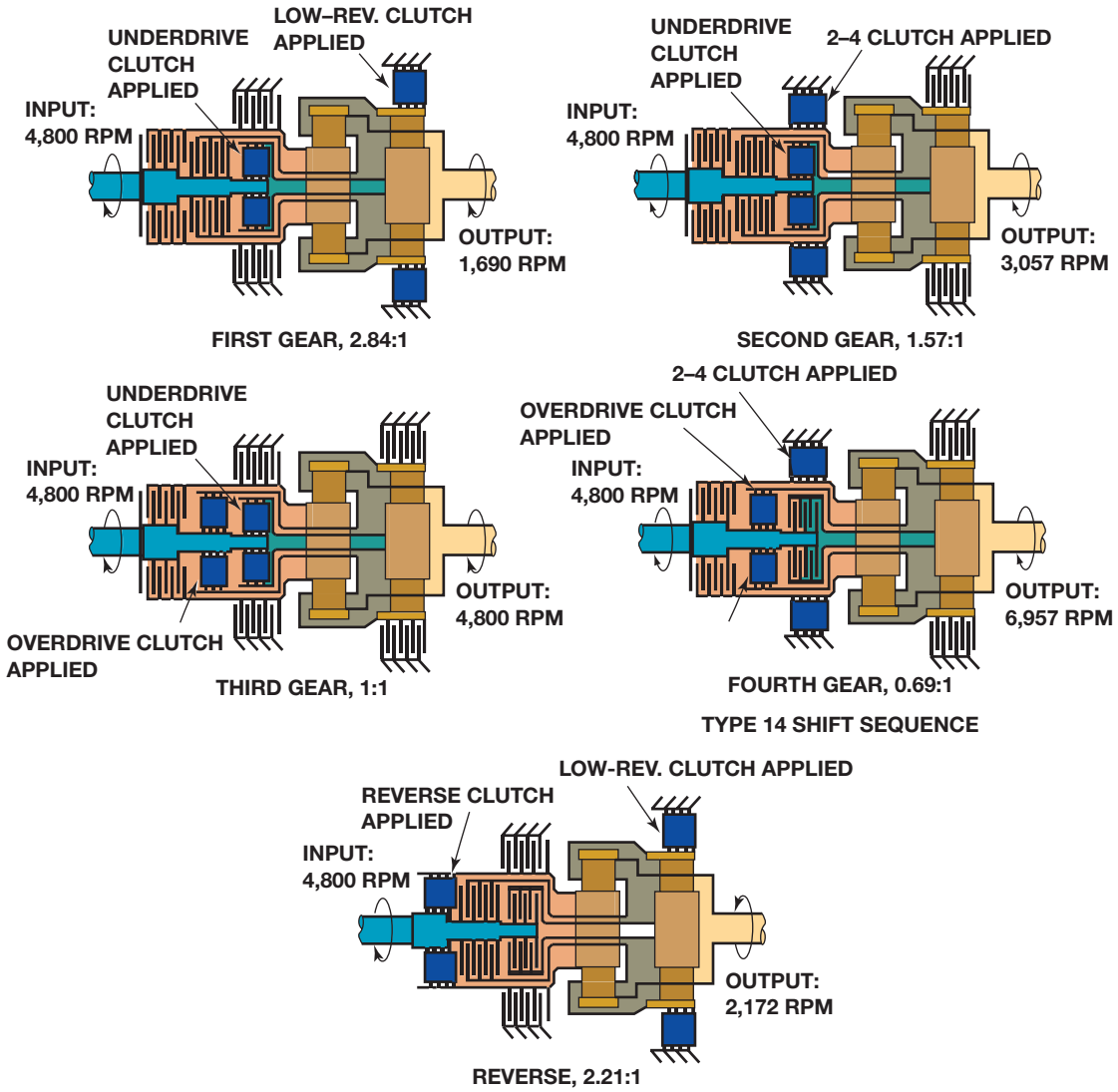


FIGURE 6–26 The full-throttle shift sequence for a type 15, 41TE transmission showing the apply devices and the output shaft speed at the 1–2, 2–3, and 3–4 upshifts and reverse.

member. The 4T60 is illustrated as a type 16 gear train. ● **SEE FIGURE 6–27.**

FORD CD4E

The Ford CD4E is another version of the four-speed gear set and is a type 17 gear train. It is a compact transaxle with a chain drive between the transmission gear set and the planetary reduction gears and differential of the final drive. The power flows through this gear set are quite similar. ● **SEE FIGURE 6–28.**

GM 6T70/FORD 6F50

OPERATION The type 18 gear set was developed jointly by Ford (6F50) and General Motors (6T70 and 6T75). It uses three simple planetary gear sets and has each carrier connected to the ring gear of another set. The sun gear of the center gear set is connected to the input shaft, so it is always driven. It uses two driving clutches, three reaction clutches (brakes), and one mechanical diode (one-way clutch). The front carrier and rear ring gear are the output. Except for first gear with the one-way clutch, it uses clutch-to-clutch shifts. It has a low 4.48:1 first gear, and an overdrive 0.74:1:1 sixth gear. ● **SEE FIGURE 6–29.**

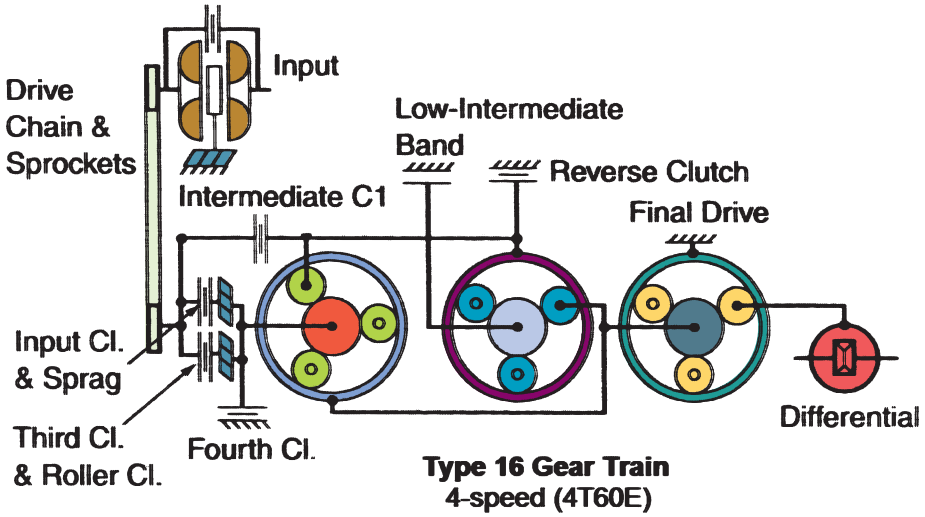


FIGURE 6–27 A schematic view of a type 16, GM 4T60 four-speed gear set. The Ford AX4N gear set is similar.

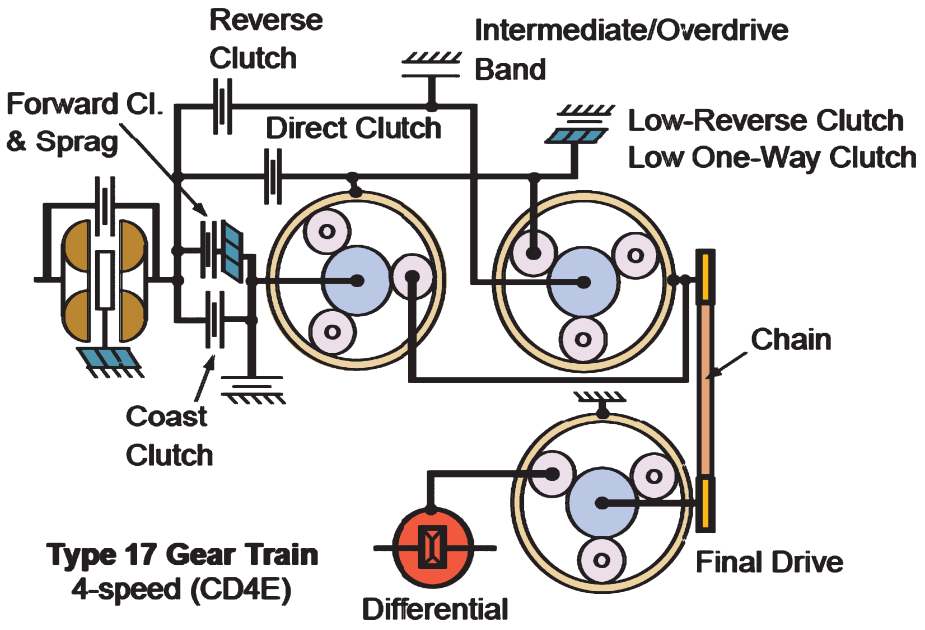


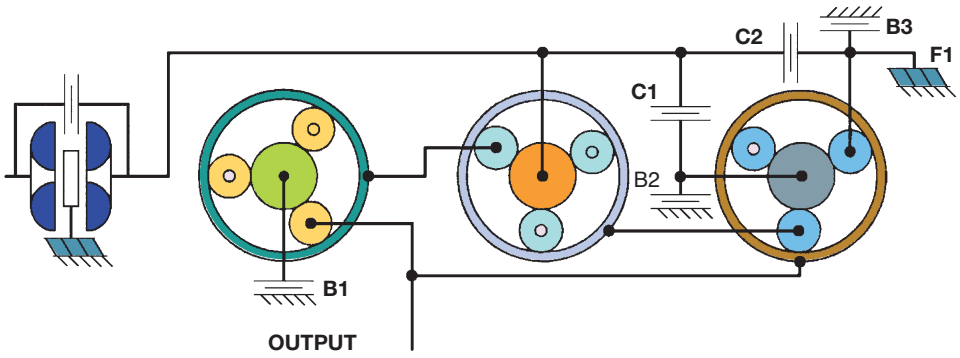
FIGURE 6–28 A schematic view of a type 17, Ford CD4E four-speed gear set.

EIGHT, NINE AND TEN SPEED AUTOMATIC TRANSMISSIONS/ TRANSAXLES

PURPOSE In an effort to achieve improved fuel economy and reduced exhaust emissions, many vehicle manufacturers are using eight, nine or ten speed automatic transmission/ transaxles. By using more gear ratios, the flowing occurs:

1. Improved vehicle performance due to a lower first gear ratio for faster acceleration from a stop.
2. Improved fuel economy because the higher gear ratios are overdrive, which results in the engine speed being reduced at highway speeds.
3. Reduced exhaust emissions due to less engine speed at highway speed due to the overdrive ratios.

SIX, EIGHT, NINE, TEN SPEED GEAR RATIOS The gear sets used in eight, nine and ten speed automatic transmissions are not straight forward, so it difficult to classify these units



JOINT VENTURE 6-SPEED GEARSET

(a)

Joint Venture Gearset							
Range	C1	C2	B1	B2	B3	F1	Ratio
1			X			X	4.48:1
Manual 1			X		X		4.48:1
2			X	X			2.87:1
3	X		X				1.84:1
4		X	X				1.41:1
5	X	X					1:1
6		X		X			0.74:1
Reverse	X				X		2.88:1

(b)

FIGURE 6–29 (a) A schematic view of (a) a type 18, joint venture six-speed gear set and (b) a clutch application chart.

GEAR	SIX SPEED (GM 6L80)	EIGHT SPEED (GM 8L80)	NINE SPEED (ZF9HP)	TEN SPEED (GM/FORD)
First	4.03	4.56	4.71	4.70
Second	2.36	2.97	2.84	2.99
Third	1.53	2.08	1.91	2.15
Fourth	1.15	1.69	1.38	1.80
Fifth	0.85	1.27	1.00	1.52
Sixth	0.67	1.00	0.81	1.28
Seventh	N.A.	0.85	0.70	1.00
Eighth	N.A.	0.65	0.58	0.85
Ninth	N.A.	N.A.	0.48	0.69
Tenth	N.A.	N.A.	N.A.	0.64

CHART 6–4

Notice that gear ratio spread is closer together with the eight, nine and ten speeds compared to the six speed transmission. This means that the engine can be kept at its most efficient speed under most conditions and speeds.

into precise planetary gear set types. Most use more than one compound gear set and in combinations to achieve the desired ratios. Always refer to service information for the detailed description for the transmission or transaxle being serviced. ● **SEE CHART 6–4** for a comparison between the gear ratios used in six, eight, nine, and ten speed automatic transmissions.

RATIO SPREAD The overall ratio spread, the ratio of the shortest gear to the tallest gear, is as follows:

- Six speed- (4.03 first gear divided by 0.67 sixth gear) = 6.0 gear spread
- Eight speed- (4.56 first divided by 0.65 eighth gear) = 7.0 gear spread
- Nine speed transaxle- (4.71 first gear divided by 0.48 ninth gear) = 9.8 gear spread
- Ten speed- (4.70 first gear divided by 0.64 tenth gear) = 7.3 gear spread

The higher the gear spread, the easier the engine speed can be kept within its most efficient RPM (torque band) resulting in the best overall performance with the lowest possible fuel consumption and exhaust emissions.

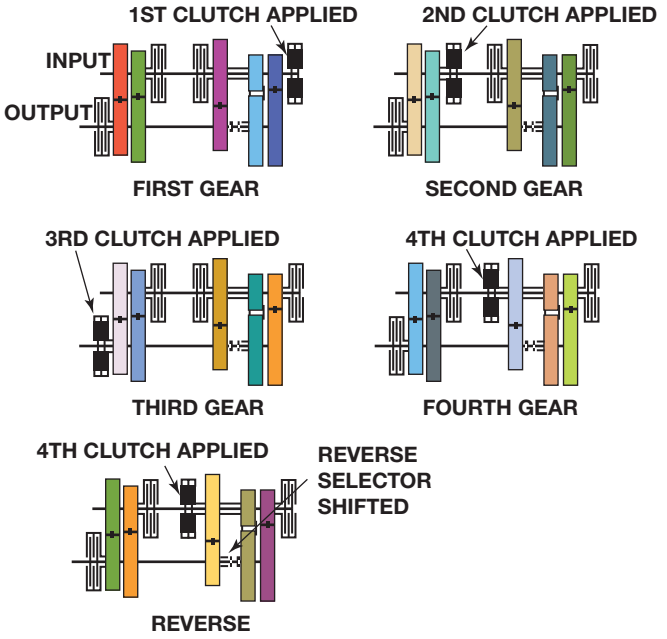


FIGURE 6–30 The shift sequence for a type 19, four-speed transmission showing the apply devices.

NONPLANETARY GEAR SETS

Several automatic transmission designs do not use planetary gear sets. These designs are attempts to produce a smaller, simpler, lighter, and less expensive transmission that will produce better fuel mileage with lower exhaust emissions.

The Hondamatic and the Saturn transaxle automatic transmission (TAAT) use constant-mesh helical gears, much like those in a manual transmission. The major difference is that manual transmissions use a mechanical clutch and synchronizer assemblies that are shifted through manual linkage, and the automatic transmissions use a torque converter and hydraulically applied clutch packs. The power flow for each gear range goes through a pair of gears and each gear range uses a different gear set.

A garage shift into first or reverse is made by applying that particular clutch pack. Upshift and downshift timing and ratio changes are made by applying the next clutch pack while releasing the previous one. All shifts, with one exception, occur with the application of a single clutch pack. The exception is reverse, which requires the movement of the reverse selector and the engagement of the fourth clutch. **SEE FIGURE 6–30.**

SUMMARY

1. The gear set in an automatic transmission must provide a (an)
   - Neutral
   - One or more gear reductions
   - Direct-drive ratio (1:1)
   - Reverse
   - Overdrive
2. In a planetary gear set, the following is done to achieve the various gear ratios and reverse.
   - One of the members is being driven (input).
   - One of the members is being held (reaction member).
   - One of the members is the output.
3. A synchronous design transmission means that during an upshift, the new driving or reaction member must be timed or synchronized with the release of a driving or reaction member.
4. A nonsynchronous transmission is a unit that uses a one-way clutch to allow an upshift that requires only the application of the next driving or reaction member.
5. There are three basic types of planetary gear sets used: Simpson, Ravigneaux, and LePelletier.
6. Combinations of Simpson or Ravigneaux gear sets with a simple planetary gear set will produce four, five, six, eight, or more gear ratios.

REVIEW QUESTIONS

1. In a planetary gear set, what needs to be done to achieve the various gear ratios and reverse?
2. How is a 1:1 ratio achieved using a planetary gear set?
3. What needs to be done with a planetary gear set to achieve neutral?
4. What is the difference between a nonsynchronous and a synchronous design?
5. What type of gears do the Hondamatic and the Saturn transaxle automatic transmission (TAAT) use?

CHAPTER QUIZ

1. How many planet pinions are used in a planetary gear set?
   a. Two
   b. Three
   c. Four
   d. Three, four, or five
2. When are the planet gears fully meshed with the sun gear and ring gear?
   a. All the time
   b. During torque multiplication
   c. During gear reduction
   d. When overdrive is occurring
3. A Simpson gear train consists of _____.
   a. Two sun gears, one planet carrier, and one ring gear
   b. One sun gear, two planet carriers, and one ring gear
   c. One sun gear with two carriers with planet gears and two ring gears
   d. Two sun gears with two planet carriers and one ring gear
4. A Ravigneaux gear set _____.
   a. Uses two carriers that have three sets of planet gears with one sun gear and one ring gear
   b. Combines one carrier that has two sets of planet gears with two sun gears, and one ring gear
   c. Combines one carrier that has one set of planet gears with two sun gears, and two ring gears
   d. Uses two carriers that have two sets of planet gears with two sun gears, and two ring gears
5. LePelletier gear train uses _____.
   a. A Ravigneaux gear set and a simple planetary gear set
   b. Two Simpson gear sets tied together
   c. A Simpson gear set and a simple planetary gear set combined
   d. Two Ravigneaux gear sets combined
6. A Nonsynchronous design _____.
   a. Requires that a clutch or band be released before another clutch is applied
   b. Allows an upshift that requires only the application of the next driving or reaction member
   c. Uses a Simpson gear set only
   d. Uses a Ravigneaux gear set only
7. A synchronous design _____.
   a. Requires that a clutch or band be released before another clutch is applied
   b. Allows an upshift that requires only the application of the next driving or reaction member
   c. Uses a Simpson gear set only
   d. Uses a Ravigneaux gear set only
8. A clutch-to-clutch automatic transmission, such as the Chrysler 41TE, does not use _____.
   a. Roller clutches
   b. Sprags
   c. Bands
   d. All of the above
9. Which transmission is a rear-wheel-drive unit?
   a. 4L60-E
   b. 41TE
   c. 6F60
   d. 4T80-E
10. What type of gears do the Hondamatic and the Saturn transaxle automatic transmission (TAAT) use?
    a. Simpson gear sets
    b. Ravigneaux gear set
    c. Helical cut constant mesh
    d. LePelletier gear set

chapter 7

CLUTCHES AND BANDS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Identify the components of a multiple-disc driving clutch and describe its operation.
3. Identify the components of a one-way driving clutch and describe its operation.
4. Discuss holding clutches and bands.
5. Explain shift quality.

KEY TERMS

Accumulator 103
Belleville plate 104
Clutch-to-clutch 94
Cushion plate 104
Direct clutch 94
Directional grooving 95
Double-wrap band 101
Driving devices 94
Drum 94
Dynamic friction 98
Flex band 101
Freewheel shift 104
Friction plates 95
Front clutch 94
Garage shifts 99
High-reverse clutch 94
Mechanical diode 100
Reaction devices 94
Rigid band 101
Separator plate 95
Shift feel 103
Single-sided plate 98
Static friction 98
Steels 95
Synchronous 94
Wave plate 104

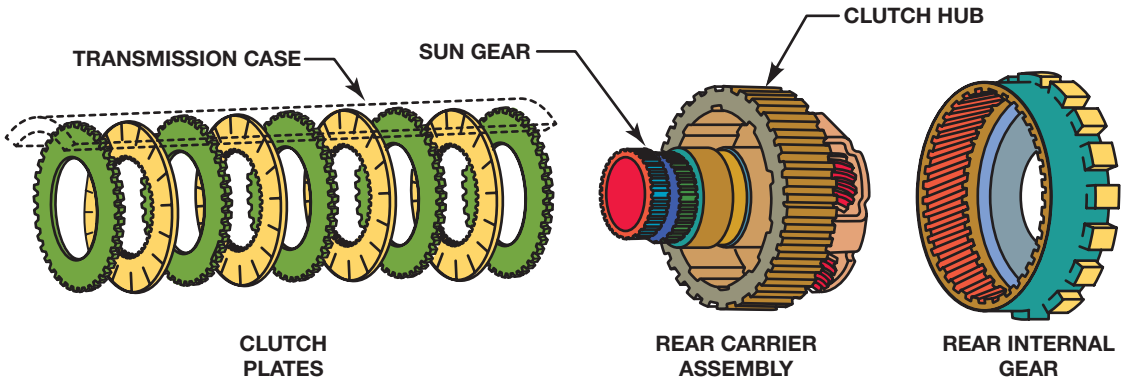


FIGURE 7–1 A multiple-disc clutch can hold, or drive a member of a gear set.

INTRODUCTION

There are several paths for power to flow through an automatic transmission, and each path provides a different gear ratio. These power paths are controlled by clutches and bands, also called driving and reaction members. The **driving devices** connect the turbine shaft from the torque converter to the elements of the planetary gear train. The **reaction devices** connect (lock) a member of the gear train to the transmission case. ● **SEE FIGURE 7–1.**

DRIVING DEVICES

PURPOSE AND FUNCTION

The driving devices provide the input to the planetary gear set. The turbine shaft (which transfers power into the transmission) is normally built as part of, or splined to, one or more of the driving devices.

TERMINOLOGY

Driving devices are usually multiple-plate disc clutches. In most cases, they will be at the front of the transmission, just behind the pump. Although the parts perform the same job, the driving clutches are often given different names by different manufacturers. An example of this involves the two clutches in front of a Simpson gear train transmission.

- Chrysler Corporation calls the first clutch the **front clutch**.
- Ford Motor Company calls it a **high-reverse clutch**.
- General Motors Corporation and Toyota call it a **direct clutch**.
- Toyota commonly calls it C2.

SYNCHRONIZING SHIFTS

Automatic shifts must be timed to happen quickly without the possibility of being in two gears at the same time. A gear set will lock up if it has two ratios at the same time. In order to prevent this from happening, transmission manufacturers adopt the following two strategies:

1. The first strategy is **synchronous**, *overlap*, or **clutch-to-clutch** shifting. This requires that one apply device be timed or synchronized with the application of the apply device for the next gear range.
2. The second strategy is called *nonsynchronous, asynchronous*, or *freewheel shifts*. Nonsynchronous shifts use one or more one-way clutches as driving or reaction devices. A one-way clutch will self-release during a shift as soon as the next clutch applies, eliminating the need to synchronize the shifts.

MULTIPLE-DISC DRIVING CLUTCHES

PARTS INVOLVED

The parts of a clutch assembly include:

- drum
- hub
- lined plates (discs)
- unlined discs (steels)
- pressure plate
- apply piston
- piston return springs.

The **drum**, also called the *housing*, has internal splines that mate with external splines on the steel plates for the externally lugged discs, usually the unlined discs (steels). The inner diameter

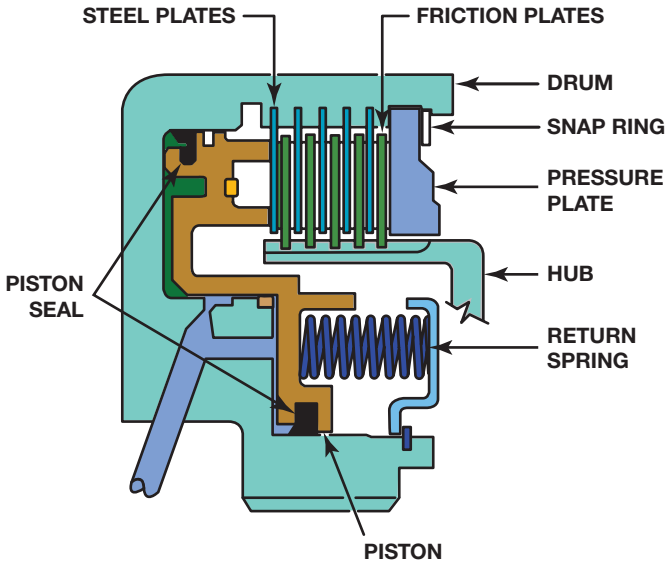


FIGURE 7–2 A sectioned view of a multiple-disc clutch. Note the piston to apply the clutch and the spring(s) to release it.

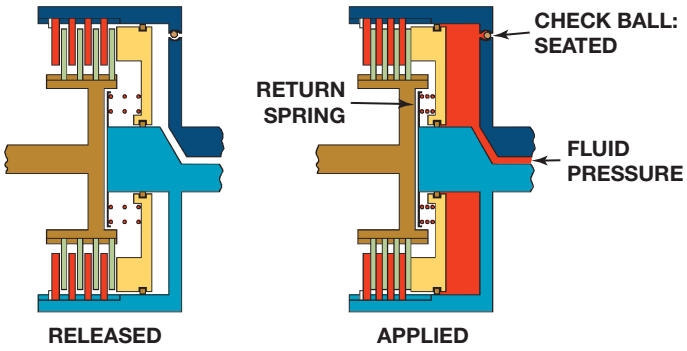


FIGURE 7–3 The apply piston is released (left) by the coil springs. Fluid pressure moves the piston to apply the clutch (right).

of the drum is machined for the apply piston and its inner and outer seals. The drum of the forward clutch is usually built as part of or splined to the input or turbine shaft. A clutch can be built as a single unit or combined with another drum or hub of a second clutch assembly. ● **SEE FIGURES 7–2 AND 7–3.**

CLUTCH PLATES

- The unlined plates are called **steels**, or **separator plates**. They are flat pieces of steel stamped into the desired shape. A steel plate is usually about 0.070 to 0.100 inch (1.78 to 2.54 mm) thick. After being stamped, the plate is carefully flattened. An out-of-flat plate will take up clutch clearance and cause drag while released. An unlined steel plate usually has lugs on its outer diameter to engage with the clutch drum/housing or transmission case. The steel plates used in current automatic transmissions are very smooth and often have a polished appearance with a surface roughness of 12 to 15 microinches. Steel plates have a secondary purpose of serving as heat sinks to help remove heat from the lined friction plates.
- Plates lined with friction material are called **friction plates**, *friction disc*, or simply *frictions*. These plates are also made from stamped steel with lining material bonded to each side. The engagement lugs are usually on the inner diameter. A friction plate is about 0.063 to 0.086 inch (1.6 to 2.2 mm) thick, and the friction material is about 0.015 to 0.030 inch (0.4 to 0.8 mm) thick.

LINING SURFACE

The lining material can have a plain, smooth, flat, or a grooved friction surface. A grooved plate can have one of several groove patterns cut or stamped into the friction material. The grooves help fluid leave or enter between the unlined and lined plates during a shift. The different groove patterns help control the speed with which the fluid leaves the friction area to produce different shift-quality characteristics. The faster the oil leaves, the faster the clutch can apply. However, the longer the oil stays between the plates, the more heat can be absorbed by the oil. Different clutch packs for the same transmission will often use lined plates with different groove patterns. Clutches that apply with the vehicle at rest can be smooth because apply rate is not important. Clutches that are used for upshifts will often have a groove pattern. Some new clutch designs use friction plates with **directional grooving**. These are a slanted groove that must face the proper direction. Some have an inner spline shape that allows the plate to be installed only in the proper direction. ● **SEE FIGURE 7–4.**

FRICTION LINING MATERIALS

Clutch lining material is a mix of natural and man-made fibers, fillers, and binders. The exact mixture is selected to provide the desired clutch apply duration and heat resistance characteristics. Clutch friction material includes the following:

- **Paper**—Paper-based friction material is the most commonly used material and offers smooth and chatter-free performance. ● **SEE FIGURE 7–5.**
- **Aramid (Kevlar)**—This synthetic material is used in clutches that are under heavy stress, such as in heavy-duty vehicle transmissions.

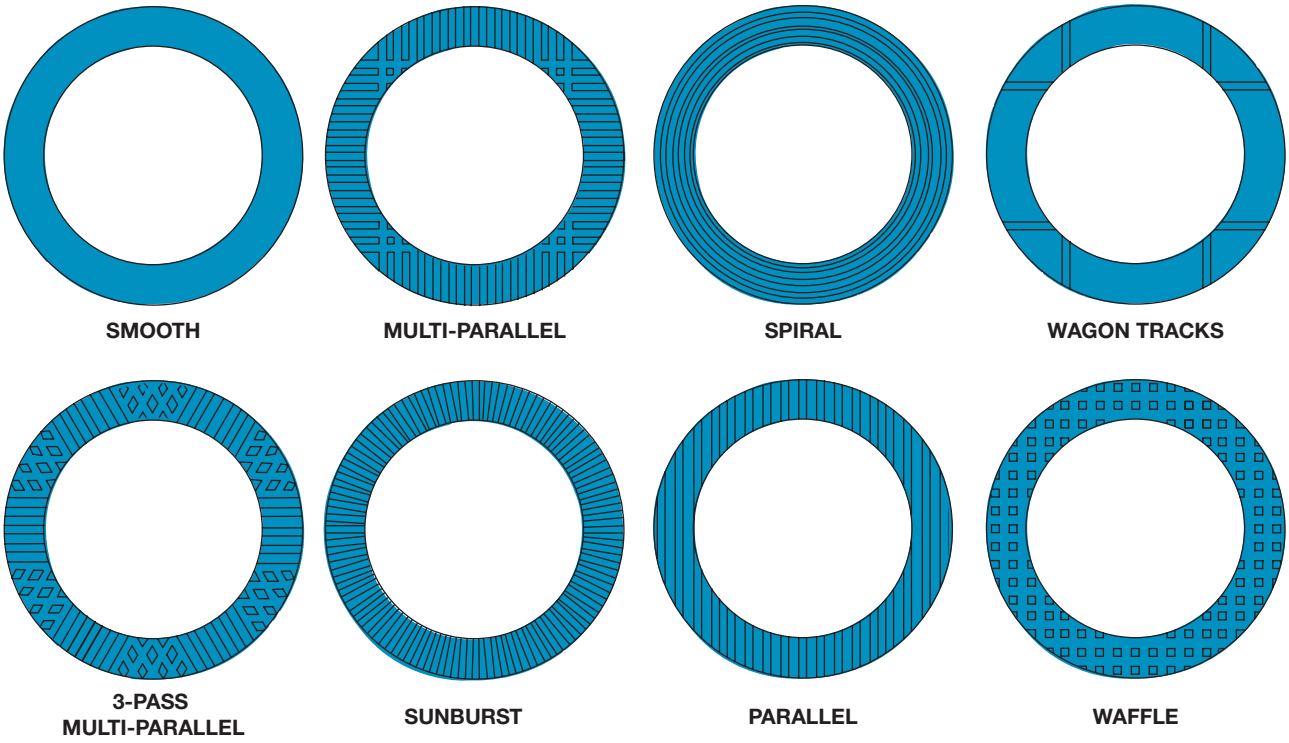


FIGURE 7–4 Friction plates often have a groove pattern to help wipe fluid away, dissipate heat, eliminate clutch noise, and change friction qualities during apply and release. A smooth plate is the coolest and slowest to apply and the waffle plate will apply the fastest.

FIGURE 7–5 Most clutches included in overhaul kits use paper as the basis for the lining material.

Fillers help determine the density, porosity, and flexibility. Some commonly used filler materials include:

- diatomaceous earth
- graphite/carbon
- friction particles

Binders hold the mix together and the most common binder is thermosetting phenolic resin.

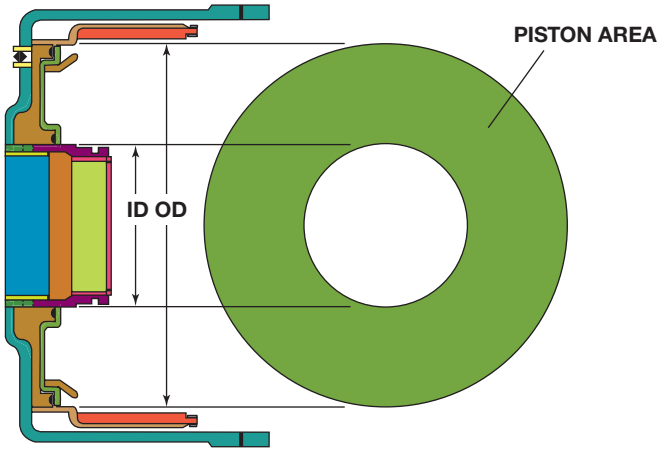
CLUTCH OPERATION

CLUTCH PACK APPLY An automatic transmission shifts when hydraulic pressure applies or releases a clutch. Hydraulic pressure causes the clutch or servo piston to move, taking up the clearance, and then squeezes the parts together. The force that a clutch piston exerts on the clutch plates is a product of piston area multiplied by hydraulic pressure. A rotating, driving clutch has a piston with an outside diameter (OD) of about 6 inches (152 mm) and an inner diameter (ID) that can vary from 2 to 5 inches (102 to 127 mm). ● **SEE FIGURE 7–6.**

Most bands use fairly small servo pistons, which generate less force than a clutch piston. Some transmissions are designed so that several different servo piston diameters can be used. ● **SEE FIGURE 7–7.**

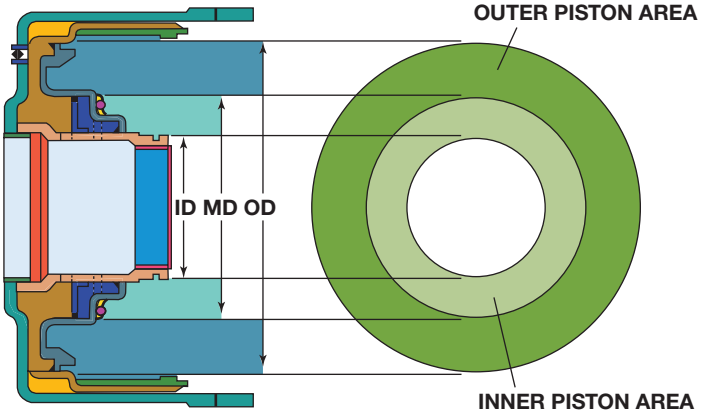
PRESSURE BALANCED RELEASE Traditionally, clutches are released by the spring(s), but this might be too slow in recent clutch-to-clutch transmissions. ● **SEE FIGURE 7–8.**

The clutch is applied when fluid pressure is sent to the apply side of the piston. Releasing pressure from the apply side



PISTON AREA: 6" OD = 28.27 cu. in. (3 × 3 × 3.1416)
3" ID = –7 cu. in. (1.5 × 1.5 × 3.1416)
AREA = 21.27 cu. in.

FIGURE 7–6 A typical clutch piston area is determined by subtracting the area of the inner diameter from the area of the outer-circle diameter.



OUTER PISTON AREA:
6" OD = 28.27 cu. in.
4" MD = –12.56 cu. in.
AREA = 15.71 cu. in.

INNER PISTON AREA:
4" MD = 12.56 cu. in.
3" ID = –7 cu. in.
AREA = 5.56 cu. in.

FIGURE 7–7 Some clutch pistons use a middle seal so the piston will have two working areas.

and sending fluid pressure, also called *compensator* or cancel pressure, to the release side produces a precisely controlled clutch release. ● **SEE FIGURE 7–9.**

CLUTCH PACK RELEASE The clutches are flooded with transmission fluid while released, and during application this fluid prevents any heat generated by friction from overheating the lining. Theoretically, there will always be a film of fluid between the friction and steel plates.

Manufacturers often provide some means of adjusting the released clearance in a clutch pack. There must be sufficient

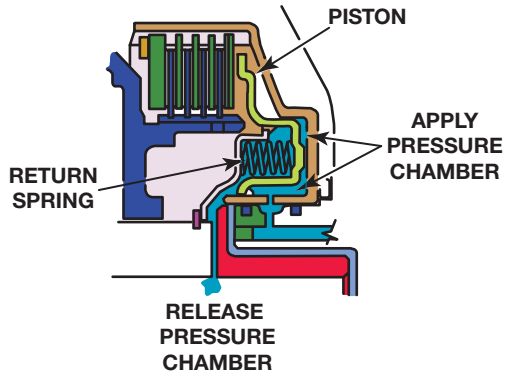


FIGURE 7–8 The baffle that supports the return springs also forms a chamber for release pressure. The clutch is released when fluid pressure enters this chamber as pressure is released from the apply side of the piston.

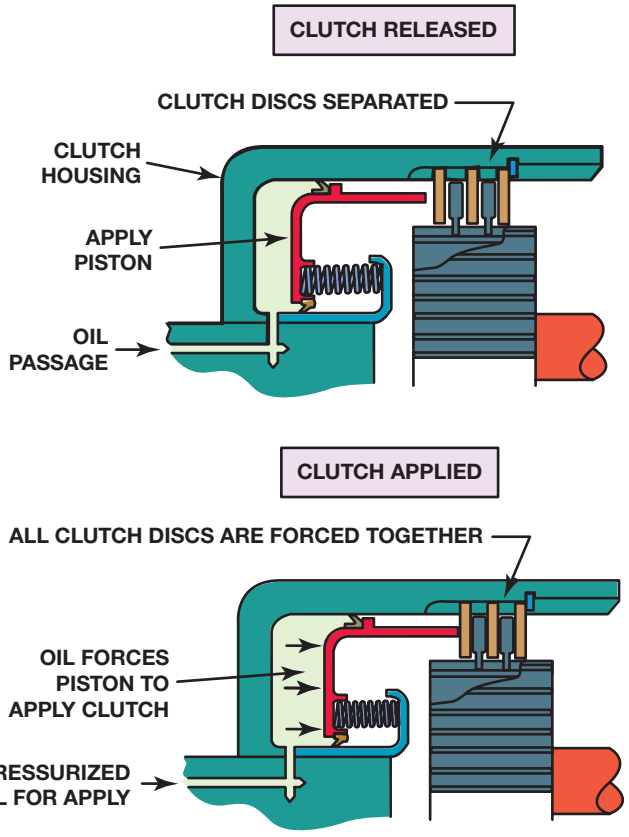


FIGURE 7–9 Pressurized oil is sent to the apply side of the piston to force the clutch discs together.

clearance between the plates to ensure that there is no drag when released. This clearance should be about 0.010 to 0.015 inch (0.25 to 0.38 mm) between each friction surface-lined and unlined plate. Clutch pack clearance is also called *piston travel*. Common methods of adjusting clutch pack clearance are selective size retaining rings, pressure plates, and steel plates. A selective part is available in several thicknesses, and when a clutch is assembled, the correct width or thickness is selected. ● **SEE FIGURE 7–10.**

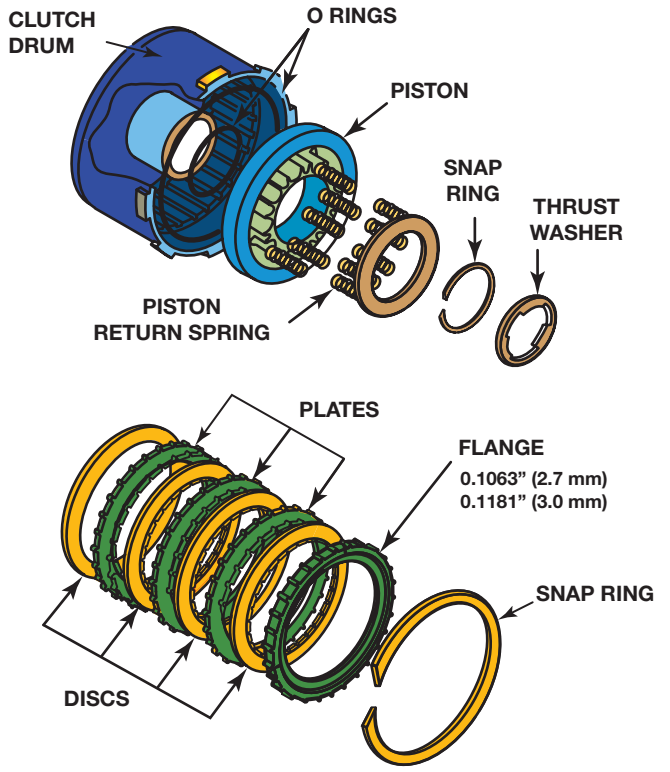


FIGURE 7–10 Clutch stack clearance is adjusted using either the large or the small flange (backing plate). Other clutches may use a selective snap ring.

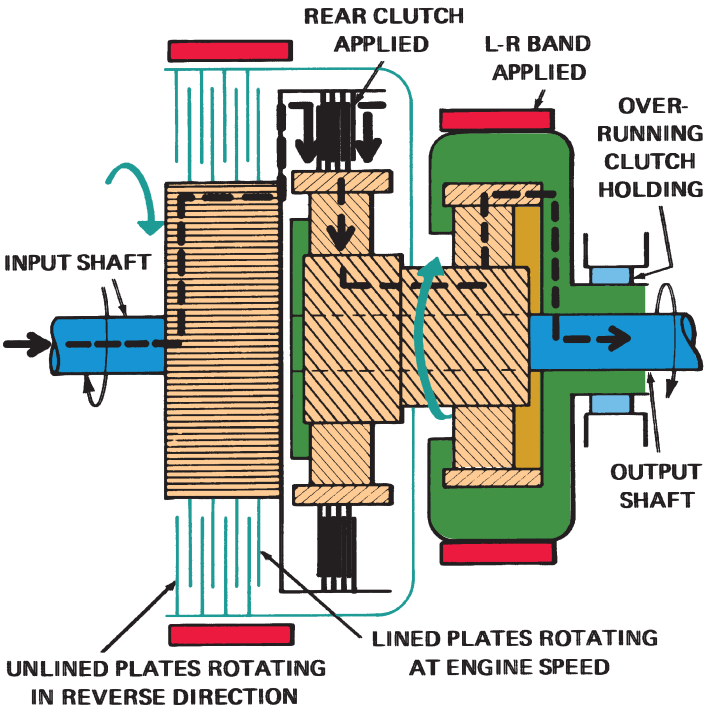


FIGURE 7–11 When this transmission is in first gear, the sun gear and unlined plates of the front clutch rotate counterclockwise while the hub and lined plates of this clutch rotate clockwise. Any drag will produce heat that can cause clutch burnout.

DOUBLE AND SINGLE-SIDED FRICTION PLATES

Single-sided plates have friction material on one side only, and half of the plates have lugs on the inner diameter while the other half have them on the outer diameter. Single-sided plates run cooler than two-sided plates, a feature that allows for more power transfer. The plates can be made thinner so that more plates can be put into a clutch pack. Single-sided plates have encountered problems of uneven heating because one side gets hotter, and the plate tends to deform into a conical shape. This problem has been solved by mechanically distorting the plates slightly or by specially designed grooves cut in the end plates.

FORCES INVOLVED When a clutch is applied, the plates are squeezed together and torque is transferred from the friction plates to the steel plates. The amount of torque that can be transferred is determined by the following factors: diameter and width of the friction surfaces, number of friction surfaces (two per lined plate), and the amount of force being applied (hydraulic pressure times the piston area). The greater the plate area, number of plates, piston size, or hydraulic pressure, the greater the torque capacity.

When a clutch is released, there must be clearance between the plates. There is often a considerable speed differential between the friction and steel plates. For example, during first gear in a Simpson gear train, the sun gear revolves at a 2.5:1 ratio in reverse (counterclockwise). Imagine the speed difference between a released high-gear clutch with the input shaft, clutch hub, and lined plates revolving at an engine speed of 3000 RPM in a clockwise direction and the drum and the unlined plates turning at 7500 RPM in a counterclockwise direction. Without sufficient clearance and lubrication, these plates would drag, create friction, and overheat. The oil flow through the grooves and between the plates helps cool the friction surfaces. ● **SEE FIGURE 7–11.**

STATIC AND DYNAMIC FRICTION A transmission engineer is concerned with three different friction conditions in a clutch:

1. While the clutch is released, there should be no friction or drag.
2. While applied, there should be sufficient **static friction** to transfer torque without slippage.
3. While applying, there should be the proper **dynamic friction** to get a good, smooth shift.

The amount of friction between two objects or surfaces is commonly expressed as a value called the *coefficient of friction* and is represented by the Greek letter μ (mu). The coefficient of friction, also referred to as the friction coefficient, is determined by dividing tensile force by weight force. The tensile force is the

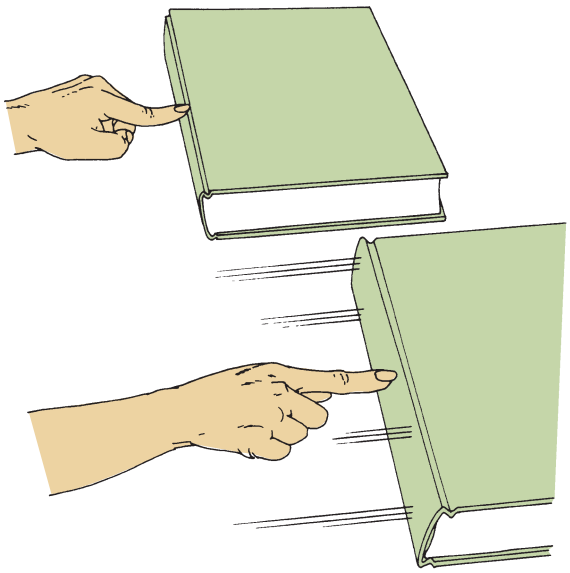


FIGURE 7–12 When pushing against a stationary book, the static friction resists motion. Pushing against the same book while it is sliding is easier because the dynamic friction is less.

pulling force required to slide one of the surfaces across the other. The weight force is the force pushing down on the object being pulled. ● **SEE FIGURE 7–12.**

The friction characteristics of a clutch are designed to work with the friction characteristics of the transmission fluid.

GARAGE SHIFTS Some clutches in an automatic transmission are applied while the vehicle is at rest. The neutral-to-drive and neutral-to-reverse shifts are called **garage shifts**.

- The clutches for first or reverse gear need a high amount of static friction because of the amount of torque required to get the vehicle moving. The garage shifts can occur slowly so they are usually less severe than the 1–2, 2–3, or 3–4 shifts; they may take 3 or 4 seconds to apply.
- Clutches that are applied while the vehicle is in motion are called *power shift* elements. They are applied under power and have to transfer substantial torque as they are applied. These clutches must have a high dynamic coefficient of friction.

ONE-WAY DRIVING CLUTCHES

PURPOSE AND FUNCTION In most transmissions, a one-way clutch allows rotation in a clockwise direction but blocks counterclockwise rotation.

? FREQUENTLY ASKED QUESTION

What Is Wet Friction?

Wet friction occurs because ATF fills the space between the clutch plates. This ATF film transmits torque between the clutch plates as the clutch is being applied. The action of the film of fluid is called *fluid shear*.

As the clutch is applied, the clutch plate clearance is reduced as the fluid is squeezed from between the plates, leaving a film of fluid. This hydrodynamic film begins transferring torque. Fluid shear, which is the resistance to motion, is the primary torque transmitting force at the start of a shift. As the plate clearance is reduced, fluid viscosity increases and its resistance to shear increases. The clutch plates make physical contact at the end of application. Since there is no movement between the plates at this time, friction lining wear is minimized.

- Applying and holding in a one-way clutch is often referred to as holding or being *effective*.
- Releasing it is called ineffective or *noneffective*.

ROLLER CLUTCH A roller clutch is made up of a smooth inner race, a ramped outer race, a series of rollers and energizing springs, and a cage or guide to contain the springs. Some roller clutches are made with a ramped inner race and a smooth outer race. Each roller fits in the ramp or cam section of the race. An energizing spring pushes the roller so there is a light contact between the roller, the ramp, and the smooth race. Counterclockwise rotation of the hub will wedge the rollers so they become locked between the inner and outer races. When locked, they will block any further rotation in that direction. Clockwise rotation will unwedge the rollers, and each roller will simply rotate, much like a roller bearing. The inner hub will rotate freely or overrun in a clockwise direction. ● **SEE FIGURE 7–13.**

SPRAG CLUTCHES A sprag clutch uses smooth, hardened inner and outer races and a series of sprags that are mounted in a special cage. A sprag is an odd-shaped part that somewhat resembles an hourglass or fat letter *S* when viewed from the end. A sprag has two effective diameters. The major diameter is greater than the space between the inner and outer races, and the minor diameter is smaller than this space. The sprags are mounted in a cage that spring loads each sprag in a direction to "stand up" or wedge the major diameter between the two races. A clockwise rotation of the inner race causes the

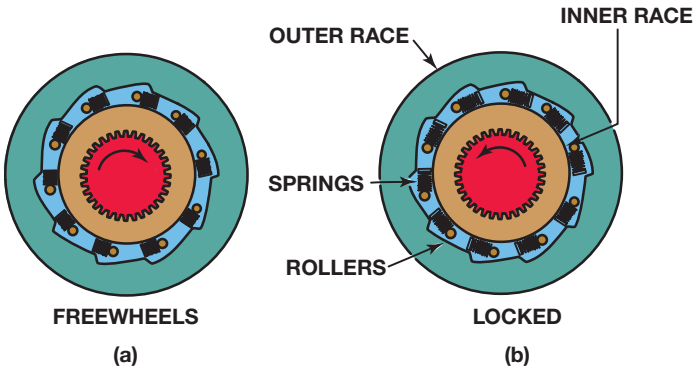


FIGURE 7–13 (a) Roller one-way clutch in released (free) position. When the inner roller clutch race rotates faster than the outer support, the rollers move out of the wedge and are free to rotate, thereby unlocking the one-way clutch. (b) Roller one-way clutch in the locked (held) position. Note how the rollers are wedged into the ramp that is machined into the outer support.

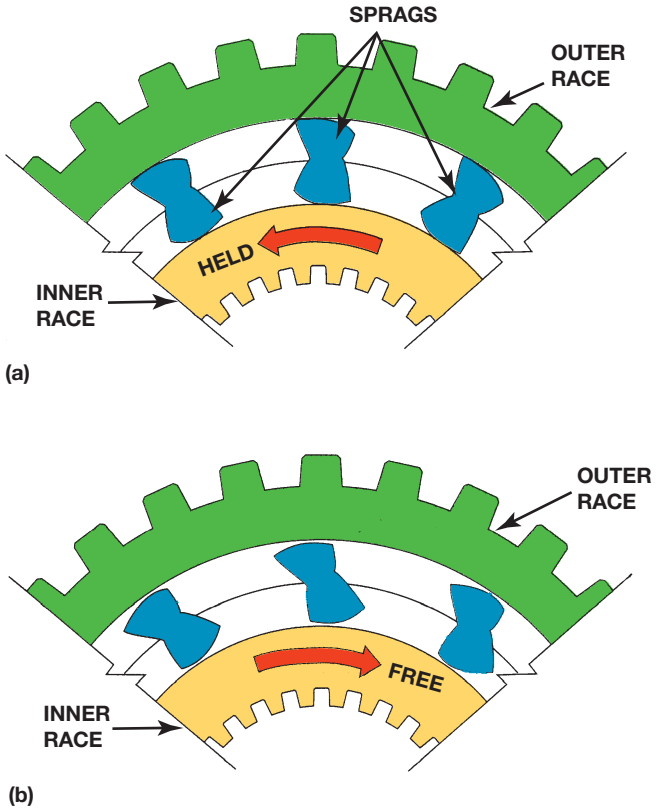


FIGURE 7–14 (a) The sprag in the holding (locked) position. Note how the long portion of the sprag is wedged between the inner and outer race. (b) The sprag in the released position. The inner race is free to rotate faster than the outer race.

sprags to rotate in the stand-up direction. This causes them to wedge firmly between the two races and lock the races together. A counterclockwise rotation of the inner race rotates the sprags in the opposite (laydown) direction. Each sprag tends to lie down so its minor diameter is between the races, and the inner race rotates freely. ● **SEE FIGURE 7–14.**

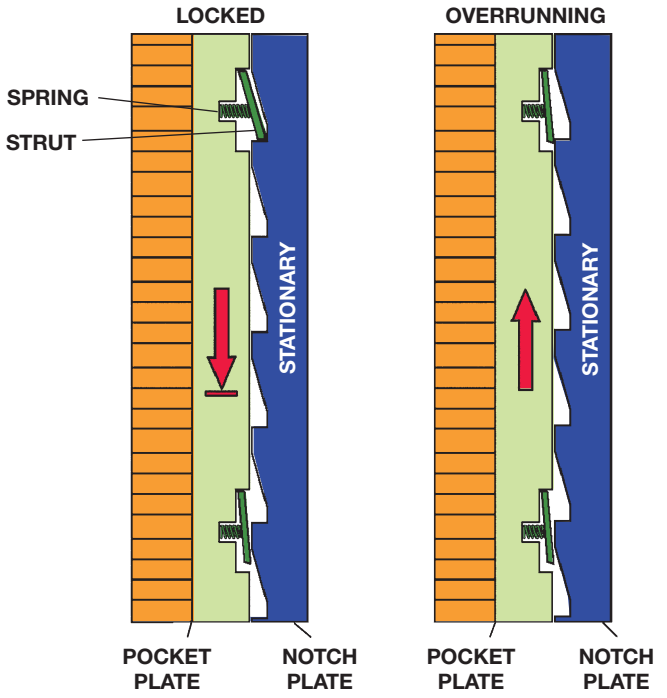


FIGURE 7–15 A mechanical diode. The struts can move out of the pocket plate to engage the notch plate, and this will lock the pocket plate. The pocket plate can overrun in the opposite direction.

MECHANICAL DIODE

A **mechanical diode** is a type of one-way clutch. It uses spring-loaded, rectangular struts in the face of one clutch ring, called the pocket plate that can engage notches in the face of another ring, called the notch plate. The struts are pushed into their pockets when the clutch is overrunning, and they can move outward, about 15 degrees, to engage the notch plate to lock up. Because the compressive forces through the strut are in the load direction, only one or two of the struts need to engage. A mechanical diode is much stronger than a roller or sprag clutch. ● **SEE FIGURE 7–15.**

ONE-WAY CLUTCH OPERATION

A one-way clutch can be placed as an input to a gear set. In transmissions like the Ford 5R55E, a one-way clutch is always driving the forward planetary gear set at input shaft speed. In other transmissions, such as the General Motors 4T65-E, one-way clutches are driven through multiple-disc clutches to become effective in first and third gears. One-way clutches will overrun as the transmission shifts into the next higher gear. ● **SEE FIGURE 7–16.**

HOLDING/REACTION DEVICES

PURPOSE AND FUNCTION

A holding member acts as a brake to hold a planetary gear set member in reaction. Three types of holding devices are used: multiple-disc clutches,

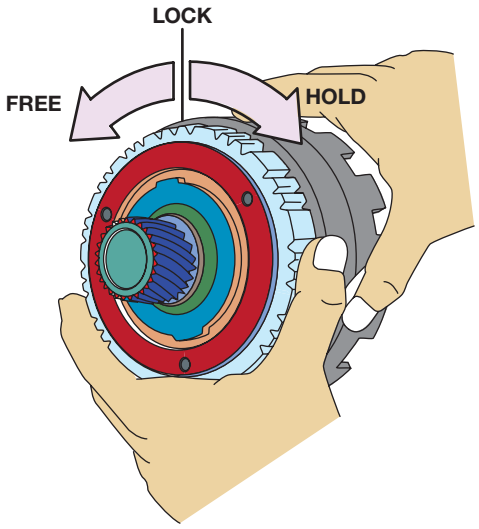


FIGURE 7–16 This clutch hub and sprag clutch should rotate freely in a counterclockwise direction but should lock up in the opposite direction.

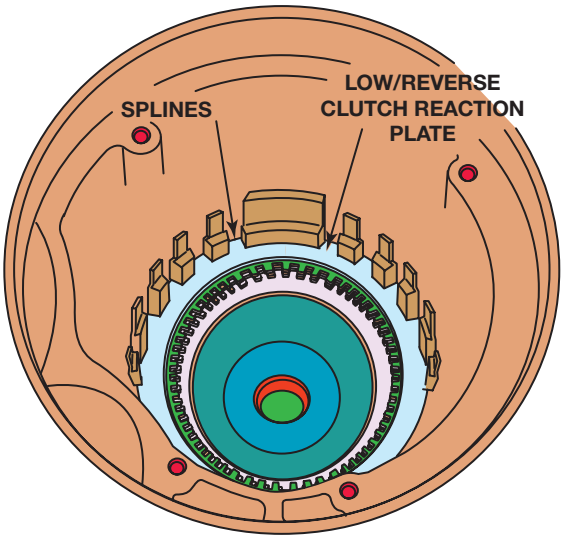


FIGURE 7–17 The 41TE transaxle low/reverse clutch is a holding clutch. Note the splines in the case for the clutch plates.

FREQUENTLY ASKED QUESTION

What Is a Clutch-to-Clutch Type Transmission?

A clutch-to-clutch transmission or transaxle is a unit that does not use one-way clutches and instead just uses multiple-plate clutches for all clamping functions. A Chrysler 41TE transaxle is an example of a clutch-to-clutch automatic transmission. The primary reason for not using one-way clutches is that the metal particles that are detached from these assemblies are attracted to the magnetic solenoids. These particles can clog the screens and reduce the flow of fluid through the solenoid valves. This leads to many types of transmission or transaxle failures that are prevented by not using steel-on-steel units such as roller clutches or mechanical diodes.

bands, and one-way clutches. Multiple-disc clutches and bands are applied by hydraulic pressure and are controlled by the valve body. A one-way clutch is mechanically controlled; it allows rotation in one direction only.

HOLDING CLUTCHES

PURPOSE AND FUNCTION A multiple-disc holding clutch is quite similar to a driving clutch. The difference is that the transmission case is the clutch drum, and the clutch plates splined to it do not rotate. Some manufacturers call these clutches a *brake*.

PARTS AND OPERATION The lugs on the outside of the unlined plates fit into slots built into the case. ● **SEE FIGURE 7–17.**

Like a driving clutch, the lugs on the inner diameter of the lined plates fit over the hub, which is often a part of the planetary gear train or the outer race of a one-way clutch.

The hydraulic piston can be built into the case, at the back of the front pump assembly, or in a center support. The stationary position of the piston and cylinder makes it relatively easy to provide fluid to it. Like a driving clutch, the piston is normally returned to a released position by springs.

ONE-WAY HOLDING CLUTCHES One-way clutches are commonly used as reaction devices. The outer race is often secured directly to the transmission case so it cannot rotate.

BANDS

PURPOSE AND FUNCTION The purpose of a band is to prevent rotation of the drum it is wrapped around. The drum can be a member of the planetary gear train.

TYPES A band is a circular strip of metal that has lining bonded to the inner surface. It wraps around the smooth surface of a drum. There are three types of bands:

1. A single thick, heavy band, also called a **rigid band**.
2. A single thin, light band, also called a *flexible* or **flex band**.
3. A split, **double-wrap**, heavy band. ● **SEE FIGURE 7–18.**

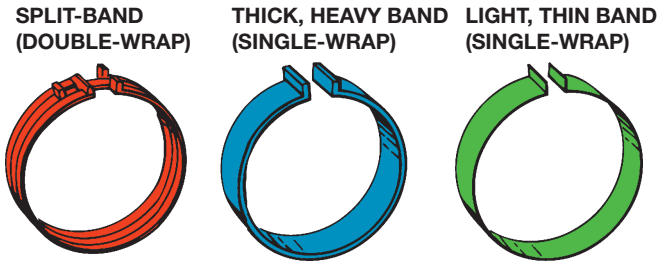


FIGURE 7–18 Transmission bands come in several designs and thicknesses.

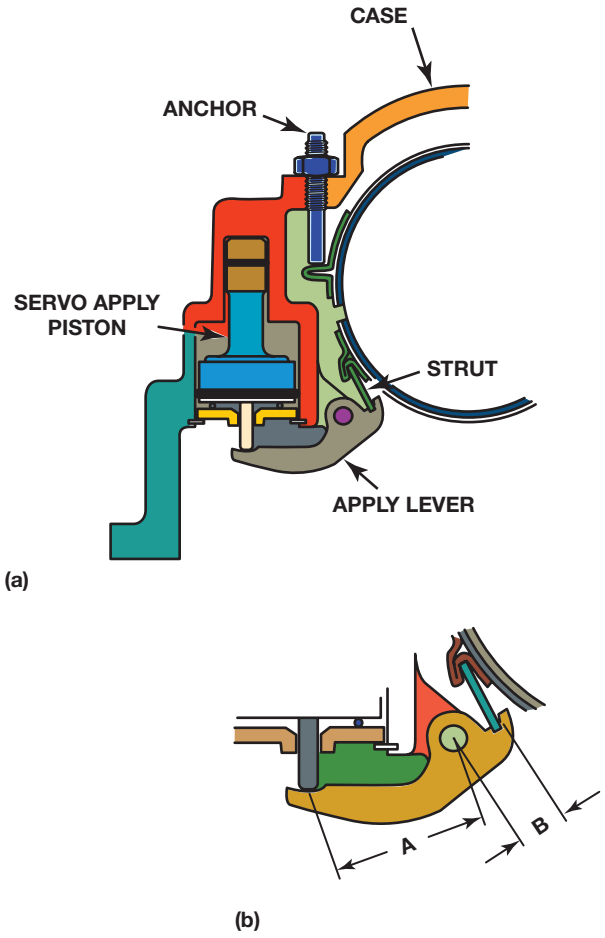


FIGURE 7–19 (a) This band uses an adjustable anchor that allows the clearance to be easily adjusted. (b) Note that the apply lever will increase apply force.

A rigid band is strong and provides a good heat sink to absorb some of the friction heat during application. The disadvantage with a rigid band is that it is relatively expensive and does not always conform to the shape of the drum. A flex band is less expensive and, because of its flexibility, can easily conform to the shape of the drum. Double-wrap bands give more holding power, and are often used for reverse or manual first gears. Each band type has end lugs so it can be attached to the anchor and the servo. A small link, commonly called a *strut*, is often used to connect the lugs of the band to the anchor or the servo piston rod. ● **SEE FIGURE 7–19.**

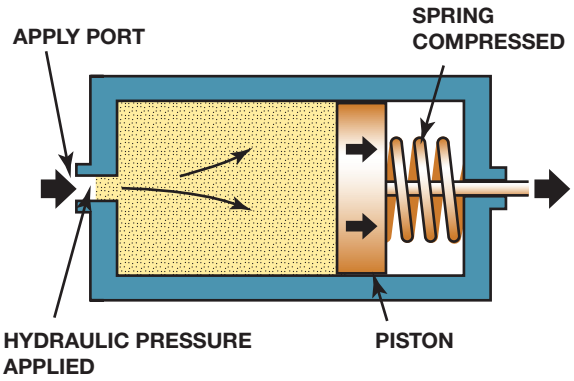


FIGURE 7–20 A servo uses hydraulic pressure to move a piston, which applies a band.

FRICTION MATERIALS ON BANDS The friction material used on a band is similar to that used on clutch plates. Paper and cloth-based materials are normally used. The drum must be a smooth cylinder with straight sides in order to have complete contact with the band lining. The lining surface of the band is often grooved to help control fluid flow during apply and release operations. Similar to a clutch, band friction material and grooving are designed to operate with a specified fluid to ensure good shift quality and long life.

SERVOS The servo is the hydraulic assembly that applies the band. Its main components include a

- cylinder
- piston
- piston rod/pin
- return spring

● **SEE FIGURE 7–20.**

The piston rod pushes directly on the end of the band on most servos. Some servo pistons are connected to the band through a lever or linkage attached to the band strut.

A band lever provides a force increase because of the lever ratio. The ratio will require more piston travel to apply the band and increases the application force acting on the end of the band. Some manufacturers incorporate a band adjustment screw in the apply lever. Other manufacturers use selective-size servo piston rods for band adjustment. ● **SEE FIGURE 7–21.**

ADJUSTMENT The anchor for the band can be a fixed or adjustable point in the transmission case. Some bands have an adjustable anchor, which provides a method of adjusting the clearance between the band and the drum. The bands that are adjustable are usually the rigid bands that have thick lining. Most bands use thin linings and are not adjustable. There must be

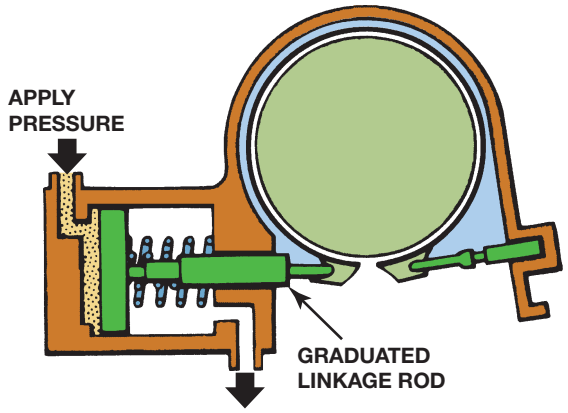


FIGURE 7–21 One end of a band is held stationary and the other end is attached to the servo.

enough clearance to ensure there is no band-to-drum contact with the band released, but too much clearance might cause slippage if the band does not apply completely. A band that is too loose or too tight has an adverse effect on shift timing.

BAND OPERATION When fluid pressure enters the servo, the servo piston moves, tightening the band around the drum. The amount of torque that a band can absorb before slipping is determined by the band-to-drum contact area, type of band, drum diameter, fluid type, and the force squeezing the band onto the drum.

When a band releases, the servo piston backs off, and the springy, elastic nature of the band causes it to move away from the drum. A servo piston can be released by either spring pressure and/or hydraulic pressure.

- When the shift has to be made to neutral, the release speed is not important. Normally, servos use only a release spring.
- During an upshift, the band release must be fast and carefully timed. The release of many bands is done by using fluid pressure from the clutch being applied. For example, in a Simpson gear train transmission during a 2–3 shift, the fluid pressure to apply the third-gear clutch is also used to release the second-gear band.
- During a downshift, band apply must be quick and firm. ● **SEE FIGURE 7–22.**

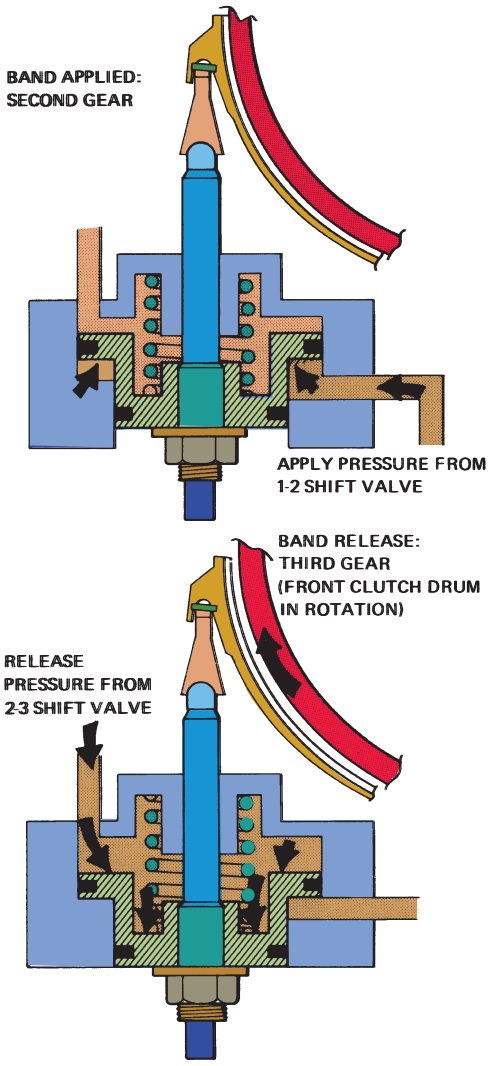


FIGURE 7–22 In this example, the band is applied when 1–2 shift valve pressure pushes upward on the servo piston (top). It will release when 2–3 shift valve pressure pushes the piston downward (bottom). Note the larger area above the piston.

SHIFT QUALITY

TERMINOLOGY As a power shift occurs, there must be a smooth transition from one apply device to the next. The smoothness of the shift is referred to as shift quality or **shift feel**.

A shift should be smooth without any unusual noises. In order for this to occur, the clutches and bands must apply smoothly and quietly. The timing of the band releasing from second gear and the clutch applying for third gear must be precise. Any improper noises such as squeaks, squawks, shrieks or operations such as engine RPM flare, jerks, bumps, or harsh application are considered faults that need to be corrected.

ACCUMULATORS An **accumulator** is tied hydraulically to the clutch or band servo, and absorbs fluid during the pressure buildup stage when a clutch or band applies. This has the effect of slowing the pressure increase and lengthening the time it takes for the friction device to lock up. ● **SEE FIGURE 7–23.**

FIGURE 7–23 A band accumulator piston and spring being removed from a GM 4T65-E.

As clutch or band apply pressure is entering the apply side of the accumulator, fluid must leave the opposite, exhaust side of the accumulator piston. The pressure on the apply side and rate of stroke depends on how easily the fluid leaves the exhaust side. An accumulator valve or shift control valve is often placed in the accumulator exhaust passage. The shift must be completed before the accumulator completes its stroke. If the accumulator piston reaches the bottom before the shift is complete, there will be a sudden pressure increase that will cause a *slide-bump shift*. This is a shift with poor quality that starts smooth, but ends harsh.

WAVE PLATE

Clutch shift quality is controlled by the type of lining material and grooving, the use of wave or Belleville plates, the type of fluid used, and the speed at which fluid moves the piston.

A **wave plate** is an unlined plate that is wavy, not flat. A **Belleville plate**, like a Belleville spring, is also not flat. These are often called **cushion plates**. ● **SEE FIGURE 7–24.**

If either plate is used in a clutch pack, it will be placed between the piston and the first unlined plate or between the last unlined plate and the pressure plate. Both plates are designed to compress slightly under pressure during clutch application. The result is to slightly prolong the clutch apply time.

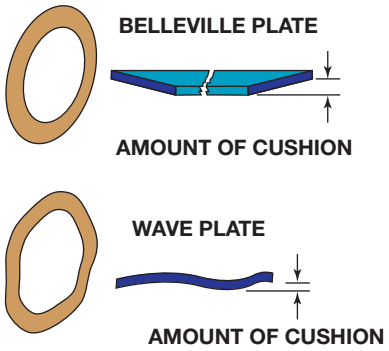


FIGURE 7–24 Two cushion plates: The Belleville plate has a coned shape; the wave plate has a wavy shape. Both of them will flatten slightly as the clutch is applied.

Many transmissions do not use Belleville or wave plates. Hydraulic controls (accumulators and orifices) are used to control piston movement and produce the desired shift quality. Electronically controlled transmissions have even greater ability to alter shift quality. The shift solenoids and hydraulic pressure control solenoids can be turned off and on, or cycled to produce the desired shifts.

SHIFTS INVOLVING ONE-WAY CLUTCHES

A one-way clutch is an ideal driving or reaction member for automatic shifts. It applies or holds when it is needed and self-releases or overruns when it is not needed. Its operation is controlled by the load direction on the inner or outer race so shift timing is automatic. When the transmission upshifts, the reaction or driving member for the next gear is applied, and the one-way clutch simply overruns. This is called a nonsynchronous or asynchronous shift and the shift elements do not need to be synchronized. It is also called a **freewheel shift**.

DECELERATION WITH ONE-WAY CLUTCHES

When the throttle is released while in a gear that uses a one-way clutch, the transmission will go into neutral as the one-way clutch overruns. This action is good if the vehicle is coasting to a stop, but can be a problem if going down a steep hill.

SUMMARY

1. The power flow through a gear set is controlled by driving and reaction devices.
2. The driving and reaction devices are multiple-disc clutches, one-way clutches, and bands.
3. Multiple-disc clutches are the primary driving devices and are also used to hold planetary members in reaction.
4. One-way clutches are primarily used to hold planetary members in reaction, but can be used with a multiple-disc clutch as a driving device.
5. Bands are used to hold a planetary member in reaction.
6. The timing of the apply devices has a direct effect on shift quality.

REVIEW QUESTIONS

1. What is the difference between a driving device and a reaction device?
2. What is a "clutch-to-clutch" type transmission?
3. What parts are included in a typical clutch pack assembly?
4. Why do some clutch discs use friction material on only one side?
5. What is the purpose and function of an accumulator?

CHAPTER QUIZ

1. The _____ connects the turbine shaft from the torque converter to the elements of the planetary gear train.
   a. Reaction devices **c.** Driving devices
   b. Accumulator **d.** Servo
2. The _____ connect (lock) a member of the gear train to the transmission case.
   a. Reaction devices **c.** Driving devices
   b. Accumulator **d.** Servo
3. The apply device that is most commonly used as a driving member is a _____.
   a. Cone clutch **c.** One-way clutch
   b. Multiple-disc clutch **d.** Band
4. Plates lined with friction material are called _____.
   a. Friction disc **c.** Friction plates
   b. Simply frictions **d.** Any of the above
5. Some clutches in an automatic transmission are applied while the vehicle is at rest. This application of the clutch(es) is often called a _____ shift.
   a. Static **c.** Synchronous
   b. Garage **d.** Nonsynchronous
6. The lining material most often used is made from _____.
   a. Paper
   b. Asbestos
   c. Inorganic fibers
   d. Any of the above depending on application
7. Typical clearance should be about _____ between each friction surface-lined and unlined plate.
   a. 0.001 to 0.005 inch (0.025 to 0.012 mm)
   b. 0.010 to 0.015 inch (0.25 to 0.38 mm)
   c. 0.020 to 0.035 inch (0.050 to 0.090 mm)
   d. 0.050 to 0.075 inch (1.3 to 1.9 mm)
8. What is an example of a one-way clutch?
   a. Multi-clutch pack
   b. Band
   c. Roller clutch
   d. Accumulator
9. The torque-carrying capacity of a clutch is determined by the _____.
   a. Number of plates
   b. Amount of lining area on the plates
   c. Amount of pressure squeezing the plates together
   d. All of the above
10. How does an accumulator work?
    a. Slows the application of the clutch or band
    b. Includes a solenoid to apply a clutch
    c. Supplies high-pressure ATF to a band so it applies quickly
    d. Accumulates extra ATF for use when it is low in the case of a leak

chapter 8

DRIVETRAIN ELECTRICITY AND ELECTRONICS

LEARNING OBJECTIVES

After studying this chapter, the reader should be able to:

1. Explain the characteristics of electricity.
2. Differentiate between conductors, insulators, and semiconductors.
3. Explain the units of electrical measurement.
4. List the parts of a complete circuit.
5. Discuss the types of electrical circuit faults.
6. Explain how to detect and measure electrical voltage, current, and resistance.
7. Discuss the purpose and function of terminals, connectors, relays, and switches.
8. Explain the operation of speed sensors and throttle position (TP) sensors.
9. State the need for networks and discuss network classifications.

KEY TERMS

Ammeter 118
Ampere 109
Conductors 108
Connector 120
Conventional theory 109
Crimp-and-seal connectors 122
Digital multimeter (DMM) 116
Digital volt-ohm-meter (DVOM) 116
Electricity 107
Electron theory 109
Hall Effect 125
High resistance 113
Insulators 108
Node 127
Ohmmeter 117
Ohms 110
Open circuit 112
Potentiometer 126
Relay 123
Schematic 111
Short-to-ground 113
Short-to-voltage 112
Semiconductor 109
Terminal 120
Volts 110
Voltmeter 116

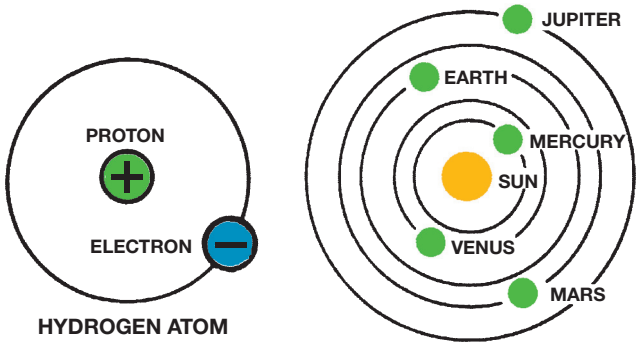


FIGURE 8–1 In an atom (left), electrons orbit protons in the nucleus just as planets orbit the sun in our solar system (right).

INTRODUCTION

The electrical system is one of the most important systems in a vehicle today. Every year more and more vehicle components and systems use electricity.

Electricity may be difficult for some people to learn for the following reasons.

- It cannot be seen.
- Only the results of electricity can be seen.
- It has to be detected and measured.

ELECTRICITY

BACKGROUND Our universe is composed of matter, which is anything that has mass and occupies space. All matter is made from slightly over 100 individual components called elements. The smallest particle that an element can be broken into and still retain the properties of that element is known as an atom. ● **SEE FIGURE 8–1.**

DEFINITION **Electricity** is the movement of electrons from one atom to another. The dense center of each atom is called the nucleus. The nucleus contains

- Protons, which have a positive charge
- Neutrons, which are electrically neutral (have no charge)
- Electrons, which have a negative charge, orbit the nucleus. Each atom contains an equal number of electrons and protons.

NOTE: As an example of the relative sizes of the parts of an atom, consider that if an atom were magnified so that the nucleus were the size of the period at the end of this sentence, the whole atom would be bigger than a house.

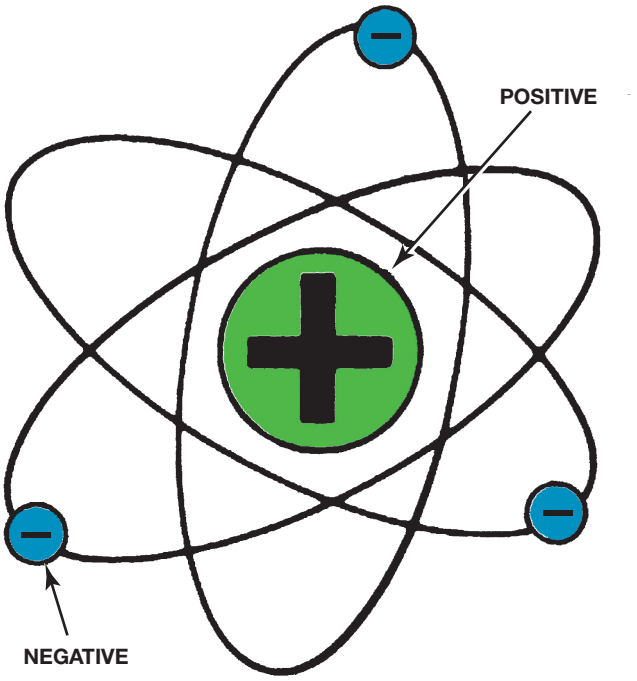


FIGURE 8–2 The nucleus of an atom has a positive (+) charge and the surrounding electrons have a negative (–) charge.

POSITIVE AND NEGATIVE CHARGES The parts of an atom have different charges. The orbiting electrons are negatively charged, while the protons are positively charged. Positive charges are indicated by the "plus" sign (+), and negative charges by the "minus" sign (–). ● **SEE FIGURE 8–2.**

These same + and – signs are used to identify parts of an electrical circuit. Neutrons have no charge at all. They are neutral. In a normal or balanced atom, the number of negative particles equals the number of positive particles. That is, there are as many electrons as there are protons. ● **SEE FIGURE 8–3.**

MAGNETS AND ELECTRICAL CHARGE An ordinary magnet has two ends, or poles. One end is called the south pole, and the other is called the north pole. If two magnets are brought close to each other with like poles together (south to south or north to north), the magnets will push each other apart, because like poles repel each other. If the opposite poles of the magnets are brought close to each other, south to north, the magnets will snap together, because unlike poles attract

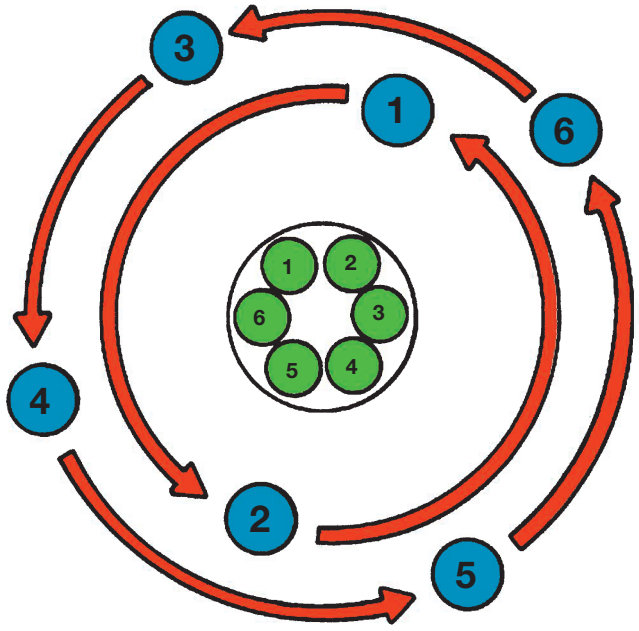


FIGURE 8–3 This FIGURE shows a balanced atom. The number of electrons is the same as the number of protons in the nucleus.

FIGURE 8–4 Unlike charges attract and like charges repel.

each other. The positive and negative charges within an atom are like the north and south poles of a magnet. Charges that are alike will repel each other, similar to the poles of a magnet. ● **SEE FIGURE 8–4.**

That is why the negative electrons continue to orbit around the positive protons. They are attracted and held by the opposite charge of the protons. The electrons keep moving in orbit because they repel each other.

ELECTRON ORBITS

Electrons orbit around the nucleus in rings and the outermost ring is called the "valence ring." Whether a material is a conductor or an insulator strictly depends on how many electrons are in the outer ring.

CONDUCTORS

Conductors are materials with fewer than four electrons in their atom's outer orbit. ● **SEE FIGURE 8–5.**

Copper is an excellent conductor because it has only one electron in its outer orbit. This orbit is far enough away from the nucleus of the copper atom that the pull or force holding the outermost electron in orbit is relatively weak. ● **SEE FIGURE 8–6.**

Copper is the conductor most used in vehicles because the price of copper is reasonable compared to the relative cost

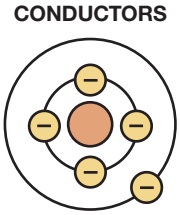


FIGURE 8–5 A conductor is any element that has one to three electrons in its outer orbit.

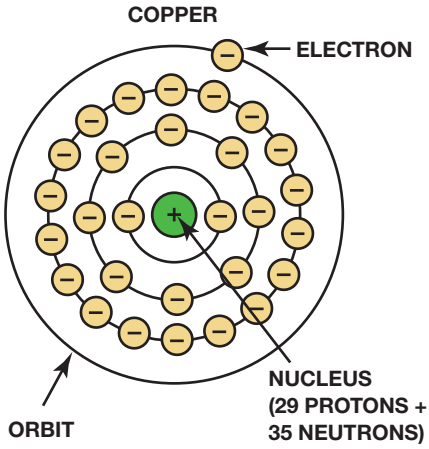


FIGURE 8–6 Copper is an excellent conductor of electricity because it has just one electron in its outer orbit, making it easy to be knocked out of its orbit and flow to other nearby atoms. This causes electron flow, which is the definition of electricity.

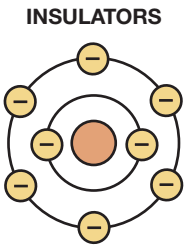


FIGURE 8–7 Insulators are elements with five to eight electrons in the outer orbit.

of other conductors with similar properties. Examples of commonly used conductors include:

- Silver
- Copper
- Gold
- Aluminum
- Steel
- Cast iron

INSULATORS

Some materials hold their electrons tightly and, as a result, electrons do not move through them very well. These materials are called insulators. **Insulators** are materials with more than four electrons in their atom's outer orbit. Because they have more than four electrons in their outer orbit, it becomes easier for these materials to acquire (gain) electrons than to release electrons. ● **SEE FIGURE 8–7.**

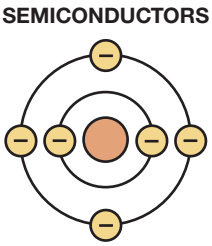


FIGURE 8–8 Semiconductor elements contain exactly four electrons in the outer orbit.

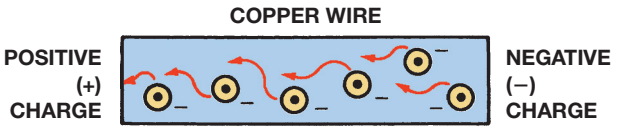


FIGURE 8–9 Current electricity is the movement of electrons through a conductor.

Examples of insulators include:

- Rubber
- Plastic
- Nylon
- Porcelain
- Ceramic
- Fiberglass

SEMICONDUCTORS Materials with exactly four electrons in their outer orbit are neither conductors nor insulators, but are called **semiconductors**. Semiconductors can be either an insulator or a conductor in different design applications. ● **SEE FIGURE 8–8.**

Examples of semiconductors include:

- Silicon
- Germanium
- Carbon

Semiconductors are used mostly in transistors, computers, and other electronic devices.

HOW ELECTRONS MOVE THROUGH A CONDUCTOR

CURRENT FLOW The following events occur if a source of power, such as a battery, is connected to the ends of a conductor—a positive charge (lack of electrons) is placed on one end of the conductor and a negative charge (excess of electrons) is placed on the opposite end of the conductor. For current to flow, there must be an imbalance of excess electrons at one end of the circuit and a deficiency of electrons at the opposite end. ● **SEE FIGURE 8–9.**

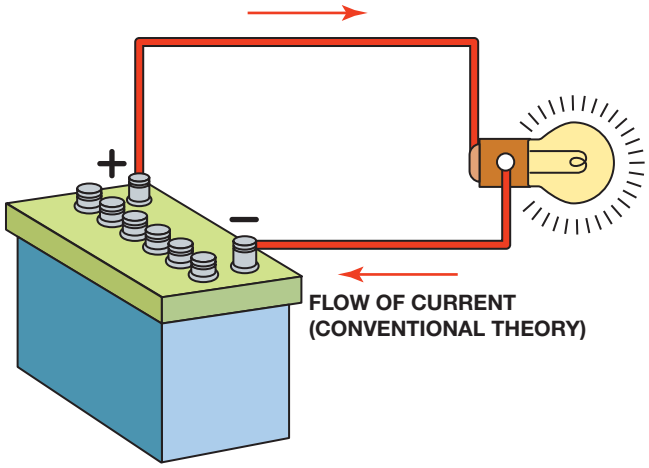


FIGURE 8–10 Conventional theory states that current flows through a circuit from positive (+) to negative (–). Automotive electricity uses the conventional theory in all electrical diagrams and schematics.

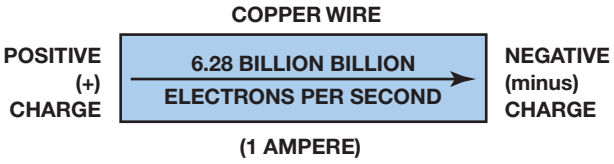


FIGURE 8–11 One ampere is the movement of 1 coulomb (6.28 billion billion electrons) past a point in 1 second.

CONVENTIONAL THEORY VERSUS ELECTRON THEORY

- **Conventional theory**: It was once thought that electricity had only one charge and moved from positive to negative. This theory of the flow of electricity through a conductor is called the conventional theory of current flow. Most automotive applications use the conventional theory. ● **SEE FIGURE 8–10.**
- **Electron theory**: The discovery of the electron and its negative charge led to the electron theory, which states that there is electron flow from negative to positive.

UNITS OF ELECTRICITY

Electricity is measured using meters or other test equipment. The three fundamentals of electricity-related units include the ampere, volt, and ohm.

AMPERE The **ampere** is the unit used throughout the world to measure current flow. When 6.28 billion billion electrons (the name for this large number of electrons is called a coulomb)

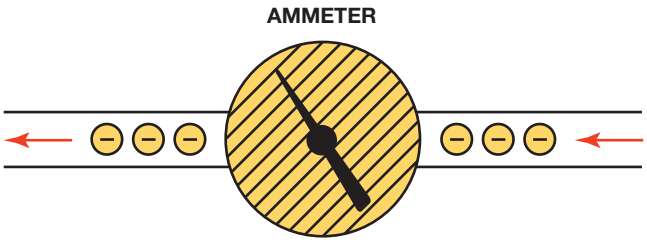


FIGURE 8–12 An ammeter is installed in the path of the electrons similar to a water meter used to measure the flow of water in gallons per minute. The ammeter displays current flow in amperes.

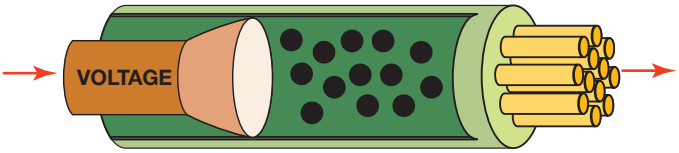


FIGURE 8–13 Voltage is the electrical pressure that causes the electrons to flow through a conductor.

move past a certain point in 1 second, this represents 1 ampere of current. ● **SEE FIGURE 8–11.**

The ampere is the electrical unit for the amount of electron flow, just as "gallons per minute" is the unit that can be used to measure the quantity of water flow. It is named for the French electrician Andrè Marie Ampére (1775–1836). The conventional abbreviations and measurement for amperes are as follows:

1. The ampere is the unit of measurement for the amount of current flow.
2. A and amps are acceptable abbreviations for amperes.
3. The capital letter I, for intensity, is used in mathematical calculations to represent amperes.
4. Amperes do the actual work in the circuit. It is the movement of the electrons through a light bulb or motor that actually makes the electrical device work. Without amperage through a device, it will not work at all.
5. Amperes are measured by an ammeter (not ampmeter). ● **SEE FIGURE 8–12.**

VOLTS The **volt** is the unit of measurement for electrical pressure. It is named for an Italian physicist, Alessandro Volta (1745–1827). The comparable unit using water pressure as an example would be pounds per square inch (PSI). It is possible to have very high pressures (volts) and low water flow (amperes). It is also possible to have high water flow (amperes) and low pressures (volts). Voltage is also called electrical potential, because if there is voltage present in a conductor, there is a potential (possibility) for current flow. ● **SEE FIGURE 8–13.**

FIGURE 8–14 This digital multimeter set to read DC volts is being used to test the voltage of a vehicle battery. Most multimeters can also measure resistance (ohms) and current flow (amperes).

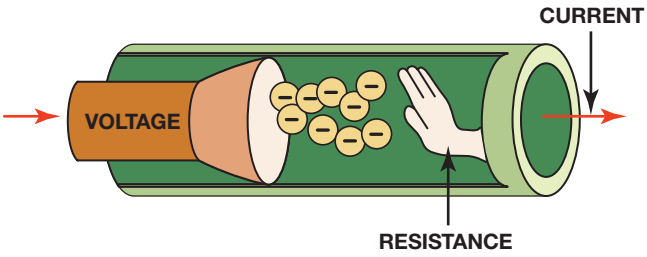


FIGURE 8–15 Resistance to the flow of electrons through a conductor is measured in ohms.

The conventional abbreviations and measurement for voltage are as follows:

1. The volt is the unit of measurement for the amount of electrical pressure.
2. Electromotive force, abbreviated EMF, is another way of indicating voltage.
3. V is the generally accepted abbreviation for volts.
4. The symbol used in calculations is E, for electromotive force.
5. Volts are measured by a voltmeter. ● **SEE FIGURE 8–14.**

OHMS Resistance to the flow of current through a conductor is measured in units called **ohms**, named after the German physicist George Simon Ohm (1787–1854). The resistance to the flow of free electrons through a conductor results from the countless collisions the electrons cause within the atoms of the conductor. ● **SEE FIGURE 8–15.**

Resistance can be:

- Desirable when it is part of how a circuit works, such as the resistance of a filament in a light bulb.

- Undesirable, such as corrosion in a connection restricting the amount of current flow in a circuit.

The conventional abbreviations and measurement for resistance are as follows:

1. The ohm is the unit of measurement for electrical resistance.
2. The symbol for ohms is Ω (Greek capital letter omega), the last letter of the Greek alphabet.
3. The symbol used in calculations is R, for resistance.
4. Ohms are measured by an ohmmeter.
5. Resistance to electron flow depends on the material used.

ELECTRICAL CIRCUITS

DEFINITION A circuit is a complete path that electrons travel from a power source (such as a battery) through a load such as a light bulb and back to the power source. It is called a circuit because the current must start and finish at the same place (power source). For any electrical circuit to work at all, it must be continuous from the battery (power), through all the wires and components, and back to the battery (ground). A circuit that is continuous throughout is said to have continuity.

PARTS OF A COMPLETE CIRCUIT Every complete circuit contains the following parts

1. A power source, such as a vehicle's battery.
2. Protection from harmful overloads (excessive current flow). (Fuses, circuit breakers, and fusible links are examples of electrical circuit protection devices.)
3. The power path for the current to flow through, from the power source to the load—a light bulb in this example—is usually an insulated copper wire.)
4. The electrical load or resistance, which converts electrical energy into heat, light, or motion.
5. A return path (ground) for the electrical current from the load back to the power source so that there is a complete circuit. (This return, or ground, path is usually the metal body, frame, ground wires, and engine block of the vehicle.) ● **SEE FIGURE 8–16.**
6. Switches and controls that turn the circuit on and off. ● **SEE FIGURE 8–17**.

ELECTRICAL SCHEMATICS

TERMINOLOGY Automotive manufacturer's service information includes wiring schematics of every electrical circuit in a vehicle. A wiring **schematic**, sometimes called a *diagram,* shows electrical components and wiring using symbols and lines to represent components and wires. A typical wiring schematic may include all of the circuits combined, or they may be broken down to show individual circuits. All circuit schematics or diagrams include:

- Power-side wiring of the circuit
- All splices
- Connectors
- Wire size
- Wire color
- Trace color (if any)

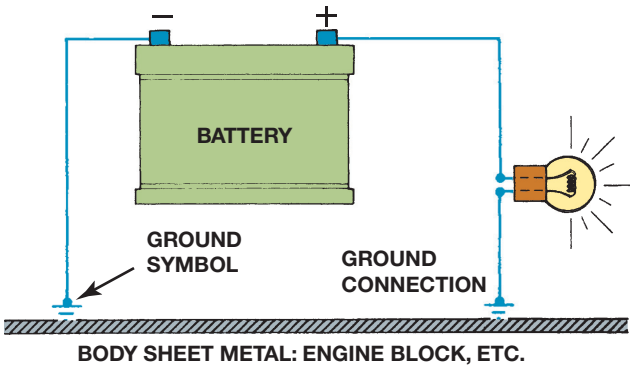


FIGURE 8–16 The return path back to the battery can be any electrical conductor, such as a copper wire or the metal frame or body of the vehicle.

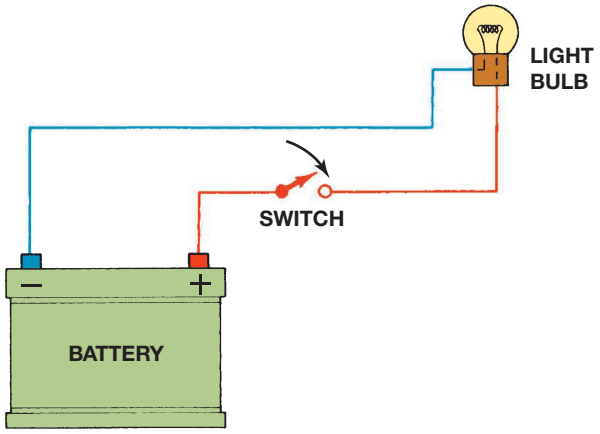


FIGURE 8–17 An electrical switch opens the circuit and no current flows. The switch could also be on the return (ground) path wire.

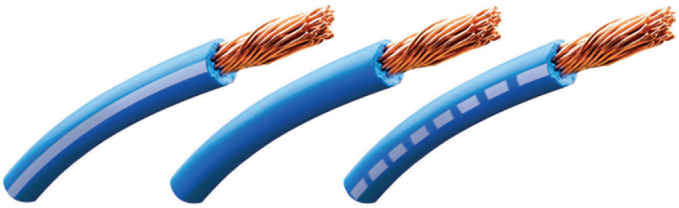


FIGURE 8–18 The center wire is a solid color wire, meaning that the wire has no other identifying tracer or stripe color. The two end wires could be labeled "BLU/WHT," indicating a blue wire with a white tracer or stripe.

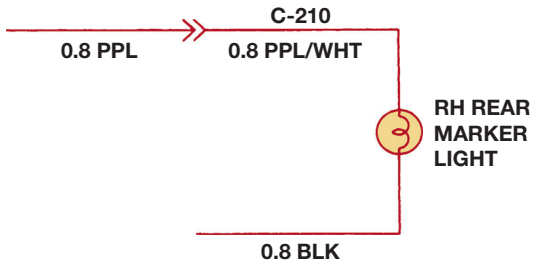


FIGURE 8–19 Typical section of a wiring diagram. Notice that the wire color changes at connection C210. The "0.8" represents the metric wire size in square millimeters.

- Circuit number
- Electrical components
- Ground return paths
- Fuses and switches

CIRCUIT INFORMATION Many wiring schematics include numbers and letters near components and wires that may confuse readers of the schematic. Most letters used near or on a wire identify the color or colors of the wire.

- The first color or color abbreviation is the color of the wire insulation.
- The second color (if mentioned) is the color of the stripe or tracer on the base color. ● **SEE FIGURE 8–18.**

Wires with different color tracers are indicated by both colors with a slash (/) between them. For example, BRN/WHT means a brown wire with a white stripe or tracer.

WIRE SIZE Wire size is shown on all schematics. For example, ● **FIGURE 8–19** illustrates a rear side-marker bulb circuit diagram where "0.8" indicates the metric wire gauge size in square millimeters (mm^2) and "PPL" indicates a solid purple wire.

The wire diagram also shows that the color of the wire changes at the number C210. This stands for "connector #210" and is used for reference purposes. The symbol for the connection can vary depending on the manufacturer. The color change from purple (PPL) to purple with a white tracer (PPL/WHT). The ground circuit is the ".8 BLK" wire.

● **SEE FIGURE 8–20**, which shows many of the electrical and electronic symbols that are used in wiring and circuit diagrams.

TYPES OF CIRCUIT FAULTS

Circuits can experience several different types of faults or problems, which often result in improper operation. The types of faults include opens, shorts, and high resistance.

OPEN CIRCUITS An **open circuit** is any circuit that is not complete, or that lacks continuity, such as a broken wire. ● **SEE FIGURE 8–21.**

Open circuits have the following features.

1. No current will flow through an open circuit.
2. An open circuit may be created by a break in the circuit or by a switch that opens (turns off) the circuit and prevents the flow of current.
3. In any circuit containing a power load and ground, an opening anywhere in the circuit will cause the circuit not to work.
4. A light switch in a home and the headlight switch in a vehicle are examples of devices that open a circuit to control its operation.

NOTE: A blown fuse opens the circuit to prevent damage to the components or wiring in the circuit in the event of an overload caused by a fault in the circuit.

SHORT-TO-VOLTAGE If a wire (conductor) or component is shorted to voltage, it is commonly referred to as being shorted. A **short-to-voltage** occurs when the power side of one circuit is electrically connected to the power side of another circuit. ● **SEE FIGURE 8–22.**

A short circuit has the following features:

1. It is a complete circuit in which the current usually bypasses some or all of the resistance in the circuit.
2. It involves the power side of the circuit.
3. It involves a copper-to-copper connection (two power side wires touching together).
4. It is also called a short-to-voltage.
5. It usually affects more than one circuit. In this case, if one circuit is electrically connected to another circuit, one of the circuits may operate when it is not supposed to because it is being supplied power from another circuit.
6. It may or may not blow a fuse. ● **SEE FIGURE 8–23.**

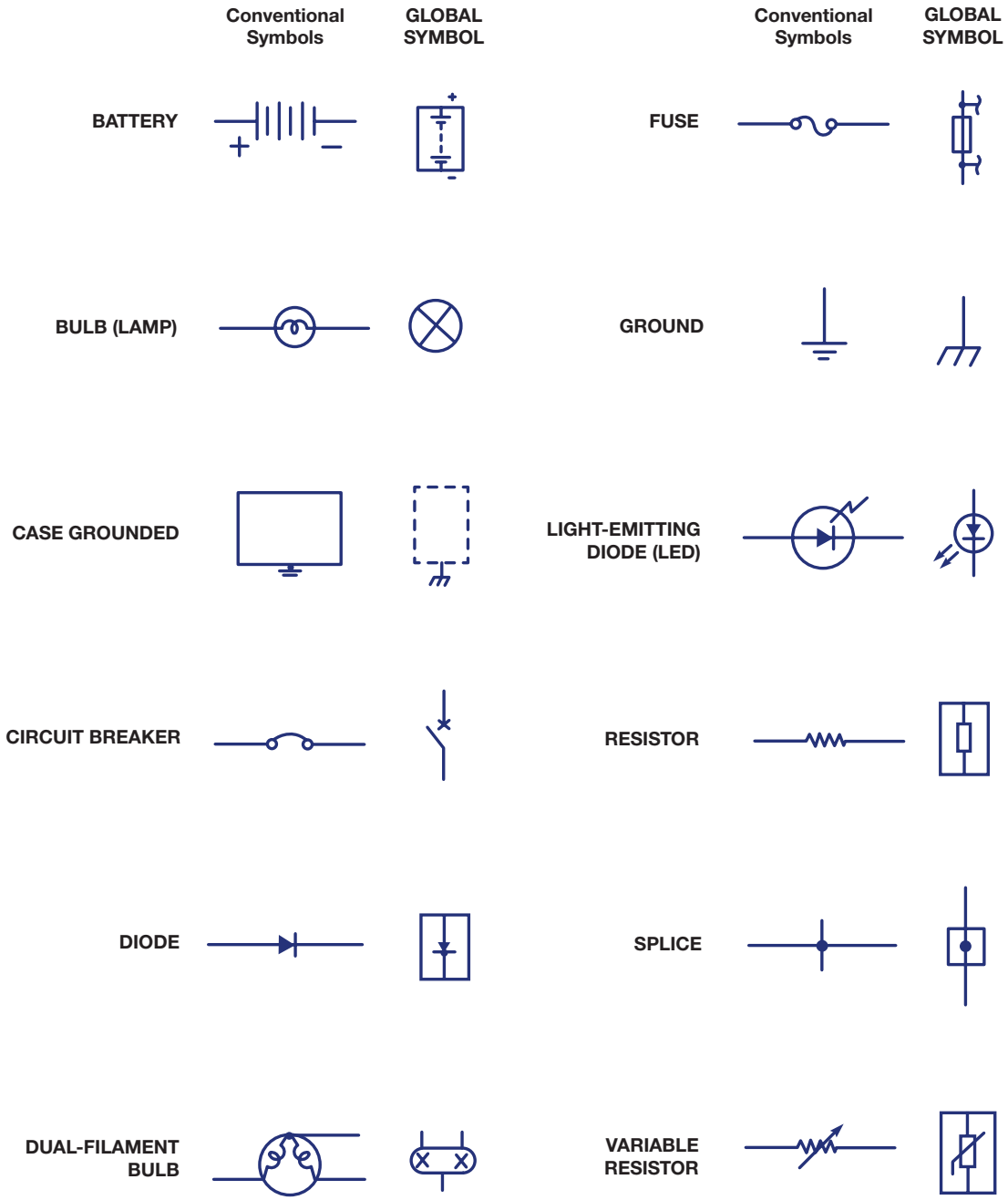


FIGURE 8–20 Typical electrical and electronic symbols used in automotive wiring and circuit diagrams. Both the conventional and the global symbols are shown side-by-side to make reading schematics easier. The global symbols are used by many vehicle manufacturers.

SHORT-TO-GROUND

A **short-to-ground** is a type of short circuit that occurs when the current bypasses part of the normal circuit and flows directly to ground. A short-to-ground has the following features.

1. Because the ground return circuit is metal (vehicle frame, engine, or body), it is often identified as having current flowing from copper to steel.
2. A short-to-ground can occur at any place where a power path wire accidentally touches a return path wire or conductor. ● **SEE FIGURE 8–24.**
3. A defective component or circuit that is shorted to ground is commonly called grounded.
4. A short-to-ground almost always results in a blown fuse, damaged connectors, or melted wires.

HIGH RESISTANCE

High resistance is resistance higher than normal circuit resistance usually caused by any of the following:

- Corroded connections or sockets
- Loose terminals in a connector
- Loose ground connections

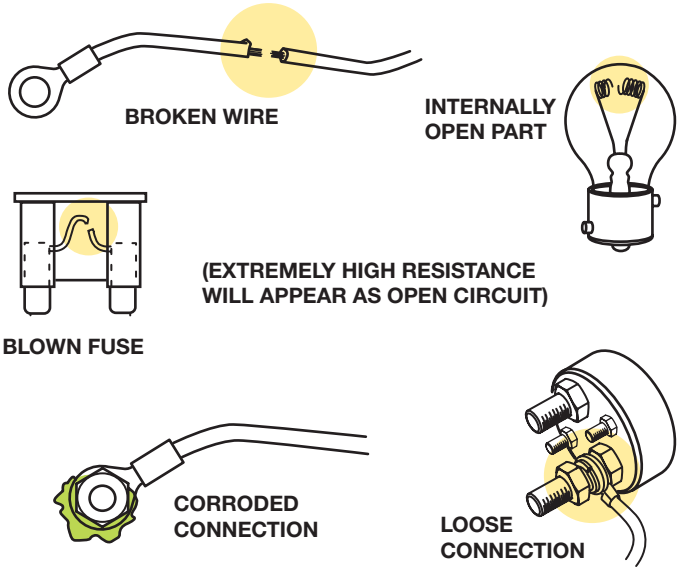


FIGURE 8–21 Examples of common causes of open circuits. Some of these causes are often difficult to find.

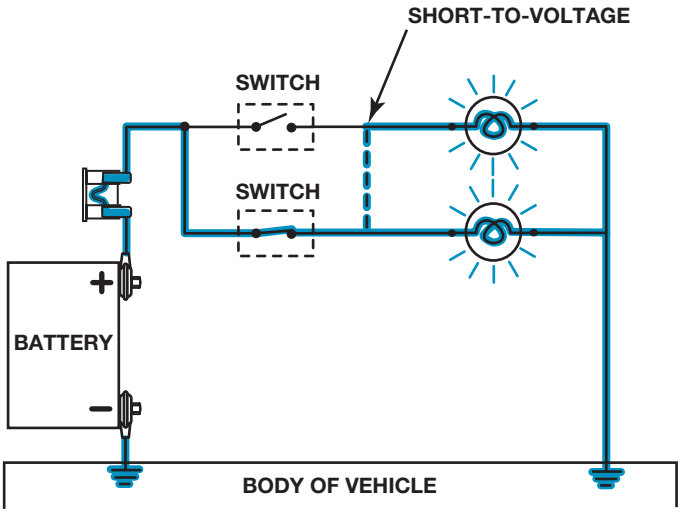


FIGURE 8–22 A short circuit permits electrical current to bypass some or all of the resistance in the circuit.

If there is high resistance anywhere in a circuit, it may cause the following problems:

1. Slow operation of a motor-driven unit, such as when the transfer case makes a range change.
2. Dim lights
3. "Clicking" of relays or solenoids
4. No operation of a circuit or electrical component

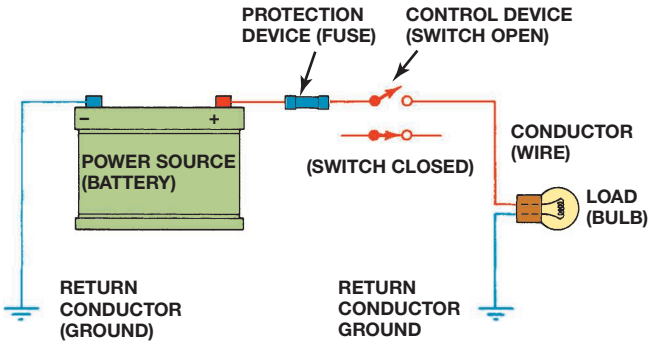


FIGURE 8–23 A fuse or circuit breaker opens the circuit to prevent possible overheating damage in the event of a short circuit.

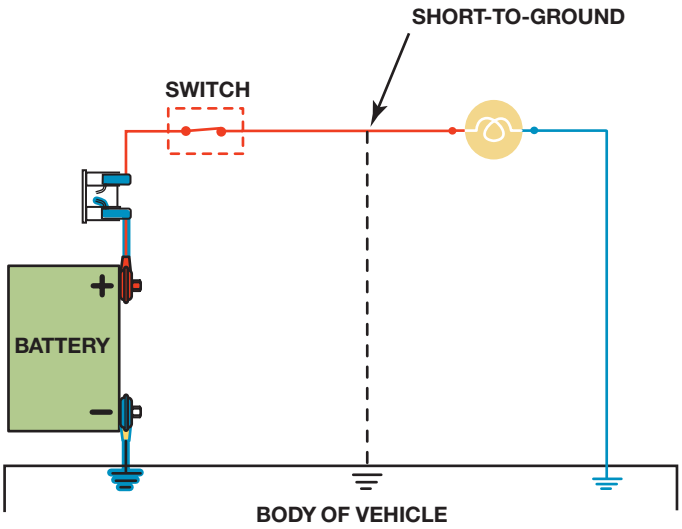


FIGURE 8–24 A short-to-ground affects the power side of the circuit. Current flows directly to the ground return, bypassing some or all of the electrical loads in the circuit. There is no current in the circuit past the short. A short-to-ground will also cause the fuse to blow.

FUSED JUMPER WIRE

PURPOSE AND FUNCTION A fused jumper wire is used to check a circuit by bypassing the switch or to provide a power or ground to a component. A fused jumper wire, also called a fused test lead, can be purchased or made by the service technician. ● **SEE FIGURE 8–25.**

It should include the following features:

- *Fuse:* A typical fused jumper wire has a blade-type fuse that can be easily replaced. A 10-ampere fuse (red color) is often the value used.
- *Alligator clip ends:* Alligator clips on the ends allow the fused jumper wire to be clipped to a ground or power

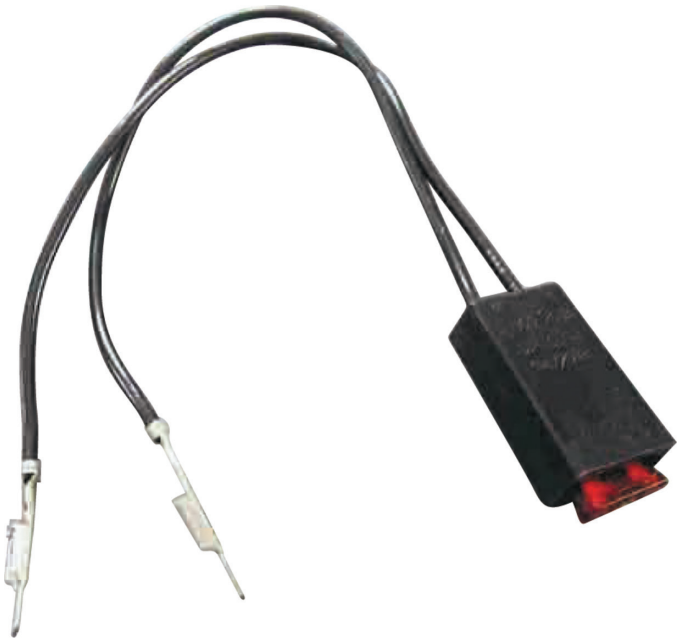


FIGURE 8–25 A technician-made fused jumper lead, which is equipped with a red 10-ampere fuse. This fused jumper wire uses terminals for testing circuits at a connector instead of alligator clips.

source while the other end is attached to the power side or ground side of the unit being tested.

- *Good-quality insulated wire:* Most purchased jumper wire is about 14 gauge stranded copper wire with a flexible rubberized insulation to allow it to move easily even in cold weather.

CAUTION: Never use a fused jumper wire to bypass any resistance or load in the circuit. The increased current flow could damage the wiring and could blow the fuse on the jumper lead. Be very cautious when working on or around any computer circuit. Permanent damage to the computer or electronic module could result if power or ground goes to the wrong circuit.

TEST LIGHT

NON-POWERED TEST LIGHT

A 12-volt test light is one of the simplest testers that can be used to detect electricity. A test light is simply a light bulb with a probe and a ground wire attached. ● **SEE FIGURE 8–26.**

A test light is used to detect battery voltage potential at various test points. Battery voltage cannot be seen or felt, and can be detected only with test equipment. The ground clip is connected to a clean ground on either the negative terminal of the battery or a clean metal part of the body and the probe

FIGURE 8–26 Testing a fuse with a test light. If the fuse is good, the test light should light on both sides (power side and load side) of the fuse.

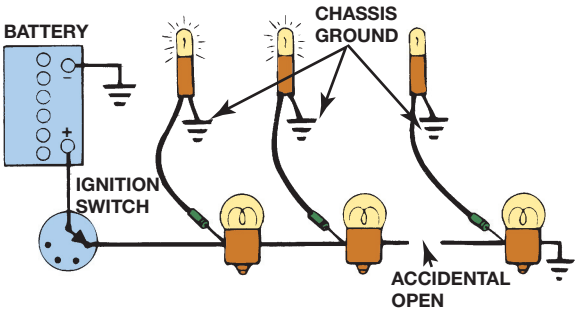


FIGURE 8–27 A test light can be used to locate an open in a circuit. Note that the test light is grounded at a different location than the circuit itself.

touched to terminals or components. If the test light comes on, this indicates that voltage is available. ● **SEE FIGURE 8–27.**

A purchased test light should be labeled as "12-volt test light." Do not purchase a test light designed for household current (110 or 220 volts), as it will not light with 12 to 14 volts.

USES OF A 12-VOLT TEST LIGHT

A 12-volt test light can be used to check the following:

- *Electrical power*: If the test light lights, then there is power available. It will not, however, indicate the voltage level or if there is enough current available to operate an electrical load. It only indicates that there is enough voltage and current to light the test light (about 0.25 A).
- *Grounds*: A test light can be used to check for grounds by attaching the clip of the test light to the positive terminal of the battery or any positive 12-volt electrical terminal. The tip of the test light can then be used to touch the ground wire. If there is a ground connection, the test light will light.

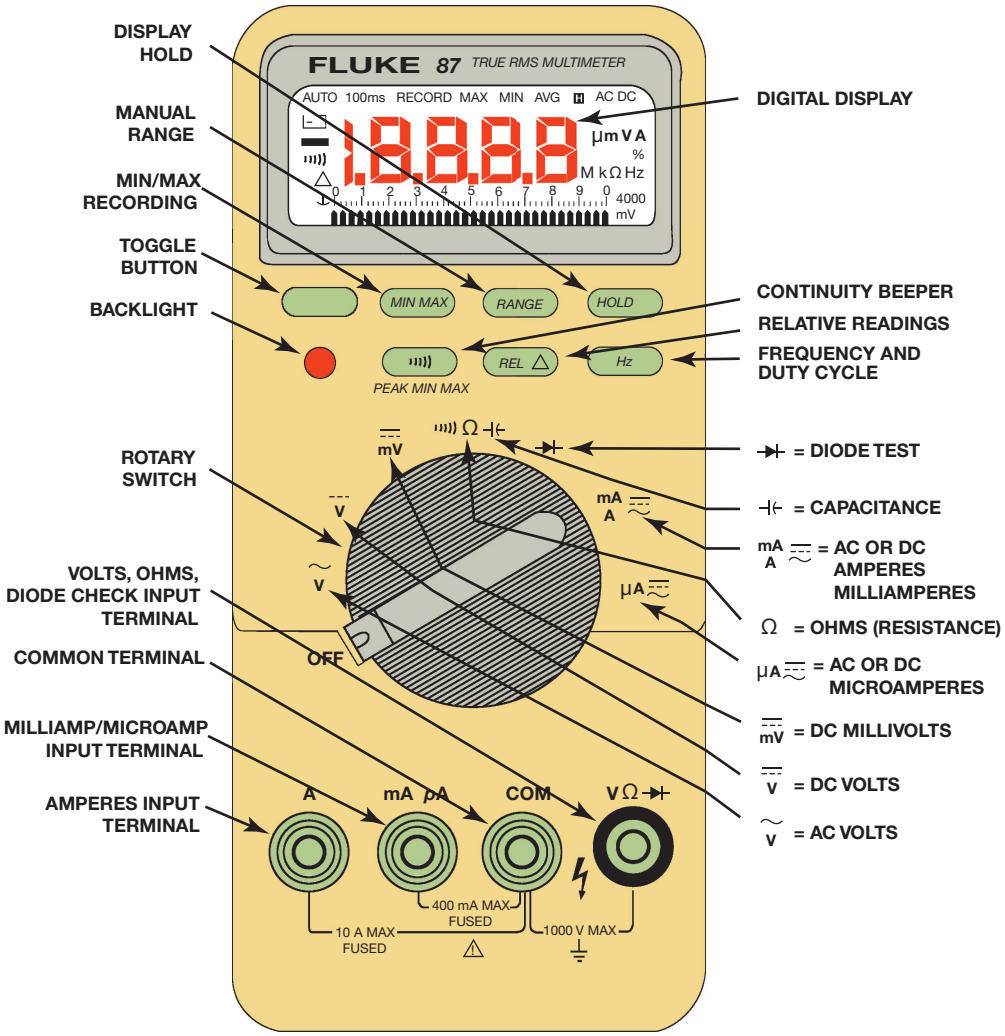


FIGURE 8–28 Typical digital multimeter. The black meter lead always is placed in the COM terminal. The red meter test lead should be in the volt-ohm terminal except when measuring current in amperes.

DIGITAL METERS

TERMINOLOGY **Digital multimeter (DMM)** and **digital volt-ohm-meter (DVOM)** are terms commonly used to describe digital meters. ● **SEE FIGURE 8–28.**

The common abbreviations for the units that many meters can measure are often confusing. ● **SEE CHART 8–1** for the most commonly used symbols and their meanings.

MEASURING VOLTAGE A **voltmeter** measures the pressure or potential of electricity in units of volts. A voltmeter is connected to a circuit in parallel. Voltage can be measured by selecting either AC or DC volts.

- *DC volts (DCV)*. This setting is the most common for automotive testing. Use this setting to measure battery voltage and voltage to all lighting and accessory circuits.

SYMBOL	MEANING
AC	Alternating current or voltage
DC	Direct current or voltage
V	Volts
mV	Millivolts (1/1,000 volts)
A	Ampere (amps), current
mA	Milliampere (1/1,000 amps)
%	Percent (for duty cycle readings only)
Ω	Ohms, resistance
kΩ	Kilohm (1,000 ohms), resistance
MΩ	Megohm (1,000,000 ohms), resistance
Hz	Hertz (cycles per second), frequency
kHz	Kilohertz (1,000 cycles/sec.), frequency
Ms	Milliseconds (1/1,000 sec.) for pulse width measurements

CHART 8–1

Common symbols and abbreviations used on digital meters.

FIGURE 8–29 Typical digital multimeter (DMM) set to read DC volts.

- *AC volts (ACV)*. This setting is used to check some computer sensors and to check for unwanted AC voltage from alternators.
- *Range*. The range is automatically set for most meters but can be manually adjusted if needed. ● **SEE FIGURES 8–29 AND 8–30.**

MEASURING RESISTANCE

An **ohmmeter** measures the resistance in ohms of a component or circuit section when no current is flowing through the circuit. An ohmmeter contains a battery (or other power source) and is connected in series with the component or wire being measured. Note the following facts about using an ohmmeter.

- Zero ohms on the scale means that there is no resistance between the test leads, thus indicating continuity or a continuous path for the current to flow in a closed circuit.
- Infinity means no connection, as in an open circuit.
- Ohmmeters have no required polarity even though red and black test leads are used for resistance measurement.

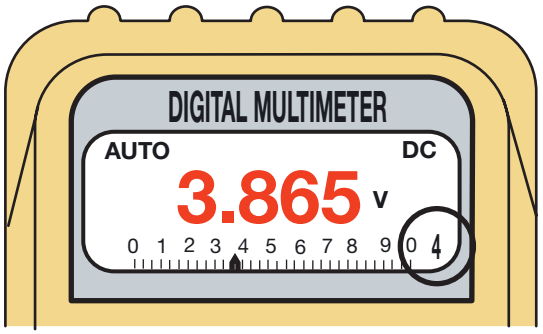
Different meters have different ways of indicating infinity resistance, or a reading higher than the scale allows. Examples of an over-limit display include the following:

- OL, meaning over limit or overload
- Flashing or solid number 1
- Flashing or solid number 3 on the left side of the display

Check the meter instructions for the exact display used to indicate an open circuit or over-range reading. ● **SEE FIGURE 8–31 AND 8–32.**

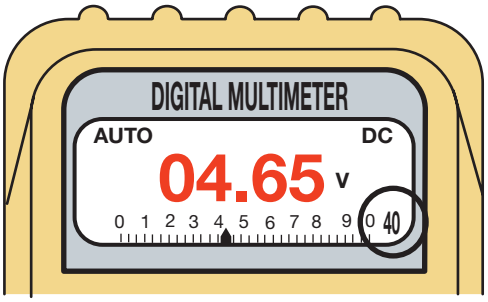
To summarize, open and zero readings are as follows:

0.00 Ω = Zero resistance (component or circuit has continuity)



BECAUSE THE SIGNAL READING IS BELOW 4 VOLTS, THE METER AUTORANGES TO THE 4-VOLT SCALE. IN THE 4-VOLT SCALE, THIS METER PROVIDES THREE DECIMAL PLACES.

(a)



WHEN THE VOLTAGE EXCEEDED 4 VOLTS, THE METER AUTORANGES INTO THE 40-VOLT SCALE. THE DECIMAL POINT MOVES ONE PLACE TO THE RIGHT LEAVING ONLY TWO DECIMAL PLACES.

(b)

FIGURE 8–30 A typical autoranging digital multimeter automatically selects the proper scale to read the voltage being tested. The scale selected is usually displayed on the meter face. (a) Note that the display indicates "4," meaning that this range can read up to 4 volts. (b) The range is now set to the 40-volt scale, meaning that the meter can read up to 40 volts on the scale. Any reading above this level will cause the meter to reset to a higher scale. If not set on autoranging, the meter display would indicate OL if a reading exceeds the limit of the scale selected.

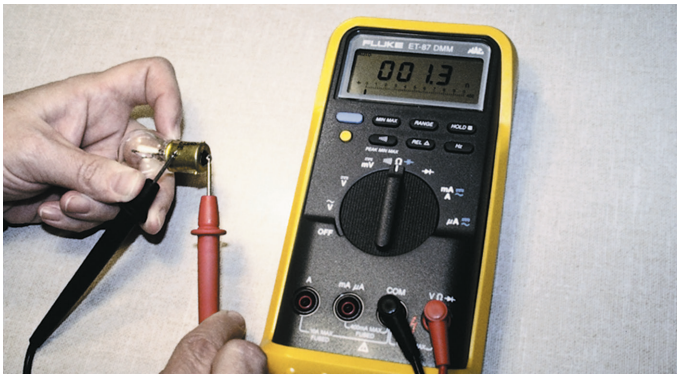


FIGURE 8–31 Using a digital multimeter set to read ohms (Ω) to test this light bulb. The meter reads the resistance of the filament.

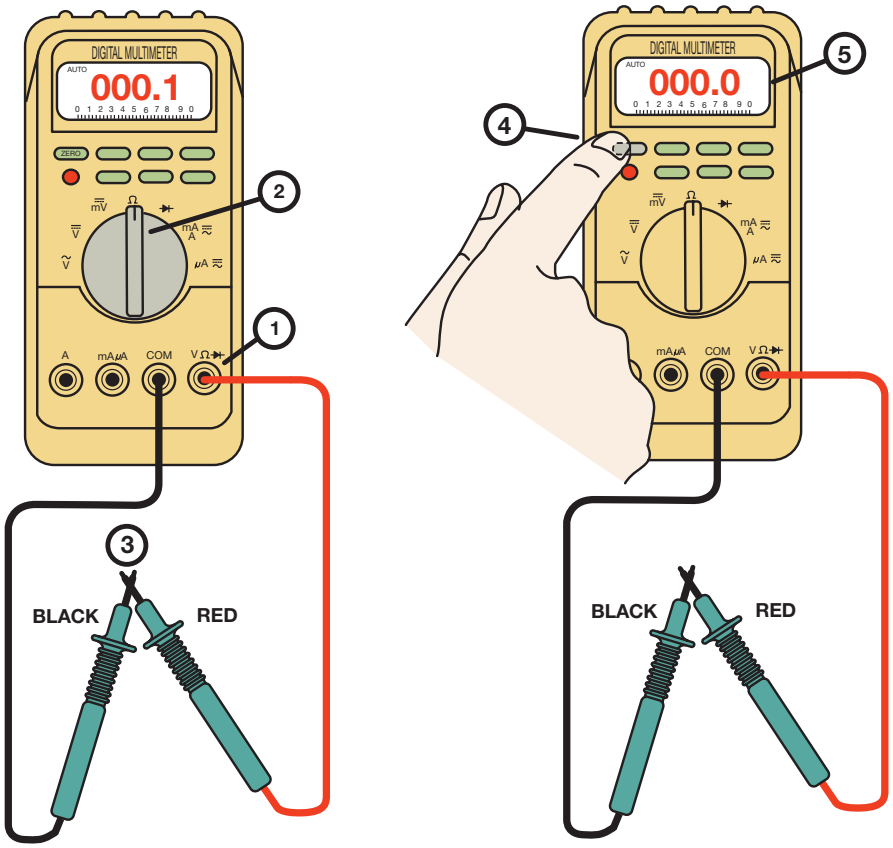


FIGURE 8–32 Many digital multimeters can have the display indicate zero to compensate for test lead resistance. (1) Connect leads in the V Ω and COM meter terminals. (2) Select the Ω scale. (3) Touch the two meter leads together. (4) Push the "zero" or "relative" button on the meter. (5) The meter display will now indicate zero ohms of resistance.

OL = An open circuit (no current flows) or the reading is higher than the scale selected.

MEASURING AMPERES

An **ammeter** measures the flow of current through a complete circuit in units of amperes or milliamperes (1/1,000 of an ampere). The ammeter has to be installed in the circuit (in series) so that it can measure all the current flow in that circuit, just as a water flow meter would measure the amount of water flow (cubic feet per minute, for example). **SEE FIGURE 8–33.**

CAUTION: An ammeter must be installed in series with the circuit to measure the current flow in the circuit. If a meter set to read amperes is connected in parallel, such as across a battery, the meter or the leads may be destroyed, or the fuse will blow, by the current available across the battery. Some DMMs beep if the unit selection does not match the test lead connection on the meter. However, in a noisy shop, this beep sound may be inaudible.

Digital meters require that the meter leads be moved to the ammeter terminals. Most digital meters have an ampere scale that can accommodate a maximum of 10 amperes. See the Tech Tip "Fuse Your Meter Leads!"

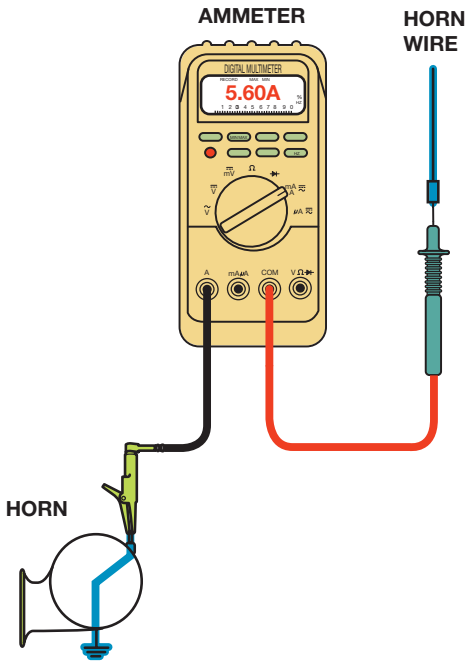


FIGURE 8–33 Measuring the current flow required by a horn requires that the ammeter be connected to the circuit in series and the horn button be depressed by an assistant.

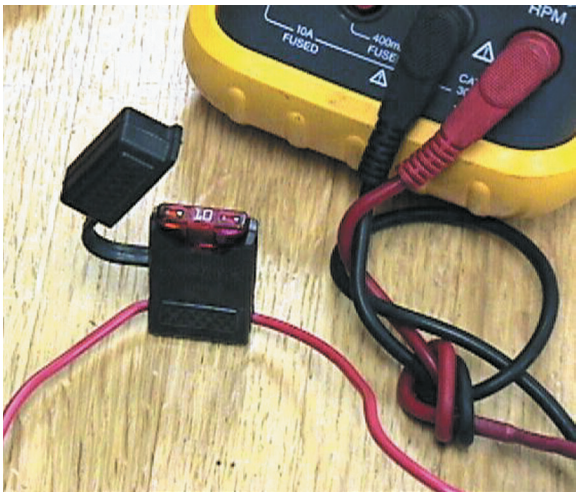


FIGURE 8–34 Note the blade-type fuse holder soldered in series with one of the meter leads. A 10-ampere fuse helps protect the internal meter fuse (if equipped) and the meter itself from damage that may result from excessive current flow if accidentally used incorrectly.

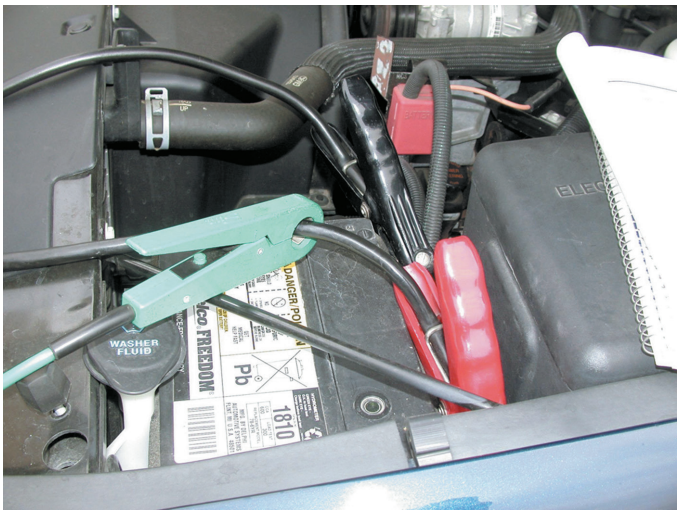


FIGURE 8–35 An inductive ammeter clamp is used with all starting and charging testers to measure the current flow through the battery cables.

TECH TIP

Fuse Your Meter Leads!

Most digital meters include an ammeter capability. When reading amperes, the leads of the meter must be changed from volts or ohms (V or Ω) to amperes (A) or milliamperes (mA). A common problem may then occur the next time voltage is measured.

Although the technician may switch the selector to read volts, often the leads are not switched back to the volt or ohm position. Because the ammeter lead position results in zero ohms of resistance to current flow through the meter, the meter or the fuse inside the meter will be destroyed if the meter is connected to a battery. Many meter fuses are expensive and difficult to find. To avoid this problem, simply solder an inline 10-ampere blade-type fuse holder into one meter lead. ● **SEE FIGURE 8–34.**

Do not think that this technique is for beginners only. Experienced technicians often get in a hurry and forget to switch the lead. A blade fuse is faster, easier, and less expensive to replace than a meter fuse or the meter itself. Also, if the soldering is done properly, the addition of an inline fuse holder and fuse does not increase the resistance of the meter leads. All meter leads have some resistance. If the meter is measuring very low resistance, touch the two leads together and read the resistance (usually no more than 0.2 ohm). Simply subtract the resistance of the leads from the resistance of the component being measured.

INDUCTIVE AMMETERS

OPERATION Inductive ammeters do not make physical contact with the circuit. Inductive ammeters have the advantage of being able to read much higher amperages than 10 amperes. A sensor is used to detect the strength of the magnetic field surrounding the wire carrying the current. The ammeter then uses the strength of the magnetic field to measure the electrical current. ● **SEE FIGURE 8–35.**

AC/DC CLAMP-ON DIGITAL MULTIMETERS An AC/DC clamp-on digital multimeter is a useful meter for automotive diagnostic work. ● **SEE FIGURE 8–36.**

The major advantage of the clamp-on-type meter is that there is no need to break the circuit to measure current (amperes). Simply clamp the jaws of the meter around the power lead(s) or ground lead(s) of the component being measured and read the display. Most clamp-on meters can also measure alternating current, which is helpful in the diagnosis of an alternator problem. Volts, ohms, frequency, and temperature can also be measured with the typical clamp-on DMM, but conventional meter leads should be used. The inductive clamp is used to measure only amperes.

THINK OF MONEY Digital meter displays can often be confusing. The display for a battery measured as 12 1/2 volts would be 12.50 V, just as $12.50 is 12 dollars and 50 cents. A 1/2 volt reading on a digital meter will be displayed as 0.50 V, just as $0.50 is half of a dollar. It is more confusing when low

FIGURE 8–36 A typical mini clamp-on-type digital multimeter. This meter is capable of measuring alternating current (AC) and direct current (DC) without requiring that the circuit be disconnected to install the meter in series. The jaws are simply placed over the wire and current flow through the circuit is displayed.

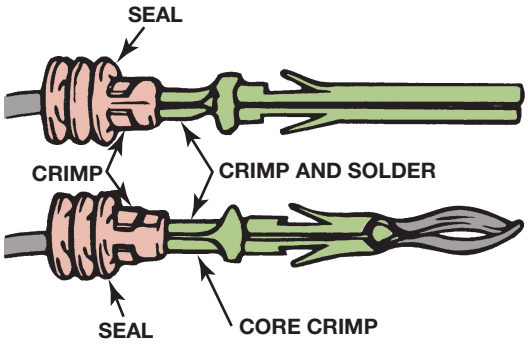


FIGURE 8–37 Some terminals have seals attached to help seal the electrical connections.

values are displayed. For example, if a voltage reading is 0.063 volt, an auto-ranging meter will display 63 millivolts (63 mV), or 63/1,000 of a volt, or $63 of $1,000. (It takes 1,000 mV to equal 1 volt.) Think of millivolts as one-tenth of a cent, with 1 volt being $1.00. Therefore, 630 millivolts are equal to $0.63 of $1.00 (630 tenths of a cent, or 63 cents). To avoid confusion, try to manually range the meter to read base units (whole volts).

If the meter is ranged to base unit volts, 63 millivolts would be displayed as 0.063 or maybe just 0.06, depending on the display capabilities of the meter.

TERMINALS AND CONNECTORS

TERMINOLOGY

A **terminal** is a metal fastener attached to the end of a wire, which makes the electrical connection. The term **connector** usually refers to the plastic portion that

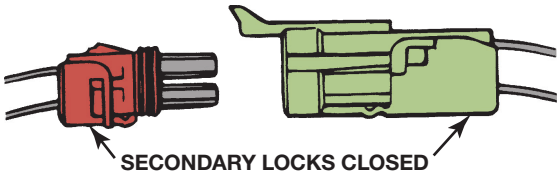


FIGURE 8–38 Separate a connector by opening the lock and pulling the two apart.

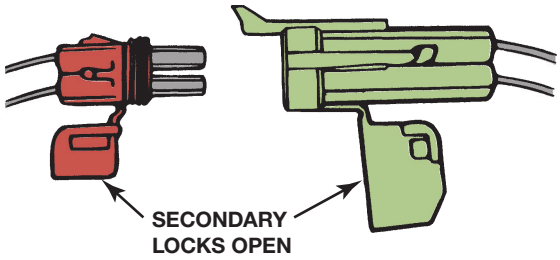


FIGURE 8–39 The secondary locks help retain the terminals in the connector.

snaps or connects together, thereby making the mechanical connection. Wire terminal ends usually snap into and are held by a connector. Male and female connectors can then be snapped together, thereby completing an electrical connection. Connectors exposed to the environment are also equipped with a weather-tight seal. ● **SEE FIGURE 8–37.**

SERVICING TERMINALS

Terminals are retained in connectors by the use of a lock tang. Removing a terminal from a connector includes the following steps.

STEP 1 Release the connector position assurance (CPA), if equipped, that keeps the latch of the connector from releasing accidentally.

STEP 2 Separate the male and female connector by opening the lock. ● **SEE FIGURE 8–38.**

STEP 3 Release the secondary lock, if equipped. ● **SEE FIGURE 8–39.**

STEP 4 Using a pick, look for the slot in the plastic connector where the lock tang is located, depress the lock tang, and gently remove the terminal from the connector. ● **SEE FIGURE 8–40.**

WIRE REPAIR

SOLDERING

Many manufacturers recommend that all wiring repairs be soldered. Solder is an alloy of tin and lead used to make a good electrical contact between two wires or connections in an electrical circuit. However, a flux must be used to help clean the area and to help make the solder flow.

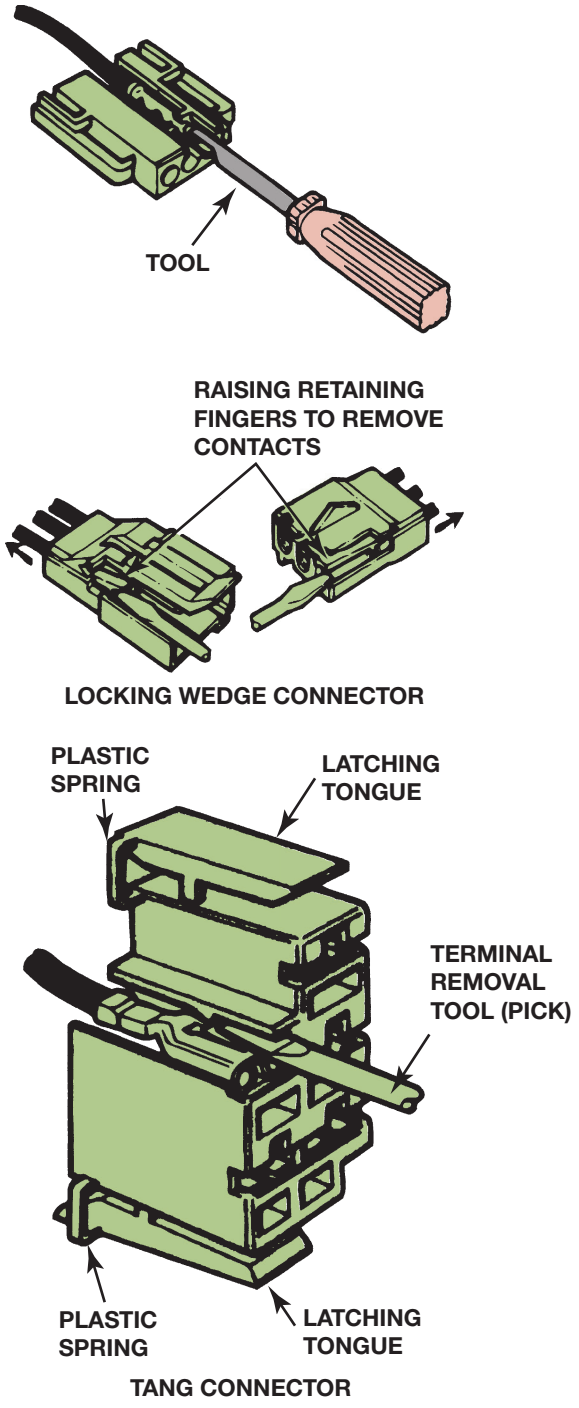


FIGURE 8–40 Use a small removal tool, sometimes called a pick, to release terminals from the connector.

Therefore, solder is made with a resin (rosin) contained in the center, called *rosin-core solder*.

CAUTION: Never use acid-core solder to repair electrical wiring as the acid will cause corrosion. ● **SEE FIGURE 8–41.**

Solder is available with various percentages of tin and lead in the alloy. Ratios are used to identify these various types of solder, with the first number denoting the percentage of tin in the alloy and the second number giving the percentage of lead. The most commonly used solder is 50/50, which means that 50% of the solder is tin and the other 50% is lead. The percentages of each alloy primarily determine the melting point of the solder.

FIGURE 8–41 Always use rosin-core solder for electrical or electronic soldering. Also, use small-diameter solder for small soldering irons. Use large-diameter solder only for large-diameter (large-gauge) wire and higher-wattage soldering irons (guns).

- 60/40 solder (60% tin/40% lead) melts at 361°F (183°C).
- 50/50 solder (50% tin/50% lead) melts at 421°F (216°C).
- 40/60 solder (40% tin/60% lead) melts at 460°F (238°C).

SOLDERING PROCEDURE Soldering a wiring splice includes the following steps:

STEP 1 While touching the soldering gun to the splice, apply solder to the junction of the gun and the wire.

STEP 2 The solder will start to flow. Do not move the soldering gun.

STEP 3 Just keep feeding more solder into the splice as it flows into and around the strands of the wire.

STEP 4 After the solder has flowed throughout the splice, remove the soldering gun and the solder from the splice and allow the solder to cool slowly.

The solder should have a shiny appearance. Dull-looking solder may be caused by not reaching a high enough temperature, which results in a cold solder joint. Reheating the splice and allowing it to cool often restores the shiny appearance.

CRIMPING TERMINALS Terminals can be crimped to create a good electrical connection if the proper type of crimping tool is used. Most vehicle manufacturers recommend that a W-shaped crimp be used to force the strands of the wire into a tight space. ● **SEE FIGURE 8–42.**

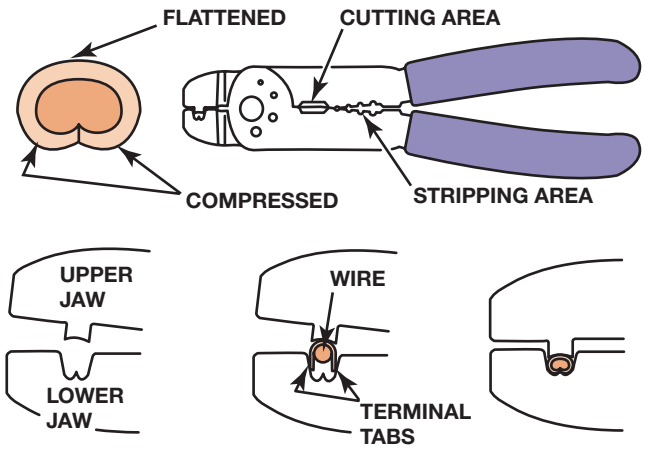


FIGURE 8–42 Notice that to create a good crimp, the open part of the terminal is placed in the jaws of the crimping tool toward the anvil or the W-shape part.

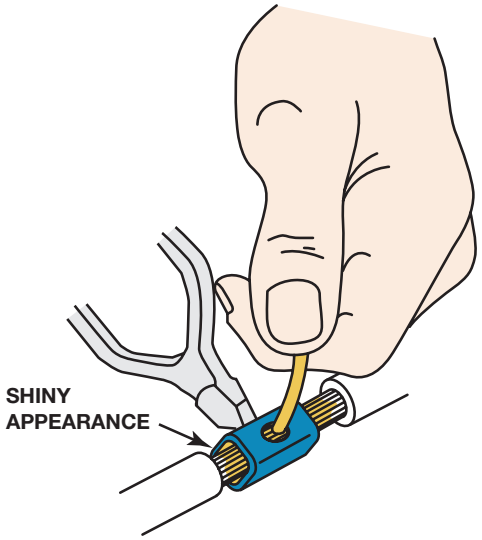


FIGURE 8–43 All hand-crimped splices or terminals should be soldered to be assured of a good electrical connection.

Most vehicle manufacturers also specify that all hand-crimped terminals or splices be soldered. ● **SEE FIGURE 8–43.**

HEAT SHRINK TUBING Heat shrink tubing is usually made from polyvinyl chloride (PVC) or polyolefin and shrinks to about half of its original diameter when heated; this is usually called a 2:1 shrink ratio. Heat shrink by itself does not provide protection against corrosion, because the ends of the tubing are not sealed against moisture. Chrysler Corporation recommends that all wire repairs that may be exposed to the elements be repaired and sealed using adhesive-lined heat shrink tubing. The tubing is usually made from flame-retardant flexible polyolefin with an internal layer of special thermoplastic adhesive. When heated, this tubing shrinks to one-third of its original diameter (3:1 shrink ratio) and the adhesive melts and seals the ends of the tubing. ● **SEE FIGURE 8–44.**

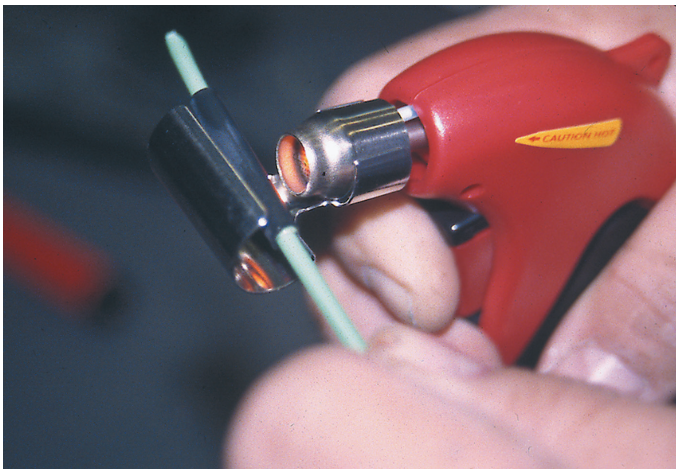


FIGURE 8–44 A butane torch especially designed for use on heat shrink applies heat without an open flame, which could cause damage.

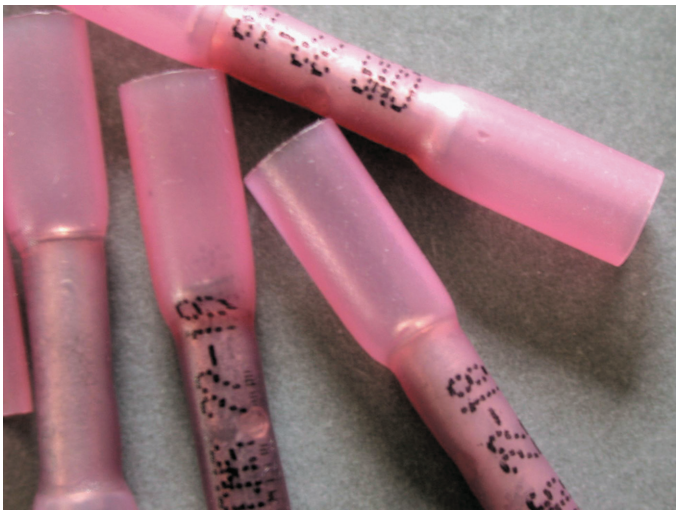


FIGURE 8–45 A typical crimp-and-seal connector. This type of connector is first lightly crimped to retain the ends of the wires and then it is heated. The tubing shrinks around the wire splice, and thermoplastic glue melts on the inside to provide an effective weather-resistant seal.

CRIMP-AND-SEAL CONNECTORS Several vehicle manufacturers recommend the use of crimp-and-seal connectors as the method for wire repair. **Crimp-and-seal connectors** contain a sealant and shrink tubing in one piece and are not simply butt connectors. ● **SEE FIGURE 8–45.**

The usual procedure specified for making a wire repair using a crimp-and-seal connector is as follows:

STEP 1 Strip the insulation from the ends of the wire (about 5/16 inch or 8 mm).

STEP 2 Select the proper size of crimp-and-seal connector for the gauge of wire being repaired. Insert the wires into the splice sleeve and crimp.

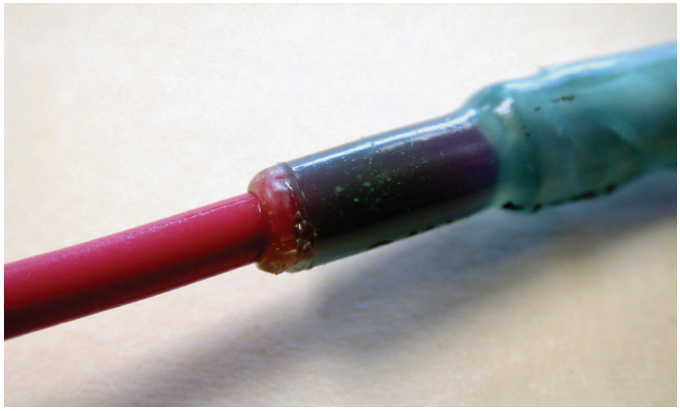


FIGURE 8–46 Heating the crimp-and-seal connector melts the glue and forms an effective seal against moisture.

NOTE: Use only the specified crimping tool to help prevent the pliers from creating a hole in the cover.

STEP 3 Apply heat to the connector until the sleeve shrinks down around the wire and a small amount of sealant is observed around the ends of the sleeve, as shown in ● **FIGURE 8–46.**

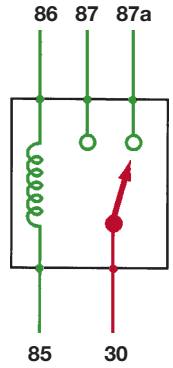
RELAYS

DEFINITION A **relay** is a magnetic switch that uses a movable armature to control a high-amperage circuit by using a low-amperage electrical switch.

TERMINAL IDENTIFICATION Most automotive relays adhere to common terminal identification. The primary source for this common identification comes from the standards established by the International Standards Organization (ISO). Knowing this terminal information will help in the correct diagnosis and troubleshooting of any circuit containing a relay. ● **SEE FIGURES 8–47 AND 8–48.**

Relays are found in many circuits because they are capable of being controlled by computers, yet are able to handle enough current to power motors and accessories. Relays include the following components and terminals:

1. Coil (terminals 85 and 86)
   - A coil provides the magnetic pull to a movable armature (arm).
   - The resistance of most relay coils is usually between 60 ohms and 100 ohms.
   - The ISO identification of the coil terminals are 86 and 85. The terminal number 86 represents the power to the relay coil and the terminal labeled 85 represents the ground side of the relay coil.
   - The relay coil can be controlled by supplying either power or ground to the relay coil winding.
   - The coil winding represents the control circuit, which uses low current to control the higher current through the other terminals of the relay. ● **SEE FIGURE 8–49.**
2. Other terminals used to control the load current
   - The higher amperage current flow through a relay flows through terminals 30 and 87, and often 87a.



(MOST RELAY COILS HAVE BETWEEN 60–100 OHMS OF RESISTANCE)

86 - POWER SIDE OF THE COIL
85 - GROUND SIDE OF THE COIL

30 - COMMON POWER FOR RELAY CONTACTS
87 - NORMALLY OPEN OUTPUT (N.O.)
87a - NORMALLY CLOSED OUTPUT (N.C.)

FIGURE 8–47 A relay uses a movable arm to complete a circuit whenever there is a power at terminal 86 and a ground at terminal 85. A typical relay only requires about 1/10 ampere through the relay coil. The movable arm then closes the contacts (#30 to #87) and can often handle 30 amperes or more.

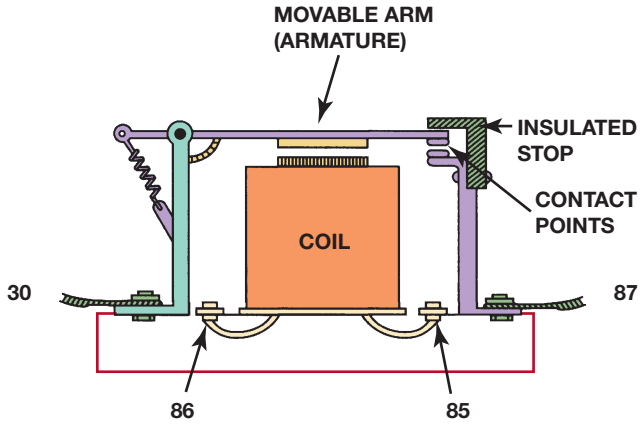


FIGURE 8–48 A cross-sectional view of a typical four-terminal relay. Current flowing through the coil (terminals 86 and 85) causes the movable arm (called the armature) to be drawn toward the coil magnet. The contact points complete the electrical circuit connected to terminals 30 and 87.

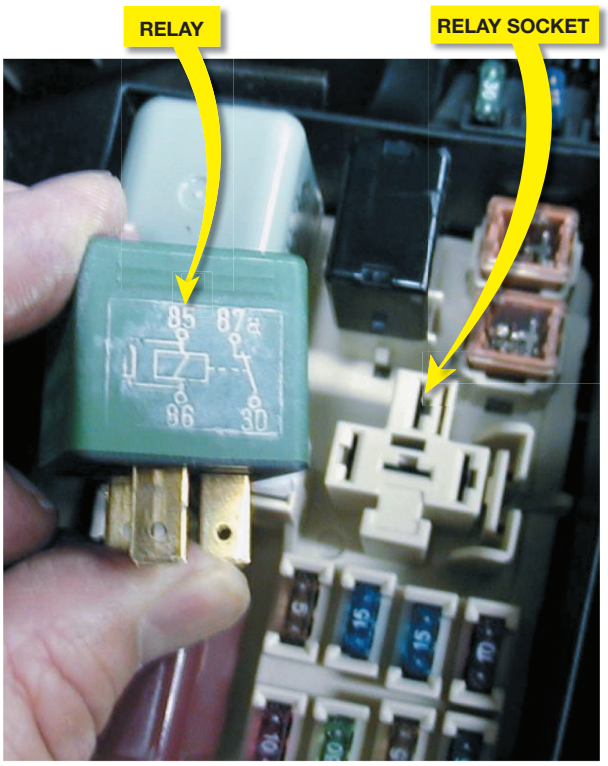


FIGURE 8–49 A typical relay showing the schematic of the wiring in the relay.

- There is power at terminal 86 and a ground at terminal 85 of the relay, a magnetic field is created in the coil winding, which draws the armature of the relay toward the coil. The armature, when energized electrically, connects terminals 30 and 87.

The maximum current through the relay is determined by the resistance of the circuit, and relays are designed to safely handle the designed current flow. **SEE FIGURES 8–50 AND 8–51.**

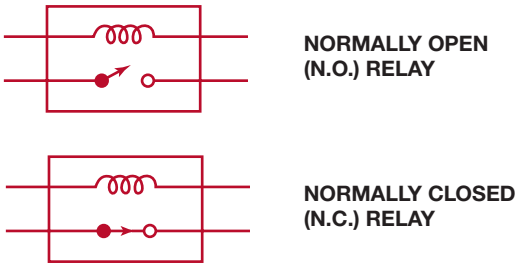


FIGURE 8–50 All schematics are shown in their normal, non-energized position.

SWITCHES

OHMMETER CHECKS A control switch can be checked by removing it from the circuit and checking it with an ohmmeter.

- The meter leads are connected to the two terminals of the switch. If there is only one terminal, one meter lead is connected to it, and the other lead is connected to the switch body. Some switches are normally open, and the reading should be high or infinite (OL). Some switches are normally closed, and the reading should be zero or nearly zero ohms.

TECH TIP

Divide the Circuit in Half

When diagnosing any circuit that has a relay, start testing at the relay and divide the circuit in half.

- **High current portion**: Remove the relay and check that there are 12 volts at the terminal 30 socket. If there is, then the power side is okay. Use an ohmmeter and check between terminal 87 socket and ground. If the load circuit has continuity, there should be some resistance. If OL, the circuit is electrically open.
- **Control circuit (low current)**: With the relay removed from the socket, check that there are 12 volts to terminal 86 with the ignition on and the control switch on. If not, check service information to see if power should be applied to terminal 86, then continue troubleshooting the switch power and related circuit.
- **Check the relay itself**: Use an ohmmeter and measure for continuity and resistance.
- Between terminals 85 and 86 (coil), there should be 60 to 100 ohms. If not, replace the relay.
- Between terminals 30 and 87 (high-amperage switch controls), there should be continuity (low ohms) when there is power applied to terminal 86 and a ground applied to terminal 85 that operates the relay. If "OL" is displayed on the meter set to read ohms, the circuit is open which requires that the relay be replaced.
- Between terminals 30 and 87a (if equipped), with the relay turned off, there should be low resistance (less than 5 ohms).

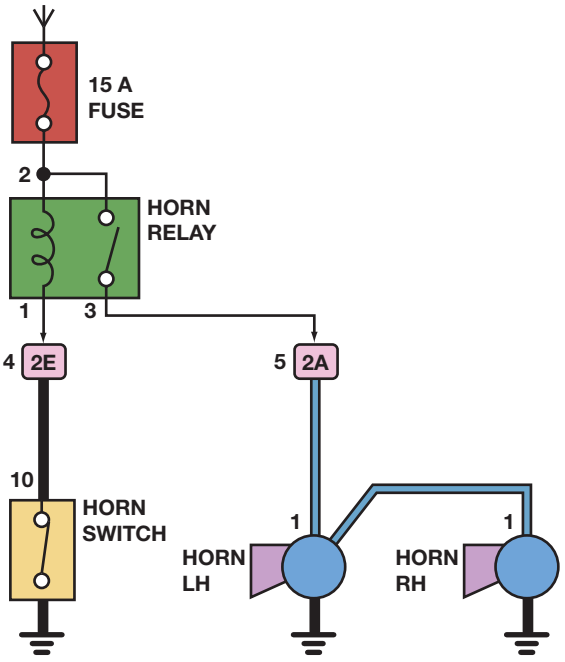


FIGURE 8–51 A typical horn circuit. Note that the relay contacts supply the heavy current to operate the horn when the horn switch simply completes a low-current circuit to ground, causing the relay contacts to close.

- When the switch is operated, the reading should change to the opposite value.
- A pressure switch can usually be operated using a specialized tester or by applying air pressure with a rubber-tipped air gun.

The *transmission range (TR)* switch, also called the *manual lever position (MLP)* switch, or neutral start switch, has several circuits and terminals. This switch is checked using service information to determine which terminals should have continuity as the switch is moved through its travel. ● **SEE FIGURE 8–52.**

VOLTMETER CHECKS

A mechanically operated switch can also be checked on the vehicle using a voltmeter.

To test a switch, perform the following steps:

STEP 1 Connect the negative meter lead to a good ground or the switch body and the positive lead to the B+ wire entering the switch. Voltage should be available to the switch.

STEP 2 Move the positive meter lead to the second switch terminal, and operate the switch. As the switch is operated, the output voltage should change from zero to the same as the input voltage or vice versa. If the voltage readings are not close to the same, there is a voltage drop, and high resistance in the switch is indicated.

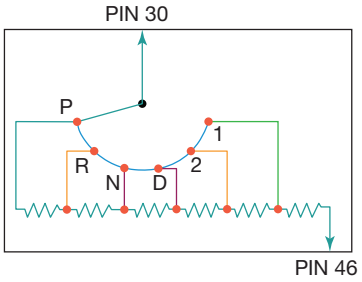


FIGURE 8–52 A typical transmission range switch is also similar to the circuit used for electronic transfer case switches. In this example, power, usually 12 volts, is applied at pin 30 and pin 46 is an input to the PCM. The change in voltage at pin 46 indicates how much resistance the circuit has, which is used to detect the gear selected.

SPEED SENSORS

OPERATION

Speed sensors can be either magnetic or Hall-effect-type sensors. A magnetic sensor consists of a notched wheel and a coil consisting of an iron core wrapped with fine wire. The notched wheel causes magnetic strength changes enough to create a usable varying AC voltage signal. ● **SEE FIGURE 8–53.**

The voltage-generating speed sensor normally uses a two-wire connector and is checked using both an ohmmeter and a voltmeter.

SPEED SENSOR TESTS

To test a speed sensor, perform the following steps:

STEP 1 Disconnect the sensor, and connect the two ohmmeter leads to the two sensor terminals.

STEP 2 There should be a complete circuit through the unit, and the resistance reading should fall within the specified range. Excessive or infinite resistance indicates a high resistance or open circuit; too low of a reading indicates a short circuit.

STEP 3 Attach the two leads of a voltmeter to the two sensor connectors, set the meter to AC volts.

STEP 4 Rotate the transmission shaft. As the shaft rotates, the voltmeter should show a fluctuating AC voltage reading, first + and then – of the same value.

Unlike the magnetic pulse generator, the Hall-Effect switch requires a small input voltage to generate an output or signal voltage. **Hall Effect** has the ability to generate a voltage signal in semiconductor material (gallium arsenate crystal) by passing current through it in one direction and applying a magnetic field to it at a right angle to its surface. If the input current is held steady

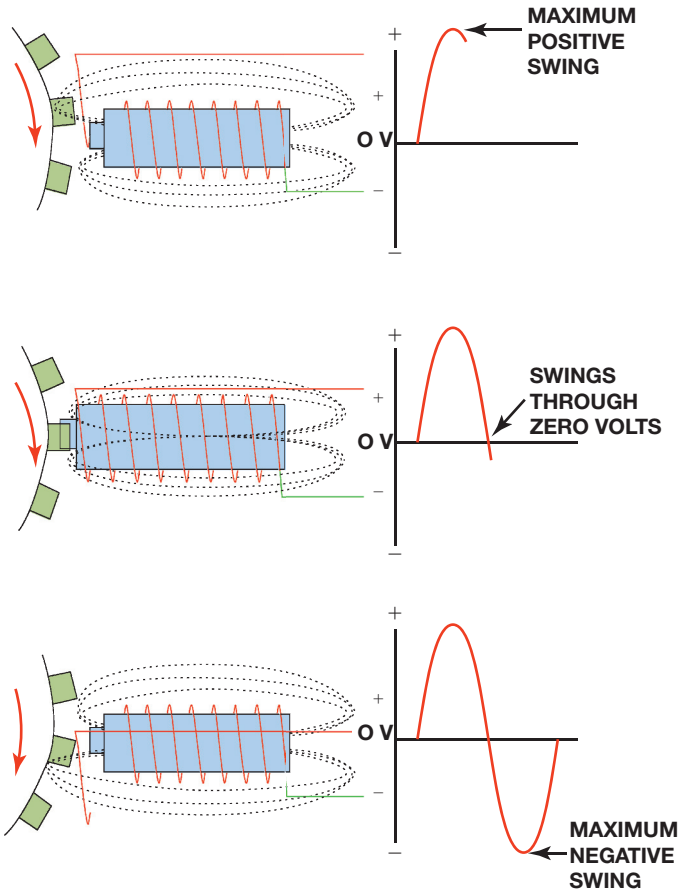


FIGURE 8–53 A magnetic sensor uses a permanent magnet surrounded by a coil of wire. The notches on the rotating shaft create a variable magnetic field strength around the coil. When a metallic section is close to the sensor, the magnetic field is stronger because metal is a better conductor of magnetic lines of force than air.

and the magnetic field fluctuates, an output voltage is produced that changes in proportion to field strength. **SEE FIGURE 8–54.**

THROTTLE POSITION (TP) SENSOR

PURPOSE AND FUNCTION The powertrain control module (PCM) uses TP sensor input to determine the amount of throttle opening and the rate of change to determine shift points of an automatic transmission and for engine management.

PARTS AND OPERATION The TP sensor consists of a **potentiometer**, a type of variable resistor. A potentiometer is a variable-resistance sensor with three terminals. One end of the resistor receives reference voltage, while the other end is grounded. The third terminal is attached to a movable contact that slides across the resistor to vary its resistance. Depending

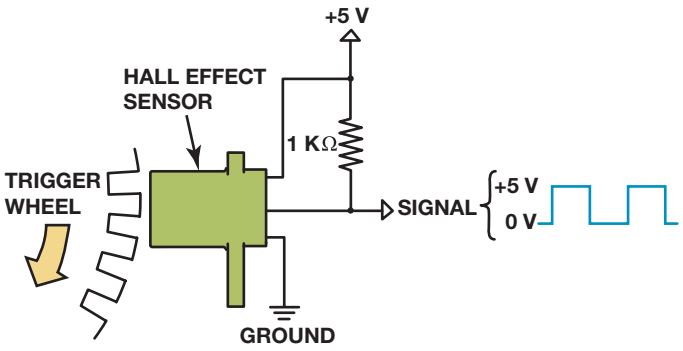


FIGURE 8–54 A Hall-Effect sensor produces an on-off voltage signal whether it is used with a blade or a notched wheel.

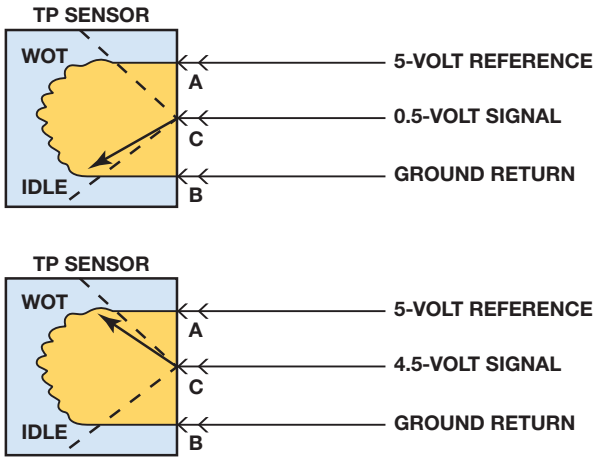


FIGURE 8–55 The signal voltage from a throttle position increases as the throttle is opened because the wiper arm is closer to the 5-volt reference. At idle, the resistance of the sensor winding effectively reduces the signal voltage output to the powertrain control module (PCM).

on whether the contact is near the supply end or the ground end of the resistor, return voltage is high or low.

A typical sensor has three wires:

- A 5-volt reference feed wire from the computer
- Signal return
- A ground wire back to the computer

SEE FIGURE 8–55.

TESTING A TP SENSOR A throttle position (TP) sensor can be checked using a voltmeter.

To test a TP sensor, perform the following steps:

STEP 1 Leave the TP sensor connector connected. Turn the ignition "ON."

STEP 2 Connect the negative lead to a good ground, and use the positive lead to probe the input voltage at the connector. It should be the specified voltage indicated in the service information.

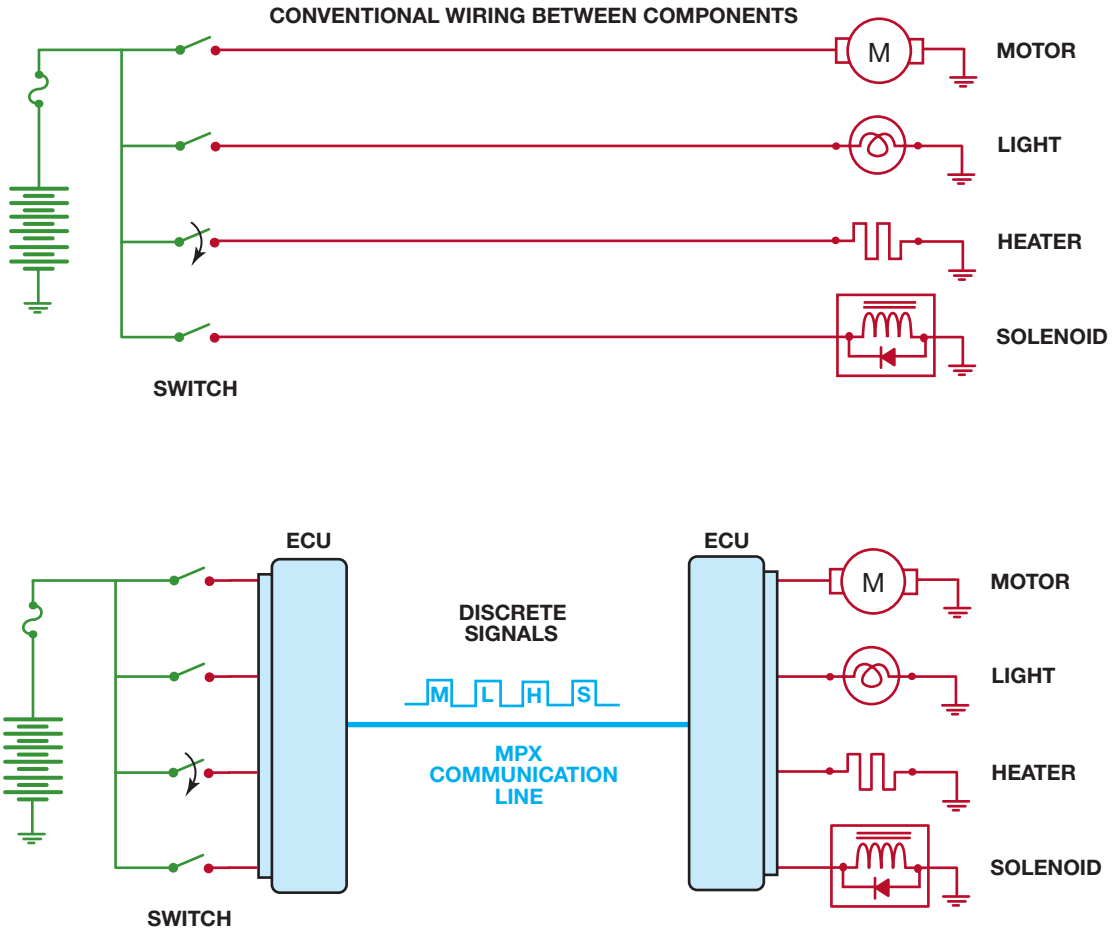


FIGURE 8–56 Module communications makes controlling multiple electrical devices and accessories easier by using simple low-current switches to signal another electronic control module (ECM), which does the actual switching of the current to the device.

STEP 3 Move the positive voltmeter lead to the TP output voltage lead, and measure the voltage as the throttle opens and closes. The output voltage should increase and decrease smoothly as the throttle is opened and closed.

NETWORKS

NEED FOR NETWORK

Since the 1990s, vehicles have used modules to control the operation of most electrical components. A typical vehicle will have 10 or more modules and they communicate with each other over data lines or hard wiring, depending on the application. **SEE FIGURE 8–56.**

MODULES AND NODES

Each module, also called a **node**, must communicate to other modules. For example, if the driver depresses the window-down switch, the power window switch sends a window-down message to the body control module. The body control module then sends the request to the driver's side window module. This module is responsible for actually performing the task by supplying power and ground to the window lift motor in the current polarity to cause the window to go down. The module also contains a circuit that monitors the current flow through the motor and will stop and/or reverse the window motor if an obstruction causes the window motor to draw more than the normal amount of current.

TYPES OF COMMUNICATION

The types of communications include the following:

- *Differential*. In the differential form of BUS communication, a difference in voltage is applied to two wires, which are twisted to help reduce electromagnetic interference (EMI). These transfer wires are called a twisted pair.
- *Parallel*. In the parallel type of BUS communication, the send and receive signals are on different wires.
- *Serial data*. The serial data is data transmitted by a series of rapidly changing voltage signals pulsed from low to high or from high to low.
- *Multiplexing*. The process of multiplexing involves the sending of multiple signals of information at the same

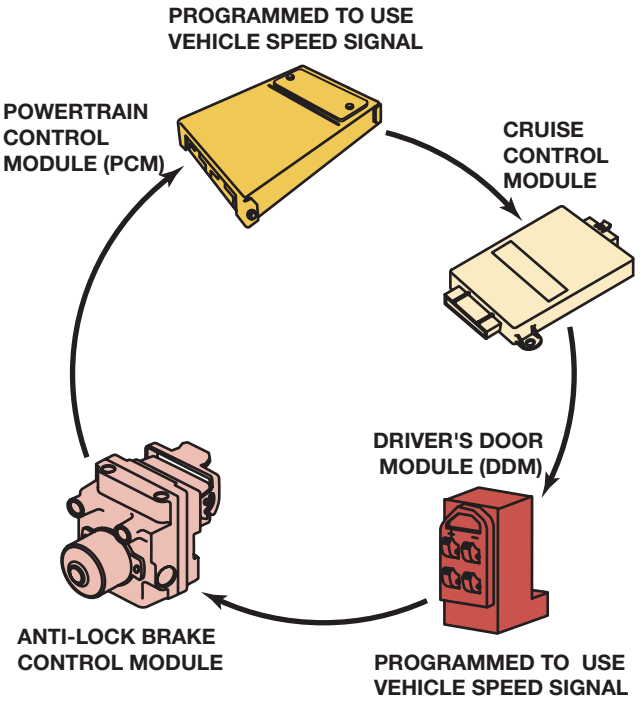


FIGURE 8–57 A network allows all modules to communicate with other modules.

time over a signal wire and then separating the signals at the receiving end.

This system of intercommunication of computers or processors is referred to as a network. ● **SEE FIGURE 8–57.**

By connecting the computers together on a communications network, they can easily share information back and forth. This multiplexing has the following advantages.

- Elimination of redundant sensors and dedicated wiring for these multiple sensors
- Reduction of the number of wires, connectors, and circuits
- Addition of more features and options to new vehicles
- Weight reduction due to fewer components, wires, and connectors, thereby increasing fuel economy
- Changeable features with software upgrades versus component replacement

NETWORK CLASSIFICATIONS

The Society of Automotive Engineers (SAE) standards include the following three categories of in-vehicle network communications.

Class A Low-speed networks, meaning less than 10,000 bits per second (bps, or 10 Kbs), are generally used for trip computers, entertainment, and other convenience features.

Class B Medium-speed networks, meaning 10,000 bps to 125,000 bps (10 Kbs to 125 Kbs), are generally used for information transfer among modules, such as instrument clusters, temperature sensor data, and other general uses.

Class C High-speed networks, meaning 125,000 bps to 1,000,000 bps, are generally used for real-time powertrain and vehicle dynamic control. High-speed BUS communication systems now use a controller area network (CAN). ● **SEE FIGURE 8–58.**

CONTROLLER AREA NETWORK

STANDARD Robert Bosch Corporation developed the CAN protocol, which was called CAN 1.2, in 1993. The CAN protocol was approved by the Environmental Protection Agency (EPA) for 2003 and newer vehicle diagnostics, and a legal requirement for all vehicles by 2008. The CAN diagnostic systems use pins 6 and 14 in the standard 16 pin OBD-II (J-1962) connector. Before CAN, the scan tool protocol had been manufacturer specific. ● **SEE FIGURE 8–59.**

? FREQUENTLY ASKED QUESTION

What Are U Codes?

The "U" diagnostic trouble codes were at first "undefined" but are now network-related codes. Use the network codes to help pinpoint the circuit or module that is not working correctly. Some powertrain-related faults are due to network communications errors and therefore can be detected by looking for "U" diagnostic trouble codes (DTCs).

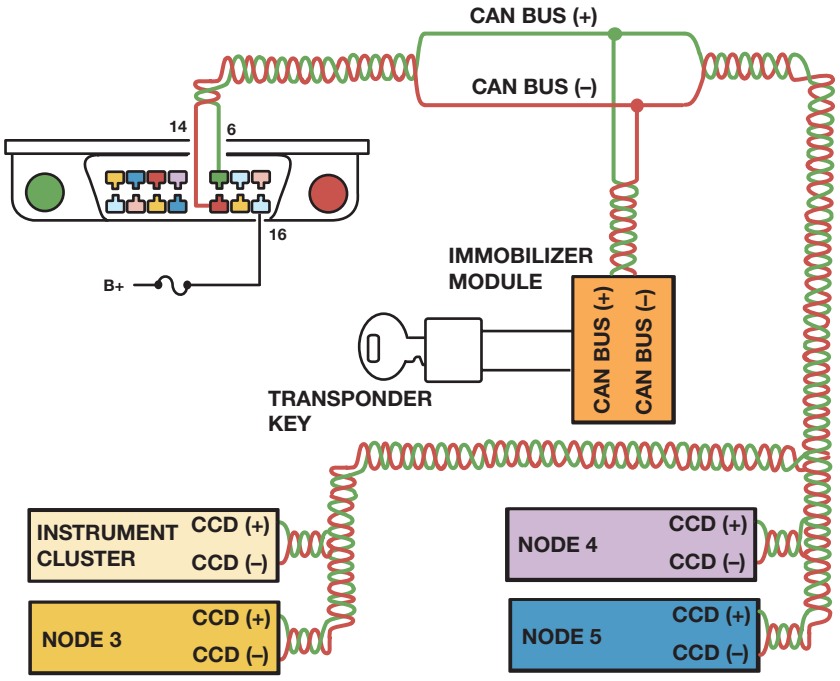


FIGURE 8–58 A typical (generic) system showing how the CAN BUS is connected to various electrical accessories and systems in the vehicle.

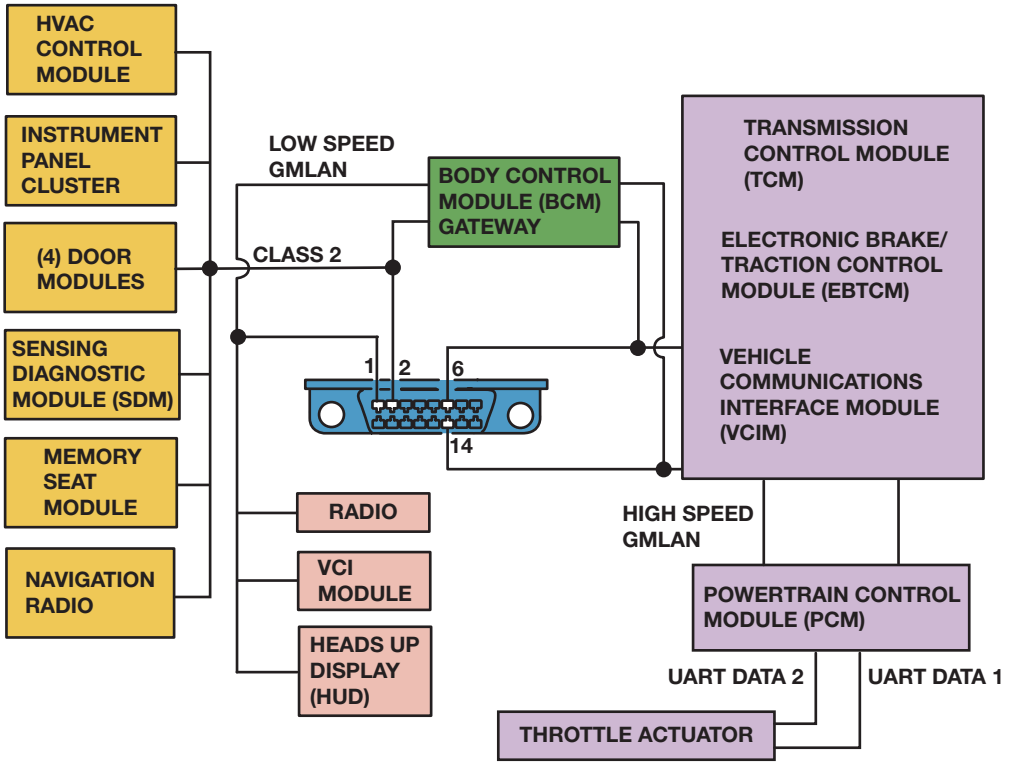


FIGURE 8–59 A schematic of a Chevrolet Equinox shows that the vehicle uses a GMLAN BUS (DLC pins 6 and 14), plus a Class 2 (pin 2). A scan tool can therefore communicate to the transmission control module (TCM) through the high-speed network. Pin 1 connects to the low-speed GMLAN network.

SUMMARY

1. Electricity is the movement of electrons from one atom to another.
2. In order for current to flow in a circuit or wire, there must be an excess of electrons at one end and a deficiency of electrons at the other end.
3. Automotive electricity uses the conventional theory that electricity flows from positive to negative.
4. The ampere is the measure of the amount of current flow.
5. Voltage is the unit of electrical pressure.
6. The ohm is the unit of electrical resistance.
7. All complete electrical circuits have a power source (such as a battery), a circuit protection device (such as a fuse), a power-side wire or path, an electrical load, a ground return path, and a switch or a control device.
8. A short-to-voltage involves a copper-to-copper connection and usually affects more than one circuit.
9. A short-to-ground usually involves a power path conductor coming in contact with a return (ground) path conductor and usually causes the fuse to blow.
10. An open is a break in the circuit resulting in absolutely no current flow through the circuit.
11. Circuit testers include test lights and fused jumper leads.
12. Digital multimeter (DMM) and digital volt-ohm-meter (DVOM) are terms commonly used for electronic test meters.
13. Ammeters measure current and must be connected in series in the circuit.
14. Voltmeters measure voltage and are connected in parallel.
15. Ohmmeters measure resistance of a component and must be connected in parallel with the circuit or component disconnected from power.
16. A terminal is the metal end of a wire, whereas a connector is the plastic housing for the terminal.
17. All wire repair should use either soldering or a crimp-and-seal connector.
18. All switches and relays on a schematic are shown in their normal position, either normally closed (N.C.) or normally open (N.O.).
19. A typical relay uses a small current through a coil (terminals 85 and 86) to operate the higher current part (terminals 30 and 87).
20. The use of a network for module communications reduces the number of wires and connections needed.
21. The SAE communication classifications for vehicle communications systems include Class A (low speed), Class B (medium speed), and Class C (high speed).

REVIEW QUESTIONS

1. What are ampere, volt, and ohm?
2. What is included in a complete electrical circuit?
3. Why must an ohmmeter be connected to a disconnected circuit or component?
4. List and identify the terminals of a typical ISO type relay.
5. Why is a communication network used?

CHAPTER QUIZ

1. An electrical conductor is an element with _____ electrons in its outer orbit.
   a. Less than 2 **c.** Exactly 4
   b. Less than 4 **d.** More than 4
2. Like charges _____.
   a. Attract each other **c.** Neutralize each other
   b. Repel each other **d.** Add
3. If an insulated wire gets rubbed through a part of the insulation and the wire conductor touches the steel body of a vehicle, the type of failure would be called a(n) _____.
   a. Short-to-voltage **c.** Open
   b. Short-to-ground **d.** Chassis ground
4. High resistance in an electrical circuit can cause _____.
   a. Dim lights **c.** Clicking of relays or solenoids
   b. Slow motor operation **d.** All of the above
5. If two power-side insulated wires were to melt together at the point where the copper conductors touched each other, the type of failure would be called a(n) _____.
   a. Short-to-voltage **c.** Open
   b. Short-to-ground **d.** Floating ground

6. When testing a relay using an ohmmeter, which two terminals should be touched to measure the coil resistance?
   a. 87 and 30
   b. 86 and 85
   c. 87a and 87
   d. 86 and 87

7. Technician A says that a good relay should measure between 60 ohms and 100 ohms across the coil terminals. Technician B says that OL should be displayed on an ohmmeter when touching terminals 30 and 87. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B

8. If a wire repair, such as that made under the hood or under the vehicle, is exposed to the elements, which type of repair should be used?
   a. Wire nuts and electrical tape
   b. Solder and adhesive-lined heat shrink or crimp-and-seal connectors
   c. Butt connectors
   d. Rosin-core solder and electrical tape

9. A module is also known as a _____.
   a. BUS
   b. Node
   c. Terminator
   d. Resistor pack

10. A high-speed CAN BUS communicates with a scan tool through which terminal(s)?
    a. 6 and 14
    b. 2
    c. 7 and 15
    d. 4 and 16

chapter 9

ELECTRONIC TRANSMISSION CONTROLS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Explain the procedure for monitoring engine load and vehicle speed for the proper functioning of hydraulically controlled transmission/transaxles.
3. Explain how the automatic transmissions/transaxles are controlled electronically.
4. Explain the function of sensors and switches for electronic control of transmission.
5. Identify the types of transmission solenoids.
6. Discuss adaptive strategies and controls for electronically controlled automatic transmissions/transaxles.

KEY TERMS

Adaptive control 142
Adaptive learning 142
Brake on/off (BOO) 138
Clutch fill volume index 143
Clutch volume index (CVI) 142
Default (Limp in) 143
Electronic pressure control (EPC) 140
Input speed sensor (ISS) 135
Output speed sensor (OSS) 135
Pressure control solenoid (PCS) 141
Scan tool 143
Torque management 142
Transmission adapt pressure (TAP) 143
Transmission control module (TCM) 133
Transmission fluid temperature (TFT) 136
Transmission range (TR) switch 134
Turbine speed sensor (TSS) 135
Vehicle speed (VS) sensor 135

TRANSMISSION CONTROL MODULE

TCM All recent automatic transmissions are controlled by electronic components and circuits. Typical transmission control systems contain many components. An automatic transmission can be controlled by its own computer, called a **transmission control module (TCM)**, or a *transmission control unit (TCU)*. The transmission can also be controlled through either the body control module (BCM) or the powertrain control module (PCM). Each manufacturer has its own design criteria and terminology. The TCM is normally located outside the transmission in a protected, relatively cool and clean location. Some newer transmissions have the TCM mounted on the valve body inside the transmission. The primary advantage is the reduction of wiring and the elimination of electrical connectors, both sources of potential problems.

TERMINOLOGY When the TCM is located inside the transmission, this design is often called a *control solenoid valve assembly, mechatronic*, and *solenoid body* and reduces the number of wires entering the transmission because of the following:

- Input and output shaft speed sensors
- Transmission range sensor
- Fluid pressure sensors
- Fluid temperature sensor
- Shift and pressure control solenoids are connected directly to the TCM

The wire connections to the rest of the vehicle include:

- Hi and Lo CAN transmits data to and from the ECM, BCM, and PCM
- Ignition on
- Diagnostic connection
- Ground

The TCM in some transmissions is about the same size as a common credit card. A concern with an internal TCM is the possibility of overheating the electronic components. One design has a thermocouple temperature sensor(s) mounted in the TCM circuit board, and if the temperature rises above 288°F (142°C), it will go into failure mode/default. The TCM normally keeps relatively cool by contact with the transmission case, and a spring bracket is used to ensure tight contact. ● **SEE FIGURE 9–1.**

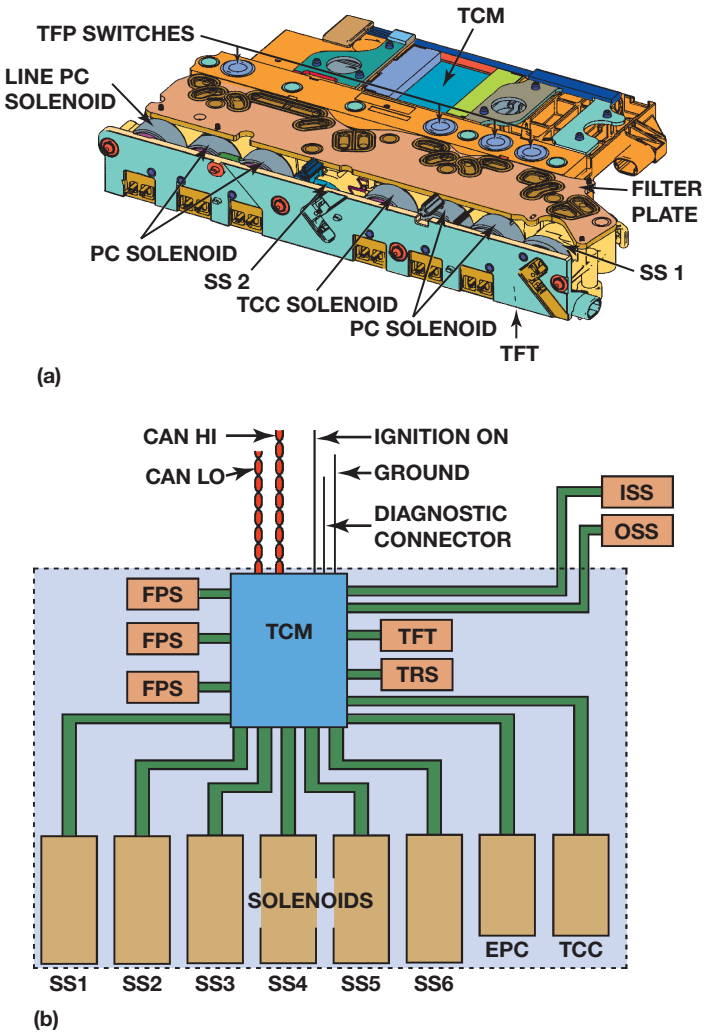


FIGURE 9–1 (a) This control solenoid assembly contains four transmission fluid pressure (TFP) switches, a line pressure control (PC) solenoid, four pressure control (PC) solenoids, two shift solenoids (SS), a torque converter clutch (TCC) solenoid, a transmission fluid temperature (TFT) sensor, and the transmission control module (TCM). It also has a vehicle harness connector with connections to the shift position switch and the input and output speed sensors. (b) A simplified view is also shown.

PURPOSE AND FUNCTION Many features of an electronic transmission, such as shift timing and quality, torque converter clutch apply timing, and quality, are software driven. A vehicle manufacturer can use the same transmission and adjust the operating characteristics with software for variations of particular vehicles. Some transmission control modules allow calibration values to be reprogrammed by technicians in the field.

The TCM receives data from the sensors and other control modules, and when these signals match the program stored in the TCM's memory, the TCM sends a signal to one or more electrical actuators to control the shifting operation of the transmission.

OPERATION The TCM can be programmed to incorporate several different operating strategies that are stored in the memory. The types of memory include:

- *Random access memory (RAM).* This is temporary memory that is cleared every time the vehicle is turned off.
- *Read-only memory (ROM).* The TCM/processor can read from ROM but cannot save any information to ROM.
- *Programmable read-only memory (PROM).* This is similar to a ROM but is programmed for a specific vehicle.
- *Electronically erasable programmable read-only memory (EEPROM).* This is similar to PROM but can be erased and reprogrammed. This is often called *reflashing*.
- *Keep alive memory (KAM).* ROM that is always connected to power so it retains memory. This can store information such as transmission adaptive strategies and the data will be lost if a battery becomes discharged or is disconnected.

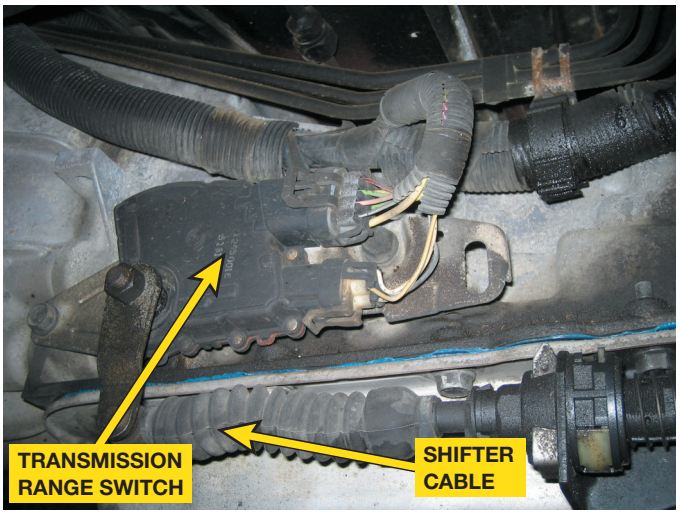


FIGURE 9–2 The transmission range switch is usually located on the case where the shifter cable attaches to the manual valve lever. The switch also includes the switch for the backup lights and the park/neutral switch, which is used to prevent the start being engaged unless the shifter is in park or neutral.

SENSORS

PURPOSE AND FUNCTION Sensors are the TCM inputs. They monitor the things that can affect transmission operation: vehicle speed, input shaft speed, transmission fluid temperature, the selected gear range, and engine coolant temperature, RPM, and load. A typical transmission sensor can be a switch that is made to open or close at certain pressures or temperatures, a transducer that senses pressure, a thermistor that senses temperature, or a speed sensor that measures vehicle speed or shaft RPM. The various sensor types (organized by the type of electrical signal) include the following:

- Frequency generators (creates an AC signal with a frequency relative to speed and the TCM monitors the signal frequency)
- Voltage generator (creates a voltage signal that is relative to speed and the TCM monitors the voltage)
- Potentiometer or variable resistor (alters resistance)
- Switches (an on–off signal)
- Thermistor (changes resistance relative to temperature)
- Transducer (changes resistance relative to pressure)
- Serial data (an on–off signal coming from another control module)

TRANSMISSION RANGE SWITCH The **transmission range (TR) switch**, also called the *manual lever position (MLP)* sensor, is used as an input to the PCM/TCM, which indicates the drive range requested by the driver. The transmission range switch is usually located on the outside of the case on the transmission/transaxle housing and attached to the shifter. As the gear range selector is moved, the TR switch can make a variety of switch connections for each gear range. These inputs allow the TCM to determine which gear range has been selected. The TR switch is used by the TCM to

- Keep the engine from starting in any gear position except park or neutral
- Allow a progressive 1–2–3–4 shift sequence in drive
- Limit upshifts in manual ranges
- Operate the backup lights in reverse. ● **SEE FIGURE 9–2.**

Some vehicles are equipped with a manual position where the driver can request one gear position by moving the shift lever to the manual position. ● **SEE FIGURE 9–3.**

SPEED SENSOR DESIGNS Speed sensors measure the speeds of the input and output shafts or sometimes of other shaft speeds in the automatic transmission or transaxle. The output shaft speed sensor is often used to provide vehicle speed information to the PCM and for adaptive learning. ● **SEE FIGURE 9–4.**

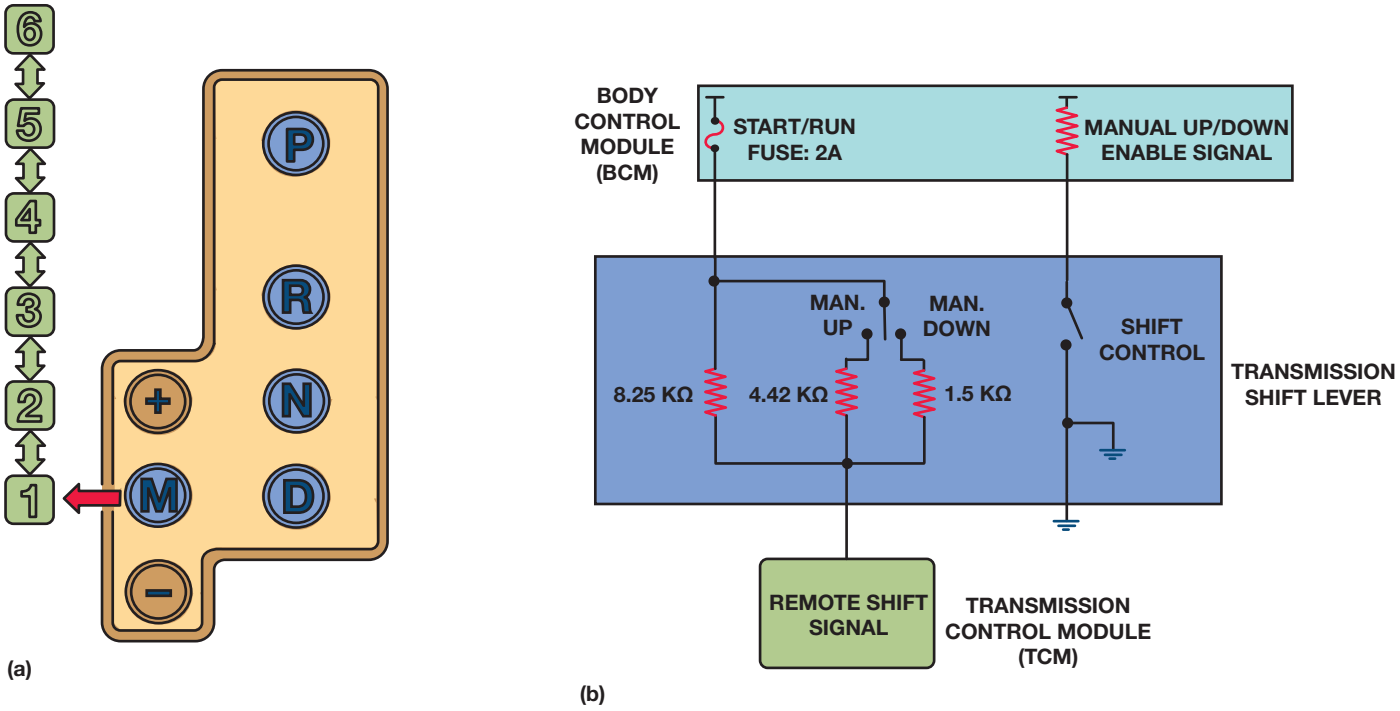


FIGURE 9–3 Moving the shift lever to the M (manual) position (a) activates the up/down, +/– switches that will cause an upshift or downshift.

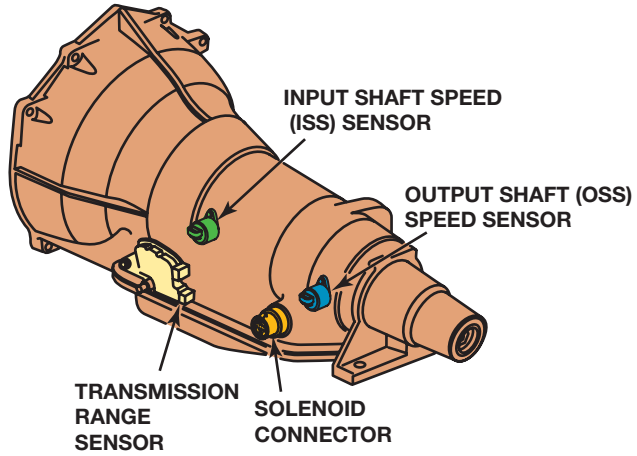


FIGURE 9–4 Speed sensors are used by the powertrain control module (PCM) or the transmission control module (TCM) to control shifts and detect faults such as slippage when the two speeds do not match the predetermined ratio for each gear commanded.

Speed sensor design includes:

- **Magnetic**—Most speed sensors use a coil of wire that is wrapped around a magnetic core. This sensor is mounted next to a toothed ring or wheel. As the toothed ring revolves, an alternating voltage is produced in the sensor. **SEE FIGURE 9–5.**
- **Hall-Effect**—Some speed sensors are Hall-Effect and create an on–off square wave signal that is used directly by the PCM/TCM for speed detection.

SPEED SENSOR LOCATIONS

- Speed sensors are used to detect the speeds of the input and output shafts on automatic transmissions/transaxles. **Input speed sensor (ISS)** measures the speed of the input shaft, which is the same or almost the same as the engine speed. This is also called **turbine speed sensor (TSS)** because it is used to determine the speed of the turbine shaft.
- The **output speed sensor (OSS)** is also called the **vehicle speed (VS) sensor** and is used by the PCM for speedometer and cruise control operation as well as for transmission/transaxle operation and shift-related fault detection. **SEE FIGURE 9–6.**

PRESSURE SENSORS/SWITCHES Most pressure sensors use a transducer, which is a variable resistance that produces a signal that is relative to pressure. The *line pressure sensor (LPS)* is a transducer that converts line pressure to a variable resistance.

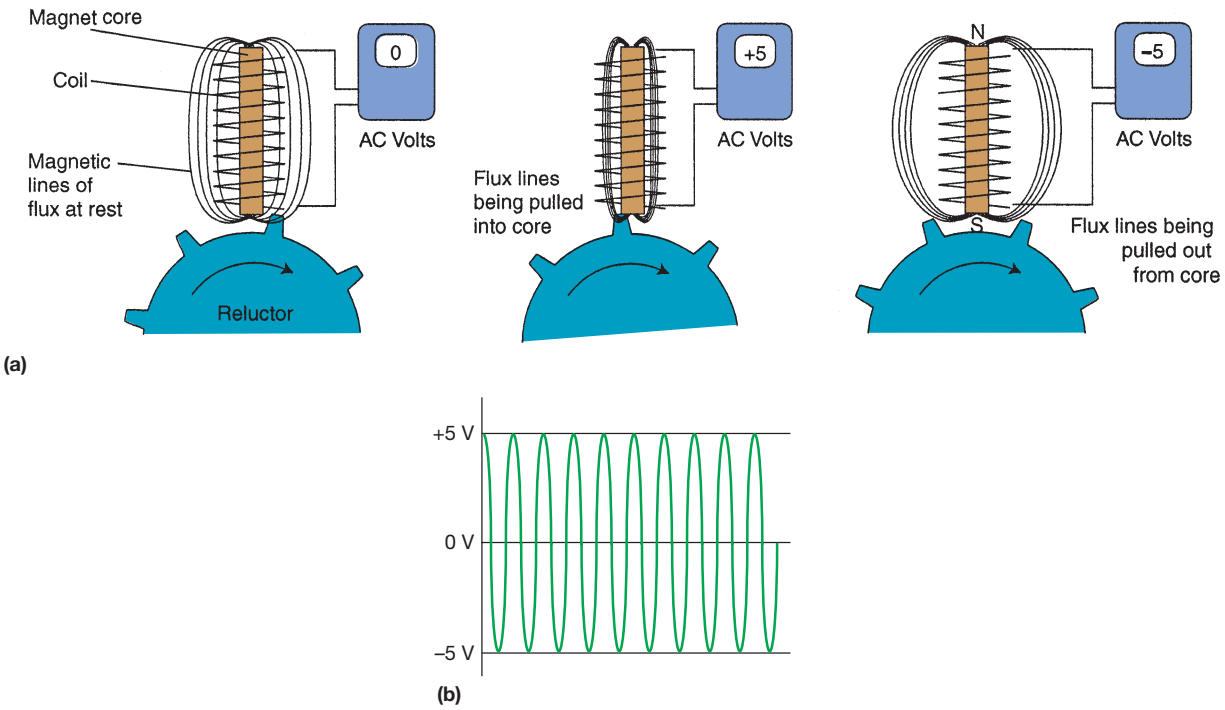


FIGURE 9–5 (a) The speed sensor switch will close as the magnet moves past it. (b) It will generate a sine wave signal, which is converted inside the PCM/TCM to a digital signal. The frequency of the signal is used to measure the speed.

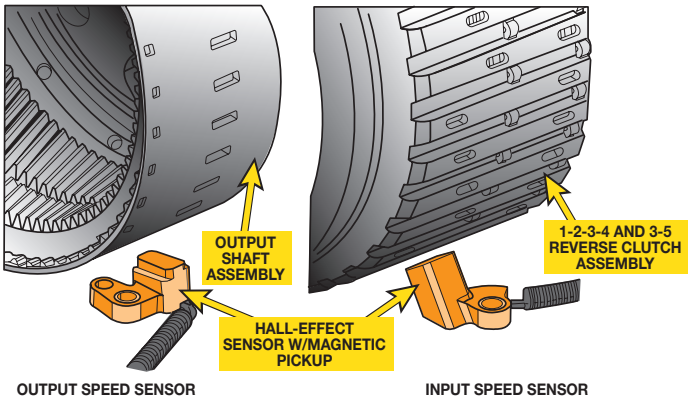


FIGURE 9–6 Input and output speed sensors are often mounted so that the notches in the rotating assembly are used to measure speed (RPM), which is used by the PCM/TCM for shift control and diagnostic information.

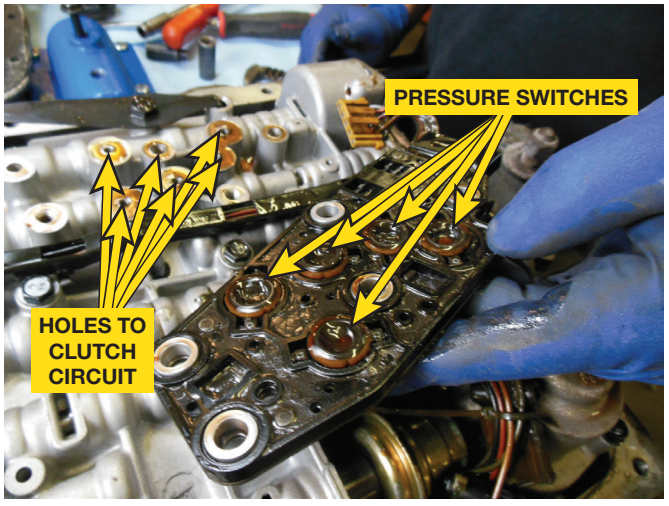


FIGURE 9–7 The pressure switch manifold (PSM) used in a GM 4L60-E consists of diaphragm switches with seals around each one that are bolted to the valve body over holes for each clutch circuit.

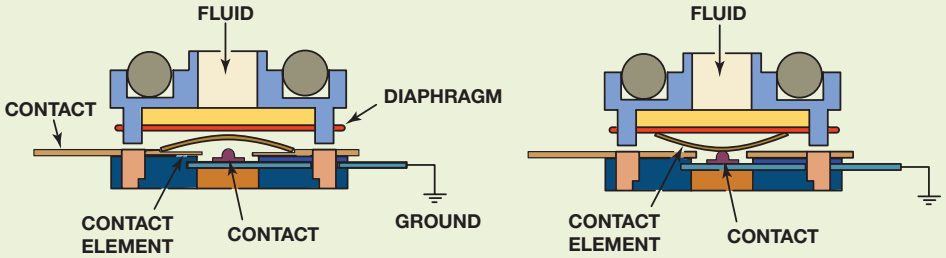
Many transmissions include *pressure switches* at the valve body. The signal from the pressure sensor tells the TCM that the circuit has pressure. The TCM uses these signals along with other information to determine TCC lockup and shift timing. ● **SEE FIGURE 9–7.**

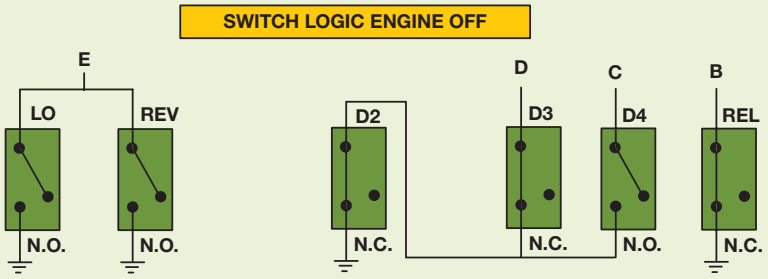
TEMPERATURE SENSORS The **transmission fluid temperature (TFT)** sensor can also be called a *transmission oil temperature (TOT) sensor*. Most temperature sensors are thermistors, a type of variable resistor that changes electrical resistance relative to temperature. These are called negative temperature coefficient (NTC) thermistors. The signal from a thermistor is the inverse of the temperature because it has high resistance at low temperatures and a low resistance at high temperatures. For example, a particular transmission fluid temperature sensor has a resistance of 37 to 100 ohms (Ω) at 32°F to 58°F (0°C to 20°C) and 1,500 to 2,700 ohms (Ω) at 195°F to 230°F (91°C to 110°C). ● **SEE FIGURE 9–9.**

FREQUENTLY ASKED QUESTION

What Is Pressure Logic?

Pressure switches are used to monitor which clutch has pressure but the PCM/TCM can use the information from the switches to verify which gear the transmission/transaxle is operating. Some pressure switches are normally open (N.O.) and others are normally closed (N.C.) and the gear that the unit is operating in can be determined by the switch positions. An open circuit is represented by a binary code "1" and measures 12 volts while a grounded circuit binary code is "0" and measures 0 volts. Depending on the position of the manual valve, fluid is routed to the pressure switch manifold (PSM). The PCM/TCM uses information from the on/off positioning of the switches to adjust line pressure, torque converter clutch (TCM) apply, and to control shift solenoid operation. ● **SEE FIGURE 9–8.**





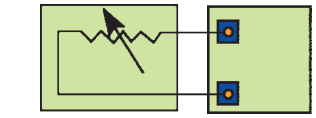
RANGE INDICATOR	FLUID					CIRCUIT		
	REV	D4	D3	D2	LO	E	D	C
PARK/NEUTRAL	0	0	0	0	0	0	1	0
REVERSE	1	0	0	0	0	1	1	0
OVERDRIVE	0	1	0	0	0	0	1	1
MANUAL THIRD	0	1	1	0	0	0	0	1
MANUAL SECOND	0	1	1	1	0	0	0	0
MANUAL FIRST	0	1	1	1	1	1	0	0

1 = PRESURIZED 0 = EXHAUSTED

1 = GROUNDED (RESISTANCE < 50 OHMS, 0 OHMS)

0 = OPEN (RESISTANCE > 50 K OHMS, 12 VOLTS)

FIGURE 9–8 Some switches are electrically normally open (N.O.) and others are normally closed (N.C.) and are used to provide gear selection information to the PCM/TCM.



(a)

Temperature		Resistance (Ohms)
°C	°F	
140	284	0.6 K
120	248	1.1 K
100	212	2.1 K
80	176	3.8 K
50	122	10 K
30	86	27 K
10	50	69 K
–10	14	193 K
–30	–22	600 K

(b)

FIGURE 9–9 (a) A transmission fluid temperature sensor can be checked by connecting an ohmmeter to the harness connector terminals. (b) The resistance should change as the temperature changes.

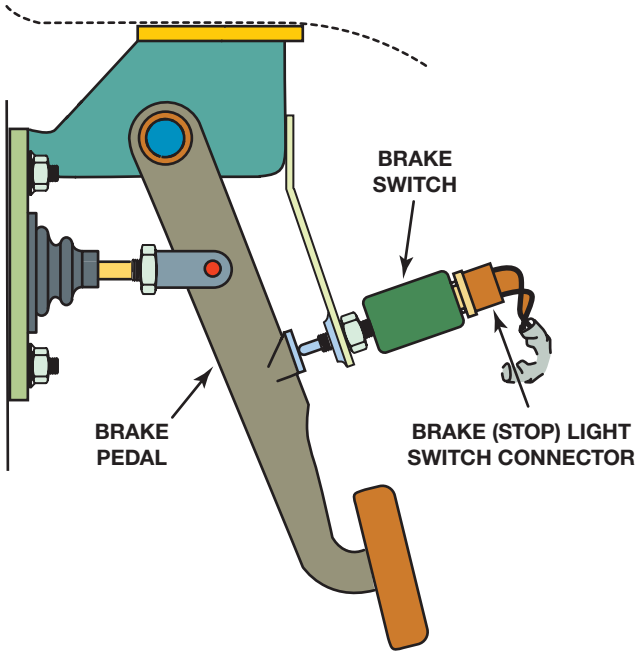


FIGURE 9–10 The brake (stop light) switch is mounted at the brake pedal. It provides a brake-apply signal to the TCM.

This sensor is used by the PCM or TCM to detect the temperature of the automatic transmission fluid. This signal is used to determine the best shift points and to regulate line pressure. It will cause the PCM or the TCM to engage the torque converter clutch (TCC) sooner and disable overdrive, to help reduce the fluid temperature if it reaches higher than normal.

BRAKE SWITCH A brake switch mounted at the brake pedal provides a signal when the brake is depressed. It signals the TCM that the brake is applied, and the TCC should be released. The brake switch is also called a **brake on/off (BOO)** switch. ● **SEE FIGURE 9–10.**

INPUTS SHARED WITH THE PCM Many factors are used by the TCM to determine when to shift. Many sensors are used by the PCM for engine operation and are also used to help the engine and transmission/transaxle work together to provide smooth efficient operation and produce the best performance with the lowest possible exhaust emission and the best possible fuel economy. The sensors that are used for both the engine and the transmission include the following:

- *Throttle position (TP) sensor.* This variable resistor (potentiometer) provides a voltage signal that is relative to throttle opening. It provides a throttle position signal to the TCM.
- *Engine coolant temperature (ECT).* This variable resistor (thermistor) monitors engine temperature. It signals the TCM that the engine is at operating temperature or approaching an overheat temperature.
- *Manifold absolute pressure (MAP)* and *mass airflow sensor (MAF)*. These sensors provide engine load signal to the PCM.

TRANSMISSION SOLENOIDS

TYPES OF SOLENOIDS An electronic transmission controls the shift points by turning a solenoid(s) on and off. The solenoids in turn control the hydraulic pressure that moves the shift valves or operates the torque converter clutch. Solenoids used in electronically controlled automatic transmissions/transaxles are as follows:

- **On–off solenoids.** These can be normally open to fluid flow or normally closed to block fluid flow. Shift solenoids control the pressure force which in turn controls the position of the shift valve. They are commanded on or off by the PCM or TCM. The resistance of most on–off shift solenoids is 10 to 15 ohms. ● **SEE FIGURE 9–11.**

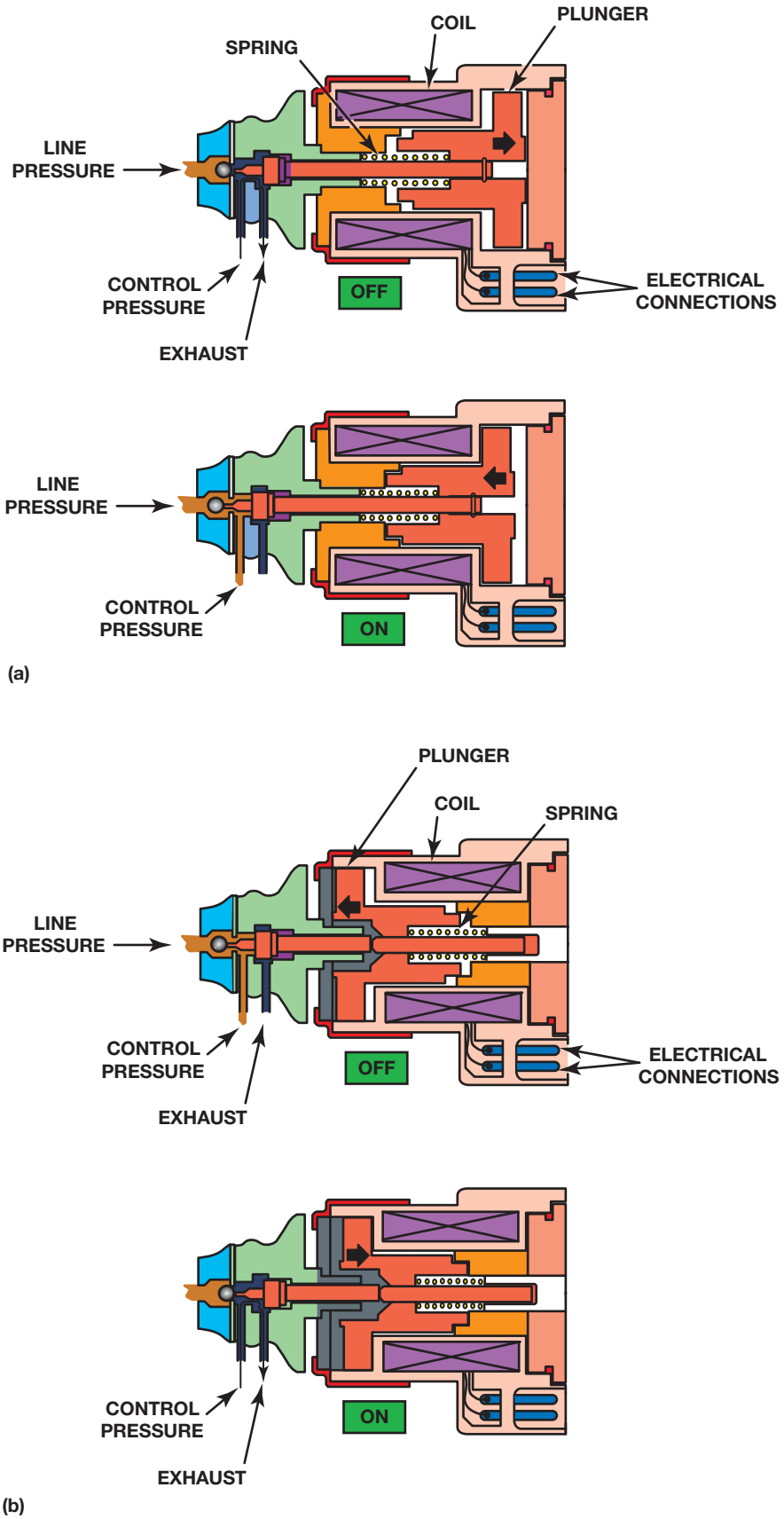


FIGURE 9–11 (a) The normally closed solenoid blocks fluid flow when it is off while opening the exhaust; and when it is on, it opens the valve. (b) The normally open solenoid allows fluid flow when it is off; and when it is on, it closes the valve while opening the exhaust.

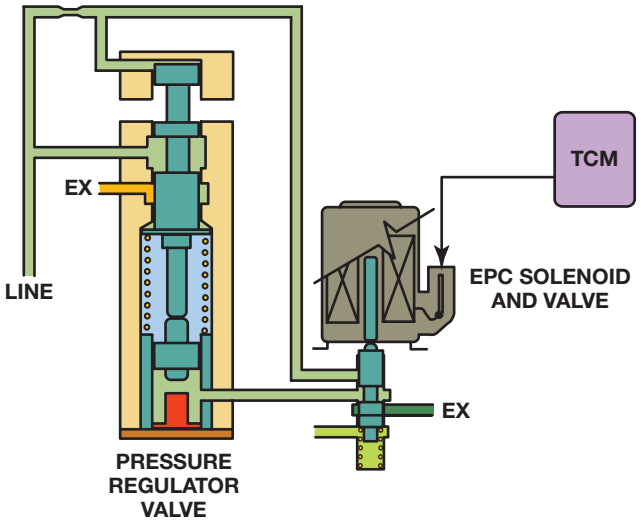


FIGURE 9–12 The signal from the TCM can cause the EPC solenoid to change the pressure regulator valve to adjust line pressure.

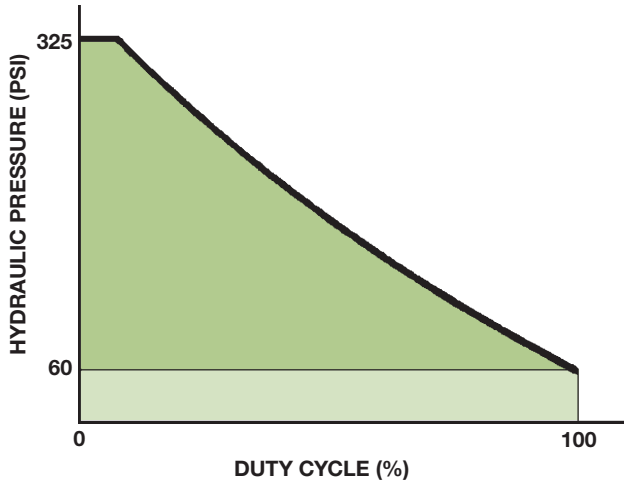


FIGURE 9–13 Line pressure increases as the duty cycle of the EPC solenoid decreases.

- **Linear solenoids.** This type of solenoid can be varied by changing the amount of on time to precisely control the fluid flow through the solenoid valve. The variable power or ground applied to the linear solenoids is pulse-width modulated (PWM) and allows the PCM precise control over the shifting and the fluid pressure. The resistance of most linear (PWM) shift solenoids is about half of the on–off type and range from 4 to 6 ohms. ● **SEE FIGURE 9–12.**

  A PWM signal is a digital signal, usually 0 volts and 12 volts, which is cycling at a fixed frequency. Varying the length of time that the signal is on provides a signal that can vary the on and off time of an output. The ratio of on time relative to the period of the cycle is referred to as duty cycle. The torque converter clutch (TCC), pressure control solenoids (PCS), and some shift solenoids are pulse-width modulated-type solenoids. ● **SEE FIGURE 9–13.**

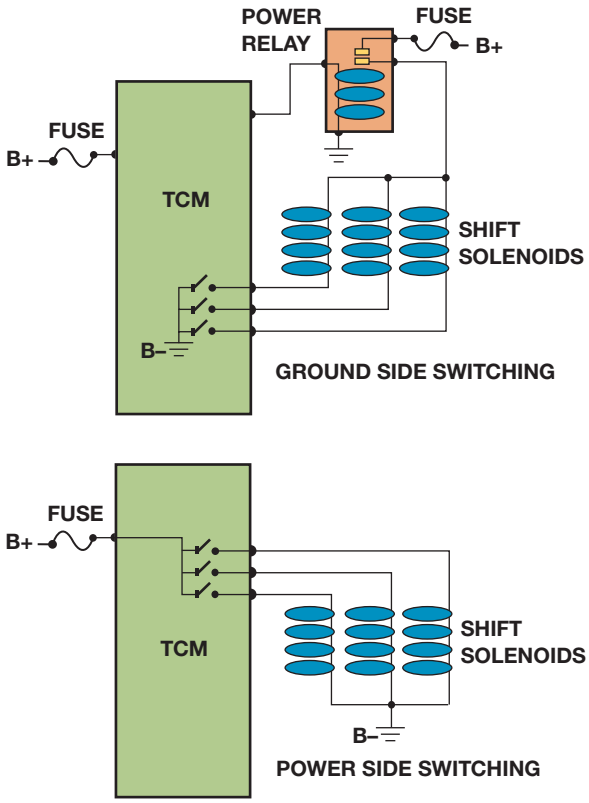


FIGURE 9–14 Solenoid control occurs when the PCM/TCM completes the circuit to ground (top) or switches on B+ (bottom). The ground connection is also B–.

LOW-SIDE AND HIGH-SIDE DRIVERS

Low-side drivers (LSD) are transistors that complete the ground path in the circuit. Ignition voltage is supplied to the solenoid and the computer output is connected to the ground side of the shift solenoid. The computer energizes the solenoid by completing the ground path. Low-side drivers can often perform a diagnostic circuit check by monitoring the voltage from the solenoid to check that the control circuit is complete. A low-side driver, however, cannot detect a short-to-ground.

High-side drivers (HSD) control the power side of the solenoid from the PCM/TCM. A ground is provided to the solenoid, so when the high-side driver switches, the solenoid will be energized. High-side drivers inside modules can detect electrical faults such as a break in continuity when the circuit is not energized. ● **SEE FIGURE 9–14.**

ELECTRONIC PRESSURE CONTROL

- The transmission's hydraulic pump pressure regulator valve is controlled by the pressure regulator valve that is controlled by a pulse-width-modulated solenoid called **Electronic pressure control (EPC) or**

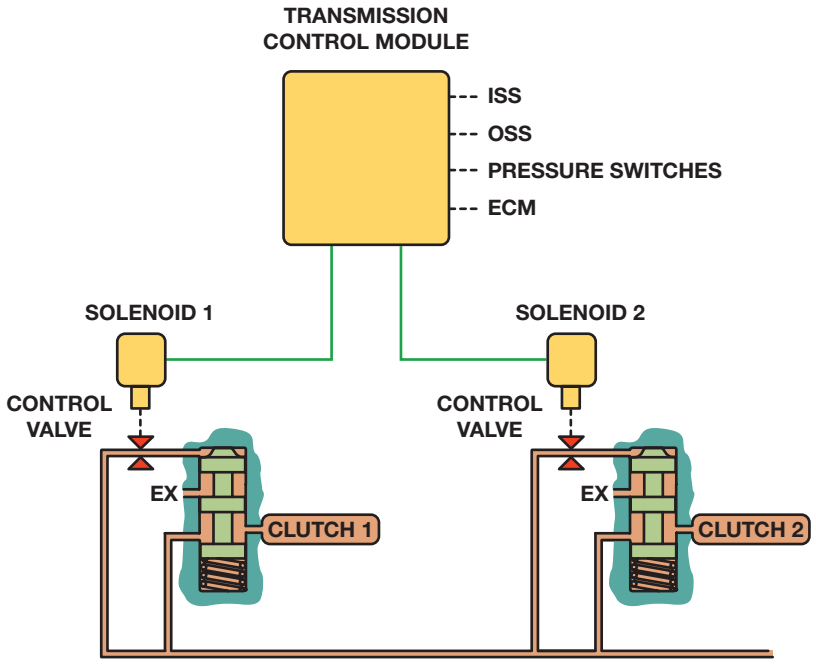


FIGURE 9–15 Using data from the various sensors, the TCM can apply or release the clutches. During an upshift, solenoid 1 can control how fast clutch 1 releases as solenoid 2 controls how fast clutch 2 applies to keep the shift time at the proper speed.

EPC AMPERES	PRESSURE PSI (kPa)
0.0	169–195 PSI (1,165–1,345 kPa)
0.1	167–194 PSI (1,151–1,338 kPa)
0.2	161–190 PSI (1,110–1,310 kPa)
0.3	155–186 PSI (1,069–1,282 kPa)
0.4	144–177 PSI (993–1,220 kPa)
0.5	133–167 PSI (917–1,151 kPa)
0.6	120–153 PSI (827–1,055 kPa)
0.7	102–138 PSI (703–952 kPa)
0.8	83–119 PSI (572–821 kPa)
0.9	62–97 PSI (427–669 kPa)
1.0	53–69 PSI (365–476 kPa)

CHART 9–1

Typical electronic pressure control (EPC) current and line pressure comparison.

- **Pressure control solenoid (PCS) or**
- ***Variable force solenoid (VFS)* or**
- ***Force motor***

The EPC is normally closed, which results in high regulated pressure.

- Current (a maximum of about 1 ampere) allows the solenoid to open, which reduces the regulated pressure.

The EPC PWM by the PCM/TCM operates at a fixed frequency, usually at 300 to 600 Hz depending on the unit.

- The higher the duty cycle, the more current and the lower the pressure.
- The lower the duty cycle, the less the current and the higher the pressure. ● **SEE CHART 9–1.**

HOW IT ALL WORKS

ELECTRONIC The transmission control module (TCM) uses information from the various engine and transmission/transaxle sensors and then commands the shift solenoids to operate, which controls the timing of the shifts. ● **SEE FIGURE 9–15.**

HYDRAULIC A solenoid can be cycled (pulsed on and off) or line pressure can be increased or decreased by adjusting the electrical signal to the electronic pressure control (EPC) or shift solenoid. The solenoids in turn control the hydraulic pressure that moves the shift valves or operates the torque converter clutch. ● **SEE FIGURE 9–16.**

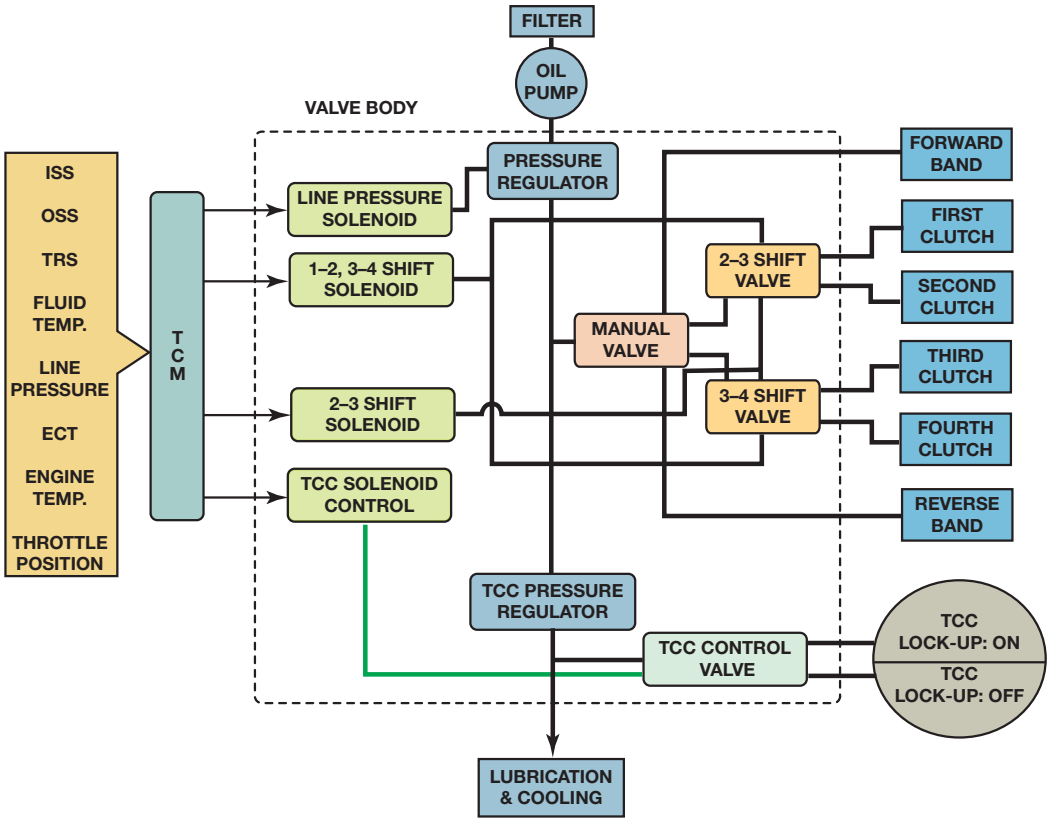


FIGURE 9–16 A diagram showing the relationship between the electronic and hydraulic controls.

FREQUENTLY ASKED QUESTION

What Is Torque Control?

Accurate control of shift timing and quality provides a smoother driving experience. In addition to improving shift quality, altering the ignition timing during the shift decreases the load on the transmission and increases transmission life. This is called **torque management** or *torque reduction* and is controlled by the PCM/TCM. ● **SEE FIGURE 9–17.**

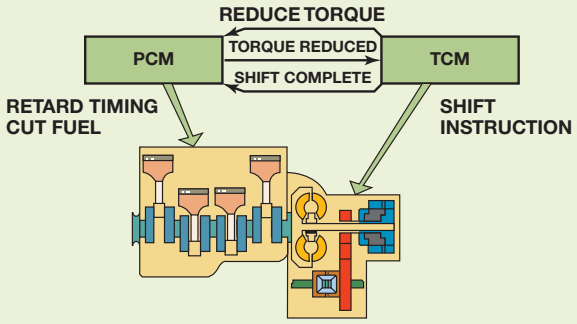


FIGURE 9–17 When the transmission control module (TCM) is ready to begin an upshift, it signals the powertrain control module (PCM) to reduce engine torque. This produces a smoother shift with less wear in the transmission.

ADAPTIVE STRATEGIES

DEFINITION Most late model electronically controlled automatic transmissions/transaxles use the PCM or TCM to monitor the time it takes to complete a shift. The PCM can determine this from the comparison between the engine speed and the output speed sensor data. When a shift is commanded, there should be a change in the speed of the output shaft. If the change in speed is more than normal, which could indicate normal wear in the clutch pack, the PCM can learn from this and start the shift sooner to allow time for the clutch to be fully engaged. The adjustment is called **adaptive control**, or **adaptive learning**, which keeps shift duration within a certain time period as determined by the driver's habits.

TYPICAL ADAPTIVE CONTROLS Transmissions use input and output speed sensors, allowing the TCM to determine the gear ratio and how long it takes to make the shift.

- Chrysler refers to the adaptive control as the **clutch volume index (CVI)**, which is the length of time it takes to fill the clutches with fluid.

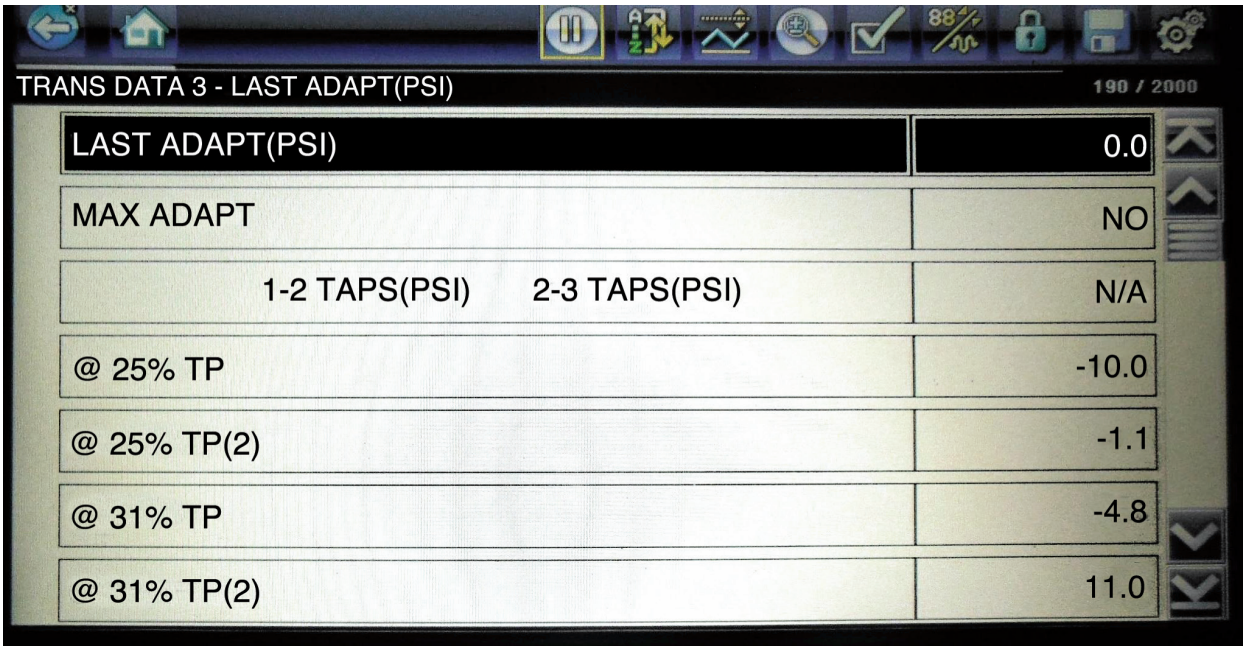


FIGURE 9–18 A scan tool display showing the adaptive (TAP) pressure changes at various throttle positions.

- General Motors call their adaptive control **Transmission Adapt Pressure (TAP)** system, which manages oil pressure to control clutch fill rates. The TAP values are sorted by cell, with each cell being a different throttle opening. The PCM/TCM can add pressure to compensate for clutch pack wear up to 30 PSI, which is displayed on a **scan tool**. **SEE FIGURE 9–18.**
- Honda calls it **clutch fill volume index** which is shown on a scan tool as a number. The higher the number, the more fluid volume is required to fill a clutch and can be used to see if there are worn friction plates in a certain clutch pack.

Check service information for details for the proper clutch volumes on the unit being serviced.

Some vehicles have additional shift control modes, and these provide earlier or later and smoother or faster shifts.

- The driver can choose economy mode, which causes the transmission to shift early with a smooth shift feel.
- When switched to power mode, the transmission shifts later and more firmly.

DEFAULT (LIMP-IN) A default (or limp-in) gear is the forward speed that is used if there is a failure in the electronic or computer system. If neither of two shift solenoids were engaged, then a default gear is actuated.

Depending on the exact make and model of the transmission or transaxle, the default gear can be second, third, or fourth gear. **SEE CHARTS 9–2 AND 9–3** for examples of two General Motors transmissions.

FREQUENTLY ASKED QUESTION

What Is Fuzzy Logic?

A method used to improve shift timing is through a process called *fuzzy logic*. In most situations, shifts simply match vehicle speed and throttle position. Fuzzy logic adapts shifts to driving conditions such as mountains, upgrades and downgrades, and while turning corners. The shifts will be delayed and firmer because of increased load and multiple changes in throttle position. Fuzzy logic and advanced electronics allow improved shifts for many different situations. **SEE FIGURE 9–19.**

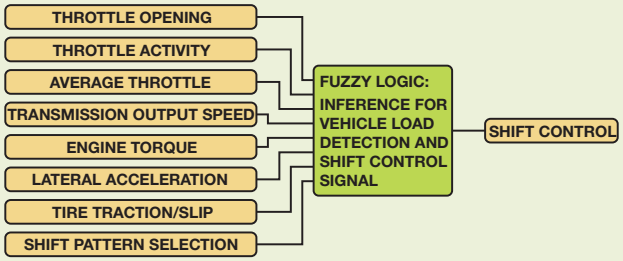


FIGURE 9–19 The fuzzy logic part of the TMC receives input signals, compares what the driver is doing with the throttle and what the vehicle is doing with normal operation, and adapts shift timing.

GENERAL MOTORS 4T60-E (FRONT-WHEEL-DRIVE TRANSAXLE)		
Gear Range	**Solenoid A**	**Solenoid B**
First gear	ON	ON
Second gear	OFF	ON
Third gear	OFF	OFF
Fourth gear	ON	OFF

CHART 9–2

In this example, the vehicle would start out and remain in third gear if there was a fault with the computer or wiring.

GENERAL MOTORS 4L80-E (REAR-WHEEL-DRIVE TRANSMISSION)		
Gear Range	**Solenoid A**	**Solenoid B**
First gear	ON	OFF
Second gear	OFF	OFF
Third gear	OFF	ON
Fourth gear	ON	ON

CHART 9–3

In this example, the vehicle would start out and remain in second gear if there was a fault with the computer or wiring.

SUMMARY

1. Electronic controls are used for accurate automatic operation of the transmission/transaxle.
2. Electronic controls use sensors to monitor various operational inputs that will be used to control the operation of the transmission.
3. The hydraulic operation of the transmission is controlled by solenoids that are switched to redirect pressurized fluid to move shift valves or change the operational pressures.
4. The PCM/TCM receives the signals from the sensors and operates the solenoids to produce upshifts and downshifts at the proper speed.

REVIEW QUESTIONS

1. What are the four sensors that are used by the automatic transmission/transaxle controller to determine when to shift?
2. What are the types of computer memory used in the PCM/TCM?
3. What is the purpose and function of the input and output speed sensors?
4. What is the purpose and function of the pressure sensors inside the automatic transmission/transaxle?
5. What is meant by adaptive controls?

CHAPTER QUIZ

1. What electronic control module is used to control the shifting of an electronically controlled automatic transmission/transaxle?
   a. PCM
   b. TCM
   c. TCU
   d. Any of the above depending on application
2. What type of sensor measures temperature?
   a. Potentiometer **c.** Transducer
   b. Thermistor **d.** Frequency generator
3. What type of sensor measures speed?
   a. Potentiometer **c.** Transducer
   b. Thermistor **d.** Frequency generator
4. The transmission range (TR) switch is used to _____.
   a. Keep the engine from starting in any gear position except park or neutral
   b. Limit upshifts in manual ranges
   c. Operate the backup lights in reverse
   d. All of the above

5. The input speed sensor is also called a _____.
   - **a.** Output speed sensor (OSS)
   - **b.** Vehicle speed (VS) sensor
   - **c.** Turbine speed sensor (TSS)
   - **d.** Any of the above depending on make and model

6. The output speed sensor is also called a _____.
   - **a.** Input speed sensor (ISS)
   - **b.** Vehicle speed (VS) sensor
   - **c.** Turbine speed sensor (TSS)
   - **d.** Any of the above depending on make and model

7. What type of sensor is the transmission fluid temperature (TFT) sensor?
   - **a.** Negative temperature coefficient (NTC) thermistor
   - **b.** Potentiometer
   - **c.** Rheostat
   - **d.** Transducer

8. Linear solenoids are used for _____.
   - **a.** TCC
   - **b.** Pressure control
   - **c.** Transducer
   - **d.** All of the above depending on application

9. What does an electronic pressure control (EPC) solenoid use to control mainline pressure?
   - **a.** Resistance
   - **b.** Torque
   - **c.** Current
   - **d.** Voltage

10. Adaptive control means _____.
    - **a.** The time it takes to make a shift
    - **b.** The delay between the command and when the shift occurs
    - **c.** The change in the pressure or timing to keep the shift occurring at the same time to make up for wear
    - **d.** The default position which may be second, third, or fourth gear depending on application

chapter 10

HYBRID ELECTRIC VEHICLE TRANSMISSIONS AND TRANSAXLES

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Identify the types of hybrid vehicles.
3. Identify the levels of hybrids.
4. Explain how an automatic transmission can be converted for use in hybrid electric vehicles.
5. Identify the components of a two-mode hybrid transmission system and explain its operation.
6. Discuss the operation of different hybrid vehicle transmissions.

KEY TERMS

Electronically variable transmission (EVT) 151

Internal combustion engine (ICE) 147

Traction battery 161

Traction motor 161

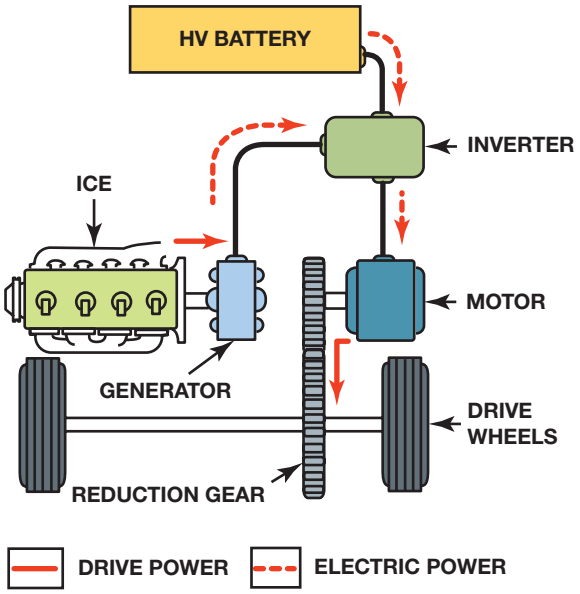


FIGURE 10–1 The power flow in a typical series-hybrid vehicle.

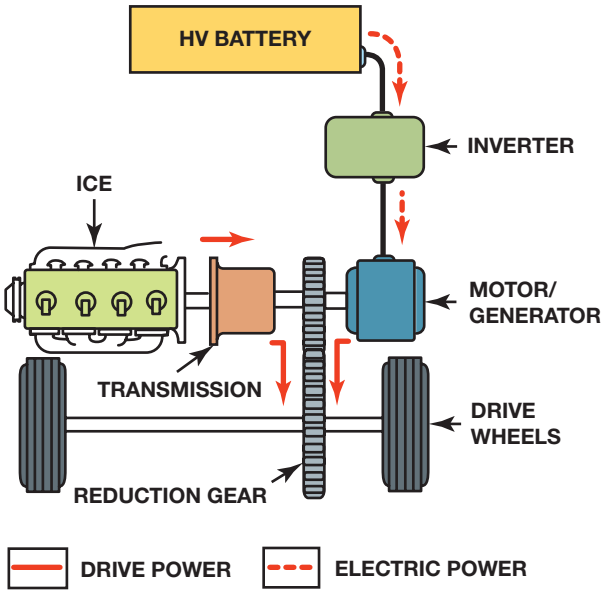


FIGURE 10–2 The power flow in a typical parallel-hybrid vehicle.

TYPES OF HYBRID VEHICLES

SERIES HYBRID The types of hybrid electric vehicles include series, parallel, and series–parallel designs. In a series hybrid design, sole propulsion is by a battery-powered electric motor, but the electric energy for the batteries comes from another on-board energy source, such as an **internal combustion engine (ICE)**. In this design, the engine turns a generator and the generator can either charge the batteries or power an electric motor that drives the transmission. The internal combustion engine never powers the vehicle directly. ● **SEE FIGURE 10–1.**

The engine is only operated to keep the batteries charged. Therefore, the vehicle could be moving with or without the internal combustion engine running. Series-hybrid vehicles also use regeneration braking to help keep the batteries charged. The engine is designed to just keep the batteries charged, and therefore, is designed to operate at its most efficient speed and load.

ADVANTAGES An advantage of a series-hybrid design is that no transmission, clutch, or torque converter is needed. A series hybrid does not give the owner "range anxiety" that often affects owners of electric vehicles who are concerned that they may not have enough electric power to make it home or to a charging station.

DISADVANTAGES A disadvantage of a series-hybrid design is the added weight of the internal combustion engine as compared to an electric vehicle. The engine is actually a heavy on-board battery charger. Also, the electric motor and battery capacity have to be large enough to power the vehicle under all operating conditions, including climbing hills. All power needed for heating and cooling must also come from the batteries, so using the air conditioning in hot weather and the heater in cold weather reduces the range that the vehicle can travel on battery power alone.

PARALLEL HYBRID In a parallel-hybrid design, multiple propulsion sources can be combined, or one of the energy sources alone can drive the vehicle. In this design, the battery and engine are both connected to the transmission. The vehicle using a parallel-hybrid design can be powered by the internal combustion engine alone, by the electric motor alone (full hybrids only), or by a combination of engine and electric motor propulsion. In most cases, the electric motor is used to assist the internal combustion engine.

ADVANTAGES One of the advantages of using a parallel-hybrid design is that by using an electric motor or motors to assist the internal combustion engine, the engine itself can be smaller than would normally be needed. ● **SEE FIGURE 10–2.**

NOTE: A parallel-hybrid design could include additional batteries to allow for plug-in capability, which could extend the distance the vehicle can travel using battery power alone.

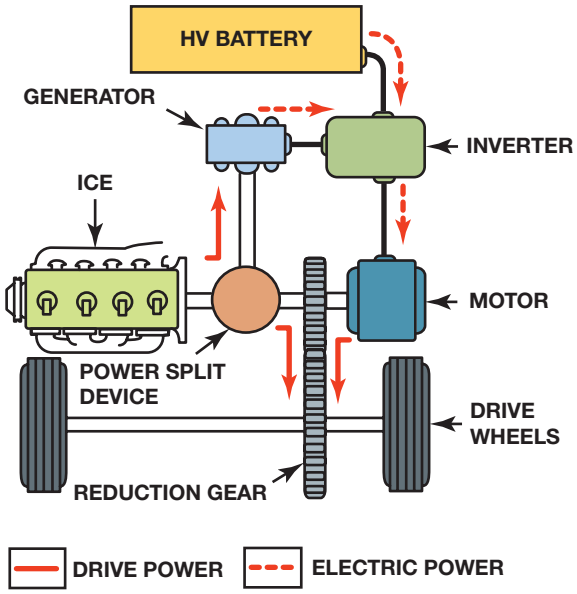


FIGURE 10–3 A series–parallel hybrid design allows the vehicle to operate in electric motor mode only or in combination with the internal combustion engine.

DISADVANTAGES One disadvantage of a parallel-hybrid design is that complex software is needed to seamlessly blend electric and ICE power. Another concern about the parallel-hybrid design is that it has to be engineered to provide proper heating and air-conditioning system operation when the ICE stops at idle.

SERIES–PARALLEL HYBRID The Toyota and Ford hybrids are classified as series–parallel hybrids because they can operate using electric motor power alone or with the assistance of the ICE. Series–parallel hybrids combine the functions of both a series and a parallel design. The internal combustion engine may be operating even though the vehicle is stopped if the electronic controller has detected that the batteries need to be charged. ● **SEE FIGURE 10–3.**

NOTE: The internal combustion engine may or may not start when the driver starts the vehicle depending on the temperature of the engine and other conditions. This can be confusing to some who are driving a hybrid electric vehicle for the first time and sense that the engine did not start when they tried to start the engine.

LEVELS OF HYBRIDS

MILD HYBRID A mild hybrid will incorporate idle stop and regenerative braking, but is not capable of using the electric motor to propel the vehicle on its own without help from the internal combustion engine. A mild hybrid system has the advantage of costing less, but saves less fuel compared to a full hybrid vehicle and usually uses a 42-volt electrical motor and battery package (36-volt batteries, 42-volt charging). An example of this type of hybrid is the General Motors parallel-hybrid truck (PHT) pickup truck and the Saturn VUE. The fuel savings for a mild type of hybrid design is about 8% to 15%.

MEDIUM HYBRID A medium hybrid uses 144 to 158-volt batteries that provide for engine stop/start, regenerative braking, and power assist. Like a mild hybrid, a typical medium hybrid is not capable of propelling the vehicle from a stop using battery power alone. Examples of a medium-hybrid vehicle include the Honda Insight, Civic, and Accord. The fuel economy savings are about 20% to 25% for medium-hybrid systems.

FULL HYBRID A full hybrid, also called a *strong hybrid*, uses a 201–300 volt battery, and provides for idle stop, regenerative braking, and is able to propel the vehicle using the electric motor(s) alone. Each vehicle manufacturer has made its decision on which hybrid type to implement based on its assessment of the market niche for a particular model. Examples of a full or strong hybrid include the Ford Escape SUV, Toyota Highlander, Lexus RX400h, Lexus GS450h, Toyota Prius, and Toyota Camry. The fuel savings are about 30% to 50% for full-hybrid systems.

ONE-MOTOR/TWO-MOTOR/ THREE-MOTOR SYSTEMS

ONE-MOTOR HYBRIDS Hybrid electric vehicles that use one electric motor include VW, Nissan, Honda, and General Motors. In these units, an electric motor is attached to the engine crankshaft and is used to perform two functions:

1. Start the gasoline engine (ICE).
2. Act as a generator to charge the high-voltage batteries.

General Motors also uses a belt alternator starter (BAS) system, which uses a belt-driven motor/generator attached to the front of the engine. Hybrids that use one motor are often mild hybrids and usually are not able to power the vehicle using electric power alone.

TWO-MOTOR HYBRIDS Hybrid electric vehicles that use two motors are the most commonly used hybrids and are used by Toyota, Ford, and General Motors in their full-size two-mode trucks. Each electric motor serves two purposes:

FIGURE 10–4 The rear electric motor on a Lexus RX400h SUV.

- The motor/generator attached to the engine, usually labeled M/G1, is used to start the gasoline engine and to charge the high-voltage batteries.
- The motor/generator that is connected to the drive wheels, usually labeled M/G2, is used to propel the vehicle and to recharge the high-voltage battery during deceleration (regenerative braking).

Two-motor hybrid electric vehicles are full (strong) hybrids and are capable of propelling the vehicle using electric motor power alone for short distances.

THREE-MOTOR HYBRIDS Three-motor hybrid electric vehicles are usually two-motor hybrids that use an additional electric motor to propel the rear wheels for all-wheel-drive capability. Hybrid electric vehicles that use three electric motors include the Toyota Highlander and Lexus RX400/450h SUVs. ● **SEE FIGURE 10–4.**

HYBRID ELECTRIC VEHICLE (HEV) TRANSMISSIONS

AUTOMATIC TRANSMISSIONS CONVERTED FOR USE IN HYBRID VEHICLES In order to adapt a conventional automatic transmission to a hybrid power train, an electric auxiliary pump is used to maintain fluid pressure in the transmission during internal combustion engine (ICE) idle stop. This pump is powered by a DC brushless (AC synchronous) motor, which requires a special controller to provide the correct operating frequency and pulse width. When the auxiliary pump is operating, it sends hydraulic pressure to the transmission regulator valve, and then on to the manual valve where it

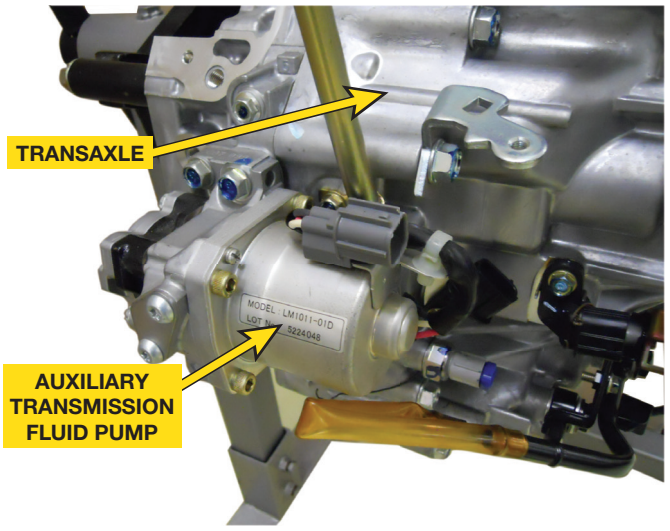


FIGURE 10–5 Honda Accord Hybrid auxiliary transmission fluid pump. This pump operates only when the ICE enters idle stop (stop–start) mode.

is directed to the appropriate clutches. This prevents the transmission from shifting into "neutral" when the ICE is in idle stop. Once the ICE restarts, the auxiliary pump is turned off and hydraulic pressure is again supplied by the mechanically driven transmission fluid pump. ● **SEE FIGURE 10–5.**

GM PARALLEL HYBRID TRUCK

DESCRIPTION AND OPERATION The transmission in the 2004–2008 Chevrolet Silverado/GMC Sierra parallel-hybrid pickup is based on the 4L60E electronically controlled automatic transmission design with minor modifications to adjust for its role in a hybrid power train. It has four forward speeds and one reverse, with the fourth speed being an overdrive. It is designed primarily for medium and large-displacement engines and is used extensively in GM pickups and SUVs. The specific model used in the hybrid pickup is known as the M33. The transmission is controlled by the PCM, which receives signals from other vehicle sensors to determine load and speed and command appropriate transmission operation.

The transmission gear selector lever can be placed in seven positions, as follows:

- P—Park
- R—Reverse
- N—Neutral
- D—Drive
- 3—Manual third

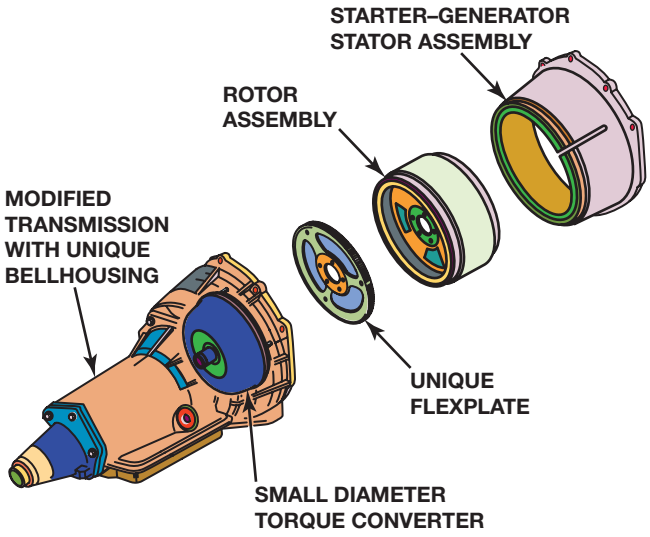


FIGURE 10–6 Integrated starter–generator (ISG) assembly adapted to a production 4L60E transmission. Note that the torque converter diameter is smaller to fit inside the rotor assembly.

- 2—Manual second
- 1—Manual first

The gear shift linkage attaches to the manual valve lever on the transmission case. This lever incorporates a transmission range switch, which signals the PCM of the selected gear.

CONSTRUCTION

The transmission case and the bell housing are made from die-cast aluminum, the same as the conventional model. However, changes were made to accommodate the addition of the *integrated starter–generator* (*ISG*) inside the bell housing assembly. The transmission was modified where it was absolutely necessary, but otherwise used as much of the original design as possible. The primary change was a decrease in the diameter of the torque converter in order for it to fit inside the rotor assembly of the ISG. ● **SEE FIGURE 10–6.**

The original torque converter is 300 mm in diameter, whereas the hybrid torque converter is 258 mm. The rotor assembly is bolted directly to the engine crankshaft and wraps around the torque converter. A separate flex plate inside the rotor is used to drive the torque converter. The bell housing is a separate part of the most recent 4L60E transmission case design, and this was replaced with a special unit that was large enough to enclose the ISG stator assembly.

To limit heat buildup in the smaller torque converter, a different TCC control strategy was used so that lockup would be commanded earlier. This also required the use of a torque converter with a multi-plate clutch (TCC) in order to handle the torque generated by the V-8 engine.

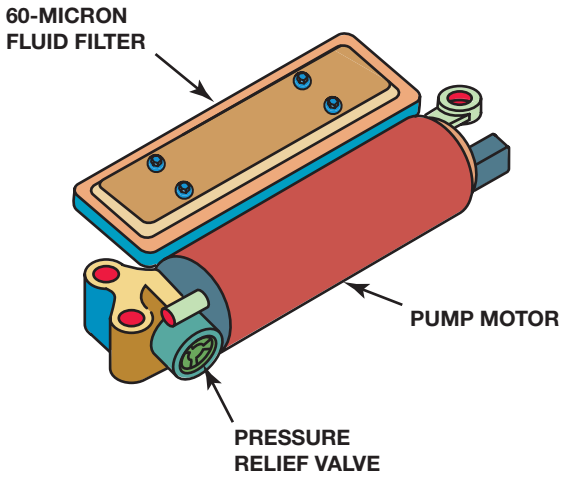


FIGURE 10–7 Electric secondary fluid pump from a 4L60E transmission in a GM hybrid pickup.

OPERATION

In start/stop (idle stop) mode the engine stops, which will in turn stop the transmission oil pump and cause the transmission to go into "neutral." To prevent this, an electric secondary fluid pump is installed on the valve body inside the transmission oil pan. Whenever the engine goes into idle stop, the electric fluid pump is turned on to maintain oil pressure on the transmission forward clutch and keep the drivetrain connected to the engine. This results in a smoother transition between idle stop and engine restarting as the vehicle resumes operation. ● **SEE FIGURE 10–7.**

To enable regenerative braking, the hybrid version of the 4L60E transmission is made to apply the overrun clutch during coasting or braking in the D4 range and either third or second gear. This allows power to be transmitted back through the torque converter, which can then be used to generate electric current for recharging the 42-volt battery pack.

SERVICE

Service and diagnostic procedures include:

- Transmission service for the 4L60E model M33 is limited to fluid and filter changes. This transmission requires Dexron VI fluid. The filter on the electric secondary fluid pump is replaceable, but is not a regular maintenance item.
- Transmission pressure testing can be performed using the line pressure tap located on the transmission case. These tests are most often done by attaching a pressure gauge to the fitting on the side of the transmission and operating the transmission under various load conditions and road speeds.
- A scan tool can be used to access DTCs (diagnostic trouble codes) and also to perform bidirectional testing of the transmission solenoids.

TWO-MODE HYBRID TRANSMISSION

POWER FLOW The transmission used in the GM two-mode hybrid (2008–2014) is designed specifically for use in hybrid vehicles. The two-mode hybrid transmission used in General Motors hybrid trucks is labeled 2ML70 and is also used by Dodge and Chrysler. This unit features two 60-kW motors inside the transmission, a 300-volt battery pack, and a V-8 engine.

A two-mode hybrid electric vehicle is capable of increasing fuel economy by about 25%, depending on the type of driving conditions. Like all hybrids, the two-mode combines the power of a gasoline engine with that of electric motors and includes:

- Regenerative braking that captures kinetic energy that would otherwise be lost
- Idle stop (start/stop)

COMPONENTS This two-mode unit is called an **electronically variable transmission (EVT)**. It includes three simple planetary gear sets with four multi-plate clutches. It has four fixed gear ratios with two EV ratios for smooth, more efficient operation. The components of the two-mode transmission include the following:

- Two 60-kW electric motor/generators assemblies called motor/generator A and B, usually abbreviated MG A and MG B.
- Three planetary gear sets (one is located in front of motor/generator A, called M/G A; another is located between the two motor/generators, and the last planetary gear set is located behind motor/generator B, called M/G B).
- Four wet plate clutches (two friction [rotating] and two [reaction/stationary] clutch assemblies). ● **SEE FIGURE 10–8.**

The vehicle starts moving in EV 1 with a variable ratio from infinite low to 1.7:1. If the vehicle is launched with the engine off, M/G A will spin the engine crankshaft so it can start running.

EV 2 has a ratio between 1.7:1 and 0.5:1.

FIRST MODE OF OPERATION The first mode is for accelerating from standstill to second gear. At low speed and light load, the vehicle can be propelled by:

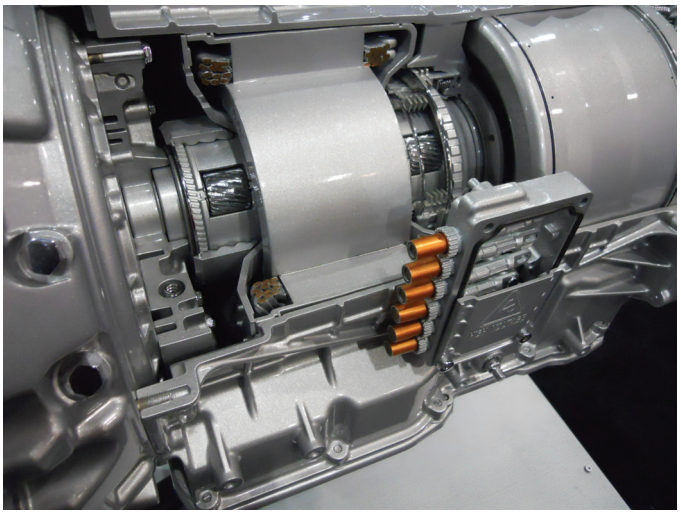


FIGURE 10–8 The two-mode transmission has orange high-voltage cables entering the unit to carry electric energy from the high-voltage battery pack to propel the vehicle and also to charge the battery during deceleration.

- Either electric motor alone
- The internal combustion engine (ICE) alone
- Or a combination of the two (electric motor and/or ICE)

In this mode, the engine (if running) can be shut off under certain conditions and everything will continue to operate on electric power alone. The hybrid system can restart the ICE at any time as needed. One of the motor/generators operates as a generator to charge the high-voltage battery, and the other works as a motor to assist in propelling the vehicle.

SECOND MODE OF OPERATION The second mode takes the vehicle from second gear through to overdrive. At higher loads and speeds, the ICE always runs. In the second mode, the motor/generators and planetary gear sets are used to keep torque and horsepower at a maximum. As the vehicle speed increases, various combinations of the four fixed ratio planetary gears engage and/or disengage to multiply engine torque, and allows one or the other of the motor/generators to perform as a generator to charge the high-voltage battery. ● **SEE FIGURE 10–9.**

TWO-MODE SERVICE Routine service is all that is needed or required of the two-mode transmission. Fluid level check and visual inspection should be all that is required until the first scheduled fluid change. Always use Dexron VI. Faults in the system will often set a diagnostic trouble code (DTC). Unit repair requires an engine hoist or the lift arm of a vehicle lift to remove the motor assembly. ● **SEE FIGURE 10–10.**

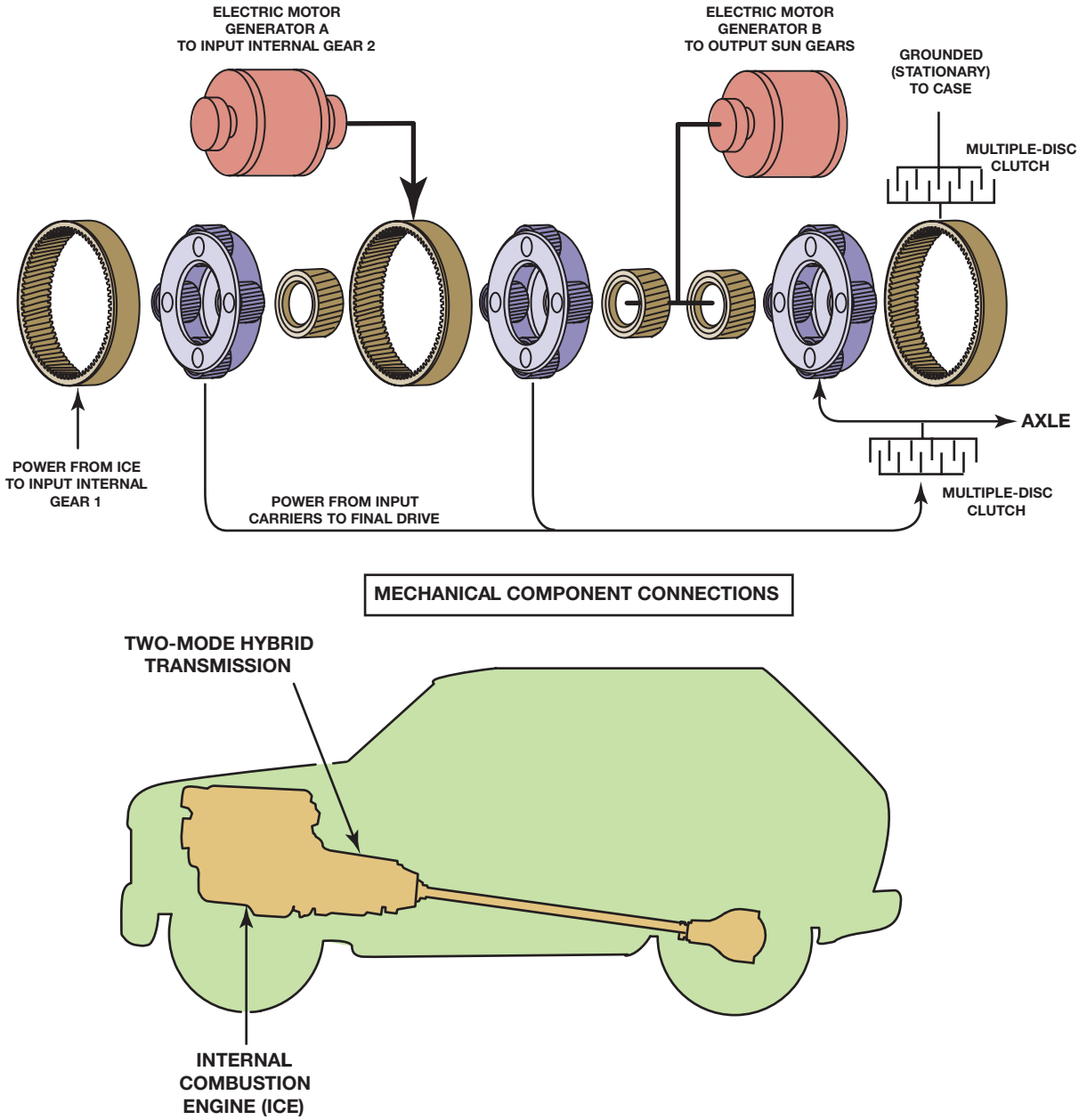


FIGURE 10–9 Using three planetary gear sets, the ICE can be maintained in the most efficient speed of about 2000 RPM under most operating conditions. The ICE powers only the the front ring gear in any mode and all three planet sets are locked together (#3 being the output set) when the rear clutch activates Hi-Mode. In low mode, the rear ring gear is grounded for deep reduction. The mode is determined by the two rear clutches.

HONDA ACCORD FIVE SPEED

DESCRIPTION AND OPERATION Honda uses an automatic transmission (transaxle) in the 2005–2007 Accord Hybrid that is similar to the units used in its vehicles with conventional nonhybrid power trains. This transmission has five forward speeds and one reverse, and uses a standard torque converter with lockup clutch. There are four parallel shafts, including the main shaft, countershaft, secondary shaft, and the intermediate shaft. This design is similar to the Honda manual transaxles, as constant-mesh helical gears and a reverse idler are used to create the gear ratios. Planetary gear sets are not utilized in this design. The various speeds are selected through the application of six multiple-disc clutches and a single one-way clutch. ● **SEE FIGURE 10–11.**

The integrated motor assist (IMA) assembly is located between the ICE and the transmission. The torque converter drive plate (flex plate) is attached to the IMA rotor, which in turn is driven by the ICE crankshaft. ● **SEE FIGURE 10–12.**

(a) (b)

FIGURE 10–10 (a) Disassembly of the 2ML70 transmission requires the use of a lift or engine hoist to remove the motor assembly. (b) The motor assembly after being removed for the transmission.

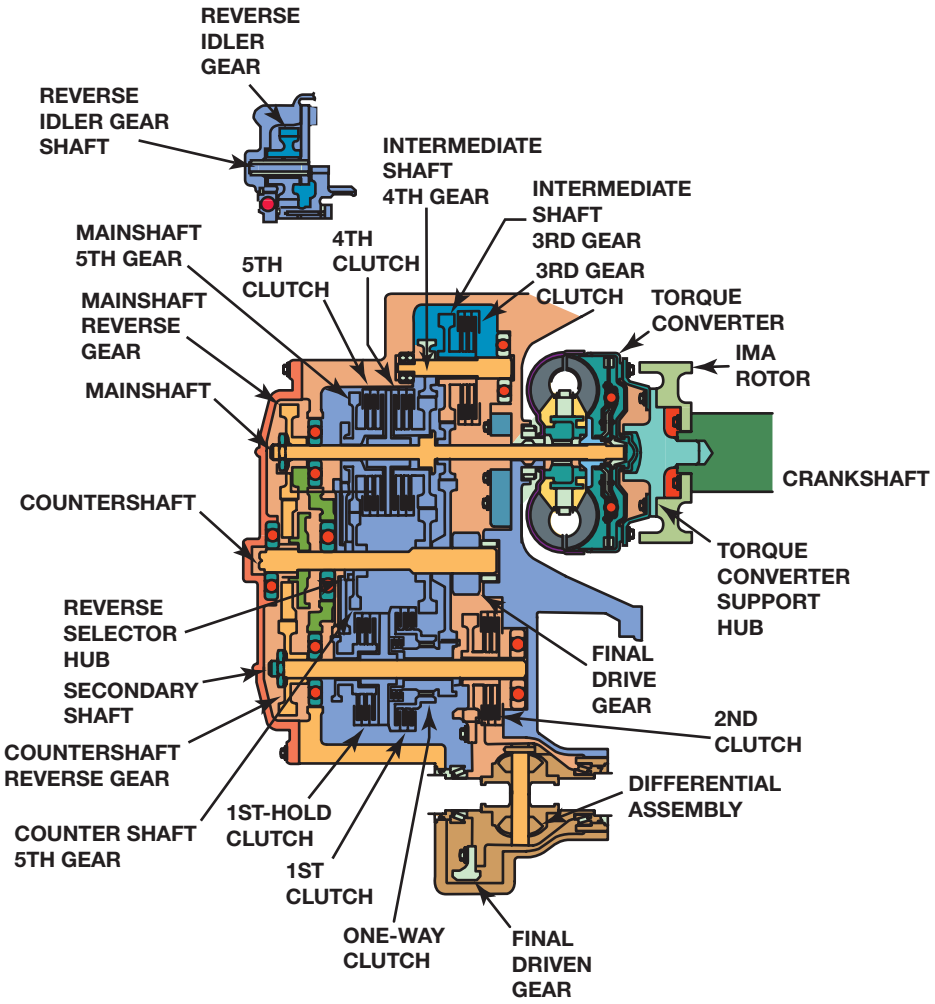


FIGURE 10–11 Cutaway view of Honda Accord Hybrid automatic transmission.

Most transmission control functions are performed electronically. Input signals from the sensors are processed by the PCM, which operates seven solenoid valves in the transmission to control shift points, shift quality, and torque converter lockup. In order to accommodate the hybrid power train, an electric auxiliary pump is used to maintain fluid pressure in the transmission during ICE idle stop. This pump is powered by an AC synchronous motor, which requires a special controller to provide the correct operating frequency and pulse width.

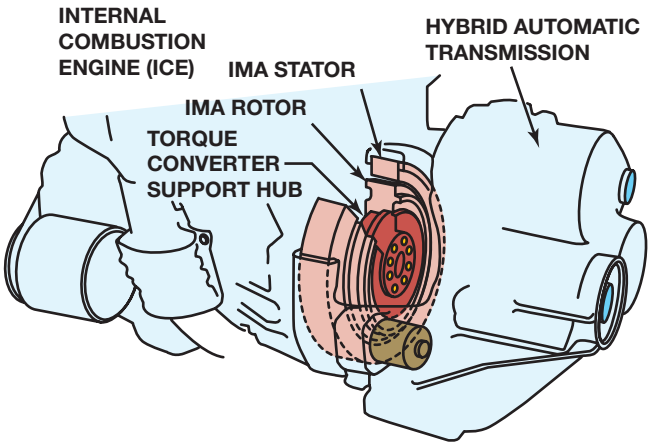


FIGURE 10–12 Honda Accord Hybrid power train, including 3.0-liter V6, IMA assembly, and 5-speed automatic transmission.

The vehicle gear selector has seven positions, including:

- P—Park
- R—Reverse
- N—Neutral
- D—Drive (first through fifth)
- D3—Drive (first through third)
- 2—Second
- 1—First

The gear shift linkage attaches to the manual valve lever on the transmission case. This lever incorporates a transmission range switch, which signals the PCM concerning the selected gear.

CONSTRUCTION The Honda Accord Hybrid automatic transaxle is housed in an aluminum case, which attaches in line with the ICE and the Integrated Motor Assist (IMA) assembly. The various gears are engaged and disengaged through the application and release of hydraulically operated multiple-disc clutches. Since there are no planetary gears used in this transmission, there is no need for holding devices (brakes). Power is directed through the transmission by applying a clutch and locking a gear to its associated shaft. The clutches are similar in function to the synchronizers in a manual transaxle.

As with any electronically controlled transmission, the mechanical workings are relatively simple but the control strategy is complex. The PCM is responsible for the automatic transmission functions, and it receives input data from many different sensors in order to make the transmission operate smoothly and efficiently. ● **SEE FIGURE 10–13.**

DIAGNOSIS AND SERVICE If a fault is detected with the hybrid transmission, the "D" indicator on the transmission range display is flashed on the instrument panel. ● **SEE FIGURE 10–14.**

The DTC related to the malfunction can be retrieved using a Honda or enhanced aftermarket scan tool. The scan tool is plugged into the data link connector (DLC) and the ignition switch is turned to the RUN position. The scan tool can then communicate with the PCM and identify any diagnostic trouble codes along with other sensor information that can help diagnose the problem at hand.

There is no specified service procedure required because the fluid is a "fill for life" system. Always check service information for the exact procedures to follow for the vehicle being serviced.

TOYOTA/LEXUS POWER-SPLIT SYSTEM

APPLICATIONS The Toyota/Lexus power-split device drive system is used in the following models:

- Toyota Prius
- Toyota Camry hybrid
- Lexus CT200h
- Toyota Highlander
- Lexus RX400h and RX450h

DESCRIPTION The power-split transaxle is a series–parallel hybrid technology. During most phases of vehicle operation, the system is operating as both series and parallel at the same time. While the control system is complex, the basic transaxle is very simple in design as it is built around a single planetary gear set (power-split device) and two electric motor/generators, called MG1 and MG2. ● **SEE FIGURE 10–15.**

A planetary gear set is comprised of three main components:

1. Ring gear
2. Planet carrier
3. Sun gear

In the power-split transaxle, a large electric motor/generator (MG2) is directly attached to the transaxle final drive and to the planetary ring gear. The ICE is connected to the planet carrier, and the small electric motor/generator (MG1) is connected to the sun gear. ● **SEE FIGURE 10–16.**

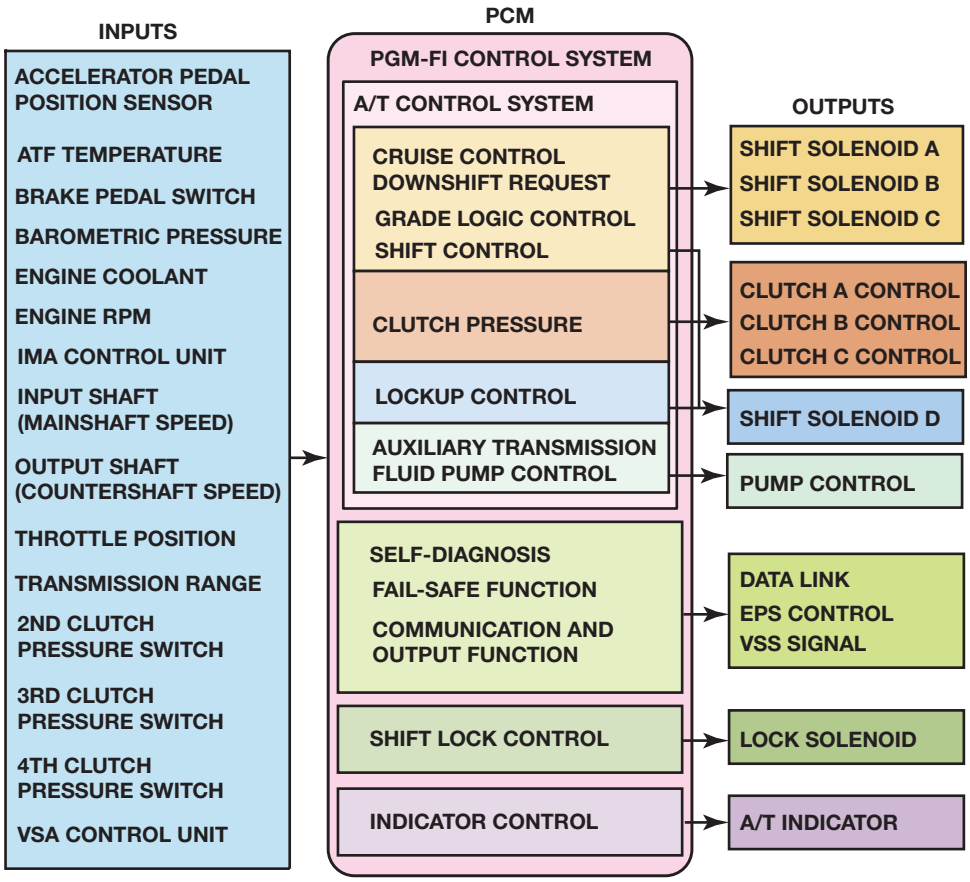


FIGURE 10–13 Control schematic for a Honda Accord Hybrid automatic transmission. Note that all sensor inputs are shown to the left of the PCM, while the output signals and actuators are shown on the right.

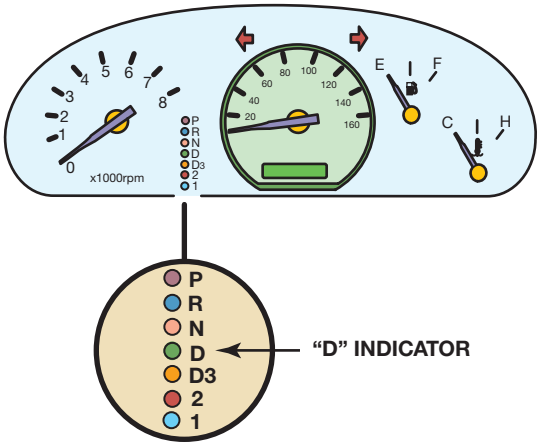


FIGURE 10–14 The Honda Accord Hybrid will alert the driver of a transmission malfunction by flashing the "D" indicator on the instrument panel.

The planetary ring gear always turns in the same direction as the drive wheels and its speed is directly proportional to vehicle speed. In other words, if the ring gear is not moving, the vehicle is not moving.

The power-split device is so named because the ICE (attached to the planet carrier) splits its torque output between the sun gear (MG1) and the ring gear (MG2 and drive wheels). The gear ratio of the planetary gear set causes the ICE to send 72% of its torque to the ring gear and the remaining 28% to the sun gear. The torque split percentages remain the same regardless of what mode the transaxle is operating in because they are determined by the number of teeth on the planetary ring gear and the sun gear. ● **SEE FIGURE 10–17.**

While torque split percentages are always the same, power split percentages will vary depending on the RPM of the various components. Horsepower is the rate at which work is performed and is a function of torque and RPM. If a shaft has torque applied to it but remains at zero RPM, no work is being performed and no horsepower is transmitted through the shaft. The same principle applies to the torque split planetary gear set. If the sun gear is stationary, it will still receive 28% of the torque of the ICE, but all of the engine horsepower will be directed through the ring gear and on to the drive wheels.

OPERATION

- **Vehicle Stopped.** When the vehicle is stopped, nothing is happening within the vehicle drive system. The ICE is shut off, and both electric motor/generators are shut off as well. There are circuits within the vehicle that will use

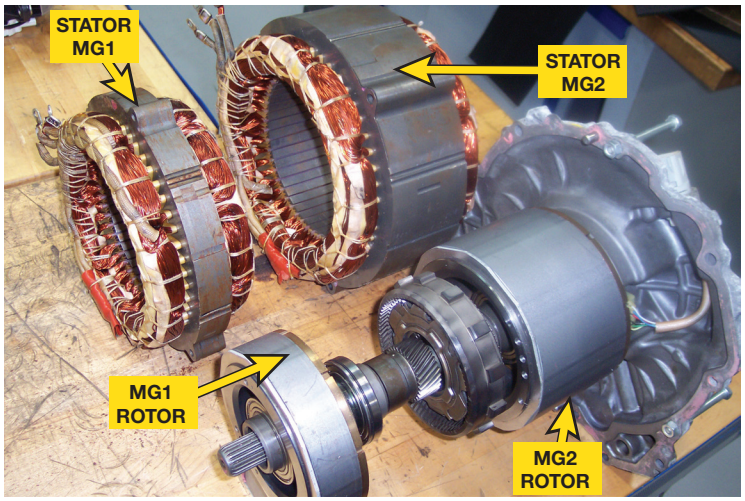


FIGURE 10–15 The Toyota Hybrid System uses two electric motor/generators (MG1 and MG2) and an ICE, all connected together by a power-split device, which is a simple planetary gear set.

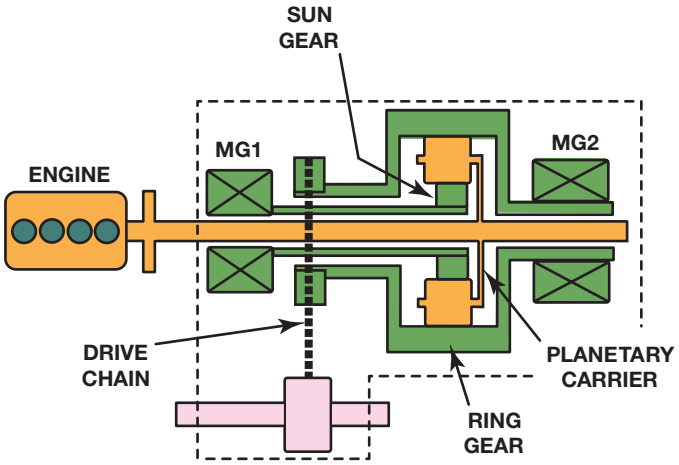


FIGURE 10–16 The power-split device from the Toyota Hybrid System. Note that the vehicle will move only when MG2 (and the ring gear) is turning.

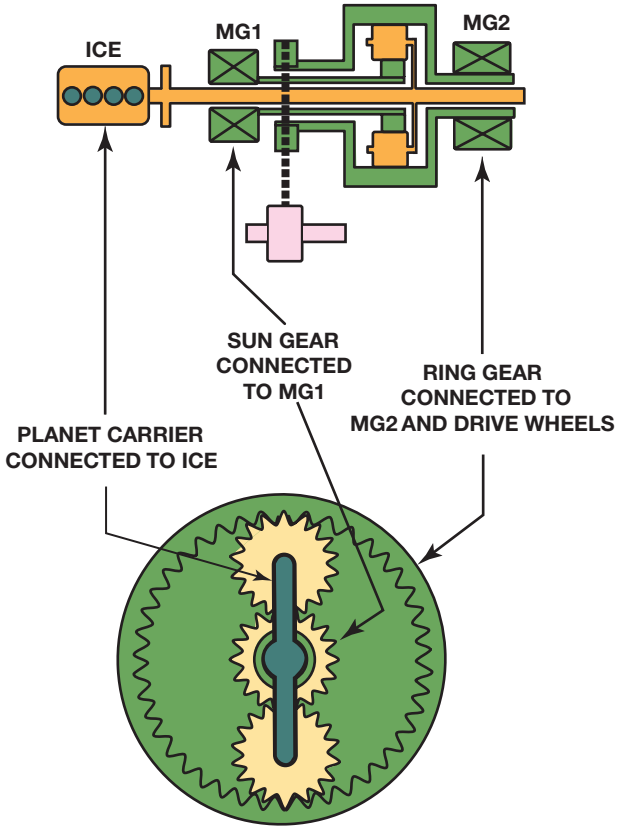


FIGURE 10–17 The planetary gear set used in the Toyota Hybrid System (THS) has 2.6 times the number of teeth in its ring gear as it has in its sun gear. This means that the ICE (attached to the planet carrier) will send 72% of its torque to the ring gear (drive wheels), and 28% of its torque to the sun gear (MG1).

electrical energy from the auxiliary battery, but the drive system itself is effectively inert. The Toyota hybrid system does not use an auxiliary starter, but instead uses the motor/generator (MG1) for starting under all conditions. ● **SEE FIGURE 10–18.**

- **Light Acceleration.** When the vehicle is driven at low speeds and light acceleration, it is driven by MG2 alone. ● **SEE FIGURE 10–19.**
- This is because the electric motor is more efficient than the ICE at low vehicle speeds. Current from the high-voltage (HV) battery is sent through the inverter and on to MG2 to move the vehicle. A special graph, known as a monograph, shows the speed relationship between the various elements. When the engine is stopped (0 RPM), MG2 is turning forward (+), and this causes MG1 to turn backward (–). ● **SEE FIGURE 10–20.**

- **Normal Driving.** When higher vehicle speeds are required, the ICE must be started so that its output can be combined with that of MG2. The ring gear is already turning clockwise as the vehicle travels in a forward direction. Since the planet carrier (attached to the ICE) is stationary, the sun gear (driven by MG1) is used to drive the planet

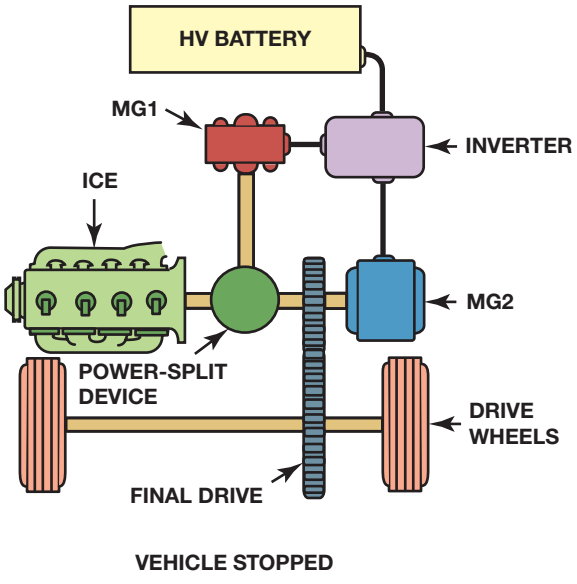


FIGURE 10–18 When the vehicle is stopped, the ICE is shut off along with both motor/generators.

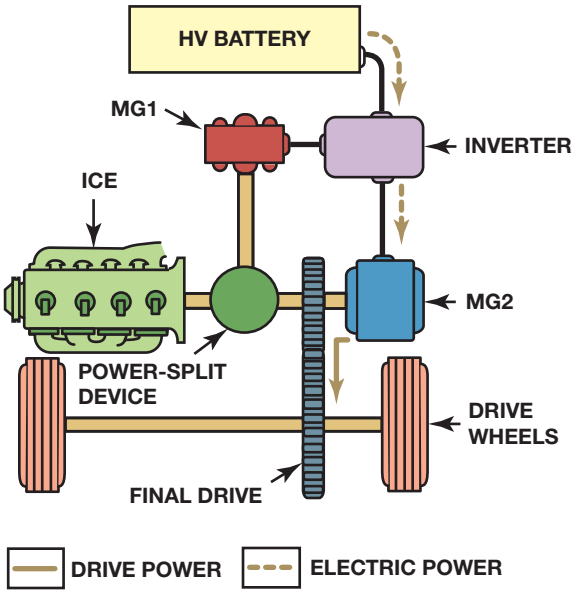


FIGURE 10–19 Under light acceleration, power is sent to MG2 to move the vehicle.

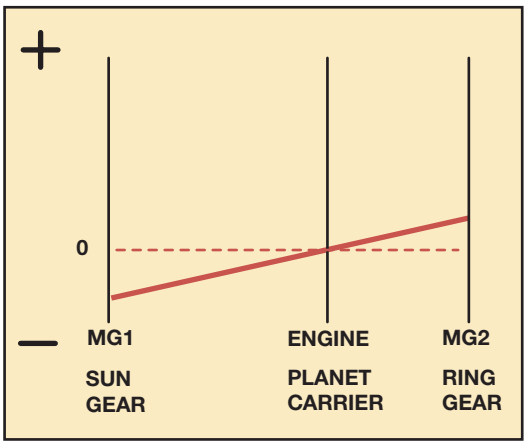


FIGURE 10–20 Light acceleration—the engine is stopped (0 RPM), MG2 is turning forward (+), and MG1 is turning backward (–).

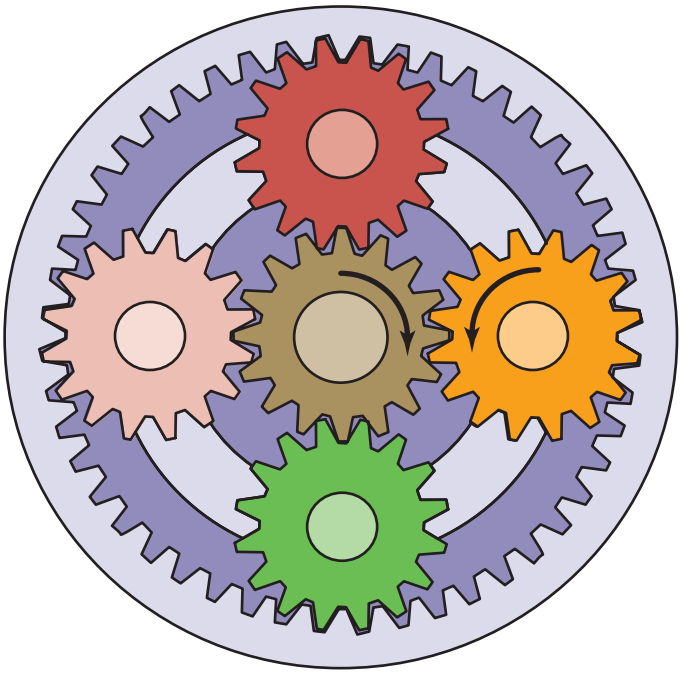


FIGURE 10–21 To start the ICE, MG1 (sun) acts as a motor and turns clockwise (CW), causing the planet carrier (attached to the ICE) to also turn CW.

carrier clockwise and start the ICE. Current from the HV battery is directed through the inverter and operates MG1 as a motor, turning clockwise and spinning the ICE up to 1000 RPM for starting. ● **SEE FIGURE 10–21.**

Once the ICE is started, MG1 operates as a generator, but turns in the counterclockwise direction. ICE output is now divided or "split" between the drive wheels (ring gear) and MG1 (sun gear). Power generated by MG1 is either directed to MG2 to help move the vehicle or is used to recharge the HV battery, if necessary. ● **SEE FIGURES 10–22 AND 10–23.**

- **Full-Throttle Acceleration and High-Speed Cruise.** When greater acceleration is required, both MG2 and the ICE continue sending torque to the vehicle drive wheels, but MG2 can also receive power from the HV battery to increase its output. As demand increases further, the ICE speed is increased for more output. To enable an increase in ICE speed, the sun gear (MG1) must rotate in a clockwise direction. It is during these times that MG1 can be configured as a motor and will draw power from MG2 during a phase known as energy recirculation. ● **SEE FIGURES 10–24 AND 10–25.**

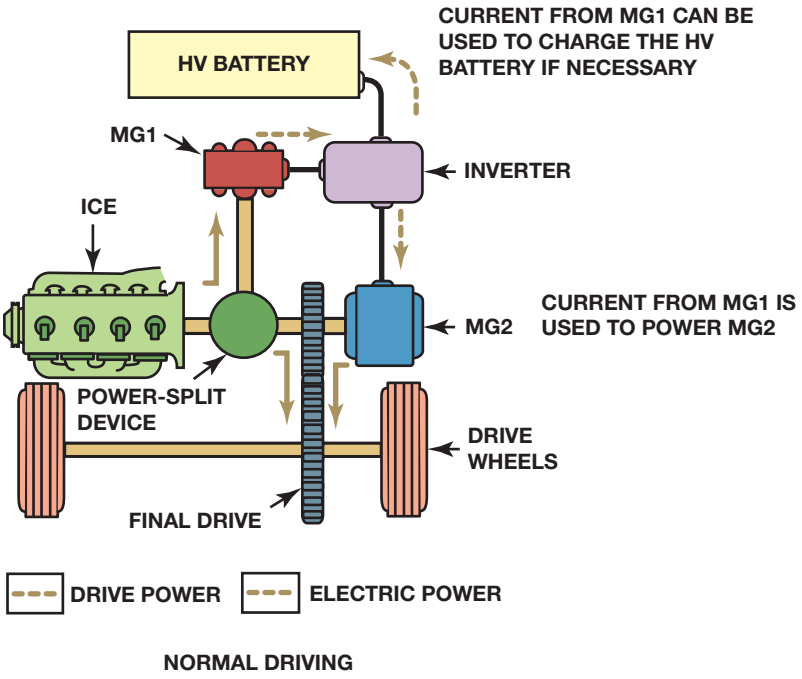


FIGURE 10–22 Normal driving—the ICE is now running and some of its torque is used to drive MG1. Electricity generated by MG1 is used to power MG2 or recharge the HV battery.

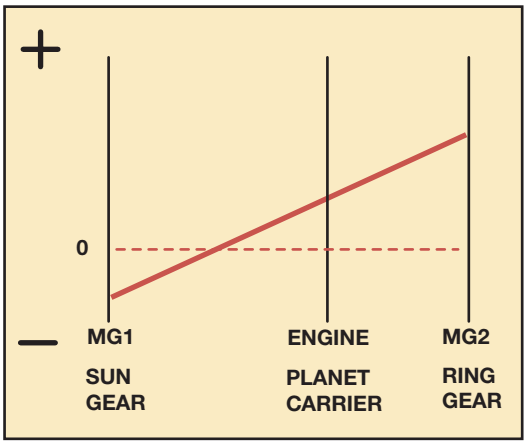


FIGURE 10–23 Normal driving—the engine is running, MG2 is turning forward (+), and MG1 is turning backward (–).

- **Deceleration and Braking.** As the vehicle is decelerating, MG2 is configured as a generator. The kinetic energy (energy of movement) of the vehicle is then converted into electrical energy by MG2. The ICE and MG1 are shut off, and current from MG2 is sent through the inverter and is then used to recharge the HV battery. **SEE FIGURE 10–26.**
- **Reverse.** If reverse is selected, power is sent from the HV battery to the inverter and then on to MG2. MG2 operates in the reverse direction to back up the vehicle, but the other components in the drive system are turned off at this time. The ICE does not run when the vehicle is being driven in reverse. **SEE FIGURE 10–27.**

CONSTRUCTION

The Toyota power-split transaxle is built with an aluminum case composed of two major assemblies. These are known as the MG1 assembly and the MG2 assembly, and each houses its respective motor/generator. Each of these major assemblies has its own water jacket for cooling the motor/generator windings in the housing. There are two water jacket unions installed in each major assembly, and these send coolant to the motors from the separate inverter cooling system. **SEE FIGURE 10–28.**

The following components are assembled on a common axis:

- Internal combustion engine (ICE)
- MG1
- Power-split device
- MG2
- Oil pump

The final drive is housed between the two major assemblies and utilizes a conventional open differential for sending torque to the front drive wheels. A chain drive attaches the ring gear of the power-split device to the counter drive gear, which drives the counter driven gear that is meshed with the ring gear of the differential assembly. This system does not use a conventional clutch or torque converter. With this design, there is no need to disconnect the engine from the input shaft. This is because the engine can turn at any speed while the vehicle is stopped (ring gear is therefore stopped) by using MG1 (sun gear) as a

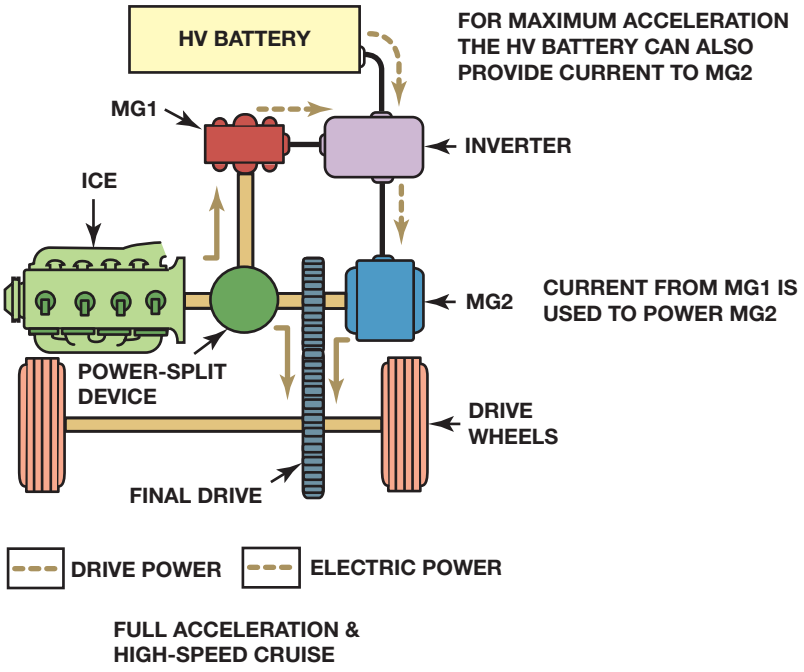


FIGURE 10–24 Full-throttle acceleration and high-speed cruise—with greater demand for acceleration, power from MG1 is combined with power from the HV battery to generate higher output from MG2. It is also possible to configure MG2 as a generator and send its power to MG1 (which then acts as a motor).

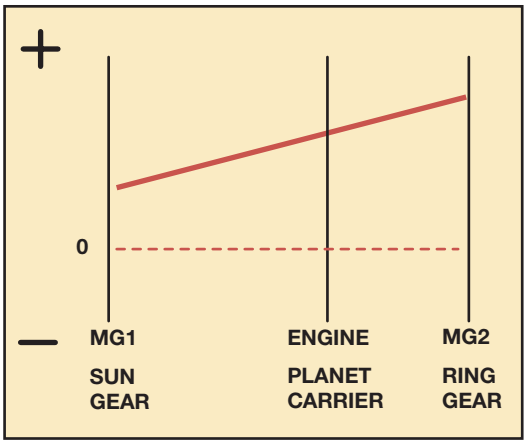


FIGURE 10–25 Full-throttle acceleration and high-speed cruise—this graph shows MG1 acting as a motor using power from MG2. This increases the speed of the ICE, allowing it to produce higher output.

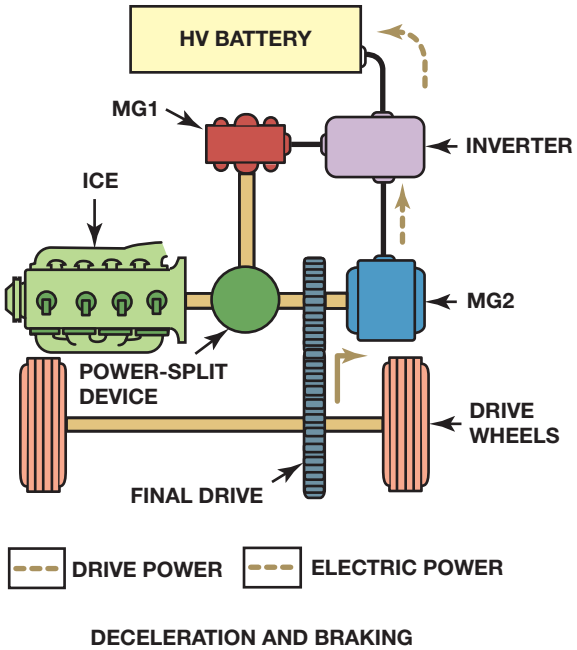


FIGURE 10–26 Deceleration and braking—MG2 is configured as a generator and recharges the HV battery.

generator. The ICE is connected directly to the transaxle input shaft using a damper disc mechanism. The transaxle oil pump is housed in the rear of the MG2 assembly and is attached to the input shaft from the ICE. This means that oil is circulated by the pump only when the ICE is running. When the vehicle is driven by MG2 only, the transaxle is splash-lubricated by the movement of the final drive gears. The transaxle for the 2001–2003 Prius has a cable-operated parking lock mechanism. This was replaced with an electrically actuated mechanism starting with the 2004 model year.

SERVICE Service procedures to be performed at specified intervals include changing the transaxle oil and the coolant for the inverter (high voltage) system. There are drain plugs for both at the bottom of the transaxle assembly. The transaxle oil is refilled through a hole in the front of the case, with the level

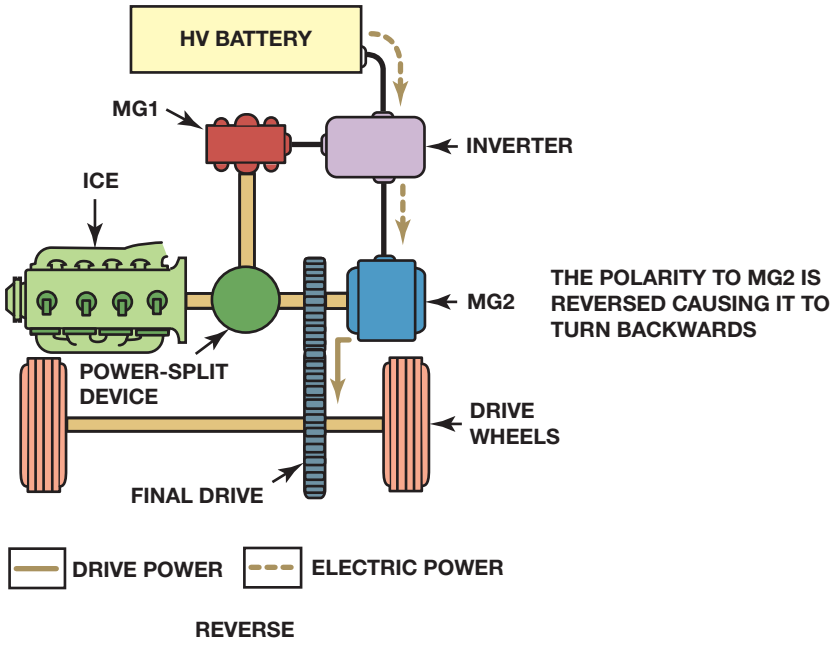


FIGURE 10–27 Reverse—MG2 alone is used to move the car in reverse. This is accomplished by reversing the direction of MG2.

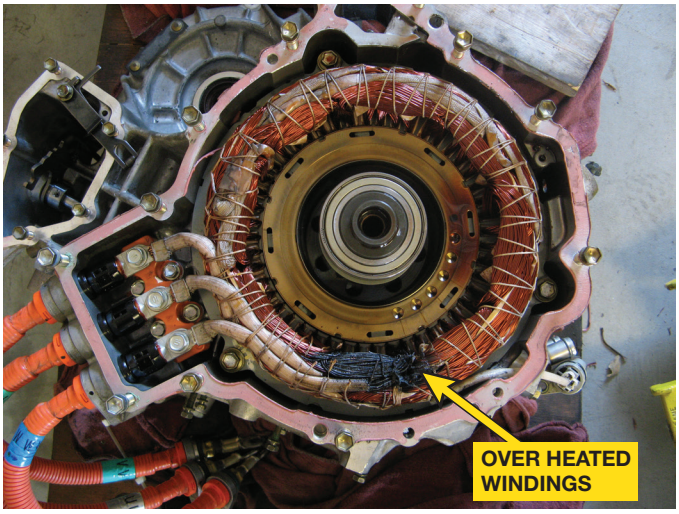


FIGURE 10–28 Excessive heat created in the electric motors must be controlled and proper maintenance of the cooling system is important for long life to help avoid overheating motor windings as shown.

being brought up to a specified distance from the bottom of the hole. The coolant is refilled at the reservoir that is located on the inverter assembly, and must be bled properly before placing the vehicle back into service. Always use the recommended fluids and procedures when servicing any vehicle.

NOTE: The fastest and most reliable way to refill the inverter cooling system is to use an airlift fluid exchange machine. This pulls the cooling system into a vacuum and then injects the coolant into the evacuated system. This method fills the system quickly and eliminates air bubbles.

FORD ESCAPE HYBRID ECVT

PARTS AND OPERATION The Ford Escape Hybrid uses an electronically controlled continuously variable transmission (eCVT) that is very similar in operation to the Toyota power-split transaxle. It is built differently, however, in that the traction motor is on a different axis and is placed above the generator motor. This was done to keep the length of the transaxle similar to that of a conventional automatic transaxle. ● **SEE FIGURES 10–29 AND 10–30.**

Another difference is that the transmission control module (TCM) is an integral part of the eCVT. This encloses the high-voltage cables and also makes it possible to cool the motors and the electronics with one heat exchanger. ● **SEE FIGURE 10–31.**

Coolant in the transaxle/electronic cooling system is sent through the water channel and absorbs heat from the ATF channel below and the heat sink for the electronic control unit above. A small oil pump inside the eCVT circulates ATF for lubricating the gear train and for cooling the two electric motors. This oil pump is driven directly by the ICE through the planet carrier of the planetary gear set. Like the Toyota system, the oil pump will not circulate ATF unless the ICE is running. This means that the gear train is splash-lubricated when the vehicle is in electric-only operation.

The traction motor in the eCVT can be used to accelerate the vehicle from a standstill. If more power is required, the ICE is

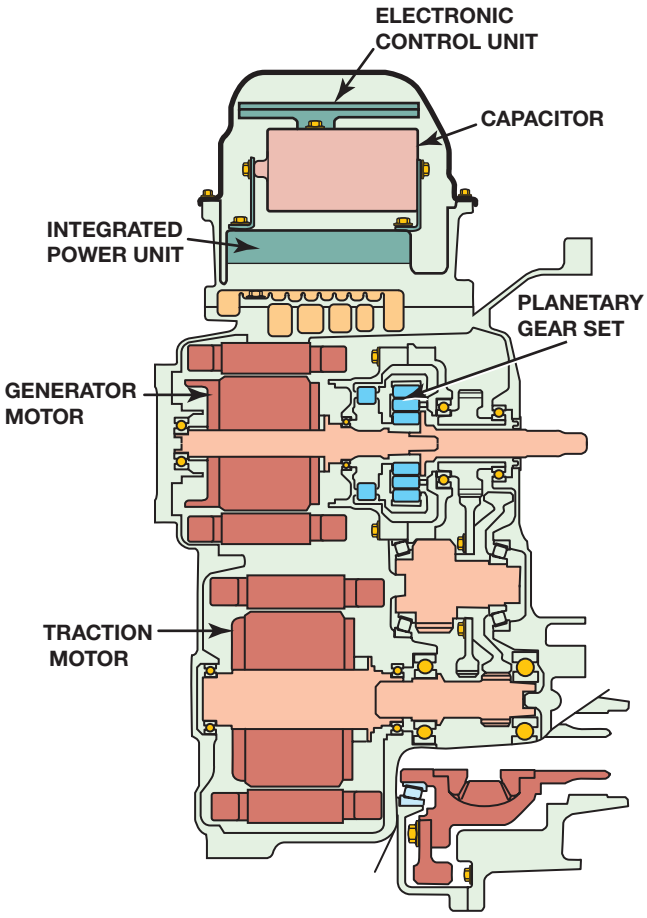


FIGURE 10–29 Cutaway view of the Ford Escape Hybrid transaxle.

started. The starting function is performed by the generator motor, which in most cases acts as a generator to provide current to the traction motor or to the high-voltage battery when required. Like the Toyota, the Escape hybrid does not use an auxiliary starter and relies on the generator motor for starting under all conditions. The generator motor is also responsible for supplying all the electrical current for vehicle operation. The high voltage from the generator is sent through a DC/DC converter to provide the 12 volts necessary for powering the vehicle accessories. During vehicle braking, the traction motor becomes a generator and provides electrical current to recharge the battery (regenerative braking).

TECH TIP

Traction Motors Move the Vehicle

Traction motors are so named because anything that propels the vehicle is said to provide a *traction force.* Traction force is also known as *tractive force.* The high-voltage battery in a Ford Escape Hybrid used to power the traction motor in the eCVT, so it is known as **a traction battery**.

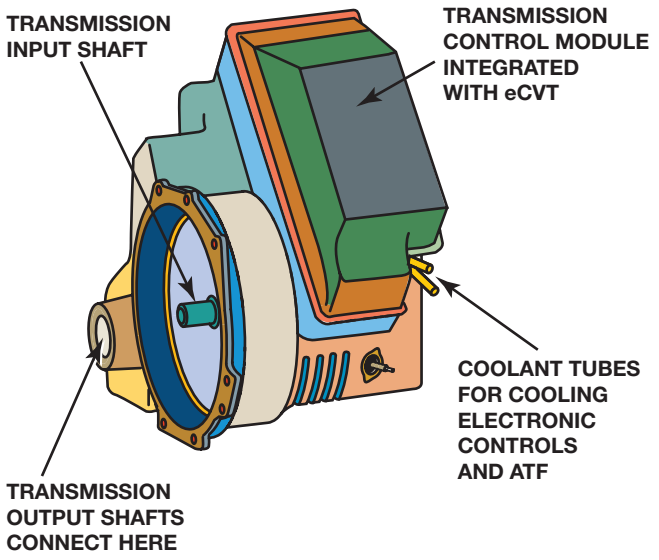


FIGURE 10–30 The Ford Escape Hybrid transaxle operates very similar to the one used in the Toyota Hybrid System, but is constructed very differently.

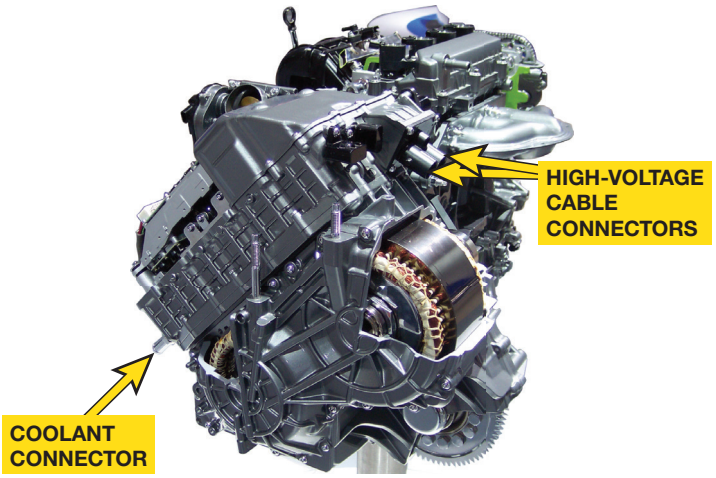


FIGURE 10–31 A Ford eCVT transaxle assembly showing the electrical connectors on the top of the assembly.

SERVICE The eCVT is lubricated-for-life with a special Mercon fluid. There is a fill plug and a drain plug located on the left side of the case, but these are used only in special service situations.

HONDA HYBRID BELT AND PULLEY CVT

PURPOSE AND FUNCTION Internal combustion engines run most efficiently in a relatively narrow RPM range. In order to achieve the best efficiency, there must be a means of controlling the RPM of an ICE during the entire vehicle operating range. Both manual and automatic transmissions have increased the number

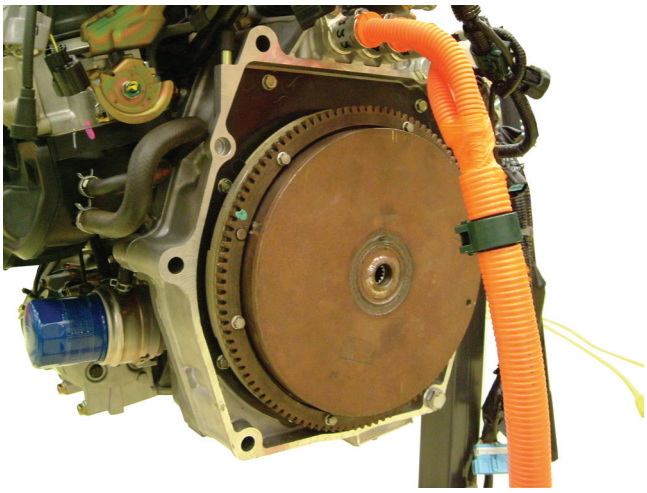


FIGURE 10–32 The Honda CVT is connected directly to the ICE through a drive plate and flywheel mechanism.

of speed ratios used in order to keep the ICE as close as possible to the most efficient RPM at all times, and the best type of transmission to use is a continuously variable transmission (CVT).

DESCRIPTION AND OPERATION One CVT design being used in hybrid electric vehicles is the belt-and-pulley system as used by Honda in the Civic and Insight. Much of this system is similar to other automatic transmissions, in that it uses a planetary gear set and multiple-disc clutches with electrohydraulic controls. However, there are no distinct speed ranges (or "shifts") in this design, as variable drive and driven pulleys are used with a special steel belt to provide nonstaged speeds forward.

There is no clutch or torque converter utilized in this design. Instead, the transmission input shaft is splined directly to the ICE through the drive plate and flywheel. This assembly is built similar to a dual-mass flywheel and is designed to dampen torsional vibrations from the engine. ● **SEE FIGURE 10–32.**

There are three multiple-disc clutches used in the internal gear train.

1. One for the forward clutch,
2. One for the reverse brake, and
3. The third for the start clutch.

In park (P) or neutral (N), none of the clutches have hydraulic pressure applied to them, which prevents engine torque from being applied to the drive pulley shaft.

The forward clutch and the start clutch are in operation whenever the transmission is placed in a forward gear position (D or L).

The start clutch has multiple responsibilities, including the following:

1. The start clutch is engaged whenever the vehicle is moving, in either forward or reverse.

WARNING

When servicing a hybrid vehicle transmission, be careful of any orange-colored electrical wire. Orange indicates the presence of high-voltage current.

2. It must help the vehicle accelerate from a standstill by slipping and then fully engaging once the vehicle is moving, similar to a manually operated clutch.

HONDA HYBRID AUTOMATIC TRANSAXLE

SYSTEM OVERVIEW Honda Accord hybrids (2005–2007) used a conventional automatic Honda transaxle and added the integrated starter/generator between the engine and the transaxle. The unit used a torque converter and a small electric motor mounted on the side of the unit to provide hydraulic pressure during idle stop mode operation. ● **SEE FIGURE 10–33.**

HYBRID TRANSMISSION DIAGNOSIS

STEPS INVOLVED When diagnosing a hybrid electric vehicle (HEV) transmission concerns, perform the following steps:

STEP 1 The first step is to verify the customer complaint.

STEP 2 Check the fluid level and condition.

STEP 3 Check for stored diagnostic trouble codes (DTCs).

STEP 4 Check for any related technical service bulletins (TSBs).

STEP 5 Check scan tool data including checking the adaptive values. ● **SEE FIGURE 10–35.**

STEP 6 Perform visual inspections, including checking for recent accident damage, previous repairs or other issues.

STEP 7 Locate the root cause of the problem.

Always follow the specified diagnostic and repair procedures for the vehicle being serviced.

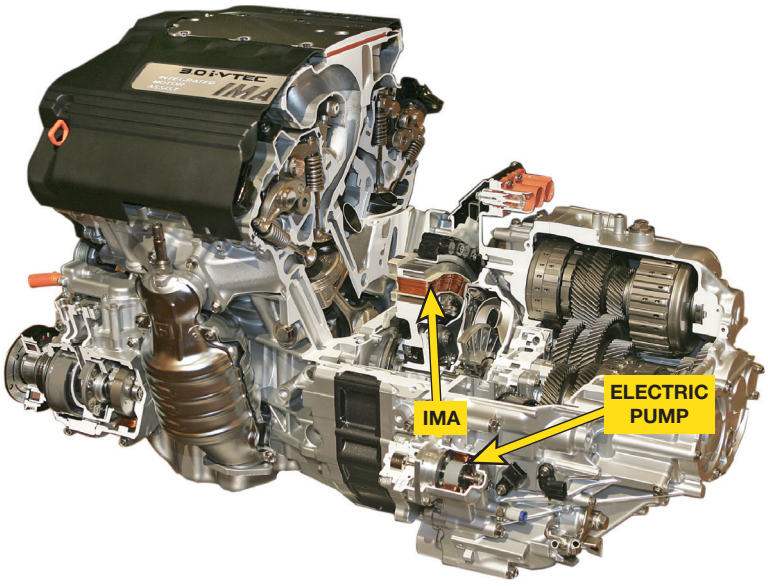


FIGURE 10–33 The Honda Accord V-6 hybrid electric vehicle uses a Honda non-planetary gear type automatic transaxle equipped with a small electric pump motor to maintain hydraulic fluid pressure during idle stop operation.

FREQUENTLY ASKED QUESTION

How Does a Hybrid Work Without a Transmission?

The Honda Accord hybrid starting with the 2014 model year (MY) uses a two-motor hybrid drive system that is totally different from that used by Toyota and Ford. It does not use a transmission. Instead, the two motor/generators are separated by a clutch and each performs two functions:

- **Primary motor/generator.** It propels the vehicle and recharges the high-voltage battery during deceleration.
- **Secondary motor/generator.** It is used to start the gasoline engine and supply electrical energy to the primary motor/generator or charge the high-voltage battery. ● **SEE FIGURE 10–34.**

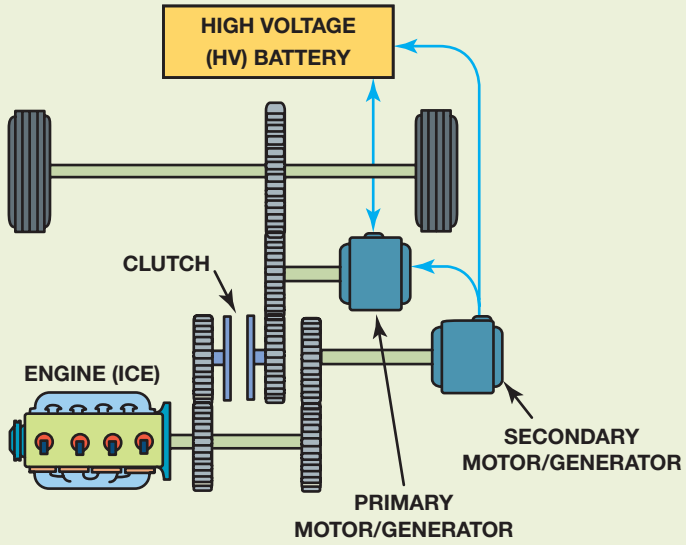


FIGURE 10–34 The primary motor/generator is used to propel the vehicle and the secondary motor/generator is used to start the engine and charge the high-voltage battery.

FIGURE 10–35 Some scan tool data may or may not be helpful unless there are codes or sub-codes that can lead to the source of a problem. For example, on this Lexus hybrid system, the screen capture shows that high voltage battery modules do not have an difference between them which eliminates the high voltage battery pack from being a concern.

SUMMARY

1. Automatic transmissions used in HEVs incorporate an electric auxiliary pump to provide transmission fluid pressure at engine idle stop.
2. Continuously variable transmissions (CVTs) utilize an infinite number of speed ratios to allow the ICE to operate in its most efficient RPM range during all phases of vehicle operation.
3. The two major types of CVTs include the belt-and-pulley system and the power-split system.
4. The power-split transaxle utilizes two electric motor/generators and a planetary gear set to create infinite speed ratios.
5. The belt-and-pulley CVT uses a special steel belt and two variable-diameter pulleys to create infinite speed ratios and a planetary gear set for reverse.

REVIEW QUESTIONS

1. What are the differences in the operation of an automatic transmission that has been modified for use in a hybrid electric vehicle?
2. What is the difference between a mild and full hybrid?
3. How does a two-mode hybrid work?
4. How does a Honda two motor/generator system work?
5. What are the purposes of MG1 and MG2 in a Toyota hybrid system?

CHAPTER QUIZ

1. In a GM two-mode hybrid electric vehicle, when can the vehicle be powered by electric power alone?
   a. During the first mode
   b. During the second mode
   c. During either the first or second mode
   d. During heavy load conditions regardless of mode
2. Modifications to automatic transmissions used in hybrid vehicles include _____.
   a. Electric auxiliary transmission fluid pump
   b. Larger torque converter
   c. Increased number of plates in multiple-disc clutches
   d. Both a and b are correct
3. Technician A says that power-split transaxle uses a torque converter. Technician B says that power-split transaxle uses an electric transmission fluid pump. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both technicians A and B
   d. Neither technician A nor B
4. All of the following statements concerning power-split transaxles are true, *except* _____.
   a. The ICE and motor/generators are all connected through a planetary gear set
   b. One of the planetary members must be held to make the power-split transaxle work
   c. The power-split transaxle can operate in electric mode only
   d. Power-split transaxle systems do not use a separate starter motor
5. The Honda CVT is connected to the ICE with a _____.
   a. Torque converter
   b. Manually operated clutch mechanism
   c. Drive plate and flywheel
   d. None of the above
6. In a Toyota/Lexus hybrid electric vehicle, how is reverse achieved?
   a. The ICE reverses direction and powers the drive wheels
   b. MG2 is used to power the vehicle in reverse
   c. MG1 is used to power the vehicle in reverse
   d. Either b or c depending on exact model and year
7. A Toyota hybrid is what type of hybrid?
   a. Series
   b. Series/parallel
   c. Parallel
   d. None of the above
8. Which type of hybrid vehicle cannot propel a vehicle from a stop using electric motor power alone?
   a. Mild hybrid
   b. Medium hybrid
   c. Strong hybrid
   d. Both a and b
9. What is meant by “range anxiety”?
   a. When the driver notices that the ICE has stopped during a stop
   b. When a driver is driving an electric only vehicle
   c. A passenger who notices that the engine starts and then stops when riding in a hybrid electric vehicle
   d. Any of the above
10. In a Toyota power-split hybrid, what type of transmission is used?
    a. Single planetary gear set
    b. CVT
    c. A manual transmission transformed to function in a hybrid electric vehicle
    d. A conventional automatic transaxle converted for hybrid use

chapter 11

CONTINUOUSLY VARIABLE TRANSMISSIONS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Describe the construction of a continuously variable transmission and discuss its advantages and disadvantages.
3. Discuss the electronic controls and operation of a CVT.
4. Explain the diagnosis of a CVT, including pressure testing and CVT fluid and noise issues.

KEY TERMS

Continuously variable transmission (CVT) 166
Input speed sensor (ISS) 169
Line pressure solenoid (LPS) 170
Output speed sensor (OSS) 169
Primary oil pressure (POP) 170
Primary pressure sensor (PPS) 170
Pull chain 168
Push belt 168
Ratio control motor 170
Rubber band effect 167
Secondary oil pressure (SOP) 170
Secondary pressure sensor (SPS) 170
Transmission range sensor (TRS) 169
Transmission temperature sensor (TTS) 170
Variators 166

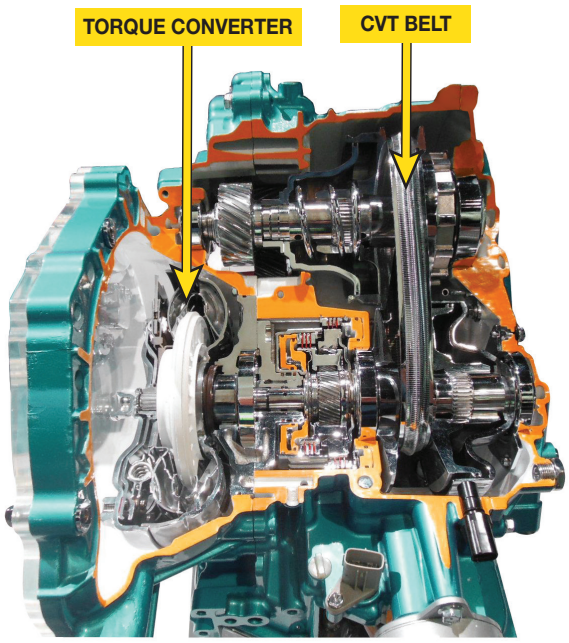


FIGURE 11–1 A typical CVT transaxle cutaway showing the torque converter and CVT belt.

CONTINUOUSLY VARIABLE TRANSMISSION (CVT)

PURPOSE AND FUNCTION A **continuously variable transmission (CVT)** is usually found on some front-wheel-drive vehicles that use a transaxle. A CVT varies the gear ratio in a continuous manner instead of in a series of steps or fixed gear ratios. The power flow is through a steel belt between two pulleys that change their width and effective diameter. When the vehicle accelerates from a standing start, the driving pulley is small and the driven pulley is large. This gives a gear reduction identical to a small gear driving a large gear, which provides an increase in torque and a decrease in speed. CVTs are more efficient than either manual or automatic transmissions while still providing the driving ease of an automatic transmission. ● **SEE FIGURE 11–1.**

ADVANTAGES A CVT offers the following advantages over a planetary-gear automatic transmission.

- Compact, very short
- Lighter weight
- Constant, stepless acceleration with engine staying at the RPM for maximum power
- Efficient fuel use and emissions, cruise with engine staying at the RPM for maximum efficiency
- Lower internal power loss

One method used to compare transmissions is the engine revolutions for a specific driving cycle. A test vehicle using a 3.0-L engine and a CVT showed 3% fewer revolutions than the same vehicle with a five-speed transmission and 11% less than with a four-speed transmission. This should equal a gain of about 12% in fuel economy. These transmissions are used by Audi, Dodge, Ford, Honda, Subaru, Toyota, and Nissan.

DISADVANTAGES The disadvantages of a CVT compared to conventional automatic transmission include:

- High and constant engine speed when accelerating rapidly.
- Requires special fluid that may not be readily available.
- Often not repaired but instead replaced as an assembly if the unit fails.

CONTINUOUSLY VARIABLE GEAR RATIOS As the speed increases, the diameter of the driving pulley increases as the sides of the pulley move together. While this happens, the driven pulley is made wider, and therefore, smaller in diameter. At cruising speeds, the driving pulley is larger than the driven pulley, which produces an overdrive ratio.

The pulleys change size smoothly and evenly, which produces a somewhat odd sensation when the vehicle accelerates from a stop. When the throttle is depressed, the engine speed increases to the point of good torque output and the gear ratio selected by the CVT causes the engine to stay at this RPM while the vehicle accelerates. The pulleys move to higher ratios as vehicle speed increases. This is a different sensation than the familiar engine speed increase in each gear and the engine speed decrease after an upshift. ● **SEE FIGURES 11–2 AND 11–3.**

CONSTRUCTION

TERMINOLOGY Instead of using three or more gears, a continuously variable transmission uses two variable-width pulleys, sometimes called **variators**, to change the gear ratio.

OPERATION The pulleys used in CVT design can vary their width by varying the hydraulic pressure applied to them. Each pulley has a movable face and a fixed face.

- The movable face for each pulley is attached to a piston that has hydraulic control pressure applied to it.
- Higher application pressure on the movable face causes the pulley to become narrow and this makes the steel

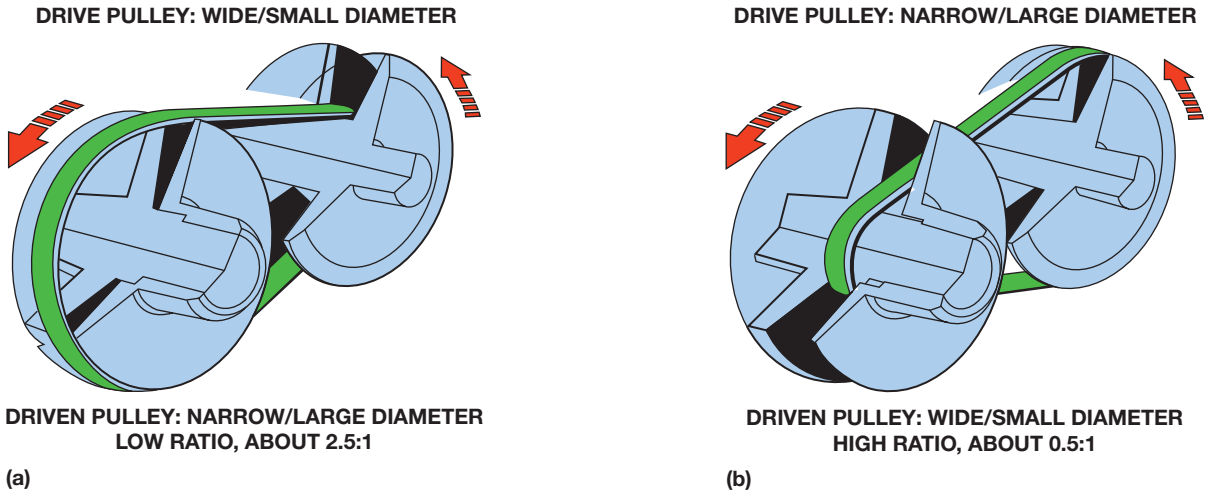


FIGURE 11–2 A belt and pulley CVT uses variable-width pulleys to provide an infinite number of speed ratios.

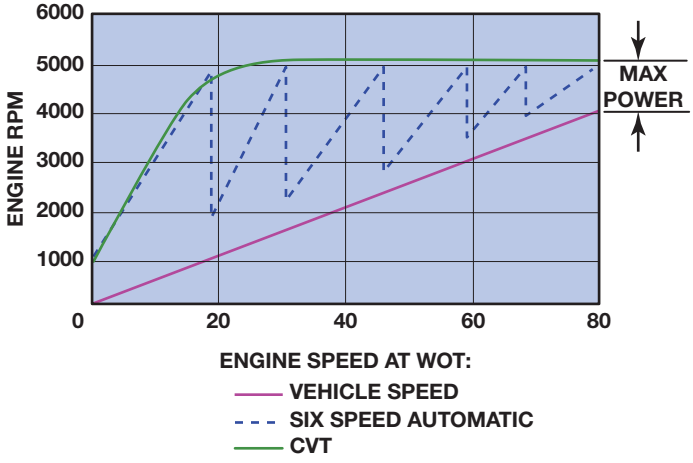


FIGURE 11–3 Engine speed and vehicle speed of a CVT transaxle compared to a typical six-speed conventional automatic transaxle.

belt ride closer to the outside diameter of the pulley. A lower application pressure will allow the pulley to become wider and the belt will ride closer to the pulley axis.

If a low hydraulic pressure is applied to the drive pulley and a high hydraulic pressure is applied to the driven pulley, a low speed ratio is achieved.

A CVT (continuously variable transmission) has an infinite number of gear ratios between its lowest ratio (about 3.7:1) and highest ratio, which is a 0.27:1 overdrive.

A CVT improves efficiency by changing ratios from underdrive/reduction to overdrive in a gradual, continuous manner. The primary/drive pulley is attached to the input shaft. The secondary/driven pulley is on the output shaft and drives the final drive gears. Each pulley, also called a *sheave*, has two sides:

1. One is fixed so it cannot move.
2. The other can float sideways to change pulley width.

FREQUENTLY ASKED QUESTION

What Is It Like to Drive a Vehicle Equipped with CVT?

For most people, driving a vehicle equipped with a continuously variable transmission (CVT) is the same as driving the vehicle equipped with a conventional automatic transmission/transaxle. The vehicle creeps slightly when the brake is released and accelerates normally when the throttle is opened. Because no shifts occur, the first thing the driver and passenger notice is that it is very smooth. If the vehicle is equipped with a tachometer, the driver may notice that the engine speed increases when first accelerating and often remains higher until the vehicle speed increases. During periods of rapid acceleration, the engine speed may be close to its maximum and thereby creates noise and vibration often not experienced in a similar vehicle. Because the vehicle speed slowly catches up to the engine speed, this effect is often referred to as the "**rubber band effect**" and is most noticeable only during periods of rapid acceleration. However, the fuel economy improvement of a CVT compared to a conventional automatic transmission makes the slight difference a reasonable trade-off.

When the vehicle is at rest, the primary pulley is wide so the belt sits low on the pulley, and the secondary pulley is narrow so the belt sits high. This produces the lowest underdrive ratio. ● **SEE FIGURE 11–4.**

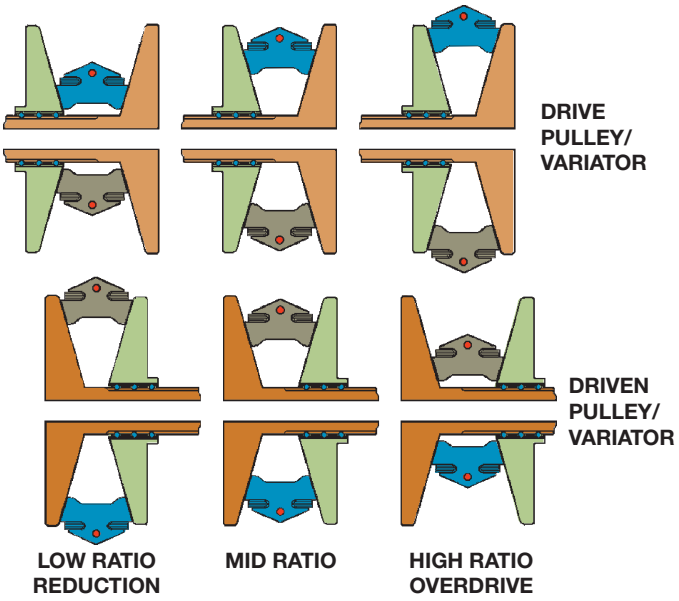


FIGURE 11–4 The drive pulley is wide while the driven pulley is narrow for a low ratio vehicle start (left). The ratio changes by making the drive pulley narrow and the driven pulley wider.

The secondary pulley is spring loaded to force it to a narrow position. The primary pulley is adjusted to control the gear ratio, and the secondary pulley is adjusted to maintain tension on the belt. The belt must never be loose between the pulleys.

- At start, the pulley halves/discs on the input (primary) shaft are spread apart, and the pair of pulley halves on the output (secondary) shaft are pushed together. This produces a small pulley driving a large pulley, which produces the lowest drive ratio.
- As the vehicle moves, the floating side of the primary pulley moves inward, making the pulley narrower and forcing the belt to move out to a wider diameter. This produces a higher gear ratio.
- Both pulleys must maintain enough pressure on the drive belt to transfer the required torque. Fluid pressure is used to force the drive piston/pulley to a narrower position and the driven pulley to a wider position. The secondary pulley is spring loaded to force it to a narrow position. The primary pulley is adjusted to control the gear ratio, and the secondary pulley is adjusted to maintain tension on the belt. The belt must never be loose between the pulleys.

A reverse gear set, controlled by a multi-plate clutch pack, is used to produce reverse.

DRIVE BELT Two different styles of fixed-length steel belts are used.

1. **Push belt** It is made up of about 400 wedge-shaped segments that are held together by two steel bands. Each band is made of multiple layers to allow flexibility. The segment sides contact the pulley sides. A push belt is often called the *Van Doorne design*. This style of belt is directional, and is usually marked with an arrow to show belt direction. ● **SEE FIGURE 11–5.**

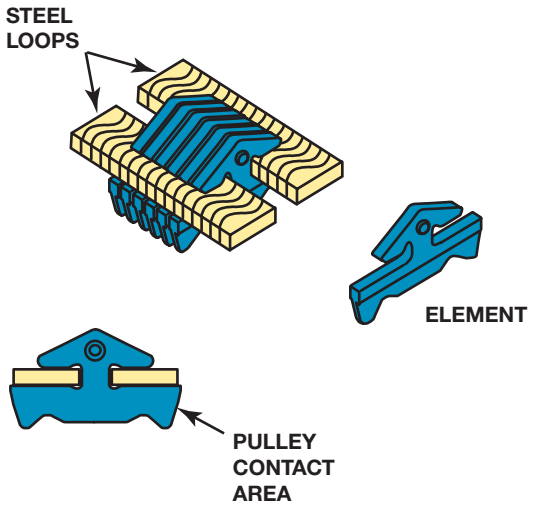


FIGURE 11–5 A Typical push-type CVT belt construction.

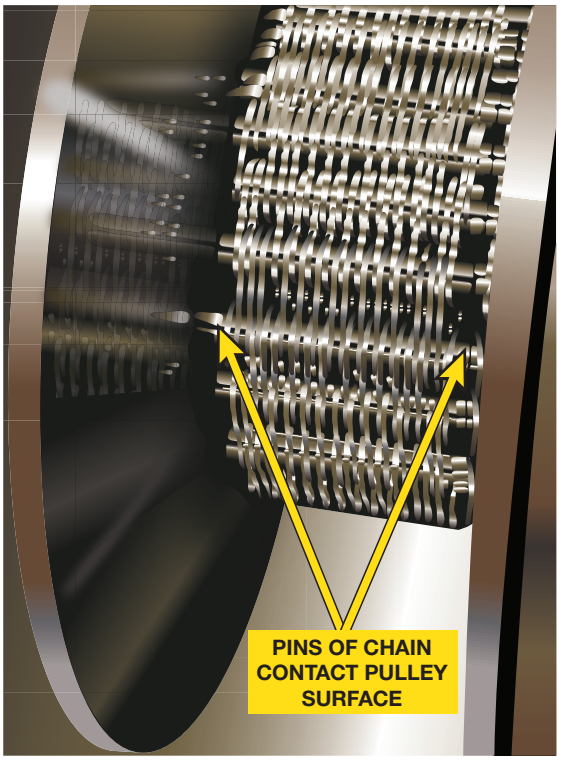


FIGURE 11–6 The pull chain looks similar to a silent chain.

2. **Pull chain** It is made up of links and link pins, much like a silent chain. The ends of the link pins contact the pulley sides. This style is also called a *Luk chain drive*. ● **SEE FIGURE 11–6.**

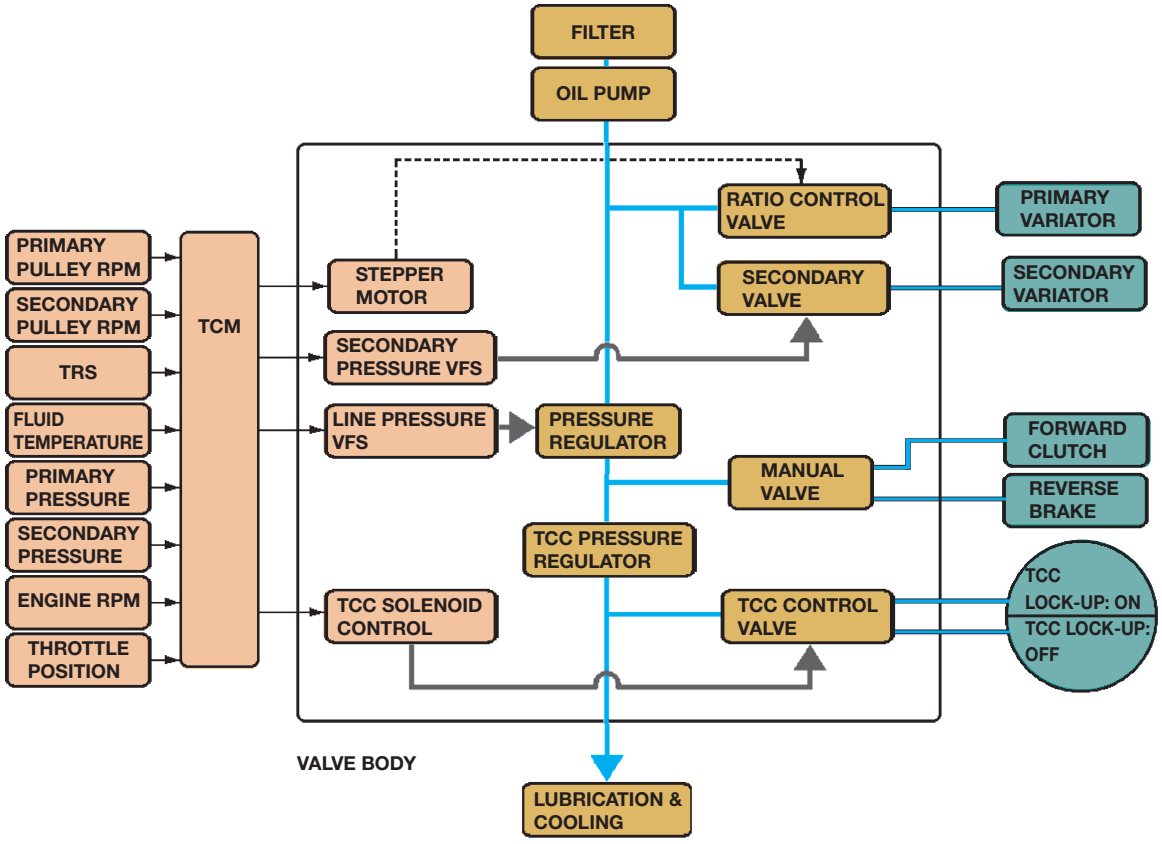


FIGURE 11–7 Block diagram showing the relationship between the TCM, electrical actuators, valve body, and hydraulic actuators for a CVT transmission.

VEHICLES THAT USE A PUSH-TYPE CVT (BELT-TYPE)	VEHICLES THAT USE A PULL-TYPE CVT (CHAIN-TYPE)
Honda (Accord, Civic, Civic hybrid, Insight hybrid)	Audi (A4, S4, RS4)
Dodge Caliber	Ford (500, Freestar, Freestyle)
Jeep (Compass, Patriot)	Mercury (Montego, Monterey)
Mini Cooper	Subaru Lineartronic (Legacy, Forester, Impreza, Outback)
Mitsubishi (Lancer, Outlander)	
Nissan (Altima, Cube, Maxima, Murano, Rogue, Sentra, Versa)	
Saturn (Aura, Ion, Vue)	
Subaru Justy	
Suzuki SX4	
Toyota Corolla	

CHART 11–1

Vehicles that use a CVT transaxle, separated by type: either push-type (belt) or pull-type (chain). Check service information for the exact years and types of transmissions used for each model.

VEHICLES THAT USE A BELT OR A CHAIN

● **SEE CHART 11–1** for list of vehicles that use each type of continuously variable automatic transaxles.

CVT ELECTRONIC CONTROLS

The transmission control module (TCM) of a CVT uses direct and indirect inputs to monitor transmission and engine operation. ● **SEE FIGURE 11–7.**

INPUTS

Direct inputs are as follows:

- **Transmission range sensor (TRS).** A multi-contact switch operated by the manual shift lever
- **Input speed sensor (ISS).** Can be a magnetic or a Hall-effect sensor
- **Output speed sensor (OSS).** Can be a magnetic or a Hall-effect sensor

- **Primary pressure sensor (PPS)**. A pressure transducer to monitor primary pulley pressure. The pressure measured is called the **primary oil pressure (POP)**
- **Secondary pressure sensor (SPS)**. A pressure transducer to monitor secondary pulley pressure. The pressure measured is called the **secondary oil pressure (SOP)**
- **Transmission temperature sensor (TTS)**. A negative temperature coefficient (NTC) thermistor used to measure the temperature of the transaxle

INPUTS FROM CAN BUS Indirect inputs from CAN bus include:

- PCM requests
- Engine output torque
- Brake switch
- ABS status signals
- Charging system voltage
- Engine RPM
- Engine coolant temperature
- Accelerator pedal position
- Vehicle speed
- A/C system requests

OUTPUTS The TCM controls the drive ratio to match vehicle needs. It can adjust the ratio during vehicle cruise to produce the maximum fuel economy, best emissions, or maximum pulling power. It continuously monitors ISS and OSS signals to ensure that the speeds match the desired ratio.

- The stepper motor, also called a **ratio control motor**, is a linear position motor that changes the position of the upper end of the pulley ratio link. The stepper motor controls the hydraulic ratio valve through the link, which in turn controls fluid flow to the piston. The lower end of this link moves with the floating side of the primary/drive pulley and the *ratio control valve* is connected to the center of this link. Movement of the stepper motor or the floating sheave will move the ratio control valve to produce a ratio change. ● **SEE FIGURE 11–8.**

  TCM outputs include:
- Stepper motor that operates the ratio control valve which controls the ratio changes commanded by the TCM.
- **Line pressure solenoid (LPS)**, which controls the line pressure to the transmission hydraulic system.

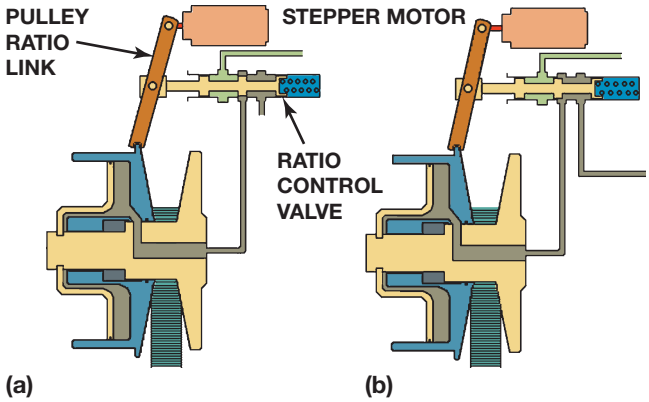


FIGURE 11–8 (a) The stepper motor and pulley ratio link with the CVT in low ratio. (b) The stepper motor has extended, moving the ratio link and ratio control valve; this should cause the primary pulley to become narrower to produce a higher ratio.

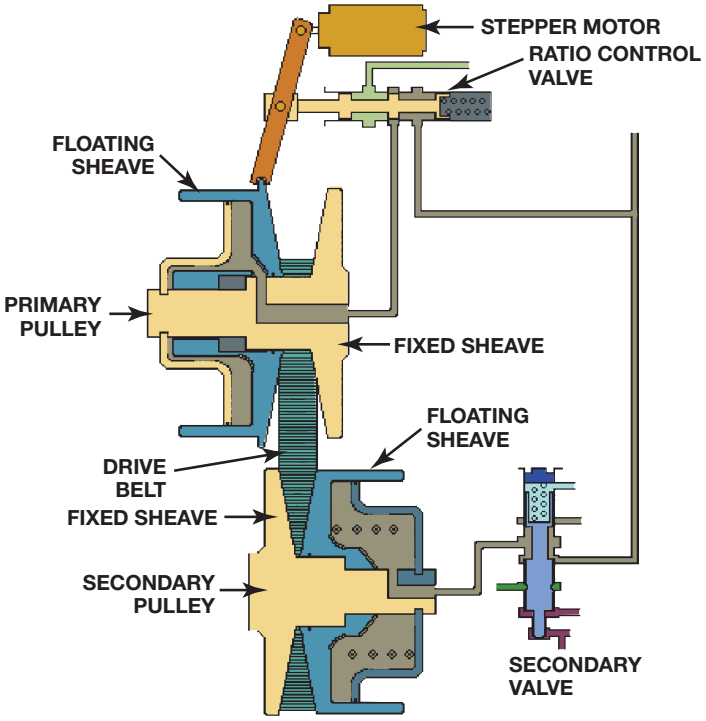


FIGURE 11–9 Movement of either the stepper motor or primary floating sheave will move the ratio control valve to add or remove fluid from the primary pulley. The secondary valve maintains the necessary pulley pressure on the drive belt.

- *Secondary pressure solenoid (SPS)*, which controls the pressure to the secondary pulley system.
- TCC lockup solenoid, which controls the torque converter clutch operation.

The TCM controls the drive ratio to match vehicle needs. It can adjust the ratio during vehicle cruise to produce the maximum fuel economy, lowest emissions, or maximum pulling power. ● **SEE FIGURE 11–9.**

The TCM also controls fluid pressure to the secondary/driven pulley and torque converter as well as TCC lockup. Some vehicles use predetermined stepper motor position to mimic upshifts and downshifts.

CVT OPERATION

STARTING With no fluid pressure, the secondary pulley spring forces the floating side to a narrow, high-belt position, which in turn moves the primary pulley to a wide, low-belt position. This produces an underdrive that is always used as the vehicle starts moving. Continued fluid flow to the primary piston will change the ratio from an underdrive/reduction through 1:1 to an overdrive.

REVERSE A planetary gear set is needed for reverse-direction operation, and this is a simple planetary with a carrier that can be held by the reverse clutch. The input shaft drives the ring/internal gear, and the sun gear drives the shaft to the primary pulley.

FORWARD OPERATION A forward clutch is mounted on the input shaft from the torque converter; it is mounted inside a clutch drum that also contains the planetary ring gear. When it applies, the forward clutch drives the planetary sun gear so both the sun and ring gears are driven. This locks the gear set to produce a 1:1 ratio.

CVT TORQUE CONVERTER

DESIGN Most CVT transmissions use a low-profile elliptical torque converter with a lockup clutch. Since CVTs are infinitely variable, the torque converter is not needed once the vehicle is moving. Therefore, the converter is used to multiply the torque to get the vehicle moving from a stop, and then becomes a mechanical connection between the engine and the CVT. The torque converter clutch apply will occur at about 12 MPH (20 km/h) and stay locked until the vehicle comes to a stop. Some small vehicles with CVTs do not use a torque converter. The forward and reverse clutches are released for stops and one will be applied to start the vehicle moving.

HONDA CVT

OPERATION The Honda CVT is also used as part of the hybrid system on some Honda vehicles. There are three multiple-disc clutches used in the internal gear train, one for each of the following:

- Forward clutch
- Reverse brake
- Start clutch

In the Honda Civic CVT, a start clutch, which slips when the vehicle is stopped with the engine running, is used instead of a torque converter. ● **SEE FIGURE 11–10.**

In park (P) or neutral (N), none of the clutches have hydraulic pressure applied to them, which prevents engine torque from being applied to the drive pulley shaft. The forward clutch and the start clutch are in operation whenever the transmission is placed in a forward gear position (D or L). ● **SEE FIGURE 11–11.**

For the reverse function, a planetary gear set is used in conjunction with the reverse brake. When the reverse brake is applied, the planet carrier is held and the sun gear (splined to the input shaft) causes the ring gear to turn backward. The ring gear is attached to the drive pulley through the forward clutch drum, so the drive pulley also turns backward. This torque is sent through the start clutch and the vehicle moves in reverse.

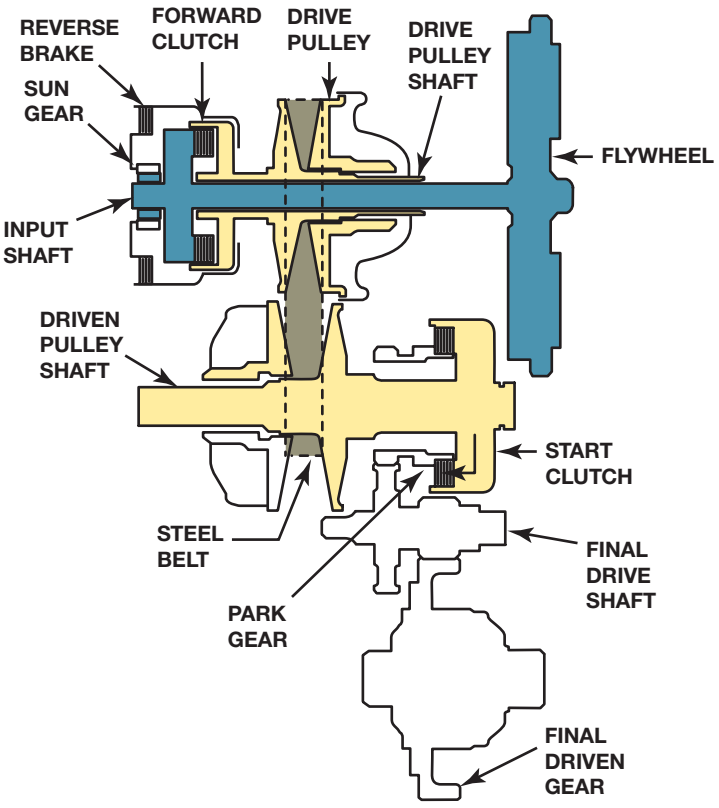


FIGURE 11–10 Honda CVT power flow in park (P) and neutral (N).

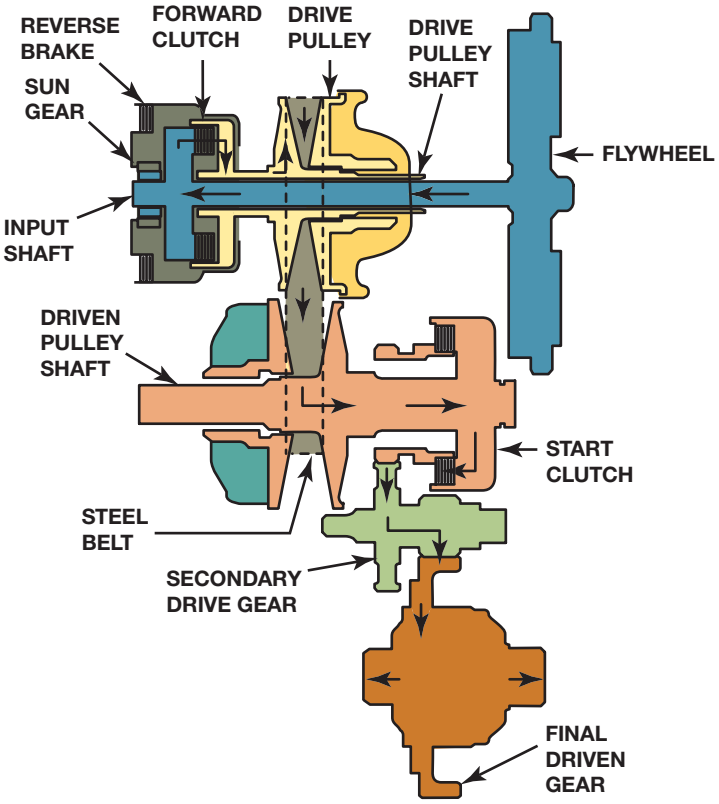


FIGURE 11–11 Honda CVT operation in drive (D) or low (L).

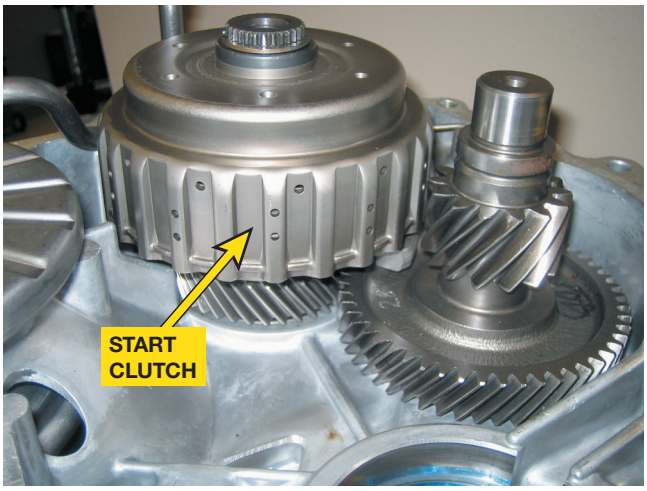


FIGURE 11–12 Location of the Honda CVT start clutch. The start clutch has been eliminated and replaced by a torque converter in newer models.

START CLUTCH The start clutch has multiple responsibilities, including:

1. The start clutch is engaged whenever the vehicle is moving, in either forward or reverse.
2. It helps the vehicle accelerate from a standstill by slipping and then fully engaging once the vehicle is moving, similar to a manually operated clutch. ● **SEE FIGURE 11–12.**

The Honda CVT, like any other automatic transmission, uses hydraulic pressure to perform its various functions. The belt drive, the multiple-disc clutches, and the control system will all stop functioning without hydraulic pressure. This pressure is supplied by a chain-driven pump that is driven by the transmission input shaft.

NOTE: Some vehicles equipped with a continuously variable transmission (CVT) have shifter paddles on the steering wheel or a manual shift mode on the gear selector. When using these paddles to upshift or downshift, the transmission control module selects preprogrammed ratios, which give the driver a sense that it is actively shifting gears.

SERVICING A HONDA CVT The Honda CVT can be pressure tested and stall tested just like any other automatic transaxle when diagnosing transmission malfunctions. These tests must be performed according to manufacturer-approved procedures, and test results compared to charts published by the manufacturer.

One service item that is unique and very important is the *start clutch calibration.* This procedure must be performed whenever any of the following vehicle components is replaced or removed.

1. Battery
2. Backup fuse
3. Transmission control module (TCM)
4. Transmission assembly
5. Lower valve body assembly
6. Engine assembly replacement or overhaul

Details for performing these procedures can be found in Honda service information. The purpose of the procedure is to allow the TCM to memorize the feedback signal for the start clutch control. Malfunctions in the start clutch control system can occur if this procedure is not performed at the appropriate time.

PRESSURE TESTING A CVT

TYPICAL PRESSURES Measuring the CVT oil pressures is similar to performing pressure testing on conventional automatic transmissions/transaxles. Always check service information for the exact procedures to follow and the location of the pressure tap. ● **SEE FIGURE 11–13.**

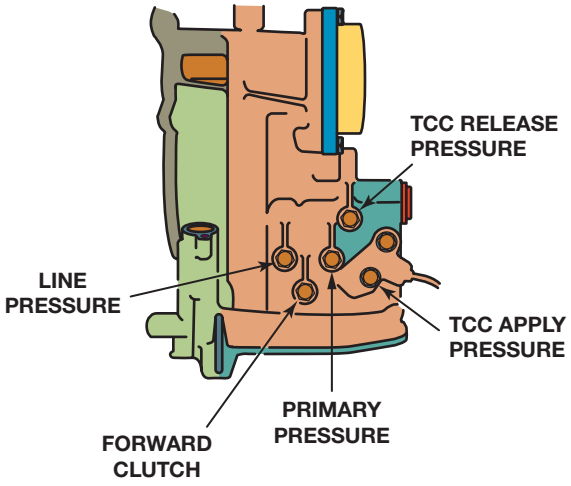


FIGURE 11–13 The pressure tap locations as found on a Dodge Caliber CVT transaxle.

FIGURE 11–14 Using the exact fluid recommended by the vehicle manufacturer is the preferred choice when servicing a CVT transaxles.

WARNING

The pressure can exceed 1,000 PSI (6,900 kPa) and a leak from the tester could cause personal injury. Always uses a high-pressure gauge and follow the vehicle manufacturer's recommended procedures.

Typical pressures include:

- Mainline pressure 70 to 900 PSI (485 to 6,200 kPa)
- Primary pressure 15 to 900 PSI (100 to 6,200 kPa)
- Secondary pressure 15 to 900 PSI (100 to 6,200 kPa)

CVT FLUID

CHECKING CVT FLUID LEVEL A dipstick is used to check the level in some units, and fluid may be poured into the dipstick pipe to bring the level up if it is low. CVT fluid is usually green to help distinguish it from conventional ATF.

CAUTION: Wipe off the dipstick before removing it to prevent any dirt from falling into the fill tube when checking the level of the fluid. Any dirt in the fluid can cause severe damage to the CVT transaxles.

REPLACING CVT FLUID When replacing the CVT fluid, make sure that the specified CVT fluid is used. There is often a drain plug on the transmission pan, and a filler hole located on the transmission case. When refilling the CVT, be sure to check the level regularly to make sure it is not being overfilled. Both the drain and filler plugs should have their gaskets replaced before installing them in their respective holes. Be certain to observe torque specifications when tightening these plugs to prevent damage to the threads in the transmission case and oil pan.

CVT FLUID OPTIONS The shop has two options when filling or replacing CVT automatic transmission fluid:

Option 1. The use of the exact specified fluid as recommended by the vehicle manufacturer is preferred in all cases. A minor disadvantage is that some fluids may be hard to find from local parts suppliers and may have to be purchased from a dealer. ● **SEE FIGURE 11–14.**

Option 2. Use a multi-vehicle fluid, also called *universal CVT fluid,* that is designed to meet the specifications of several different makes and both belts and chains used in CVTs. This is commonly used by many shops and can be successfully used if the fluid is within the specified viscosity and the fluid manufacturer states that it meets the O.E. requirement for friction coefficient.

CVT NOISE ISSUES

Some CVTs tend to have three types of noise issues.

1. A "growl" caused by a faulty gear bearing, which can be repaired in-vehicle in most cases.

Case Study

The Case of the Delayed Shift Subaru

The owner of a Subaru Legacy complained that the CVT (TR580) transmission was slow to engage from park to reverse and from drive to reverse. The technician assigned to the vehicle was able to verify that it required as long as four seconds to shift from drive to reverse or from neutral to reverse. After performing a through visual inspection, including a fluid level check, and not finding any issues, a scan tool was used to see if there were any transmission related diagnostic trouble codes. There were none so the technician checked for any technical service bulletins (TSBs) and found one (#16-97-15) that did address the customer complaint. In the TSB, there was a procedure to follow to relearn the TCM, which stated that this should be performed if there is a lag time greater than 1.5 seconds. The technician performed the relearn control procedure that included the following steps:

- Shift into "N" for 5 second, then shift into "R" for 3 seconds, and then shift back into "N". Repeat 10 times.
- Stay in "N" for 5 seconds, then shift into "D" for 3 seconds, and then shift back into "N". Repeat 10 times.

After 10 times, perform the "time lag test" again to confirm if this procedure corrected the customer complain.

The technician was pleased that the relearn procedure did result in a delay time of less than a second. The customer was very pleased too because it did not require an expensive repair.

SUMMARY:

Complaint—Customer complained of excessive time into a drive gear.

Cause—The transmission needed to be relearned.

Correction—The relearn procedure as found in a TSB was used to relearn the shifting of the CVT. ● **SEE FIGURE 11–15.**

2. A "whine" that is usually caused by a damaged gear. This gear plus the intermediate shaft output gear and differential ring gear must be replaced, requiring transmission disassembly.
3. A "ticking" heard in park and neutral caused by a faulty input bearing. Replacement of the bearing requires transmission disassembly or replacement of the entire assembly based on the vehicle manufacturer's recommendations.

FIGURE 11–15 The "fix" to the customer concern was to perform a relearn procedure using the gear selector following the instructions found in a TSB.

Always follow the specified vehicle manufacturer's recommended diagnosis and repair procedures.

CVT-RELATED DIAGNOSTIC TROUBLE CODES

For some of the diagnostic trouble codes (DTCs) associated with a CVT transmission and the description, ● **SEE CHART 11–2.**

DIAGNOSTIC TROUBLE CODE (DTC)	DESCRIPTION
P0219	Engine speed excessive—check for speed sensor or transmission slip codes
P0571	Brake switch fault detected
P0707; P0708	TCM detects improper signal from transmission range switch (P0707—signal low; P0708—signal high)
P0711; P0712; P0713	Transmission temperature sensor (TSS) fault detected (P0711—circuit performance; P0711—signal low; P0713—signal high)
P0716; P0717	Transmission input speed sensor (ISS) fault detected (P0716—circuit performance; P0717—no signal)
P0721; P0722	Transmission output speed sensor (OSS) fault detected (P0721—circuit performance; P0722—no signal)
P0730	Incorrect gear ratio detected (transmission slip)
P0746	Line pressure sensor performance issue detected
P0776; P0777	Secondary pressure sensor (SPS) fault detected (P0776—performance fault; P0777—stuck on)
P0842; P0843	Primary oil pressure (POP) sensor fault detected (P0842—sensor circuit low; P0843—sensor circuit high)
P0847; P0848	Secondary oil pressure (SOP) sensor fault detected (P0847—sensor circuit low; P0848—sensor circuit high)

CHART 11–2

Typical continuously variable transmission (CVT) diagnostic trouble codes (DTCs) and code description. Transmission-related DTCs are usually P07XX or P08XX, where XX represents the specific fault code.

SUMMARY

1. A continuously variable transmission (CVT) varies the gear ratio in a continuous manner instead of in a series of steps or fixed gear ratios.
2. A pair of hydraulically controlled variable-size pulleys is used with a steel-link drive belt or chain.
3. Two different styles of fixed-length steel belts are used. A push belt or a pull chain is used.
4. The transmission control module (TCM) of a CVT uses direct and indirect inputs to monitor transmission and engine operation.
5. The stepper motor, also called a ratio control motor, is a linear position motor that changes the position of the upper end of the pulley ratio link.
6. Measuring the oil pressure is similar to performing pressure testing on conventional automatic transmissions/transaxles.

REVIEW QUESTIONS

1. What is the advantage of a CVT compared to a regular six-speed transmission?
2. What are the types of belts used in a CVT?
3. What controls the movement of the variator?
4. What is the purpose and function of the ratio control motor?

CHAPTER QUIZ

1. How is a variable ratio achieved in a CVT?
   a. By using multiple gears
   b. By using a steel belt with two variable-width pulleys
   c. By using a start clutch assembly
   d. By using a variable-torque converter
2. What is meant by "rubber band effect"?
   a. A CVT uses a large rubber band
   b. A rubber band is used to apply the clutches inside a CVT
   c. The vehicle speed slowly catches up to the engine speed
   d. A slang term for the variator pulleys
3. What is the difference between a push belt and a pull chain?
   a. A push belt is made up of about 400 wedge-shaped segments
   b. A pull chain is made up of links and link pins
   c. A pull chain looks similar to a silent chain
   d. All of the above
4. Which is NOT an advantage of a CVT?
   a. Larger in size
   b. Lighter weight
   c. Lower internal power loss
   d. Efficient fuel use
5. Which statement is *false*?
   a. The primary/drive pulley is attached to the input shaft
   b. Both sheaves are fixed so they cannot move
   c. The movable face for each pulley is attached to a piston that has hydraulic control pressure applied to it
   d. The primary pulley is adjusted to control the gear ratio, and the secondary pulley is adjusted to maintain tension on the belt
6. Which of these is a *direct input* to the TCM?
   a. Accelerator pedal position
   b. Primary pressure sensor (PPS)
   c. Vehicle speed
   d. Brake switch
7. TCM outputs include a _____.
   a. Stepper motor that operates the ratio control valve
   b. Line pressure solenoid (LPS)
   c. Secondary pressure solenoid (SPS)
   d. All of the above
8. Mainline pressure on a CVT can exceed _____.
   a. 500 PSI (3,450 kPa)
   b. 750 PSI (5,200 kPa)
   c. 900 PSI (6,200 kPa)
   d. 2,000 PSI (13,800 kPa)
9. The recommended fluid to use in a CVT is usually _____.
   a. Dexron VI ATF
   b. Specific CVT fluid
   c. Mercon V or Dexron VI
   d. Any of the above depending on the specific unit
10. Which diagnostic trouble code is associated with a transmission-related fault?
    a. P0776
    b. P0300
    c. P0440
    d. P0172

chapter 12

DUAL CLUTCH AUTOMATIC TRANSMISSIONS/ TRANSAXLES

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Discuss the parts and operation of a dual clutch transmission/transaxle.
3. Explain the construction of a GETRAG DCT 450 transaxle.
4. Describe the diagnostic and service procedures for a dual clutch transmission/transaxle system.

KEY TERMS

Automated manual transmission (AMT) 178
Clutch cooling flow solenoid (CCFS) 182
Clutch pressure cut (CPCUT) 182
Clutch shift pressure solenoid 182
Concentric clutch 179
Direct shift gearbox (DSG) 178
Line pressure solenoid (LPS) 182
Parallel clutch 179
Porsche Doppelkupplung (PDK) 178
Shift cooling multiplex solenoid (SHCMS) 182
Twin clutch transmission 178

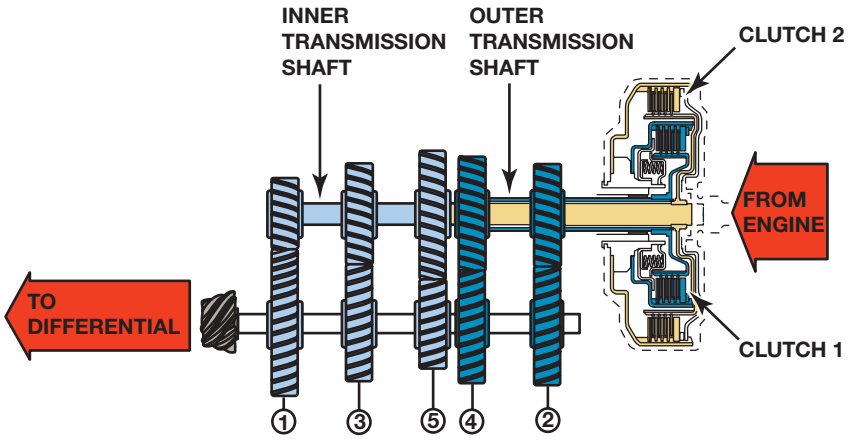


FIGURE 12–1 A dual clutch automatic uses the best features of an automatic transmission without the power loss of a torque converter.

PURPOSE AND FUNCTION

A dual clutch automatic transmission or transaxle uses a manual-type transmission and two clutches that engage either the inner or outer transmission shaft. This type of transmission is designed to achieve the following goals, compared to a conventional automatic transmission or transaxle equipped with a torque converter and planetary gear sets.

1. Improve fuel economy.
2. Reduce the cost of assembly by using manual transmission components.
3. Improve the speed of gear changes.
4. Provide smoother operation.

TERMINOLOGY A dual clutch automatic transmission/transaxle can also be referred to as

- **Direct shift gearbox (DSG)**. Most commonly used by the VW/Audi Group (VAG) of vehicles.
- **Porsche Doppelkupplung (PDK)**. The Porsche term used to describe their dual clutch automatic.
- **Automated manual transmission (AMT)**. Original term no longer commonly used.
- **Twin clutch transmission**. Another variation of the term used for a dual clutch automatic transmission.

PARTS AND OPERATION

A dual clutch automatic transmission/transaxle uses two clutches that are mounted together. One clutch drives the odd number gears (first, third, fifth, and seventh). The other clutch drives the even number gears (second, fourth, and sixth). ● **SEE FIGURE 12–1.**

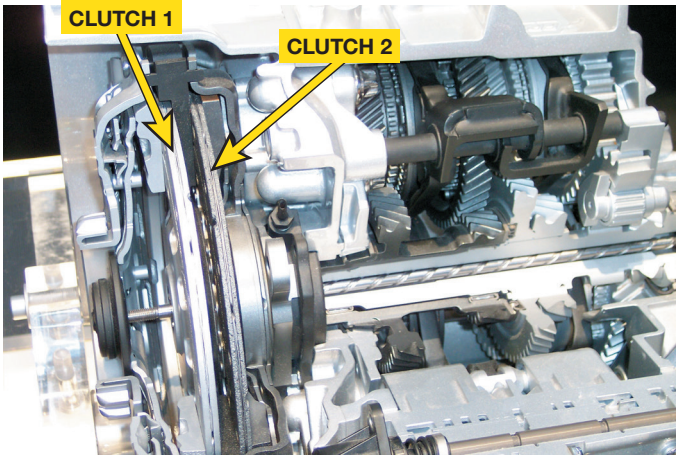


FIGURE 12–2 Dual clutch automatic transaxles that use two dry clutches. The larger clutch drives the odd number gear ratios (first, third, and fifth) and the smaller clutch drives the even numbered gear ratios (second, fourth, and sixth).

The shifts occur without interrupting the torque from the engine by applying torque to the clutch while at the same time disconnecting the other clutch. These actions result in a rapid shift without the slight delay usually associated with an automatic transmission.

There are two types of clutches used depending on application.

1. Dual dry clutches are used in low powered vehicles, such as small front-wheel-drive vehicles. ● **SEE FIGURE 12–2.**
2. Dual wet clutches are often used in higher powered vehicles.

Vehicles that use a dual clutch automatic-type transmission /transaxle include certain models of Audi, Nissan, Mercedes, BMW, Porsche, Ford, Ferrari, VW, and Mitsubishi.

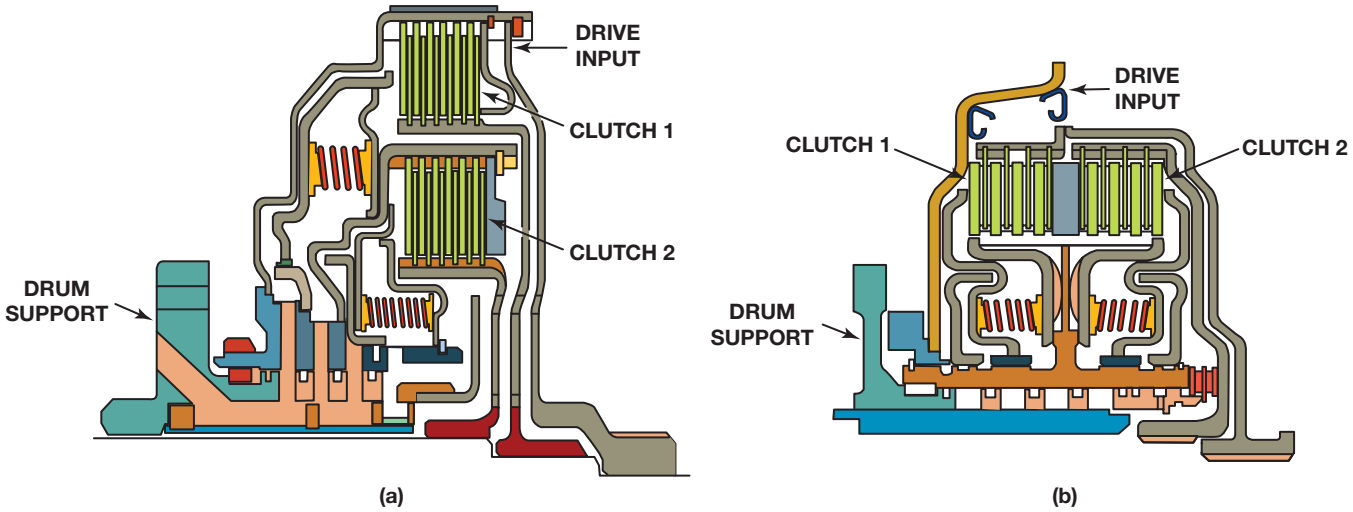


FIGURE 12–3 (a) A concentric (nested) clutch design, the assembly is shorter in length but taller in height. (b) A parallel clutch design is longer but has a smaller diameter drum assembly.

ADVANTAGES The advantages of a dual clutch automatic transmission/transaxle compared to a conventional automatic transmission include:

1. Quicker throttle response
2. No drop in engine speed when the driver releases the throttle
3. Instant gear changes
4. Improved fuel economy

DISADVANTAGES The disadvantages of a dual clutch automatic transmission/transaxle compared to conventional or continuously variable automatic transmissions include:

1. No torque multiplication advantage of a torque converter
2. Not as fuel efficient as a continuously variable transmission (CVT) or transaxle

DUAL CLUTCH TRANSAXLE

TERMINOLOGY A dual clutch transaxle is essentially two transmissions built into one case. Each portion is driven by one of the clutches, and these clutches are applied, one at a time, to transfer power. A dual clutch transmission is essentially an automatic transmission that uses manual transmission-style gear layout and synchronizers with two countershafts. The shifts can occur vary rapidly, being controlled by how fast each clutch can be applied and with partially engaging one clutch while slipping the other during shifts.

CONCENTRIC AND PARALLEL CLUTCH DESIGNS There are two basic wet clutch designs used in dual clutch automatic transmissions.

1. A **concentric clutch** (also called a *nested-type clutch*) is a design where both plates share the same vertical plane and provides a shorter assembly.
2. A **parallel clutch** design is used in a side-by-side arrangement. ● **SEE FIGURE 12–3.**

GEAR ARRANGEMENTS The 1–3 and 5 synchronizer assemblies are driven by clutch 1 and the 2–4 and 6-reverse synchronizers are driven by clutch 2. Vehicle movement begins with the 1–3 synchronizer shifted to first gear and clutch 1 applied. The 2–4 synchronizer is then shifted into second gear by a hydraulic servo, and the 1–2 upshift will occur when clutch 1 is released and clutch 2 is applied. The remaining upshifts occur in the same manner, with the synchronizer preshifted or shifted early, and the actual shift occurring when the clutches are cycled. ● **SEE FIGURE 12–4.**

The driver can control the transmission/transaxle using a floor-mounted shift lever or one of a pair of paddles mounted on the steering wheel.

- Clutches 1 and 2 are applied by hydraulic pressure, similar to automatic transmission clutches.
- The hydraulic flow to the clutches and servos is controlled electronically by a control module.

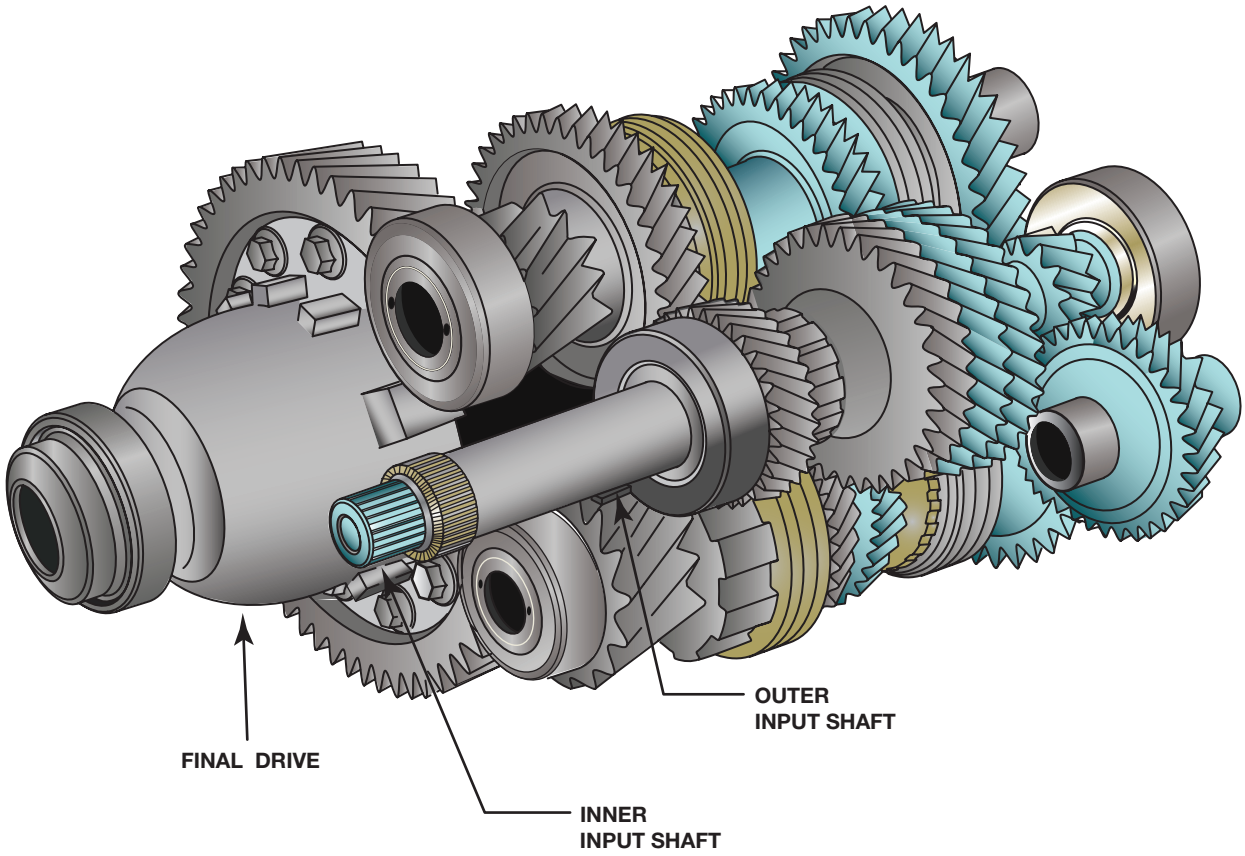


FIGURE 12–4 Notice the two concentric input shafts. Each shaft is splined to a clutch.

GETRAG DCT 450

A Getrag DCT 450 transaxle is a dual clutch automatic transaxle commonly used in a number of Ford and Volvo vehicles starting in 2008. This is a six-speed unit and uses clutch 1 for the odd-numbered gears (1, 3, 5) and clutch 2 for the even-numbered gears (2, 4, 6).

GEAR CHANGE EXAMPLE Using the DCT 450 as the example, the shift from first to second includes the following actions:

STEP 1 Clutch 1 is on and drives the inner shaft. ● **SEE FIGURE 12–5.**

STEP 2 Second gear control device is pressurized to get ready to shift to second gear.

STEP 3 Clutch 2 is starting to be filled with hydraulic pressure (both clutches work at the same time during shifting).

STEP 4 First gear torque delivery through clutch 1 is being reduced as clutch 2 is being applied and starting to transmit engine torque.

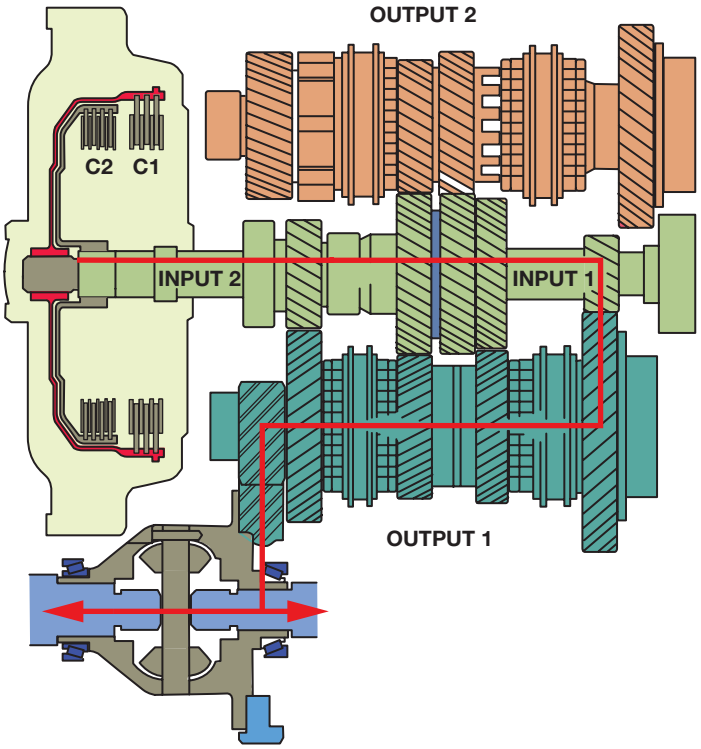


FIGURE 12–5 First gear engaged using clutch 1 (C1) to transmit engine torque.

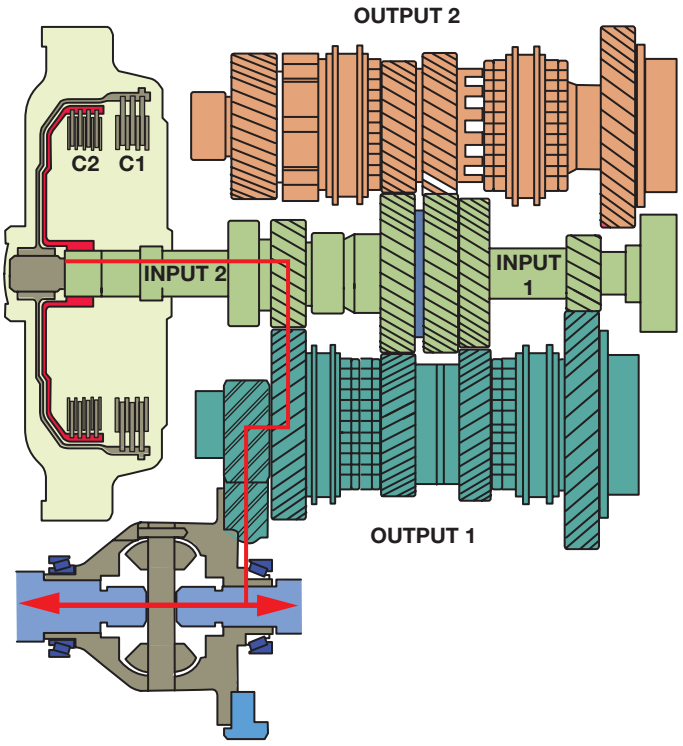


FIGURE 12–6 Second gear engaged using clutch 2 (C2) to transmit engine torque.

STEP 5 Engine torque through clutch 1 is zero and full engine torque is being transmitted through clutch 2. ● **SEE FIGURE 12–6.**

SHIFT FORKS

There are four gearshift forks in this Getrag DCT 450 transaxle. The gear positions per gearshift fork include:

- Gearshift fork 1 (odd): R-N-5
- Gearshift fork 2 (odd): 3-N-1
- Gearshift fork 3 (even): 2-N-4
- Gearshift fork 4 (even): P-N-6

The gearshift forks mechanically engage the gears. The forks are moved by hydraulic pistons, which are controlled by shift solenoids. The transmission control module (TCM) operates shift solenoids. The solenoids move pistons, which in turn apply force to the shift forks through lever points to help increase the force applied. Both an even and an odd gear can be commanded at the same time in parallel.

- Fifth gear and neutral are blocked if the reverse gear is engaged.
- Neutral and first gear are blocked if third gear is engaged. ● **SEE FIGURE 12–7.**

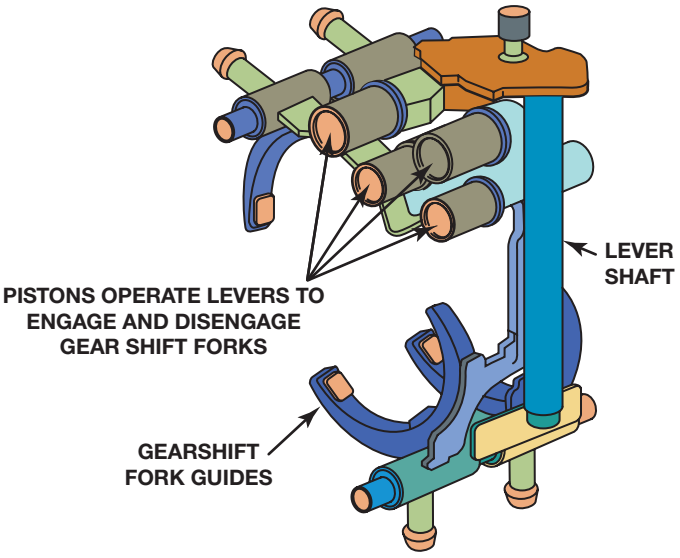


FIGURE 12–7 The shift forks are similar to those used in a manual transmission but are moved using hydraulic pistons.

? FREQUENTLY ASKED QUESTION

How Does a Dual Clutch Type Transmission Achieve Better Fuel Economy?

One of the advantages of a dual clutch automatic is that it is able to provide improved fuel economy over a conventional torque converter-type automatic. One strategy is to have the unit go into neutral when the vehicle is stopped by disengaging the clutches. This allows the engine to remain running but reduces the load on the engine, which improves fuel economy and reduces vibrations. The clutch is engaged when the driver releases the brake.

SPEED SENSORS

Speed sensors include:

- **Engine RPM sensor.** Inputs the engine RPM to the TCM from the sensor located on the clutch drum housing.
- **Speed sensor input shaft odd gears.** Gives the TCM information on input shaft RPM (after the C1 clutch) for odd gears, 1, 3, 5, and R.
- **Speed sensor input shaft even gears.** Gives the TCM information on input shaft RPM (after the C2 clutch) for even gears, 2, 4, and 6.

TEMPERATURE SENSORS

Temperature sensors include:

- **Clutch fluid temperature.** Used to measure the temperature of the fluid leaving the clutches.

- **Transmission fluid temperature.** Used to measure the temperature of the fluid in the transmission.
- **Oil temperature sensor.** Located on the TCM, which provides information on transmission oil temperature.

The TCM uses temperature information to determine correct system pressure, for controlling the clutch, for cold starts, and for overheating protection.

PRESSURE SENSORS Pressure sensors give the TCM information on hydraulic pressure of the clutches. The TCM supplies the sensors with 5 volts. The sensors register the oil pressure to control the clutch pressure so that the TCM can control the solenoids to provide correct clutch pressure for each clutch.

POSITION SENSORS Position sensors include:

- *Fork position sensors*—These sensors give the TCM information on the position of the four gear shift forks that handle shifting in the transmission. Includes 1-R; 3-5; 2-4; and 6-N.
- *Transmissions Range Sensor (TRS)*—This sensor provides the actual P R N D gear selection.

The transmission electronic control module uses information from the sensors to determine the proper clutch and shift servo operation. Once the TCM determines the required gear range and driving conditions, actuators are turned on or off to control hydraulic pressure, gear selection, clutch control, and shift lock.

? FREQUENTLY ASKED QUESTION

Why Is the TCM Using the Position of the Steering Wheel?

The steering wheel position (SWP) sensor information is sent to the transmission control module (TCM) over the network to prevent the transmission from upshifting when cornering. This helps the driver by allowing the vehicle to be accelerated when exiting a corner. If the steering wheel position was not part of the shift program, the transmission might likely upshift to a higher gear as the vehicle slows then the transmission may have to downshift again when the vehicle exits the corner.

SOLENOIDS

A typical dual clutch automatic transmission/transaxle includes the following solenoids:

- **Line pressure solenoid (LPS)**—Controls system pressure in the transmission by directing the hydraulic oil to clutch, shifting, cooling flow, and then returning the oil to the oil sump.
- **Clutch cooling flow solenoid (CCFS)**—Controls hydraulic oil for cooling of clutches.
- **Shift cooling multiplex solenoid (SHCMS)**—Controls position of gearshift forks as well as cooling of clutch.
- **Clutch shift multiplex solenoid (CSMS1)**—Leads the pressure between odd clutch and shifting, activates odd gears, as well as controls cooling flow for clutches.
- **Clutch shift multiplex solenoid (CSMS2)**—Leads the pressure between even clutch and shifting, controls cooling flow for clutches, and can turn off the valve for dumping clutch pressure.
- **Clutch shift pressure solenoid (CSPS1)**—Controls hydraulic pressure for odd clutch or shifting.
- **Clutch shift pressure solenoid (CSPS2)**—Controls hydraulic pressure for even clutch or shifting.
- **Clutch pressure cut (CPCUT)**—Safety valve that controls pressure dumping in the hydraulic system.
- **Shift select solenoid (SHSS1)**—Controls shifting for gearshift fork 1 and 3.
- **Shift select solenoid (SHSS2)**—Controls shifting for gearshift fork 2 and 4.

SHIFT FORK POSITION The transmission control module (TCM) operates shift solenoids. These pistons apply force to the shift forks through lever points to help increase the force applied. Both an even and an odd gear can be commanded at the same time in parallel. Position sensors are located inside the case and this information is used by the TCM to determine the actual position of each shift fork. **SEE FIGURE 12–8.**

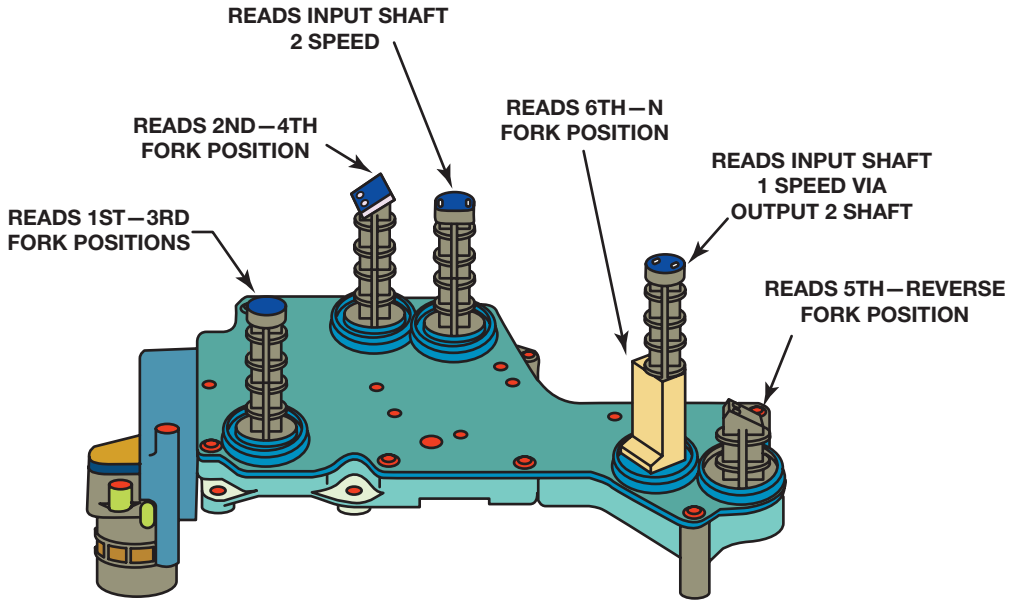


FIGURE 12–8 Fork position and shaft speed sensors are used as inputs to the TCM.

DIAGNOSIS AND SERVICE

DIAGNOSTIC PROCEDURES To diagnose faults with dual clutch automatic transmission/transaxle systems, follow the recommended procedures found in service information. The usual procedure involves the following steps:

STEP 1 Verify the customer concern (complaint). This step includes trying to duplicate what the customer or driver is concerned about.

STEP 2 Perform a thorough visual inspection, including:

- Checking the level and condition of the fluid
- Checking the drivetrain mounts for damage or faults

STEP 3 Check service information for the specified procedure to follow. Most vehicles require the use of a factory-brand scan tool. ● **SEE FIGURE 12–9.**

STEP 4 Follow the troubleshooting procedure as specified to fix the root cause of the problem. This means following the instructions displayed on the scan tool or service information.

STEP 5 Repair the fault.

STEP 6 Road test the vehicle under the same conditions that were performed to verify the fault to ensure that the repair is completed.

FIGURE 12–9 The use of a factory or a factory-level aftermarket scan tool is often needed to diagnose the dual clutch transmission system.

TYPICAL DIAGNOSTIC TROUBLE CODES As part of any diagnostics, checking for diagnostic trouble codes is one of the first steps. ● **SEE CHART 12–1** for some examples of dual clutch automatic transmission related DTCs.

FLUID AND FILTER SERVICE The transmission fluid is usually high-quality synthetic oil, which is unique for this type of

P0715	Input shaft 1 (odd number gear axle) speed sensor system (output high range out)
P0716	Input shaft 1 (odd number gear axle) speed sensor system (poor performance)
P0717	Input shaft 1 (odd number gear axle) speed sensor system (output low range out)
P0746	Line pressure solenoid system (drive current range out)
P0753	Shift select solenoid 1 system (open circuit)
P0758	Shift select solenoid 2 system (open circuit)
P0776	Clutch cooling flow solenoid system (drive current range out)
P0842	Clutch 1 pressure sensor system (output low range out)
P0960	Line pressure solenoid system (open circuit)

CHART 12–1

Selected dual clutch transmission-related diagnostic trouble codes.

transmission. Dual clutch transmission fluid is usually green to help identify it as a unique fluid and to help prevent someone from using conventional automatic transmission fluid. Always use the specified fluid.

For example, the Ford Dry Dual Clutch Fluid is specifically formulated for use in the DPS6 power shift twin dry clutch transmission. This fluid is manufactured with synthetic base oils and performance additives, providing improved shifting at all ambient temperatures. This fluid is used only in transmissions requiring a fluid meeting WSS-M2C200-D2.

Most dual clutch automatic transmissions/transaxles use an external filter that is serviceable and an internal filter that is a nonserviceable part unless the unit is totally disassembled. Always follow the vehicle manufacturer's recommended fluid and filter service intervals.

SUMMARY

1. A dual clutch automatic transmission or transaxle uses a manual-type transmission and two clutches that engage either the inner or outer transmission shaft.
2. A dual clutch automatic transmission can also be referred to as direct shift gearbox (DSG), Porsche Doppelkupplung (PDK), automated manual transmission (AMT), or a twin clutch transmission.
3. A dual dry clutch system is mostly used for lower-powered front wheel drive vehicles, whereas dual wet clutches are used for most high-powered front and rear wheel drive vehicles.
4. There are two basic wet clutch designs used in dual clutch automatic transmissions.
   - A concentric clutch (also called a nested-type clutch) is a design where both plates share the same vertical plane and provides a shorter assembly.
   - A parallel clutch design is used in a side-by-side arrangement.
5. Speed sensors are used to measure the speed of the odd gear shaft and the even gear shaft.
6. Position sensors are used to detect the positions of the shift forks.
7. Solenoids are used to make the actual shifts by moving the shift forks.
8. Dual clutch automatic transmissions use a unique fluid.

REVIEW QUESTIONS

1. What are the benefits of using a dual clutch automatic transmission compared to a conventional automatic transmission?
2. What are the disadvantages of a dual clutch automatic transmission?
3. What type of vehicles use two dry clutches?
4. What are the two designs of wet clutches?
5. How is a shift made from first to second on a dual clutch automatic transmission?
6. What sensors are used in a typical dual clutch automatic transaxle?

CHAPTER QUIZ

1. All of the following are advantages of a dual clutch automatic transmission/transaxle *except*.
   - **a.** Instant gear changes
   - **b.** No torque multiplication advantage of a torque converter
   - **c.** Quicker throttle response
   - **d.** Improved fuel economy
2. A dual clutch automatic transmission/transaxle may be called _____.
   - **a.** Direct shift gearbox (DSG)
   - **b.** Porsche Doppelkupplung (PDK)
   - **c.** Automated manual transmission (AMT)
   - **d.** Any of the above
3. A dual dry clutch system is used in what type of vehicle?
   - **a.** Small front-wheel drive
   - **b.** Heavy rear-wheel drive
   - **c.** All-wheel drive trucks and SUVs
   - **d.** High power front-wheel drive
4. A concentric clutch is _____.
   - **a.** A type of wet clutch
   - **b.** A type of dry clutch
   - **c.** Also called a nested-type clutch
   - **d.** Both a and c
5. How does a dual clutch transmission/transaxle achieve better fuel economy compared to a conventional automatic transmission?
   - **a.** By using a high capacity torque converter
   - **b.** By engaging neutral when the vehicle is stopped
   - **c.** By skipping gears
   - **d.** By slipping the clutches to achieve smoother operation
6. In a Getrag DCT 450 transaxle what does gear shift fork 2 control?
   - **a.** R-N-5
   - **b.** 3-N-1
   - **c.** 2-N-4
   - **d.** P-N-6
7. Why is the steering wheel position sensor used as an input to the TCM?
   - **a.** To help determine when to shift when driving straight
   - **b.** To help control line pressure based on steering wheel angle
   - **c.** To prevent an upshift if the vehicle is turning
   - **d.** As a diagnostic input to help retrieve DTCs
8. The fluid used in dual clutch automatic transmissions and transaxles is usually _____.
   - **a.** Dexron VI
   - **b.** Special synthetic fluid often green in color
   - **c.** Mercon V
   - **d.** Any of the above depending on make, model, and year
9. What is the purpose of the clutch shift multiplex solenoid (CSMS2)?
   - **a.** Leads the pressure between even clutch and shifting, controls cooling flow for clutches, and can turn off the valve for dumping clutch pressure
   - **b.** Controls hydraulic pressure for odd clutch or shifting
   - **c.** Safety valve that controls pressure dumping in the hydraulic system
   - **d.** Controls shifting for gearshift fork 2 and 4
10. A P0753 diagnostic trouble code (DTC) means that the TCM has detected a fault with _____.
    - **a.** Input shaft 1 (odd number gear axle) speed sensor system
    - **b.** Line pressure solenoid system (open circuit)
    - **c.** Shift select solenoid 1 system (open circuit)
    - **d.** Input shaft 1 (odd number gear axle) speed sensor system (output high range out)

chapter 13

TRANSMISSION CONDITION DIAGNOSIS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Outline the procedures involved in the first step of the automatic transmission diagnostic process—verifying customer concern.
3. Outline the procedures involved in the second step of the automatic transmission diagnostic process—fluid level and condition.
4. Outline the procedures involved in the third and fourth steps of the automatic transmission diagnostic process—retrieving diagnostic trouble codes and checking for technical service bulletins.
5. Outline the procedures involved in the fifth step of the automatic transmission diagnostic process—scan tool testing.
6. Outline the procedures involved in the sixth step of the automatic transmission diagnostic process—visual inspections.
7. Outline the procedures involved in the seventh step of the automatic transmission diagnostic process—finding the root cause.

KEY TERMS

Clutch volume index (CVI) 197
Powertrain control module (PCM) 192
Recalibration 195
Transmission control module (TCM) 192

THE DIAGNOSTIC PROCESS

STEPS INVOLVED When diagnosing automatic transmission concerns, perform the following steps:

STEP 1 The first step is to verify the customer complaint. This step usually includes performing a road test to see if the complaint can be duplicated. If the problem cannot be duplicated, then the repair cannot be verified.

STEP 2 Check the fluid level and condition.

STEP 3 Check for stored diagnostic trouble codes (DTCs).

STEP 4 Check for any related technical service bulletins (TSBs).

STEP 5 Check scan tool data including checking the adaptive values.

STEP 6 Visual inspections, including the following:

- Check for obvious faults such as damaged or worn driveshafts or U-joints
- Check for evidence of recent transmission or drivetrain service work
- Check the body and frame for evidence of a collision or recent collision repairs
- Check for leaks

STEP 7 Locate the root cause of the problem. This step involves performing more detailed tests, such as pressure testing.

STEP 8 Replace all components that do not meet factory specifications.

STEP 9 Perform an adaptive relearn and drive the vehicle to verify that the repairs corrected the customer concern.

NOTE: Steps 8 and 9 are discussed in Chapter 17 after the transmission/transaxle has been repaired or rebuilt and reinstalled in the vehicle.

STEP 1—VERFIY THE CUSTOMER CONCERN

ROAD TEST A road test is used to verify the customer's concern and check the general overall condition of the transmission. The vehicle should be road tested at the start of the diagnosis and after the repair. The first road test helps the technician understand the customer's concern as well as the nature of the problem. The road test after repairs have been completed confirms that the repairs were successful. A road test may involve simply driving the vehicle and mentally reviewing the transmission operation.

FIGURE 13–1 Selecting all of the shift modes of an automatic transmission/transaxle helps pinpoint the area where the fault is located.

ITEMS TO CHECK The following points are normally checked during a road test:

- Quality of the garage shifts (neutral–drive and neutral–reverse) ● **SEE FIGURE 13–1.**
- Engagement time for the garage shifts
- Quality of each upshift and downshift at various loads
- Timing of each upshift and downshift at various loads
- Any hunting between gear ranges
- Operation of the torque converter and torque converter clutch (TCC)
- Slipping in any gear range
- Binding or tie-up in any gear range
- Noise or vibration in any gear range
- Engine (compression) braking during deceleration in drive and manual gear ranges
- Speedometer operation (shows output from the vehicle speed (VS) sensor)
- Proper engine operation

There are many shift quality and timing problems that can occur. The common terms used to describe abnormal shifts are described in ● **CHART 13–1.**

THROTTLE POSITION VERSUS SHIFT POINTS The technician operates the vehicle at various throttle positions during

TERM	MEANING
Binding	A very noticeable drag that causes the engine to slow down and labor.
Bump	A sudden, harsh application of a clutch or band.
Chuggle	A bucking or jerking condition, similar to the sensation of clutch chatter or acceleration in too high of a gear with a standard transmission (could be engine related).
Delayed or late shift	The shift occurs some time after normally expected.
Double bump	Two sudden, harsh applications of a clutch or band, also called "double feel."
Dropout	An unexpected shift to neutral or a lower gear, also called "fallout."
Early	The operation occurs before normally expected. An early shift results in a laboring engine, poor acceleration, and sometimes a chuggle.
End bump	A shift feel that becomes noticeably firmer as it is completed, also called "end feel" or "slip bump."
Firm shift	A quick, easily felt shift that is not harsh or rough.
Flare	A rapid increase in engine speed, usually caused by slippage.
Harsh or rough shift	An unpleasantly firm band or clutch application.
Hunting	A repeated up-and-then-down shifting sequence that produces noticeable repeated engine RPM changes.
Shudder	A more severe form of chuggle.
Slipping	A noticeable loss of power transfer that results in an increase in engine RPM.
Soft shift	A very slow shift that is barely noticeable.
Stacked shifts	An upshift that occurs immediately after a prior upshift.

CHART 13–1

Typical automatic transmission/transaxle fault descriptions and their meaning.

the road test. Light-, medium-, full-throttle, and through detent or wide-open throttle (WOT) upshifts are made to check shift quality and timing under each of these conditions. The vehicle is also operated under different closed-throttle conditions. The various throttle positions used are defined as follows:

- Minimum—the least throttle opening that produces acceleration
- Light—when the throttle is about one-fourth open
- Medium—when the throttle is about one-half open
- Heavy—when the throttle is about three-fourths open
- Wide-open throttle (WOT)—fully opened throttle without forcing a downshift
- Closed—a complete release of the throttle, which results in coasting
- Engine braking—a closed-throttle manual downshift to produce a condition where engine compression slows the vehicle

Manufacturers publish shift points. These are the vehicle speeds at which upshifts and downshifts should occur relative to the different throttle openings. To check the shift points, accelerate the vehicle using different throttle openings, and watch the tachometer or listen for the engine speed change that indicates a shift. Have an assistant record the speed for comparison with the specifications. If no specifications are available, the approximate shift points are shown in **CHART 13–2.**

STEP 2—FLUID LEVEL AND CONDITION

The driver of a vehicle should periodically check the fluid level in an automatic transmission. A good time to check this is at every engine oil change. If the level is low, fluid of the correct type should be added. It usually takes 1 pint (0.5 L) to move the fluid level from low to the full mark on the dipstick.

Most transmission dipsticks are marked for both cold and *hot fluid* temperatures. **SEE FIGURE 13–2.**

The most obvious markings are for the hot level, which is the normal operating temperature, about 150°F to 170°F (66°C to 77°C). Room temperature of about 65°F to 85°F (18°C to 29°C) is considered cold for transmission fluid. If the fluid at the end of the dipstick is too hot to hold, then the fluid is hot. When the fluid is cold, use the cold markings on the dipstick. Some

MINIMUM THROTTLE	SPEED MPH (km/h)	PART THROTTLE	SPEED MPH (km/h)	WOT	SPEED MPH (km/h)
1–2	5–10 (8–16)	1–2	15–30 (24–48)	1–2	35–45 (56–72)
2–3	15–25 (24–40)	2–3	25–45 (40–72)	2–3	55–65 (89–105)
3–4	30–45 (48–72)	3–4	40–55 (64–90)	3–4	Above 60/100
4–3	30–40 (48–64)	4–3	35–45 (56–72)	4–3	Above 60/100
3–2	10–15 (16–24)	3–2	30–40 (48–64)	3–2	55–65 (89–105)
3–1	5–10 (8–16)	2–1	10–20 (16–32)	2–1	25–40 (40–64)

CHART 13–2

Typical shift points for a four-speed automatic transmission/transaxle. Always observe all speed limits and traffic regulations during a road test.

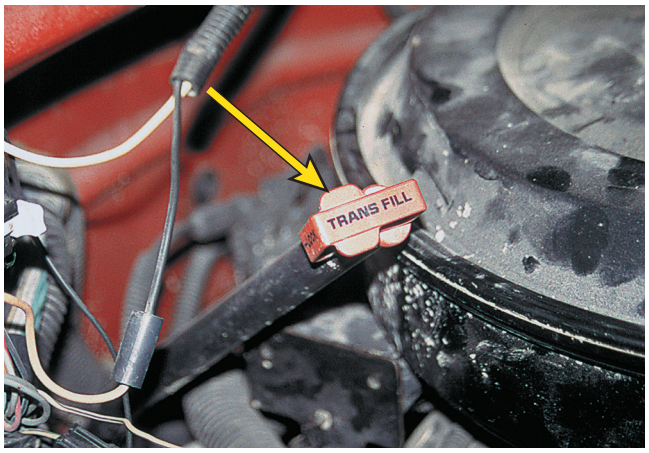


FIGURE 13–2 A typical automatic transmission dipstick (fluid level indicator). Many use a clip to keep it from being forced upward due to pressure changes inside the automatic transmission. A firm seal also helps keep water from getting into the fluid, which can cause severe damage to the clutches and bands.

transaxles use a thermostatic valve to raise the fluid level in the upper valve body pan as the transaxle warms up. These units have a lower hot level and a higher cold level. The exact procedure for checking the fluid level can be found in the vehicle owner's manual, or occasionally it is printed on the dipstick.

OVERFILLED OR UNDERFILLED

It is never a good idea to operate a transmission with the fluid level too high (an *overfill* condition) or too low (an *underfill* condition).

- An underfill is below the low, cold level on the dipstick and it is sometimes marked "Do not drive." An underfill condition can allow air to enter the filter and pump intake, which can cause mushy operation. It may go into neutral, may slip, or the torque converter clutch (TCC) may fail to lock and unlock properly.
- Overfilling can cause slippage and mushy operation because of the air in the foamy fluid. An overfill condition can bring the fluid level up to the point where it contacts the spinning gear sets. This in turn causes foaming of the fluid and fluid may flow out through the vent or filler pipe. There have been cases of vehicle fires caused by the fluid spilling out of the filler pipe and onto a hot exhaust manifold.

Case Study

The Slipping Dodge Truck

A Dodge Durango (89,000 mi) transmission slips when taking off and during the 1–2 shift when cold. The fluid level was okay when it was checked with the transmission in park. However, the fluid level has to be checked in neutral, not park, and was found to be 1.5 quarts low. Adding the correct amount of fluid fixed this problem.

SUMMARY:

Complaint—Owner complained that the transmission would slip when cold.

Cause—The transmission fluid was low because it had been checked in park instead in neutral.

Correction—The transmission fluid was restored to the proper level which corrected the customer complaint.

CHECKING FLUID LEVEL WITH A DIPSTICK

To check transmission fluid with a dipstick, check the procedure stamped on the dipstick. The usual procedure includes the following steps:

STEP 1 Park the vehicle on a level surface, apply the parking brake securely, and place the gear selector in park or neutral as recommended by the manufacturer. Start the engine, and let the temperature of the transmission come up to operating temperature.

FIGURE 13–3 The "add" mark on most automatic transmission dipsticks indicates the level is down 0.5 quart (0.5 L). Always follow the instructions stamped or printed on the dipstick.

STEP 2 Apply the service brakes firmly, and move the gear selector to each of the operating ranges. Leave the selector in each position long enough for each gear to become completely engaged.

STEP 3 Return the selector lever to park or neutral, depending on the transmission. Leave the engine running at idle speed.

STEP 4 Clean any dirt from the dipstick cap, and remove the dipstick.

STEP 5 Wipe the dipstick clean and return it to the filler pipe, making sure that it is fully seated.

STEP 6 Pull the dipstick out again and read the fluid level. ● **SEE FIGURE 13–3.**

Carefully grip the end of the dipstick between two fingers to get an indication of the fluid temperature.

a. If it feels cold, use the COLD marks.

b. If it feels warm, the correct fluid level will be between the HOT and COLD marks.

c. If it is too hot to hold onto, use the HOT marks.

STEP 7 Replace the dipstick completely into the filler tube.

CHECKING FLUID LEVEL WITHOUT A DIPSTICK

Some units do not use dipsticks. Fluid level is checked by following the procedure stated in the service information. When checking sealed units, a general procedure is to bring the transmission to operating temperature, and then remove the fluid level plug. Fluid will trickle or weep out of the plug if the level is correct.

- If it runs out, the level is high.
- If there is no fluid, the level is low.

Some manufacturers require a special procedure or tool in order to check the fluid level of their sealed transmissions, so it is wise to review their fluid-checking procedures. A general procedure follows.

To check transmission fluid level on a vehicle without a dipstick, perform the following steps:

STEP 1 Check service information for the correct checking procedure.

STEP 2 Check the transmission temperature using a scan tool. This is very important and the vehicle will usually need to be driven for several miles before the specified fluid temperature is achieved. ● **SEE FIGURE 13–4.**

WARNING

Any fluid that comes out of the fluid level opening will be extremely hot. Personal injury or a vehicle fire can be caused by ATF leaking or spilling onto a hot exhaust system.

STEP 3 Locate and carefully remove the fluid level plug. Note that the level plug can be small, like a pressure check plug, or large, like a conventional plug. The plug can be located in the transmission case or on the bottom or side of the pan. ● **SEE FIGURE 13–5.**

STEP 4 If fluid drips or seeps from the hole, the level is correct. If fluid runs out, the level is too high, allowing the excess fluid to drain out. Some transmissions use a stand pipe. ● **SEE FIGURE 13–6.**

If no fluid comes out, the level is low. Add additional fluid of the correct type until the level is correct. If necessary, add additional fluid by pumping it into the fill port located at the side of the case or up through the fluid level checking plug opening.

FLUID CONDITION

Fluid condition should always be checked when checking fluid level. A transmission technician will normally smell the fluid and check the color for unusual characteristics. The fluid should be a bright reddish color with a smell that is similar to new fluid. It should be noted that some fluids will normally darken and take on a definite odor after a few hundred miles. One manufacturer states that a smoky odor with light brown color is normal. ● **SEE FIGURE 13–7.**

Following are indications of fluid breakdown:

- Dark brown or black color indicates dirt or burned friction material.

NOTE: Some highly friction-modified ATFs do tend to turn light brown after a short period of time and this should not be used as a sign of fluid breakdown.

- A definite burned odor indicates slippage or overheating.
- Pink fluid or a milky color indicates a coolant leak at the heat exchanger in the radiator.
- A varnish-like odor indicates fluid oxidation and breakdown. This is often accompanied by a gold-brown varnish coating on the dipstick.

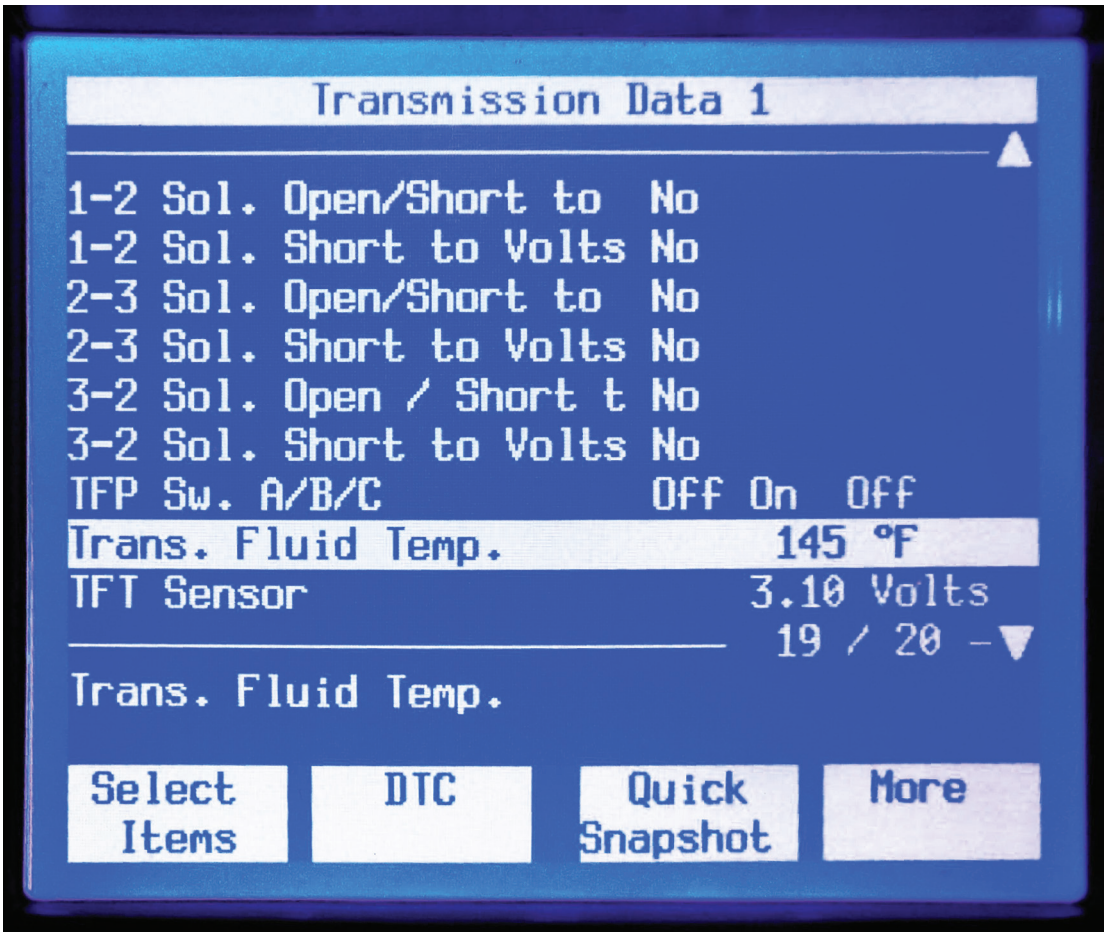
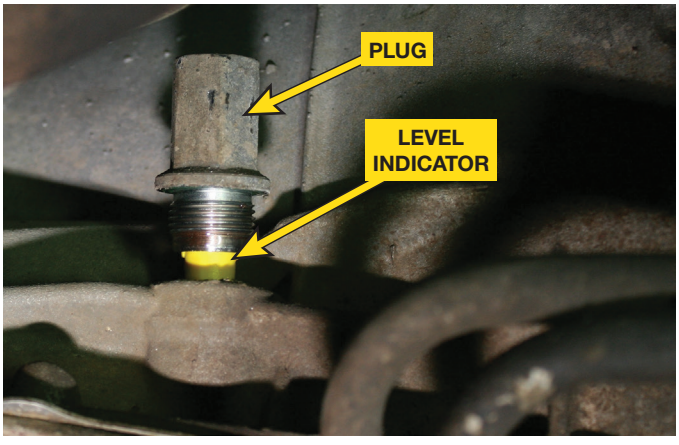


FIGURE 13–4 The temperature of the automatic transmission fluid is displayed on a factory or factory-level scan tool. It may require that the vehicle be driven under a load for the fluid to reach the specified temperature and can often not be achieved by simply allowing the engine to idle.



(a)

(b)

FIGURE 13–5 (a) The fluid level indicator is reached from under the vehicle on this Ford 6R80 rear-wheel-drive transmission. (b)The level indicator can be removed after removing the plug, and then the fluid level can be read on the stick.

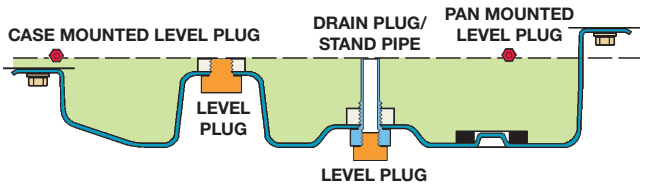


FIGURE 13–6 Fluid level on sealed units (without a dipstick) is checked by removing the level plug, which can be mounted in the bottom or side of the pan or in the case. It is normal for some fluid to drip from this type of level indicator because normal operation of the transmission causes fluid to fill the stand pipe.

FIGURE 13–7 Fluid condition can be checked by placing a sample on clean, white, absorbent paper. Clean fluid will spread out and leave only a wet stain. Dirty fluid will leave deposits of foreign material.

Case Study

The Automatic VW

A shop drained the dirty transmission fluid and replaced the filter in the VW Passat and then noticed that there was no dipstick to check the fluid level. The problem was how to properly adjust the fluid level.

On this vehicle, the recommended fluid level is to install 2 quarts of the proper fluid, start the engine, and monitor the transmission fluid temperature. At 96°F (35°C), fluid should flow from the fluid level port. If no fluid flows, the level is low and more should be added. The exact procedure published by the manufacturer for each transmission should be followed.

SUMMARY:

Complaint—The shop discovered that the transaxle did not have a dipstick.

Cause—Service information was used to find the recommended procedure.

Correction—The specified refill procedure was followed.

FREQUENTLY ASKED QUESTION

What Is Wrong When the ATF Looks Like a Strawberry Milkshake?

If water or coolant gets into the automatic transmission fluid, it makes the ATF look like a strawberry milkshake. Common reasons for this condition include:

A leak in the AFT cooler inside the radiator.

Water getting into the transmission/transaxle through the vent at the top of unit. This could be caused by driving through high water or due to a flood where the vehicle is under water or partially under water.

The transmission/transaxle will require a complete overhaul because the clutch and band friction material is held to the steel backing using water-soluble glue. The water that is mixed with the ATF will loosen this glue and cause the friction material to become detached from the steel backing making the transmission unable to transmit engine torque. **SEE FIGURE 13–8.**

FIGURE 13–8 If the ATF looks like a strawberry milkshake, then the transmission/transaxle will require to be overhauled and the source of the coolant or the water found and corrected.

- Metallic appearance or very fine metal particles indicate wear.
- Foam might indicate a leak in the pump intake system or incorrect fluid level.

STEP 3—RETRIEVE DIAGNOSTIC TROUBLE CODES

HOW THE PCM/TCM SETS CODES One of the roles of the **powertrain control module (PCM)** and/or the **transmission control module (TCM)** is to monitor transmission operation and determine if malfunctions may be occurring. The

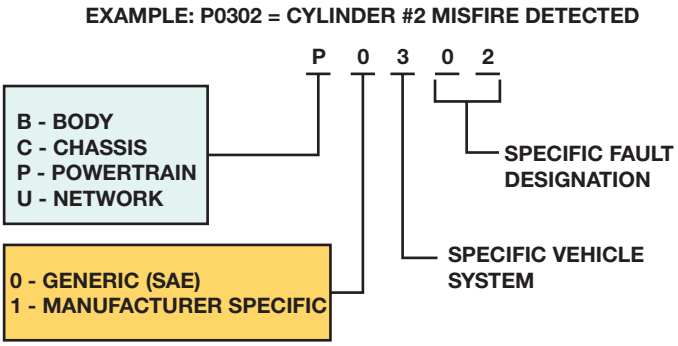


FIGURE 13–9 OBD-II DTC identification format.

PCM/TCM will run frequent self-tests of the electrical circuitry and will also analyze the sensor data to look for transmission slippage, overheating, or other problems. When a problem has been detected, the PCM will generate a diagnostic trouble code (DTC) and may also place the transmission in limp-home mode, depending on what sort of problem has been detected. Limp-home mode is when the transmission stays in one gear only (second gear is a common option) and gives the driver the ability to take the vehicle to the closest service center without having to call a tow truck.

If a diagnostic trouble code (DTC) is present in the PCM/TCM memory, it may illuminate the malfunction indicator lamp (MIL), commonly labeled "check engine" or "service engine soon." Any code(s) that is displayed on a scan tool when the MIL is *not* on is called a pending code or a transmission code for a fault that would not result in an increase in exhaust emissions. Although this pending code is helpful to the technician to know that a fault has, in the past, been detected, further testing will be needed to find the root cause of the problem. ● **SEE FIGURE 13–9.** ● **SEE CHART 13–3** for transmission-related diagnostic trouble codes.

TECH TIP

Look for DTCs in "Body" and "Chassis"

Whenever diagnosing a customer concern with a transmission, transfer case or other driveline components, check for diagnostic trouble codes (DTCs) under chassis and body systems and do not just look under engines. Engine or emission control type codes are "P" codes, whereas module communications are "U" codes. These are most often found when looking for DTCs under chassis or body systems. Chassis-related codes are labeled "C" and body system-related codes are labeled "B" codes. These can cause drivetrain issues if they affect a sensor that is also used by the HVAC system for example. ● **SEE FIGURE 13–10.**

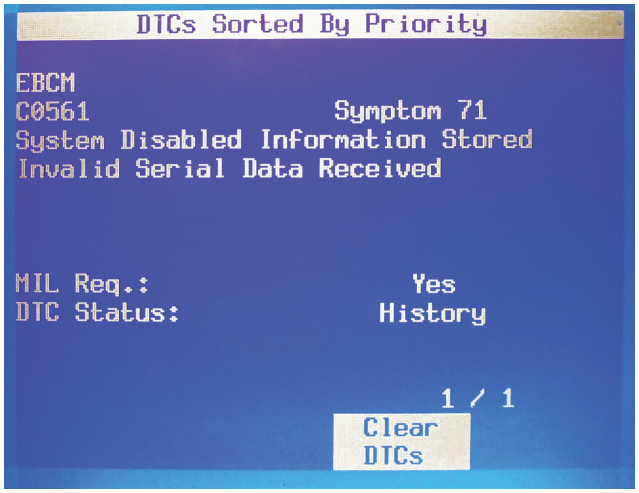


FIGURE 13–10 A "C" diagnostic trouble code was stored along with a note "symptom 71" which gives additional information about the possible cause of this serial data fault code being set.

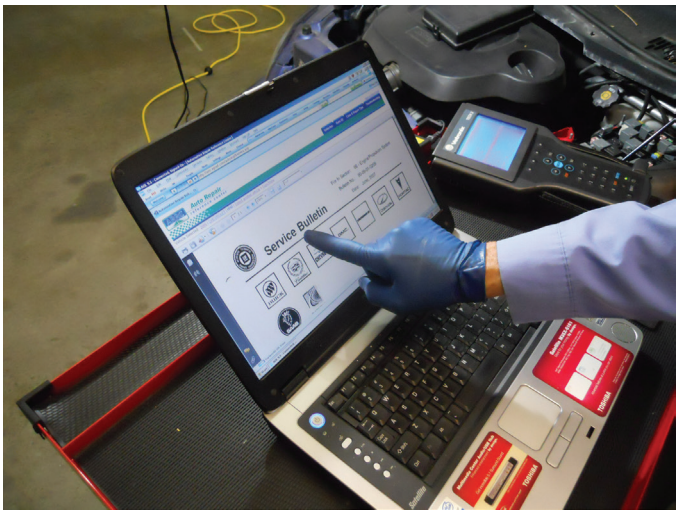


FIGURE 13–11 After checking for stored diagnostic trouble codes (DTCs), the wise technician checks service information for any technical service bulletins (TSBs) that may relate to the vehicle being serviced.

STEP 4—CHECK FOR TECHNICAL SERVICE BULLETINS

Check for corrections or repair procedures in technical service bulletins (TSBs) that match the symptoms. According to studies performed by automobile manufacturers, as many as 30% of vehicles can be repaired following the information, suggestions, or replacement parts found in a technical service bulletin. DTCs must be known before searching for service bulletins, because bulletins often include information on solving problems that involve a stored diagnostic trouble code. ● **SEE FIGURE 13–11.**

TRANSMISSION-RELATED DTCS

P0703	Brake switch input circuit	P0741	Torque converter clutch system performance or stuck off
P0705	Transmission range sensor circuit problem (PRNDL input)	P0742	Torque converter clutch system stuck on
P0706	Transmission range sensor circuit range or performance	P0743	Torque converter clutch system electrical
P0707	Transmission range sensor circuit low input	P0745	Pressure control solenoid problem
P0708	Transmission range sensor circuit high input	P0746	Pressure control solenoid performance or stuck off
P0710	Transmission fluid temperature sensor problem	P0747	Pressure control solenoid stuck on
P0711	Transmission fluid temperature sensor range or performance	P0748	Pressure control solenoid electrical
P0712	Transmission fluid temperature sensor low input	P0750	Shift solenoid A problem
P0713	Transmission fluid temperature sensor high input	P0751	Shift solenoid A performance or stuck off
P0715	Input or turbine speed sensor circuit problem	P0752	Shift solenoid A stuck on
P0716	Input or turbine speed sensor circuit range or performance	P0753	Shift solenoid A electrical
P0717	Input or turbine speed sensor circuit no signal	P0755	Shift solenoid B problem
P0720	Output speed sensor circuit problem	P0756	Shift solenoid B performance or stuck off
P0721	Output speed sensor circuit range or performance	P0757	Shift solenoid B stuck on
P0722	Output speed sensor circuit no signal	P0758	Shift solenoid B electrical
P0725	Engine speed input circuit problem	P0760	Shift solenoid C problem
P0726	Engine speed input circuit range or performance	P0761	Shift solenoid C performance or stuck off
P0727	Engine speed input circuit no signal	P0762	Shift solenoid C stuck on
P0728	Gear 6 incorrect ratio	P0763	Shift solenoid C electrical
P0730	Incorrect gear ratio	P0765	Shift solenoid D problem
P0731	Gear 1 incorrect ratio	P0766	Shift solenoid D performance or stuck off
P0732	Gear 2 incorrect ratio	P0767	Shift solenoid D stuck on
P0733	Gear 3 incorrect ratio	P0768	Shift solenoid D electrical
P0734	Gear 4 incorrect ratio	P0770	Shift solenoid E problem
P0735	Gear 5 incorrect ratio	P0771	Shift solenoid E performance or stuck off
P0736	Reverse incorrect ratio	P0772	Shift solenoid E stuck on
P0740	Torque converter clutch system problem	P0773	Shift solenoid E electrical

CHART 13–3

Transmission/transaxle-related diagnostic trouble codes (DTCs). For transmission-related diagnostic trouble codes for vehicles older than 1996, check service information on how to retrieve and read the codes.

STEP 5—SCAN TOOL TESTING

TYPES OF SCAN TOOLS Scan tools are the most important tools for any diagnostic work on all vehicles. Scan tools can be divided into the following three basic groups:

1. **Factory scan tools.** These are the scan tools required by all dealers that sell and service a specific brand of vehicle. Examples of factory scan tools include:
   - General Motors— GDS2, MDI2 or TECH 2 ● **SEE FIGURE 13–13.**
   - Ford—IDS (Integrated Diagnostic Software)
   - Chrysler—DRB-III, Star Scan, or WiTECH
   - Honda—HDS or Master Tech
   - Toyota—Master Tech and Tech Stream

   All factory scan tools are designed to provide bidirectional capability, which allows the service technician the opportunity to operate components using the scan tool, thereby confirming that the component is able to work when commanded. Also, all factory scan tools are capable of displaying all factory parameters.
2. **Aftermarket scan tools.** These scan tools are designed to function on more than one brand of vehicle. Examples of aftermarket scan tools include the following:
   - Snap-on (various models, including the Ethos, Modis, Versus, and Solus).

FREQUENTLY ASKED QUESTION

What Is Meant by Flashing a Module?

Flashing a module is the updating of the programming of an electronic control module such as the PCM or TCM to solve an issue or customer concern. Flashing a PCM/TCM, also called *programming, reprogramming,* and *calibrating*, can be done to correct possible software problems. Occasionally there is a concern that a transmission has improper shift points, delayed shifts, or just does not work right, and a thorough diagnosis fails to locate any problems. TCMs use an electronically erasable programmable read-only memory (EEPROM) that determines the operating parameters of the TCM. The TCM determines when the transmission upshifts or downshifts, when the TCC applies or releases, and the hydraulic system pressures in some transmissions. This memory function can be changed by connecting a computer interface to the TCM that will erase the old instructions and send new instructions to the vehicle TCM. Flashing will remove adaptive learned values.

A SAE J2534 compliant module is available that, with a computer (preferably a laptop) and the update program, can flash all vehicles. With some makes of vehicles, this will include all or most of the ECM/PCMs, while other makes limit flashing to the powertrain modules. A speedometer that is reading incorrectly can be recalibrated in some vehicles.

Recalibration is often necessary when a new TCM is installed. The process must be performed exactly as directed by the manufacturer. The TCM can be recalibrated outside of the vehicle in some cases. The TCM in some vehicles has a learn strategy that can compensate for some transmission faults such as low line pressure. These units should be recalibrated after a major repair or overhaul. ● **SEE FIGURE 13–12.**

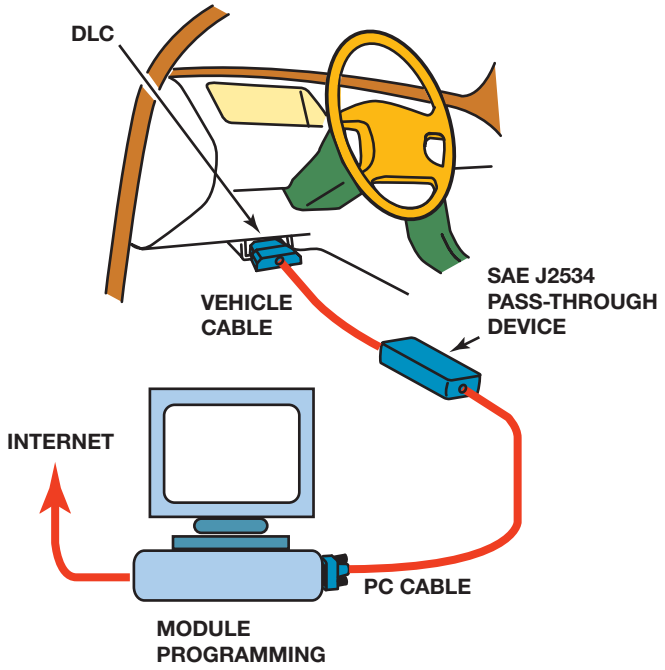


FIGURE 13–12 The J2534 pass-through reprogramming system does not need a scan tool to flash the PCM on most 2004 and newer vehicles.

FIGURE 13–13 A TECH 2 scan tool is the factory scan tool used on General Motors vehicles.

- OTC (various models, including Pegasus, Genisys, EVO, Nemisys, and Task Master). ● **SEE FIGURE 13–14.**
- AutoEnginuity and other programs that use a laptop or handheld computer for display.

While many aftermarket scan tools can display most if not all of the parameters of the factory scan tool, there can be a difference when trying to troubleshoot some faults.

3. **Global scan tools.** The vehicle diagnostic trouble codes (DTCs) and data can be acquired by looking at the global (generic) part of the PCM and does not need to have the vehicle information entered into the scan tool. All global scan tools display only emission-related data stream information and do *not* display faults or codes for any other system or transmission.

FIGURE 13–14 An OTC Genisys being used to troubleshoot a vehicle. This scan tool can be used on most makes and models of vehicles and is capable of diagnosing other computer systems in the vehicles such as automatic transmissions.

SENSOR VALUES A scan tool can display information about the various sensors and components that can assist the service technician in determining the cause of many automatic transmission/transaxle problems.

A properly operating engine should display the following readings with the engine at idle and operating in closed loop.

- **Engine coolant temperature (ECT)**—between 180°F and 215°F (82°C and 102°C)
- **Throttle position (TP) sensor**—usually between 0.5 and 4.5 volts and varying directly with throttle movement
- **Accelerator pedal position sensor (APPS)**—usually two or more sensors on differing scales (0.4 to 4.6 volts) and varying with accelerator pedal movement
- **Fuel injector pulse width**—1.5 to 3.5 ms
- **Upstream oxygen sensor (O2S)**—voltage varying between 200 and 800 mV
- **Air–fuel ratio sensor(s)** (if equipped)—scan tool to read fairly low and steady
- **Transmission fluid temperature (TFT)**—less than 275°F (135°C)
- **Brake switch**—scan data to show a change when brake pedal is pressed and released
- **Manifold absolute pressure (MAP) sensor**—with the engine idling in park or neutral, the voltage should be between 0.88 and 1.62 volts or between 102 and 109 Hz for a Ford MAP sensor
- **Mass airflow sensor (MAF)**—warm engine in park with no load typically reads grams per second within 20% of the engine's liters of displacement. A 3.5 L engine will show fairly close to 3.5 g/s of airflow at idle
- **Vehicle speed (VS) sensor**—source can vary: derived from ABS wheel speed sensors, output speed sensor of transmission, or a dedicated sensor on transmission or transfer case
- **Idle speed**—check for normal idle speed. Vehicles with electronic throttle control will display 2% to 3% open at warm idle in park and vehicles with IAC (idle air control) valves will display 10 to 30 steps or counts on a scan tool
- **Shift solenoids**—check for the proper voltage and current of the shift solenoids using a factory or factory-level scan tool

Observe the operation of the command for the shift solenoids and the TCC solenoid while driving the vehicle. This information confirms that the PCM is commanding the operation and it does not mean that the solenoids are working correctly. Therefore, if the scan data indicates that a particular solenoid is being commanded on and nothing occurs, then the problem could be caused by a defect with the following:

1. Hydraulic component (clutch, band, etc.)
2. Solenoid
3. Fault in the wiring to the solenoid or from the solenoid to the PCM or TCM ● **SEE FIGURE 13–15.**

TECH TIP

Use All Resources

An experienced technician will check all available diagnostic service information from technical service bulletins (TSBs) for the vehicle. Some vehicles have known problems, and their repair is described in a TSB. These are called *pattern failures*. Diagnostic information is also available on the Internet through various organizations, such as the Automatic Transmission Rebuilders Association (ATRA), Automatic Transmission Service Group (ATSG), Identifix, and International Automotive Technicians Network (iATN).

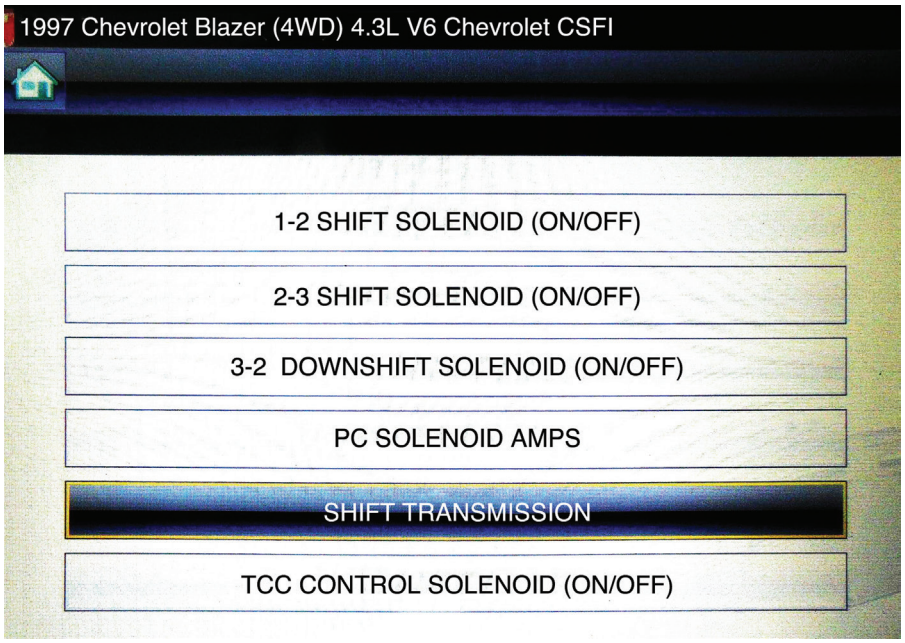


FIGURE 13–15 A Snap-on scan tool is able to shift the transmission and display pressure control (PC) solenoid current (amperes).

CLUTCH VOLUME INDEX Some vehicles include a code for **clutch volume index (CVI)**, also called *transmission adapt pressure (TAP)* or clutch fill volume index. The index monitors the time needed to fill a clutch as it applies. Each clutch should fill and stroke the clutch in a specified time. This time period usually increases with normal wear.

The TCM determines CVI from the speed differential between the input and output speed sensors. The TCM can determine the actual ratio and how long it takes to complete a shift from the speed differential of the two speed sensors. A high CVI usually indicates a clutch with excessive slippage. ● **SEE FIGURE 13–16.**

STEP 6—VISUAL INSPECTIONS

ITEMS TO CHECK The diagnostic procedure should determine if the problem is *inside the transmission* (faulty hydraulic or mechanical operation) or *outside the transmission* (linkage or electrical problems).

Many technicians begin their diagnosis by making a visual check of the battery and wiring. Green, corroded battery terminals or loose terminals can easily cause improper electrical operation.

- The shifts can be forced electrically by providing the proper electrical signal to operate the solenoids using a special diagnostic tool or a factory level scan tool.
- Try removing the fuse that supplies power to the transmission control unit, and conduct a second road test. Without power, the TCM will shut down, causing the transmission operation to revert to a limp-in mode. In this mode, forward operation in the drive range is limited to a single gear, usually second or fourth. Gear operation is controlled by the manual valve, and there will be no automatic upshifts or downshifts. If the second road test has the same problems as the first, then this confirms that the problem is not in the electronic controls.

SOURCES OF NOISE The three most common sources of transmission noise are

1. Bearings
2. Gears
3. Hydraulic system

Bearings, both ball and roller, consist of three parts: the bearing element (rollers or balls with cage), and the inner and outer races. The races can be separate parts or a hardened portion of a shaft, gear, or carrier. Bearing noise, often described as a *whine,* is caused by damage, pits, or scoring that makes the bearing surface rough.

Gear noise is usually the result of a rough gear surface or a worn bearing that allows the gear to change position. Gear noise usually shows up as a whine in a certain gear or multiple gears. Another type of gear noise is a *clack* or *clunk* that occurs when there is a change in power flow; it is the result of

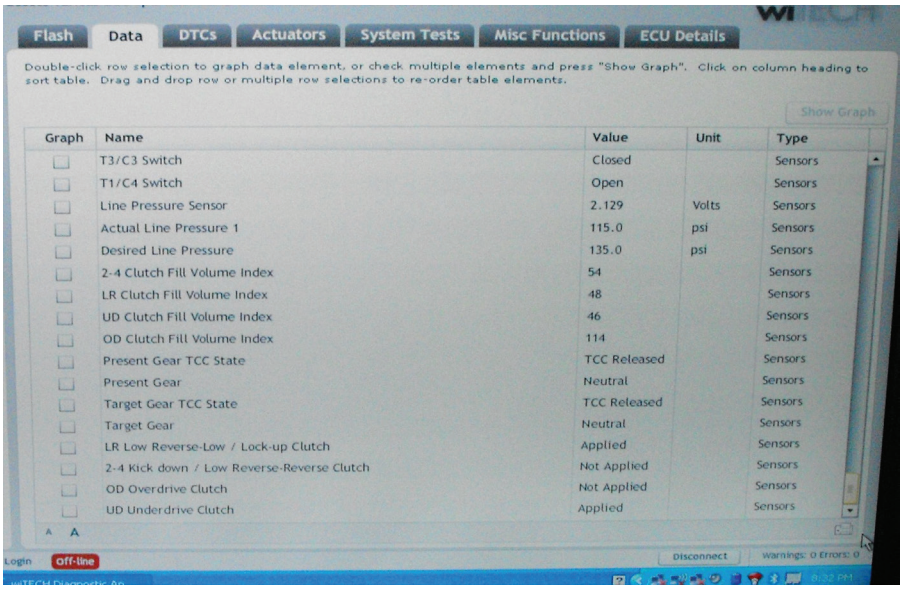


FIGURE 13–16 The clutch fill volume index as displayed on a Chrysler wiTECH scan tool.

Case Study

The Starbucks Syndrome

A BMW 520i (122,000 miles) came in with only second gear, limp-in mode. The customer said the car would operate normally one day and have only second gear the next day. The fluid level is correct and appears in good condition.

The shop checked for fault codes and found two:

1. Gear position switch
2. Speed sensor

Testing revealed faults in the gear position switch and speed sensor circuits (called Starbucks syndrome). *Starbucks syndrome* is a name given to the results of coffee and food spills onto the center console control switches. Corrosion caused by the spills increases resistance at the wire connections. Replacement of these two components fixed the problem.

SUMMARY:

Complaint—Customer complained that the transmission would be stuck in second gear at times.

Cause—Corrosion found at the electrical connections for two components.

Correction—The gear position and speed sensors were replaced.

TECH TIP

Chassis Ears

A noise, vibration, and harshness (NVH) diagnostic tool, "Chassis Ears," consists of a headset and six sensors that can be attached to various locations under the vehicle. The vehicle can be driven on a road test while the technician listens to the six locations. This should help locate the exact source of the noise. ● **SEE FIGURE 13–17.**

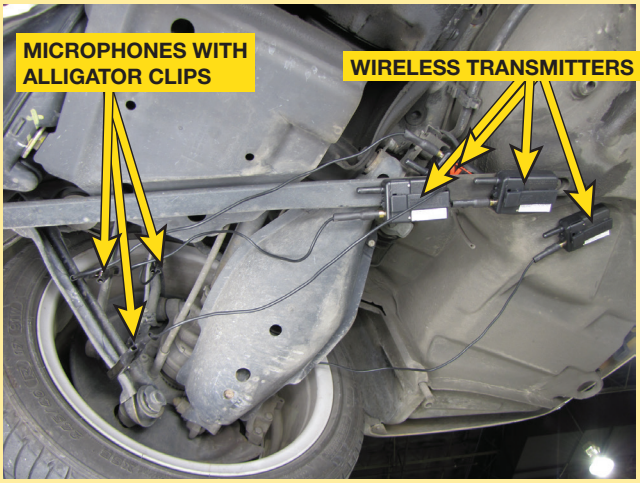


FIGURE 13–17 Chassis ear microphones attached to various under-vehicle components using the integral clamps. The sound is transmitted wirelessly to the receiver inside the vehicle where an assistant technician can listen for noises while the vehicle is being driven.

excessive clearance in the gear train. Worn differential gears and differential pinion shaft are a major cause of neutral-to-drive or neutral-to-reverse clunk.

Hydraulic noise, often described as a "buzz," is the result of rapid fluid pressure pulsations. With many transmissions, it will occur for a short time period while the fluid is cold and then go away.

When troubleshooting noise problems, it helps to determine how the noise fits into the following categories.

- **Speed relation**—related to engine or vehicle speed
- **Gear range**—related to gear range
- **Pitch/frequency**—low (rumble), medium (growl), or high (squeal)
- **Load sensitive**—heavy throttle, light throttle, or coast
- **Direction**—straight or right or left turn

LOCATING THE SOURCE OF THE NOISE

To locate the cause of a transmission noise, perform the following steps:

STEP 1 Raise the vehicle so you have access to the transmission mounts. Visually check their condition, and if the mounts appear weak, pry upward on the transmission to check for possible separation of the mounts.

STEP 2 Start the engine and shift the transmission through its gear ranges while observing for any mount problems.

STEP 3 With the engine running and the gear selector in P or N, listen for the noise. Shift into D, and with the brake firmly applied, listen for the noise. A torque converter problem is indicated if the noise occurs with the transmission in gear but not in P or N. A pump problem is indicated if the noise occurs in both D and P or N. A faulty input drive chain and sprockets can also cause this problem.

STEP 4 With the engine running, shift from N to R while listening for the noise. A hydraulic problem is indicated if the noise increases when shifted into R. Shift into D and alter the signal to the EPC solenoid using a scan tool to boost line pressure. A hydraulic problem is indicated if the noise increases.

STEP 5 Perform a road test and listen for noise changes as the transmission shifts through the gear ranges. A transmission gear set problem is indicated if the noise changes depending on the gear range, especially if it is quiet during the range with a 1:1 ratio.

STEP 6 Repeat step 5 and listen for a noise that increases as the vehicle speed increases. A final drive problem is indicated if the noise intensity or frequency increases with vehicle speed. Note that the final drive can include transfer gears or chain drives depending on the transaxle.

Case Study

The Case of the Noisy Neon

A Dodge Neon (87,000 mi) had a bad, tinny rattle noise coming from the torque converter area. The noise occurs whenever the engine is running. Visual inspection through the inspection cover area does not show a problem. A cracked flexplate is suspected. Removal of the transaxle allowed inspection of the torque converter and flexplate. Visual inspection showed that a balance weight had come loose. Replacement of the torque converter fixed this noise problem.

SUMMARY:

Complaint—Customer complained about a rattle noise.

Cause—A balance weight on the torque converter was loose.

Correction—The torque converter was replaced.

NOISE	PROBABLE CAUSE
Chain noise	A whine or growl that increases in frequency and amplitude with vehicle speed. Most noticeable under light acceleration. Input chain noise can be heard in park and neutral.
Final drive	A hum related to vehicle speed. Usually torque sensitive.
Gear noise	A whine or growl related to vehicle speed. Usually torque and gear-range sensitive.
Pump noise	A high-pitched whine that increases in amplitude with engine speed. Most noticeable in park or neutral with cold transmission fluid.

CHART 13–4

Typical noise problem descriptions.

Transmission noise problem areas usually fit into the categories shown in **CHART 13–4.**

VIBRATION CHECKS

Torque converter problems cause an engine-speed-related vibration problem. Output shaft vibration problems are vehicle-speed related. These are often accompanied by driveline clunk. FWD output shaft problems

will usually be most noticeable on turns because of the increased differential and CV joint action.

- Engine-speed-related vibrations occur during particular engine speed ranges and these vibrations change when the transmission shifts gears. There are several causes leading to this, for example, belt-driven accessories such as the fan, alternator, air-conditioning compressor, or internal engine unbalance. Belt-driven problems can be identified by running the engine with the belt removed. If the vibration is gone, then the source of the vibration is one of the units being driven by the accessory drive belt.
- Identifying a torque converter problem begins with removing the converter cover and carefully inspecting the torque converter and flex plate. Look for a wobble (runout) of the converter during engine rotation. Torque converter runout can be caused by the following:
- Improper tightening of the torque-converter-to-flex plate bolts.
- A damaged flex plate. **SEE FIGURE 13–18.**
- Improper mounting of the torque converter into the crankshaft. If there is no runout, then replace the torque converter.

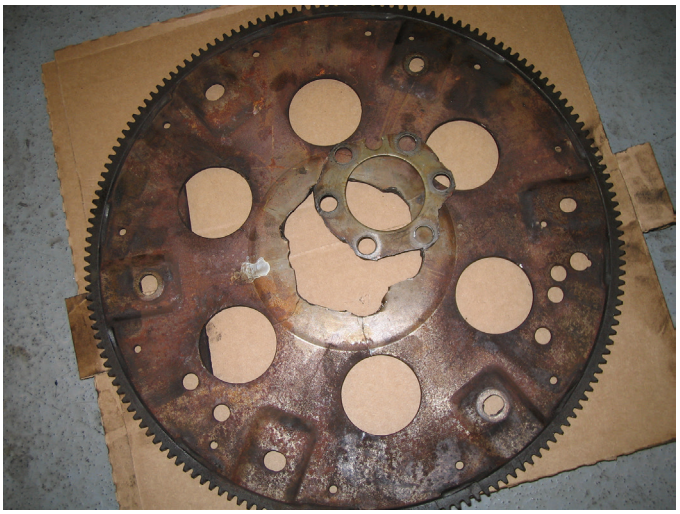


FIGURE 13–18 A broken flexplate that made a lot of noise and then the engine would not crank when it finally broke.

FIGURE 13–19 This is a normal amount of wear material in the bottom of an automatic transmission pan.

STEP 7—FIND THE ROOT CAUSE

OIL PAN DEBRIS CHECK When it has been determined something is wrong with the transmission/transaxle, the next step is to drain the oil and remove the pan for inspection. The debris in the pan can give a good indication of what is occurring in the transmission.

- A small amount of debris with a dark brown oil film is normal. A small amount of metal can be attributed to the wear that occurs during break-in and normal operation. **SEE FIGURE 13–19.**
- An excess of loose, black material is burned lining material from a slipping band or clutch. It usually has a burned smell.
- A heavy golden brown coating is from badly oxidized, old fluid. The lower part of the case and valve body will also have this varnish coating. It usually has a strong odor similar to varnish and indicates that the transmission ran hot.
- An excess of metal is from a gear set, thrust washers, bushings, or the transmission case. Steel and iron are usually from the gears, needle bearings, a spring, or a spring retainer. Aluminum is from the case, a carrier, or a clutch piston. Brass or bronze is from a bushing or thrust washer.
- Any plastic debris (broken or melted) is from a thrust washer, spacer, or clutch spring retainer.

ELECTRICAL SYSTEM CHECKS An electronic system cannot function without adequate power or a good ground. The power and ground connections are often overlooked by the technician who is eager to solve a transmission problem. The case connector should be checked as it is exposed to road hazards as well as water, snow, and mud. **SEE FIGURE 13–20.**

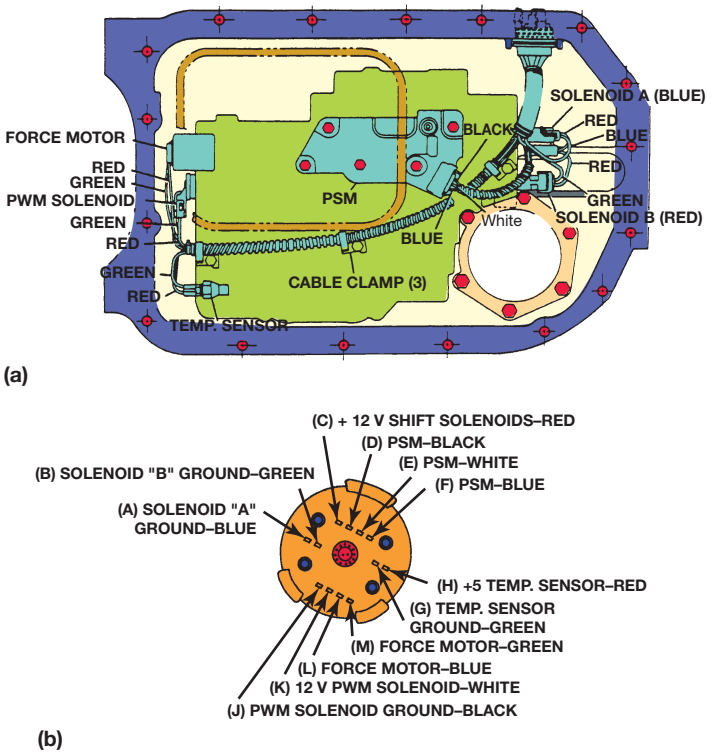


FIGURE 13–20 A visual inspection of the transmission electrical connector ensures that the terminals are clean and in good condition as well as being completely engaged.

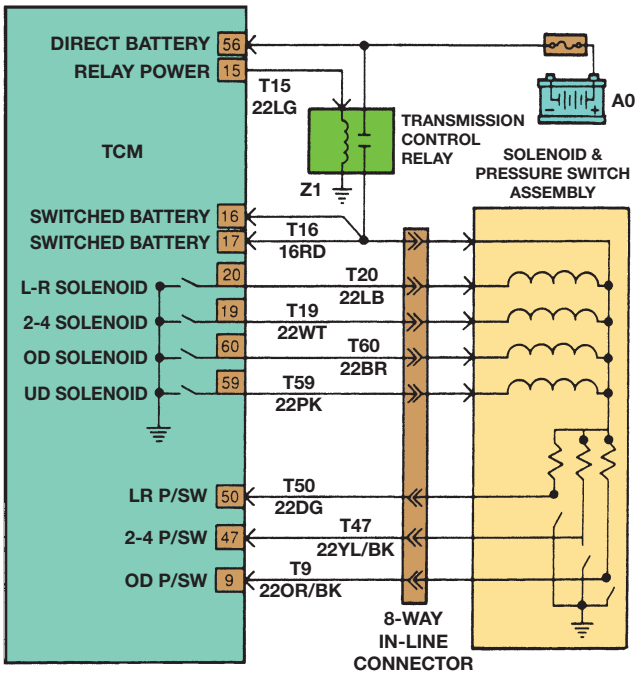


FIGURE 13–21 TCM terminals 16 and 17 receive B+ when the transmission relay is energized.

After determining there is a problem in the electronic system, an experienced technician will check B+ voltage at the battery and then at the TCM and transmission power relay if there is one. There should be at least 12.6 volts with the engine off and 13.6 to 15 volts with the engine running. There should also be a minimum voltage drop between the TCM ground (B–) terminal and ground 0.2 volt or less. ● **SEE FIGURE 13–21.**

- When checking a circuit, make sure that all connectors are properly latched. Disassemble the connector and check for loose, bent, or pushed-back pins, cracked connectors, and water intrusion that will cause corrosion.
- A signal generator can be used to input ISS and OSS signals, and if the TCM responds properly, the speed sensor in question must be faulty.

Case Study

The Case of the Drips

The owner of a BMW 535i arrived at a shop with a complaint of fourth-gear dropout. This occurs when it is hot with the A/C on. Normal operation returns after the car is shut off for a while. The technician checked the A/C evaporator drain and found that it was dripping water onto the transmission harness connector. Sealing/waterproofing this electrical connector fixed this problem.

SUMMARY:

Complaint—Customer complained that transmission would drop out of fourth gear.

Cause—Water from the A/C system dripped on the electrical connector to the transmission.

Correction—The wiring harness was sealed.

HYDRAULIC SYSTEM PRESSURE TESTS The operation of an automatic transmission is dependent on hydraulic pressure. A technician uses a pressure gauge to check the condition of the hydraulic system. Some hydraulic system problems can be fixed with the transmission still in the vehicle.

All transmissions have a pressure test port, and some have more than one. If there is only one port, it will usually be for line pressure. The additional ports provide the apply or release pressure of a particular clutch. Service information includes illustrations to identify these test ports. ● **SEE FIGURE 13–22.**

PRESSURE GAUGES A common analog hydraulic pressure gauge is normally dampened, so minor pressure fluctuations are lost. The electrical transducer of an electronic

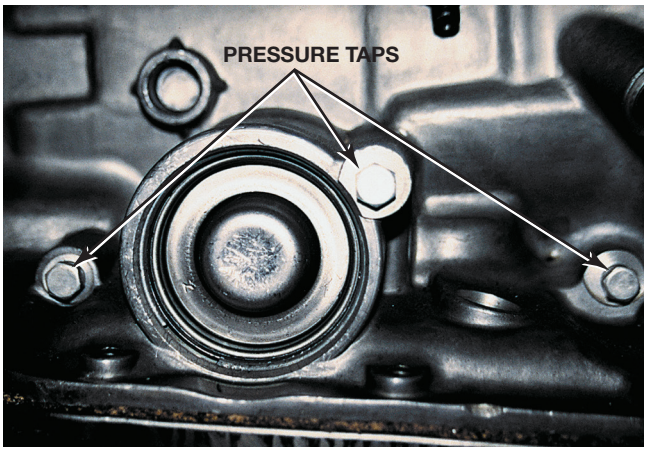


FIGURE 13–22 The locations (taps) for connecting a pressure gauge to measure the pressure of the various hydraulic circuits are usually found on the side of the automatic transmission/transaxle. Check service information for the exact locations for the vehicle being tested.

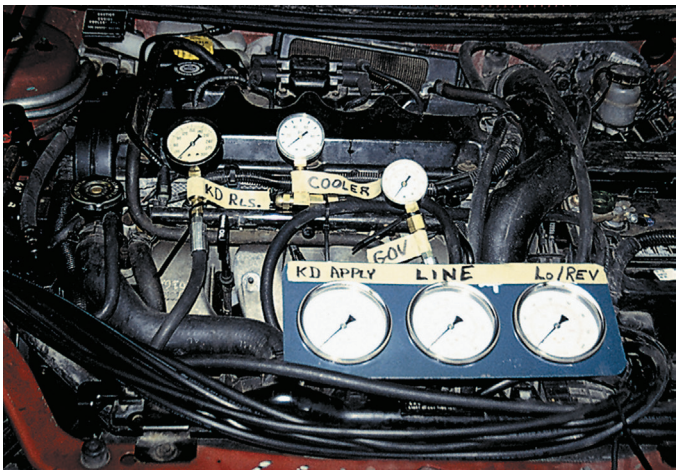


FIGURE 13–23 Six pressure gauges are installed on this vehicle to show students how the pressures vary and how the gauges can be used to find faults or possible problem areas before the unit is removed and disassembled.

gauge can be connected to a scope, which can be used to watch small pressure changes and find an important clue to the cause of a problem. When using a hydraulic pressure gauge, it is recommended that the range of the gauge be 0 to 300 PSI (0–2 kPa) to prevent gauge damage while testing reverse gear pressure.

To test transmission hydraulic pressures, perform the following steps:

STEP 1 Raise and securely support the vehicle on a hoist or jack stand.

STEP 2 Locate the pressure ports, remove the plugs, and connect the gauge(s) to the ports. Note that most domestic transmission ports use female, 1/8-inch National Pipe Threads (NPT). Always double-check that the fitting has the same threads as the transmission port by turning the adapter inward several turns using hand force only.

STEP 3 Connect a scan tool to the vehicle to monitor engine speed.

STEP 4 Route the various lines and wires so they can be read while the vehicle is operated. Be sure to keep them away from the hot exhaust system and rotating parts. Do not run the hydraulic lines or gauges inside the vehicle.

STEP 5 Place the gear selector in park, securely apply the brakes, start the engine, and note the readings on the various gauges.

STEP 6 Run the engine at idle speed, then shift the gear selector through each of the gear ranges and record the pressure readings. While testing pressure during a road test, watch the gauge pressure before, during, and after a shift. The pressure should drop and then come back. A lower pressure after a shift indicates a leaking fluid circuit.

STEP 7 Make sure the brakes are securely applied, then increase the engine speed to 1000 RPM and repeat step 6. ● **SEE FIGURE 13–23.**

INTERPRETING PRESSURE READINGS A technician compares the pressure readings to specifications to determine if the system is operating correctly. The most likely causes for a pressure problem in park or neutral are the pump, intake filter, and pressure regulator because the fluid flow path is usually through the filter, valve body, transmission case, pump assembly, and back through the transmission case to the valve body. These are the circuits that are supplying fluid or are under pressure in that gear range. In park and neutral, the throttle valve, torque converter, and cooler are open to flow, but the flow to the rest of the transmission is shut off at the manual valve. High or low pressures in neutral are usually caused by a problem in the throttle valve, torque converter, and cooler circuits. If no specifications are available, the approximate pressures in most transmissions will be as follows:

- Neutral, park, and drive at idle: 50 to 60 PSI (350 to 400 kPa)
- M1 and M2: 50 to 60 PSI; in some transmissions: 100 to 125 PSI
- Reverse: 150 to 250 PSI

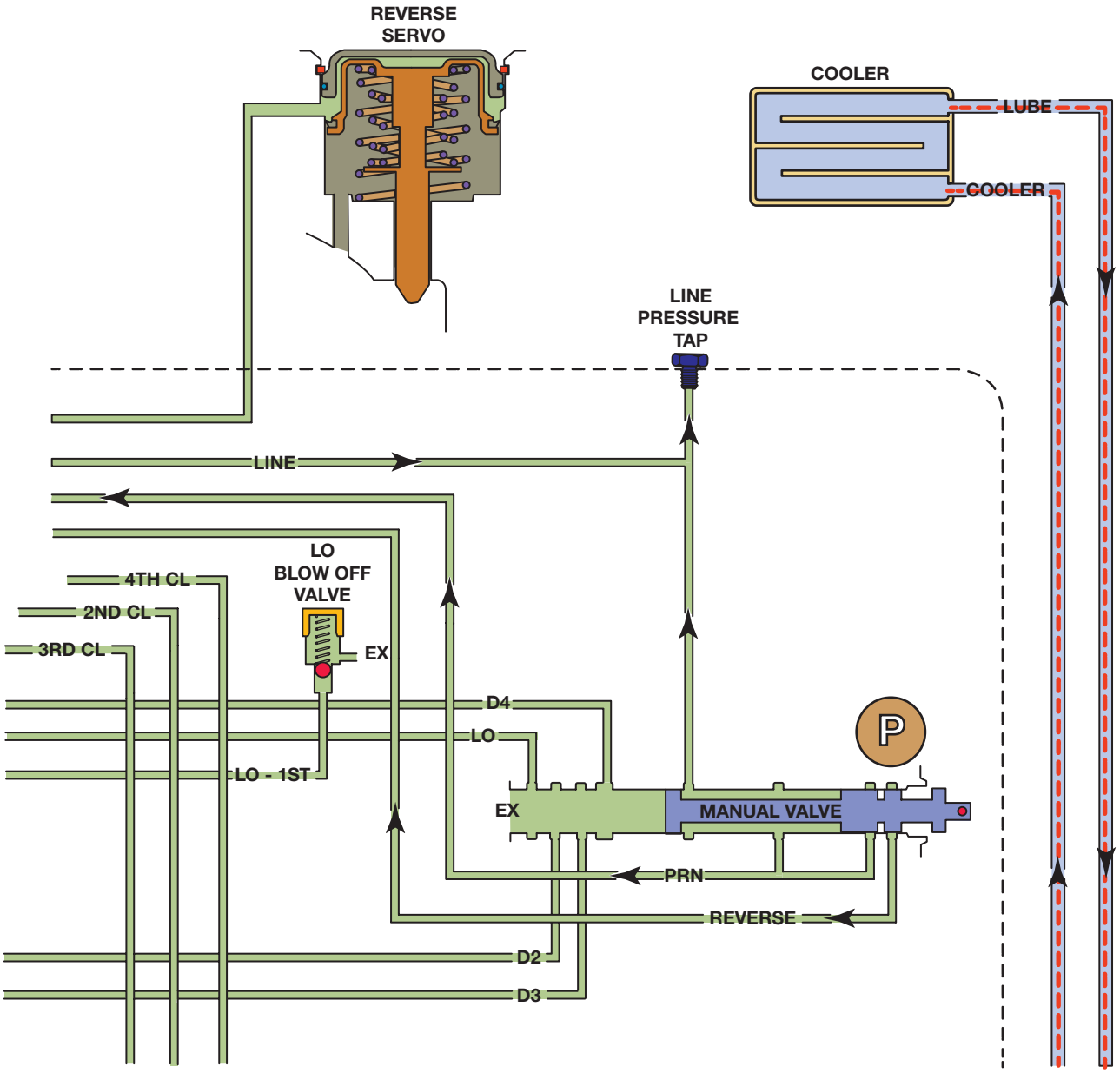


FIGURE 13–24 A portion of a typical hydraulic schematic showing part of the hydraulic system and pressure tap.

Increase the engine speed to 2000 RPM, observe the pressure gauge, and switch the ignition off. If the pressure increases to normal or above as the engine stops, there is a problem in the electronic pressure control (EPC) circuit. Any transmission that develops normal pressure in reverse is sure to have a good pump and pressure control circuit.

Control pressure test results are as follows:

- If normal in any range, the pump and pressure regulator pressure control solenoid and circuit are normal.
- If normal in reverse, the pump and pressure regulator valve or pressure control solenoid and circuit are normal.
- If low in all ranges, there is probably a clogged filter, defective pump, or defective pressure regulator valve, or faulty pressure control solenoid or circuit.
- If low in any gear range, there is a problem in that circuit, probably defective seals or sealing rings.

Clutch and band apply pressures are checked by moving the gear selector to the different gear ranges. For example, normal pressure in every range except drive-3 and reverse indicates leakage in the clutch that is applied for the drive-3 and reverse circuits. This pressure loss can cause slippage in high and reverse.

INDIVIDUAL CIRCUIT TEST PORTS When a transmission has test ports for individual apply circuits as well as line pressure, the condition of that circuit can be easily determined by comparing its pressure with line pressure. For example, if line pressure is 75 PSI (520 kPa) and third-gear pressure is also 75 PSI, then the third-gear circuit, and all of the piston seals and sealing rings are in good condition. If any circuit is more than 10 PSI (70 kPa) lower than line pressure, there is a sealing problem in that gear circuit that must be corrected.

FLUID FLOW DIAGRAMS Manufacturers provide hydraulic schematics/fluid diagrams of the fluid passages and valves. ● **SEE FIGURE 13–24.**

They are used to locate the cause of a problem such as low fluid pressure or no upshift. The diagrams are used to trace the fluid flow through a circuit in the same way that you would use a street map to locate the roads between two points. The symbols (such as for check valves or exhaust ports) vary between manufacturers. ● **SEE FIGURE 13–25.**

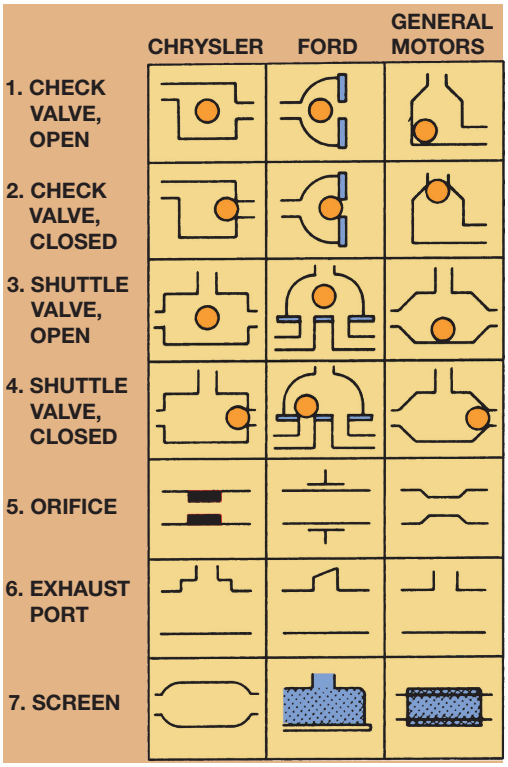


FIGURE 13–25 Hydraulic symbols used by domestic vehicle manufacturers.

SUMMARY

1. The diagnostic process includes the following steps:
   - **STEP 1** The first step is to verify the customer complaint. This step usually includes test driving the vehicle to see if the complaint can be duplicated. If the problem cannot be duplicated, then the repair cannot be verified.
   - **STEP 2** Check the fluid level and condition.
   - **STEP 3** Check for stored diagnostic trouble codes (DTCs).
   - **STEP 4** Check for any related technical service bulletins (TSBs).
   - **STEP 5** Check scan tool data including the adaptive values.
   - **STEP 6** Perform visual inspections.
   - **STEP 7** Locate the root cause of the problem.
   - **STEP 8** Replace all components that do not meet factory specifications and clear all codes and reset all adaptive factors.
   - **STEP 9** Test drive the vehicle to verify that the repairs corrected the customer concern.
2. A road test is used to verify the customer's concern and check the general overall condition of the transmission.
3. To check transmission fluid with a dipstick, check the procedure stamped on the dipstick.

REVIEW QUESTIONS

1. What is the diagnostic procedure that most vehicle manufactures suggest be followed when diagnosing an automatic transmission/transaxle customer concern?
2. How is the automatic transmission fluid level checked on an automatic transmission/transaxle that does not have a dipstick?
3. What is the difference between a factory scan tool and an aftermarket scan tool?
4. What does a high CVI indicate on a scan tool display?
5. How are pressure gauges attached to an automatic transmission/transaxle?

CHAPTER QUIZ

1. Why should the transmission control system be checked for diagnostic trouble codes (DTCs) before checking for technical service bulletins (TSBs)?
   a. Some TSBs refer to stored DTCs
   b. If there are no DTCs then there will not be any TSBs
   c. The two are not related so it does not matter in which order they are checked
   d. TSBs refer to fluid level checking only
2. Why does the customer concern need to be verified?
   a. To make sure that there is a real concern
   b. To be able to verify the repair
   c. To determine under what conditions the fault is noticed or occurs
   d. All of the above
3. An "end bump" is best described as _____.
   a. The operation occurs before normally expected
   b. A shift feel that becomes noticeably firmer as it is completed
   c. A repeated up-and-then-down shifting sequence that produces noticeable repeated engine RPM changes
   d. The shift occurs sometime after normally expected
4. An automatic transmission or transaxle that is underfilled may experience which symptom?
   a. Mushy operation
   b. Goes into neutral
   c. Slipping
   d. Any or all of the above
5. What is needed to properly check the ATF level on an automatic transmission or transaxle NOT equipped with a dipstick?
   a. A special tool
   b. A scan tool to determine ATF temperature
   c. A scan tool to check the fluid level sensor reading
   d. A high-pressure gauge
6. If the ATF is pink, this usually means that _____.
   a. It is a synthetic ATF
   b. The fluid has been aerated (filled with air)
   c. Indicates a coolant leak at the heat exchanger in the radiator
   d. The fluid has been oxidized
7. A high CVI reading on a scan tool usually indicates _____.
   a. A worn clutch pack
   b. A defective one-way clutch
   c. Low ATF level
   d. Incorrect gear ratio detected
8. A factory or factory-level scan tool can _____.
   a. Read DTCs
   b. Read TSBs
   c. Command shifts
   d. Both a and c
9. During oil pan debris check, what is considered to be normal?
   a. Loose, black material
   b. Heavy golden brown coating
   c. A small amount of debris with a dark brown oil film
   d. Plastic debris
10. If no specifications are available, the approximate pressures in most transmissions will be _____.
    a. Neutral, park, and, drive at idle: 50 to 60 PSI (350 to 400 kPa)
    b. Neutral, park, and, drive at idle: 100 to 120 PSI (690 to 827 kPa)
    c. Neutral, park, and, drive at idle: 120 to 160 PSI (827 to 1,100 kPa)
    d. Neutral, park, and, drive at idle: 160 to 200 PSI (1,100 to 1,380 kPa)

chapter 14

IN-VEHICLE TRANSMISSION/ TRANSAXLE SERVICE

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "B" (In-Vehicle Transmission and Transaxle Service).
2. Discuss fluid replacement.
3. Describe the procedure to follow when replacing seals.
4. Perform linkage adjustments in automatic transmissions.
5. Describe the correct procedure for replacing powertrain mounts and performing band adjustments.

KEY TERMS

Fluid flushing 209
Fluid change 207
Fluid exchange 209
Stop-off tool 211

TECH TIP

Test Drive Before and After Every Service

The wise technician test drives any vehicle being serviced, especially one where a routine automatic transmission service is being requested. Sometimes, a vehicle owner will ask that a service be performed hoping that it will fix an issue that has been noticed. To help avoid misunderstandings and to insure good customer relations, test drive the vehicle and let the customer know if any transmission-related issues are discovered before performing a routine transmission service. Then, of course, test drive the vehicle after the service has been performed to verify that everything is normal and operating properly.

IN-VEHICLE SERVICE ITEMS

OVERVIEW Automatic transmissions and transaxles can operate properly for many miles. Some that fail could have had a longer service life had they been properly maintained. Several surveys of transmission shops have shown that over 80% of transmission failures were the result of neglecting to change the fluid. Maintaining the correct fluid level and changing the fluid are primary maintenance tasks.

FLUID CHANGES

RECOMMENDED INTERVAL Most manufacturers recommend fluid changes every 100,000 miles (160,000 km) under normal driving conditions. Some recommend a **fluid change** at 50,000 miles (80,000 km). Fluid change recommendations are usually accompanied with a recommendation that the change interval be shortened to as low as 15,000 miles (24,000 km) when the vehicle is used under severe driving conditions. Such severe driving conditions include the following:

- Frequent trailer pulling
- Heavy city traffic, especially in areas where the temperature exceeds 90°F (32°C)
- Very hilly or mountainous conditions
- Commercial use such as taxi or delivery service
- Police or ambulance usage

FLUID LIFE (MILES/KM)	TEMPERATURE (F/C)
100,000/160,000	175°/80°
50,000/80,000	195°/90°
25,000/40,000	215°/100°
12,550/20,000	235°/113°
6,250/10,000	255°/124°
3,125/5,000	275°/135°
1,560/2,500	295°/146°
780/1,250	315°/157°

CHART 14–1

The higher the ATF temperature, the shorter the life expectancy of the fluid.

The fluid should be changed when it starts to break down, which is best indicated by the fluid appearance and smell. It is wise to change the fluid early, before transmission damage occurs. Dirty fluid may cause the shift valves and solenoids to start sticking, which in turn can cause sluggish shifts and slippage and thus more fluid heat, breakdown, contamination, and damage.

ATF TEMPERATURE AND LIFE EXPECTANCY The main factor that determines transmission fluid life is heat or how hot the fluid is during vehicle operation. If the fluid temperature is kept below 175°F (79°C), the fluid should easily last 100,000 miles. At higher temperatures the fluid oxidizes, causing it to break down at a rate one-half its expected life for every increase of 20°F (11°C).

- Varnish begins forming at temperatures above 240°F (116°C).
- Rubber seals start hardening at temperatures above 260°F (127°C).

See transmission fluid life relative to temperature in **CHART 14–1.**

OLD FLUID CHANGE ISSUES If the old transmission fluid is extremely dirty, be aware that when the fluid is changed, the new ATF contains a fresh supply of detergents and dispersants that could result in the following:

- Loosen varnish and other deposits that have accumulated inside the transmission
- Carry this material throughout the transmission, including valves and solenoids

FIGURE 14–1 Draining the fluid from an automatic transaxle by allowing the fluid to flow into a container after most of the retaining bolts have been removed.

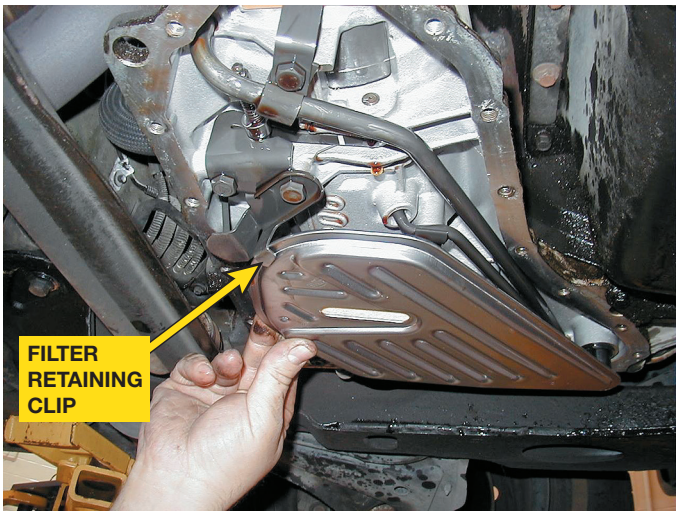


FIGURE 14–2 Always check that the filter is secured by a clip or other fastener to keep it from dropping out of its position.

- Possibly remove varnish that has formed over worn seals and open up a leak.
- The supply of new friction modifier will increase the "slippery" level of the fluid, which might increase slipping on upshifts.

SAFETY ISSUES The safety data sheets (SDS) for most transmission fluids indicate that there are a few safety hazards when working with new fluid. Some indicate a possible skin reaction. Used fluid, however, goes through an unknown change inside the transmission that might cause it to be more of a hazard. Experts usually recommend the following precautions:

- Wear goggles or a face shield.
- Wear gloves or barrier cream for skin protection.
- Clean any skin contact with ATF using soap and water.
- Change clothing that has contacted ATF.
- Wash any clothing that has contact with ATF.
- If ATF under pressure breaks the skin, medical attention should be sought.

FLUID CHANGING, DROPPING THE PAN

PROCEDURE The procedure for changing the fluid in a specific vehicle can be found in service information. To be specific, the procedure usually includes the following steps:

STEP 1 Safely hoist the vehicle.

STEP 2 Select the best direction for fluid to spill from the pan. Place a large drain pan in this area, and remove all but two of the pan bolts. The remaining two bolts should be at the end away from the drain pan and they serve as the "hinge" for lowering the pan. ● **SEE FIGURE 14–1.**

STEP 3 When the pan lowers to an angle of about 30° to 45°, support it by hand, then remove the remaining two bolts and finish draining the pan.

STEP 4 Remove the filter, which is usually attached to the valve body. Watch for any small parts that may come loose with the filter. Set aside the old filter for comparison with the new filter.

STEP 5 Inspect the pan, filter, and pan magnet for debris and varnish buildup. The magnet in most automatic transmission pans is used to collect steel particles to keep them from getting circulated throughout the transmission/transaxle. A few metal particles are considered normal. These result from wear and transmission break-ins. Inspect the inside of the transmission for any visible damage or varnish buildup.

STEP 6 Install a new filter using a new gasket or O-ring, and tighten the mounting bolts to the correct torque, if equipped. If an O-ring is used, it should be lubricated with transmission assembly lube, petroleum jelly, or automatic transmission fluid (ATF) before installation. ● **SEE FIGURE 14–2.**

STEP 7 Clean the oil pan and check and straighten if needed any bends at the pan bolt holes.

FIGURE 14–3 In this case, the cork-rubber gasket is glued to the pan and is ready to be installed. The retaining bolts need to be tightened in sequence, but be aware that over-tightening will cause a leak. Also, some manufacturers recommend using only an RTV sealer, but never use an RTV sealer and a gasket together.

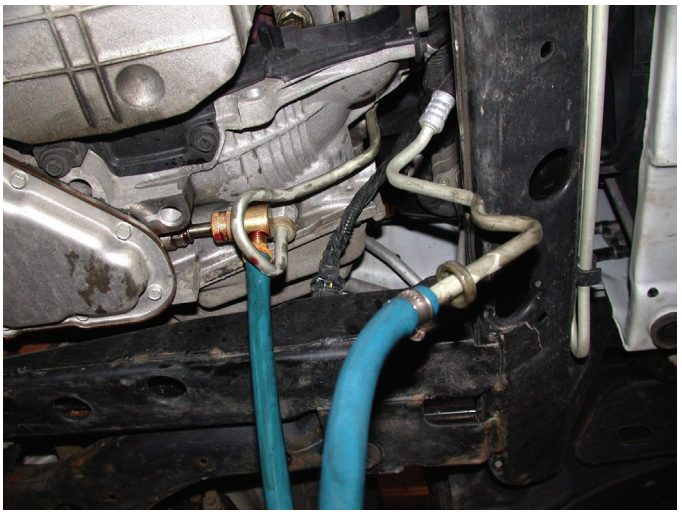


FIGURE 14–4 The lines from the fluid exchange machine can often be connected to the cooling lines from underneath the vehicle as on this front-wheel-drive General Motors vehicle.

STEP 8 Install a new gasket on the pan, and install the pan on the transmission. ● **SEE FIGURE 14–3.**

STEP 9 The bolts should be tightened in a back-and-forth, across-the-pan sequence to the specified torque.

STEP 10 Lower the vehicle, and add the proper amount of fluid. A rule of thumb is 4 quarts. Start the engine and check the fluid level. Add additional fluid to correct the level if necessary.

STEP 11 Dispose of the old transmission fluid according to Federal, State, and local laws and regulations.

NOTE: This procedure only changes the fluid in the pan, which is about one-quarter to one-third (1/4 to 1/3) of the total fluid capacity still in the transmission. The remaining fluid stays in the torque converter, clutches and band servos, accumulators, cooler, and fluid passages.

Case Study

TSB to the Rescue

A Dodge Durango came in to the shop with a customer complaint of delayed engagement into reverse after sitting for a while. A check of a TSB (21-016-05) described filters with defective check valves. Replacement of the filter cured this problem.

SUMMARY:

Complaint—Customer complained of a delayed engagement into reverse after the vehicle sat for a while.

Cause—The original filter had a defective check valve.

Correction—A replacement filter fixed the concern.

FLUID EXCHANGE AND FLUSH UNITS

TERMINOLOGY **Fluid flushing** typically uses a chemical to dissolve varnish and other deposits. **Fluid exchange** usually means taking out the old fluid and replacing it with new fluid of the correct type. By using a fluid exchange machine, all of the fluid in the system is replaced.

If the flush is needed to remove solid debris, there must be enough flow velocity to break the material loose and carry it out of the component. More efficient flush machines will pulsate the flow to increase the cleaning power. In severe cases, such as a plugged cooler, the flush can be set up to pump the solvent into the cooler outlet and remove it from the inlet.

TYPICAL PROCEDURE Fluid exchange machines are usually connected into the transmission cooler lines so that the machine can pump new fluid to the return line as it captures the fluid leaving the transmission. ● **SEE FIGURE 14–4.**

Case Study

The Case of the Bent Pan

A Nissan minivan van (147,000 mi) would go into neutral under varying conditions. During a test drive it operated normally in all gears until accelerating from a stop but then it went to neutral and after a short period of time, back into gear. The fluid appeared and smelled normal. The transmission electrical connections were checked, and these were clean and tight. The pan was checked—it was bent upward, apparently blocking flow to the filter. The pan was removed, bent back to the proper shape, and was reinstalled. This repair fixed the problem.

SUMMARY:

Complaint—Customer complained that the transaxle would go into neutral when accelerating.

Cause—The pan was bent upward apparently blocking fluid flow to the filter.

Correction—The pan was straighten which corrected the customer concern.

Running the engine will pump the old fluid out of the transmission, and a pump in the fluid exchange machine will pump new fluid into the return line. When new, clean fluid starts leaving the transmission, the fluid exchange is complete.

Always follow the manufacturer's instructions when using a fluid exchanger, which usually includes the following steps:

STEP 1 Identify which cooler line is the return line.

STEP 2 Disconnect the return line from the cooler, and connect the line to the NEW FLUID connector of the machine. Connect the USED FLUID connector of the machine to the cooler.

STEP 3 Apply the parking brake and shift the transmission into park. Start the engine and observe the fluid flow in the machine. To prevent starving the transmission of fluid, new fluid should enter the machine at the same rate that used fluid leaves.

STEP 4 When the used fluid has the same appearance as new fluid, stop the engine.

STEP 5 Disconnect fluid connections to the machine, and reconnect the cooler return line.

STEP 6 Start the engine and check the line connection for leaks.

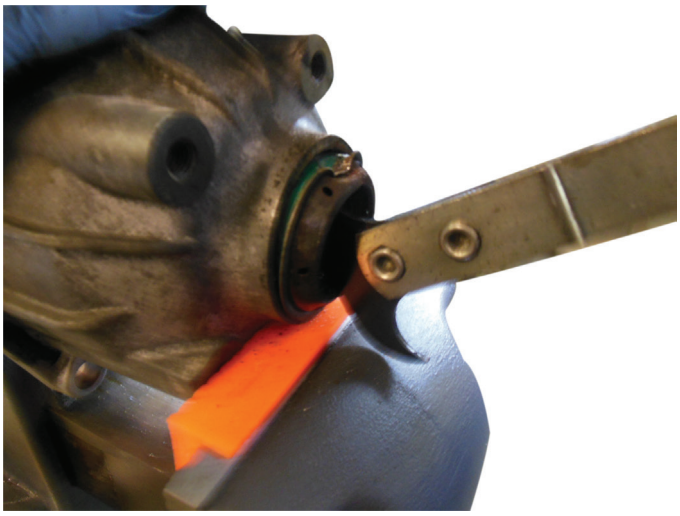


FIGURE 14–5 This seal is being removed using a seal puller.

STEP 7 Check the transmission fluid level and adjust as necessary.

STEP 8 Dispose of the used transmission fluid in an approved manner.

SEAL REPLACEMENT

TWO SEALING SURFACES

A standard metal-backed lip seal must seal against two different surfaces:

1. A dynamic seal with the movable shaft at the inner bore.
2. A static seal where it fits into its bore. The static seal is made when the slightly oversize seal backing is driven into the bore.

GENERAL REPLACEMENT PROCEDURE

A chisel, slide hammer, or seal puller can be used to remove a seal after the shaft has been removed. **SEE FIGURE 14–5.**

Be careful when installing the seal over a shaft or a shaft into a seal. The sharp lip of the seal is easily cut or torn.

- When installing a seal over a shaft, it is good practice to protect the sealing lip with a seal protector, especially if there are any rough or sharp edges on the shaft. A piece of slick paper wrapped around the shaft will work as a seal protector in many cases.
- The lip of the seal should always be lubricated to prevent wear. Automatic transmission assembly lube, petroleum jelly, or automatic transmission fluid (ATF) can be used for a lubricant.

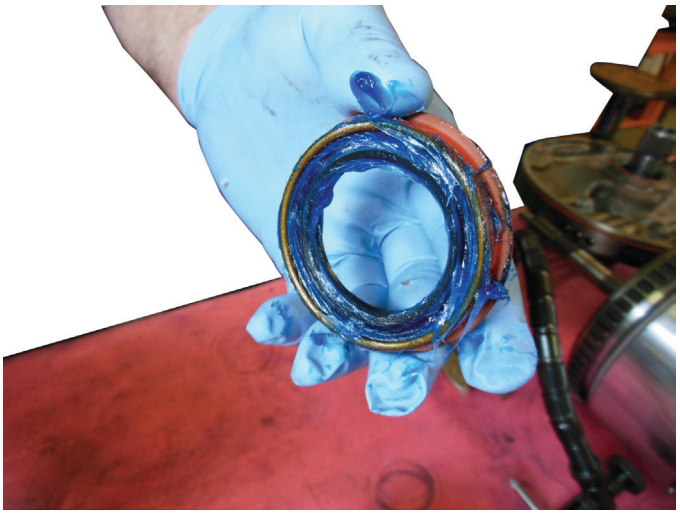


FIGURE 14–6 The lip of the seal around the garter spring is packed with assembly lube to help keep the spring from falling out when it is driven into the transmission housing.

- Some seals include a garter spring to increase sealing lip pressure. This garter spring can be dislodged as the seal is driven into position. Filling the recess with assembly lube or petroleum jelly will keep the garter spring in place during installation. **SEE FIGURE 14–6.**

EXTENSION HOUSING SEAL To remove and replace a transmission extension housing seal, perform the following steps:

STEP 1 Raise and support the vehicle on a hoist that allows access to the transmission and driveshaft.

STEP 2 Place alignment marks on the rear universal joint and rear-axle pinion flange.

STEP 3 Disconnect the driveshaft from the rear axle. ATF will begin leaking out of the driveshaft opening. You should either raise the rear of the vehicle enough to stop the flow or place a container to catch the flow. A **stop-off tool** or old U-joint slip yoke can be used to stop the fluid leak. **SEE FIGURE 14–7.**

STEP 4 Pull or pry out the rear seal using a suitable tool.

STEP 5 If necessary, remove the rear bushing using a suitable tool.

STEP 6 If the bushing is removed, use a suitable tool to drive the new bushing completely into place.

STEP 7 Use a correctly sized driver to drive the new seal into place. If the replacement seal does not have an outer sealant coating, a film of sealant should be spread around the outer surface of the seal case.

FIGURE 14–7 Using a plug helps prevent fluid loss when the driveshaft is removed.

MANUAL LINKAGE CHECKS

NEED TO CHECK ADJUSTMENT The manual linkage is adjustable on most automatic transmissions. This ensures the manual valve is positioned correctly relative to the gear selector.

Detents are internal to the transmission and keep the manual valve aligned with the selected position. Because the detents act on the internal linkage, they normally stay correctly aligned with the valve position.

CHECKING MANUAL LINKAGE ADJUSTMENT To check manual linkage adjustment, the specified procedure usually includes the following steps:

STEP 1 Firmly set the parking brake and leave the engine off.

STEP 2 Move the selector level through the ranges, and observe the range pointer and the position of the internal detents. The detents engage as the pointer aligns with the gate for each gear position indicator.

STEP 3 Move the selector lever to park, and the parking pawl should freely engage to lock the transmission.

STEP 4 Check that the starter operates in park and neutral but not in other gear positions.

Always check service information for the proper procedure. **SEE FIGURE 14–8.**

MAKING A MANUAL LINKAGE ADJUSTMENT The manual linkage should be adjusted if the starter engagements

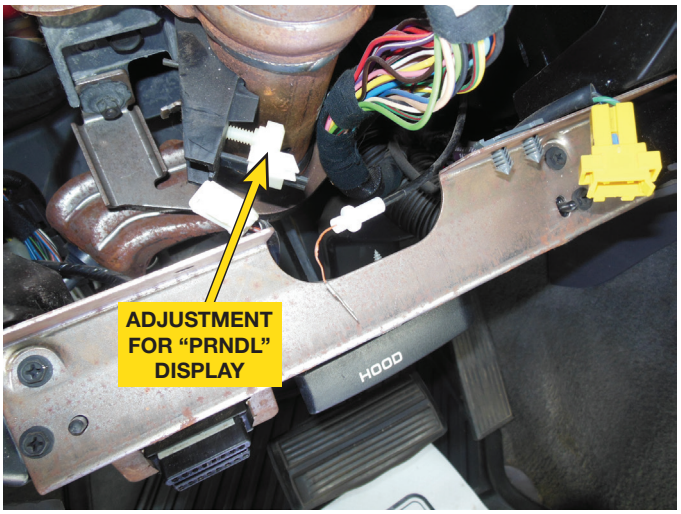


FIGURE 14–8 The position for the pointer ("PRNDL" display) on this Dodge truck is adjustable.

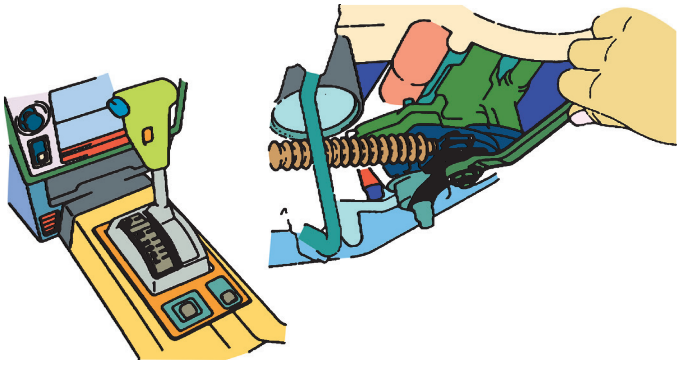


FIGURE 14–9 The manual shift lever is in park. The linkage is being tightened to lock the adjustment in after making sure that the transmission is in park.

occur in the wrong position or the transmission detents do not align correctly relative to the gear range pointer. The procedure will vary with vehicle makes and models. Check service information for the exact procedure for a particular vehicle. ● **SEE FIGURE 14–9.**

SHIFT INTERLOCK MECHANISM The shift interlock mechanism locks the shifter in park position when the ignition key is removed. On most vehicles, the brake pedal must be depressed before the shifter can be moved, and the ignition key cannot be removed unless the lever has been shifted into park. These systems operate either electrically or through a mechanical linkage. The mechanical systems usually have an adjustment to ensure proper positioning. These systems vary, so service information for that particular vehicle should be consulted when diagnosing problems or checking adjustments.

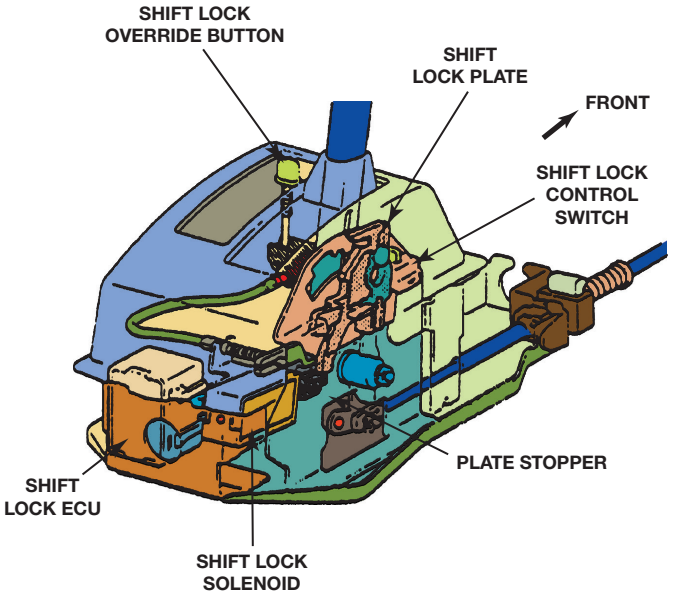


FIGURE 14–10 This shift lock mechanism includes a solenoid that can mechanically hold the shift lock plate. Note the shift lock override button that can be used to release the shift lock.

A shift interlock can get out of adjustment or fail to release. Vehicle manufacturers have incorporated a fail-safe mechanism so the vehicle can be operated. Located near the shift lever is a small lever or button that can be used to override the shift lock and release the lever. The release is often located under a cover that must be removed for access. This procedure is normally described in the vehicle owner's manual. ● **SEE FIGURE 14–10.**

POWERTRAIN MOUNTS

REPLACING MOUNTS Powertrain mounts often require replacement due to damage or wear. Defective powertrain (engine and transmission) mounts are replaced by lifting the engine and/or transmission slightly to remove the weight, and then removing the mounting bolts. The old mount is then removed and the new mount is installed.

The mount for a rear-wheel-drive (RWD) transmission is aligned by the bolts through slotted holes in the mount. Alignment is required so the engine, transmission, and exhaust system do not contact the frame or body. A front-wheel-drive (FWD) transaxle must be aligned to the two front driveshafts. The alignment check is accomplished by completely compressing both inboard CV joints, and measuring the distance between the joint and the transaxle. The position of the transaxle is then adjusted so that both distances are equal. Adjustment is

accomplished by loosening the mounts and sliding the engine and transaxle sideways. ● **SEE FIGURE 14–11.**

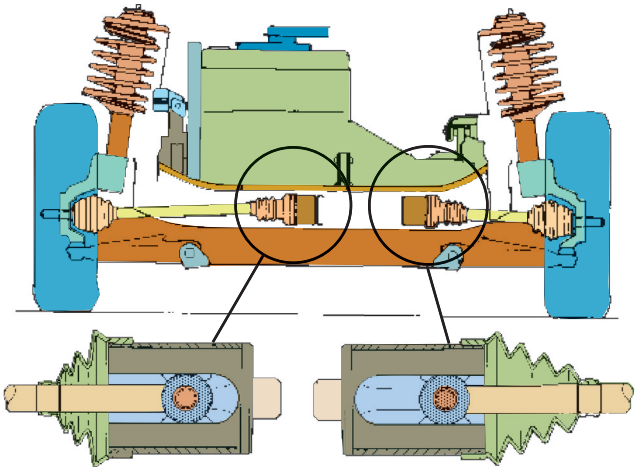


FIGURE 14–11 The enlarged views of the inner CV joints show that the engine and transaxle are misaligned; they should be moved toward the right.

BAND ADJUSTMENTS

The band in many transmissions is used only in manual ranges for engine compression braking and is expected to last the life of the transmission. Most recent transmissions have no provision for in-vehicle adjustments.

- Some older transmissions have threaded adjusters extending through the case to allow an easy readjustment of the band.

Case Study

The Case of the Chrysler Pacifica

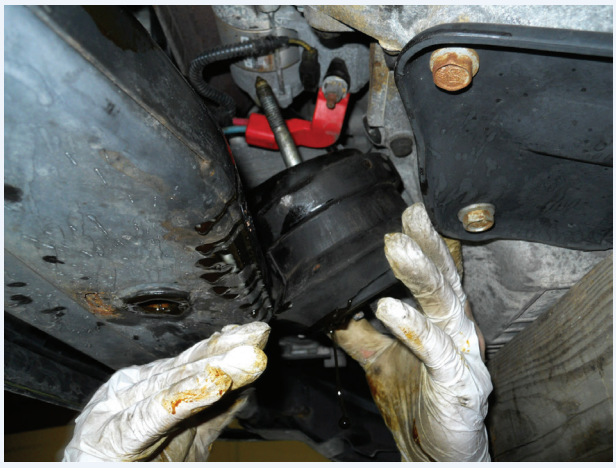
The owner of a Chrysler Pacifica complained of a transmission concern that seemed to occur only when accelerating rapidly. The vehicle would shake and a loud knock sound was heard when decelerating, but everything seemed to be normal if the vehicle was accelerated slowly. Everything seemed to be fine when driven in reverse. The technician was able to confirm the situation and felt that an engine mount had failed. A visual inspection confirmed that the mount was torn. Replacing the mount solved the "transmission" problem. ● **SEE FIGURE 14–12.**

SUMMARY:

Complaint—Owner complained that the vehicle would shake during rapid acceleration and a loud knock sound was heard during deceleration.

Cause—The engine mount was found to be defective due to leaking mount fluid.

Correction—The engine mount was replaced and this corrected the customer concern.



(a)

(b)

FIGURE 14–12 (a) The old front engine mount contained hydraulic fluid. The oil was leaking from the split in the mount. (b) The new original equipment (OE) mount ready to be installed.

- Some band adjustments are made inside the transmission and it is necessary to drop the pan to gain access to the adjuster.

ADJUSTMENT PROCEDURE Service information should be checked to determine the exact adjustment procedure for each particular vehicle.

To readjust a band, the usual procedure includes the following steps:

STEP 1 Loosen the lock nut on the adjuster screw several turns. ● **SEE FIGURE 14–13.**

STEP 2 Tighten the adjuster screw to the specified torque. Special adjuster wrenches with preset torque settings are available for this operation.

STEP 3 Mark the adjusting screw position, and then back it off the specified number of turns. Hold the adjuster screw stationary and retighten the lock nut to the specified torque.

STEP 4 Road test the vehicle to check the adjustment.

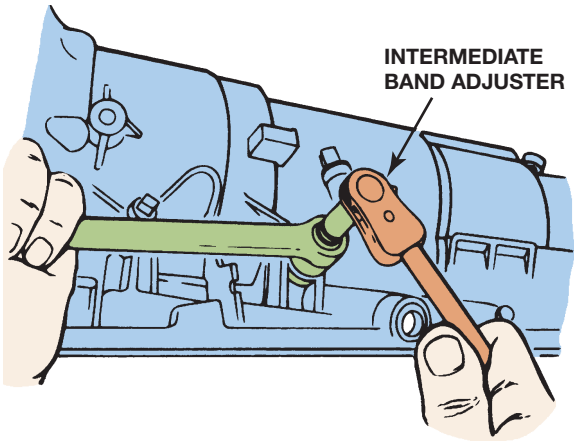


FIGURE 14–13 Adjusting the intermediate band on a Ford A4LD transmission.

1 The owner of this Dodge pickup complained that automatic transmission fluid was leaking from the pan gasket.

2 The transmission fluid leak is found to be from small holes that had rusted through the steel pan.

3 The retaining bolts being removed from the pan.

4 The retaining bolts on one side are kept attached and then loosened to allow fluid to drain from one side of the pan.

5 The pan is then gently lowered and the ATF is caught dripping from the valve body.

6 The pan is then emptied into an oil drain unit.

CONTINUED ▶

STEP BY STEP

7 The old filter is removed.

8 The shop purchased a new original equipment filter and a new, improved transmission pan gasket.

9 The new filter is installed.

10 The replacement pan is installed and the fasteners tightened to factory specifications. The new pan is galvanized steel compared to painted steel on the original.

11 The specified ATF is installed.

12 The level is checked with the engine running and the gear selector in neutral as per the instructions on the dipstick.

SUMMARY

1. Maintaining the correct fluid level and changing the fluid are primary maintenance tasks.
2. Most manufacturers recommend fluid changes every 100,000 miles (160,000 km) under normal driving conditions.
3. Fluid flushing typically uses a chemical to dissolve varnish and other deposits. Fluid exchange usually means taking out the old fluid and replacing it with new fluid of the correct type.
4. The safety data sheets (SDS) for most transmission fluids indicate that there are a few safety hazards when working with new fluid. Some indicate a possible skin reaction. Used fluid, however, goes through an unknown change inside the transmission that might cause more hazards.
5. A chisel, slide hammer, or seal puller can be used to remove a seal after the shaft has been removed.
6. The manual linkage should be adjusted if the starter engagement occurs in the wrong position or the transmission detents do not align correctly relative to the gear range pointer.
7. Defective powertrain (engine and transmission) mounts are replaced by lifting the engine and/or transmission slightly to remove the weight, and then removing the mounting bolts. The old mount is then removed and the new mount is installed.

REVIEW QUESTIONS

1. What are severe driving conditions that may require the automatic transmission fluid to be changed more often than when driven under normal conditions?
2. What issues may be the result of replacing fluid in a vehicle that has not had the specified fluid changes?
3. What is the difference between a fluid flush and a fluid exchange?
4. What is the general seal replacement procedure?
5. What are the typical steps involved with a band adjustment?

CHAPTER QUIZ

1. Most manufacturers recommend fluid changes every _____.
   a. 10,000 miles (16,000 km)
   b. 25,000 miles (40,000 km)
   c. 50,000 miles (80,000 km)
   d. 100,000 miles (160,000 km)
2. Severe service includes _____.
   a. Extensive highway driving
   b. Commercial use, such as police or taxi use
   c. A combination of city and highway driving
   d. Driving in temperatures below freezing
3. The life of ATF is reduced if the temperature of the fluid is above _____.
   a. 32°F (0°C)
   b. 100°F (38°C)
   c. 175°F (80°C)
   d. None of the above
4. The material safety data sheets (MSDS) (SDS) for most transmission fluids indicate which safety hazards when working with new fluid?
   a. Possible skin reaction
   b. Possible skin cancer
   c. Possible exposure to HIV
   d. Possible swelling of spots exposed to the fluid
5. When being exposed to ATF, what should a technician do?
   a. Wear goggles or a face shield
   b. Wear gloves or barrier cream for skin protection
   c. Clean any skin contact with ATF using soap and water
   d. All of the above
6. Fluid flushing typically _____.
   a. Uses a chemical to dissolve varnish and other deposits
   b. Another name for fluid exchange
   c. Pulsates the flow to increase the cleaning power
   d. Both a and c
7. Why is there a magnet in the bottom of many automatic transmission pans?
   a. To keep the pan in place as it is being installed
   b. To attract any steel particles and keep them from flowing through the transmission
   c. Used in assembly only
   d. Any of the above depending on make and model
8. A lip seal requires what type of tool to remove?
   a. A chisel or slide hammer and/or a seal puller
   b. A plastic trim removing tool
   c. A large ball peen hammer
   d. A clutch installation tool

9. What is the purpose of the shifter interlock system?
- **a.** Keeps the transmission from being forced into reverse when the vehicle is moving forward
- **b.** Allows for the selection of all forward gears and reverse when the vehicle is stopped
- **c.** Prevents the shifter from being moved into drive or reverse unless the brake pedal has been depressed
- **d.** Prevents the vehicle from rolling backwards on a hill if in the drive position

10. Which statement(s) is/are true about band adjustments?
- **a.** The band in many transmissions is used only in manual ranges for engine compression braking and is expected to last the life of the transmission
- **b.** Most recent transmissions have no provision for in-vehicle adjustments
- **c.** Some older transmissions have threaded adjusters extending through the case to allow an easy readjustment of the band
- **d.** All of the above are correct

chapter 15

TRANSMISSION/ TRANSAXLE REMOVAL AND DISASSEMBLY

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "C" (Off-Vehicle Transmission/Transaxle Repair).
2. Describe automatic transmission repair options.
3. Describe the automatic transmission/transaxle inspection process.
4. List the steps needed to be followed to remove an automatic transmission/transaxle.
5. Explain the procedure for disassembling a transmission/transaxle.

KEY TERMS

Aftermarket 223
Hard parts 223
Overhaul 220
Rebuild 220
Remanufactured transmission/ transaxle 220
Retaining bracket 222
Selective 226
Soft parts 223

REPAIR OPTIONS

REPAIR A repair is an operation that replaces faulty parts and performs the needed labor to correct a transmission fault. Most transmission shops are equipped to perform all repairs needed to the vehicle's transmission. Repairing the original transmission ensures that the transmission will be the proper one for the vehicle.

REPLACEMENT A replacement is the removal and installation of the automatic transmission/transaxle. The replacement may be new, remanufactured, or a wrecking (recycling) yard unit. For example, many shops install remanufactured transmissions because they are often less expensive than rebuilding or updating the original transmission. A **remanufactured transmission/transaxle** is a unit that has been disassembled, cleaned, inspected, and reassembled using new or like-new parts. It will have any necessary modifications and updates required for proper operation of the transmission. These units are commonly used by dealers to repair transmission problems that occur while a vehicle is still under its new-vehicle or extended warranty. Remanufacturing is done on a production line, with many transmissions of the same model being rebuilt at the same time. Many smaller shops will use remanufactured transmissions when the vehicle's unit is so badly damaged that the cost of the parts comes close to or exceeds the cost of a remanufactured unit.

COMPLETE OVERHAUL A complete overhaul includes disassembling the entire transmission/transaxle and replacing all needed parts, gaskets and seals to restore the transmission to perform like a new unit. A defective transmission with considerable mileage, damage, or wear is a candidate for overhaul or replacement. An **overhaul** implies a **rebuild**, which is generally considered to include the following steps:

- Transmission teardown or disassembly
- Replacement of all gaskets and seals
- Replacement of all friction materials
- Replacement of worn bushings
- Replacement of the filter and modulator, if equipped
- Cleaning and inspection of the planetary gears
- Cleaning and inspection of the valve body and all related components
- Cleaning and inspection of the torque converter
- Reassembling with a check of all necessary clearances

Some states have rules and regulations that define what an automatic transmission rebuild or overhaul must include. The California Bureau of Automotive Repair (BAR) states that a rebuilt, remanufactured, reconditioned, or overhauled transmission must include the following steps:

- Cleaning and inspection of all internal and external parts
- Valve body disassembly, cleaning, and inspection
- Front and intermediate bands replaced with new or relined units
- Replacement of the following parts: lined frictions, internal and external seals, rotating metal sealing rings, gaskets, and organic media filters
- All worn or defective parts repaired or replaced with new, rebuilt, or good parts
- Torque converter inspected or replaced with a new or rebuilt unit

NOTE: The California Bureau of Automotive Repair (BAR) regulations require that if a transmission is "exchanged," a descriptive term such as *new, used, rebuilt, remanufactured, reconditioned,* or *overhauled* shall accompany the exchange.

VERIFY THE NEED FOR UNIT REPAIR

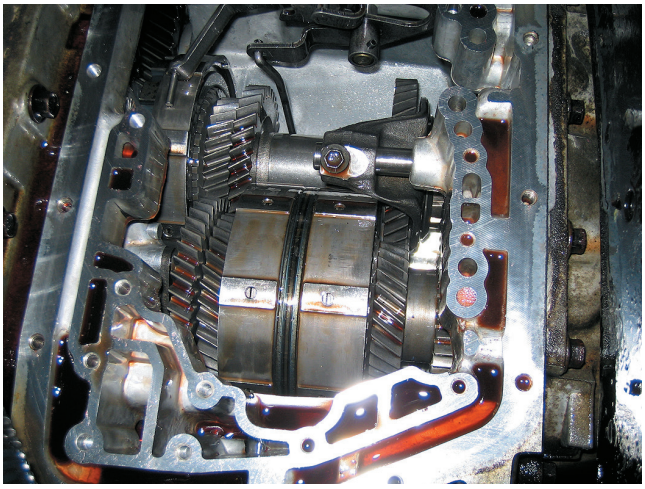
VERIFY THE FAULT It is not unusual for a transmission or transaxle to be removed from the vehicle when the fault could have been repaired with the unit still in the vehicle. The fault could also be due to an electrical or engine-related fault outside the transmission/transaxle. Check with all of the following to be sure that the unit needs to be removed from the vehicle.

- A knowledgeable technician
- The archives at www.iatn.net
- A hotline service provider, such as Identifix (www.identifix.com)

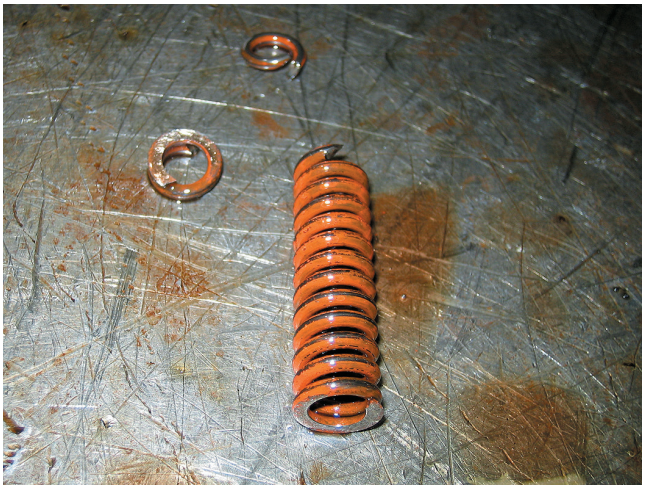
Use these resources to verify that the fault is inside, not outside, the unit.

IN-VEHICLE REPAIRS Not all mechanical faults require that the automatic transmission/transaxle be removed from the vehicle. Faults that can usually be repaired with the unit still in the vehicle include any valve-body-related concerns. **SEE FIGURE 15–1.**

(a)



(b)



(c)

FIGURE 15–1 (a) This Saturn did not shift correctly and one technician was ready to replace the unit. However, another technician thought that the problem could be due to a fault in the valve body. (b) Removing the valve body shows the non-planetary gears used in the Saturn automatic transaxle. (c) The valve body was disassembled and a broken pressure regulator spring was found to be the cause of the customer concern.

Depending on the transmission/transaxle, it may be possible to disassemble and repair many mechanical components of the unit while it remains in the vehicle. Parts and components that may be replaced with the transmission/transaxle still in the vehicle include the following:

- Pressure switches
- Transmission range switch
- Turbine and output speed sensors
- Extension housing gasket
- Drive axle seals
- Valve body replacement

Check service information for details on what can be replaced with the unit in the vehicle.

IDENTIFY THE UNIT Before removing the transmission/transaxle for replacement or repair, be sure that the unit is properly identified. This identification is critical because of the following:

1. The final drive ratio in transaxles can vary depending on the application; and using the wrong unit can cause shifting and other issues such as gear ratio–related diagnostic trouble codes.
2. The internal gear ratios can vary depending on exact application of the unit.
3. Sometimes the vehicle identification number (VIN) is needed to obtain the correct parts, but more often the transmission/transaxle identification number, also called the *tag number*, is the identification needed to be assured of ordering and receiving the proper parts. ● **SEE FIGURE 15–2.**

REMOVING THE AUTOMATIC TRANSMISSION/ TRANSAXLE

STEPS INVOLVED Removing an automatic transmission/transaxle from a vehicle includes many steps to avoid, which would otherwise cause damage to the vehicle or harm the personnel working on it. Always follow the vehicle manufacturer's recommended procedures. Most procedures include the following steps.

STEP 1 Disconnect the negative (–) battery cable from the battery. This prevents the possibility of an accidental

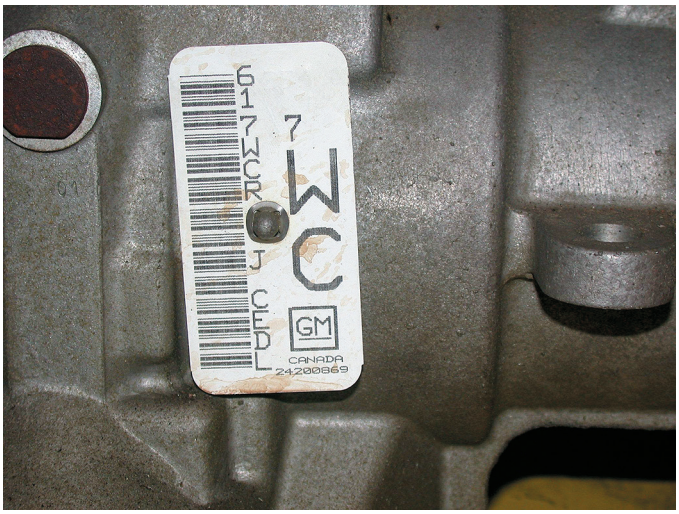


FIGURE 15–2 A transmission identification number on the side of the unit. The information on this tag is needed when ordering parts, as there are often several versions of the same transmission used in similar vehicles and the differences could affect the parts needed.

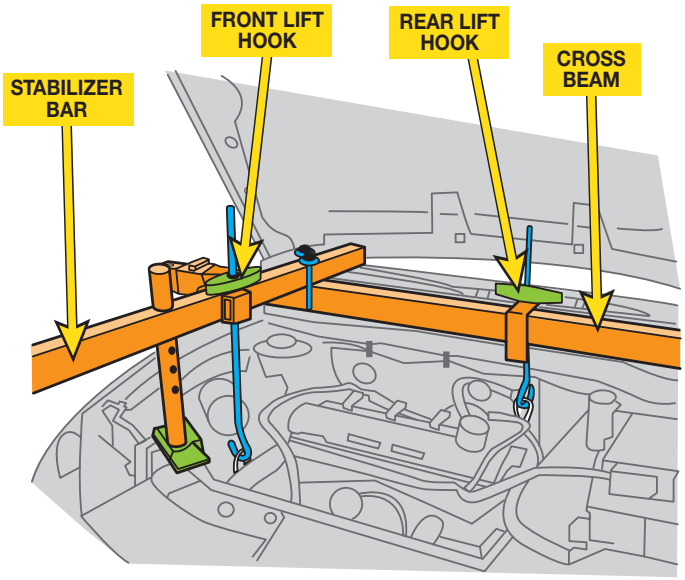


FIGURE 15–3 A holding fixture being used on this front-wheel-drive vehicle to support the engine when the transaxle is removed.

short circuit that could damage the vehicle or cause a spark that could start a fire.

STEP 2 Hoist the vehicle safely and drain the fluid from the unit.

STEP 3 Disconnect the driveshaft or drive axle shafts.

STEP 4 Disconnect all cooler lines, linkage, and electrical connections. Be sure to label each to ensure proper reinstallation.

STEP 5 Disconnect the torque converter from the flex (drive) plate of the engine.

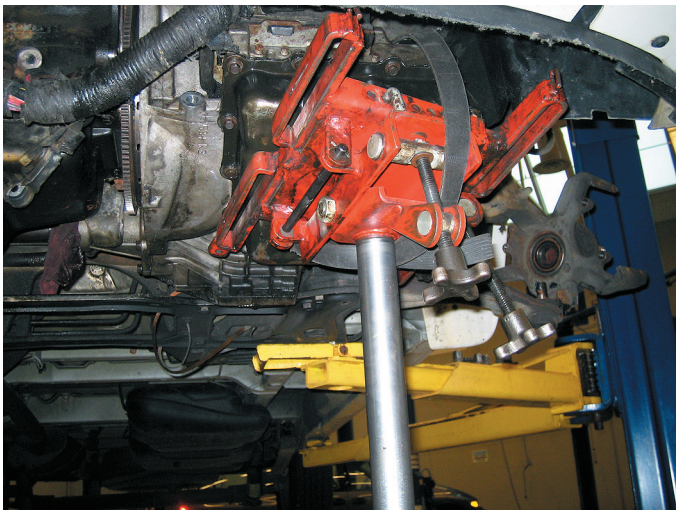


FIGURE 15–4 A transaxle being supported by a transmission jack prior to removal of the unit from underneath the vehicle.

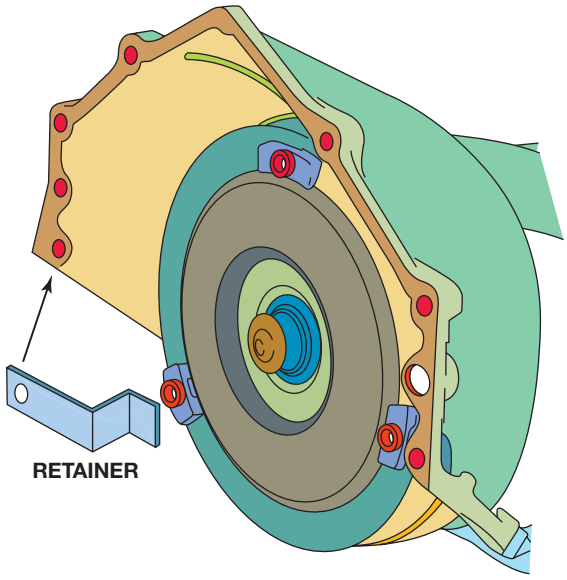


FIGURE 15–5 When the transmission/transaxle is being removed from the vehicle, either remove the torque converter or install a retaining bracket to keep it from falling off the splines.

STEP 6 Support the engine before disconnecting the automatic transmission/transaxle. ● **SEE FIGURE 15–3.**

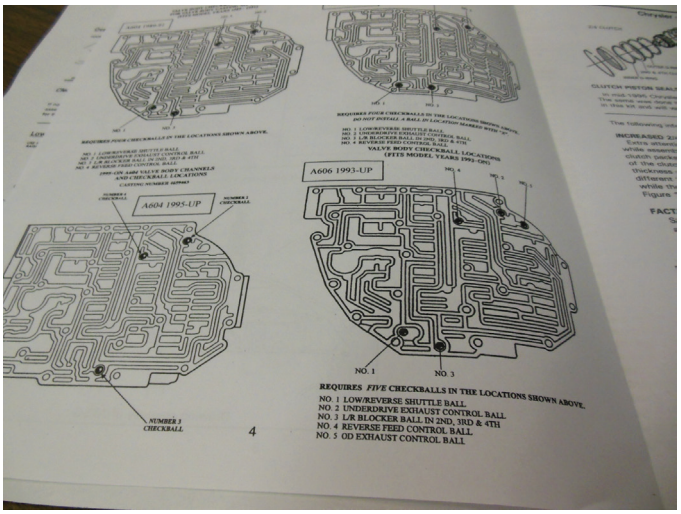
STEP 7 Remove the transmission/transaxle mounting fasteners.

STEP 8 Support the transmission/transaxle on a jack and remove the attaching bolts at the bell housing of the engine. ● **SEE FIGURE 15–4.**

STEP 9 Remove the transmission/transaxle from the vehicle.

CAUTION: There is a possibility that the converter can slide off its splines and fall as the transmission is being removed. It is heavy and can cause injury or damage if it falls. Some manufacturers recommend installing a converter retaining bracket. ● **SEE FIGURE 15–5.**

(a)



(b)

FIGURE 15–6 (a) A Typical automatic transaxle overhaul kit for a Chrysler 41TE. (b) The kit includes instructions and diagrams to help identify the unit being overhauled so that the correct parts are used from the kit.

AUTOMATIC TRANSMISSION PARTS

HARD PARTS Major transmission components, such as pumps, clutch drums, or gear sets are called **hard parts**. New hard parts are generally available only from the manufacturer or an aftermarket supplier of automatic transmission parts. Some aftermarket companies specialize in used or rebuilt hard parts.

SOFT PARTS On the other hand, **soft parts** are those parts that are normally replaced during an overhaul. These include the gaskets, seals, and friction material.

The parts needed to overhaul a transmission are available from various sources. The vehicle manufacturer can supply all parts needed to repair or overhaul a transmission. Soft parts can be purchased from **aftermarket** sources (a supplier other than the vehicle manufacturer). These parts are usually available as individual components or as part of a kit. Kits are available in several forms, and the contents of a kit will vary between suppliers.

KITS A kit is more convenient and often less expensive than buying individual parts. A variety of kits is available to fit the needs of the particular job. Some of the kits available include the following:

- *Banner kit*—an overhaul kit plus the friction clutch plates
- *Bearing kit*—all bearings for the transmission
- *Compliance kit*—includes all parts that must be replaced as required for a rebuilt transmission in particular states
- *Deluxe or super kit*—a master kit plus filter, band(s), bushings, modulator (if used), and bonded pistons as required for the transmission
- *Filter kit*—the filter and pan gasket
- *Master kit*—an overhaul kit plus the friction and steel clutch plates
- *Overhaul kit*—all gaskets, O-rings, metal-clad seals, and lip seals
- *Sealing ring kit*—all seals made from Teflon, metal, or other materials
- *Solenoid kit*—shift, PWM, and force motor solenoids, which may include the wiring harness
- *Valve body kit*—additional parts needed for replacing worn valve body parts, including check balls, filters, springs, valves, and other needed parts **SEE FIGURE 15–6.**

TRANSMISSION/ TRANSAXLE DISASSEMBLY

PREDISASSEMBLY CLEANUP Cleanliness is a must during a transmission overhaul. Many shops steam clean or pressure wash the outside of the transmission as soon as it is removed from the vehicle. Pre-cleaning removes all exterior dirt and other debris and helps keep the work area clean. An alternate cleanup method is to use solvent or an engine degreaser with a parts-cleaning brush and scraper. Always

FIGURE 15–7 A power washer being used to remove the road grime from the unit before it is disassembled.

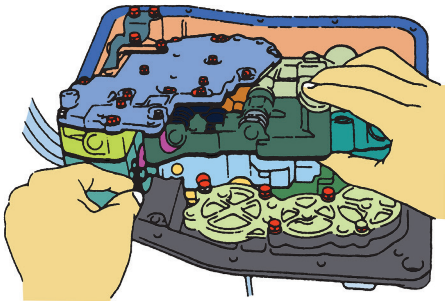


FIGURE 15–9 The valve body can be removed after the pan has been removed.

dispose of hazardous waste following the appropriate disposal procedures and requirements. ● **SEE FIGURE 15–7.**

TEARDOWN BENCH AND HOLDING FIXTURES Many shops use a teardown bench that has a steel top designed to catch the fluid and drain it into a catch pan. During disassembly, the transmission is placed on the bench and torn down. It is usually placed upside down and rolled over as needed. Some shops use transmission holding fixtures during overhaul. Holding fixtures allow the unit to be easily rotated to the best working position, which makes the work faster and easier. When using a holding fixture, a drain pan should be placed under the transmission to catch the dripping fluid. ● **SEE FIGURE 15–8.**

FIRST THINGS FIRST The first teardown step is to remove the oil pan, filter, and valve body. The procedure is to remove the pan, inspect the debris (if it has not been done already), wash the pan in solvent, and air dry it. Next, the filter

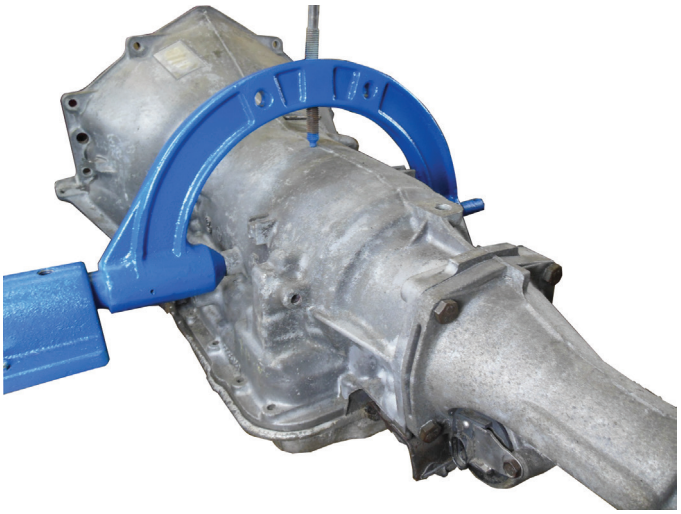


FIGURE 15–8 Using a holding fixture is the preferred method to use when disassembling and assembling an automatic transmission/transaxle. It allows the unit to be tilted and rotated as needed to get access to the internal and external components.

and gasket are removed and set aside for comparison with the new filter. The valve body is then removed and set aside for cleaning and inspection. ● **SEE FIGURE 15–9.**

CAUTION: Valve body bolts are often of different lengths. Either identify where they belong or leave them in the valve body holes after they are loosened.

Inspect for check balls as the valve body is removed, and note their location. Save the valve body gasket (if used) so it can be compared with the replacement gasket. Remove any check balls and screens under the valve body.

The valve body of some transmissions can serve as the cover for the accumulator or servo piston(s). Note the position of the piston(s) and spring (if used), and remove them. In other transmissions, a separate cover is used for the accumulator or servo. Each accumulator has its own spring and piston configuration. They may look alike, but there are slight differences. Improper assembly will cause shift timing and quality problems. ● **SEE FIGURE 15–10.**

RETAINING RINGS Retaining rings are used to hold many parts in the proper position. One example is like a standard snap ring and another looks like a round wire. The two types of retaining rings are external and internal. External rings fit over a shaft and need to be expanded for removal or installation. Internal rings fit into a bore and are contracted or compressed for removal or installation. ● **SEE FIGURE 15–11.**

Snap-ring pliers are often used to remove and install retaining rings and specially designed snap-ring pliers are

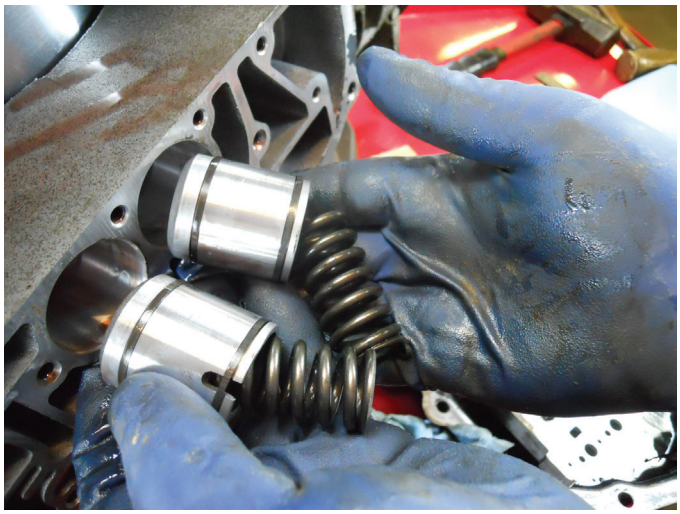


FIGURE 15–10 The accumulators used in a Chrysler 41TE look the same but use different springs.

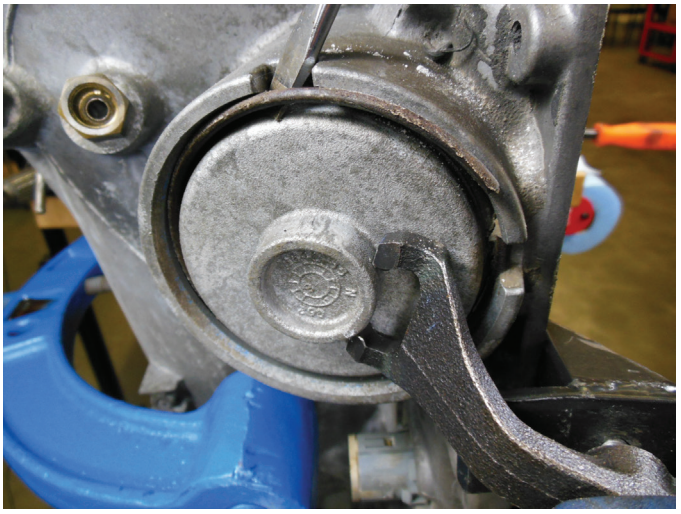


FIGURE 15–11 A round retaining ring being removed after the accumulator piston plate/cover has been compressed using a compressing tool.

TECH TIP

Magnetic Trays

Many shops use magnetic trays to help keep bolts and nuts organized. For example, one tray can be used just for the oil pan bolts and another for valve body bolts. When not being used, they should be stored attached to a metal workbench or tool box. If a magnetic tray is stored on a wooden workbench, the magnet can lose some of its holding power. ● **SEE FIGURE 15–12.**

FIGURE 15–12 Magnetic trays are an excellent tool to help keep fasteners organized so they do not get misplaced. Some technicians use a separate tray for the fasteners from each major component such as the valve body bolts.

FIGURE 15–13 The most common types of retaining rings are (a) external pin type, (b) internal pin type, (c) plain external, (d) plain internal, and (e) E-clip.

WARNING

Use caution during servo cover removal because some servos use a strong piston spring. These require a special tool to hold the spring compressed during retainer ring removal and then allow the spring to be safely extended.

sometimes required for snap rings that are hard to remove. The correct type and size of snap-ring pliers must be used. Once removed, it is recommended that the retaining ring be replaced with a new one. ● **SEE FIGURE 15–13.**

END-PLAY CHECK It is standard practice to measure the input shaft end play before removing the pump. End play is the in-and-out movement of the shaft.

- If there is no end play, there will be drag and a possible binding of the internal components.
- Too much end play allows misalignment of the internal parts which could cause damage from the excess movement.

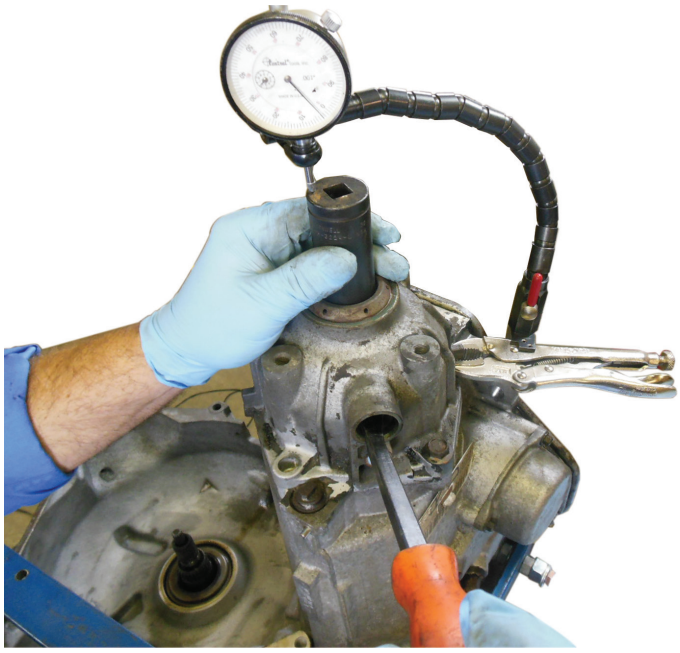


FIGURE 15–14 Using a dial indicator to check the end play before the transmission is disassembled.

- If the end play is correct, the internal thrust washers are probably in good shape. If the end play is excessive, there is internal wear, which must be corrected during the rebuild. End play is normally measured using a dial indicator.

To measure input or output shaft end play, the usual method includes the following steps:

STEP 1 Place the transmission in a vertical position with the input shaft pointing up. Some transmissions require that a special fixture be used to hold the output shaft during end-play checks.

STEP 2 Attach a dial indicator onto the case or front pump, and position the measuring stylus against the end of the input shaft.

STEP 3 Pull the shaft slightly upward and then push it inward as far as it goes. Now adjust the indicator to read zero. ● **SEE FIGURE 15–14.**

NOTE: On some transmissions, the input shaft is not attached and can be easily pulled out of the transmission. On these units, end play is checked by measuring the distance from the end of the stator support to the end of the turbine shaft. End play on some of these units can be measured by prying upward on the gear train or specifying that the tailshaft (output) be lifted up and allowed to fall when checking total end play. This allows the entire stacked unit to be checked.

STEP 4 On most transmissions, pull up on the shaft and read the movement on the dial indicator. This is the amount of shaft end play.

STEP 5 Repeat steps 3 and 4 until you get consistent, reliable readings. Then make three more measurements and, if there is a slight difference, average them.

STEP 6 Record your reading and compare it to the specification.

Some manufacturers specify gear train end-play checks at the output shaft or other locations or require additional end-play checks. This helps locate excessive wear in specific areas or determines if the correct selective thrust washers or spacers are being used. For example, a transmission with a center support should have end play on each side of the center support. Manufacturers specify end-play checks between various components of the gear train. **Selective** washers or snap rings are produced in various sizes. This lets the technician select the proper size thrust washer for the best end play or clearance.

PUMP REMOVAL

The pump assembly is the front cover that holds the gear train inside the case on RWD transmissions. Its removal allows the disassembly of the rest of the internal parts. The pump is held in place by a set of bolts. The close fit between the outer pump diameter and the case plus a rubber sealing ring and/or gasket makes pump removal a little difficult. Several methods can be used to remove the pump. These include:

- Slide hammers,
- Special screw-type pullers. ● **SEE FIGURE 15–15.**

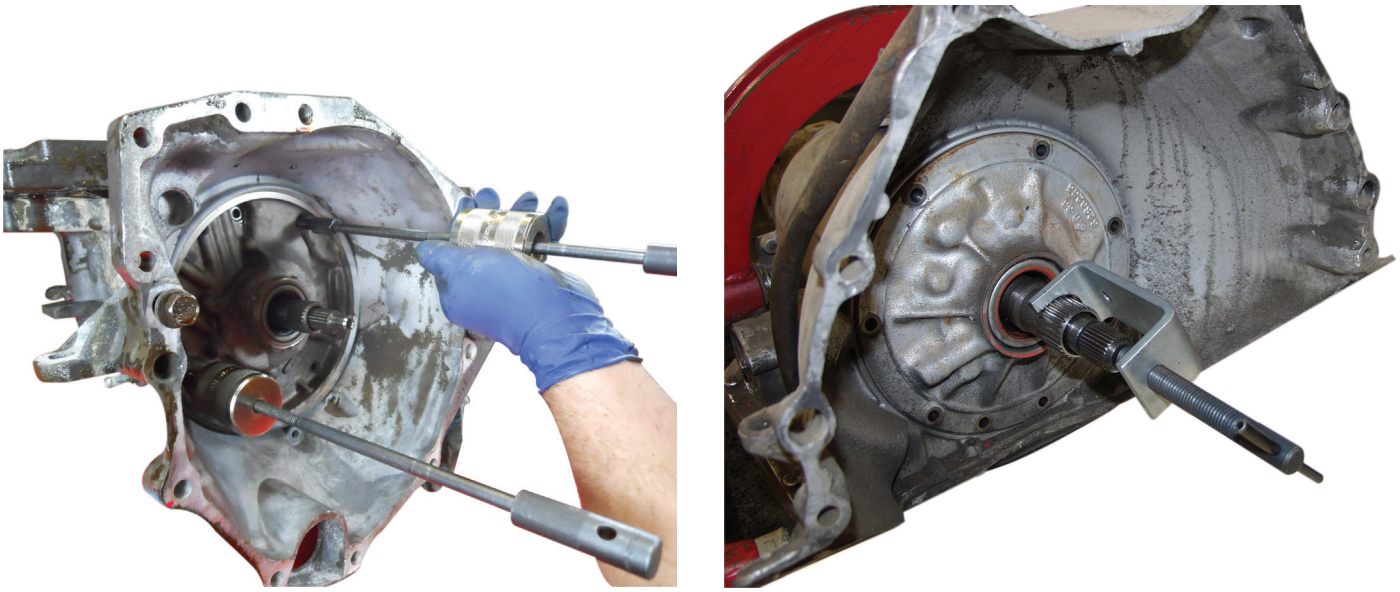
TRANSAXLES USING INPUT CHAIN DRIVE

Some transaxles use a chain and sprockets for gear train input. The main gear train is behind the valve body. Removal of these parts provides access to the driven sprocket support, which supports the input end of the gear train.

The drive chain and sprockets are exposed after the valve body and case cover/channel plate assembly have been removed. The chain should be checked for:

- Wear/link stretch—If the chain has stretched, it should be replaced.
- The master link—It may be a different color. Also note which side is up or down. ● **SEE FIGURE 15–16.**

NOTE: If the chain is replaced with the master link in the opposite position, it can be noisy. This noise will occur whenever the engine is running, even in park and neutral.



(a) (b)

FIGURE 15–15 (a) Two slide hammers are used to removed the pump in some transmissions/transaxles. (b) A special puller being used to remove the pump.

FIGURE 15–16 The master link in this GM 4T65-E is facing upward and is colored black.

FIGURE 15–17 A snap ring being removed after the clutch piston has been compressed to allow access to the snap ring on this GM 4T65-E transaxle.

CASE DISASSEMBLY

Service information should be followed for the disassembly procedure. To complete transmission disassembly, the usual procedure includes the following steps:

STEP 1 To remove a band, carefully note the position of the band struts, loosen the band adjusting screw, and remove the servo cover and piston. Remove the band struts and band. On transmissions using a clutch mounted next to the pump, remove the clutch friction, steel, and pressure plates. Be sure to note the position of the various clutch plates.

STEP 2 Remove the driving clutch assemblies. ● **SEE FIGURE 15–17.**

STEP 3 Remove the bolts retaining the extension housing, if equipped. It may be necessary to remove the snap ring and the extension housing.

STEP 4 The planetary gear train can be slid out of the case as one assembly on some transmissions. The condition of each part should be checked as it is removed.

STEP 5 If the transmission uses a center support, remove the retainer, usually a large snap ring, and lift the center support out of the case.

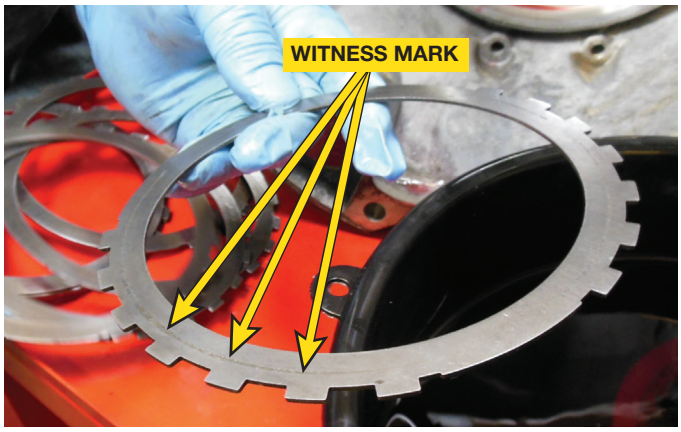


FIGURE 15–18 Witness marks are sometimes hard to see but there is often wear when two parts operate together, and should be reinstalled in the same position.

TECH TIP

Look for Witness Marks

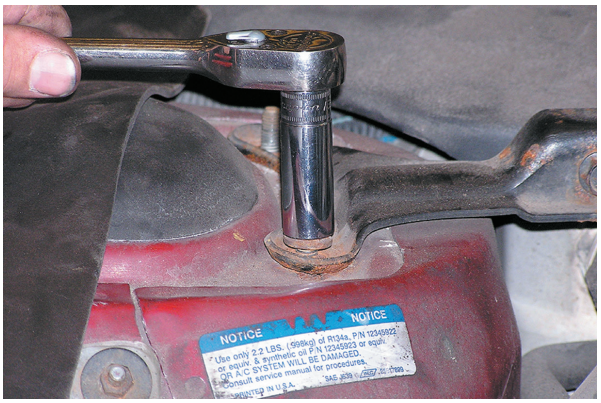
Many transmissions use a drive shell that is connected to a clutch through a set of lugs, and a wear pattern will be established between them. These wear patterns are commonly referred to as *witness marks*. While reassembling, it is important to assemble them in the original position. While disassembling, it is a good practice to place index marks on both parts. ● **SEE FIGURE 15–18.**

FIGURE 15–19 The final drive assembly on a GM 4T65-E.

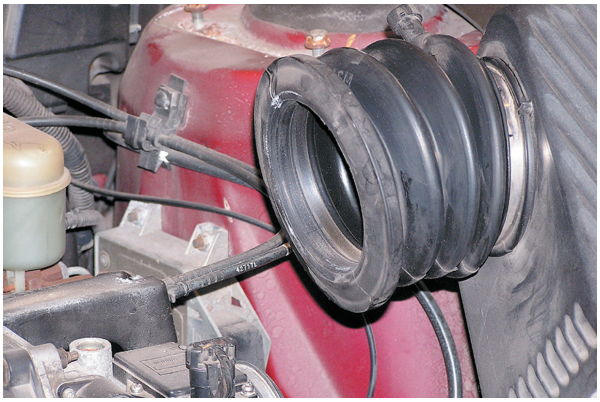
STEP 6 As the park gear is removed, the gear and park pawl should be inspected for wear and damage. Also, the pawl return spring should be checked to ensure that the park pawl is moved completely away from the gear when released.

STEP 7 On rear-wheel-drive (RWD) transmissions, remove any remaining parts as required by the manufacturer's instructions. On transaxles, remove the final drive gears and differential plus any other remaining parts. ● **SEE FIGURE 15–19.**

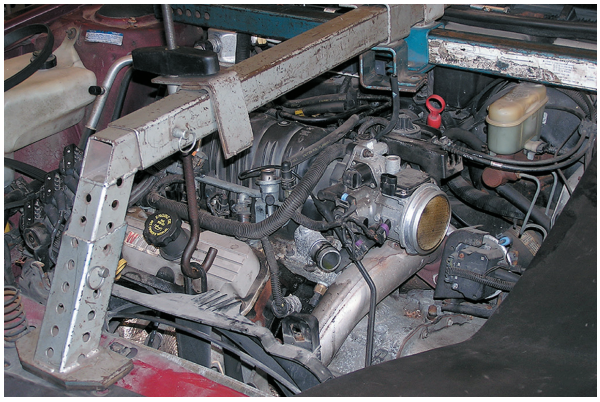
1 For safety purposes, remove the negative battery cable before starting the transaxle removal procedure.



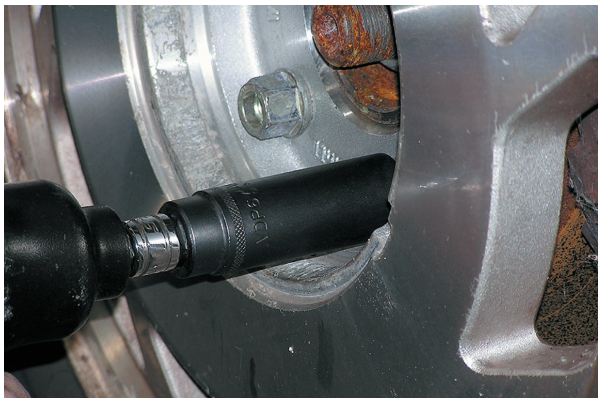
2 Remove engine bay cross members that may interfere with access to the transaxle fasteners.



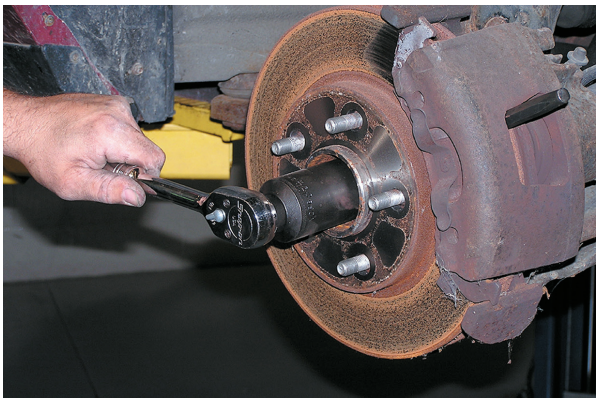
3 Remove the air intake and air filter assembly, which is covering the transaxle in this vehicle.



4 Install a support for the engine.



5 Safely hoist the vehicle and remove the wheels.

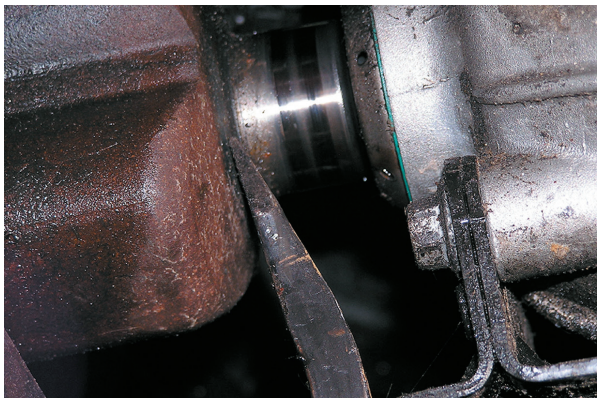


6 Remove the retaining nut from the drive axle shaft.

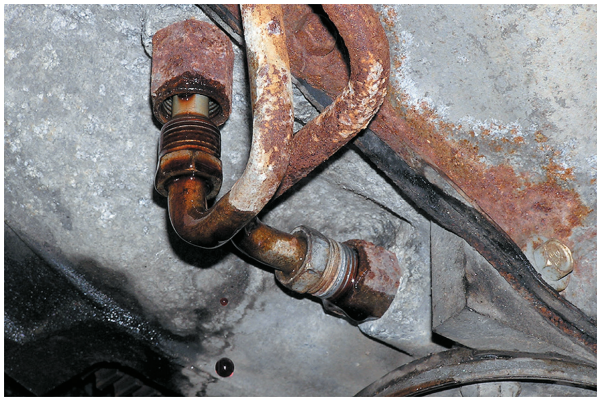
CONTINUED ▶

STEP BY STEP

7 Disconnect the lower ball joint on the front-wheel-drive vehicle to allow removal of the drive axle shaft.

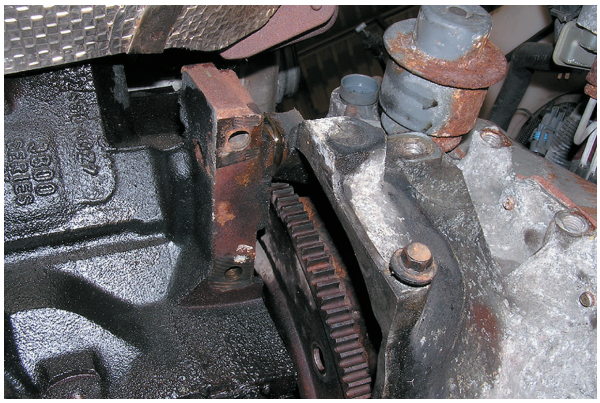


8 Remove the drive axle shaft from the transaxle using a pry bar.

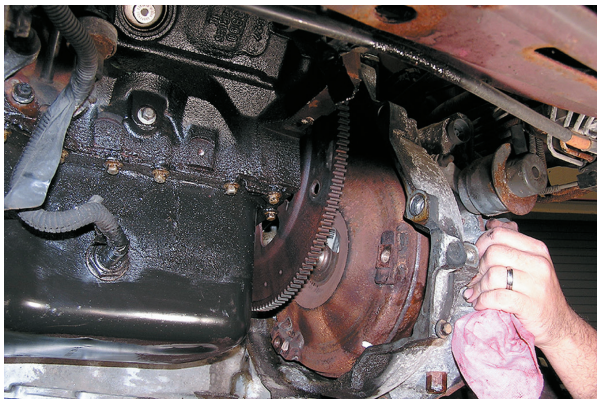


9 Disconnect the cooler lines from the transaxle using a line wrench.

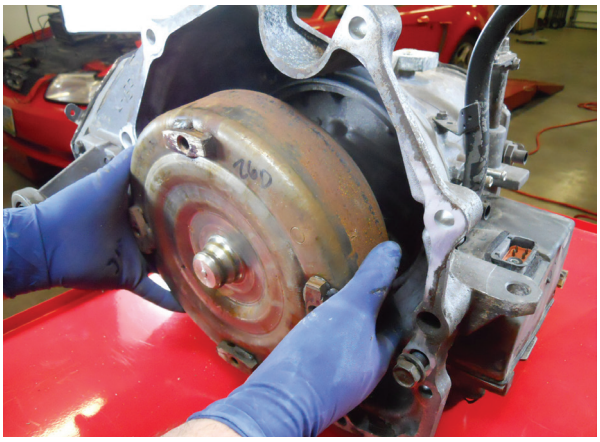
10 Unbolt the torque converter from the flexplate, then remove the transaxle mounts.



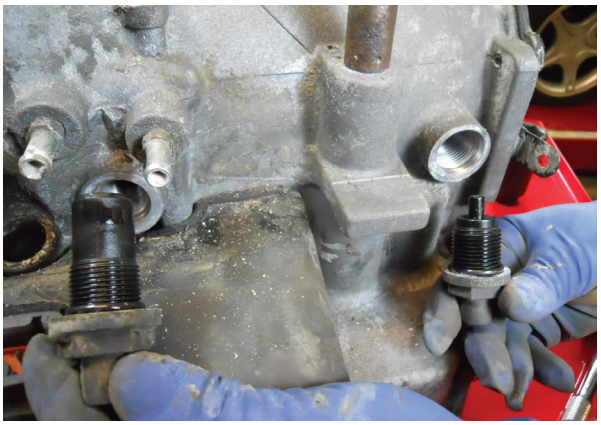
11 With the transaxle supported on a transmission jack, remove the retaining bolts from the bell housing.



12 Carefully remove the transaxle from the vehicle.



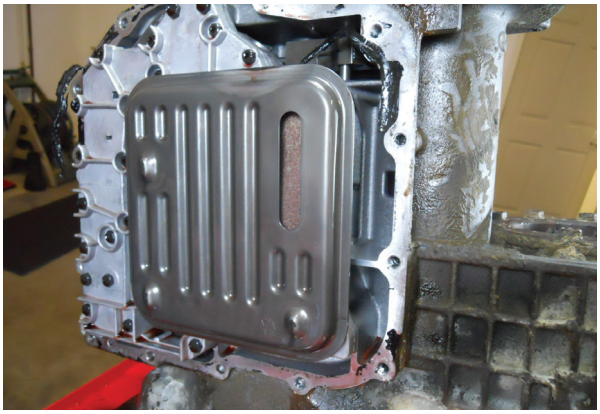
1 The torque converter is removed.



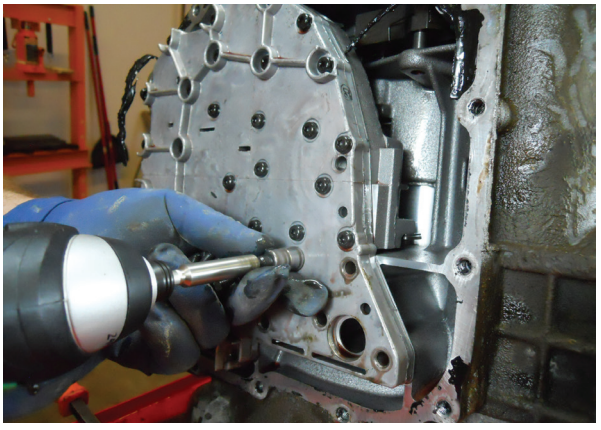
2 The input (left) and output (right) speed sensors are being removed. They are different sizes so they can't be mixed up.

3 A pressure sensor sealing ring being removed.

4 The cover for the TCM is made of rubber and is attached to the case using plastic "Christmas tree"-type clips.



5 After the pan has been removed, the filter can be accessed and then removed before removing the valve body assembly.



6 Removing the valve body.

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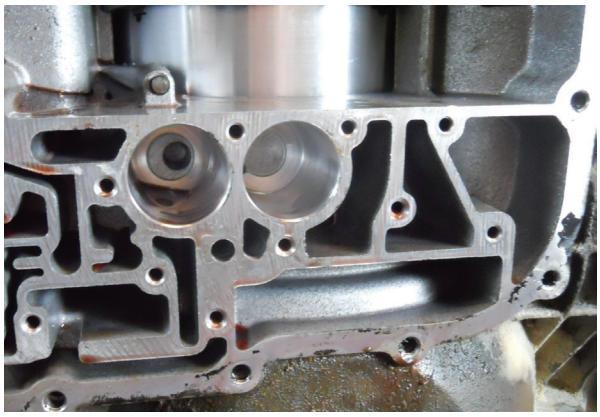
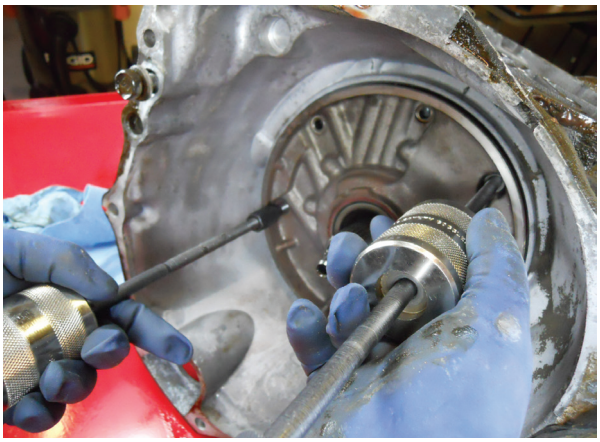
STEP BY STEP



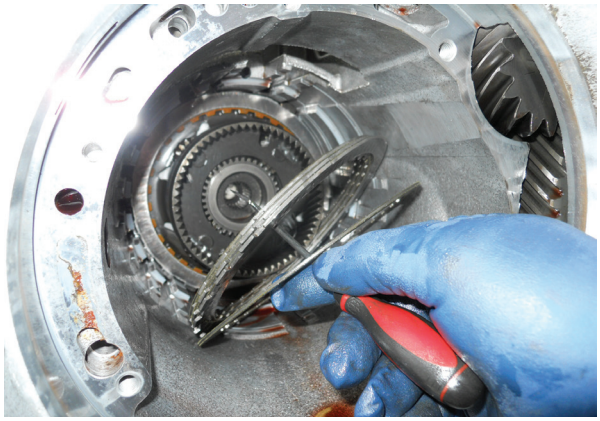
7 The accumulator bores are checked for wear after removing the accumulator pistons.



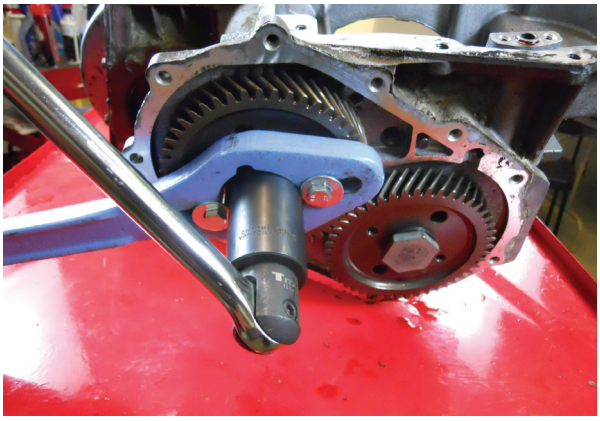
8 The pump is being removed using two slide hammers.

9 The input clutch assembly is being removed.

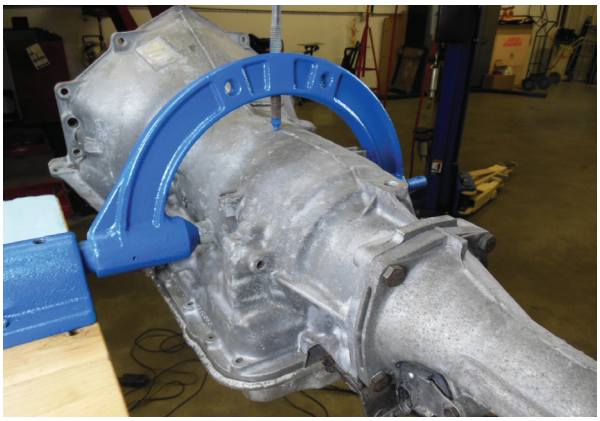
10 The 2/4 clutch return spring is being compressed so the retaining ring can be removed.



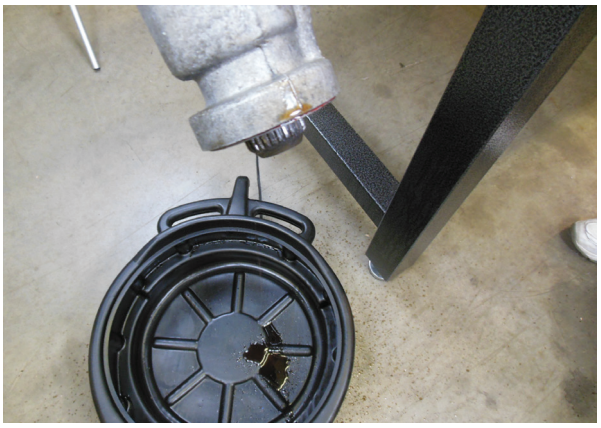
11 Removing the 2/4 clutch pack assembly.



12 The rear carrier assembly is removed after the retaining bolts are removed.

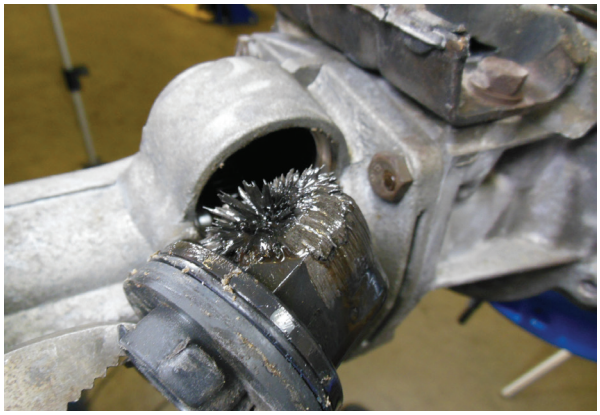


1 Before disassembling, it is preferred that the unit be mounted on a holding fixture.

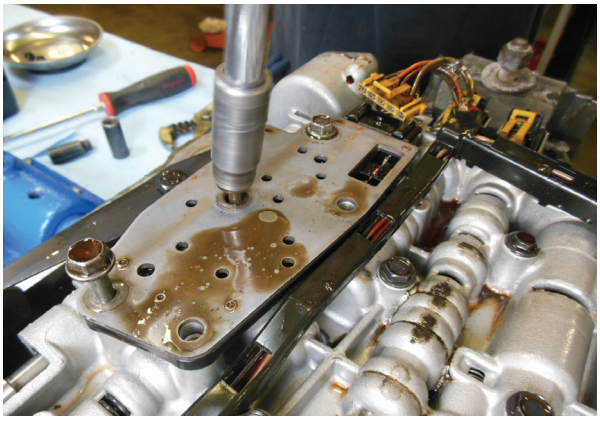


2 The unit is tipped and fluid drained. The fluid looked burned and watery.

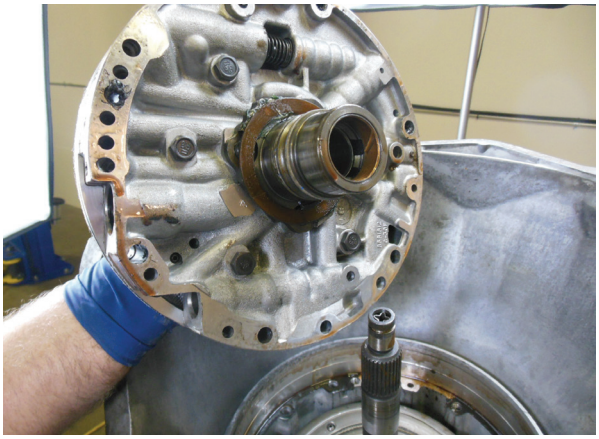
3 After removing the pan, the filter is removed.



4 When the magnetic vehicle speed sensor was removed, it showed lots of metal filings which indicates that something is worn or damaged inside the unit.



5 The pressure switch manifold being removed prior to removing the valve body.



6 The pump assembly is being removed from the unit.

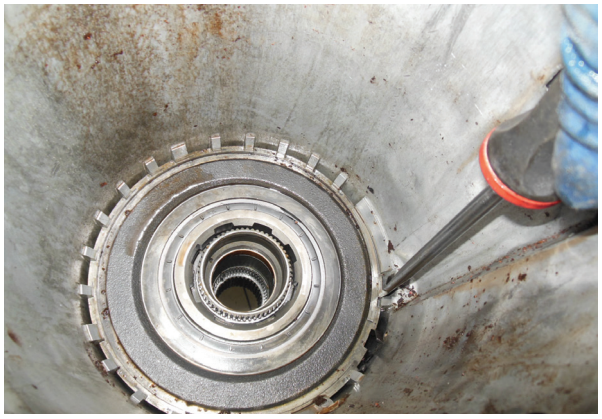
CONTINUED ▶

STEP BY STEP

7 Removing the input housing and shaft assembly.

8 The cause of the metal shavings was found to be an excessively worn planet carrier.

9 The reaction carrier and shaft with internal bushing being removed.



10 Removing a snap ring used to retain the low-reverse clutch assembly.

11 Removing the second gear apply piston assembly from the side of the case.

12 Visual inspection of the fluid in this unit shows that it has been overheated and, of course, there are hard parts needed to return this unit to useful service.

SUMMARY

1. Transmissions are removed to make repairs, for overhaul, or for replacement.
2. The removal procedures are similar for most transmissions and transaxles.
3. Always check the service information before removing an automatic transmission/transaxle as per the required tools and procedures that are specified.

REVIEW QUESTIONS

1. What is the difference between a transmission repair and an overhaul?
2. Why is it important to look carefully at the master chain link used in a transaxle?
3. Why is the proper identification of the automatic transmission/transaxle critical?
4. What are the steps involved in removing an automatic transmission/transaxle from a vehicle?
5. What is the difference between hard parts and soft parts?
6. How is end play measured?

CHAPTER QUIZ

1. What component or part cannot be replaced with the transmission/transaxle in the vehicle?
   a. Torque converter
   b. Shift solenoids
   c. Valve body
   d. Output speed sensor
2. What is the first step usually specified by vehicle manufacturers when removing an automatic transmission (rear-wheel drive) from the vehicle?
   a. Remove the driveshaft
   b. Remove the torque converter inspection cover
   c. Disconnect the negative battery cable
   d. Hoist the vehicle
3. What parts can usually be removed with the automatic transmission/transaxle still in the vehicle?
   a. Pressure switches
   b. Transmission range switch
   c. Turbine and output speed sensors
   d. Any of the above
4. What information is often needed when ordering parts for an automatic transmission/transaxle?
   a. Number of bolts used on the pan
   b. VIN/Tag number
   c. The length of the extension housing
   d. The diameter of the torque converter
5. Some states have rules and regulations that define what an automatic transmission rebuild or overhaul must include when performing which service or repair?
   a. Fluid exchange service
   b. Filter replacement
   c. Overhaul
   d. Extension housing seal replacement
6. What can be used to prevent the converter from sliding off its splines and falling as the transmission is being removed?
   a. Keep the torque converter attached to the flexplate
   b. Pack assembly lube into the splines
   c. Use a retaining bracket
   d. Tilt the transmission upward at the rear
7. An overhaul kit may be called a (an) _____ depending on the parts that are included.
   a. Compliance kit
   b. Master kit
   c. Overhaul kit
   d. Any of the above
8. After the automatic transmission/transaxle has been removed from the vehicle, many service technicians use _____ to clean the road grime and dirt from the unit before starting disassembly.
   a. A power washer
   b. Hot soapy water and a steel wire brush
   c. An acid bath
   d. A scraper and a used tooth brush
9. It is standard practice to _____ before removing the pump assembly.
   a. Remove the extension housing
   b. Remove the direct (forward) clutch assembly
   c. Check end play
   d. Loosen the band adjustment
10. What is the preferred tool to use when removing a pump?
    a. A chain
    b. Slide hammers
    c. Special screw-type puller
    d. Either b or c

chapter 16

VALVE BODY SERVICE

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "A" (General Transmission and Transaxle Diagnosis).
2. Describe the purpose and function of the valve body.
3. Describe the parts and operations of a valve body.
4. Discuss valve body service and replacement procedures.

KEY TERM

Free fall test 237

VALVE BODY SERVICE

PURPOSE Despite its complexity, the valve body is one of the more reliable parts in a transmission, probably because the valves are so well lubricated. In a way, valves do little, as they move only slightly and only once in a while. The biggest "enemies" of a valve body include

1. Dirt (from dirty fluid or dirt getting into the fluid through the dipstick tube or opening).
2. Overheated fluid, which can cause varnish buildup on the valves and bores.
3. Solenoids can fail and, being magnetic, can attract iron and steel particles which can restrict their flow and prevent them from working properly in many cases.
4. All filter screens should be replaced and are usually included in most overhaul kits.

Most valve body service operations consist of the following:

- disassembly
- cleaning
- checking for free movement
- replacing defective solenoids
- replacing all filter screens
- reassembly. **SEE FIGURE 16–1.**

VALVE RETAINING METHODS Several methods are used to retain the valve(s) in a bore.

- Many units use a cover plate that holds one or more valves. Removal of the retaining screws allows removal of the plate, valve(s), and spring(s).
- Many valves use a plug or sleeve at the end of each bore. The plug/sleeve is retained with a keeper, which can be a pin, plate, or key. Some valve bodies use a coiled spring pin (roll pin) to hold the valve plug/sleeve in place. In some cases, this coiled pin can be pulled out by gripping it with a pair of pliers or using an extractor tool.

VALVE BODY CHECKS AND TIPS Most technicians place a lint-free shop cloth(s) or a carpet scrap under the valve body while disassembling it. The cloth helps keep the check balls, screws, and pins from rolling away and might prevent a nick or dent in a valve if one happens to drop.

Case Study

The Case of the Stalling Ford

The owner of a Ford Mustang (61,000 mi) came in with a complaint of stalling when shifted to drive after the transmission warmed up. A scan-tool check showed no unusual activity of the shift or TCC solenoids. The TCC solenoid seemed sticky so it was replaced along with the Manual Lever Position Sensor (MLPS), which did not help. The valve body was checked, and several of the aluminum valves were severely scored and worn. Valve body replacement fixed this problem.

SUMMARY:

Complaint—The engine would stall when shifted into drive when the vehicle was warm.

Cause—The valve body had worn valves.

Correction—The valve body was replaced which corrected the customer concern.

The **free fall test** is a standard check for a sticking valve. Hold the valve body so the bore is vertical. In this position, a steel valve should fall freely from one end of the bore to the other and it should at least fall through the area of normal valve movement. Any valve that does not fall freely is sticking, which can be a fault of the valve, the bore, or both. **SEE FIGURE 16–2.**

- Aluminum valves and valve bodies should be checked for wear. Position the valve as deep in the bore as possible. Some valves can be inserted into the bore backward for this check. Next, try to move the valve vertically, and note the amount of movement. Vertical movement should be very small. Compare the amount of movement to a new or known-good valve body.
- A wet air test can also be used to check for wear. Valve body wear can also be checked using a vacuum test; more information for this test can be found at www.sonnax.com/.
- Fluid can leak out of the end of the bore, past the plug. If a round, aluminum plug is used, it can be enlarged by using a tubing cutter to score a groove around the plug. This displaces and raises metal and should create a tighter fit.
- Short valves that are located between fluid pressure and a spring tend to tip in the valve bore. This can cause ridges in the bore, leading to jamming of the valve.
- Carefully inspect the valve and valve body for varnish, which can be a light brown or golden brown coating. It can be cleaned off with brake cleaner. **SEE FIGURE 16–3.**

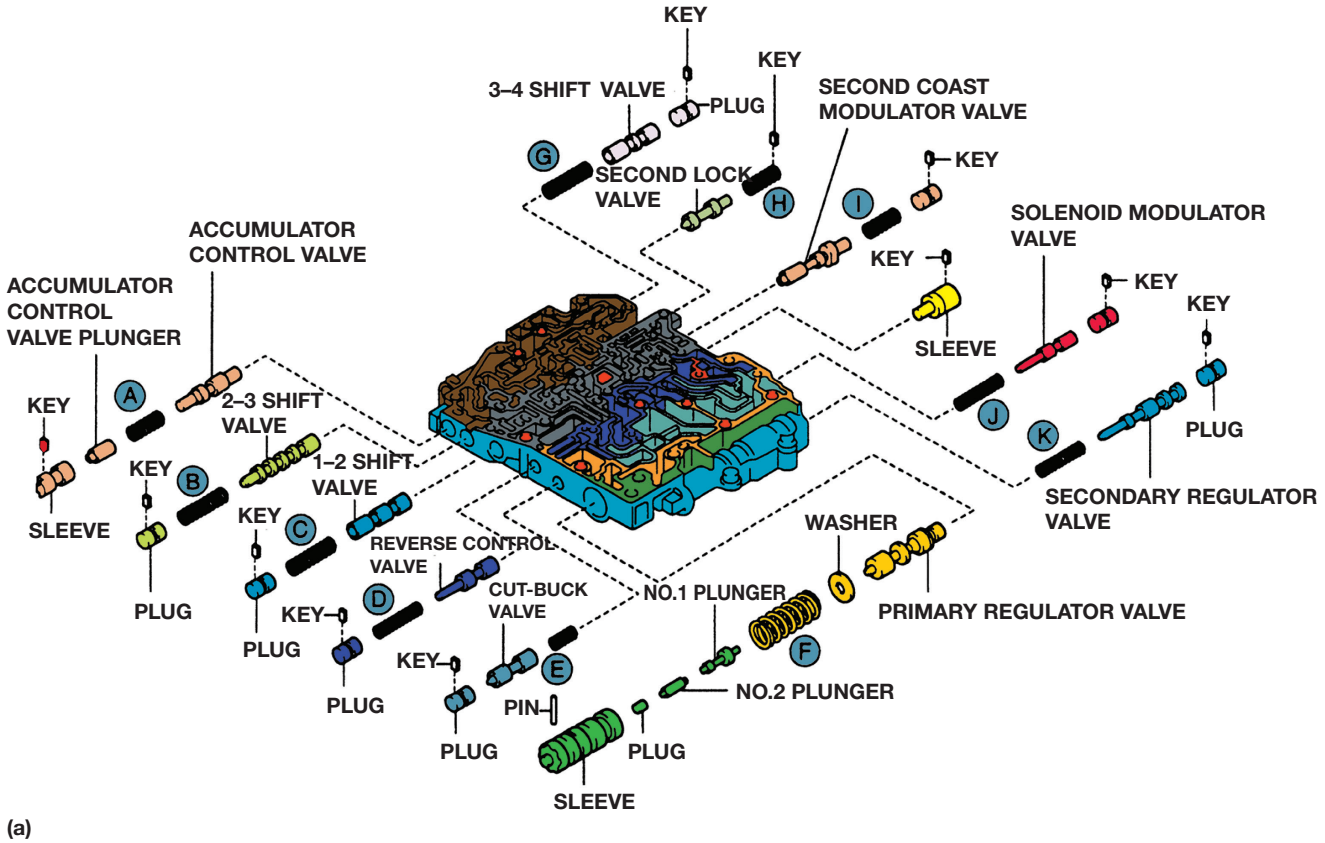


FIGURE 16–1 (a) An exploded and (b) cutaway view of the valve body from a four-speed transaxle. Note the various valve groups and how they are retained in their bore.

- If a valve is smooth but still sticks in the bore, carefully examine the bore for debris or nicks that might cause raised metal.
- A valve that has excessive movement, such as a pressure regulator valve, can wear into the bore and cause excess leakage.

TESTING SHIFT SOLENOIDS

Shift solenoids control the pressure force which in turn controls the position of the shift valve.

To test a solenoid, perform the following steps:

STEP 1 Disconnect the solenoid connector and connect one ohmmeter lead to each of the solenoid electrical terminals.

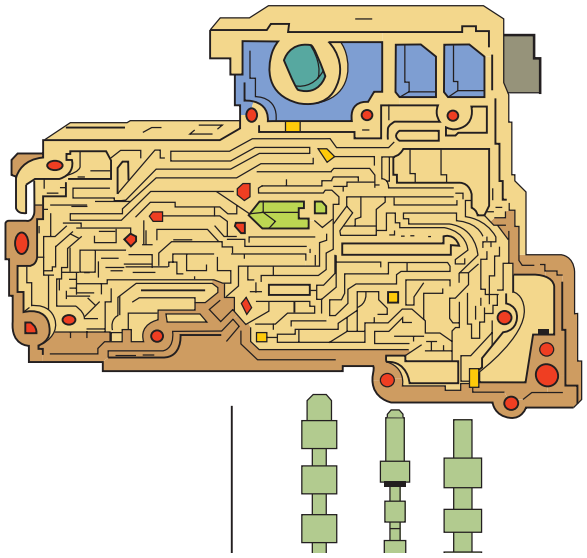


FIGURE 16–2 If the valve body is moved to a vertical position, steel valves should slide freely from the bore. Be prepared to catch the valves when making this check.

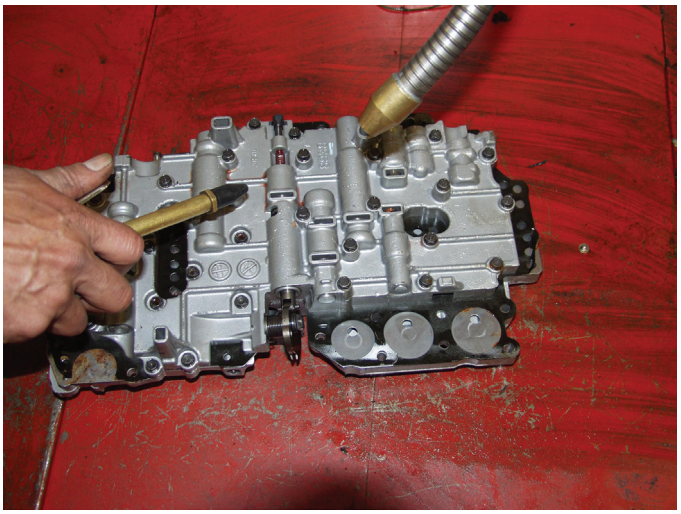


FIGURE 16–3 A valve body being washed and air dried in a parts washer. It will be cleaned again when the two major parts are separated.

FREQUENTLY ASKED QUESTION

How Is a Solenoid Tested That Has a Diode Across the Leads?

Some solenoids include a diode to eliminate voltage spikes that might occur when the solenoid is de-energized. As the solenoid is tested, the diode is also checked to see if it allows a flow in one direction but not in the other.

Measure the solenoid coil resistance with the analog (needle-type) ohmmeter, the reading should be about 20 to 40 Ω depending on the coil temperature. If the reading is less than 20 Ω, the coil or diode is shorted. If the reading is greater than 40 Ω or infinite, there is an open or broken circuit. In either case, the solenoid is faulty.

To check the diode, reverse the meter leads. The meter reading should now be lower than it was before, usually about 2 to 15 Ω. If the reading does not change, the diode is open or shorted, and the solenoid is faulty.

TECH TIP

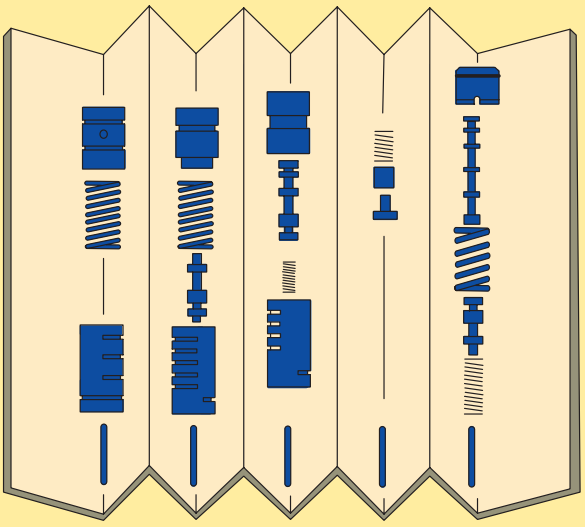
Solenoids Are Wear Items

Many technicians consider solenoids, especially PWM solenoids, to be "wear items" and automatically replace them if the transmission experiences problems after about 90,000 miles (150,000 km).

TECH TIP

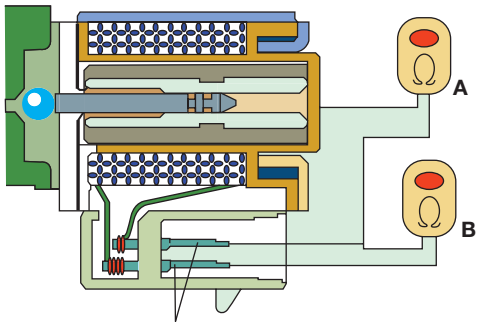
Technician-Made Valve Body Organizer

Some technicians make a valve organizer by folding a piece of cardboard into an accordion shape. The biggest problem during valve body repair is getting it back together with everything in the right order and location and using something like this helps with the organization. ● **SEE FIGURE 16–4.**

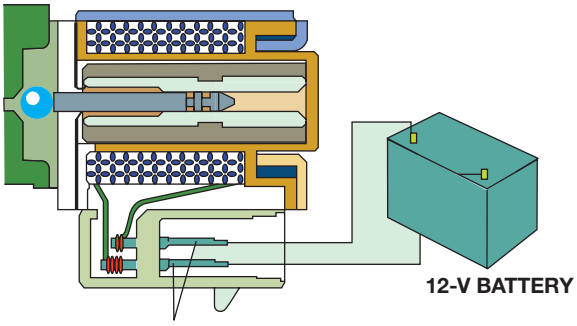


FOLDED CARDBOARD VALVE HOLDER

FIGURE 16–4 A sheet of stiff paper has been folded to create this simple valve holder. Note that a valve group can be placed in order and be labeled.



(a)



(b)

FIGURE 16–5 (a) Ohmmeter A is checking for a grounded solenoid coil; the reading should be infinite. Ohmmeter B is measuring the coil resistance; it should be within the specifications for this solenoid. (b) Connecting a solenoid to a 12-V battery should cause it to operate. Make sure the battery is connected using the correct polarity in case the solenoid has an internal diode.

STEP 2 Read the resistance, and compare the reading to the specifications.

STEP 3 Move one of the leads to the solenoid body or base to check the ground circuit.

NOTE: A two-wire solenoid should not have continuity to ground. A single-wire solenoid will be grounded through the solenoid case, and it should have continuity when one of the ohmmeter leads is connected to the case and the other to the solenoid terminal.

STEP 4 A quick solenoid check is to apply power to the solenoid and listen for a click. This is done by connecting a jumper wire from the solenoid lead to the battery for a single-wire solenoid. A two-wire solenoid will also need to be grounded. The solenoid should click indicating the coil windings are complete and the plunger is moving. ● **SEE FIGURE 16–5.**

TECH TIP

Do Not Use a Magnet on Check Balls

It is easy to use a magnet to retrieve the steel check balls out of the pockets in the valve body. However, using a magnet or placing the steel check balls in a magnetic tray may cause them to become magnetized.

If the balls become magnetized, they may be attracted to the steel separator plate and not be free to move to block passages as designed.

CAUTION: Do not perform this quick check on a PWM solenoid because the lower coil resistance will allow excessive current flow that can damage the solenoid.

STEP 5 The mechanical operation of a solenoid also should be checked. Because solenoids are basically electromagnets operating in an area that might have some metal debris, they tend to attract metal particles. These can cause sticking or binding of the solenoid plunger or blocking of the fluid passage. Test the solenoid by blowing air into the fluid passage while energizing and de-energizing the coil. ● **SEE FIGURE 16–6.**

VALVE BODY REPAIR KITS

A kit has been developed to repair some valve bores. This kit contains a drill jig (reamer guide), a replacement valve, and a spring. The reamer is used to restore the bore to be round, straight, and to the correct size for the new valve. For additional information on valve-body kits and tools, visit www.sommax.com.

REASSEMBLY

After all the valves, springs, and valve body are cleaned and the valves move freely in their bores, the valve body can be reassembled.

- The springs should be checked to make sure they are not damaged and do not have distorted coils.
- Each valve should be dipped in ATF before installation. The reassembly procedure is generally the reverse of the disassembly procedure. As each valve is installed, make sure that it moves freely in its bore.
- Ensure that all check balls and filter screens are replaced in their proper locations. ● **SEE FIGURE 16–7.**
- Be sure to tighten each fastener to the correct torque. ● **SEE FIGURE 16–8.**

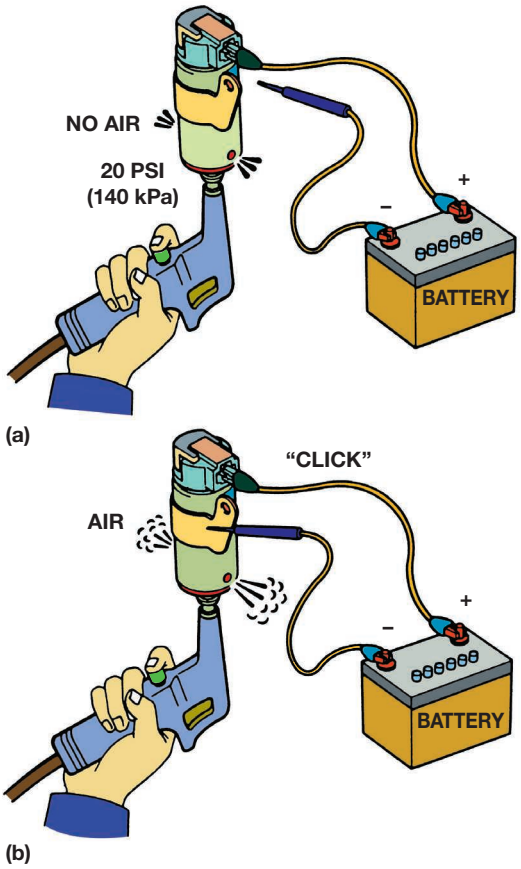


FIGURE 16–6 Air should not be able to flow through this solenoid if it is not activated. If it is connected to a 12-V battery, it should make a "click," and air should be able to flow through it.

FIGURE 16–7 Using assembly lube is a great way to keep check balls in place during the reassembly of the valve body.

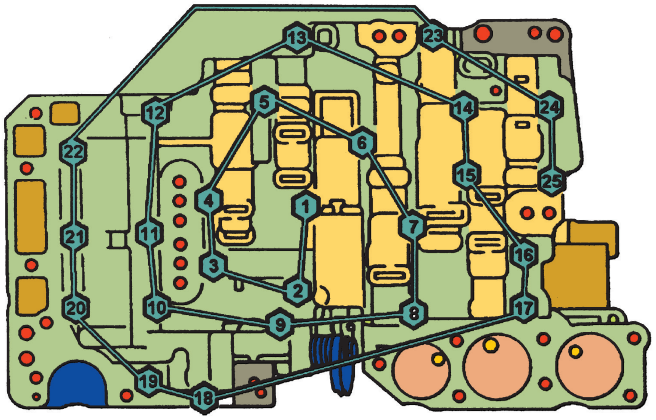


FIGURE 16–8 The valve body bolts should be tightened in order, starting from the center and working in an outward spiral.

TECH TIP

The Shop Light Trick

If a faulty check ball–transfer plate seat is suspected, place the ball on its seat and hold a flashlight behind the transfer plate. Light shining between the ball and the transfer plate indicates a problem. **SEE FIGURE 16–9.**

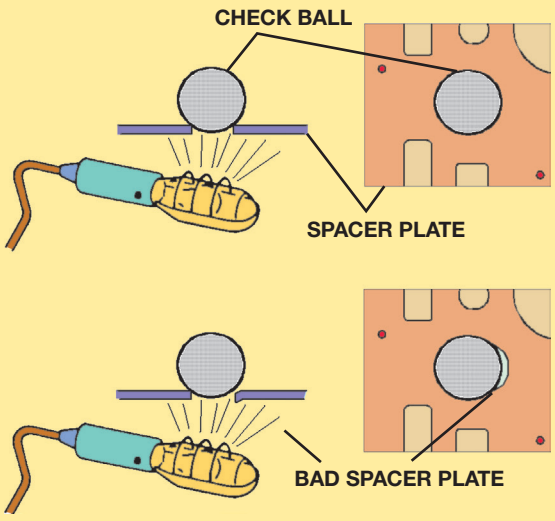


FIGURE 16–9 A check ball should seal off light from coming through the spacer plate. A problem is indicated if light shines through an opening alongside of the check ball.

TECH TIP

Check Manual Valve Operation

Whenever servicing the valve body, carefully check the operation of the manual valve and it linkages to the shift lever and parking paw. If there is any misalignment or binding in this mechanism, the transmission will not operate as designed. ● **SEE FIGURE 16–10.**

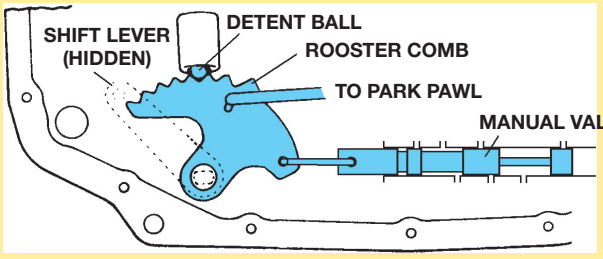


FIGURE 16–10 The manual valve is moved by the shift lever and held in position by the detent lever (cam).

SUMMARY

1. Most valve body service operations consist of the following:
   - disassembly
   - cleaning
   - checking for free movement
   - replacing defective solenoids
   - replacing all filter screens
   - reassembly.
2. All solenoids used in electronically controlled automatic transmissions and transaxles should be tested for proper operation during valve body service.

REVIEW QUESTIONS

1. What are the biggest enemies of valve bodies?
2. What are the commonly performed valve body service procedures?
3. What methods are used to retain solenoids to the valve body?
4. What is the free fall test?
5. What steps are needed to be performed to test solenoids?

CHAPTER QUIZ

1. What can cause valves in a valve body to stick?
   - **a.** Overheated ATF can cause varnish to form
   - **b.** Dirt can cause sticking valves
   - **c.** Solenoids are magnetic and they can attract iron and steel particles
   - **d.** Any of the above
2. Valves can be checked for proper operation by using what test(s)?
   - **a.** Wet air test
   - **b.** Free fall test
   - **c.** Vacuum test
   - **d.** All of the above
3. What part separates the lower valve body from the upper valve body?
   - **a.** Separator plate
   - **b.** Divider
   - **c.** Valve body channel
   - **d.** Valve springs
4. Where are most orifices located?
   - **a.** In the valve body channel
   - **b.** Under the valve springs
   - **c.** In the separator plate
   - **d.** Between the gaskets
5. Solenoids are considered to be _____.
   - **a.** Wear items
   - **b.** Stationary items
   - **c.** Electrical only and not wear items
   - **d.** Copper items
6. What valve body service operations are usually performed?
   - **a.** Disassembly
   - **b.** Cleaning
   - **c.** Replacing all filter screens
   - **d.** All of the above
7. The biggest "enemies" of a valve body include _____.
   - **a.** City and highway driving
   - **b.** Cold ATF
   - **c.** Dirt and overheated fluid
   - **d.** Magnetism
8. The free fall test is a standard check for _____.
   - **a.** Check balls
   - **b.** Shift valves
   - **c.** Accumulators
   - **d.** Shift solenoids
9. Technician A says that if a check ball is magnetized, it may not work as designed. Technician B says a solenoid is magnetic and can attract metal particles and affect its operation. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both technicians A and B
   - **d.** Neither technician A nor B
10. What can be used to make sure that a check ball is properly seated to a spacer plate?
    - **a.** A magnet
    - **b.** A light
    - **c.** Low pressure air from an air nozzle
    - **d.** ATF from a squirt can

chapter 17

TRANSMISSION/ TRANSAXLE ASSEMBLY AND INSTALLATION

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Prepare for ASE Automatic Transmissions (A2) certification test content area "C" (Off-Vehicle Transmission/Transaxle Repair).
2. Identify the different methods of component cleaning.
3. Explain bushing, bearing, and thrust washer service.
4. Discuss friction material service.
5. Explain internal seal and ring service.
6. Describe the procedure for performing case and pump service.
7. Explain the procedure for clutch assembly and disassembly.
8. Discuss gear set service and air testing.
9. Explain the procedure to perform a final transmission assembly.
10. List the steps involved in installing a transmission/transaxle.

KEY TERMS

Aqueous-based solutions 245
Bearings 246
Bushings 246
Clutch pack clearance 257
Cross leak 252
Scarf-cut 251
Selective 247
Subassemblies 251
Torrington 246
Thrust washers 246
Warpage 252

FIGURE 17–1 A pressure jet washer is similar to a large industrial-sized dishwasher. This type of cleaning unit can be used for most automotive components including engines and transmissions. Each part is then rinsed with water to remove chemicals or debris that may remain there while it is still in the tank.

FIGURE 17–2 Transmission parts being cleaned in a water-based solvent cleaning tank.

WARNING

The petroleum solvent–air mixture from drying the parts is highly flammable. Never use cleaning solvent around an open flame, spark, or source of ignition.

COMPONENT CLEANING

CLEANING OPTIONS The internal parts, case, and extension housing are cleaned after disassembling. Some technicians set major components aside to be thoroughly cleaned as they are disassembled and serviced. Cleaning methods that are commonly used include:

- Hot spray wash
- Solvent wash
- Water (aqueous) solution wash
- Microbe cleaning

The parts should be dried using compressed air after washing. Each technician or shop has a preferred method of cleaning.

HOT SPRAY WASHING A hot spray wash cabinet resembles a large dishwasher. The parts are placed inside the cabinet, and the washer sprays the parts with a hot-water-based detergent solution as the parts are rotated. It is an effective and quick cleaner. Newer machines are designed to trap the sludge and dirt to make waste disposal easy and inexpensive. The used cleaning solution, sludge, and dirt waste is an identified hazardous waste that is carefully monitored in many areas. ● **SEE FIGURE 17–1.**

SOLVENT WASHING Solvent washing is usually done for small parts. Rubber seals, Teflon thrust washers, bands, and lined friction plates should not be cleaned in petroleum solvent because the solvent can destroy the seals and other friction materials. This method of cleaning parts is labor intensive. The parts are brushed as they are dipped or sprayed with a petroleum- or water-based solvent. Petroleum solvents are flammable and can cause redness and soreness of the skin. They are also considered pollutants because of the emissions released into the atmosphere and are treated as a hazardous waste when disposed.

WATER-BASED CHEMICAL CLEANING Because of environmental concerns, most chemical cleaning is now performed using water-based solutions (also called **aqueous-based solutions**). Most aqueous-type chemicals are silicate based and are mixed with water. Aqueous-based solutions can be used in one of two ways.

- Sprayed on
- Used in a tank for soaking parts ● **SEE FIGURE 17–2.**

MICROBIAL CLEANING Microbial cleaning uses microbes that are living organisms (single-celled bacteria) that

FIGURE 17–3 A microbial cleaning tank uses microbes to clean grease and oil from parts.

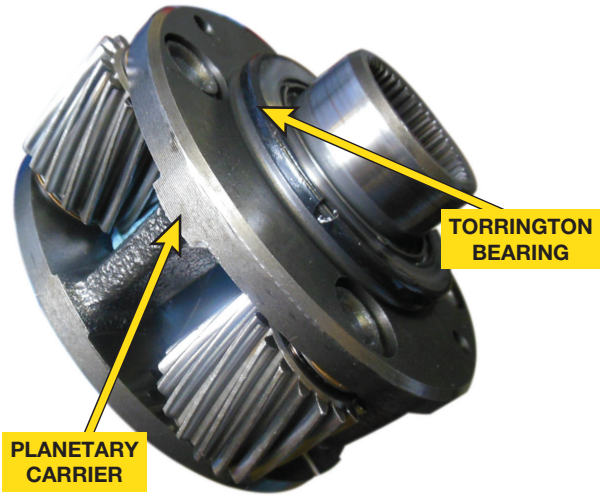


FIGURE 17–4 A Torrington bearing used to absorb thrust loads on a planetary gear set.

literally "eat" the hydrocarbons (grease and oils) off the parts being cleaned. The typical microbial cleaning system includes three steps.

1. A liquid assists the microbes by breaking the hydrocarbons to a smaller (molecular) size.
2. The microbes, stored in a dormant phase until ready for use, give an indefinite shelf life to the product. Once the microbes come into contact with the liquid, they wake up from the dormant state and begin to feed.
3. A third part is a blend of nutrients to ensure that the microbes start to multiply in the shortest possible time to help speed the cleaning time needed.

Microbial cleaning is environmentally friendly, but is slower to clean parts. ● **SEE FIGURE 17–3.**

BUSHING, BEARING, AND THRUST WASHER SERVICE

DESCRIPTION **Bushings** and **bearings** are used to support rotating shafts. **Thrust washers** are used to separate rotating parts from each other or from stationary parts. Bushings are plain metal bearings that require a flow of ATF lubricant to reduce friction. Bearings have much less friction because they have rolling members, either balls or rollers, as well as a lubricant to reduce friction. Bushing, bearing, or thrust washer failure causes wear as the hard parts turning at different speeds rub against each other.

Thrust washers can be made from plastic, fiber, or bronze- or tin-lined iron. When end-play positioning is critical or thrust loads are very high, a radial needle bearing commonly called a **Torrington** is used. This bearing type uses needle bearings to absorb the loads. These bearings must run against a very smooth, hard surface—either the face of a gear or a race. A bushing or thrust washer must have an operating clearance of about 0.003 to 0.005 inch (0.076 to 0.157 mm) to allow a good oil flow across the bearing surface. The condition of a Torrington is checked by feeling for rough operation under load. ● **SEE FIGURE 17–4.**

BUSHING REMOVAL A bushing is a metal sleeve that is lined with a soft bearing material, usually bronze, tin, or both. Any scoring, galling, flaking, excess wear, or rough operation is cause for replacement. A bushing is relatively inexpensive, but the damage caused by a worn bushing is very expensive to repair. The front (pump) and rear (extension housing) bushings are usually replaced during every transmission rebuild. If the bore is straight, the bushing is normally pressed or driven straight out the other end of the bore. The driving tool is usually a stepped disk that fits into the bushing bore and has a raised shoulder to press against the end of the bushing. Most manufacturers do not publish clearance or size specifications for bushings. Generally, anything over 0.006 inch (0.15 mm) clearance is excessive. ● **SEE FIGURE 17–5.**

BUSHING INSTALLATION Replacement bushings are available as individual items or as part of an overhaul kit.

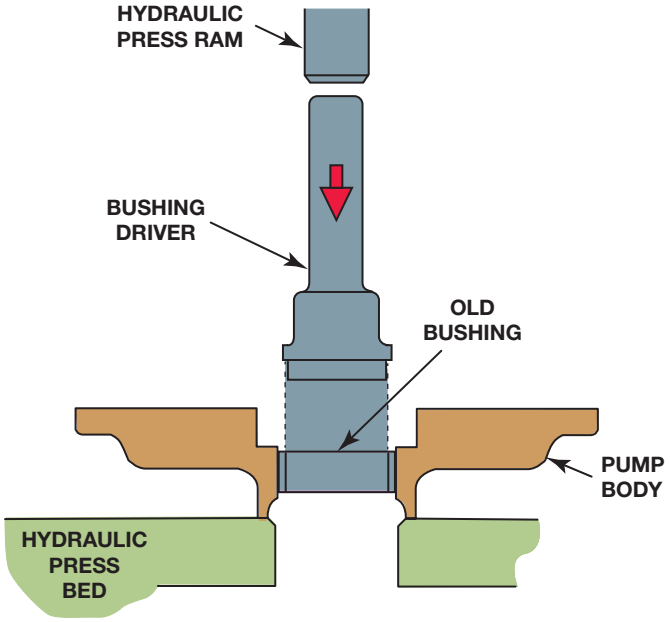


FIGURE 17–5 Worn pump bushings can be removed using a hydraulic press and a tool that applies force only to the bushing.

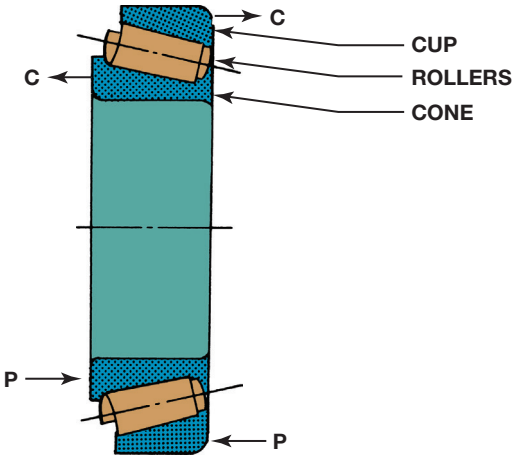


FIGURE 17–6 The cup, rollers, and cone of a tapered roller bearing are machined at an angle as shown. This allows them to resist a thrust in the direction indicated by the P arrows. The bearing is preloaded in this direction; any clearance at the sides of the bearing (C arrows) is called free play.

A bushing installer should be used to push the new bushing into its bore to prevent damaging it or the bore. This is often the same tool that was used to remove the bushing. In most cases, the bushing is placed on the tool and pressed or driven into the bore to the correct depth. Some bushing drivers have steps so they "bottom out" and stop at the correct depth. A bushing with a groove or oil passage should be aligned in the original position.

After staking a bushing (making a dent at the end using a blunt chisel), remove any raised metal with a scraping tool or sharp knife. Some bushings have a hole that must be aligned with an oil passage to permit lubrication of other parts. It is recommended to use a locking compound such as Loctite® to prevent the bushing from rotating in its bore and shutting off the lube flow.

TAPERED ROLLER BEARING SERVICE Some transaxles use tapered roller bearings. The bearing consists of the *inner race*, *rollers*, *cage*, and *cup*. ● **SEE FIGURE 17–6.**

These bearings are checked by visual inspection and by rotating the cleaned and lubricated bearing with a pressure between the bearing and the cup. Any scoring or flaking of the cup or roller surfaces, or a rough feel is cause for replacement. These bearings are often press-fit onto the shaft, and the cup is press-fit into the bore. Special tools are usually required to remove and replace the bearing and its cone. If a bearing or its cup is damaged, both should be replaced. If the bearings and cups are to be reused, they should be marked or tagged so a bearing will be installed with the original cup.

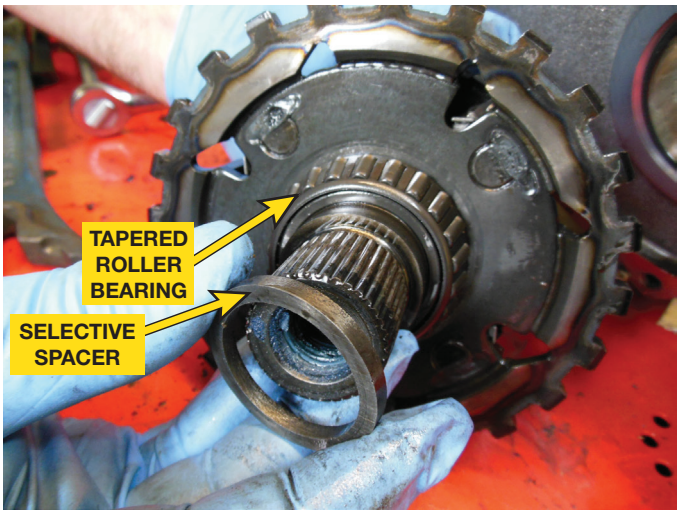


FIGURE 17–7 The selective spacer used at the final drive on a Chrysler 41TE. This unit uses two tapered roller bearings facing each other to support the final drive.

Tapered roller bearings must be adjusted to get the correct end play or preload. This adjustment is normally accomplished by changing **selective**-sized shims that can be positioned under the cup. A shim of the proper size is selected to provide the correct end play or preload. The procedure for this adjustment varies between manufacturers. ● **SEE FIGURE 17–7.**

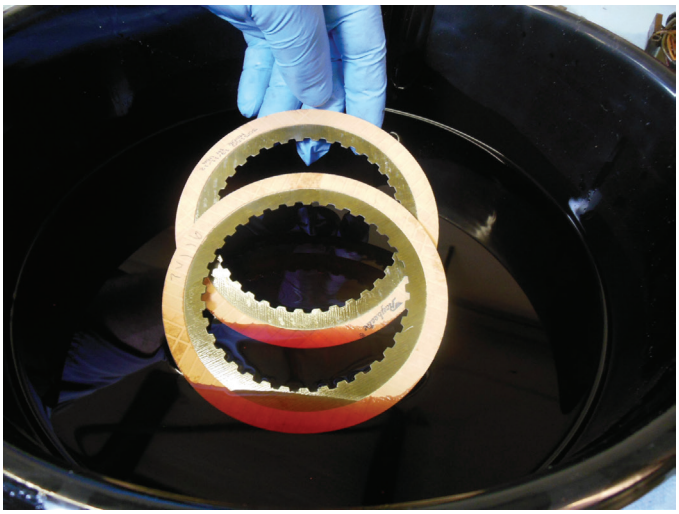


FIGURE 17–8 All lined friction material should be submerged in a shallow pan of ATF and allowed to soak before being installed in the automatic transmission/transaxle.

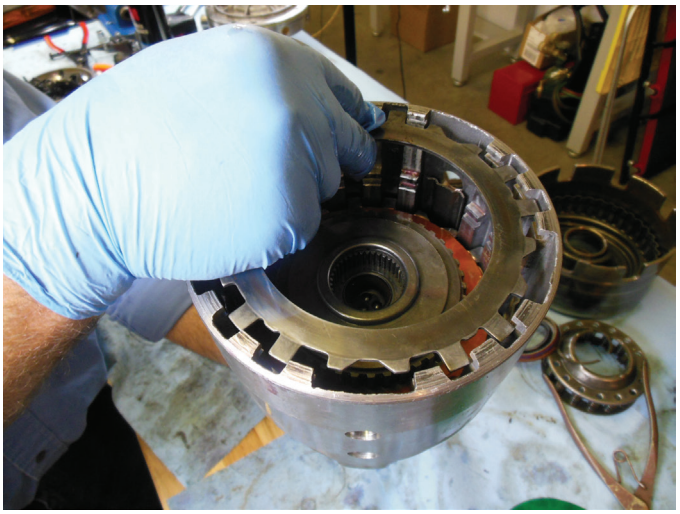


FIGURE 17–9 Steel plates can usually be reused if no faults are found during a visual inspection.

FRICTION MATERIAL SERVICE

LINED PLATE SERVICE If lined plates are to be reused, they should be carefully inspected. The requirements for reuse of a lined plate include the following:

- The lining wear is minimal.
- There must be no breaking up or pock marks in the lining.
- There must be no metal particles embedded in the lining.
- The lining must not come apart when scraped with a coin, fingernail, or knife blade.
- The lining must not have a glazed, shiny appearance.
- The lining material must not be severely discolored.
- The plate must be flat.
- The splined area must be flat and even.

New lined material should be soaked in ATF for at least 20 minutes before installation and some shops soak the plates overnight. ● **SEE FIGURE 17–8.**

STEEL PLATE SERVICE Unlined steel plates are often reused. They must be carefully inspected before reuse for the following:

- The plate must be flat (except for wave or Belleville plates).
- There must be no sign of surface irregularities.

TECH TIP

A Stack of Plates Test

A quick way to check the plates for flatness is to stack the plates and look for any gaps between them. Overheated plates tend to warp into either a slightly conical or a "potato chip" shape. Gaps indicate warped, unusable plates. Restack the plates, turning every other one upside down, and recheck for gaps. Any gaps indicate faulty, unusable plates.

- The notches must be flat and even.
- Slightly burned plates must be replaced or reconditioned.

A "good" steel plate is reusable. Other than cleaning, no further preparation is needed. The friction surface of the lined plate has to wear slightly until it matches the surface of the unlined plate. Too rough a steel plate surface produces severe operation and rapid friction material wear. The ideal surface finish for a used steel plate is a tumbled-finish, smooth, very flat surface like that of a new steel plate. ● **SEE FIGURE 17–9.**

BAND SERVICE If a band is to be reused, it should be checked to ensure the following:

- The lining material is sound with no breaking up or pock marks. ● **SEE FIGURE 17–10.**
- The lining material does not come apart when scraped with a thumbnail or knife blade.

FIGURE 17–10 A badly chipped and pitted band. This band requires replacement.

- The lining thickness is almost the same as that of a new band.
- The lining material is not badly discolored or does not appear burned.
- There are no metal particles embedded in the friction material.
- The end lugs appear tight and unworn.

The drum surface for a band must also be in good condition. The drum surface should be very smooth and flat. A rough, badly scored drum should be replaced.

INTERNAL SEAL AND RING SERVICE

RUBBER SEALS An O-ring seal (round or square-cut) is first checked by placing it in the bore by itself. The seals can be checked for size by placing them one at a time in their operating position. A round O-ring should produce some drag and a square-cut seal is normal if it produces a barely noticeable drag. A lip seal is checked the same way. Just like an O-ring seal, it must produce a drag on the way into the drum, but it is okay if it falls outward when turned over. On a piston that uses three lip seals, each one should be checked, one at a time. A seal should never be installed dry. Both the bore and the seals should be lubricated with ATF, transmission assembly lubricant, or petroleum jelly. ● **SEE FIGURE 17–11.**

(a)

(b)

(c)

FIGURE 17–11 (a) Piston seals as supplied in an overhaul (OH) kit. (b) These seals are being lubricated in ATF before installation. (c) Installing a lip seal.

FIGURE 17–12 A round flat plastic ring is often included in overhaul kits and makes seal installation easier.

FIGURE 17–13 A dial indicator is set up to measure clutch pack clearance and then it is air checked to verify proper operation.

INSTALLING PISTONS WITH LIP SEALS

The clutch piston should be inspected before seal installation. A piston that is manufactured from sheet metal stampings should be checked for broken welds or cracks. Also make sure that the check ball moves freely in its cage and seals properly.

During installation, a lip seal often catches the edge of the bore and will roll outward. This will probably cut the seal lip and cause a fluid leak. Several procedures can be used to ease installation and produce a reliable clutch: use a wax lubricant, an installing tool, a seal guide, and compress the seal lip.

- Seal installation tools are commercially available. As the piston is being installed, use this tool to coax the seal lip into the bore. ● **SEE FIGURE 17–12.**
- Seal guides are available for some clutch units. These are smooth steel bands with a slight funnel or cone shape. They are placed in the drum and lubricated. As the piston is being installed, the guides prevent the seal lips from catching on the edge of the bore.

After the clutch is completely assembled, it should be air checked to ensure that the seals are good, the piston strokes properly, and the clutch applies and releases. ● **SEE FIGURE 17–13.**

FITTING SEALING RINGS

A sealing ring has to make a seal on one of its sides and at the outer diameter. Fluid pressure plus the elasticity of the ring pushes the ring outward, where it engages the bore. If the bore is rotating, the sealing ring rotates with the bore. Rubbing action should always take place between one side of the sealing ring and the groove. Some sliding action takes place between the ring and the bore.

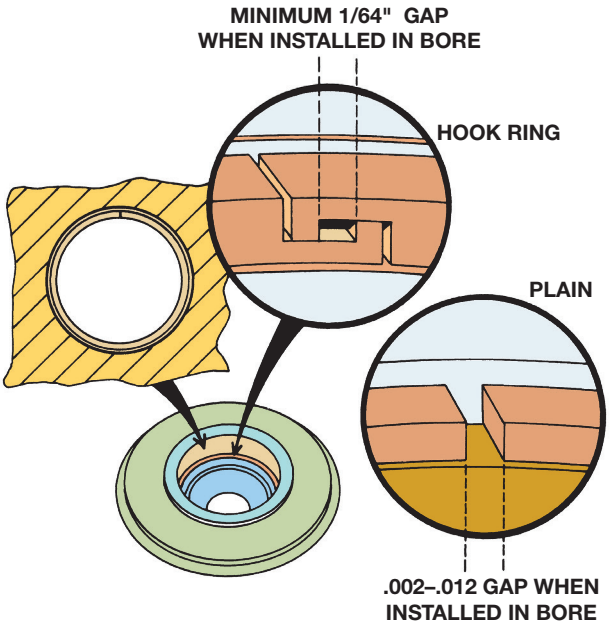


FIGURE 17–14 A metal sealing ring has been hooked and placed into its bore. It should enter with a slight pressure and make full contact with the bore. There should be a slight gap at the ends of the ring as shown.

End play allows the bore along with the drum to move forward and backward.

A metal sealing ring, either *open/plain end* or *hook ring,* should be checked by placing it in its bore. There should be a tight and close fit between the outer diameter of the ring and the bore. Open-end metal rings should have a slight gap, about 0.002 to 0.015 inch (0.05 to 0.3 mm), between the ends of the ring to allow for expansion of the ring metal. ● **SEE FIGURE 17–14.**

Next, check the ring in the groove. A hook- or interlock-type ring should be hooked after installation. There should be

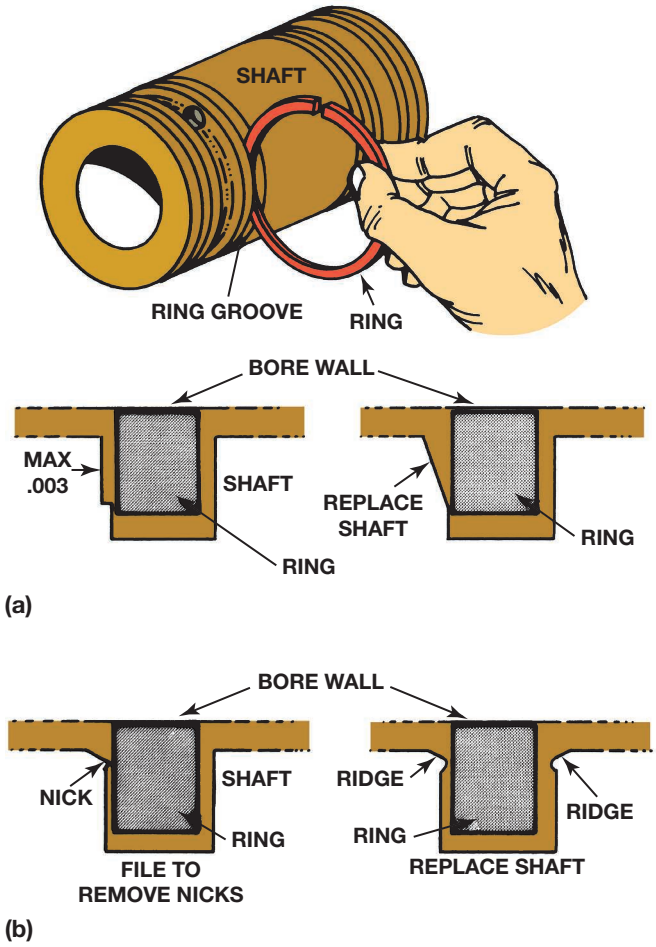


FIGURE 17–15 (a) Side clearance of a metal sealing ring is checked by placing the ring into the groove and measuring the clearance using a feeler gauge. (b) While making this check, look for damage to the seal groove.

a maximum of about 0.003 inch (0.07 mm) of groove wear, and the sides of the groove should be smooth and straight. Small imperfections can be smoothed using a small file. Excessive or tapered wear requires shaft or clutch support replacement. ● **SEE FIGURE 17–15.**

INSTALLING TEFLON SEALING RINGS

Scarf-cut, Teflon sealing rings are installed by placing them in the groove with the ends lapped in the correct direction. ● **SEE FIGURE 17–16.**

Uncut Teflon rings require two special tools for installation:

1. An installing tool.
2. Resizing tool.

To install a Teflon ring,

- place the installing tool over the shaft
- adjust it to the correct depth if necessary
- lubricate the ring and the tool
- slide the ring over the tool and into its groove

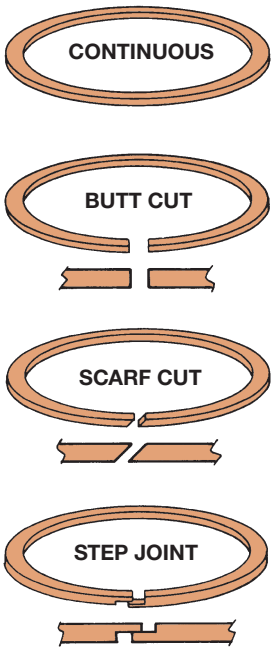


FIGURE 17–16 Four styles of Teflon rings; the uncut, continuous ring requires special tools for installation. The other styles are placed into the groove with overlapping ends positioned properly.

The ring will stretch during installation. Next, lubricate the ring and the resizing tool, and work the resizing tool over the ring, being sure the ring enters its groove correctly. The resizing tool should compress the ring to the correct diameter. Once the transmission operates and the ring gets hot, it will take the shape of the bore. ● **SEE FIGURE 17–17.**

SUBASSEMBLIES

TYPICAL PROCEDURES

Inspection, service, and repair operations are done to each of the transmission **subassemblies** as part of the transmission overhaul. Subassemblies include clutch packs, the pump, and the valve body. Most technicians disassemble the transmission and then service each of the subassemblies separately before starting to reassemble the transmission.

CASE SERVICE

FLUID PASSAGES

Several areas of the case should be checked or serviced after it has been cleaned. These include the bushings, all fluid passages, the valve body worm tracks (grooves for the valve body fluid flow), all bolt threads, the clutch plate lugs, and the governor bore, if equipped.

(a)

(b)

(c)

FIGURE 17–17 (a) Using a seal installation tool allows the seal to slide down over the shaft without harming the seal. (b) After the seal has been placed in the groove, use a sizing tool to reduce the size of the seal. (c) The seal after it has been sized.

TECH TIP

Sealing Ring Tip

Warming the ring in hot water will soften the material and make installation and resizing easier. It is helpful to leave the seal-resizing tool on the seal until ready to install the shaft. ● **SEE FIGURE 17–18.**

FIGURE 17–18 Using water that has been heated in a microwave to help soften a Teflon sealing ring before installing it on the shaft.

Some cases have an output shaft bushing, and it should be checked and replaced if it is worn or scored. Occasionally a bushing will seize and spin with the shaft, which can ruin the case. The repair procedure is to ream the bore oversize and install an oversized bushing.

Every fluid passage in the case must be clean and open. It is a good practice to

- Blow air into each passage and make sure that it comes out through the other end.
- Next, plug off one end of the passage while air pressure is applied and if air is escaping, there is a leak.

WARPAGE Check for **warpage** in the worm track area. Warpage can produce a **cross leak**, which is a leak from one passage to another. A cross leak can cause an unwanted, partial application of a clutch or band that can lead to an early failure. Case warpage is checked by placing a precision straightedge over the area to be checked and trying to slide a feeler gauge between the case and straightedge. Check service information for the specified maximum warpage, which is usually less than 0.002 inch (0.05 mm).

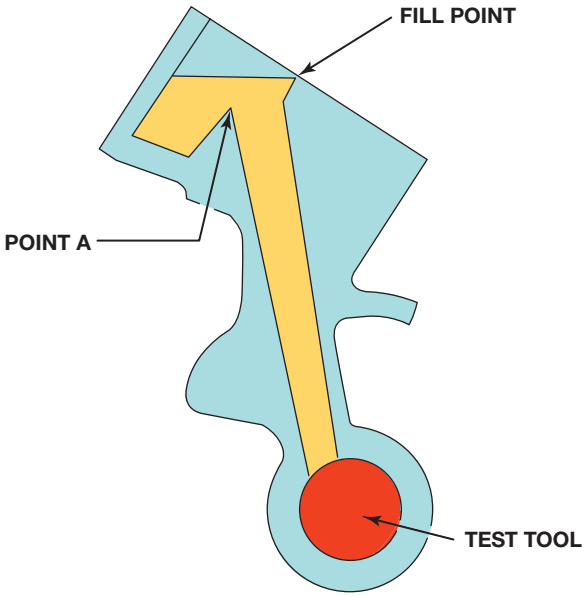


FIGURE 17–19 Filling the passage with ATF and then seeing how long it takes for the fluid to leak down to point A. A test tool instead of the component can be used to check for leakage around a bore if available.

CHECK BORES

Check all bores in the case.

1. Accumulator bore size can be checked by placing the accumulator into its bore and filling the passages with ATF. The bore should be repaired if the fluid leaks out too quickly (to point A in less than 30 sec.). ● **SEE FIGURE 17–19.**
2. Some accumulator bores tend to wear because of repeated accumulator piston oscillation. This produces leakage at the accumulator piston and will ruin the case. A repair sleeve can be installed into the accumulator bore, and this sleeve along with a matching piston will allow the case to be reused.

BOLTS

Most faulty bolt threads are found during disassembly. It is good practice to check all bolt threads visually to make sure they are in good shape. Always replace questionable bolts. The telltale sign of failure is when the bolts come out with aluminum on the threads. If aluminum is found to be on the threads of a bolt, the threaded hole has to be repaired using a Heli-coil® or other type of thread insert.

PUMP SERVICE

STEPS INVOLVED

Servicing most pumps involves the following operations:

- Disassembly
- Inspection of the pumping members, stator support shaft, front bushing, clutch support surface, and sealing ring grooves
- Checking of all valves
- Cleaning of all fluid passages, including the drain back hole
- Replacement of the front seal and bushing
- Reassembly

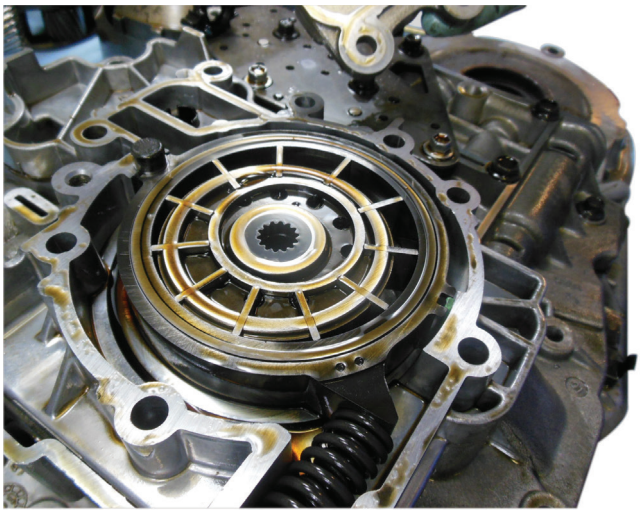


FIGURE 17–20 A pump assembly after the cover has been removed.

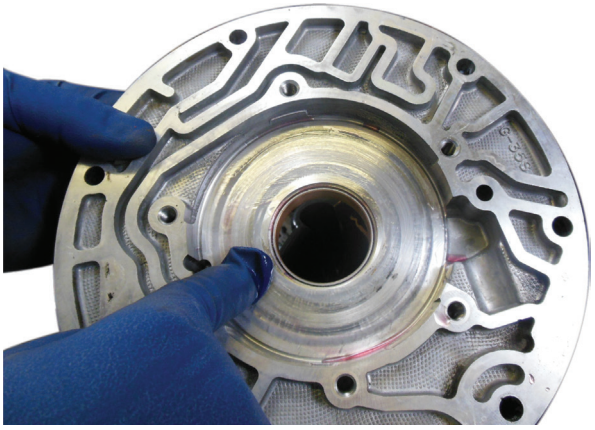


FIGURE 17–21 The pump housing should be inspected for wear and replaced if grooved or damaged.

To disassemble a pump, simply remove the bolts that secure the cover onto the body. ● **SEE FIGURE 17–20.**

VISUAL INSPECTION

Experienced technicians check a pump by visual inspection—carefully checking the areas where wear normally occurs. The pump has a high-pressure area, and this high pressure tries to force the gears outward. Inspect the following areas for wear.

- Sides of the gears or rotors.
- Body and cover where the gears move. ● **SEE FIGURE 17–21.**

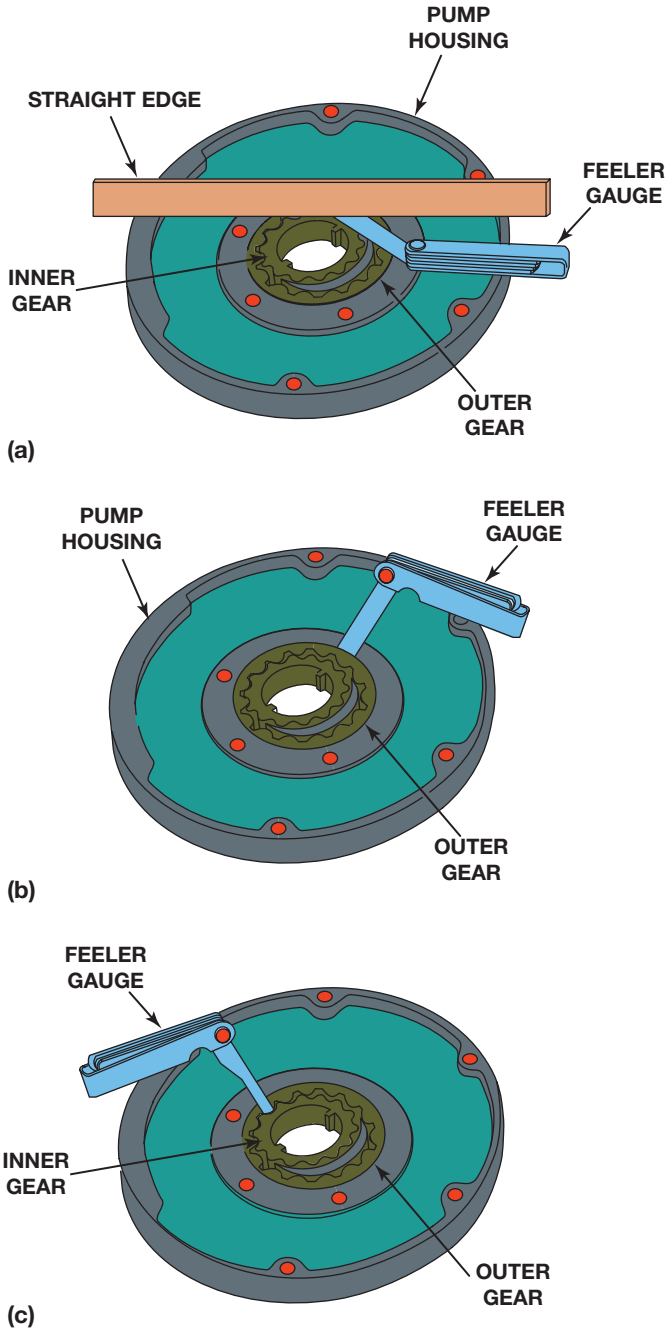


FIGURE 17–22 Clearance checks of the pump gears include (a) end clearance, (b) gear-to-housing clearance, and (c) gear-tooth clearance.

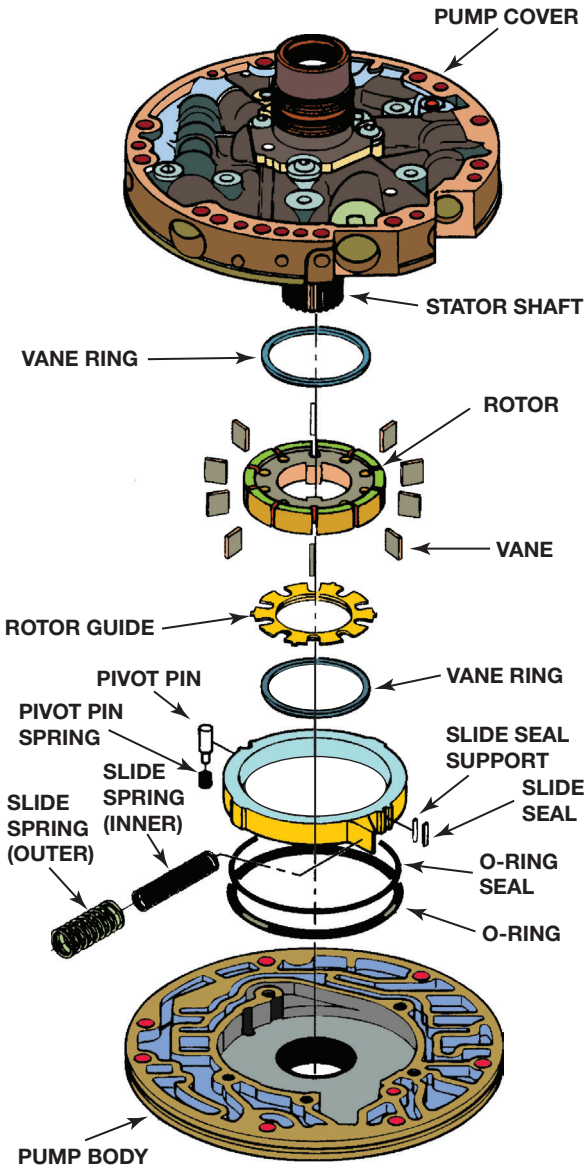


FIGURE 17–23 An exploded view of a vane-type pump. Wear checks include the rotor, vanes, slide, pump body, and pump cover.

- Flanks of the gear teeth/rotor lobes for score marks
- Pump bushing

Manufacturers sometimes publish clearance specifications for the pump wear locations. These clearances can be checked using a feeler gauge. A worn pump requires replacement with a new or rebuilt unit. ● **SEE FIGURE 17–22.**

Vane-type pumps are also checked by visual inspection by checking the following:

- pump guide rings
- vanes
- rotor
- pump guide
- slide
- slide seals
- seal support
- slide pivot pin
- spring
- slide sealing ring
- backup seal. ● **SEE FIGURE 17–23.**

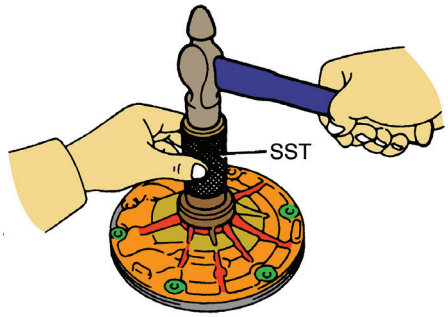


FIGURE 17–24 A new front seal is being installed using a seal driver which is a special service tool (SST).

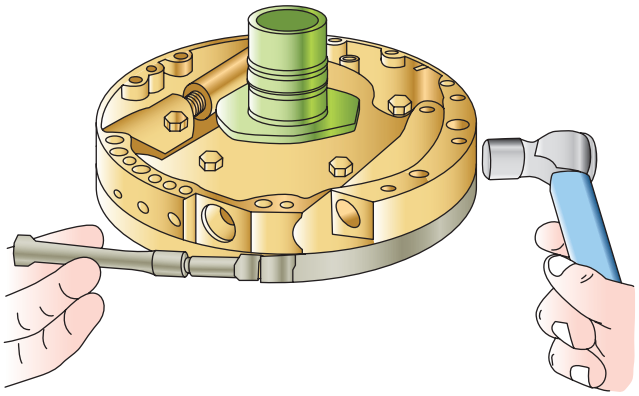


FIGURE 17–25 Using an alignment band to assemble both pump halves to ensure proper alignment. Many experts recommend lightly tapping the outer edges of the pump while tightening the clamp.

FRONT SEAL INSTALLATION The pump is disassembled, usually when the front seal and bushing are to be replaced. It should be noted that some manufacturers recommend replacing the pump assembly if the front bushing is damaged. A seal driver should be used when installing the new front seal. ● **SEE FIGURE 17–24.**

ASSEMBLING THE PUMP After the pump has been cleaned, thoroughly checked, and the bushings and seal replaced, it can be reassembled. The gears or rotor and slide assembly should be well lubricated and placed in the pump body.

On some pumps, the cover has a much smaller diameter than the body. In this case, the cover is placed in position and the bolts are installed and tightened to the correct torque. Other pump covers and bodies have the same outer diameter. These diameters are only slightly smaller than the bore in the transmission case. The two outer diameters have to be exactly aligned before tightening the bolts. Pump cover alignment can be accomplished by using various commercially available band-type aligning tools or a large screw-type hose clamp. ● **SEE FIGURE 17–25.**

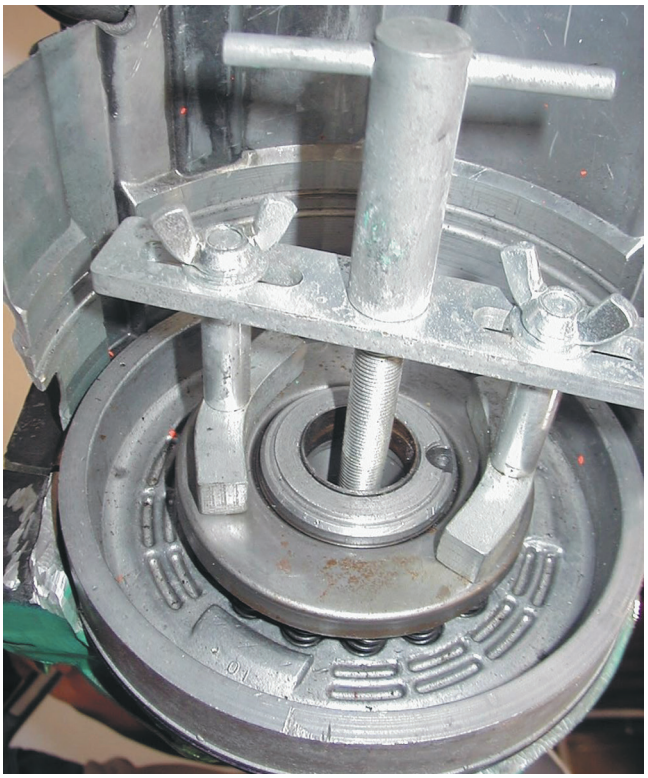


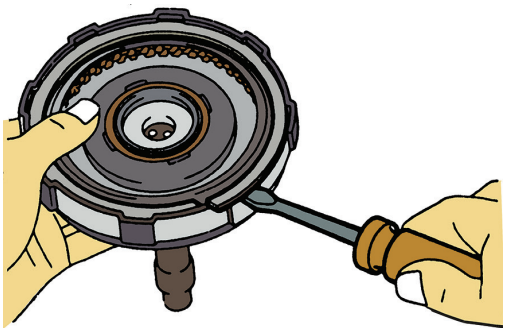
FIGURE 17–26 A compressor tool is usually necessary to compress the springs of the clutch piston to remove and install the snap ring.

CLUTCH ASSEMBLY

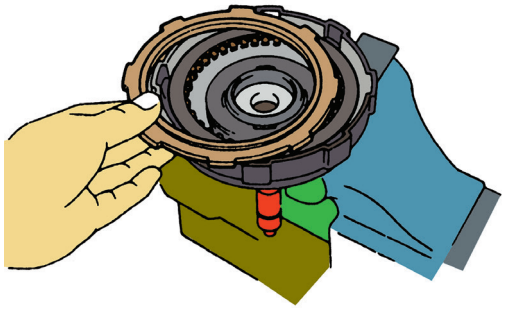
TYPICAL PROCEDURE The service procedure for most clutch assemblies is as follows:

- Remove the clutch plates and disassemble the return spring(s) and piston using the specified clutch compressor ● **SEE FIGURE 17–26.**
- Thoroughly clean the parts
- Inspect the drum, piston, and check ball, as well as the bushing and seal ring area
- Install new seals on the piston
- Install the piston and return spring(s)
- Soak all new friction plates in ATF
- Install the clutch plates
- Check the clutch clearance

CLUTCH PACK DISASSEMBLY Clutch plate removal first requires taking the snap ring out of its groove using a screwdriver or a seal pick. The pressure plate and clutch plates are removed next. ● **SEE FIGURE 17–27.**



(a)



(b)

FIGURE 17–27 (a) The large snap ring can usually be removed using a screwdriver or a seal pick, and then (b) the pressure plate and clutch plates can be removed.

WARNING

Be careful when compressing the spring(s), removing the retainer, and allowing the spring(s) to extend. Some springs store quite a bit of energy and if they fly loose, can cause personal injury.

A spring compressor is usually required to remove the piston return spring(s) and retainer. There is a large variety of spring compressors, and no one unit will work best for all clutches, because some have a bore in the center, a shaft in the center, or are in the case. Many shops use bench- or floor-mounted spring compressors because these are usually faster.

Some clutch pistons almost fall out of the bore when the springs and retainer are removed. Other pistons have to be coaxed with air pressure in the clutch apply oil hole, or by tapping the clutch drum piston side down onto a block of wood. With the piston out, remove the old seals, wash the parts in solvent, and dry them using compressed air.

The clutch check ball should be captured in its cage but still be free to rattle when shaken. It should move with either an air blast or with the use of a seal pick. Fill the drum with ATF and check that it does not leak. The check ball assembly can be removed and replaced in stamped steel drums. ● **SEE FIGURE 17–28.**

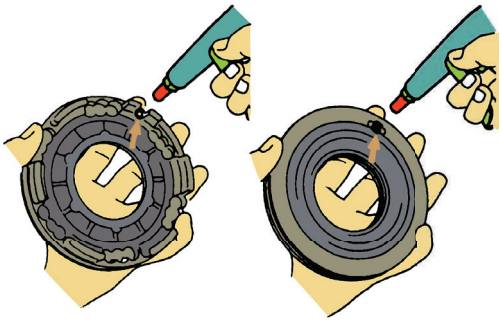


FIGURE 17–28 The check ball should be free to move inside its cage. It should also seal low-pressure airflow in one direction (left) and leak in the other (right).

Case Study

The Case of the Abused Minivan

A Dodge Caravan (143,000 mi) was working fine when the fluid was replaced a few weeks ago. Since the fluid change, it got stuck in snow, and had to be rocked out. Now it moves forward in all shift lever positions, even neutral. The shift linkage was checked and found to be working normally. When the transmission was disassembled, the front clutch plates were found to have gotten so hot that they welded together. Rebuilding the transmission fixed this problem.

SUMMARY:

Complaint—Driver stated that vehicle only moves forward in all shift lever positions.

Cause—Front clutch plates were melted together.

Correction—Rebuilding the transmission fixed this problem.

ASSEMBLING A CLUTCH PACK

When the clutch parts check out and are thoroughly clean, perform the following operations:

- Soak all frictions plates in ATF. ● **SEE FIGURE 17–29.**
- Install the new seals.
- Thoroughly lubricate the seals and bore.
- Carefully install the piston completely into the bore.
- Replace the return springs and retainer.

If three piston seals are used, be sure they all face in the proper direction.

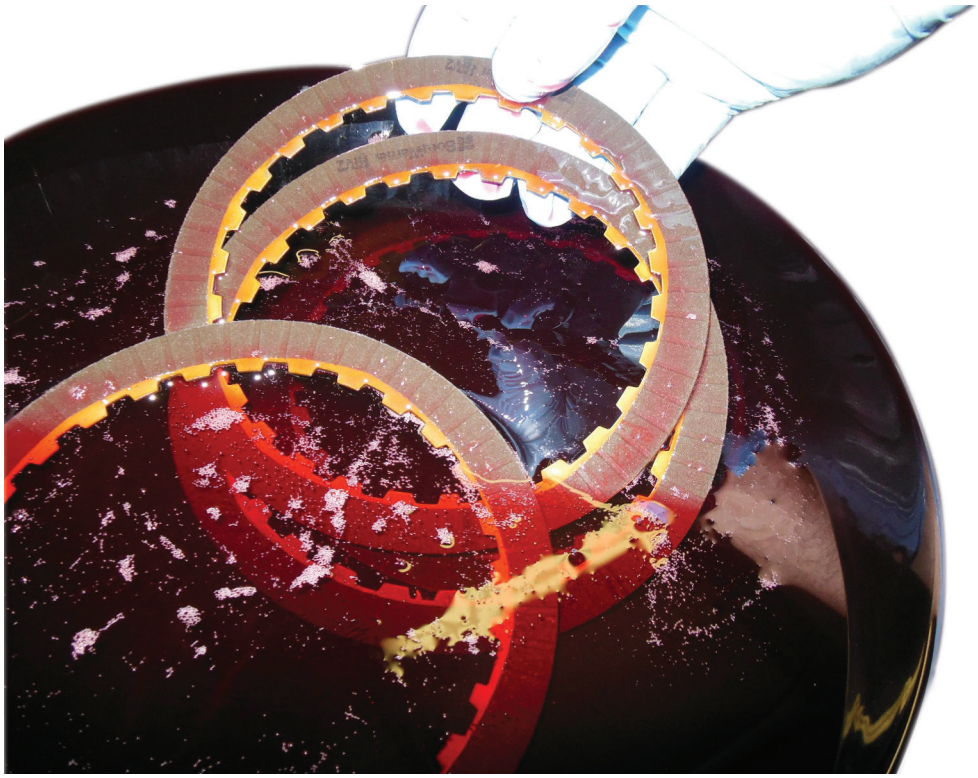


FIGURE 17–29 All new friction plates should be soaked in ATF for at least 20 minutes or until bubbles no longer rise to the surface of the shallow pan of ATF.

A clutch is assembled by stacking the parts in the correct order. Some units use a thick apply plate next to the piston to distribute the apply force onto the plates. The stack is an alternating series of lined and unlined plates followed by a backing/pressure plate. Some units use a wave, Belleville, or selective plate under the backing plate.

When a clutch pack is assembled, the clearance should always be checked and adjusted if necessary. The clearance check ensures that the clutch is assembled correctly and will produce a smooth shift. Depending on the transmission and the particular clutch, different selective parts may be used to adjust clutch clearance. The parts that can be of variable (selective) thickness are the piston, pressure plate, snap ring, apply ring, steel plate, and lined plate. Typically, a selective snap ring is used. Most manufacturers publish clearance specifications for some, if not all, of the clutches used in their transmissions. If clearance specifications are not available, use the rule of thumb that the clearance should be 0.010 inch (0.5 mm) for each lined plate.

Clutch pack clearance, also called *piston travel*, is normally measured using a feeler gauge placed between the pressure plate and the snap ring. If a waved snap ring is used, position the feeler gauge in the widest area under a wave portion. ● **SEE FIGURE 17–30.**

Clearance can also be measured using a dial indicator. Position the dial indicator and raise and lower the backing plate to measure its vertical travel, which is the clutch clearance. If a wave or Belleville plate is used, the pressure plate should be pushed downward with a light, even pressure so the cushion plate(s) is not distorted.

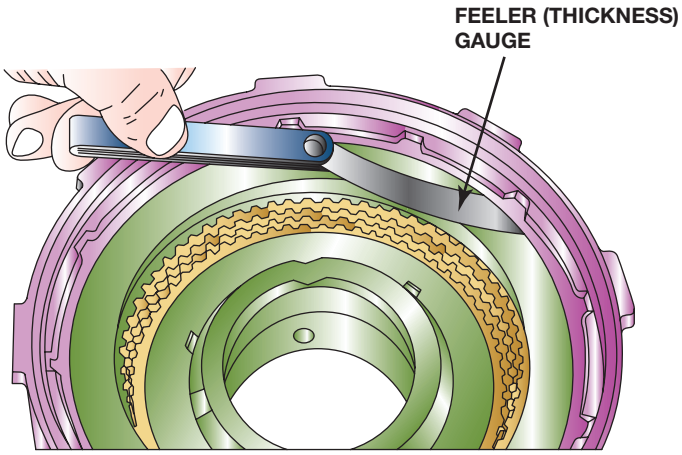


FIGURE 17–30 All clutch packs should be checked for proper clearance. Here, a feeler (thickness) gauge is used to check the clearance to make sure it is within factory specifications.

The clutch is ready for installation at this point. If the selective parts do not correct the clearance or are not available, clutch clearance can be reduced by using extra-thick steel plates or by adding an extra unlined steel or lined friction plate. ● **SEE FIGURE 17–31.**

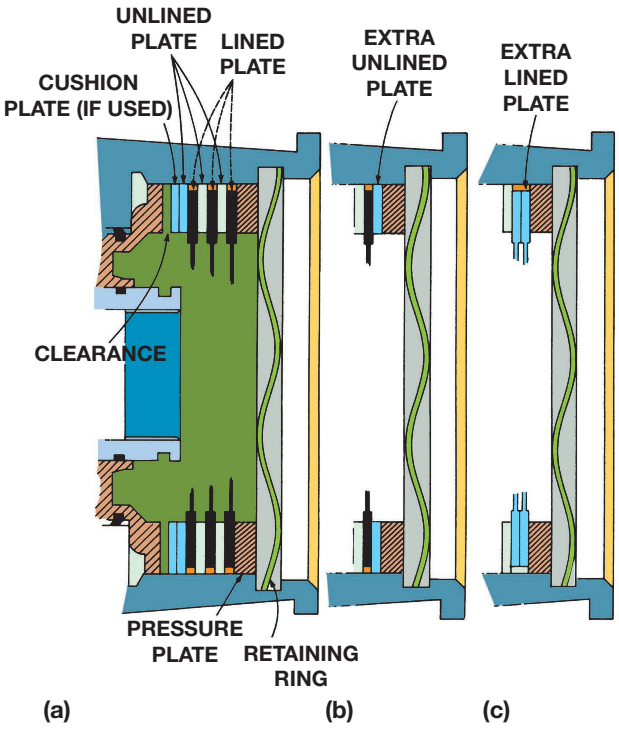


FIGURE 17–31 (a) and (b) Clutch clearance can be reduced by adding an extra unlined plate, or (c) lined plate. If two lined plates are next to each other as in (c), clearance can be increased by shaving the lining off one or both adjacent sides of the two lined plates.

ONE-WAY CLUTCH SERVICE

TYPICAL PROCEDURES One-way clutches (OWCs) are visually inspected during transmission disassembly and reassembly. The commonly encountered problems are severe wear from poor lubrication or metal fragments peeling from a failed part or wear or scoring of the race(s), rollers, or sprags. One-way clutches should always be lubricated using assembly grease, petroleum jelly, or ATF during assembly. After assembly, they should be tested to ensure that they rotate freely in the proper direction and lock up in the opposite direction. ● **SEE FIGURE 17–32.**

GEAR SET SERVICE

VISUAL INSPECTION Servicing gear sets is primarily a visual inspection of the various gears and a side play and rotation check of the planet gears. In some cases there is also an end-play check of the assembled gear train to ensure the thrust washers are not worn excessively. ● **SEE FIGURE 17–33.**

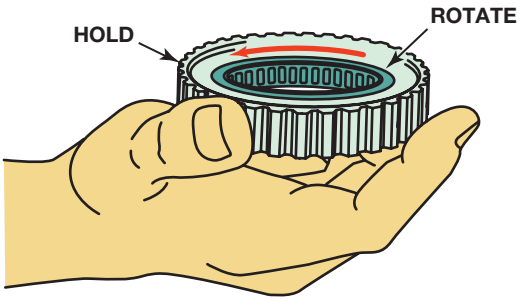


FIGURE 17–32 Service information states that this one-way roller clutch should be installed as shown. Check by holding the outer race so that the inner race is free to rotate counter-clockwise as shown.

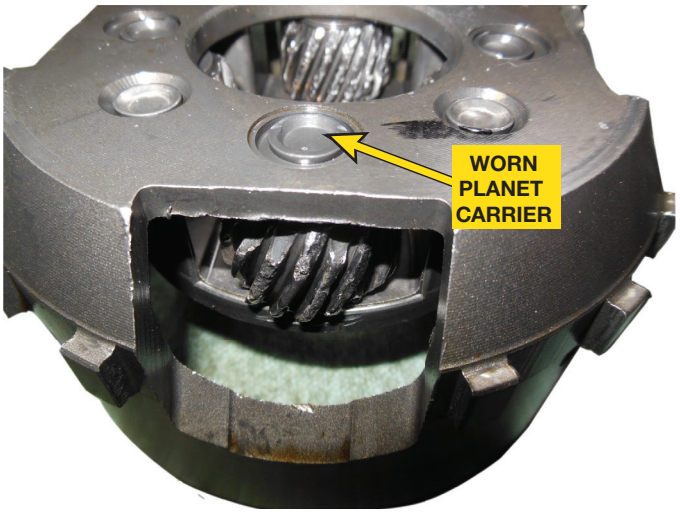


FIGURE 17–33 This planetary gear set is excessively worn and wear metal from this failure has likely contaminated many other parts in the transmission.

In many transmissions, the gear set comes out one part at a time. After cleanup, the parts are carefully inspected again. Parts to rebuild a planetary are available from aftermarket sources. All ring and sun gears should be checked for chipped or broken teeth and worn or stripped drive splines. The thrust surfaces at the sides of the gears and any support bushings or bushing surfaces should be checked for scores, wear, or other damage. Drive shells should be checked for stripped splines, damaged lugs, or cracks.

When checking a carrier, the pinion gears must be undamaged and turn freely. Check for worn or missing pinion thrust bushings and measure the pinion gear end play and/or side clearance. ● **SEE FIGURE 17–34.**

Some manufacturers provide pinion gear side clearance specifications, but if no specifications are available, use the rule

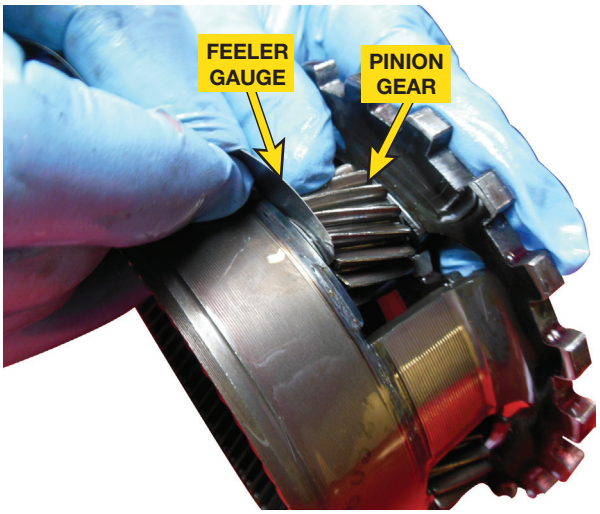


FIGURE 17–34 Using a feeler gauge to measure the pinion gear side clearance.

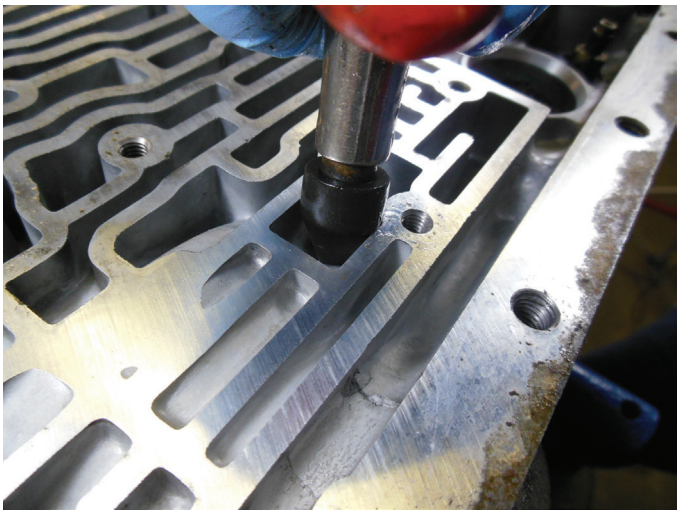


FIGURE 17–36 Using a rubber-tipped air nozzle in a passage to check the operation of a clutch or band.

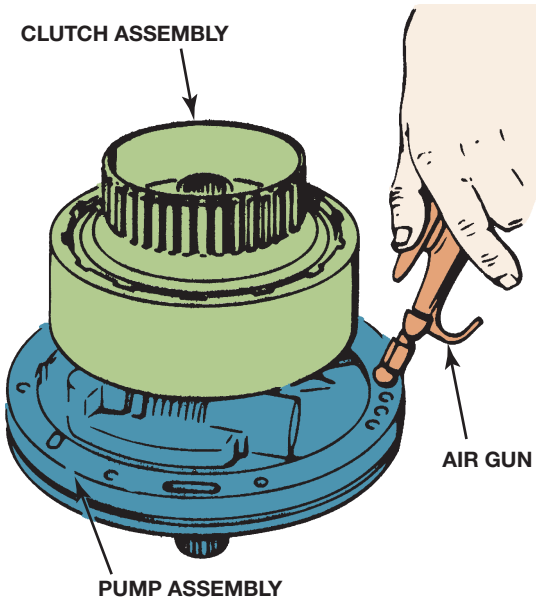


FIGURE 17–35 Air testing a clutch pack before installing it into an automatic transmission or transaxle.

of thumb of 0.005 to 0.025 inch (0.167 to 0.635 mm). In some cases, the pinion gear assembly can be removed from the carrier to replace the bearings, gear, or thrust washers. Shims are available to tighten the side clearance on some carriers.

AIR TESTING

PURPOSE OF THE TEST Air testing is a valuable diagnostic tool, which is also used as a final quality-control check during transmission assembly. Air tests are used to tell if a clutch or band servo operates, and if the passages are properly sealed. ● **SEE FIGURE 17–35.**

WARNING

Always wear eye protection when making air tests. Always adjust the air pressure to the level specified in service information.

Many manufacturers provide illustrations in their service information that identifies these passages. A rubber-tipped air gun pushed against the end of the passage to make a seal is normally used when making air tests. ● **SEE FIGURE 17–36.**

It is possible to air check the whole transmission or an individual circuit by blowing air into the pressure test ports. If checking the whole transmission, insert the rubber tip of the air gun into the "line" test port, set the air pressure to about 90 PSI (620 kPa), and apply air pressure. Depending on the location of the test port in the hydraulic circuit, the airflow can be controlled using the manual valve. In some cases with the transmission on the bench, the pump will rotate, but it can be held stationary by installing the torque converter. If the transmission has pressure test ports for the different circuits, each of these circuits can be checked by pressurizing each port. While performing these checks, be sure to listen for escaping air, which indicates leaks.

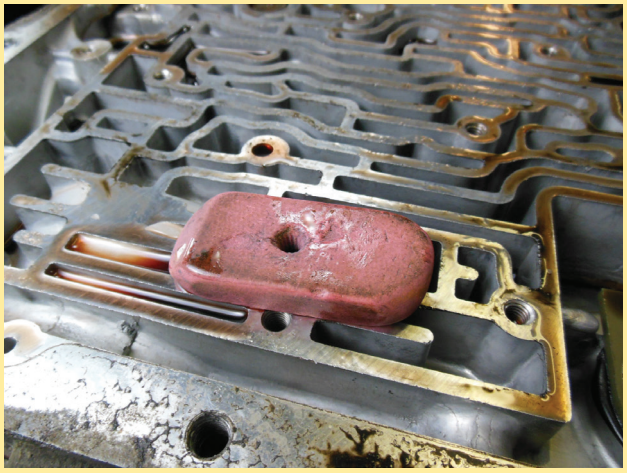
As different components are air tested, the results can vary.

- **Band servos**—When air is applied, the band should apply with a very small amount of air leakage. Removal of the air gun from the passage should result in band release. Some bands require that air be used to apply the band and a second air nozzle position be used to release the band. When the second air nozzle is removed,

TECH TIP

Air Testing Tricks

Some technicians use an air gun that is modified with a piece of rubber tubing for hard-to-reach locations. An eraser with a hole drilled through the center can be used to seal passages. This makes air testing at the valve body easy. **SEE FIGURE 17–37.**



(a)

(b)

FIGURE 17–37 (a) An eraser with a hole drilled through it used to seal passages during an air test. (b) Using an air nozzle and the eraser to test hydraulic circuits at the valve body.

the band will reapply, and when the first air nozzle is removed, spring pressure will release the band.

- **Clutches**—When air is applied to a clutch, a "kachunk" noise indicates the clutch applied. Removal of the air gun should result in the sound of a clutch release. If the air nozzle is kept in place, good clutch seals should hold air pressure for about 5 seconds or more after the air is turned off.

FIGURE 17–38 Using an electronic torque wrench to tighten the pump retaining bolts to factory specifications.

FINAL ASSEMBLY

ASSEMBLE THE UNIT The following parts are installed into the case according to the prescribed procedure found in service information:

- Planetary gear sets
- Clutch packs
- Bands

PUMP INSTALLATION After the planetary gear sets, clutches, and bands are assembled, the pump is installed and the retaining bolts torqued to factory specifications. Always follow the vehicle manufacturer's specified assembly procedures and final checks. **SEE FIGURE 17–38.**

END PLAY CHECK Perform all end play checks during assembly to ensure that the unit was properly assembled and that the proper internal clearances are achieved. **SEE FIGURE 17–39.**

TRANSAXLE DIFFERENTIALS/CHAINS Transaxle differentials should be checked to make sure that the differential gears, thrust washers, and the differential pinion shaft are in good condition. A differential can usually be disassembled by removing the lock pin and driving the differential pinion shaft out. This allows removal of the gears and thrust washers. The gears should be inspected for chipped or broken teeth and scoring on the bearing surfaces. The thrust washers and differential pinion shaft should be checked for wear and scoring.

Some differentials are combined with a planet carrier that includes a set of planet pinions along with the differential. Like

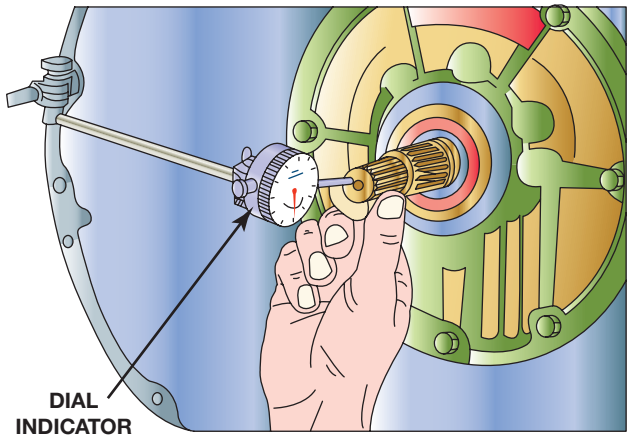


FIGURE 17–39 A dial indicator being used to measure the end play of an input shaft. If the end play is not within factory specifications, the unit may not have been assembled correctly.

FIGURE 17–40 Checking gear clearance using a dial indicator on a final drive assembly on a Chrysler 41TE transaxle.

those inside the transmission, these pinion gears must turn freely on their shafts and not have excessive end play. The thrust washers and needle bearings can be replaced. If differential clearance is excessive, replace the thrust washers. In many cases, the new thrust washers will correct the clearance. ● **SEE FIGURE 17–40.**

Some transaxles use a chain/sprockets and need to be installed with the black link of the chain in the same direction (usually up) as when it was disassembled. Check service information for the specified procedure to follow.

VALVE BODY, FILTER, AND PAN INSTALLATION

After completing all of the end play checks and air tests, the valve body can be installed. ● **SEE FIGURE 17–42.**

FINAL COMPONENTS INSTALLATION After the valve body and filter have been installed, the final components need to be installed:

TECH TIP

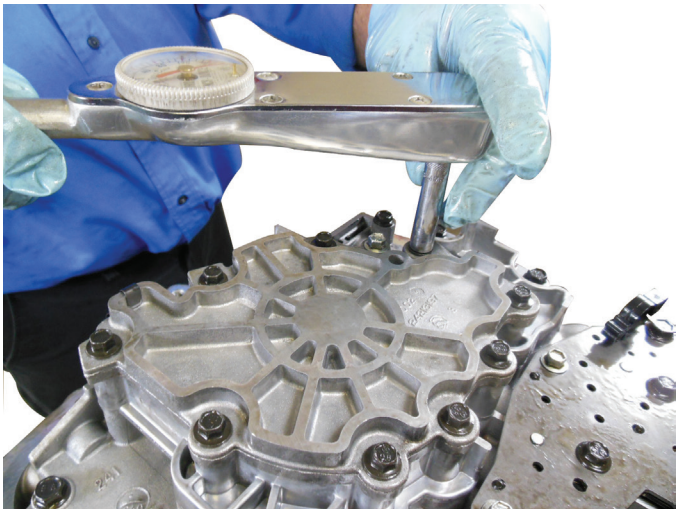
Avoid Using Red Assembly Lube

Assembly lube is used during the reassembly of automatic transmissions. If red assembly lube is used on seals, it may look like an automatic transmission fluid leak when the transmission gets hot and the lube melts. If you use blue, green, brown, or clear assembly lube, then the color will immediately identify it as assembly lube. ● **SEE FIGURE 17–41.**

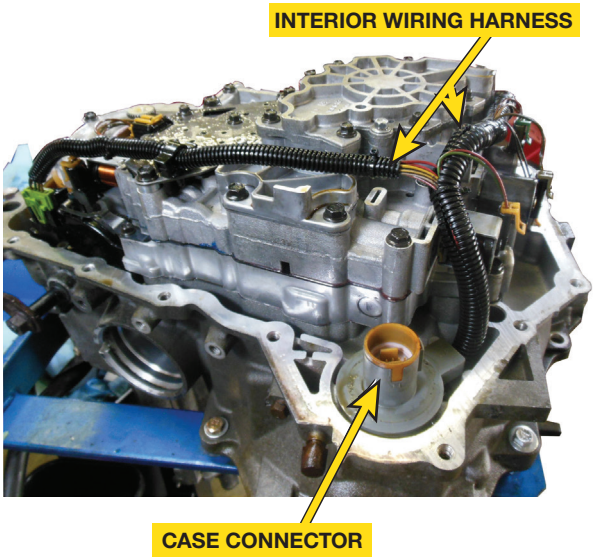
Many transmissions have been disassembled because the service technician thought that the red liquid dripping from parts of the transmission was automatic transmission fluid when, in fact, it was only assembly lube that melted and ran when the transmission reached normal operating temperature.

FIGURE 17–41 Blue assembly lube.

- Turbine shaft seal
- Accumulators and transmission range switch
- Solenoid blocks
- Internal wiring harness
- Speed sensors ● **SEE FIGURE 17–43.**
- Carefully install the torque converter onto the input shaft, being sure to fully engage the following:
  1. Pump gear
  2. Stator splines
  3. Turbine splines
- Finally, conduct a visual check to make sure that all fasteners are properly tightened.



(a)



(b)

FIGURE 17–42 (a) The valve body retaining bolts being torqued to factory specifications. (b) After the valve body has been installed, the interior wiring harness and case connector are installed. This unit is ready for the filter and pan to be installed.

FIGURE 17–43 Installing an output speed sensor that has been equipped with a new O-ring seal.

Case Study

The Case of the Broken Flex Plate

The 5.7-L engine in a Chevrolet Suburban was replaced at 185,000 miles with a reputable remanufactured engine. After 7,000 miles, it came back with a knock. Inspection revealed a broken flex plate, which was replaced. It returned again after another 7,000 miles with a knock, and another broken flex plate. A new GM flex plate was installed. It returned a third time with the same problem.

After the transmission was removed, it was discovered that the replacement engine did not come with the alignment dowels, and this omission was overlooked three times. Installation of the alignment dowels and a new flex plate solved this problem.

SUMMARY:

Complaint—Customer complained about a knocking sound.

Cause—The replacement engine block did not have alignment dowels installed.

Correction—The installation of the alignment dowels and a new flex plate solved this problem.

DYNAMOMETER TESTING

A rebuilt automatic transmission/transaxle can be tested for proper operation on a dynamometer powered by:

- An electric motor. **SEE FIGURE 17–44.**
- A gasoline engine. **SEE FIGURE 17–45.**

Most dynamometers are equipped with a load applying unit and pressure gauges so that their proper operation can be checked before installation.

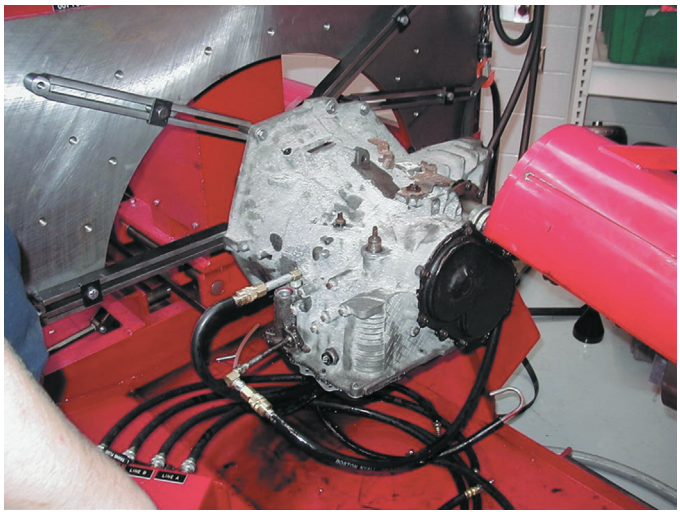


FIGURE 17–44 An electric motor-driven dynamometer being used to check the operation of a 41TE transaxle.

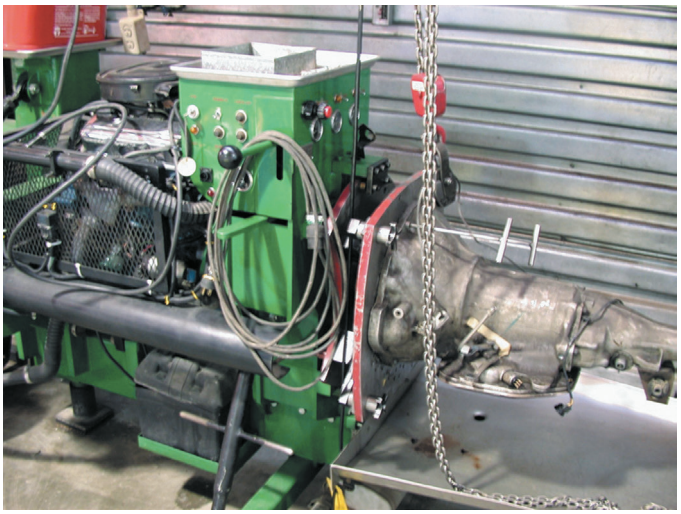


FIGURE 17–45 A gasoline-powered dynamometer being used to test a rear-wheel-drive automatic transmission.

TRANSMISSION INSTALLATION

STEPS INVOLVED Installing a transmission is the reverse of the removal procedure. The last operation in the removal is usually the first step in the installation.

Installation of an automatic transmission or transaxle usually involves the following steps:

STEP 1 Before installing the transmission, make sure that the transmission alignment dowels and the wiring harness are in place and all of the connectors are properly connected.

STEP 2 Raise the transmission into position and slide it to place it against the engine.

CAUTION: Do not use the bolts to pull the transmission/transaxle to the engine block.

STEP 3 Install the transmission-to-engine bolts and tighten them to the correct torque.

STEP 4 Place the transmission supports into position, lower the transmission onto the mounts, and tighten the mounting bolts to the correct torque.

STEP 5 Slide the converter forward to align with the flex plate. Install the bolts and tighten them to the correct torque.

STEP 6 Connect the cooler lines and tighten them to the correct torque.

STEP 7 Replace the driveshaft(s) and tighten any retaining bolts to the correct torque.

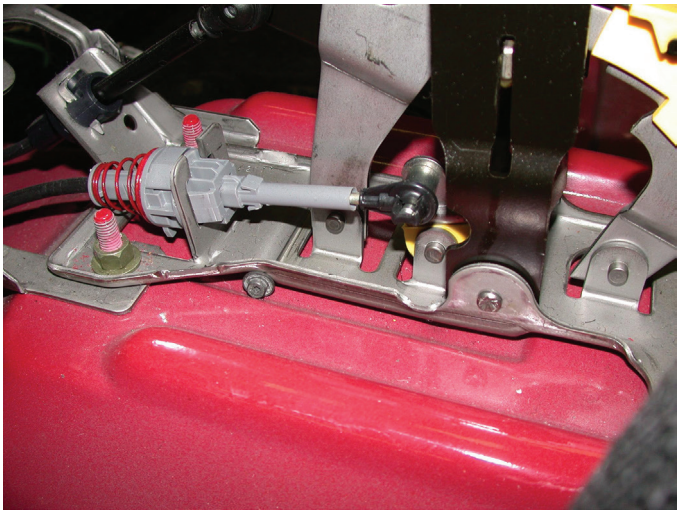


FIGURE 17–46 Check the linkage for proper adjustment so that the shift interlock works correctly and the PRNDL is aligned with the transmission range switch.

STEP 8 Reconnect all linkage and wire connections that were disconnected, making sure they are routed properly. ● **SEE FIGURE 17–46.**

After installation, the transmission should be filled with the correct amount of ATF and the engine started. Adjust the fluid level after starting the engine and operating the transmission in the different gear ranges.

FAST LEARN THE PCM/TCM For an electronic transmission/transaxle to operate correctly, a "fast learn" or a "quick learn" should be performed with a scan tool before the vehicle is driven. This action will get the adaptive settings close

to what they should be and will help prevent damage to the unit if this procedure is not done. In addition, Chrysler has a torque converter burnishing mode that can be activated on the scan tool for some models.

Adapts and fast-learn procedures should be performed if any of the following occur:

- Internal transmission repairs have been performed
- The valve body was replaced
- The control solenoid valve assembly was replaced
- The TCM was recalibrated or replaced
- Internal repairs such as replacing worn clutch friction plates were performed that could affect shift quality

To perform a fast learn

- Use a scan tool capable of performing the fast-learn procedure. **SEE FIGURE 17–47.**
- Transmission fluid temperature (TFT) should be 158°F to 230°F (70° to 110°C). Move the selector in/out of gear three times.
- Select the fast learn process from the scan tool menu.
- Place the transmission in "drive" with the vehicle stationary. The TCM will individually apply the clutches and calculate the clutch volume.

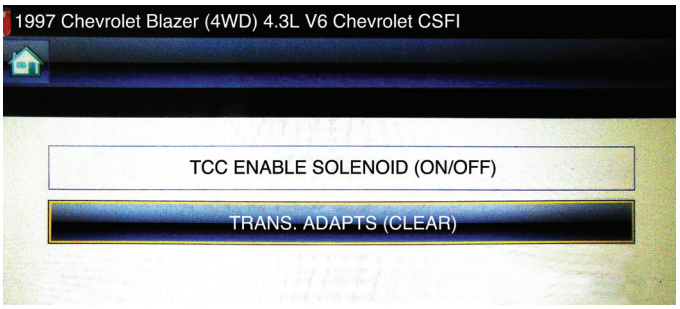


FIGURE 17–47 A screen shot on a Snap-on Solus scan tool showing where to clear the adaptives prior to test driving the vehicle after an overhaul.

- Place the transmission in "reverse" with the vehicle stationary. The TCM will individually apply the clutches and calculate the clutch volume.
- Shut off the engine for at least 30 seconds.

ROAD TEST PROCEDURE Carefully drive the vehicle checking for proper operation and shift points. Hoist the vehicle and check for any possible ATF leaks before returning vehicle to the customer.

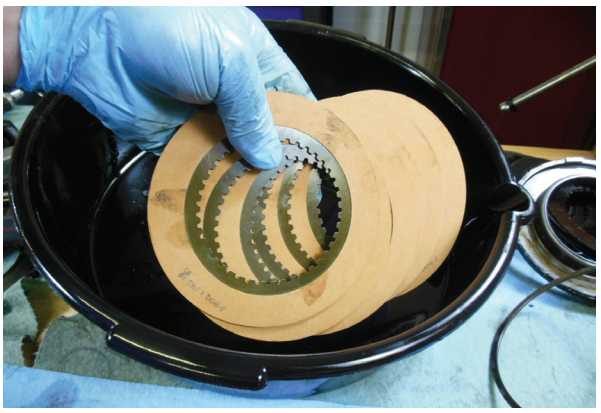
1 After cleaning all of the parts, read, understand and follow the instructions that come with the overhaul kit.

2 A new seal is installed.

3 All bearings and thrust washers should be lubricated with assembly lube during assembly.

4 The band is installed after soaking in ATF.

5 All of the seals being laid out and compared before being installed. They too should be covered with ATF or assembly lube before being installed.



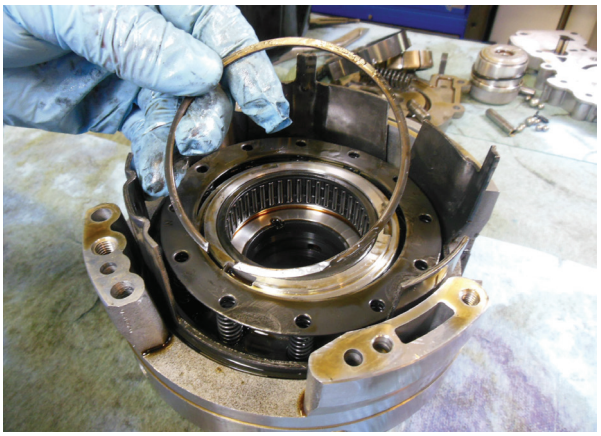
6 All friction discs should be soaked in ATF for at least 20 minutes or until the bubbles stop.

CONTINUED ▶

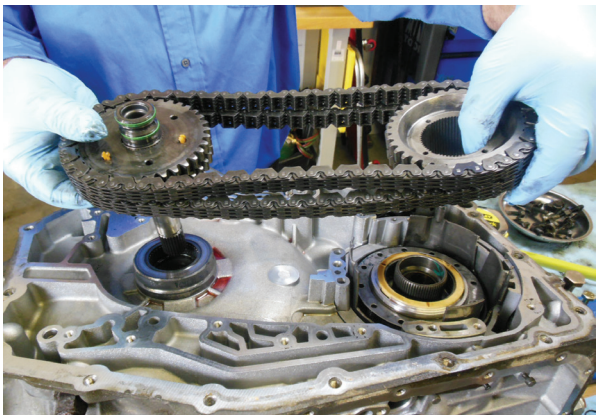
STEP BY STEP

7 All piston seals are replaced as part of the overhaul procedure. The piston is then installed using a lip seal plastic disc to help prevent the seal lip from curling over during installation.

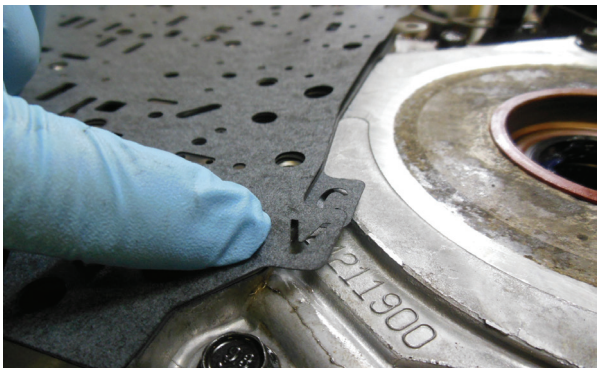
8 Assembling a clutch pack with soaked frictions and then steel plates.



9 The return springs have to be compressed before installing the retaining ring.



10 The drive chain being installed after checking that the black link is up the same way it was when it was disassembled.



11 Before assembling the valve body, always check the valve body gasket labeled "V" and the gasket that goes against the case, label "C" to make sure that they match the ones that were removed when the unit was disassembled.

12 All fasteners should be tightened to factory specifications using a torque wrench.

SUMMARY

1. A transmission overhaul includes disassembling, cleaning, replacing worn parts, and reassembling to its original clearances.
2. Transmission parts cleaning methods that are commonly used include:
   - Hot spray wash
   - Solvent wash
   - Water (aqueous) solution wash
   - Microbe cleaning
3. Bushings and bearings are carefully checked and replaced as necessary. A bushing or thrust washer must have an operating clearance of about 0.003 to 0.005 inch (0.076 to 0.157 mm) to allow a good oil flow across the bearing surface.
4. Clutches are serviced by inspecting and replacing the friction material and seals.
5. Sealing rings must be replaced and the surfaces they seal against must be carefully inspected and serviced as needed. An O-ring should produce some drag and a square-cut seal is normal if it produces a barely noticeable drag.
6. Uncut Teflon rings require two special tools for installation:
   a. An installing tool.
   b. A resizing tool.
7. Warpage can produce a cross leak, which is a leak from one passage to another. A cross leak can cause an unwanted, partial application of a clutch or band that can lead to an early failure.
8. The pump is disassembled and inspected. The bushings and seals are replaced before reassembly.
9. When rebuilding a clutch, the friction plates, piston seals, and bushings are replaced.
10. Air testing is a valuable diagnostic tool and is also used as a final quality-control check during transmission assembly. Air tests are used to tell if a clutch or band servo operates, and if the passages are properly sealed.
11. For an electronic transmission/transaxle to operate correctly, a "fast learn" or a "quick learn" should be performed with a scan tool before the vehicle is driven.

REVIEW QUESTIONS

1. What cleaning methods can be used to clean automatic transmission/transaxle parts?
2. What is a Torrington bearing?
3. Uncut Teflon rings require what two special tools for installation?
4. What are the two ways to check clutch pack clearance?
5. Why should clutches and bands be air checked?
6. Why does the adaptive learning need to be reset after an overhaul?

CHAPTER QUIZ

1. Cleaning methods that are commonly used include _____.
   a. Hot spray wash
   b. Water (aqueous) solution wash
   c. Microbe cleaning
   d. All of the above
2. A radial needle bearing is commonly called a _____.
   a. Bushing **c.** Bearing
   b. Torrington **d.** Cup
3. Tapered roller bearings must be adjusted to get the correct end play or preload. This is usually achieved by using _____.
   a. Selective thickness shims
   b. Various sizes of races
   c. Different size rollers
   d. Different tapers used for the bearings
4. New lined material should be soaked in ATF for at least _____ before installation.
   a. 5 minutes **c.** 20 minutes
   b. 10 minutes **d.** 60 minutes (an hour)
5. What is needed to properly fit a Teflon seal?
   a. An installation tool
   b. A sizing tool
   c. Hot water to soften the ring
   d. All of the above
6. Clutch pack clearance can be checked using _____.
   a. A feeler gauge
   b. A dial indicator
   c. Either a or b depending on the clutch and access to measure the clearance
   d. Both methods should be used to insure accuracy

7. Air testing is used to _____.
   a. Check the operation of the pump
   b. Test the valve body valve operation
   c. Test the clutches and bands for proper operation and to detect possible leaks
   d. Operate the speed sensors

8. Technician A says that an end play check should be performed to make sure that the unit has been correctly assembled. Technician B says that the end play check can be used to check for proper internal clearances. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B

9. What should be done when installing a transmission/transaxle into a vehicle?
   a. Make sure that the transmission alignment dowels are installed.
   b. Connect the cooler lines and tighten them to the correct torque.
   c. Check the linkage for proper adjustment so that the shift interlock works correctly and the PRNDL is aligned with the transmission range switch.
   d. All of the above.

10. "Fast learn" or a "quick learn" should be performed using _____ before the vehicle is driven.
   a. Pressure gauges
   b. Scan tool
   c. Dial indicator
   d. Valve body tester

appendix 1
SAMPLE A2 ASE CERTIFICATION-TYPE TEST

A GENERAL TRANSMISSION/TRANSAXLE DIAGNOSIS 25 QUESTIONS

1. Two technicians are discussing an electronically controlled automatic transmission that will not go into forward or reverse gears. Technician A says that a defective computer could be the cause. Technician B says that an excessively worn torque converter clutch could be the cause. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
2. A vehicle equipped with an electronically controlled transaxle stalls whenever slowing to a stop after being driven over 20 miles (32 km). Technician A says that one of the shift solenoids could be defective. Technician B says that a torque converter clutch solenoid is likely to be defective. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
3. An electronically controlled automatic transmission operates normally in reverse but the vehicle does not shift at all when moving forward. Technician A says that a defective torque converter is the likely cause. Technician B says that a defective computer could be the cause. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
4. An electronically controlled overdrive automatic transmission is equipped with a transmission fluid temperature sensor. Technician A says that the shift points may be changed if the fluid temperature is too low. Technician B says that overdrive may be disabled if the transmission fluid temperature is too high. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
5. An automatic overdrive transmission does not shift into overdrive. It functions normally in all other gear ranges. Technician A says that the gear selector display (PRNDL) or manual linkage may not be properly adjusted. Technician B says the governor may be defective. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
6. An automatic transmission in a rear-wheel-drive vehicle does not go into either drive or reverse. Which is the most likely cause?
   a. A defective vacuum modulator
   b. A defective governor
   c. An incorrectly adjusted TV cable
   d. A defective pump
7. An automatic transmission is not shifting correctly. A check of the fluid level indicates that the fluid is full of air bubbles. Technician A says that the fluid level may be too high (overfilled). Technician B says that the fluid level may be too low. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
8. A rear-wheel-drive vehicle equipped with an automatic transmission shudders during hard acceleration from a stop. Technician A says that the transmission mounts may be collapsed causing a change in the driveshaft angle. Technician B says that a slipping direct (forward) clutch is a possible cause. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
9. Two technicians are discussing the diagnosis of an automatic transmission that is not shifting correctly. Technician A says that the mainline pressure should be checked. Technician B says that the cooler pressure should be checked if a pressure tap is available. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B

10. All of the following service operations should be performed during a routine troubleshooting procedure of an automatic transmission/transaxle fault except
    a. Checking the fluid level
    b. Adjusting the TP sensor
    c. Checking the line pressure
    d. A thorough test drive

11. The line to the vacuum modulator was removed and automatic transmission fluid ran out of the hose. Technician A says that this is normal and that the line should be reinstalled as quickly as possible to avoid spilling any additional fluid. Technician B says the line should only be removed when the engine is running. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

12. ATF is observed leaking out of the bell housing area of an automatic transmission. Technician A says that the fluid may have been overfilled and it is leaking out of the vent pipe. Technician B says that the front seal may require replacement. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

13. A vehicle equipped with an electronically controlled automatic transmission has a defective throttle position (TP) sensor. Technician A says that the transmission will default to second or third gear and will not upshift regardless of how fast the vehicle is driven. Technician B says that the transmission may or may not shift differently depending on the vehicle. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

14. Two technicians are discussing an electronically controlled automatic transmission that does not shift correctly. Technician A says that a shift valve may be stuck. Technician B says that the transmission range switch may be out of adjustment. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

15. An electronically controlled automatic transmission shifts harshly. Technician A says that the electronic pressure control (EPC) solenoid may be defective. Technician B says that the torque converter clutch solenoid may be defective. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

16. During a stall test, the engine speed is lower than specifications. Technician A says that the clutch inside the torque converter may be defective. Technician B says that the engine may have a drivability problem, which would cause it to produce less than normal power. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

17. A vehicle is slow in accelerating at low vehicle speed only yet shifts at the proper speeds. Technician A says that the torque converter may be defective. Technician B says that the torque converter clutch may be slipping. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

18. A customer complained of poor fuel economy. Technician A says that the torque converter clutch may be defective. Technician B says that the automatic transmission/transaxle may not be shifting into overdrive. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

19. Technician A says that a defective brake switch can prevent the operation of the torque converter clutch. Technician B says that a fault in the engine operation can be felt as a transmission fault by many drivers. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

20. Two technicians are discussing pressure gauge readings. Technician A says that if the pressure is too low, a clogged filter or an internal leak could be the cause. Technician B says if the pressure is too high at the wrong time, such as at gear changes, an internal leakage at a servo or clutch seal is likely. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

21. After an overhaul, an electronically controlled transaxle shifts too harshly. Technician A says that the electrical connector(s) at the transaxle may not be properly attached. Technician B says that the wrong type of ATF may be the cause. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B

22. A pressure test is being performed with the engine running and the gear selector in park except where stated. All of the following test results are within standard parameters *except*
    a. Mainline pressure is 50 PSI
    b. Governor pressure is 50 PSI
    c. Cooler line pressure is 50 PSI
    d. Low/reverse is 150 PSI (in reverse)

23. A stall test is being performed with the results shown. The specification for this vehicle is 1850 to 1950 RPM. What is the most likely cause?
a. A weak or excessively worn engine
b. A slipping forward clutch
c. A defective torque converter clutch
d. A defective or out-of-adjustment manual valve

24. Pressure gauges are attached to the transmission and the vehicle is being test driven. The pressures are all within specifications until the vehicle is accelerated rapidly and the mainline pressure decreases. Which is the most likely cause?
a. A slipping forward clutch
b. A defective (slipping) torque converter clutch
c. A stuck shift valve
d. A clogged filter

25. A vibration is being diagnosed on a rear-wheel-drive vehicle. The torque converter was separated from the flexplate and the vibration was eliminated. Which is the *most likely* cause?
a. A worn or damaged pump assembly
b. A defective torque converter
c. A defective U-joint(s)
d. A worn extension housing bushing

B IN-VEHICLE TRANSMISSION/TRANSAXLE MAINTENANCE AND REPAIR 12 QUESTIONS

26. A technician performed an automatic transmission fluid service and refilled the unit with the incorrect automatic transmission fluid (friction modified instead of highly friction modified). Technician A says that the transmission will slip. Technician B says that shudder or harsher than normal shifts are likely to occur. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

27. The pan has been removed from an automatic transmission and nonmetallic material is found at the bottom. Technician A says that it is normal to have some friction material at the bottom of the pan. Technician B says that the transmission should be disassembled to find the exact location where the wear has occurred. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

28. Two technicians are discussing the adjustment of the band shown. Technician A says that the locknut should be loosened and the adjustment screw torqued to factory specifications, and then the locknut tightened. Technician B says the adjustment screw is used to adjust the clearance between the drum and the band. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

29. When checking for excessive voltage drop of the battery ground connection, what meter selection should be used?
a. DCV
b. ACV
c. Hz
d. A

30. Technician A says that the manual linkage may get out of adjustment if an engine or transmission mount were to fail. Technician B says that the shift selector (PRNDL) should be adjusted so it matches the manual valve detents. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

31. What is the usual method to tighten the retaining bolts for the pan on automatic transmission/transaxles?
a. Start by hand to avoid cross threading
b. Tighten gradually
c. A torque wrench should be used to achieve the final torque
d. All of the above

32. A hydraulically controlled automatic transmission is not shifting correctly. Which service operation should the technician perform first?
a. Perform a pressure test
b. Adjust the bands
c. Check the transmission fluid
d. Check for proper engine vacuum

33. An electronically controlled automatic transmission is not shifting correctly. All of the following should be performed to locate the cause except
a. Checking the transmission fluid
b. Checking scan tool data (PID)
c. Retrieving stored diagnostic trouble codes (DTCs)
d. Reflashing the computer

34. Proper operation of electronically controlled automatic transmission/transaxles depends on proper charging voltage. The proper charging voltage should be _____.
a. 5 volts
b. 10 to 12 volts
c. 13 to 15 volts
d. 16 volts or higher

35. Technician A says that the cooler should always be flushed whenever replacing an automatic transmission/transaxle. Technician B says that aqueous (water-based) solvent should be used to flush a cooler. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

36. An automatic transmission/transaxle pump volume test is being performed. Technician A says that a good pump should be able to pump about 2 quarts (2 liters) in 30 seconds through the cooler. Technician B says that the engine should be operated at about 1000 RPM during the cooler flow test. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

37. Two technicians are discussing an automatic transmission fluid leak from the rear seal of the extension housing on a rear-wheel-drive automatic transmission. Technician A says that the driveshaft has to be removed to replace the seal. Technician B says that the bushing in the extension housing may also need to be replaced. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

C OFF-VEHICLE TRANSMISSION/TRANSAXLES REPAIR 13 QUESTIONS

38. Regulated air pressure is often used to test _____.
a. Clutch packs
b. TV adjustment
c. Vacuum modulators
d. Governors

39. Technician A says that all friction and steel plates in a clutch pack should be replaced during an overhaul. Technician B says that the automatic transmission fluid cooler should always be flushed when a unit is rebuilt or replaced. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

40. What part(s) should be marked before removal?
a. Pump gears
b. The direction the steels are installed in the clutch packs
c. The snap rings
d. The planetary gears

41. Two technicians are discussing removal of an automatic transmission from a rear-wheel-drive vehicle. Technician A says that the cooler lines have to be removed before the driveshaft is removed. Technician B says that the engine should be supported before removing the transmission. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

42. Two technicians are discussing overhauling an automatic transmission/transaxle. Technician A says that all rubber seals and the friction discs should be replaced. Technician B says that all the steel discs should also be replaced as part of an overhaul. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

43. Technician A says that all clutch packs should be air checked before being installed into the automatic transmission/transaxle. Technician B says that the clutch pack clearance can be checked with a dial indicator. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

44. Technician A says that selective thickness snap rings or pressure or retaining plates are used to obtain the proper clutch pack clearance. Technician B says that air checking a clutch pack will determine whether or not the clutch pack clearance is okay. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

45. Technician A says that friction discs should be soaked in ATF before being assembled in a clutch pack. Technician B says that the seals and O-rings should be soaked for several hours before being installed in a clutch pack. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

46. Proper assembly of an automatic transmission/transaxle can be verified by performing the following tests except:
a. End play measurements
b. Clutch pack measurements
c. Vacuum testing the regulator valve
d. Air pressure checks

47. Technician A says that assembly lube can be used on all seals and O-rings during assembly of an automatic transmission/transaxle. Technician B says that automatic transmission fluid can be used to lubricate seals and O-rings during the assembly of an automatic transmission/transaxle. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

48. Technician A says that pulse-width-modulated solenoids have higher resistance than shift solenoids that are simply pulsed on and off. Technician B says that all solenoids should be checked for proper resistance before the automatic transmission/transaxle is installed in the vehicle. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

49. The clutch pack clearance is less than that specified. Technician A says that too many friction discs may have been installed. Technician B says that too thin a clutch pack pressure plate may have been installed. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

50. A technician left out the wavy spring from a clutch pack. Technician A says that the shift may be too soft. Technician B says that the shift may be too harsh. Which technician is correct?
a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B

ANSWERS

1.	d	**14.**	c	**27.**	a	**40.**	a
2.	b	**15.**	a	**27.**	b	**41.**	b
3.	b	**16.**	b	**29.**	a	**42.**	a
4.	c	**17.**	a	**30.**	c	**43.**	c
5.	a	**18.**	c	**31.**	d	**44.**	a
6.	d	**19.**	c	**32.**	c	**45.**	a
7.	c	**20.**	a	**33.**	d	**46.**	c
8.	c	**21.**	b	**34.**	c	**47.**	c
9.	c	**22.**	b	**35.**	a	**48.**	b
10.	b	**23.**	b	**36.**	c	**49.**	a
11.	d	**24.**	d	**37.**	c	**50.**	b
12.	b	**25.**	b	**38.**	a		
13.	b	**26.**	b	**39.**	b		

appendix 2
2013 NATEF CORRELATION CHART

MLR—Maintenance & Light Repair
AST—Auto Service Technology (Includes MLR)
MAST—Master Auto Service Technology (Includes MLR and AST)

AUTOMATIC TRANSMISSION AND TRANSAXLE (A2)

TASK	PRIORITY	MLR	AST	MAST	TEXT PAGE #	TASK PAGE #
A. GENERAL: TRANSMISSION AND TRANSAXLE DIAGNOSIS						
1. Identify and interpret transmission/transaxle concern, differentiate between engine performance and transmission/transaxle concerns; determine necessary action.	P-1		✔	✔	187–204	34
2. Research applicable vehicle and service information fluid type, vehicle service history, service precautions, and technical service bulletins.	P-1	✔	✔	✔	20–21; 187–194	3, 4, 5, 17
3. Diagnose fluid loss and condition concerns; determine necessary action.	P-1	✔ Fluid condition and check for leaks only	✔	✔	188–192	35
4. Check fluid level in a transmission or a transaxle equipped with a dipstick.	P-1	✔	✔	✔	189	36
5. Check fluid level in a transmission or a transaxle not equipped with a dipstick.	P-1	✔	✔	✔	190	36
6. Perform pressure tests (including transmissions/transaxles equipped with electronic pressure control); determine necessary action.	P-1			✔	201–203	37
7. Diagnose noise and vibration concerns; determine necessary action.	P-2			✔	187–188; 197–200	38
8. Perform stall test; determine necessary action.	P-3		✔	✔	60–61	12
9. Perform lock-up converter system tests; determine necessary action.	P-3		✔	✔	58–59; 193–196	13
10. Diagnose transmission/transaxle gear reduction/multiplication concerns using driving, driven, and held member (power flow) principles.	P-1		✔	✔	70–76	39
11. Diagnose electronic transmission/transaxle control systems using appropriate test equipment and service information.	P-1			✔	192–197	30
12. Diagnose pressure concerns in a transmission using hydraulic principles (Pascal's Law).	P-2		✔	✔	30–36	10

TASK	PRIORITY	MLR	AST	MAST	TEXT PAGE #	TASK PAGE #
B. IN-VEHICLE TRANSMISSION/TRANSAXLE MAINTENANCE AND REPAIR						
1. Inspect, adjust, and replace external manual valve shift linkage, transmission range sensor/switch, and park/neutral position switch.	P-2	✔	✔	✔	211–212	42
2. Inspect for leakage; replace external seals, gaskets, and bushings.	P-2	✔	✔	✔	210–211	44; 56
3. Inspect, test, adjust, repair, or replace electrical/electronic components and circuits including computers, solenoids, sensors, relays, terminals, connectors, switches, and harnesses.	P-1		✔	✔	134–144	42
4. Drain and replace fluid and filter(s).	P-1	✔	✔	✔	208–209	41
5. Inspect, replace, and align powertrain mounts.	P-2	✔	✔	✔	212–213	40
C. OFF-VEHICLE TRANSMISSION AND TRANSAXLE REPAIR						
1. Remove and reinstall transmission/transaxle and torque converter; inspect engine core plugs, rear crankshaft seal, dowel pins, dowel pin holes, and mating surfaces.	P-1		✔	✔	221–222; 263–264;	45
2. Inspect, leak test, and flush or replace transmission/transaxle oil cooler, lines, and fittings.	P-1		✔	✔	207–210	43
3. Inspect converter flex (drive) plate, converter attaching bolts, converter pilot, converter pump drive surfaces, converter end play, and crankshaft pilot bore.	P-2		✔	✔	61–63	14
4. Describe the operational characteristics of a continuously variable transmission (CVT).	P-3	✔	✔	✔	166–175	32
5. Describe the operational characteristics of a hybrid vehicle drivetrain.	P-3	✔	✔	✔	147–163	31
6. Disassemble, clean, and inspect transmission/transaxle.	P-2			✔	223–228	46
7. Inspect, measure, clean, and replace valve body (includes surfaces, bores, springs, valves, sleeves, retainers, brackets, check valves/balls, screens, spacers, and gaskets).	P-2			✔	237–242	55
8. Inspect servo and accumulator bores, pistons, seals, pins, springs, and retainers; determine necessary action.	P-2			✔	224–225	57
9. Assemble transmission/transaxle.	P-2			✔	246–262	58
10. Inspect, measure, and reseal oil pump assembly and components.	P-2			✔	253–255	11
11. Measure transmission/transaxle end play or preload; determine necessary action.	P-1			✔	260	59
12. Inspect, measure, and replace thrust washers and bearings.	P-2			✔	246–247	47
13. Inspect oil delivery circuits, including seal rings, ring grooves, and sealing surface areas, feed pipes, orifices, and check valves/balls.	P-2			✔	250–251	48
14. Inspect bushings; determine necessary action.	P-2			✔	246–247	49
15. Inspect and measure planetary gear assembly components; determine necessary action.	P-2			✔	258–259	50

TASK		PRIORITY	MLR	AST	MAST	TEXT PAGE #	TASK PAGE #
16.	Inspect case bores, passages, bushings, vents, and mating surfaces; determine necessary action.	P-2			✔	251–253	51
17.	Diagnose and inspect transaxle drive, link chains, sprockets, gears, bearings, and bushings; perform necessary action.	P-2			✔	226	52
18.	Inspect measure, repair, adjust, or replace transaxle final drive components.	P-2			✔	260–261	53
19.	Inspect clutch drum, piston, check balls, springs, retainers, seals, and friction and pressure plates, bands, and drums; determine necessary action.	P-2			✔	255–257	54
20.	Measure clutch pack clearance; determine necessary action.	P-1			✔	257	54
21.	Air test operation of clutch and servo assemblies.	P-1			✔	259	54
22.	Inspect roller and sprag clutch, races, rollers, sprags, springs, cages, and retainers; determine necessary action.	P-2			✔	258	16

GLOSSARY

Aboveground storage tank (AGST) A storage tank that stores used oil and is located above ground.

Accumulator A device used to dampen fluid apply pressure so as to cushion or soften a shift.

Actuator An electromechanical device that performs mechanical movement as commanded by a controller.

Adaptive control The PCM can learn how long a shift takes to complete and will command that the start the shift occurs sooner to allow time for the clutch to be fully engaged. The adjustment is called *adaptive learning*.

Adaptive learning See Adaptive control.

Additives Chemicals added to automatic transmission fluid (ATF) to improve the operating characteristics.

Aftermarket Referring to repair parts produced by companies other than OEM.

All-wheel drive (AWD) Vehicles are four-wheel-drive vehicles equipped with a center (inner-axle) differential so they can be operated on pavement in four-wheel drive.

Ammeter An electrical test instrument used to measure amperes (unit of the amount of current flow).

Ampere The unit of the amount of current flow. Named for André Ampère (1775–1836).

Aqueous-based solutions Water-type chemicals that are silicate based and mixed with water. Aqueous-based solutions can sprayed on or used in a tank for soaking parts.

Asbestosis A health condition where asbestos causes scar tissue to form in the lungs, causing shortness of breath.

Automated manual transmission (AMT) Another term used to describe a dual-clutch automatic transmission/transaxle.

Automatic transmission A transmission that changes forward-gear ratios automatically.

Automatic transmission fluid (ATF) The oil used in automatic transmissions.

Balance valve A valve that is in a balanced position between two opposing forces.

Battery Council International (BCI) A trade organization of battery manufacturers.

Bearings Nonfriction bearings that use balls or rollers as rolling elements to reduce friction.

Belleville plate A Belleville plate, like a Belleville spring, is not flat and are often called *cushion plates*.

Bench grinder A type of electric motor driven grinder that mounts to a bench.

Bevel gear A gear with teeth that are cut at an angle so it can transmit power between shafts that are not parallel.

Bolt The major type of threaded fastener used with a nut to secure parts together.

Breaker bar A long-handled socket drive tool.

Brake on/off (BOO) Another name for the brake switch.

Bushing A simple soft metal bearing surface that must use lubricants to reduce friction.

Bump cap A hard plastic hat to protect the head from bumps.

Calibration codes Codes used on many powertrain control modules.

Campaign A recall where vehicle owners are contacted to return a vehicle to a dealer for corrective action.

Casting number An identification code cast into an engine block or other large cast part of a vehicle.

Cheater bar A bar used on a wrench to increase the amount of torque that can be applied to a fastener. Not recommended.

Check ball A check ball is the simplest method of controlling fluid flow. A one-way check valve resembles a steel bearing or plastic ball located over a hole in the separator plate.

Chisels A type of hand tool used with a hammer to cut or mark metal and other materials.

Clean Air Act (CAA) Federal legislation passed in 1970 and updated in 1990 that established national air quality standards.

Clutch A device that controls the power transfer between two points. It can allow or stop the transfer.

Clutch cooling flow solenoid (CCFS) The solenoid that controls hydraulic oil for cooling of clutches of a dual clutch automatic transmission.

Clutch pack clearance The clearance in between the plates in a clutch pack and is normally measured using a feeler gauge placed between the pressure plate and the snap ring.

Clutch pressure cut (CPCUT) The safety valve that controls pressure-dumping in the hydraulic system in a dual clutch automatic transmission.

Clutch shift pressure solenoid Controls hydraulic pressure for odd clutch or shifting in a dual clutch automatic transmission.

Clutch volume index (CVI) Transmissions use an input and an output speed sensors allowing the TCM to determine the gear ratio and how long it takes to make the shift. Chrysler refers to the adaptive control as the clutch volume index (CVI), which is the length of time it takes to fill the clutches with fluid.

Clutch-to-clutch A transmission that shifts by releasing one clutch as it applies another clutch to change the power flow.

Code of Federal Regulations (CFR) A compilation of the general and permanent rules published in the federal register by the executive departments and agencies of the federal government.

Concentric clutch A clutch design where both plates share the same vertical plane provides a shorter assembly.

Conductors A material that conducts electricity and heat. A metal that contains fewer than four electrons in its atom's outer shell.

Connector The plastic part of an electrical connection that includes a locking tab to keep two parts together.

Constant-velocity (CV) joint A type of driveline joint that are designed to rotate without changing speed.

Continuously variable transmission (CVT) A transmission that uses two variable-width pulleys and a belt to change ratios from the lowest to the highest in a continuous, stepless manner instead of a group of fixed ratios.

Conventional theory The theory that electricity flows from positive (+) to negative (–).

Coupling phase A condition where the torque converter turbine speed is almost equal to that of the impeller.

Creep Creep is the slight movement of the vehicle when the engine is at idle speed and the brakes are released and is normal for a vehicle equipped with an automatic transmission.

Crimp-and-seal connectors A type of electrical connector that has glue inside which provides a weather-proof seal after it is heated.

Cross leak A cross leak can cause an unwanted, partial application of a clutch or band that can lead to an early failure.

Cushion plate See Bellville plate.

Damper assembly An assembly that uses springs to dampen engine power pulses from being transferred to the rest of the drivetrain.

Default (Limp in) A default (or limp-in) gear is the forward speed that is used if there is a failure in the electronic or computer system. If neither of two shift solenoids were engaged, then a default gear is actuated.

Depth filter A depth filter traps particles as they try to pass through the filter material. Depth filters use felt or a synthetic material of various thickness. The depth of the material allows room to trap particles as well as room for fluid flow.

Differential A gear arrangement that allows the drive wheels to be driven at different speeds.

Digital multimeter (DMM) A digital multimeter is capable of measuring electrical current, resistance, and voltage.

Digital volt-ohm-meter (DVOM) A digital multimeter is capable of measuring electrical current, resistance, and voltage.

Direct clutch The clutch in front of a Simpson gear train transmission. Also called a *front clutch* or a *high-reverse clutch.*

Directional grooving Slanted grooves in the friction plates that must face the proper direction.

Direct shift gearbox (DSG) Another term used to describe a dual-clutch automatic transmission/transaxle.

Double-wrap band A type of transmission band gives more holding power, and are often used for reverse or manual first gears.

Drive axle An assembly containing the differential assembly and the drive axles.

Driveshaft A shaft that transfers engine torque from the output of the transmission to the rear axle (differential) assembly.

Drive sizes The size in fractions of an inch of the square drive for sockets.

Driving devices Driving devices connect the turbine shaft from the torque converter to the elements of the planetary gear train.

Drum The drum, also called the *housing*, has internal splines that mate with external splines on the steel plates for the externally lugged discs, usually the unlined discs (steels). The inner diameter of the drum is machined for the apply piston and its inner and outer seals.

Dynamic friction The relative amount of friction between two surfaces that are at different speeds. *See* Static friction.

Dynamometer A machine used to measure engine torque.

Electricity The movement of free electrons from one atom to another.

Electron theory The theory that electricity flows from negative (–) to positive (+).

Electronically variable transmission (EVT) The term used to describe the transmission used a General Motor's two-mode unit. It includes three simple planetary gear sets with four multi-plate clutches. It has four fixed gear ratios with two EV ratios for smooth, more efficient operation.

Electronic pressure control (EPC) A pulse-width-modulated solenoid used to control the transmission's hydraulic pump pressure regulator valve.

Environmental Protection Agency (EPA) A governmental agency that is charged with protecting human health and with safeguarding the natural environment: air, water, and land.

Extensions A socket wrench tool used between a ratchet or breaker bar and a socket.

Eye wash station A water fountain designed to rinse the eyes with a large volume of water.

Files A type of hand tool used to smooth metal and other materials.

Final drive The last set of reduction gears before the power flows to the differential and drive axles.

Fire blanket A fire-proof wool blanket used to cover a person who is on fire to smother the fire.

Fire extinguisher classes The classification of fire extinguishers by the type of fires they are designed to handle.

Flex band A type of transmission band that is less expensive and, because of its flexibility, can easily conform to the shape of the drum.

Flexplate The thin drive plate that connects the torque converter to the crankshaft of the engine.

Fluid change The replacement of the automatic transmission fluid. Most manufacturers recommend fluid changes every 100,000 miles (160,000 km) under normal driving conditions. Some recommend a fluid change at 50,000 miles (80,000 km).

Fluid exchange Fluid exchange usually means taking out the old fluid and replacing it with new fluid of the correct type. By using a fluid exchange machine, all of the fluid in the system is replaced.

Fluid flushing Fluid flushing typically uses a chemical to dissolve varnish and other deposits.

Fluid Power A method of transmitting motion and/or force using a fluid.

Force motor *See* Pressure control solenoid.

Four-wheel drive (4WD) Four-wheel drive (4WD) is often designated as "4 × 4" and refers to a vehicle that has four driven wheels.

Free fall test The free fall test is a standard check for a sticking valve. Hold the valve body so the bore is vertical. In this position, a steel valve should fall freely from one end of the bore to the other and it should at least fall through the area of normal valve movement.

Freewheel shift Freewheel shifts, also called nonsynchronous *shifts* use one or more one-way clutches as driving or reaction devices. A one-way clutch will self-release during a shift as soon as the next clutch applies, eliminating the need to synchronize the shifts.

Friction modifier An additive that changes the lubricity of a fluid.

Friction plates Plates lined with friction material, also called friction *discs* or simply *frictions*. These plates are also made from stamped steel with lining material bonded to each side.

Front clutch The clutch in front of a Simpson gear train transmission and is also called a *direct clutch* or a *high-reverse clutch*.

Front-wheel drive (FWD) A vehicle that uses the engine to drive the front wheels.

Garage shift A shift from neutral or park to drive or reverse.

GAWR Abbreviation for gross axle weight rating.

Gear ratio The relationship between two gears determined by dividing the number of teeth on the driving gear by the number of teeth on the driven gear and expressed as a ratio to 1.

Gerotor A design of oil pump.

Grade The strength rating of a bolt.

GVWR Abbreviation for gross vehicle weight rating.

Hacksaws A type of hand tool that is used to cut metal and other materials.

Half shaft Drive axles on a front-wheel drive vehicle or from a stationary differential to the drive wheels.

Hall effect A semiconductor moving relative to a magnetic field, creating a variable voltage output. Used to determine position and named for Edwin H. Hall, who discovered the Hall Effect in 1879.

Hammers A type of hand tool used to force objects into position using a swinging motion.

Hard parts Major transmission components such as the pump, a clutch drum, or a gear set.

Hazardous waste materials Chemicals or components that are no longer needed and pose a danger to the environment or people.

Helical gear A gear that has the teeth cut at an angle.

HEPA vacuum High efficiency particulate air filter vacuum used to clean brake dust.

HEV Hybrid electric vehicle.

High resistance A type of electrical circuit fault that causes a reductions in current flow.

High-reverse clutch The clutch in front of a Simpson gear train transmission and also called a *front clutch* or a *direct clutch*.

Horsepower A measure of engine power derived from the torque and engine speed on revolutions per minute measurements.

Hydraulics The transfer of power through fluids under pressure.

Hypoid gear A special form of a bevel gear that has the teeth cut in a curvature and that positions the gear on nonintersecting planes; commonly used in rear-wheel-drive (RWD) final drives.

Impeller The input member of the torque converter; also called *converter pump*.

Input speed sensor (ISS) The sensor that measures the speed of the input shaft which is the same or almost the same as the engine speed. This is also called *turbine speed sensor (TSS)* because it is used to determine the speed of the turbine shaft.

Insulators A material that does not readily conduct electricity and heat. A nonmetal material that contains more than four electrons in its atom's outer shell.

Internal combustion engine (ICE) The term used to describe a gasoline or diesel fuel powered engine.

Internal–external gear When an external gear drives an internal gear, the two gears will rotate in the same direction.

Land The large-diameter portion of a spool valve.

LED Light emitting diode.

LePelletier gear train An automatic transmission gear train that combines a simple planetary gear set with a Ravigneaux gear set to produce six or more gear ratios.

Line pressure solenoid (LPS) The solenoid that controls the line pressure to the transmission hydraulic system.

Mainline pressure Regulated fluid pressure, also called, line, or control pressure is the working pressure for the entire hydraulic system.

Manual transmission A transmission that is shifted by the driver.

Manual valve The valve operated by the gear selector that directs pressure to the apply devices needed to put a transmission in gear.

Material safety data sheets (MSDSs) Forms containing data regarding the properties of a particular substance. Now called *safety data sheets (SDS)*.

Mechanical diode A one-way clutch that uses a set of spring-loaded struts for a lighter but stronger clutch action.

Mercury A heavy metal that is liquid at room temperature.

Metric bolts Bolts manufactured and sized in the metric system of measurement.

Micron A unit of measurement equal to one millionth of a meter.

MSDS Abbreviation for *material safety data sheets,* now called *safety data sheets (SDS)*.

Node Another name for a control module used in a network.

Nonsynchronous A design of an automatic transmissions where one clutch does not need to be released before the next clutch is applied. A nonsynchronous transmission is a unit that uses a one-way clutch to allow an upshift that requires only the application of the next driving or reaction member.

Nut A threaded fastener that is used with a bolt.

Occupational Safety and Health Administration (OSHA) A governmental agency that regulates workplace safety.

Ohmmeter An electrical tester deigned to measure electrical resistance in ohms.

Ohms The unit of electrical resistance. Named for George Simon Ohm.

Open circuit Any circuit that is not complete and in which no current flows.

Open/plain end ring A seal ring with the ends cut at a right angle.

Orifice A restricted opening in a fluid passage designed to reduce fluid pressure while fluid is flowing.

Output speed sensor (OSS) This speed sensor, also called the vehicle speed (VS) sensor, is used by the PCM for speedometer and cruise control operation as well as for transmission/transaxle operation and shift-related fault detection.

Overdrive A gear arrangement that causes the output shaft to turn faster than the input shaft.

Overhaul A complete overhaul includes disassembly of the entire assembly and replacing all needed parts and gaskets and seals to restore the transmission to like new performance.

Paper filter A filter made of a woven screen of metal or synthetic material such as dacron or polyester.

Parallel clutch A clutch design used in a dual clutch automatic where the clutches rearranged side-by-side.

Pinch weld seam A strong section under a vehicle where two body panels are welded together.

Pinion gear A small gear that meshes with a larger gear.

Pitch The distance between threads of a bolt and nut; the relative number of teeth or spacing of the teeth on a gear.

Pitch diameter The pitch diameter is the effective diameter of the gear. Note how the contact points slide on the gear teeth as they move in and out of contact.

Planetary gear set A gear set that contains a sun gear, ring gear, and a carrier with planet pinion gear to produce one or more gear ratios.

Planet carrier The part of a planetary gear set that contains the planetary pinion gears.

Pliers A type of hand tool that has two moveable parts and are used to hold or rotate an object or fastener.

Porsche Doppelkupplung (PDK) Another term used to describe a dual-clutch automatic transmission/transaxle used in Porsche vehicles.

Positive displacement pump A type of pump where each rotation of the pump delivers the same volume of oil and everything that enters must exit.

Potentiometer A 3-terminal variable resistor that varies the voltage drop in a circuit.

Powertrain control module (PCM) The electronic control module that it is used to control both the engine and transmission systems.

Power transfer unit The term used to describe the transfer case function used with a transaxle.

PPE Personal protective equipment.

Pressure balanced release A clutch design that uses fluid pressure to help release the clutch.

Pressure control solenoid (PCS) A computer-controlled solenoid that maintains the proper pressure in the hydraulic system of an electronically controlled automatic transmission. Also called a *variable force solenoid* or *force motor.*

Pressure regulator valve The valve that maintains the proper pressure in the hydraulic system.

Primary oil pressure (POP) The fluid pressure applied to the primary pulley in a CVT transmission/transaxle.

Primary pressure sensor (PPS) The sensor used to measure the fluid pressure applied to the primary pulley in a CVT transmission/transaxle.

Pull chain A type of chain used in a CVT transmission/transaxle that is made up of links and link pins, much like a silent chain. The ends of the link pins contact the pulley sides. This style is also called a Luk chain drive.

Pump A device that transfers fluid from one point to another.

Punches A type of hand tool used with a hammer to drive pins or other similar uses.

Push belt A type of belt used in a CVT transmission/transaxle that is made of about 400 wedge-shaped segments that are held together by two steel bands. Each band is made from multiple layers to allow flexibility. The segment sides contact the pulley sides. A push-belt is often called the Van Doorne design.

Ratchet A hand tool used to drive a socket wrench that is capable of being changed to tighten or loosen a fastener.

Ratio The relative value between two things.

Ratio control motor A stepper motor that changes the position of the upper end of the pulley ratio link in a CVT transmission/transaxle. The stepper motor controls the hydraulic ratio valve through the link, which in turn, controls fluid flow to the piston.

Ravigneaux gear set Ravigneaux gear set combines one carrier that has two sets of planet gears with two sun gears, and one ring gear.

Reaction devices The reaction devices connect (lock) a member of the gear train to the transmission case.

Rear-wheel drive (RWD) A vehicle uses the engine to drive the rear wheels.

Rebuild See Remanufactured.

Rebuilt *See* Remanufactured.

Recall A notification to the owner of a vehicle that a safety issue needs to be corrected.

Recalibration Flashing a PCM/TCM, also called programming, reprogramming, and calibrating, is done to correct possible software problems.

Relay An electromagnetic switch that uses a movable arm.

Remanufactured transmission/transaxle See remanufactured.

Remanufactured A term used to describe a component that is disassembled, cleaned, inspected, and reassembled using new or reconditioned parts.

Resource Conservation and Recovery Act (RCRA) This law states that hazardous material users are responsible for hazardous materials from the time they become a waste until the proper waste disposal is completed.

Retaining bracket A bracket that is used to hold a part(s) in place.

Right-to-know laws Laws that state that employees have a right to know when the materials they use at work are hazardous.

Rigid band A type of transmission band that a single thick, heavy band.

Ring gear The outer gear of a planetary gear set; also called an *internal gear.*

Roller clutch A one-way clutch that uses a series of rollers positioned in a special cam for the locking elements.

Rooster comb A detent that is a spring-loaded roller or ball that drops into notches in the cam to position the manual valve properly in its bore.

Rotary flow The fluid motion inside a torque converter in the same direction as the impeller and turbine.

Rubber band effect A condition that affect some CVT units where the vehicle speed slowly catches up to the engine speed, and is most noticeable only during periods of rapid acceleration.

Scan tool An electronic test device that can communicate with the vehicle's control module and determine operational data.

Scarf cut A seal ring with the ends cut at an angle.

Schematic a wiring diagram showing components and connecting wires.

Screwdrivers A type of hand tool designed to remove screws.

Secondary oil pressure (SOP) The fluid pressure applied to the secondary pulley of a CVT transmission/transaxle. The pressure measured is called the secondary oil pressure (SOP).

Secondary pressure sensor (SPS) A pressure transducer used to monitor secondary pulley pressure. The pressure measured is called the secondary oil pressure (SOP).

Selective Washers or snap rings are produced in various size which lets the technician select the proper size thrust washer for the best end play or clearance.

Semiconductor A material that is neither a conductor nor an insulator; has exactly four electrons in the atom's outer shell.

Separator plate The flat steel plate that separates the case part of the valve body from the valve body part. Also another name for an unlined steel plate used in a clutch pack.

Servo A hydraulic device that changes fluid pressure into mechanical motion or force.

Shift cooling multiplex solenoid (SHCMS) Controls position of gearshift forks as well as cooling of clutch in a dual clutch automatic transmission/transaxle.

Shift feel A clutch or band application or release that is usually described, for example, as firm or soft.

Shift valve Valves that controls the fluid flow to the band servos and to clutch apply pistons for drive, low, and reverse gears.

Short-to-ground A short circuit in which the current bypasses some or all the resistance of the circuit and flows to ground. Because ground is usually steel in automotive electricity, a short-to-ground (grounded) is a "copper-to-steel" connection.

Short-to-voltage A circuit in which current flows, but bypasses some or all the resistance in the circuit. A connection that results in a "copper-to-copper" connection.

Simpson gear train The Simpson gear set consists of a double sun gear that is meshed with the planet gears of the two carriers and is a compound gear set.

Single-sided plate Single-sided plates have friction material on one side only, and half of the plates have lugs on the inner diameter while the other half have lugs on the outer diameter.

Snips A type of hand tool used to cut sheet metal and other thin materials.

Socket A type of tool that fits over the top and used to remove a threaded fastener.

Socket adapter An adapter that allows the use of one size of driver (ratchet or breaker bar) to rotate another drive size of socket.

Spiral bevel gear Spiral bevel gears, like helical gears, have curved teeth for quieter operation.

Soft parts Parts that are normally replaced during an overhaul. These include the gaskets, seals, and friction material.

Solvent Usually colorless liquids that are used to remove grease and oil.

Special service tools (SSTs) Tools that are developed by OEM so service or repair procedures can be done.

Spontaneous combustion Self-ignition of oily rags without the use of an ignition source.

Solenoid An electromagnet actuator that uses a movable core.

Spool valve Spool valves sliding in a round bore are used to control fluid flow. A spool valve gets its name because it looks similar to the spool that holds thread.

Sprag The locking element in a one-way sprag clutch.

Spur gear A gear with straight-cut teeth.

Stall speed The maximum engine RPM that can be achieved with an automatic transmission in gear, with the brakes applied and the accelerator wide open.

Static friction The relative amount of friction between two stationary surfaces or two surfaces that are turning at the same speed. *See* Dynamic friction.

Static seal A static seal is used to seal the space between two parts that are stationary relative to each other. Static seals include gaskets and O-rings that are placed between the two parts and squeezed tightly as the parts are fastened together.

Stator A component in the torque converter that is used to change the direction of fluid motion.

Steels Another name for the unlined clutch discs.

Stop-off tool A stop-off tool or old U-joint slip yoke can be used to stop the fluid leak.

Stud A short rod with threads on both ends.

Subassemblies The major transmission components.

Sun gear The gear in the center of a planetary gear set.

Supply pressure The pressure-regulated fluid. Also called supply mainline pressure.

Surface filter A surface filter traps the foreign particles at the outer surface.

Synchronous A type of shift that requires that one apply device be timed or synchronized with the application of the apply device for the next gear range.

Technical service bulletin (TSB) A form that describes a particular vehicle concern and the recommended correction procedure.

Tensile strength The maximum stress used under tension (lengthwise force) without causing failure.

Terminal The metal end of a wire which fits into a plastic connector and is the electrical connection part of a junction.

Thrust washers Bearings that separate rotating parts that turn against each other.

Torque Turning or twisting effort; usually measured in foot-pounds or Newton-meters.

Torque converter A fluid coupling that transfers power from the engine to the transmission and can produce a torque increase.

Torque converter clutch (TCC) The clutch inside the torque converter that locks the turbine to the impeller to prevent any slippage; also called a *lockup torque converter*.

Torque management The program inside the powertrain control module that controls shift timing and quality to provide a smoother driving experience.

Torrington Bearings that operate against a very smooth, hard surface—either the face of a gear or a race.

Torsional vibrations Torsional vibrations are small speed increases and slowdowns as the crankshaft revolves between engine cylinder firing pulses. These vibrations can produce gear noise in the transmission and drivetrain as well as a noticeable vibration and harshness in the vehicle.

Traction battery The high-voltage battery used to power the traction motor which can propel the vehicle.

Traction motor The electric motor used propel the vehicle in an electric and hybrid electric vehicles.

Transaxle A transmission that is combined with the final drive assembly; normally used in front-wheel-drive (FWD) vehicles.

Transfer case A transfer case is normally attached to the rear of the transmission. It has a single input shaft from the transmission and two output shafts, one to the front drive axle and one to the rear drive axle. Some transfer cases are two-speed and include a set of reduction gears for lower-speed, higher-torque operation.

Transmission A device in the powertrain that provides different forward-gear ratios as well as neutral and reverse.

Transmission adapt pressure (TAP) The General Motor's term for which manages oil pressure to control clutch fill rates to allow for adaptive control and which compensates for clutch pack wear.

Transmission control module (TCM) The term given to the computer that controls An automatic transmission and called a *transmission control unit (TCU)*.

Transmission fluid temperature (TFT) A temperature sensor that measures the automatic transmission fluid temperature.

Transmission range (TR) switch The transmission switch, also called the manual lever position (MLP) sensor, is used as an input to the PCM/TCM which indicates the driver request for which drive range is being requested.

Transmission range sensor (TRS) A multi-contact switch operated by the manual shift lever.

Transmission temperature sensor (TTS) A Negative Temperature Coefficient (NTC) thermistor used to measure temperature of the transaxle.

Trouble light A light used to help a service technician see while performing service work on a vehicle.

Turbine The output member of a torque converter.

Turbine speed sensor (TSS) The sensor that measures the speed of the input shaft which is the same or almost the same as the engine speed. This is also called input speed sensor (ISS).

Turbulator A turbulator built into the inside of a cooler line causes turbulence in the fluid flow to ensure constant mixing and thorough cooling of all the fluid.

Twin clutch transmission Another term used to describe a dual-clutch automatic transmission/transaxle.

UNC Unified national coarse.

Underground storage tank (UST) Underground storage tank used to store used oil.

UNF Unified national fine.

Universal joint (U-joint) A joint in a steering or drive shaft that allows torque to be transmitted at an angle.

Used oil Any petroleum-based or synthetic oil that has been used.

Valve body The valve body enables an automatic transmission to operate automatically and is often referred to as the "brains" of the transmission. It supplies the force to apply the clutches, bands and the valves that control pressure and direct the fluid for automatic shifts.

Vane pump Vane pumps are also positive displacement in that they will pump a certain volume on each revolution, but the displacement, and therefore the fluid volume, can be changed.

Variable displacement pumps allow a large output to produce the fluid volume needed for shifts and lubrication and a reduced output when it is not needed.

Variable force solenoid *See* Pressure control solenoid.

Variators Two variable width pulleys to change the gear ratio in a continuously variable transmission.

Vehicle emission control information (VECI) An underhood label with emission control information.

Vehicle speed (VS) sensor A sensor that measures the speed of vehicle. It can use the output speed sensor or the wheel speed sensor depending on the vehicle.

VIN Vehicle identification number.

Voltmeter An electrical test instrument used to measure volts (unit of electrical pressure). A voltmeter is connected in parallel with the unit or circuit being tested.

Volts unit of electrical pressure.

Vortex flow A recirculating fluid flow in the converter that is outward in the impeller and inward in the turbine.

Warpage A fault that occurs when mating surfaces become less flat.

Washer A thin metal disk with a hole used to support the load of a threaded fastener.

Wave plate An unlined clutch plate that is wavy, not flat.

Worm gear A type of gear used in an older type of steering gear, which is attached to the steering shaft.

WHMIS Workplace Hazardous Materials Information Systems.

Worm tracks The fluid passages in a value body for the various transmission hydraulic circuits cast into them. These are sometimes called *worm holes.*

Wrench Any of various hand or power tools, often having fixed or adjustable jaws, used for gripping, turning, or twisting objects such as nuts, bolts, or pipes.

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