CHAPTER 13

FOUR-WHEEL DRIVE THEORY

OBJECTIVES

After completing this chapter, you should be able to:

1. Explain the requirements and limits for 4WD and AWD.
2. Identify the parts of a transfer case and know the purpose for each.
3. Trace the power flow through the major types of transfer cases or power transfer units for each gear range.
4. Identify the parts of a front drive axle assembly and know the purpose for each.
5. Identify the different types of hubs used on front drive axles.

KEY TERMS

All-wheel-drive (AWD) (p. 395)
Automatic hub (p. 407)
Bevel gear (p. 395)
Center differential (p. 395)
Closed knuckle (p. 405)
Front drive axle (p. 393)
Full-time 4WD (p. 395)
Integrated wheel end disconnect (p. 406)
Interaxle differential (p. 395)
Locking hub (p. 406)
Mechanical hub (p. 406)
Open design (p. 405)
Part-time 4WD (p. 395)
Planetary gear (p. 395)
Power transfer unit (PTU) (p. 393)
Rear drive axle (p. 393)
Transfer case (p. 393)
Twin-traction axle (p. 402)
Viscous coupling (p. 395)

INTRODUCTION

Four-wheel drive (4WD) for cars, pickups, and light trucks has steadily evolved from the somewhat crude but rugged Jeep of World War II to some very sophisticated sport coupes and sport-utility vehicles of today. 4WD can be based on a vehicle with front engine–RWD, front engine–FWD, mid engine–RWD, or rear engine–RWD.

4WD systems can be:

- **Part time:** Designed primarily for slow speed, off-road use. Both front and rear drive axles are driven at the same speed, and the tires must slip to compensate for speed differential on turns.
- **Full time:** Designed for on-road use. A center differential allows front to rear speed differential for turns. Both front and rear axles must drive the wheels at the same speed.
- **On demand:** A coupler to the front or rear drive axle is automatically applied when additional traction is needed. On demand systems normally apply the coupler for brief periods. These systems can be controlled using speed or torque sensing.

A 4WD vehicle needs a drive axle at both the front and rear ends; of course, the front drive axle must be steerable. One or both of the axles can be a solid axle design, as described in Chapter 11, or one or both axles can be of an independent suspension design. Solid axles are more rugged and less expensive, but the independent suspension designs have better ride and handling qualities (Figure 13-1).

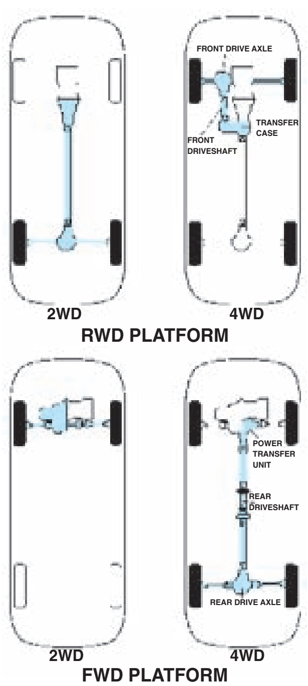


FIGURE 13-1 4WD vehicles are based on RWD and FWD platforms. Some AWD vehicles are based on a FWD, longitudinal engine (not shown).

In this chapter, we concentrate on the 4WD sport-utility vehicle, SUV, which is the most common 4WD/AWD vehicle. Some of these vehicles are based on a front engine—RWD platform, with the major additions to the drivetrain being a **transfer case**, front driveshaft, and **front drive axle** (Figure 13-2). An ever-increasing number of these vehicles are based on a front transverse engine—FWD platform, with the major additions being a **power transfer unit (PTU)**, rear driveshaft, and **rear drive axle** with coupling device.

It should be remembered that most 4WD vehicles do not drive all of the wheels all of the time (Figure 13-3). This is because most vehicles have open differentials in the front and rear drive axles and some AWD vehicles have an open center differential. Limited slip and locking differentials or couplings with torque management capability increase the ability to actually transfer torque to all four wheels.

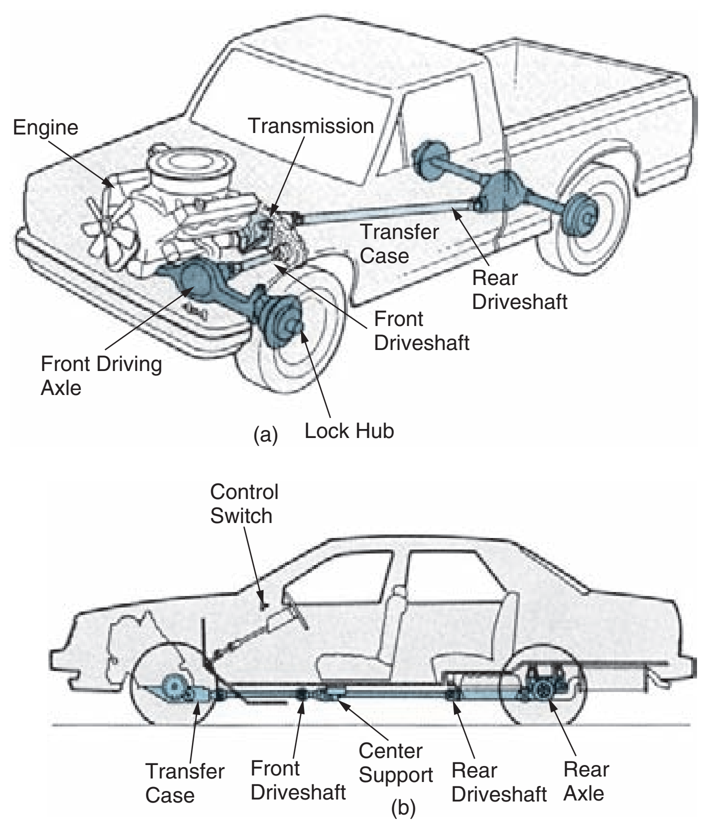


FIGURE 13-2 The 4WD pickup uses a transfer case to split and engage the power flow to the front drive axle when the driver wants 4WD (a). The AWD car uses a transfer case to split the power flow between the front differential in the transaxle and the rear drive axle (b). *(Courtesy of Ford Motor Company)*

Drivetrain	Differential Type(s)	Wheels with Full Torque
2WD	Open	1
2WD	Locked	2
4WD, PT	F & R Open	2 (1 front & 1 rear)
AWD	F, C, & R Open	1
AWD	F & C Open, C Locked	2 (1 front & 1 rear)
AWD	F Open, C & R Locked	3
AWD	F, C, & R Locked	4
AWD	Torque Managed Differentials	4

FIGURE 13-3 The ability of 4WD and AWD vehicles to drive all four wheels is dependent on the types of differential or couplers used at the front, center, and rear differentials.

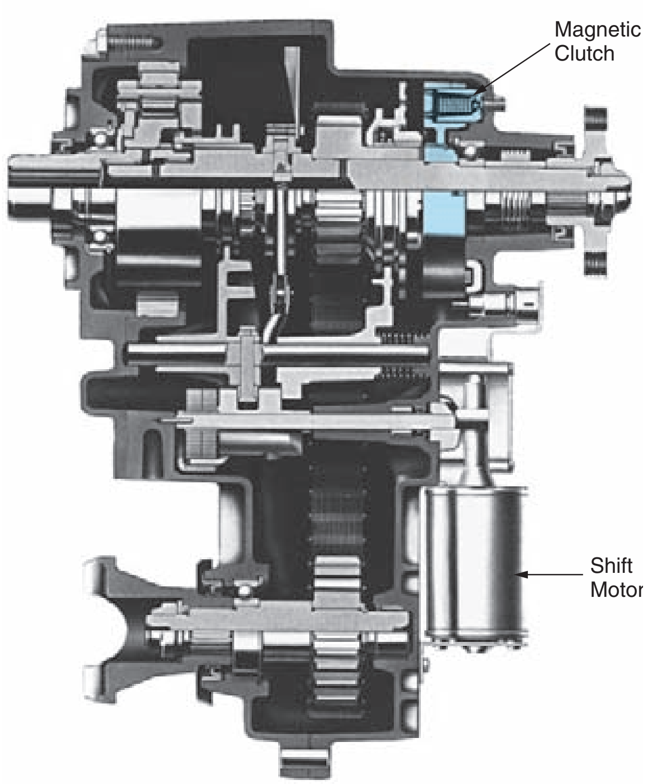


FIGURE 13-5 This transfer case uses a magnetic clutch to allow engagement of 4WD while the vehicle is moving and an electric motor to complete the 2WD–4WD shift. This motor also makes the shift to low range. *(Courtesy of BWD Automotive Group)*

POWER TRANSFER UNITS AND TRANSFER CASES

The transfer case is the gear assembly used to control the power flow to the front axle and somewhat to the rear axle. In some FWD-based vehicles, the transfer gears are attached the transaxle. In short-wheelbase vehicles, the transfer case is attached directly to the transmission; and in many instances, the transmission extension and mainshaft are modified so that the transfer case and transmission form a more compact package (Figure 13-4). Longer wheelbase vehicles often mount the transfer case separately from the transmission, and a U-joint or short driveshaft couples it to the transmission.

Both integral and separate transfer cases have one input shaft and two output shafts, one to each drive axle. Power is sent to the rear driveshaft almost all of the time. Some transfer cases include a neutral. An internal dog clutch or synchronizer assembly is used to control the power flow to the front driveshaft. Many 4WDs use a floor-mounted shift lever to engage or disengage the dog clutch. Normally, this is done with the vehicle stopped. However, many modern transfer cases use electronic controls for shifts, which can shift while the vehicle is in motion. This is called "shifting on the fly." These cases have a magnetic clutch that synchronizes the speeds of the clutch parts and an electric shift control motor that moves the clutch into engagement (Figure 13-5).

Many transfer cases include a gear mechanism to provide a lower range, a reduction of around 2:1. Control of low range is by either the same lever that controls the 2WD–4WD shift, a separate lever, an electronic control using the electric shift control motor, or vacuum controls and vacuum motors. Low range is limited to 4WD operation because it doubles the torque to the drive axles, and this is often more than one axle is designed to handle. There are essentially two styles of trans-

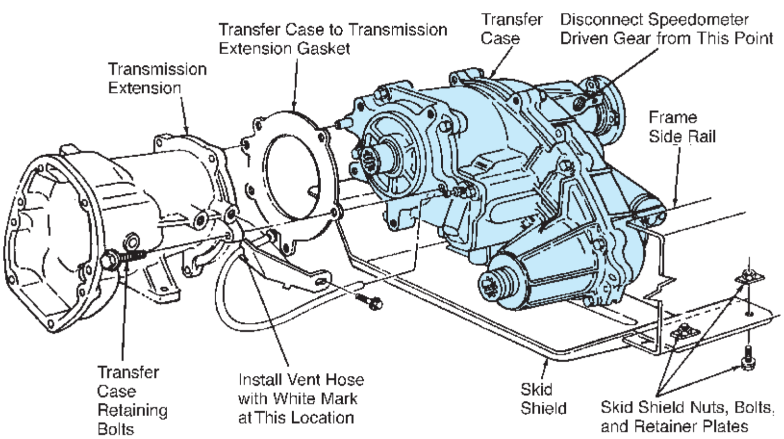


FIGURE 13-4 A transfer case is usually mounted to the rear of the transmission. *(Courtesy of Ford Motor Company)*

fer cases: those that use gears to drive the front output shaft and those that use a chain and sprockets.

There are two major types of 4WD vehicles and transfer cases, and these are part-time and full-time styles. **Full-time 4WD** is also called **all-wheel-drive (AWD)** or anytime 4WD. Traditional, pickup, and Jeep-based vehicles use part-time 4WD that is designed to be used off-road. **Part-time 4WD** has a positive, mechanical connection between the front and rear driveshafts when shifted into 4WD. 4WD is used only where there is poor traction because the front or rear tires must be able to slip on the road surface while cornering. Gear train bind up will occur if turns are made on pavement. AWD vehicles include a center differential that allows the front and rear driveshafts to be driven at different speeds to prevent drivetrain binding. AWD transfer cases that deliver power to both driveshafts all of the time are called *mechanically active*. A few modern AWD vehicles are passenger car-based AWD using AWD to enhance driving on wet or icy roads.

AWD Transfer Cases

Full-time 4WD or all-wheel drive (AWD) transfer cases maintain constant power to both the front and rear axles and include a **center differential**, or **interaxle differential**, between the front and rear output shafts (Figure 13-6). Remember that as a vehicle turns a corner, the outside wheels go faster than the inside ones, and the front wheels go faster than the rear wheels because of the different turning radius of each wheel (Figure 13-7). The differential used with AWD is often a **bevel gear** type like that used in transaxles and rear drive axles. It can also be a **planetary gear** type or a **viscous coupling** (Figure 13-8). Some planetary differentials are designed to split torque unevenly; one, for example, splits torque so that 35% goes to the front axle and the remaining 65% goes to the rear axle.

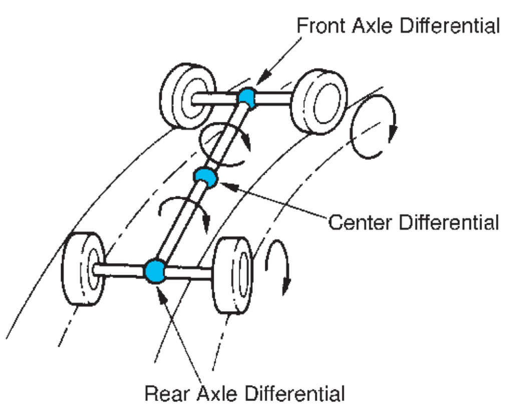


FIGURE 13-6 An AWD vehicle has a center differential to split the torque between the front and rear axles, allowing the axles to travel at different speeds. The differentials in the front and rear axles split torque between each pair of wheels and allow the wheels to travel at different speeds.

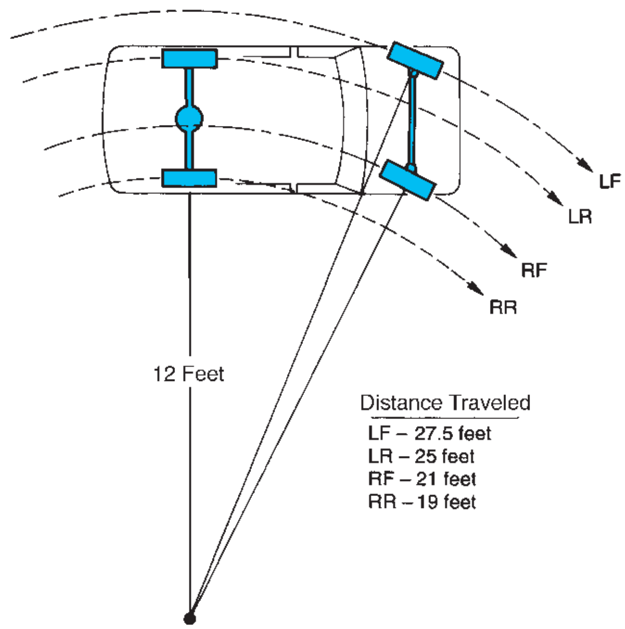


FIGURE 13-7 If a vehicle makes a right-angle turn with an inside rear-wheel radius of 12 ft, the four tires will travel the distances indicated in the same amount of time; the outside front tire will have to go about 70% faster than the inside rear tire.

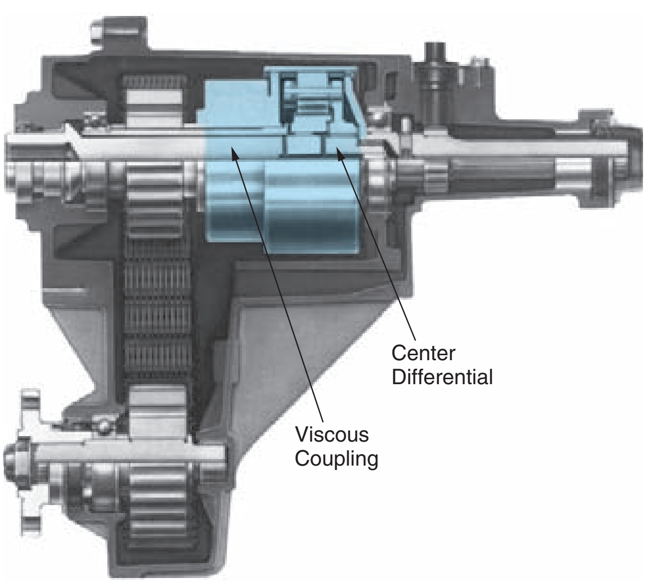


FIGURE 13-8 Single-speed AWD transfer case that includes a center, planetary gear type of differential with a viscous coupling to control the differential. This differential will split the torque so that 65% goes to the rear axle and 35% to the front. *(Courtesy of BWD Automotive Corporation)*

Most center differentials, however, split torque equally. It is possible, though, to lift one wheel and not get enough torque to the other three wheels to move the vehicle (Figure 13-9). Thus, a center differential includes a lockout. With the lockout, at least both driveshafts and one wheel at each end will be driven.

Some modern AWD vehicles use *smart transfer cases* that automatically lock up or drive both or either output shaft as needed for the driving conditions. Some act through electronic sensors, noting unequal wheel speeds and tire slippage and applying an internal clutch using an electric motor. Others use a hydraulically applied internal clutch much like the Quadra-Trac II (Hydra-Lok) limited slip differential (Figure 13-10).

TECH TIP

It is normally recommended to use the manufacturer's recommendation for the fluid type and quantity. If a unit is noisy or experiences hard shifting, a fluid replacement might cure the problem. A lubrication guide showing the recommendation of a leading rebuilder of manual transmissions and transfer cases is given in Appendix 2.

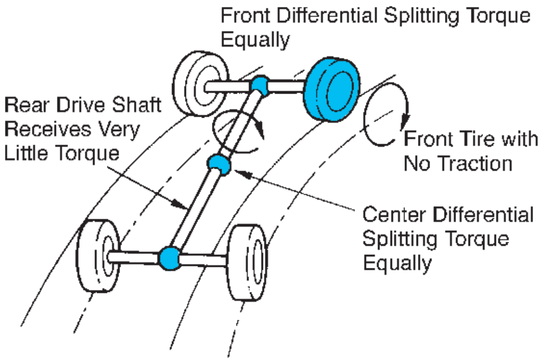


FIGURE 13-9 If the center and front differential split torque equally, an AWD vehicle can become stuck when one wheel loses traction, as shown here.

AWD vehicles must have four equal-diameter tires. Unequal diameters produce different axle speeds, and this will cause excessive wear at the drive axle or center differential. A viscous coupling at the center differential will not last if it has to operate constantly.

Some AWD vehicles produced by Audi, Land Rover, Lexus, Toyota, and VW use a Torsen® differential for the center differential. Torsen center differentials are designed with a torque bias ratio of 2.5:1 to 3.5:1. The two driveshafts can operate at different speeds without spin-out problems at the front or rear and smooth turning action (Figure 13-11). The Torsen differential is mechanically active.

There are essentially two styles of transfer cases: those that use gears to drive the front output shaft and those that use a chain.

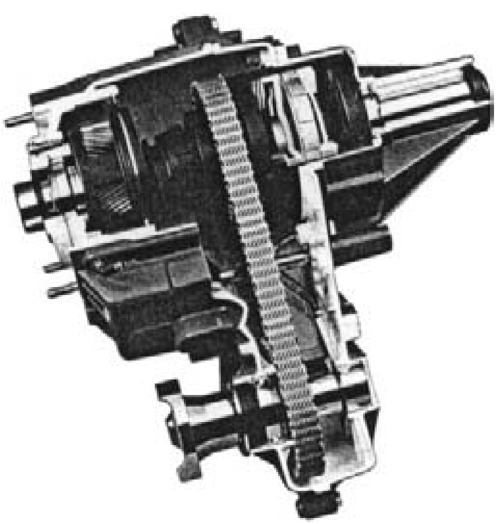


FIGURE 13-10 The Quadra-Trac II on-demand transfer case includes a gerotor oil pump that is driven when the front and rear driveshafts operate at different speeds. If there is too much speed differential, the fluid pressure can apply the internal clutch to transfer torque to each one.

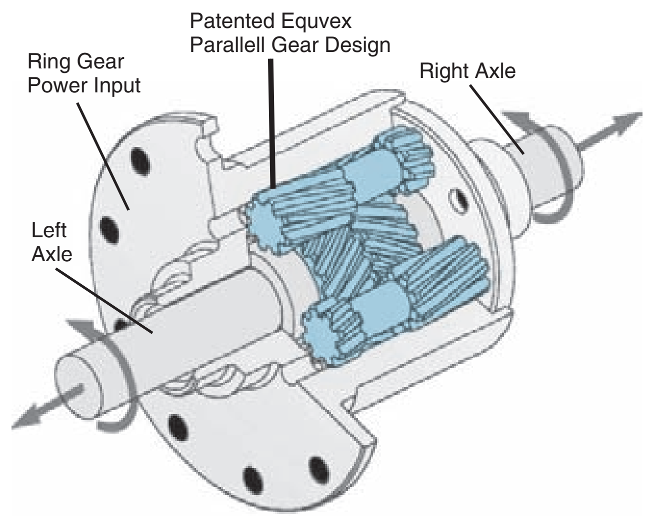


FIGURE 13-11 A cutaway view of a Torsen T-2 differential from a drive axle. A transfer case version will have a different housing. Note that the Equvex gear train floats in the outer housing. *(Courtesy of Zexel Torsen, Inc.)*

Gear-Drive Transfer Case

The gear-drive transfer case uses a set of six gears on four shafts with two sliding shift assemblies (Figure 13-12). Three of the gears transfer power to the front output for 4WD, and all but one of the gears are used in 4L (4WD–low range). Most early transfer cases were of this design.

There are three ways for power to flow through this transfer case plus neutral (Figure 13-13). In 2H (2WD–high range), the sliding dog clutch (range clutch) on the upper shaft couples the input shaft to the rear output shaft so that power can pass straight through at a 1:1 ratio to the rear wheels. In 4H, the upper clutch is still engaged as it was in 2H, and the lower sliding dog clutch is moved to couple the high gear on the lower shaft with the lower, or front, output shaft. Now power passes through the front gears of the gear train to drive the front wheels at a 1:1 ratio. In 4L, both sliding clutches are moved to the rear. Power to the rear output shaft now passes through the idler gear set, and power to the front output shaft passes through the front-drive low gear. Both output shafts will be driven at a reduced speed because of the gear ratios. Neutral occurs when the range clutch is between high and low ranges.

TECH TIP

A full-time AWD vehicle with an active or viscous transfer case should never be operated with either the front or rear wheels stationary. Severe transfer case damage will occur if one pair of wheels is spinning and the other pair is stopped. This applies to emission testing using a dynamometer.

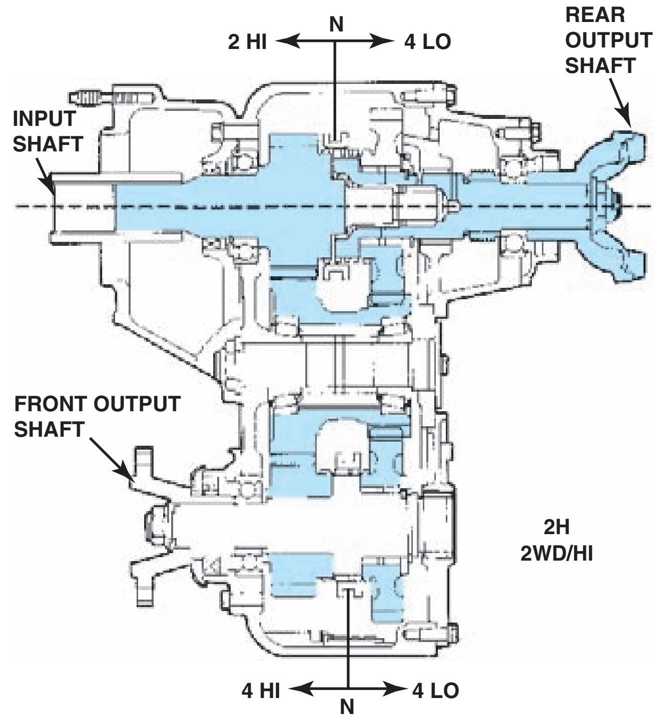


FIGURE 13-12 A gear-drive transfer case uses a gear arrangement, as shown here. *(Courtesy of DaimlerChrysler Corporation.)*

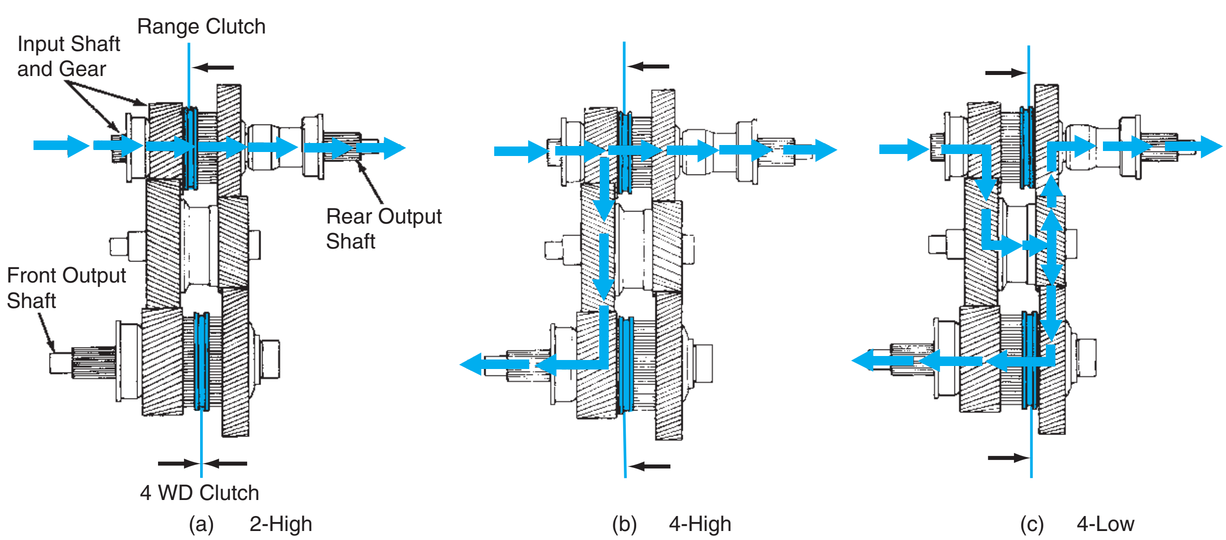


FIGURE 13-13 Power flow through a gear-drive transfer case in 2H (a), 4H (b), and 4L (c). Note the positions of the upper and lower shift collars (range and 4WD clutches). *(Courtesy of Ford Motor Company)*

Chain-Drive Transfer Case

This is a very popular style of transfer case. There is some variety in these units, but each uses a large silent chain to transfer power from the upper shaft to the lower, front output shaft (Figure 13-14). There are three ways for power to flow through this transfer case plus neutral (Figure 13-15). Low range is provided by a set of planetary gears. Power enters the gear set through the carrier of the gear set, which is connected to the input shaft; a dog clutch is used to control the power flow for 4WD to the drive-chain sprocket.

In high range, the planetary gears are locked up by shifting the sun gear into mesh with both the planet pinion gears and the planet carrier. In low range, the sun gear is shifted so that it is in mesh with only the planet pinions, and the ring gear is held stationary. Now when the sun gear is driven, the planet gears will be forced to "walk" around the inside of the ring gear, and the carrier will be driven at a reduced speed. In AWD transfer cases, the output from the planetary gear set enters the differential, which has one output to the rear output shaft and another to the sprocket of the drive chain for the front output shaft (Figure 13-16).

Power Transfer Unit

4WD/AWD vehicles that are based on FWD vehicles integrate a power transfer unit into the transaxle. In its simplest form, a PTU is just a right angle gear set (Figure 13-17). This gear set is driven by the front differential, and it can drive the rear driveshaft at the same speed as the front wheels. Some PTUs include a sliding gear or multiplate coupling (Figure 13-18). Some transfer gears include a differential lockout device so that the same speed and torque can be sent to both front and rear differentials. Compared to a transfer case or PTU, a coupler is about 65 pounds (30 kg) lighter, which should improve fuel mileage.

COUPLERS

Couplers are connected in series with other drivetrain members and are used to transfer torque, much like a clutch. Active couplers used in on-demand systems are dynamic and are applied as needed. These are a usually a multiplate clutch that is applied by the speed differential between the

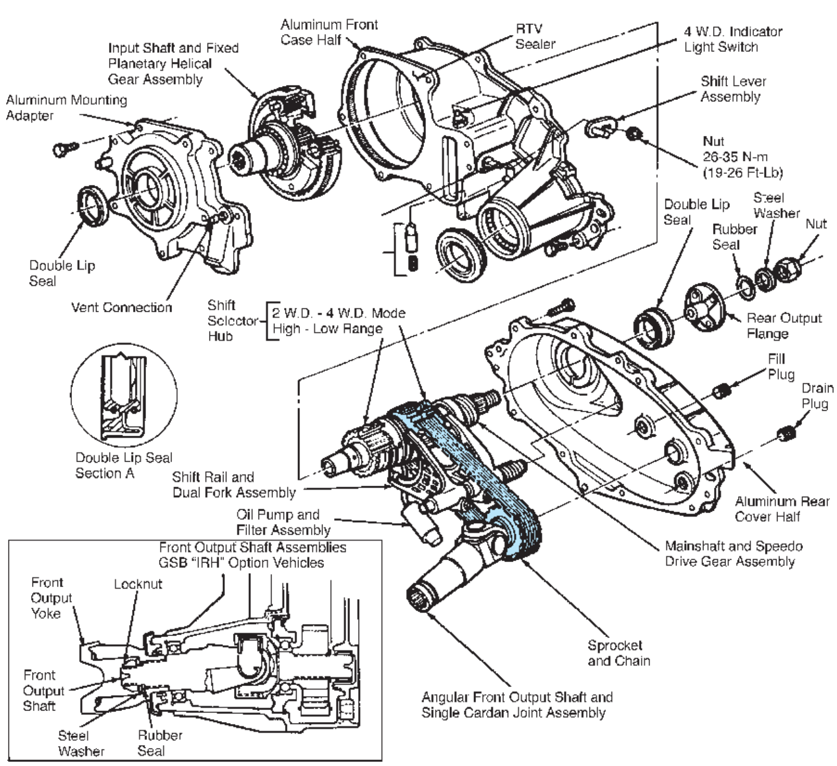


FIGURE 13-14 A chain-drive transfer case uses a Morse chain to transfer power to the front output shaft. *(Courtesy of Ford Motor Company)*

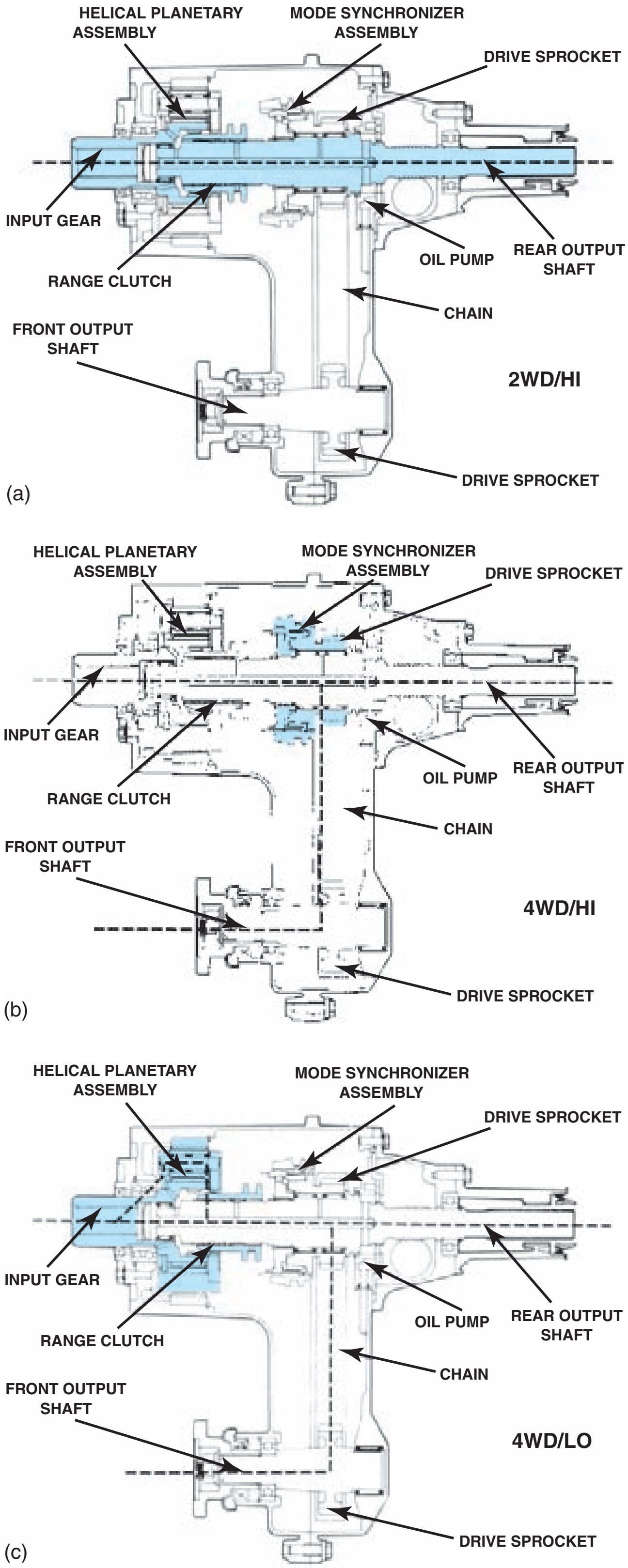


FIGURE 13-15 Power flow through a chain-drive transfer case in 2H (a), 4H (b), and 4L (c). *(Courtesy of DaimlerChrysler Corporation)*

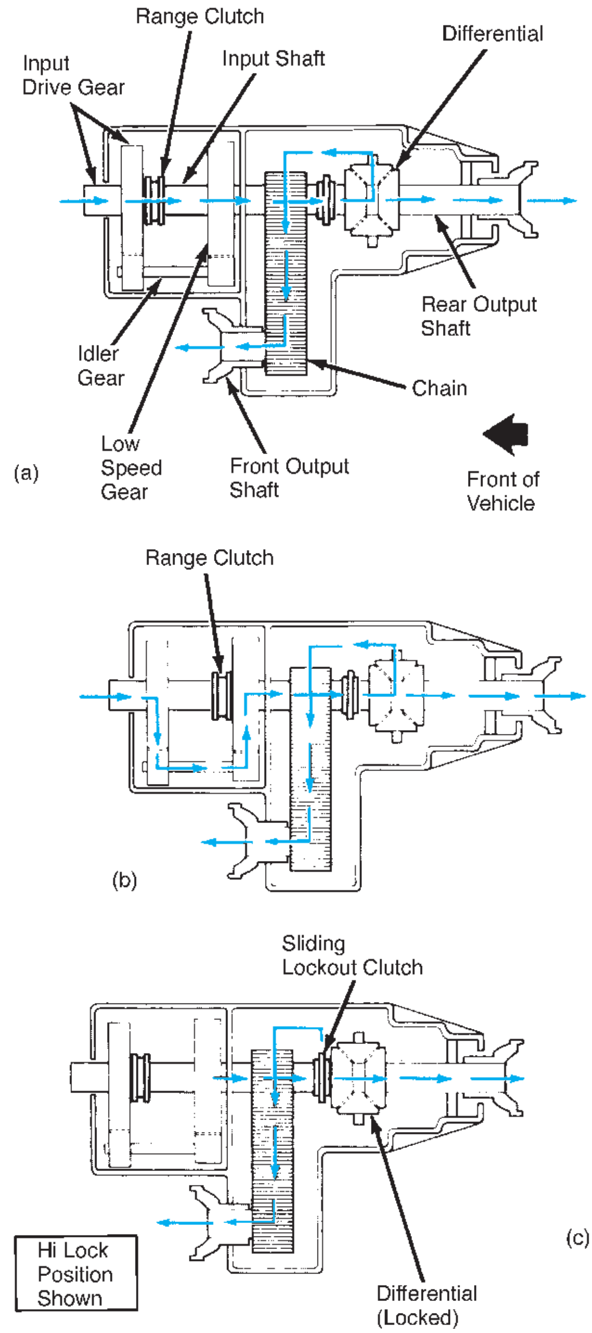


FIGURE 13-16 Power flows through an AWD transfer case in HI (a), LO (b), and HI Lock with the differential locked up (c). *(Courtesy of Ford Motor Company)*

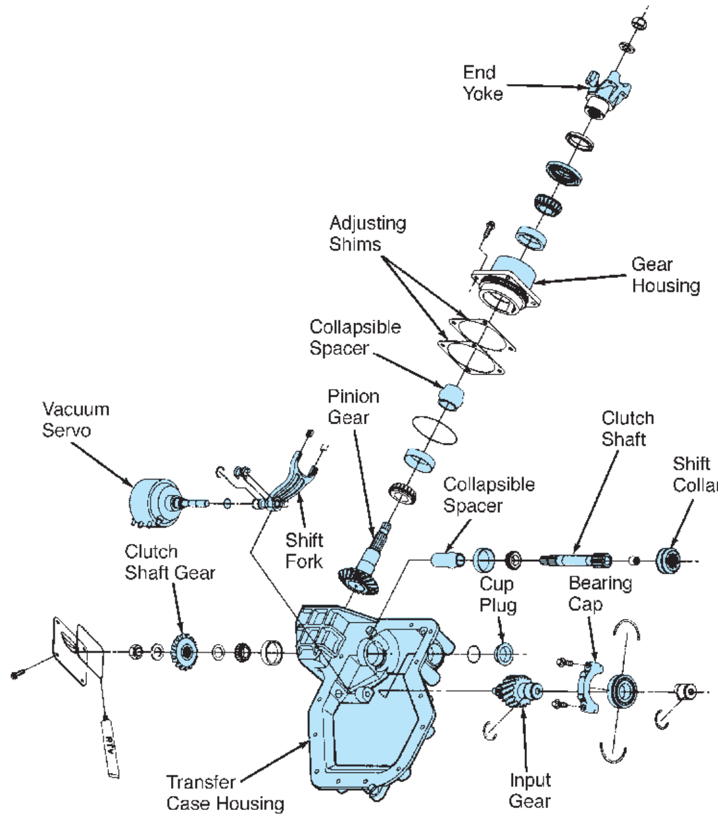


FIGURE 13-17 An exploded view of a power transfer unit (PTU) that is attached to the transaxle. *(Courtesy of Ford Motor Company)*

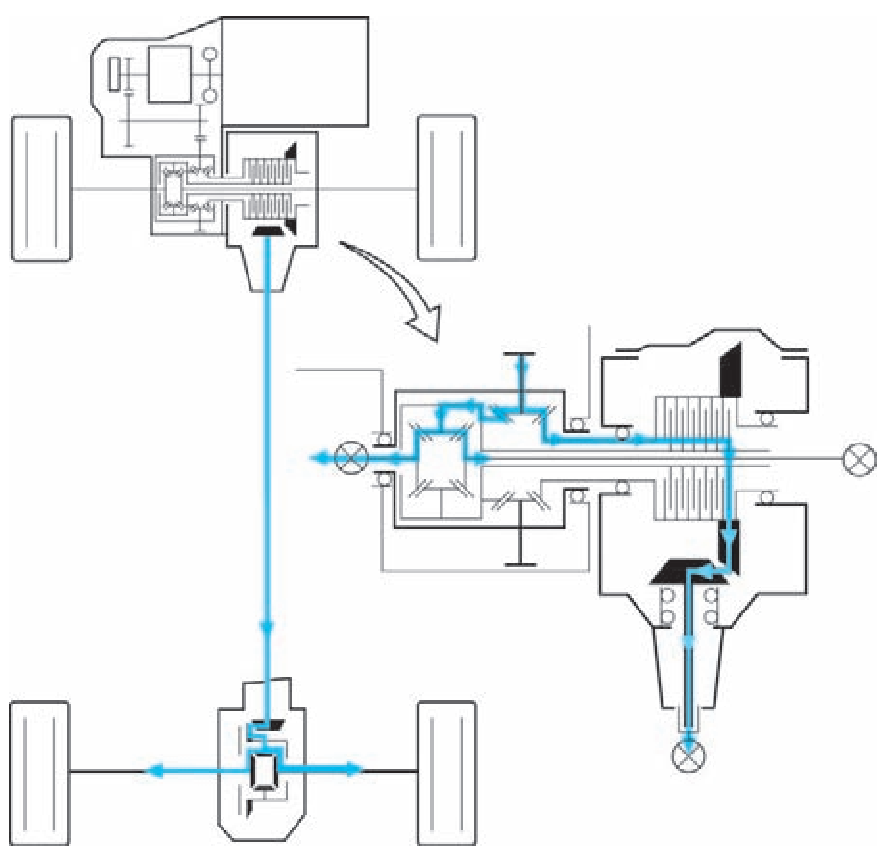


FIGURE 13-18 This PTU has an inter axle differential that drives the front axle differential and the transfer gears to the rear drive shaft. The multiplate clutch in the PTU can also transfer power to the transfer gears. *(Courtesy of Toyota Motor Sales USA, Inc.)*

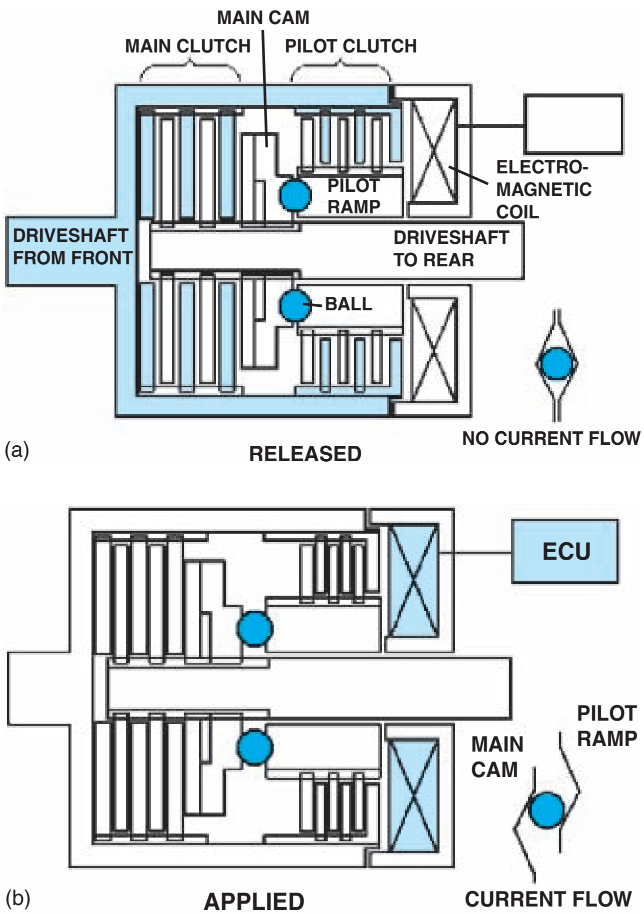


FIGURE 13-19 An electromagnetic coupler in a released (a) and applied (b) condition. When the ECU energizes the electromagnet, the pilot clutch applies to cause a speed differential between the pilot ramp and main cam and this applies the multiplate clutch.

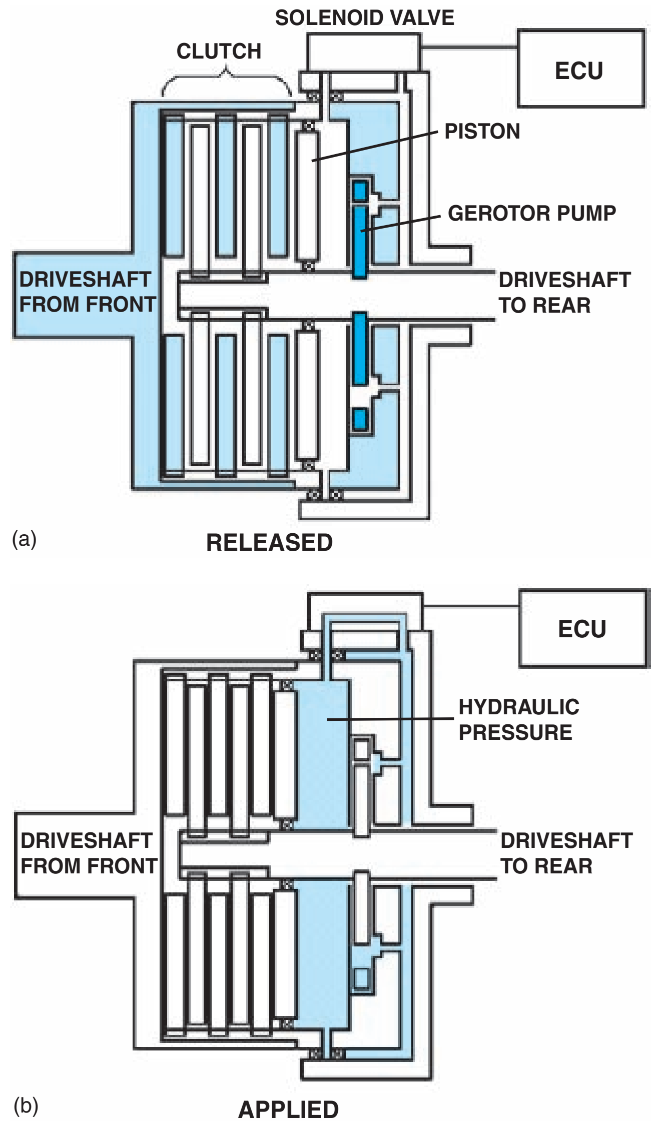


FIGURE 13-20 A hydraulic coupler in a released (a) and applied (b) condition. An input shaft, output shaft speed differential will cause the pump to develop hydraulic press, and when the ECU energizes the solenoid valve, the pressure will apply the multiplate clutch.

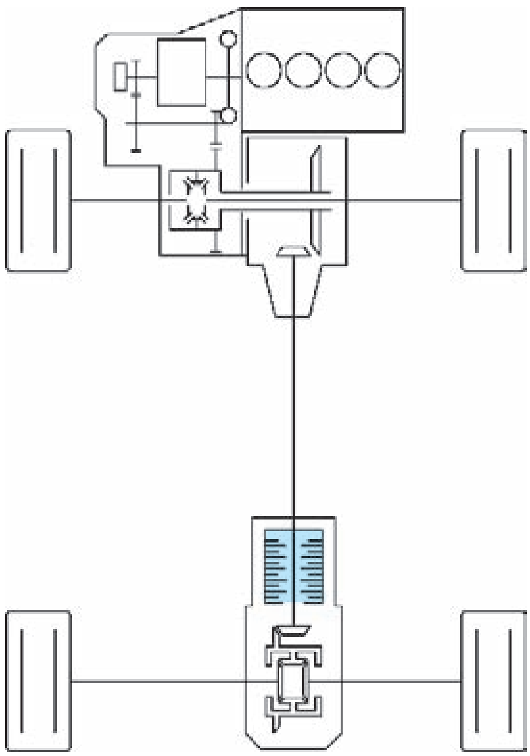
input and output shafts. In one design, an electromagnetic clutch applies a pilot clutch that in turn applies the main clutch that transfers power (Figure 13-19). Another design uses a solenoid to control hydraulic pressure from a gerotor hydraulic pump; this pressure applies the clutch when needed (Figure 13-20).

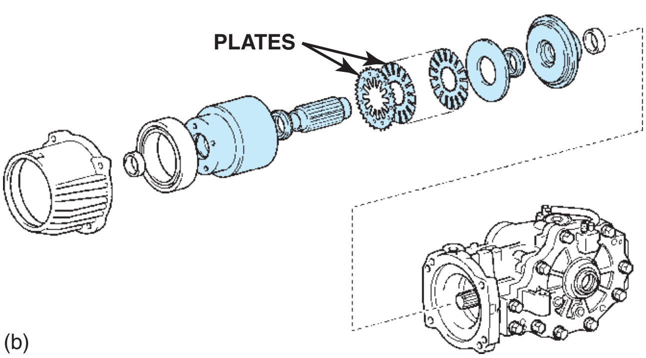
Viscous Couplers

Some AWD vehicles use a viscous coupling attached to the input of the rear drive axle (Figure 13-21). During normal driving, the coupling allows enough slippage for the front and rear wheels to travel at different speeds while turning corners. If a tire loses traction and spins, the fluid inside the coupling will quickly heat, increase viscosity, and transfer power to the rear wheels. Viscous couplers are passive; they apply themselves after a certain amount of slippage.

Electromagnetic Clutch Coupler

These systems are called *Torque Management, Interactive Torque Management System, Intelligent AWD System*, or *Active Torque Dynamics*. A multiplate clutch is used in the coupling to transfer torque to the rear drive axle, and this clutch is applied by an electromagnetic coil (Figure 13-22). Current to the clutch is controlled by a 4WD ECM that uses sensors for front and rear wheel speeds. If the front wheel speed is excessively faster than the rear-wheel speed, the ECM applies the clutch to drive the rear wheels. The rear wheels are driven only when necessary to improve traction.


(a)

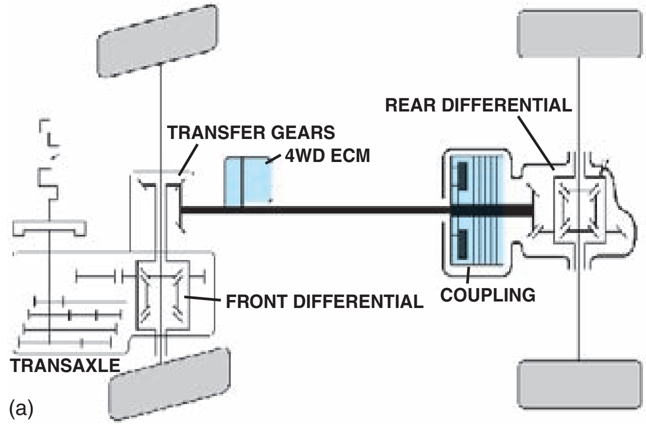


(b)

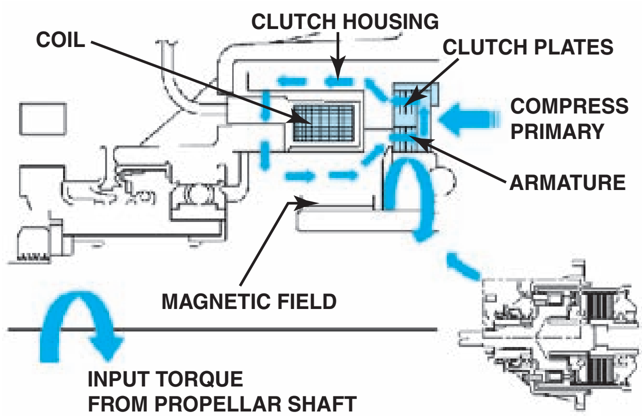
FIGURE 13-21 This AWD vehicle uses a viscous coupler at the rear drive axle (a). The exploded view of the coupler shows some of the internal plates (b). *(Courtesy of Toyota Motor Sales USA, Inc.)*

Electro-Hydraulic Coupler

Haldex All-Wheel-Drive System. The Haldex system is currently being used on several domestic and European vehicles. The major part is a coupling that can be installed onto the rear drive axle to connect it to the FWD system (Figure 13-23). The coupling uses a multidisc clutch that is applied hydraulically when there is an excessive speed difference between the input and output shafts (Figure 13-24). Hydraulic pressure to apply the clutch is generated in the clutch when the input and output shafts turn at different speeds. When there is no speed difference, there will be no pressure. The clutch application rate is controlled electronically by software designed for the particular vehicle.



(a)



(b)

FIGURE 13-22 This AWD vehicle uses an electromagnetic coupler at the rear drive axle (a). The exploded view of the coupler shows the magnetic force applying the pilot clutch (b). *(Courtesy of Hyundai Motor America)*

FRONT DRIVE AXLES

Except for the outer ends of the axle housing, which allow steering, most early 4WD utility vehicles use a solid front drive axle that is essentially the same as the one used in the rear (Figure 13-25). The carrier is normally offset to the side so that the front driveshaft can pass alongside the engine, and the carrier itself is the same as the rear carrier. The ring and pinion gears of the front gear set are cut for reverse rotation.

Some front drive axle assemblies include a feature that allows disconnecting one of the axle shafts (Figure 13-26). As the vehicle is driven, the wheels will drive the axles, differential, and driveshaft. A collar is shifted to connect or disconnect the two parts of the shaft. Either a vacuum or electric shift motor is used for this with the controls being activated by shifting the transfer case into or out of 4WD.

Many Ford pickups and utility vehicles use a swing-axle style of independent suspension (Figure 13-27). This unit, called a **twin-traction axle**, has two axle assemblies that have their inner ends connected to the vehicle frame through a pivot bushing. The left-side axle assembly supports the car-

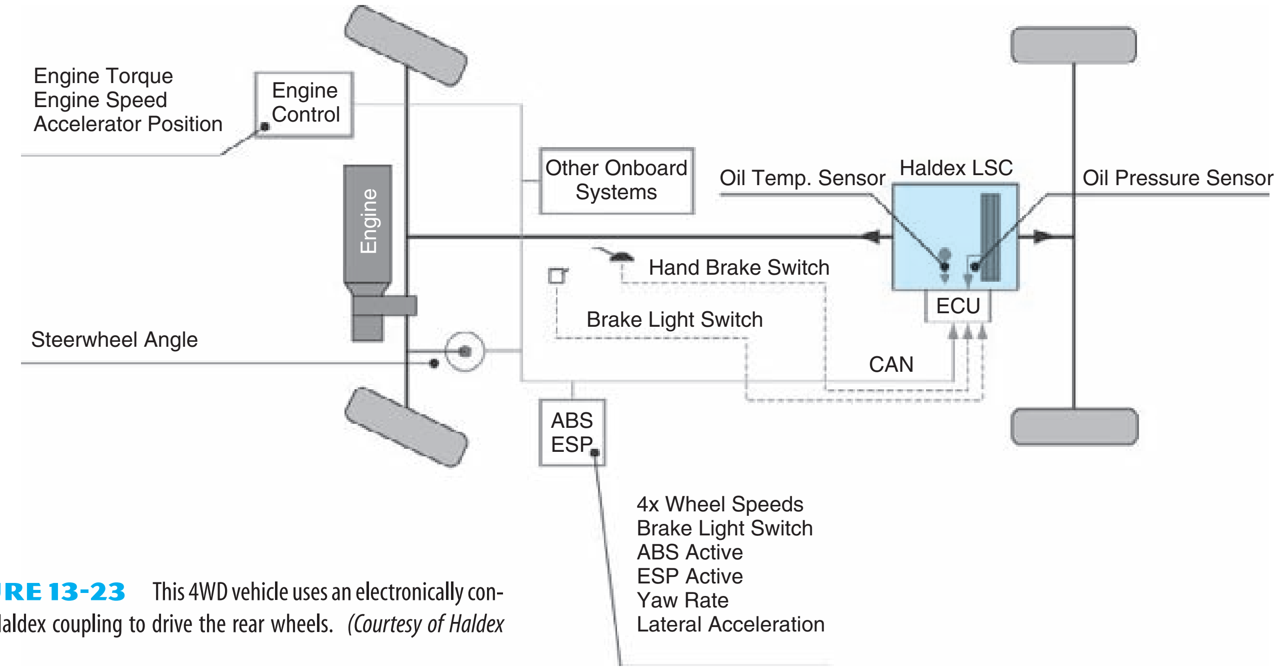


FIGURE 13-23 This 4WD vehicle uses an electronically controlled Haldex coupling to drive the rear wheels. *(Courtesy of Haldex Traction)*

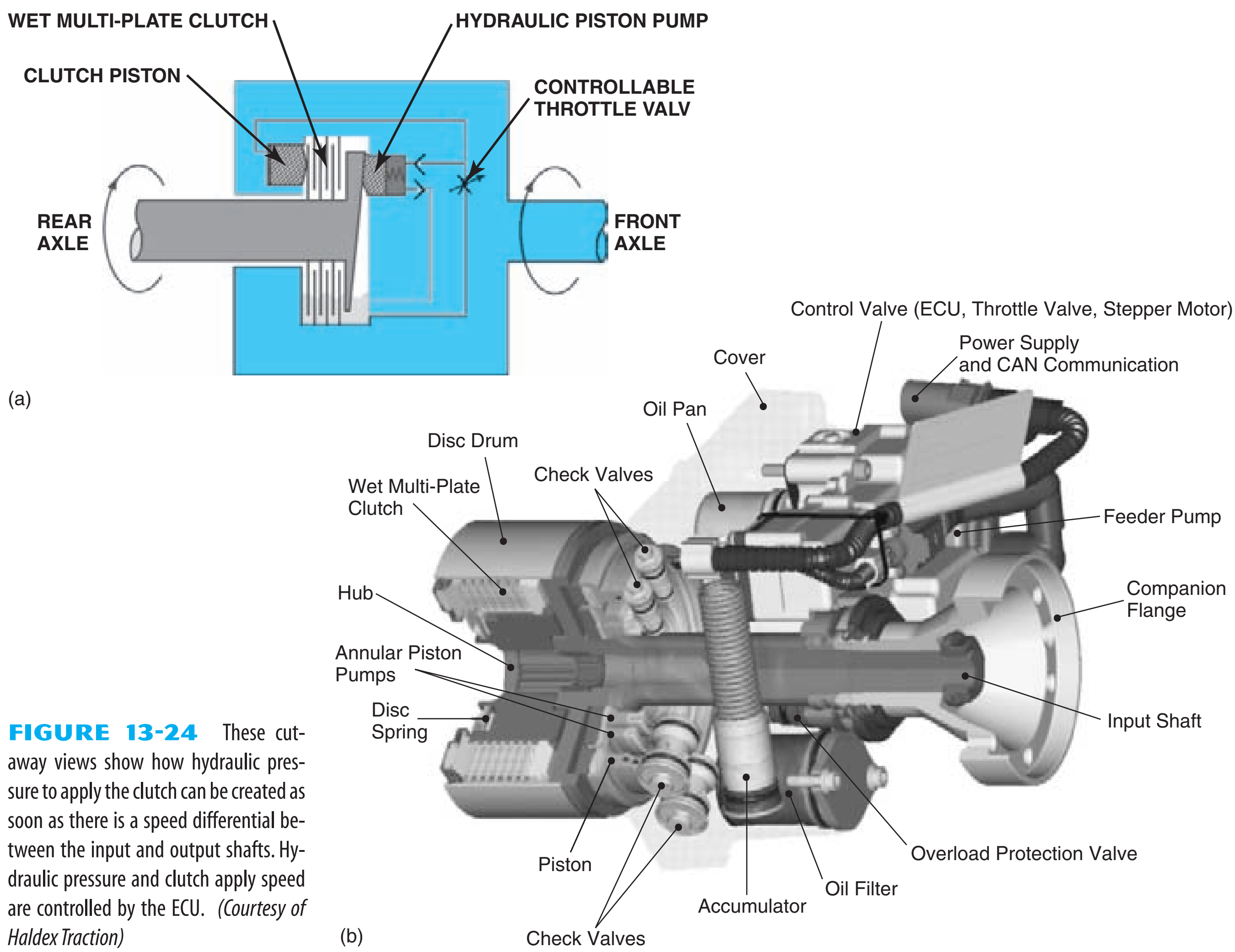


FIGURE 13-24 These cutaway views show how hydraulic pressure to apply the clutch can be created as soon as there is a speed differential between the input and output shafts. Hydraulic pressure and clutch apply speed are controlled by the ECU. *(Courtesy of Haldex Traction)*

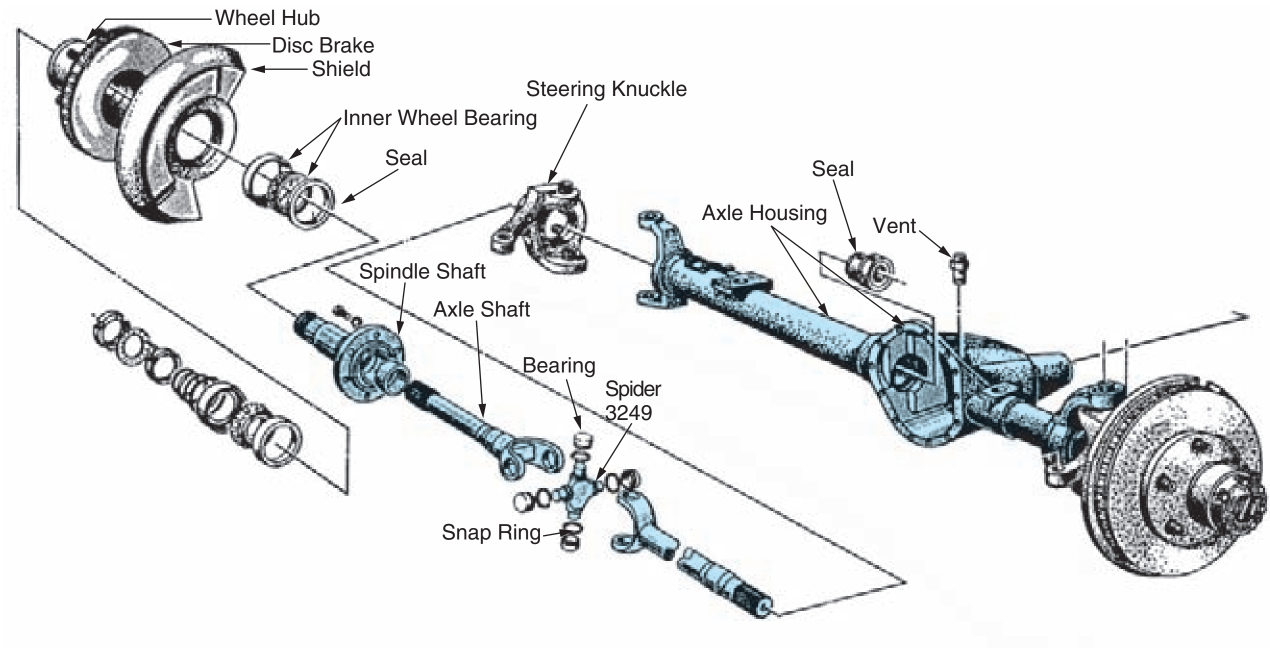


FIGURE 13-25 Solid front drive axle housing with the left-side axle shaft and hub assembly. *(Courtesy of Ford Motor Company)*

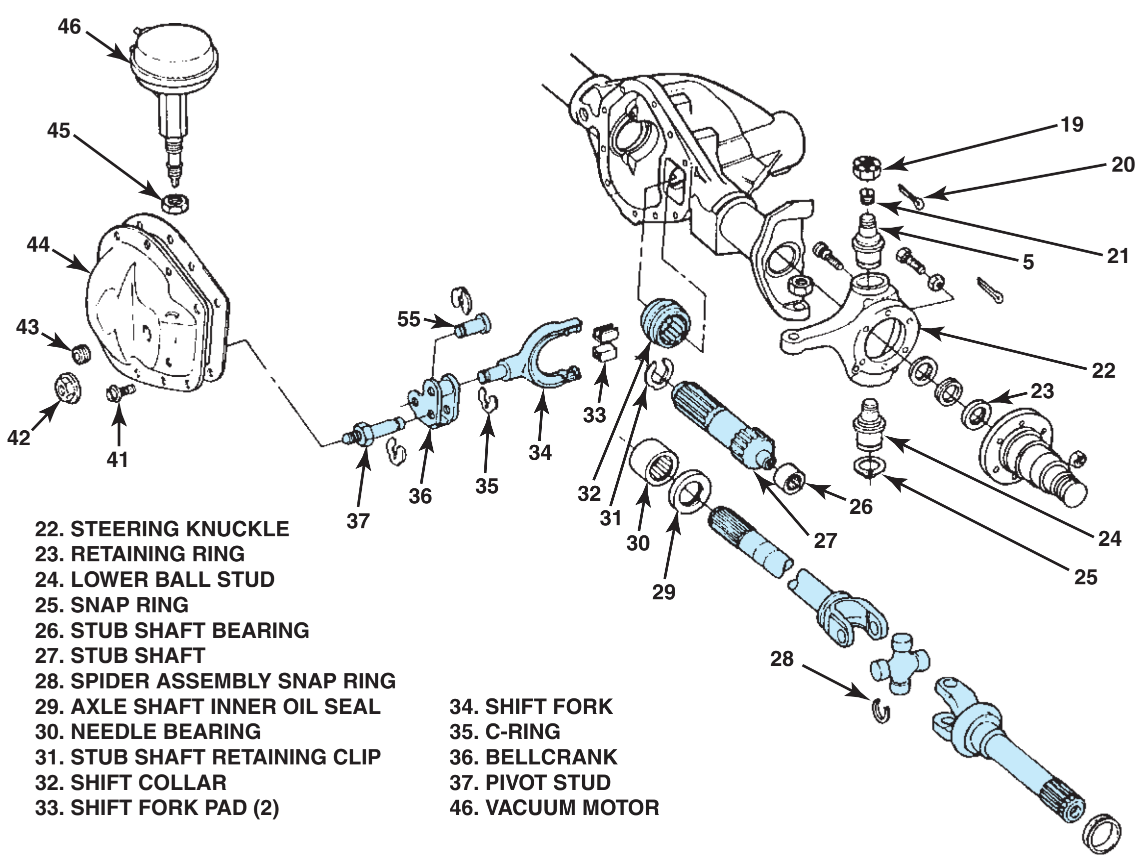


FIGURE 13-26 This axle has a vacuum shift feature that allows disconnecting the left axle. *(Courtesy of DaimlerChrysler Corporation)*

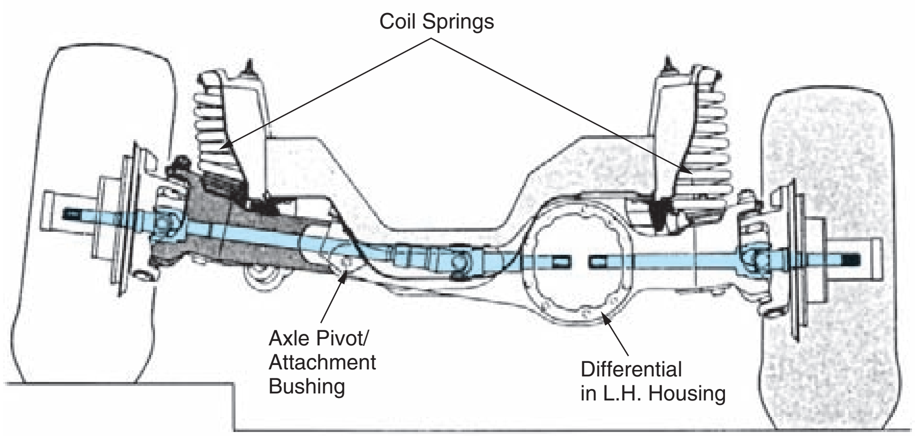


FIGURE 13-27 A twin-traction drive axle allows independent front suspension. *(Courtesy of Ford Motor Company)*

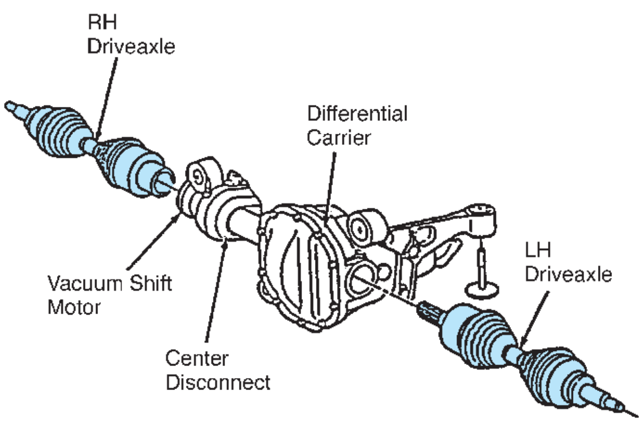


FIGURE 13-28 Front axle assembly for independent front suspension (IFS); note the axle assemblies, which are similar to those of a FWD car. *(Courtesy of Ford Motor Company)*

rier and the left steering knuckle. The right-side axle assembly supports the right steering knuckle. The right-side shaft is much longer than the left, and it is a three-piece assembly with two Cardan U-joints.

Most modern 4WD light trucks and utility vehicles use a version of a short–long arm (SLA) suspension similar to that used by many RWD passenger cars. This suspension produces much better ride quality and handling (Figure 13-28).

A steering knuckle support, which has provision for the steering pivots, is formed into the outer ends of the front drive axle housings. Some early units and larger units in use today use a **closed knuckle**, which has a large rounded housing that encloses a CV joint; these units use a pair of tapered roller bearings for the steering pivots (Figure 13-29). Most front drive axles use an **open design** with ball joints for the steering pivots and a Cardan U-joint (Figure 13-30).

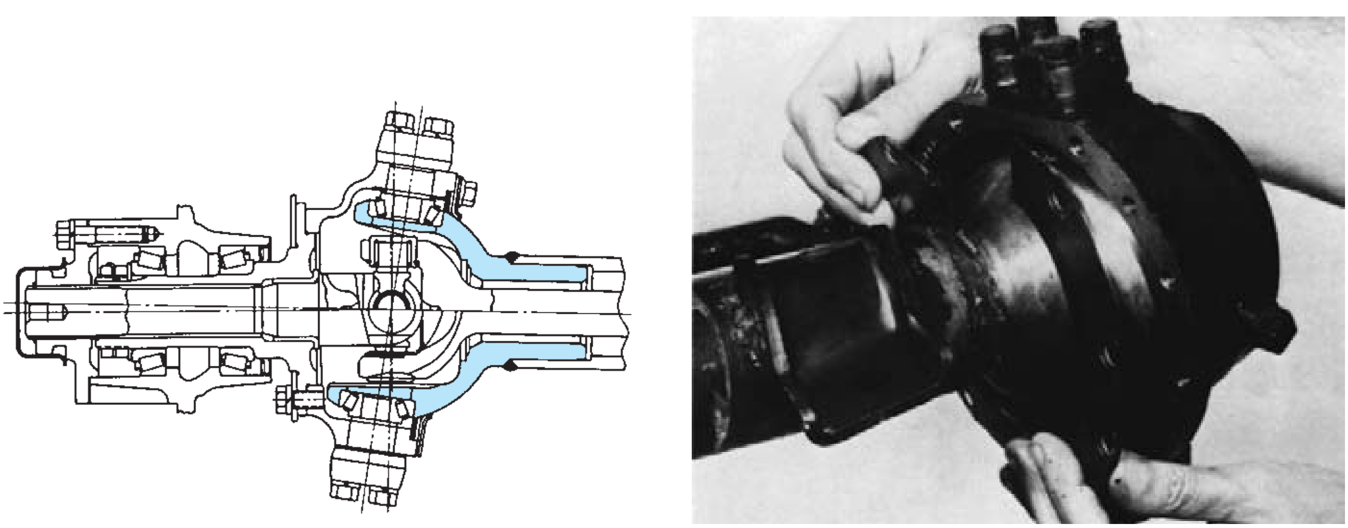


FIGURE 13-29 A closed-end axle encloses the CV joint in a round chamber, keeping it clean and lubricated. *(Courtesy of Dana Corporation)*

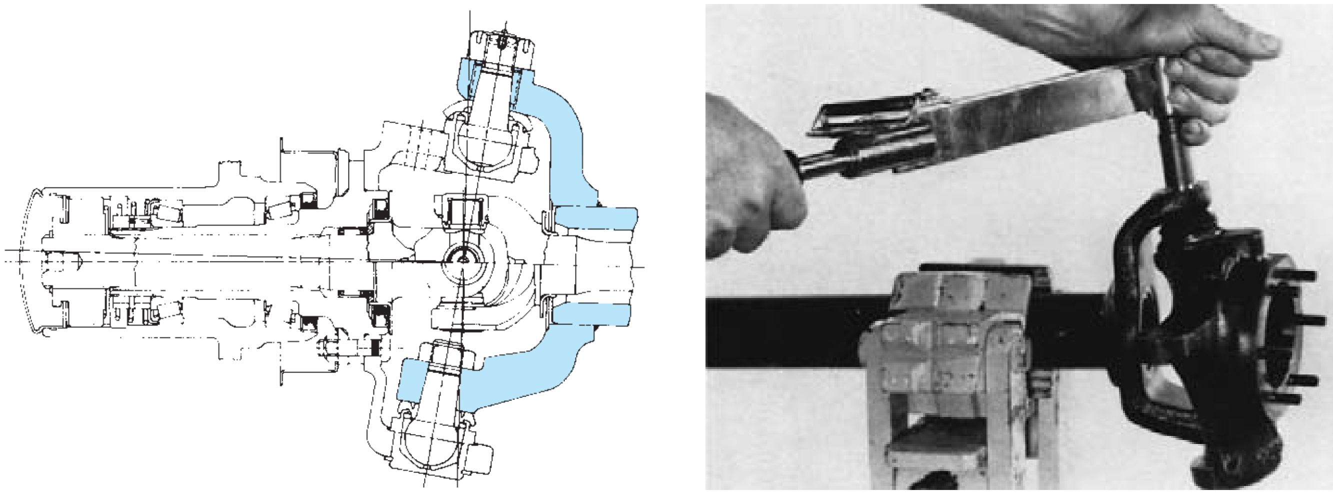


FIGURE 13-30 An open-end axle uses a standard Cardan U-joint exposed to the elements. *(Courtesy of Dana Corporation)*

TECH TIP

The front axle of many part-time 4WD vehicles does not get used very often; it is common to go many months without 4L or 4H being used. During this time, the oil will drain off the bearings and gears, and rusting, corrosion, or other deterioration can occur. It is recommended that the vehicle be driven in 4H a short distance, 10 to 20 yards or meters, every month or so to recoat the parts of the drive axle with gear oil.

Most axle shafts consist of two pieces: an inner axle that connects to the axle gear in the differential, the U-joint, or CV joint; and an outer axle that connects to the wheel hub. In most cases, a special hub unit is used to make the connection at the wheel hub. Some 4WDs mount the differential carrier to the vehicle frame or body and use a fully independent suspension that is similar to that of some FWD cars.

Integrated Wheel End Disconnect

The transfer case can only disconnect the power from the driveshaft to the one drive axle. This is the front axle of RWD-based vehicles or the rear axle of vehicles based on FWD designs. But, the wheels of that axle will still drive the axle shaft and gears as well as the driveshaft, causing unnecessary wear and a fuel economy loss (about 0.5 mpg).

Some 4WD vehicles are equipped with special hubs that can be manually manipulated to lock or unlock the power flow; other hubs operate automatically. An **integrated wheel end disconnect** system has been recently developed that is used to connect or disconnect the outboard CV joint with the wheel hub. This is controlled by a 4WD electronic control so that the wheel ends connect when 4WD is engaged and disconnect when shifted back to 2WD (Figure 13-31).

A coupler, which resembles a synchronizer sleeve, is used to connect the CV joint with the wheel hub (Figure 13-32). The coupler is released by vacuum and engaged by a wave spring. Vacuum remains at the release piston during 2WD operation. A vacuum loss will cause the wheel ends to engage; if the system should fail, 4WD engages. The engine intake manifold provides the vacuum, which is controlled by the vacuum control valve. The control valve is controlled by the 2WD–4WD mode switch.

Wheel Hub

Several styles of hubs are used to connect the front drive axle to the wheel hub. In some cases, it is simply a unit with internal splines that is bolted directly to the wheel hub. A simple hub is not used on some vehicles because it will drive the front axle and driveshaft while the transfer case is in 2WD. This drag causes wear, a loss of power, and reduced fuel mileage.

Many 4WD utility vehicles use a type of **locking hub** that disconnects during normal driving (Figure 13-33). There are two major types of locking hubs: mechanical and automatic. **Mechanical hubs** contain a dog clutch that is shifted by rotating the hub unit manually to engage or disengage the dog clutch (lock the hub) or disengage it. The hub engages when an internal cam moves a spline on the clutch hub into mesh

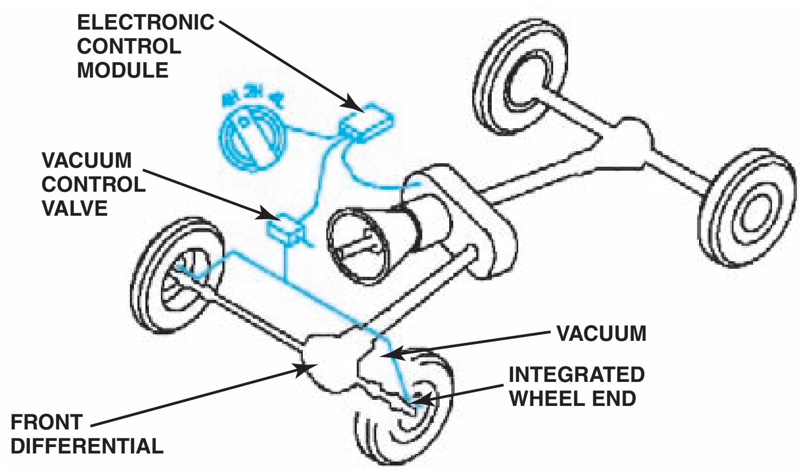


FIGURE 13-31 This wheel end disconnect system can connect or disconnect torque transfer from the CV joints to the wheel hubs. The vacuum control system is controlled by the vacuum control valve and the electronic 4WD controls. *(Courtesy of Warn Industries)*

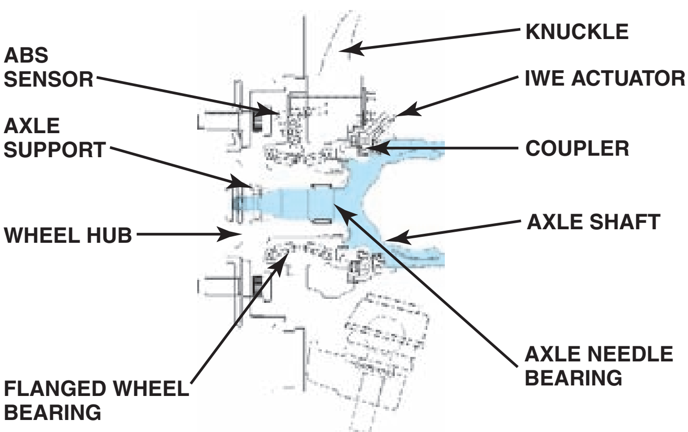


FIGURE 13-32 On an integrated wheel end, the coupler is moved to the left by a wave spring to lock the wheel hub to the axle shaft/CV joint housing. The coupler is moved to the right by vacuum to disconnect the wheel hub from the axle shaft. *(Courtesy of Warn Industries)*

with a spline in the wheel hub. Some hubs have an automatic feature in which rotation of the axle causes the cam in the hub to operate. Some early **automatic hubs** used a two-direction, one-way clutch that allowed the axle to drive the hub in addition to the dog clutch. Automatic hubs allow the driver to engage 4WD without having to get out of the vehicle and go to the hubs to lock them. They also include a method of manually engaging the dog clutch so that they will stay locked in engagement. Some automatic hubs are applied when the axle drives the hub in either forward or reverse, and they are disengaged by driving in the opposite direction. Other automatic hubs use a vacuum diaphragm to apply the hub. Vacuum is sent to the hubs to apply them and vented to release them.

4WD hubs use tapered roller wheel bearings much like a 2WD vehicle, only larger (Figure 13-34). Besides the diameter, the major difference is that two nuts are used. An inner nut is used to adjust bearing clearance, and an outer nut is used to lock or jam the inner one. A washer, which also serves to lock the adjustment, separates the two nuts.

Locking and automatic hubs are disliked by some motorists, usually those that don't understand their operation. Some manufacturers use axle disconnect mechanisms; these use a vacuum or electric motor to move a shift collar that couples the two-piece axle shaft for 4WD and uncouples it in 2WD. The axles and differential gears will rotate in 2WD, but the ring and pinion gears are not driven.

TECH TIP

After 4WD operation, one manufacturer recommends driving in reverse for 10 feet to ensure release of the automatic hubs. If one or both hubs remain engaged, drive axle noise or wear can occur.

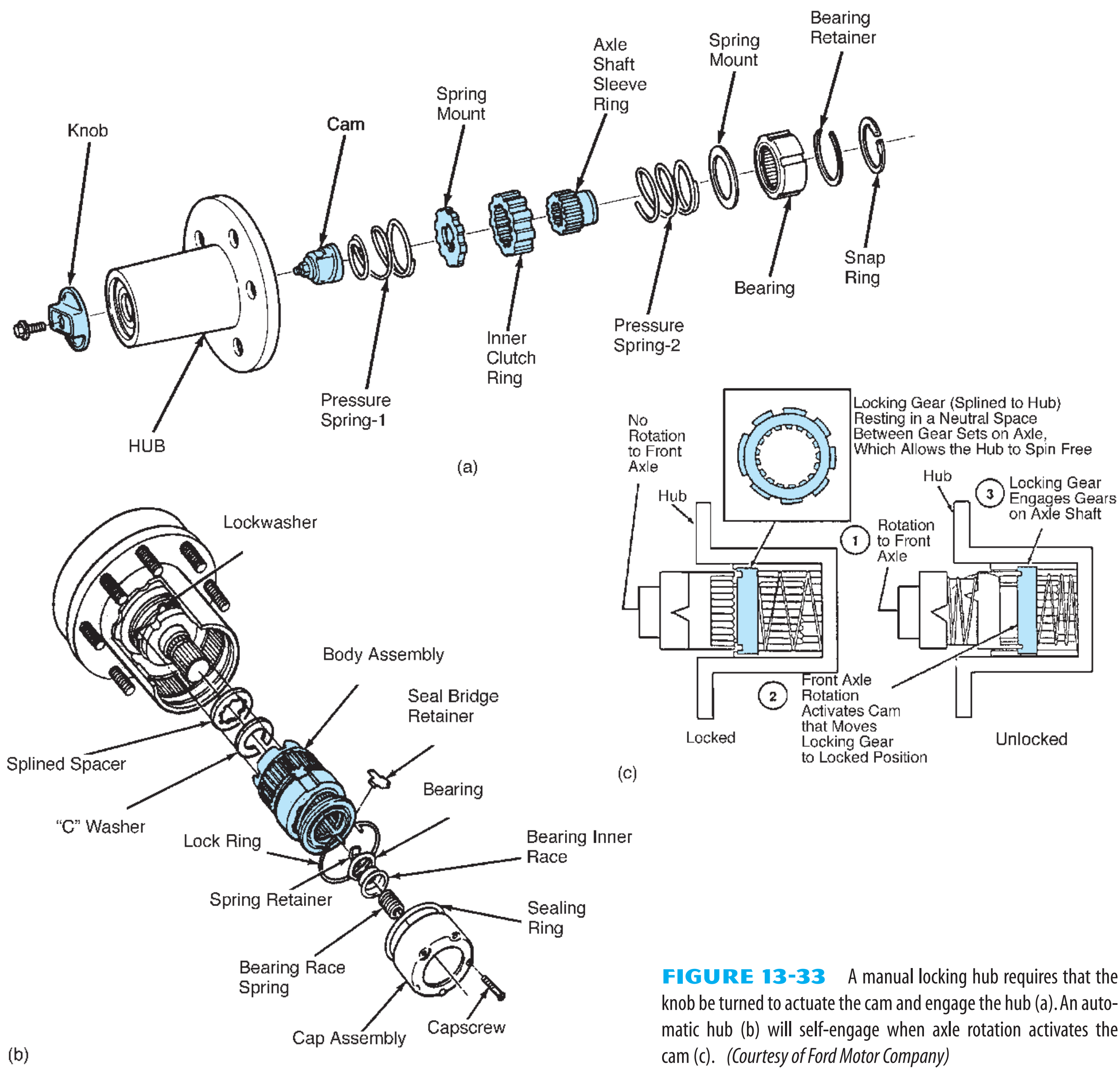


FIGURE 13-33 A manual locking hub requires that the knob be turned to actuate the cam and engage the hub (a). An automatic hub (b) will self-engage when axle rotation activates the cam (c). *(Courtesy of Ford Motor Company)*

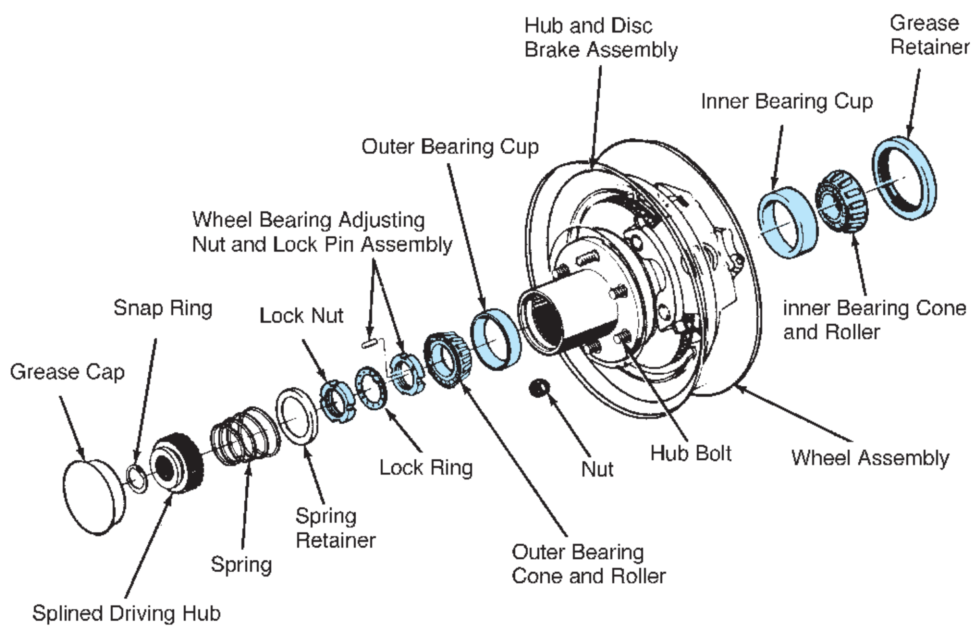


FIGURE 13-34 Exploded view of the front wheel bearings from a front drive axle. Note that this unit has a permanently engaged hub. *(Courtesy of Ford Motor Company)*

SUMMARY

1. Early 4WD vehicles were based on front engine, RWD vehicles. Many of today's 4WD/AWD vehicles are based on front engine FWD vehicles.
2. A transfer case or power transfer unit drives the additional axle.
3. Transfer cases/PTUs can include a differential, viscous coupler, or electromechanical clutch for AWD.
4. Transfer cases can use a gear set or silent chain to drive the second output shaft.
5. Some transfer cases include a planetary gear set for low range.
6. A front drive axle has outboard U-joints to allow steering.
7. Front wheel hubs can be disconnected using a mechanical, automatic, or vacuum operation.

REVIEW QUESTIONS

1. A typical transfer case will have ____________ input and ____________ output shafts.
2. Full-time four-wheel-drive or all-wheel-drive vehicles use a center ____________.
3. Excessive wear in the center differential or drive axle could be caused by unequal ____________ diameters.
4. The two most popular types of transfer cases are ____________ and ____________ drives.
5. The front drive axle uses a ____________ ____________ so that 4WD can be disconnected during normal road driving.
6. Four-wheel-drive front axle hubs are either ____________ or self-locking.

CHAPTER QUIZ

1. A transfer case is used to (A) control the power flow to the second driveshaft; (B) provide a gear reduction for additional torque. Which is correct?
   - **a.** A only
   - **b.** B only
   - **c.** Both A and B
   - **d.** Neither A nor B
2. To transfer power to the front output shaft, a transfer case uses (A) a helical gear train; (B) a large silent chain. Which is correct?
   - **a.** A only
   - **b.** B only
   - **c.** Both A and B
   - **d.** Neither A nor B
3. An AWD transfer case must include a
   - **a.** shifter for the front output shaft.
   - **b.** differential.
   - **c.** low-range gear set.
   - **d.** all of these.
4. Low range in many transfer cases (A) is available only while in 2WD mode; (B) sends the power flow through a planetary gear set. Which is correct?
   - **a.** A only
   - **b.** B only
   - **c.** Both A and B
   - **d.** Neither A nor B
5. At its outer ends, a 4WD front drive axle uses (A) CV joints; (B) Cardan U-joints. Which is correct?
   - **a.** A only
   - **b.** B only
   - **c.** Both A and B
   - **d.** Neither A nor B
6. A 4WD vehicle has automatic front hubs; the control on the hubs is to (A) prevent one front wheel from spinning while the other one is not; (B) disengage the hub from the driving axle for driving on the road. Which is correct?
   - **a.** A only
   - **b.** B only
   - **c.** Both A and B
   - **d.** Neither A nor B
7. The drive train of a FWD-platform based AWD vehicle with a transverse engine will include a
   - **a.** transfer case.
   - **b.** power transfer unit.
   - **c.** coupler.
   - **d.** both b and c.
8. Which of the following is a passive-type of coupler?
   - **a.** Electromagnetic clutch.
   - **b.** Electro-hydraulic coupler.
   - **c.** Viscous coupler.
   - **d.** all of these.