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SAMPLE CHAPTER

ELECTRONICALLY CONTROLLED AUTOMATIC TRANSMISSIONS

Fundamentals of

Medium-Heavy Duty Commercial Vehicle Systems

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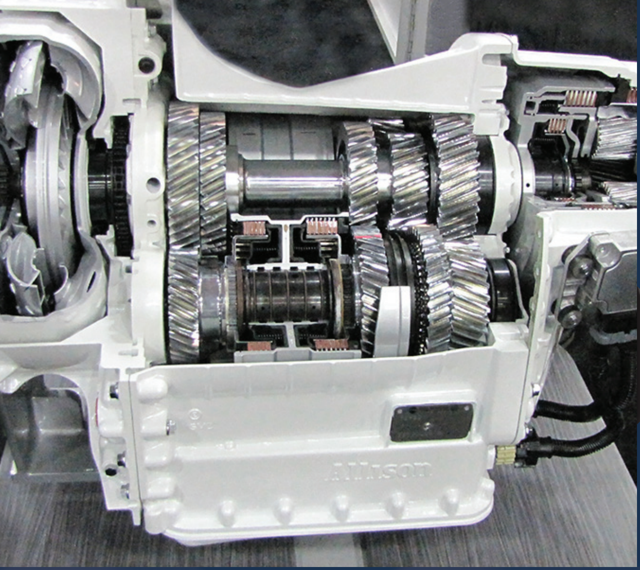
BRIEF CONTENTS



CHAPTER 46

NATEF Tasks

Drive Train

Transmission	Page
■ Inspect and test operation of automatic transmission electronic shift controls, shift solenoids, shift motors, indicators, speed and range sensors, electronic/transmission control units (ECU/TCU), neutral/in gear and reverse switches, and wiring harnesses.	155–156
■ Inspect and test operation of automatic transmission electronic shift selectors, switches, displays, indicators, and wiring harnesses.	157
■ Use appropriate electronic service tool(s) and procedures to diagnose automatic transmission problems; check and record diagnostic codes, clear codes, and interpret digital multi-meter (DMM) readings; determine needed action.	159

Knowledge Objectives

After reading this chapter, you will be able to:

1. Describe the operation of Allison Automatic Transmission Electronic Control (ATEC) and Commercial electronic control (CEC). (pp. 102–117)
2. Describe the operation of Allison World Transmissions (WT). (pp. 118–121)
3. Explain the powerflows of the Allison World Transmission (WT). (pp. 122–127)
4. Describe the operation of the World Transmission Electronic Control (WTEC) and later models WTECII and WTECIII. (pp. 127–144)
5. Describe the operation of the electronic controls in Allison Fourth and Fifth Generation transmissions. (pp. 144–170)
6. Describe the operation of the Allison TC-10-TS transmission. (p. pp. 160–170)
7. Explain the operation of Voith transmission's DIWA Drive. (pp. 170–177)
8. Describe ZF Friedrichshafen AG (ZF) Ecomat and Ecolife transmissions. (p. 177)
9. Describe Caterpillar CX-28, CX-31, and CX-35 transmissions. (p. pp. 177–179

Electronically Controlled Automatic Transmissions

Skills Objectives

After reading this chapter, you will be able to:

1. Scan the TCM. (p. 158) **SKILL DRILL 46-1**
2. Inspect, adjust, repair, or replace electronic shift controls, electronic control unit, wiring harnesses, sensors, control module, vehicle interface module, and related components. (p. 159) **SKILL DRILL 46-2**

Introduction

Controlling automatic transmissions electrically is not a new concept. As far back as the 1950s and 1960s, it made sense to operate the transmission electrically in certain off-road and industrial applications. Using electric controls eliminated the need for mechanical connections and meant that the controls could be located at virtually any remote location instead of having to be located precisely at the transmission. Allison invented an electrical control known as a shift pattern generator (SPG) that used pitot tube pressure to measure rotational speed. Allison used SPG primarily in its series of transmissions developed for off-highway use.

Allison was not the only early adopter of electrically controlled automatic transmissions. Voith DIWA drive transmissions were always controlled electrically, as were the ZF bus and coach transmissions (the EcoLife and the EcoMat). Over the years, however, increased competition in the business environment has caused companies to insist on ever higher fuel efficiency as a way to keep costs under control. As a result, electrical control of automatic transmissions has been replaced by increasingly sophisticated electronic control technology.

This chapter will introduce you to the electronically controlled automatic transmissions commonly used in the North American market. The dominant company in this market is Allison—throughout its history, it has produced over 5,000,000 commercial vehicle transmissions worldwide. Because Allison is the primary heavy-duty transmission manufacturer in North America, we will concentrate our discussion in this chapter on Allison products. We will also look at the Voith DIWA series transmissions and the ZF bus transmission models and will briefly discuss Caterpillar's CX series of automatic transmissions used it its CT660 on-highway trucks.

Basics of Electronic Control—ATEC and CEC

Allison's initial foray into electronic control began with its original MT-600, HT-700, and V-series (bus) transmissions. The original electronic control was called the **Allison Transmission Electronic Control (ATEC)**. This system is now called the **Commercial Electronic Control (CEC)**, but it is essentially the same system. The mechanical components of these transmissions are identical to their hydraulically controlled counterparts discussed in the chapter on Hydraulically Controlled Automatic Transmissions and so will not be discussed again in this chapter. If necessary, take time to review the mechanical transmission operation material in that chapter before continuing on in this chapter.

You Are the Truck Technician

A vehicle with an Allison ATEC transmission is brought to your shop in northern Minnesota on a particularly icy day when overnight temperatures were well below zero. The driver complains that, when he first started the vehicle, the transmission would not go into gear for over five minutes. Then, the transmission would not shift out of first gear until he had driven for another minute, but now it seems to shift normally. The driver had not driven this vehicle previous to today and is concerned that transmission damage may have occurred. You check the fluid level, and it is correct. The fluid itself is bright red and shows no signs of contamination. You then perform a stall test and a road test and find that the vehicle is performing as it should.

1. What could be the cause of this condition?
2. Should you remove the oil pan and look for clutch damage?
3. Could this be normal operation for this vehicle?

All automatic transmissions require at least three inputs in order to be able to shift properly:

- The driver's gear selection
- A load sensitive signal
- A speed sensitive signal

Without these three inputs, automatic transmissions would not know when to shift. In hydraulically controlled transmissions, those three inputs are provided by the mechanical shift selector, the modulator or throttle valve as the load sense, and the centrifugal governor as the speed sense.

The ATEC/CEC system is completely drive by wire. That is, there is no mechanical connection to the transmission. The only connections in and out of the transmission are electrical. The driver's gear selector consists of either a push button control pad or an optional shift lever. Either way, all of the selections are made electronically. The load sensitive signal, the modulator valve, is replaced by a throttle position sensor (TPS), and the centrifugal governor input, or speed sensitive signal, is replaced by a vehicle speed sensor (VSS). These inputs and more are sent to the **transmission electronic control unit (ECU)**, also called the **transmission control unit (TCU)**. The transmission control unit, or transmission electronic control unit, is the brains of the control system. It processes the received data and decides when shifts should occur. Some manufacturers call this unit the TCM; others call it the transmission ECM **FIGURE 46-1**. The transmission controller then issues commands to solenoids inside the transmission to obtain the desired range.

Transmission Electronic Control Unit or ECU

The transmission control unit provides all of the shifting "thought process" for the transmission. The unit receives signals from the driver and the transmission and then decides on the best shift strategy for the operating conditions. There have been three different types of ECUs used by the Allison CEC **FIGURE 46-2**. The first, and now obsolete, Splash Proof model ECU was replaced by the Sealed Standard ECU. The third type, the Sealed-Plus 11, includes an additional connector which allows a remotely mounted operator interface for remote power take-off (PTO) operation and other special features.

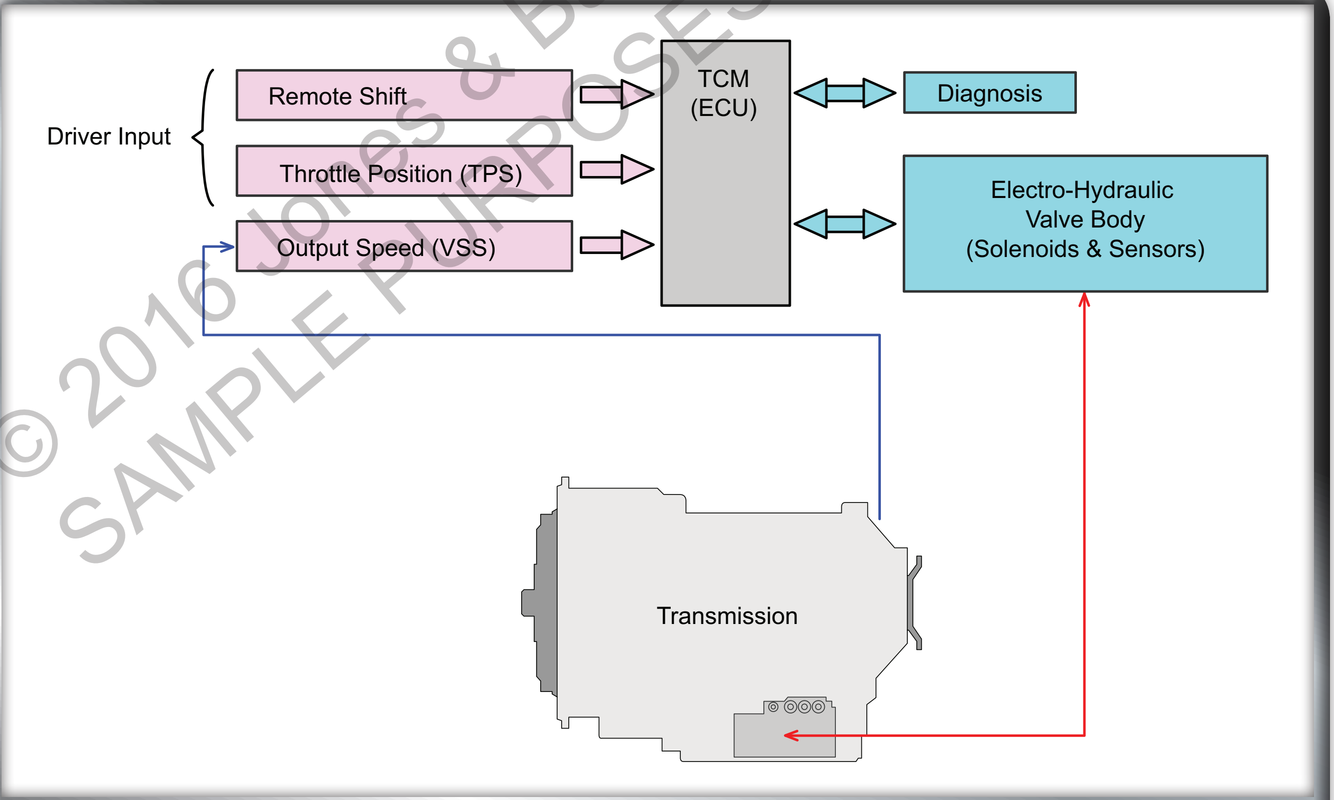


FIGURE 46-1 The transmission controller receives inputs from the shifter, the TPS, and the VSS and then controls solenoids in the electro-hydraulic valve body to shift the transmission.

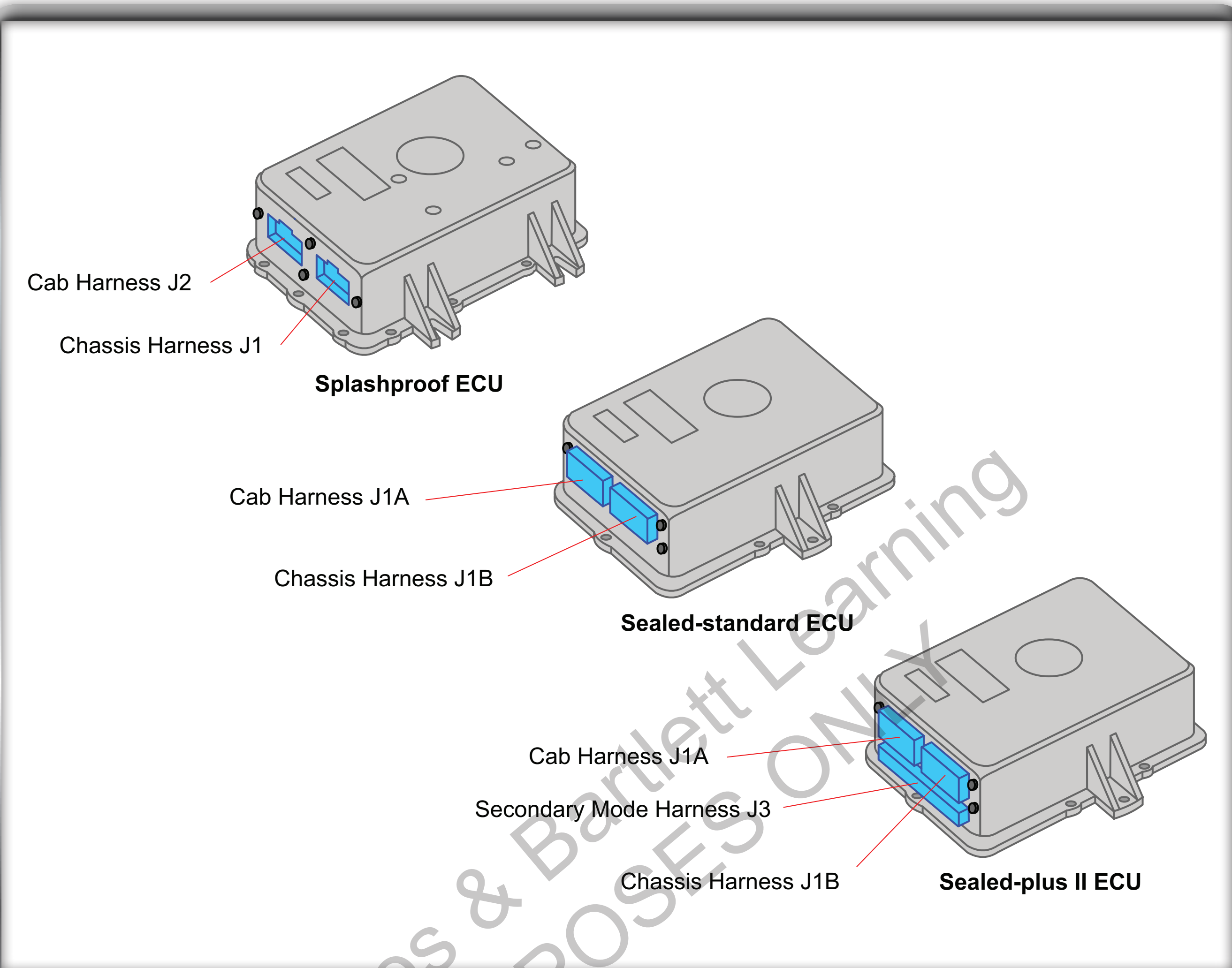


FIGURE 46-2 The ATEC/CEC electronic control unit had three generations.

Each transmission ECU is fitted with a **programmable read-only memory (PROM) chip** FIGURE 46-3. PROM chips are essential to the proper functioning of the transmission and unique to vocation of the particular vehicle in which they are found, such as a fire truck, garbage truck, and so on. PROM chips allow the same ECU to be used in all installs because each ECU contains its own replaceable PROM chip. The PROM chip is the only serviceable part in the ECU. It is accessed through a small cover in the ECU case. Installing the wrong PROM chip can severely affect vehicle performance.

Transmission Inputs

The Driver's Input or Shift Control

The shift control can be a push button unit used to activate gear changes FIGURE 46-4. The gear range selections are usually R, N, D, 3, 2, and 1. In some applications, however, there may be fewer choices. When the driver selects a range, the information is relayed to the transmission ECU.

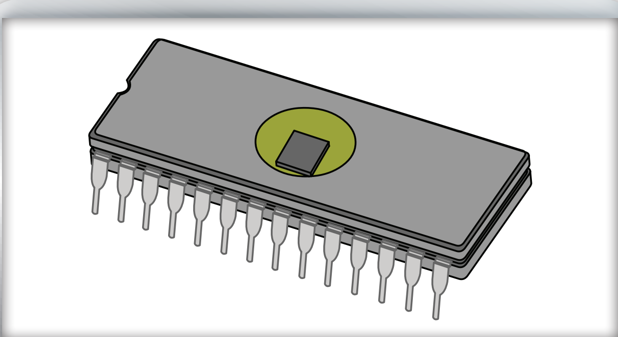


FIGURE 46-3 The prom chip is replaceable in order to change the shift programming to suit a specific vehicle vocation.

FIGURE 46-4 The driver's input can be a push button control as shown or a shift lever type.

FIGURE 46-5 The vehicle interface module allows for communication between the engine and transmission when necessary.

Lever-type shift selectors usually have the same six gear positions as shift-button selectors or fewer. When the driver moves the Allison supplied shift lever, it actuates Hall effect switches. The Hall effect switches send a corresponding signal to the transmission ECU. If necessary, the vehicle can be also equipped with a remote shift control unit for special applications.

Throttle Position Sensor

On non-electronic engines, the throttle position sensor (TPS) can be OEM or Allison supplied. With an OEM-supplied TPS, the signal may have to pass through a communications adapter called a vehicle interface module before the signal can be read by the transmission ECU FIGURE 46-5.

The TPS replaces the modulator throttle valve used on hydraulically controlled transmissions and gives the transmission ECU the load sensitive signal required for shift timing and strategies. The Allison-supplied TPS is a cable-actuated linear potentiometer. As the throttle is actuated, the potentiometer sends a voltage signal to the transmission ECU, and the ECU converts this voltage into "counts." **Counts** is the term Allison uses to monitor the TPS position FIGURE 46-6.

The sensor's range is from 0 to 255 counts, which equates to the sensor's ability to travel approximately 1.5 inches. The sensor's actual movement, however, equates to only about 100 counts, or the equivalent of .75 inches. On installation, the sensor is set up so the throttle movement takes place in the middle of the sensor's range. Setting the sensor up at the midpoint allows the sensor to be self-correcting. As the throttle cable stretches over time, the sensor can reset itself so that idle and wide-open throttle still fall within the acceptable counts range. When the vehicle is shut down, the ECU records the minimum and maximum throttle positions during that drive cycle. Each time the vehicle is started, the ECU sets minimum and maximum travel at 15 counts past the last recorded reading and then adjusts the reading to reflect actual throttle movement. Those adjustments act to recalibrate the TPS on each drive cycle. Another critical adjustment that can be made by the technician is the ability to set error zones in the sensor's range. When counts from 0 to 14 and from 233 to 255 are set as error zones, the ECU can detect a broken cable or other serious problem. If the ECU reads data in the error zones, it will generate a code and turn on the check transmission/do not shift light.

Vehicle Speed Sensor (VSS)

The **vehicle speed sensor (VSS)** is an inductive pick-up sensor that reads the speed of the transmission output

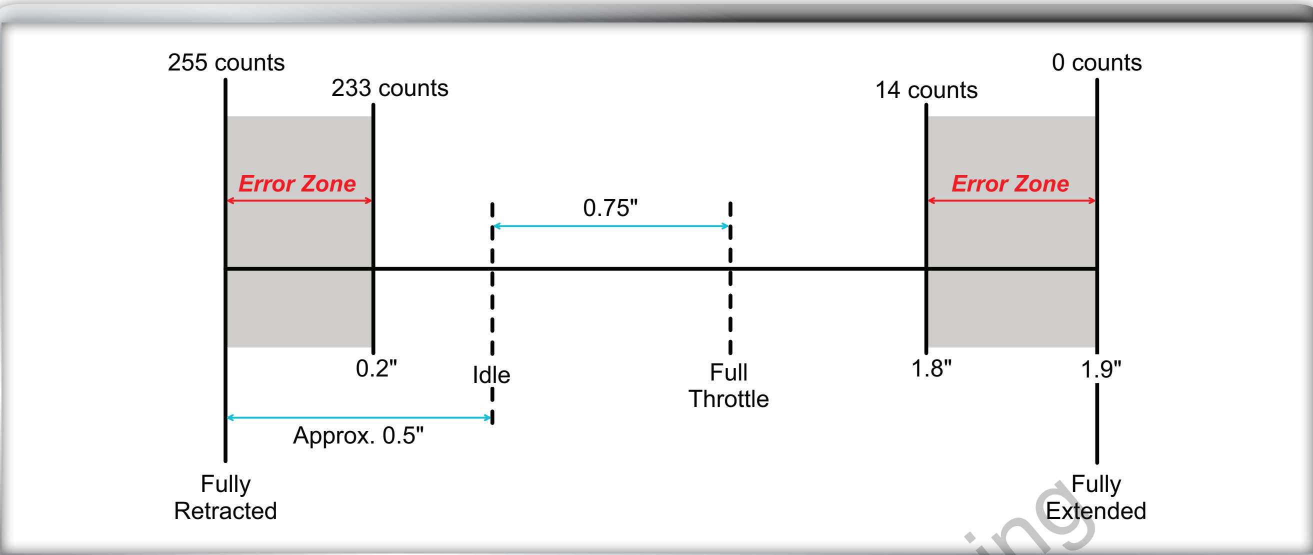


FIGURE 46-6 The transmission ECU converts the voltage signal from the Allison TPS into "counts."

shaft **FIGURE 46-7**. An inductive pick-up is simply a coil of wire wrapped around a permanent magnet core. The pick-up is placed in close proximity to a tone wheel (a toothed ring) splined to the output shaft. As the shaft rotates and the teeth on the wheel approach the magnet, the magnetic field builds and collapses.

The rising and falling levels of the magnetic field send an alternating current to the transmission ECU, which reads the voltages cross counts (i.e., the number of times the voltage changes from positive to negative) and translates the currents as output shaft speed. The VSS sensor provides a road-speed signal used with the TPS to determine shift timing. As such, the VSS replaces the centrifugal governor used on hydraulically controlled transmissions.

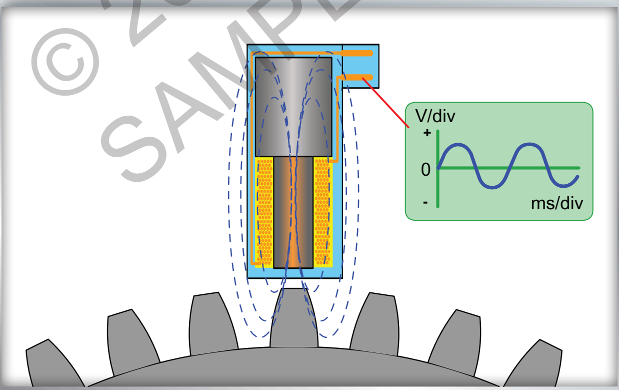


FIGURE 46-7 A vehicle speed sensor (VSS) produces an AC voltage signal that rises in frequency and amplitude as speed increases.

Fluid Sensors

Fluid sensors are a critical part of electronically controlled automatic transmissions. The most common sensors monitor pressure and temperature.

Forward and Reverse Pressure Switches

The forward and reverse pressure switches are threaded oil-pressure switches plumbed into the forward and reverse hydraulic circuits. The contacts in these switches are normally open and close, respectively, when the forward range or reverse circuit is pressurized. The transmission ECU can determine that a forward or reverse range has been achieved by monitoring these switches.

Fluid Temperature Sensor

Severe transmission damage can occur if the transmission fluid is either too hot or too cold. The transmission, therefore, has a temperature sensor that is monitored by the ECU. In on-highway models, the sensor is mounted on the valve body wiring harness inside the transmission oil pan.

The ECU will not allow shifts into any gear range if the fluid temperature is below -25°F (-32°C). As the fluid temperature rises, the controller will allow limited shifts to first or reverse only while the temperature is between -25°F and +25°F (-32°C to +4°C). If the fluid temperature increases to 270°F (132°C), the check transmission light on the shift control will be illuminated, a code will be recorded in the transmission ECU's memory, and, in on-highway models, a shift to top gear will be inhibited. Certain emergency vehicle applications will not inhibit top gear for high temperature, but the check transmission/do not shift light will illuminate and a code will be set.

Oil Pressure Switch/Sensor

The transmission ECU relies on two other inputs—the oil temperature sensor and one of three additional sensor types:

- The lube oil pressure switch
- The low oil level pressure sensor
- The fluidic oil level sensor

Inputs to those three additional sensors are used more for transmission protection rather than shift strategy, however.

It is important for the technician to know which of the above type of switch/sensor is installed because the electrical circuit for each type will react differently during testing. The installed switch can be determined by calling Allison Electronic Control Information System (ECIS), available through authorized Allison dealers, with the transmission assembly number from the plate on the side of the transmission case **FIGURE 46-8**. The PROM chip in the transmission ECU must also be programmed correctly to the type of switch, so care must be taken if either the switch/sensor or the PROM chip needs replacing.

The first type of switch/sensor is a simple oil pressure switch (called a lube pressure switch by Allison) that is plumbed into the transmission lube oil circuit. The switch contacts are normally open and close when lube oil pressure is present. If the switch contacts remain open after the vehicle is started, the check transmission/do not shift light will be illuminated and a trouble code will be set in the transmission ECU's memory.

The second type is the low oil level/pressure sensor. This sensor is bolted to the bottom of the **electro-hydraulic valve body**, also known as the **electro-hydraulic control** which is the central transmission control consisting of solenoids, spool valves, and pressure switches. The low oil level/pressure sensor bolted to the electro-hydraulic control has pressurized lube oil directed to a small orifice in the body of the sensor. The effect of the lube oil going through the orifice creates a stream of lube oil exiting one side of the sensor. A pressure switch with normally open contacts is plumbed into an opening on the other side of the sensor. The sensor is mounted in such a way that when the oil reaches operating temperature, the higher oil level caused by thermal expansion surrounds the opening on the sensor and dissipates the flow of the stream of oil exiting the sensor **FIGURE 46-9**.

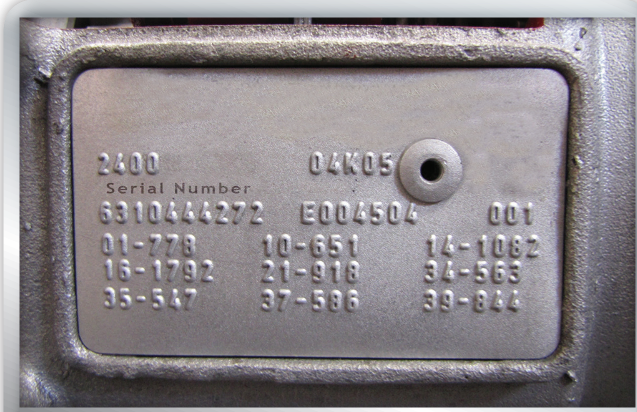


FIGURE 46-8 The plate on the side of the transmission contains important information about the transmission. Never remove the information plate.

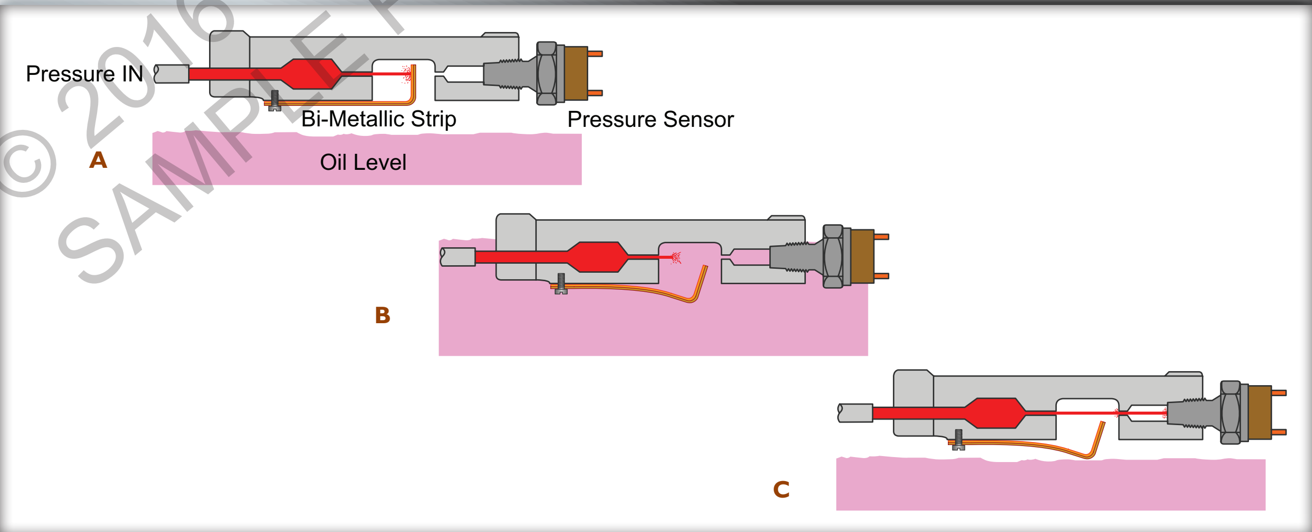


FIGURE 46-9 Low oil level/pressure sensor at **A.** Cold temperature. **B.** Normal temperature. **C.** Normal temperature, low level.

When the transmission is cold, a bi-metallic strip blocks the flow of oil, so the sensor works a bit differently. When the vehicle is started, a pressurized stream of oil flows from the orifice on one side of the switch. Because the transmission is cold at start-up, the fluid level will be below the opening in the sensor, but the bi-metallic strip will block the stream of pressurized oil from reaching the pressure switch on the other side and closing its contacts. As the transmission warms up, the bi-metal strip flexes out of the way, but, by that time, the warming transmission fluid expands and fills the opening in the sensor. The presence of the fluid in the sensor opening dissipates the oil flow and prevents it from closing the switch contacts. A stream of fluid that reaches the switch after the fluid is warm indicates that the fluid level is low. A code is then generated and the check transmission/do not shift light is illuminated.

The fluidic oil level sensor is very similar to the low oil level/pressure sensor but without a bi-metallic strip FIGURE 46-10. The transmission ECU is programmed to ignore signals from the sensor until the fluid temperature reaches operational levels, so the bi-metal strip is not required. The pressure switch that the fluidic sensor uses is a normally closed switch. If the fluid level is low, pressurized transmission fluid reaches the switch after the transmission warms up. The contacts open, a code is generated, and the check transmission/do not shift light is illuminated.

Wiring Harnesses

Transmissions are supported by one of two general types of wiring harness. The **chassis wiring harness** is the wiring that connects the transmission, the TPS, and the VSS to the transmission ECU. The **cab harness** connects the shift selector to the ECU and also contains the bi-directional communications connector to allow the transmission ECU to "talk" to Detroit Diesel DDEC systems, the diagnostic data link (DDL) connector. The **diagnostic data link (DDL) connector** is the place on the vehicle where the technician can plug in diagnostic software. (Technicians using a Pro-Link or other electronic service tool can connect to the DDL and access trouble codes stored in the ECU). The cab harness also contains various interface wiring for optional transmission strategies, such as brake interlocks, low floor operating/no-shift options, and so on.

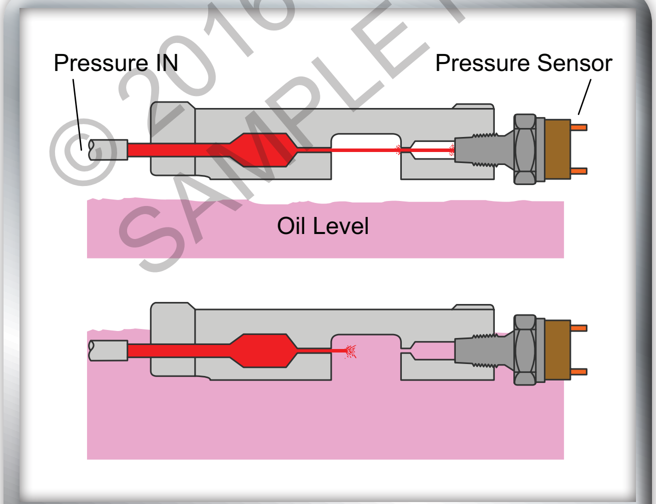


FIGURE 46-10 Fluidic oil level sensor.

Solenoids

Inside the ATEC/CEC transmission, the hydraulic circuitry is changed somewhat when compared to its hydraulically controlled predecessor. Whereas hydraulically controlled Allison transmissions use spool valves exclusively to control fluid flow, ATEC/CEC transmissions use solenoids in addition to spool valves. The solenoids direct the flow of main pressure to control the transmission shifting and other functions. The solenoids use a spring-loaded check ball to control fluid flow. Solenoids have three components:

- An inlet port controlled by the ball
- A circuit port leading to the hydraulic circuit the solenoid controls
- An exhaust port

When the solenoid is closed, the hydraulic circuit that is controlled is open to the exhaust port. When the solenoid is opened, the exhaust port is sealed, and the inlet port is connected to the hydraulic circuit.

The ATEC/CEC system uses two types of solenoids—latching and non-latching solenoids FIGURE 46-11. **Latching solenoids** require only a short burst of electricity to cause them to move. Once they do, they latch, or stay in that position. Another burst of electricity causes the solenoid to unlatch and move back to the starting position. Therefore, these solenoids do not require constant power. That reduces the amount of heat that would build up in the solenoid coil and extends the life of the solenoids. This latching feature also gives some transmission operability during electrical power failure. We will discuss failsafe operational strategies later in the chapter. As their name implies, **non-latching solenoids** do not stay in an open position unless they have a constant voltage supply. As soon as the voltage disappears, they return to their starting, or closed, position.

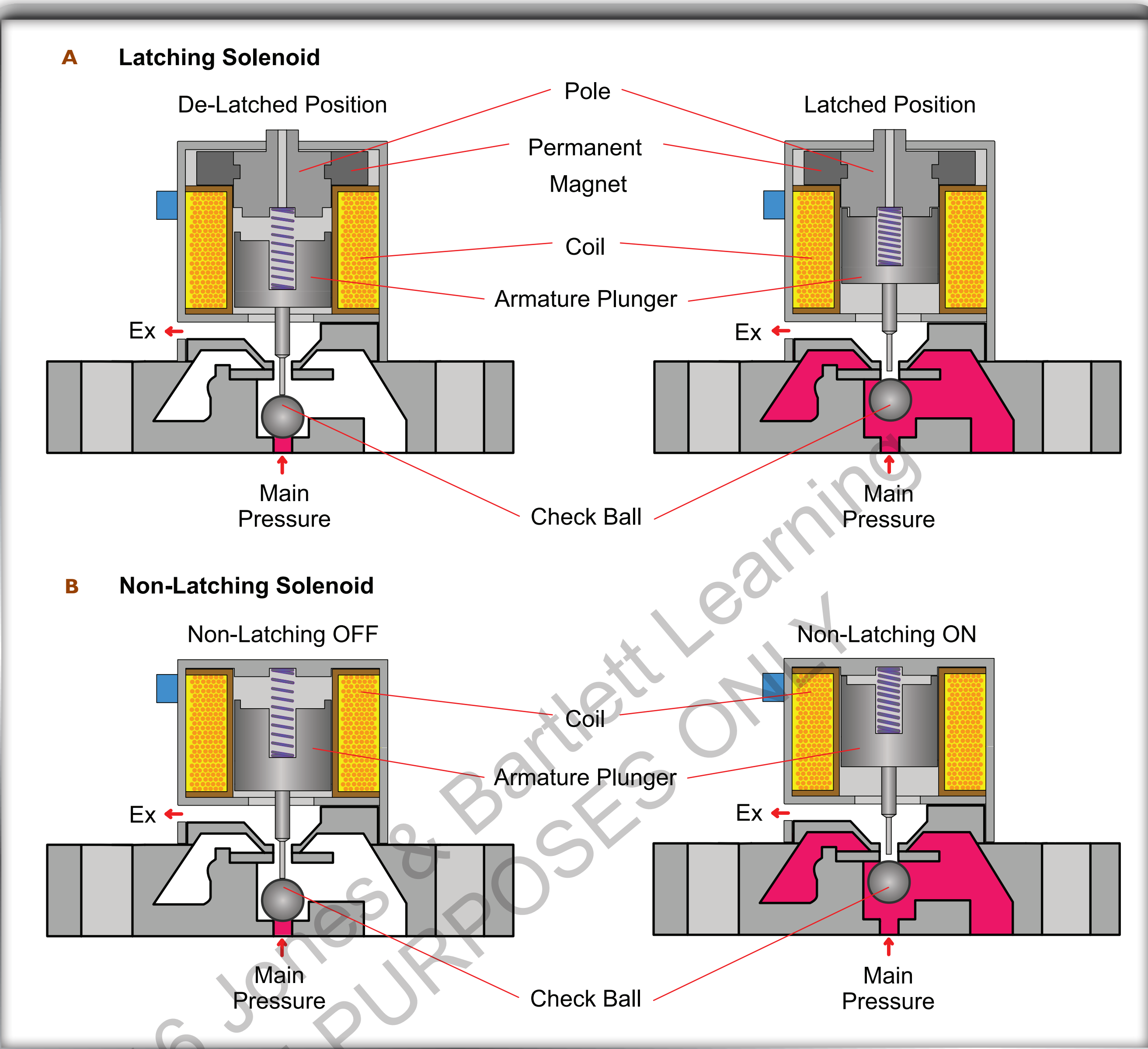


FIGURE 46-11 The ATEC/CEC transmission uses two types of solenoids: latching and non-latching. **A.** Momentary application of power to a latching solenoid moves it to an open position, and it stays there until energized again. **B.** Non-latching solenoid require continuous voltage to remain open.

Solenoid Usage

There are up to nine solenoids in the transmission: solenoids A, B, C, D, E, F, G, H, and J. (There is no "I" solenoid). The solenoids are located in an electro-hydraulic valve body and can either be clamped to or bolted to the valve body **FIGURE 46-12**.

The hydraulic circuits of the transmission are altered so that the solenoids control the flow through the main valve body. The solenoids are mounted such that they have main pressure present at their base. That pressure is blocked when the solenoid is closed, but when the solenoid is opened electrically, main pressure is redirected to the appropriate valves in the main valve body. In hydraulically controlled transmissions, the shift signal valves control the shift relay valves. In the ATEC/CEC transmissions, however, the shift signal valves are replaced with latching solenoids A, B, C, and D. The shift relay valves in the ATEC/CEC are simply called the shift valves and control the following functions:

- Solenoid A controls the low to first shift valve on five-speed models.
- Solenoid B controls the first to second shift valve.

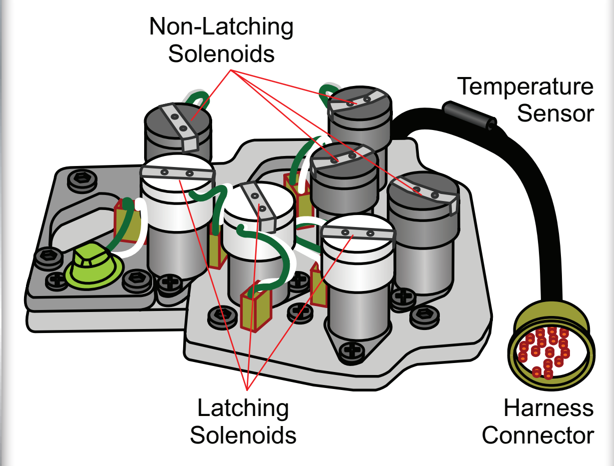


FIGURE 46-12 The electro-hydraulic valve body holds the solenoids and the forward and reverse pressure switches.

- Solenoid C controls the second to third shift valve.
- Solenoid D controls the third to fourth shift valve.

Based on control functions, five-speed models have all four solenoids (A–D). Four-speed models only require three solenoids (B–D), and three-speed models used in some buses only require two solenoids (B and C).

Likewise in the ATEC/CEC, the manual valve is replaced by two solenoid-controlled valves: the neutral range valve and the forward reverse valve. The neutral range valve position is controlled by solenoid H (non-latching) and solenoid J (latching). The forward reverse valve position is controlled by solenoid F (latching).

Solenoid E (non-latching) controls the flow of main pressure to the bottom of the trimmer regulator valve to control shift quality. Solenoid G (non-latching) controls the flow of main pressure to the torque converter lock-up clutch relay valve when lock up is desired.

Shift Logic

The transmission ECU receives range request data from the gear selector, throttle position data or load request from the TPS, and vehicle road speed from the VSS. Based on this input—along with input from the temperature sensor, pressure switches, and the vehicle interface—the transmission controller energizes and de-energizes the solenoids to provide an appropriate range for vehicle operation. These shift timing strategies are known as **shift logic**.

Remember that the ATEC/CEC transmission mechanical systems are relatively identical to the hydraulically controlled models discussed in the chapter Hydraulic Automatic Transmissions. Review that chapter if necessary to understand the power flows. TABLE 46-1 is the clutch application chart for the ATEC/CEC transmission.

Let's examine the fluid flows in the transmission in more depth using a typical four-speed transmission as our example FIGURE 46-13.

On start up, the pump will direct fluid to the main pressure regulator valve. As the valve moves down in its bore and against spring pressure, a passage to the torque converter opens, allowing the converter to fill. Fluid is simultaneously directed into the main pressure circuit of the electro-hydraulic valve body and through the solenoid priority valve to all the solenoids. In addition, fluid flows through three valves—the direction priority valve, the 2-3 shift valve, and the 1-2 shift valve—and into the first clutch. As the main pressure regulator valve moves further down in its bore, it opens a passage back to the transmission sump. The valve becomes balanced against the pressure setting main pressure in the transmission.

Just as in the older hydraulic-controlled models, other pressures can be brought to bear against the main pressure regulator valve as a way to lower its pressure during forward range and converter lock-up operation. Main pressure is again highest in reverse range when forward

TABLE 46-1: Clutch Application Chart for the ATEC/CEC Transmission

Range	Forward Clutch	Fourth Clutch	Third Clutch	Second Clutch	First Clutch
Neutral					Applied
First range	Applied				Applied
Second range	Applied			Applied	
Third range	Applied		Applied		
Fourth range	Applied	Applied			
Reverse		Applied			Applied

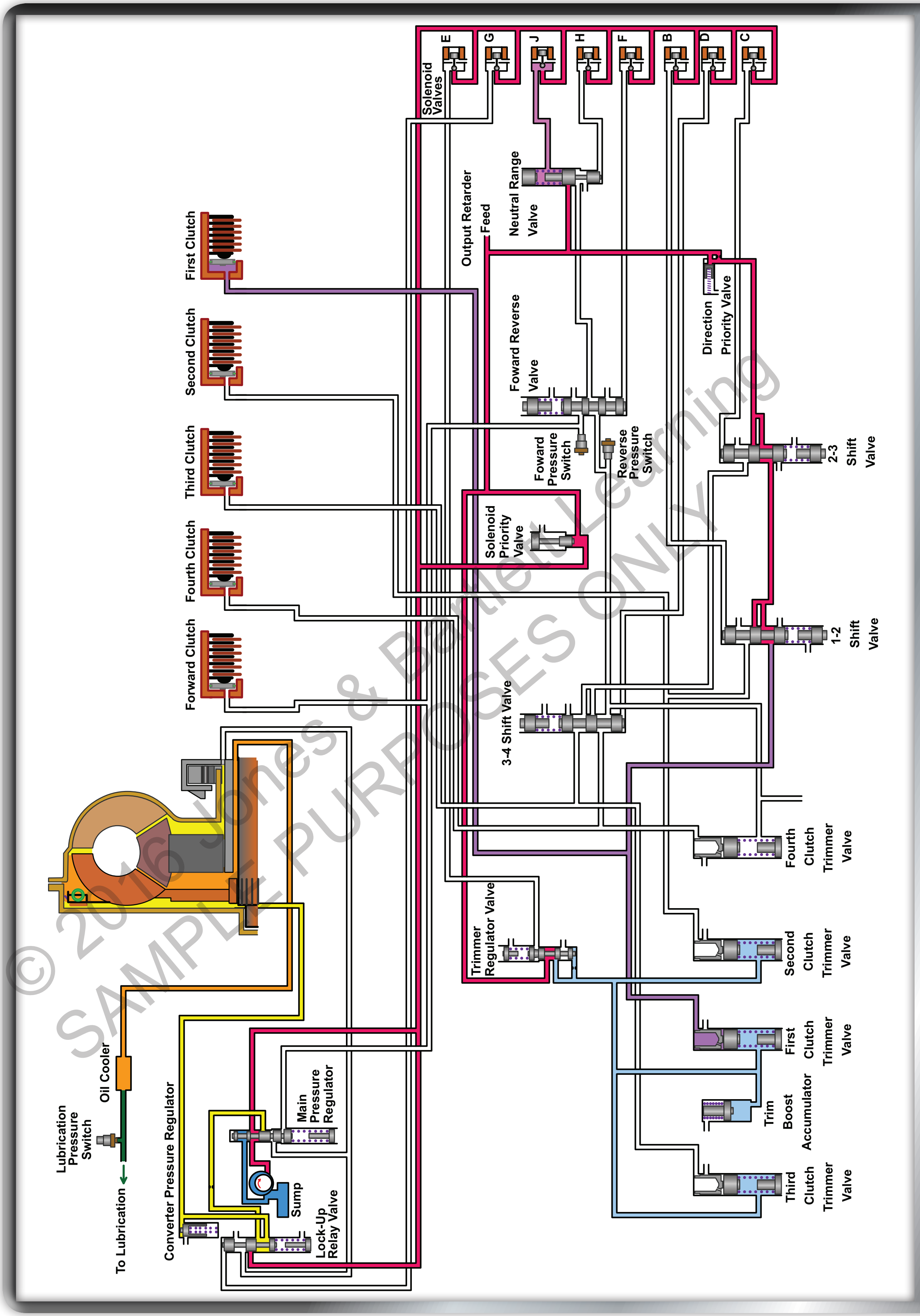


FIGURE 46-13 This complete hydraulic schematic of the ATEC/CEC series of transmissions can be referenced while following the fluid flows.

regulator and lock-up pressures are not influencing the main pressure regulator valve (MPRV). And in both the hydraulically-controlled Allison transmissions as well as in the ATEC/CEC, increasing main pressure causes first clutch to apply.

As we continue the discussion of shift logic, please note the hydraulic circuits shown in the supporting schematics are simplified for clarity.

ATEC/CEC Neutral

In neutral, solenoid J is the only energized or "open" solenoid. Solenoid J (latching) requires only momentary power to open. When J does open, main pressure is directed to the top of the neutral-range valve, keeping the valve seated in its bore. This action prevents internal leakage from causing the neutral-range valve to move up and cause an unwanted range selection. With the neutral-range valve in this position, main pressure dead heads at the valve and cannot flow to the forward reverse valve. First clutch is the only clutch applied so the transmission is in neutral FIGURE 46-14.

ATEC/CEC First Range

As the driver selects first range, solenoid H becomes energized and solenoid J is energized momentarily to close its valve. The pressure above the neutral-range valve is exhausted through solenoid J. Non-latching solenoid H sends main pressure to the bottom of the neutral-range valve, and the valve moves up in its bore. This allows the fluid that had been blocked at the neutral-range valve now to be directed to the forward reverse valve. Latching solenoid F is also energized momentarily to open. When solenoid F opens, main pressure is sent to the bottom of the forward reverse valve, moving the valve up in its bore. With the valve in this position, the fluid flows through the forward reverse valve and into the forward clutch circuit, applying the forward clutch. The first clutch and forward clutch are now applied; the transmission attains first range FIGURE 46-15. Fluid flowing to the forward clutch is also directed to the main pressure regulator valve to reduce main pressure.

ATEC/CEC Second Range

As the vehicle accelerates, the ECU will command a shift to second range. Solenoid F remains open as it is latching. Solenoid H remains energized, so the forward clutch remains applied. Latching solenoid B is momentarily energized and opens. This sends main pressure to the top of the 1-2 shift valve and causes the valve to move down in its bore. That movement exhausts first clutch at

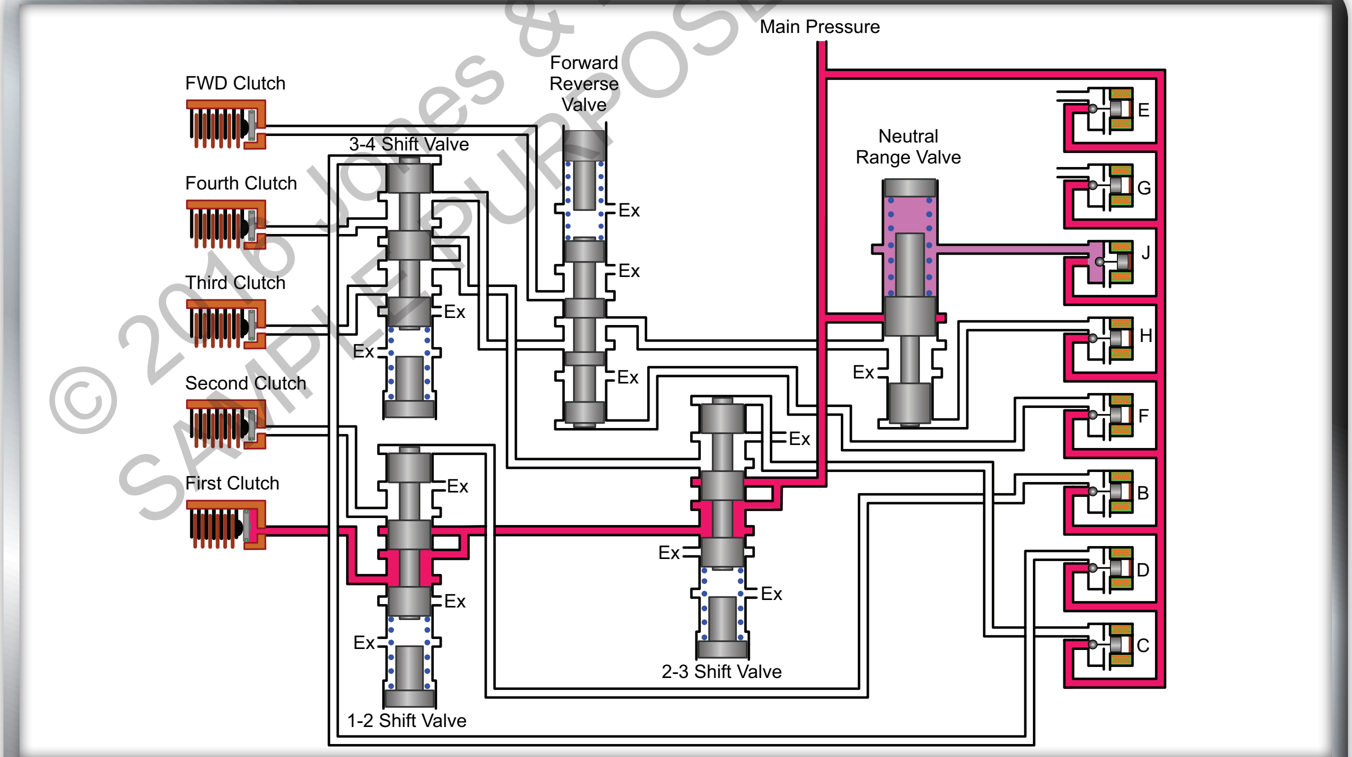


FIGURE 46-14 Neutral fluid flow. In neutral, only solenoid J is open. Solenoid J is latching and only requires momentary energizing to remain open.

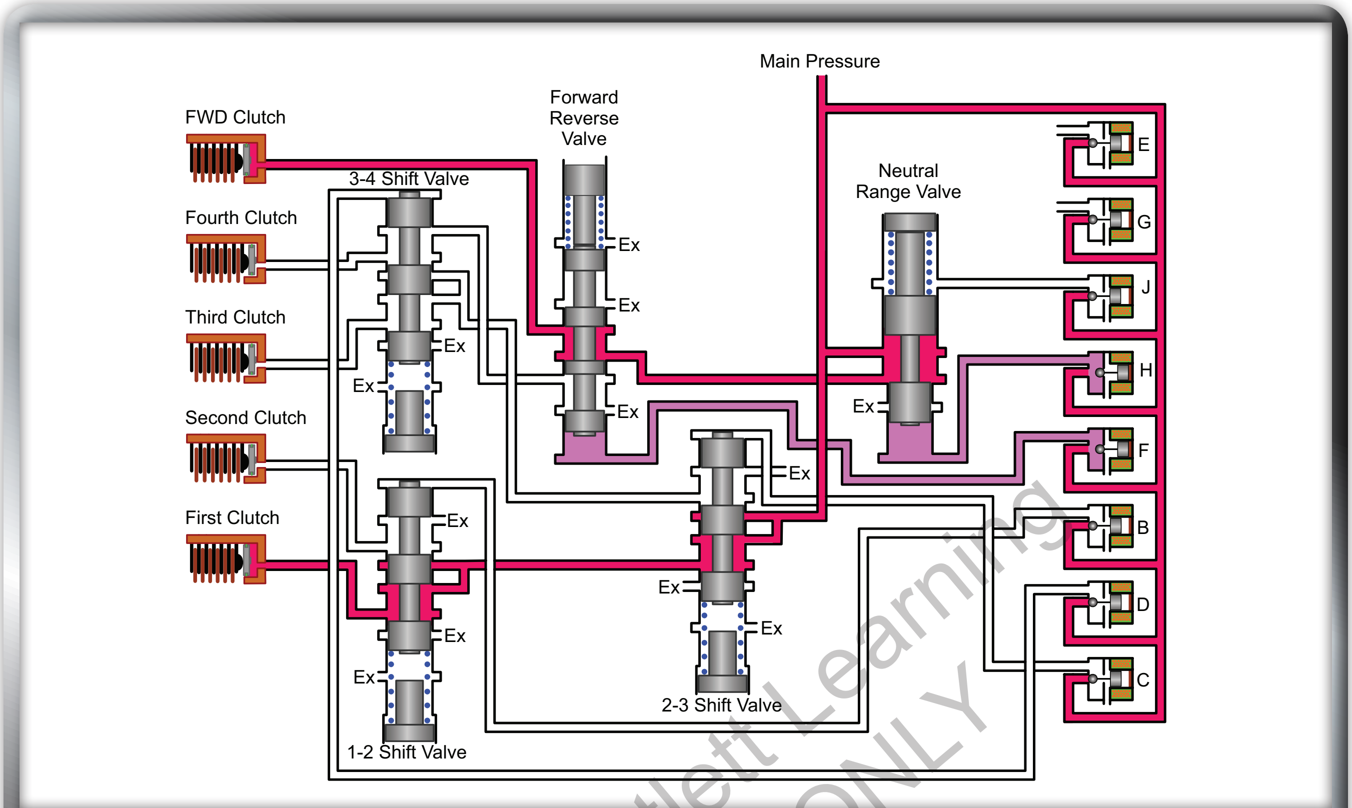


FIGURE 46-15 First range. In first range, latching solenoid F is momentarily energized to open, non-latching solenoid H is energized and holds F open, and latching solenoid J is momentarily energized to close.

the valve. At the same time, the movement sends pressure to the second clutch circuit, applying the clutch. Forward and second clutches are now applied, and the transmission attains second range FIGURE 46-16.

ATEC/CEC Third Range

As the vehicle continues to accelerate, the transmission ECU commands a shift to third. Solenoid F remains open as it is latching. Solenoid H remains energized, so forward clutch remains applied. Latching solenoid C is momentarily energized and opens. The opening causes the 2-3 shift valve to move in its bore and exhausts the second clutch at the valve. The motion redirects main pressure to the third clutch. Forward and third clutch are applied, and the transmission attains third range FIGURE 46-17.

ATEC/CEC Fourth Range

After continued acceleration, the ECU will command a shift to fourth range. Solenoid F remains open as it is latching. Solenoid H remains energized, so the forward clutch remains applied. Latching solenoid D is energized momentarily, and this causes the 3-4 shift valve to move in its bore. That movement exhausts third clutch at the valve and also redirects main pressure to the fourth clutch so forward and fourth clutches are applied, and the transmission attains fourth range FIGURE 46-18.

ATEC/CEC Reverse

Reverse begins with the transmission in neutral. Recall from Figure 46-13. that, in neutral, main pressure flows from the direction priority valve, down through the 2-3 shift valve and the 1-2 shift valve, and into the first clutch, applying it. Latching solenoid J is in the open position holding the neutral-range valve down in its bore, causing main pressure to be blocked at the valve. As the driver shifts the selector to reverse, solenoid J is momentarily energized to close its valve and exhaust the pressure above the neutral-range valve at the solenoid. Non-latching solenoid H becomes energized, and that sends pressure to the bottom of the neutral range valve moving it up in its bore. This redirects the fluid blocked at the neutral-range valve towards the forward reverse valve. Latching solenoid F is closed, and spring pressure holds the forward reverse valve down in its bore. The fluid is redirected through the 3-4 shift valve and on to the fourth clutch applying it. Since first and fourth clutch are applied, the transmission shifts into reverse FIGURE 46-19.

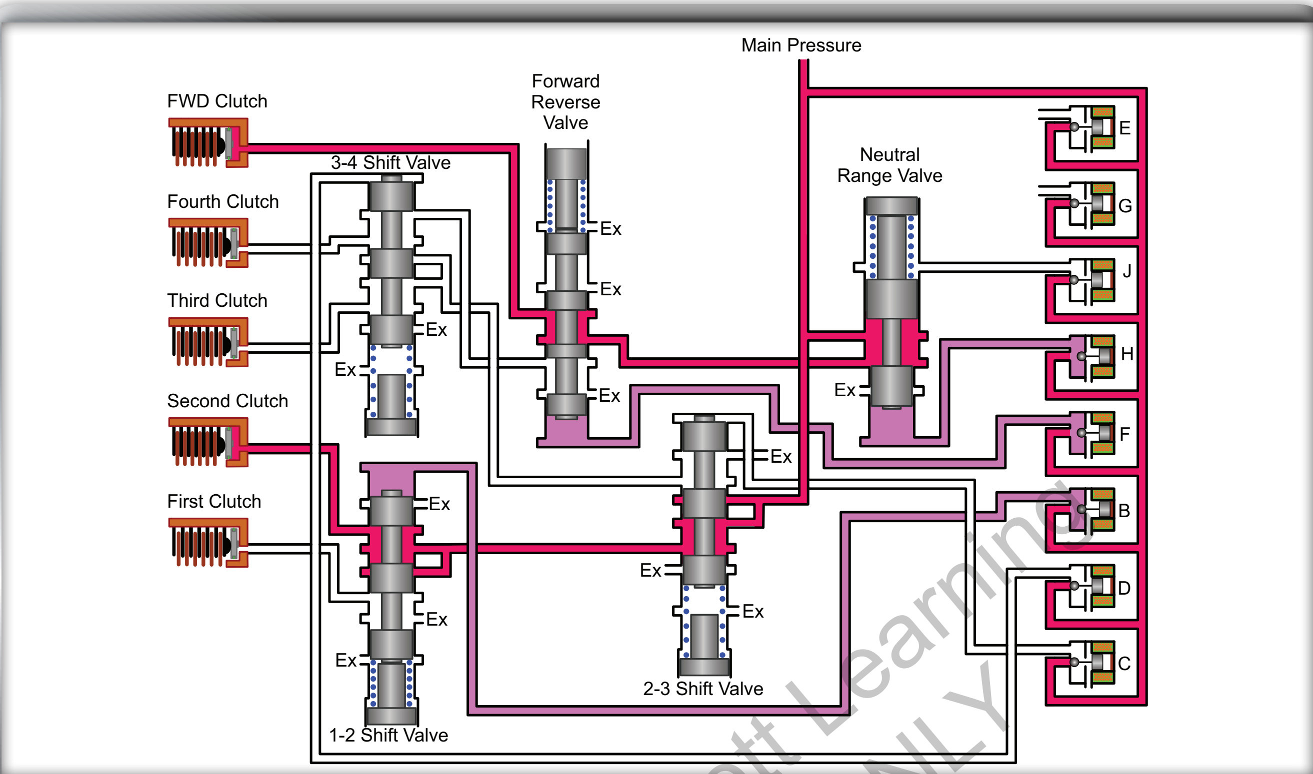


FIGURE 46-16 Second range. To achieve second range, the transmission ECU momentarily energizes latching solenoid B to open sending fluid to the 1-2 shift valve.

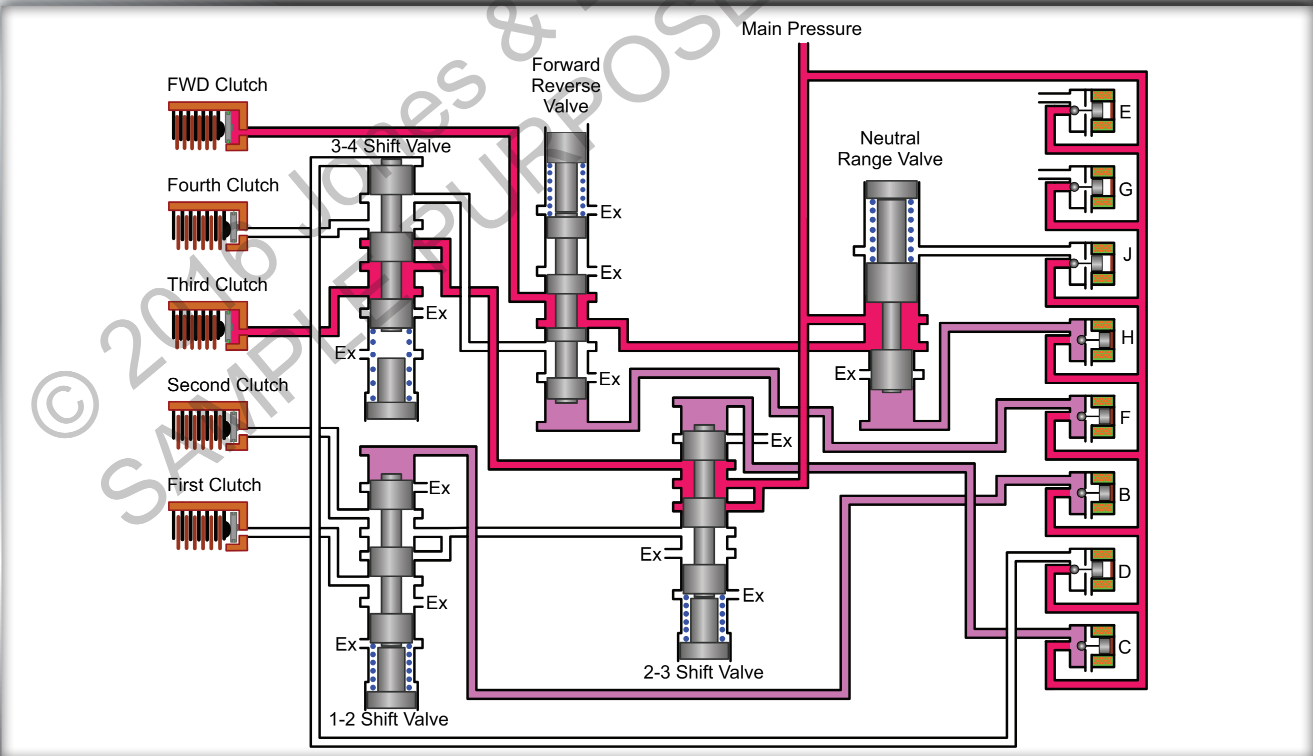


FIGURE 46-17 Third range. To shift to third, the ECU momentarily energizes latching solenoid C to open sending pressure to the 2-3 shift valve.

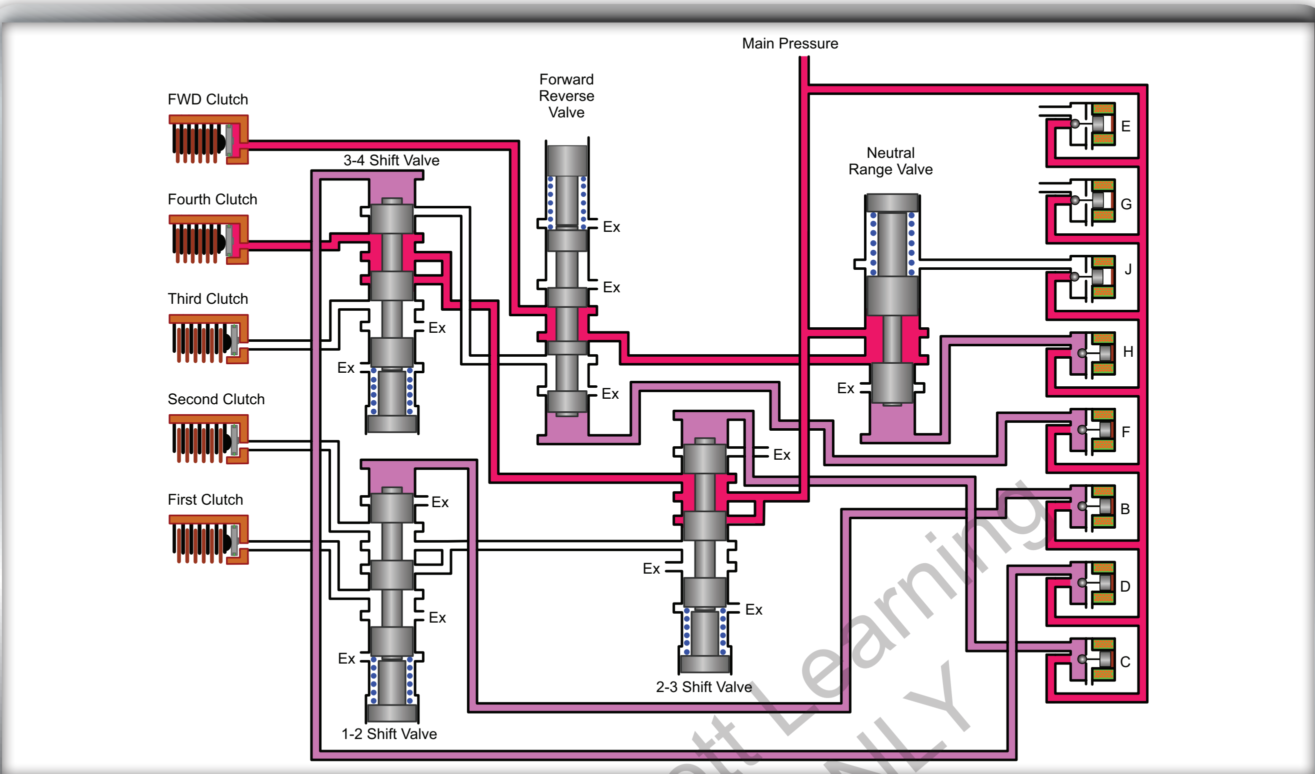


FIGURE 46-18 Fourth range. To achieve fourth range, the ECU momentarily energizes latching solenoid D to open it sending pressure to the 3-4 shift valve.

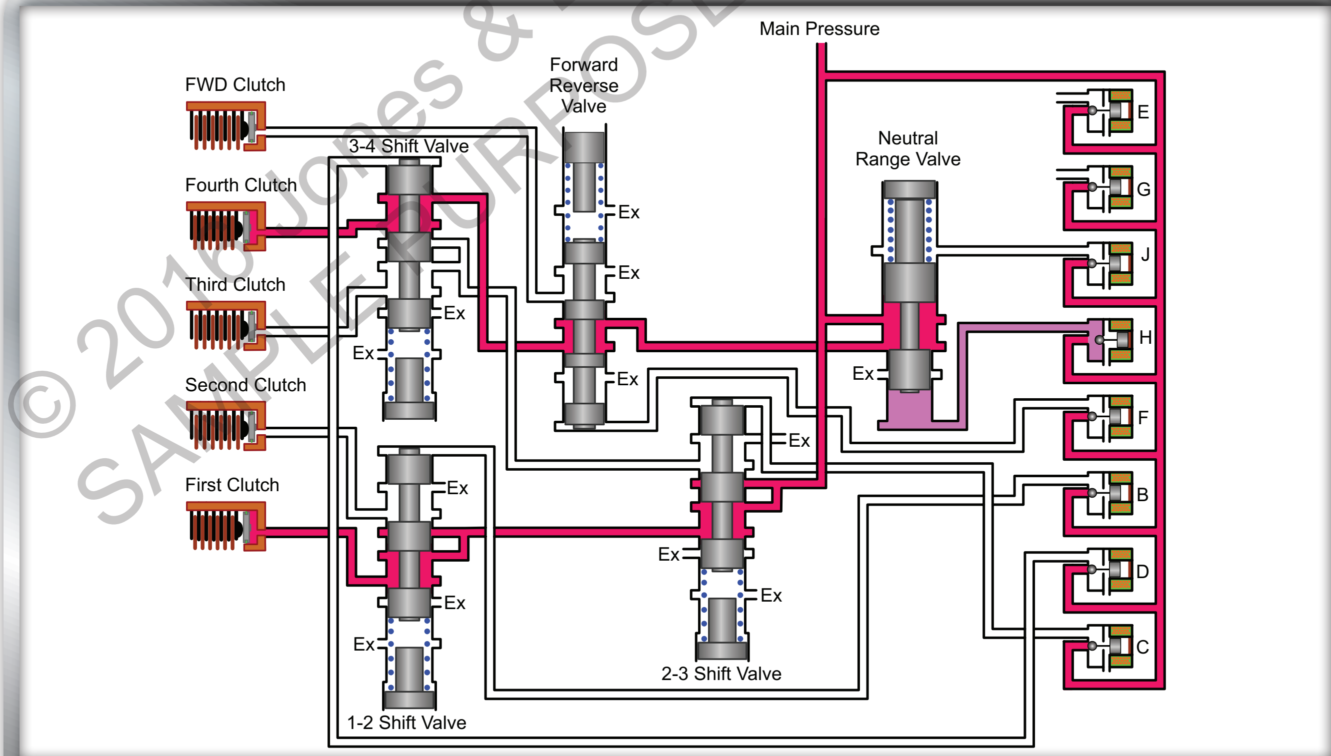


FIGURE 46-19 Reverse. The shift to reverse starts when neutral latching solenoid J is momentarily energized to close and non-latching solenoid H is energized to open.

Trimmer Operation

As in the hydraulically controlled Allison transmissions, shift quality is controlled by trimmer valves. A **trimmer** is an accumulator used in the ATEC and CEC systems to smooth out the shift process. Each clutch, with the exception of the forward clutch, has its own trimmer. Recall from the chapter on Hydraulically Controlled Transmissions that trimmers work as a kind of accumulator system to slow down clutch application to make the shift softer. In hydraulically controlled transmissions, the speed of the trimmer operation is controlled by the trimmer regulator valve, which in turn is controlled by modulator pressure. As a result, at low speeds, shifts are slower and smoother. At high speed/load conditions, the trimmer works more quickly, resulting in faster and harsher shifts with less slippage.

In the ATEC/CEC system, the trimmer regulator valve is controlled by non-latching solenoid E. During light-load, low-throttle shifts, solenoid E is energized. Solenoid E lifts the trimmer regulator valve in its bore and blocks the flow of trimmer regulator pressure to the bottom of the trimmers. With no fluid pressure beneath the trimmer valves, the trimming action takes a longer time to accomplish, so shifts are softer and slower. Under heavier loads or higher-speed shifting, the ECU will de-energize non-latching solenoid E. When this happens, the trimmer regulator valve spring will force the valve back down in its bore. This allows main pressure to leak through the valve and into the bottom of the trimmer valves. Oil pressure beneath the trimmers causes the trimming action to speed up, so shifts occur faster and harsher with less clutch slippage. The ECU bases the decision on whether to energize solenoid E on several inputs, including TPS, VSS, sump temperature, and other inputs. Typically, however, solenoid E will be energized until a throttle level of approximately 60% and de-energized at a throttle level above 60% FIGURE 46-20.

Torque Converter Lock-Up Control

Non-latching solenoid G controls the torque lock-up relay valve. When the transmission ECU determines the correct conditions have been met, the transmission will energize solenoid G to move the lock-up relay valve, thereby redirecting main pressure to the lock-up clutch piston in the torque converter FIGURE 46-21.

Transmission Operation during Electrical Failure

If electric power is lost, all of the latching solenoids will stay in their current position, meaning that the transmission will stay in the range it was in at the time of the power loss. Non-latching solenoid E will be de-energized, returning the trimmer regulator valve to its at-rest position. Non-latching solenoid G will be de-energized and release the torque converter clutch. At the bottom of the neutral range valve, non-latching solenoid H will also be de-energized. Oil flowing through the valve, however, will cause the neutral range valve to remain in the open

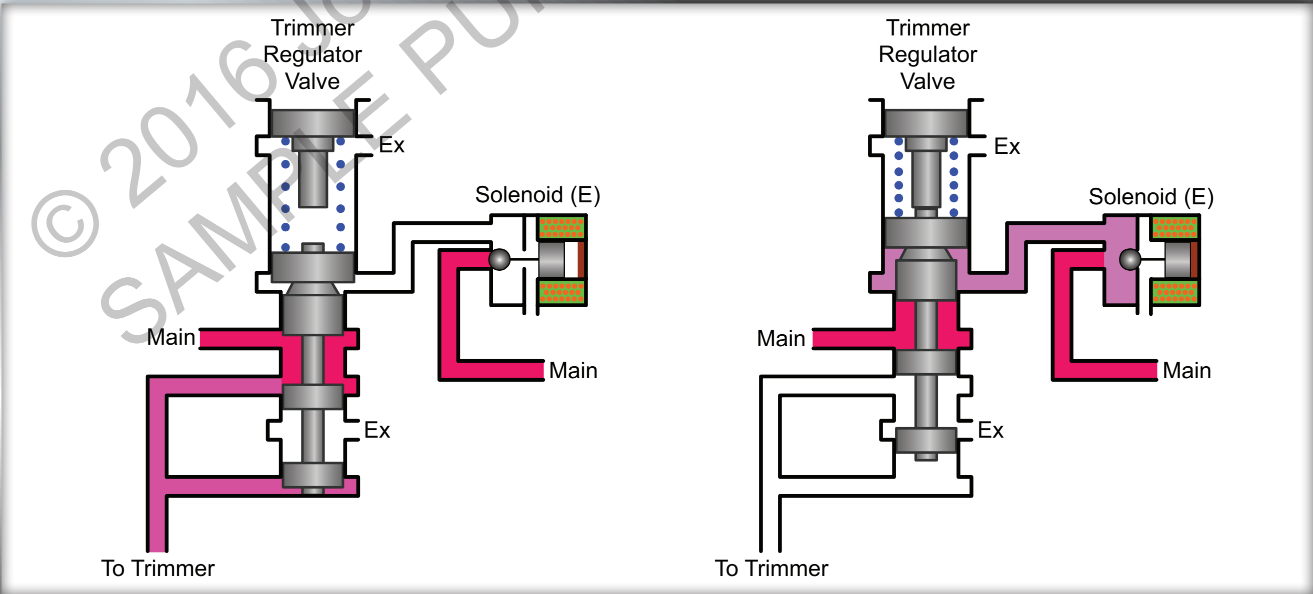


FIGURE 46-20 The trimmer regulator valve has only two positions. Shifts made with 60% throttle or less will have full trimming and be softer, while shifts made above 60% throttle will be harsher.

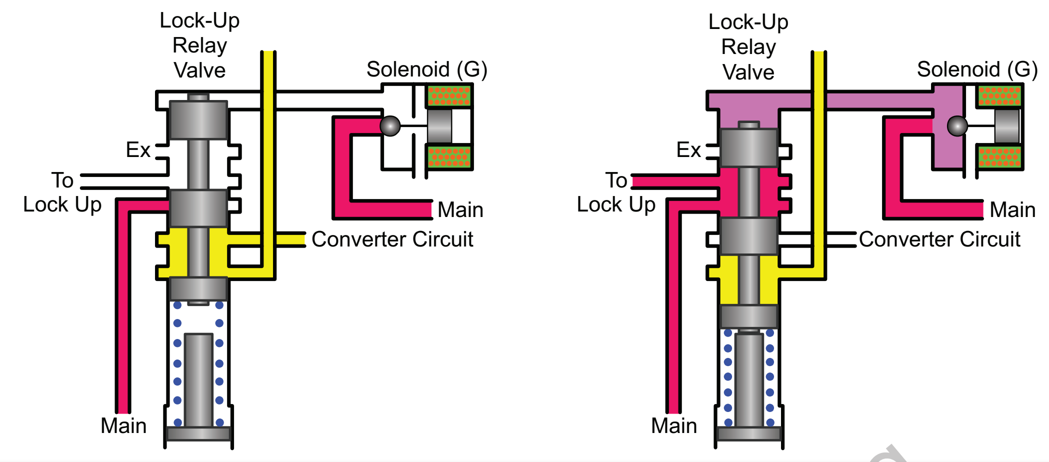


FIGURE 46-21 Torque converter lock-up is controlled by non-latching solenoid G.

position. (This occurs because of the difference in the size of the lands where the oil flows through the valve. The top land is larger in area than the bottom land, and so the valve remains open).

Once the vehicle is shut off, oil flow stops, and spring force pushes the neutral-range valve to the bottom of its bore. On restart, the latching solenoids continue to remain in position, but there is no flow through the neutral-range valve. The transmission, therefore, stays in neutral. This failsafe strategy allows the vehicle to be driven to a shop after electrical failure. Once the engine is shut off, the oil pressure holding up the neutral range valve is lost and the transmission will not go back into gear on restart **FIGURE 46-22**.

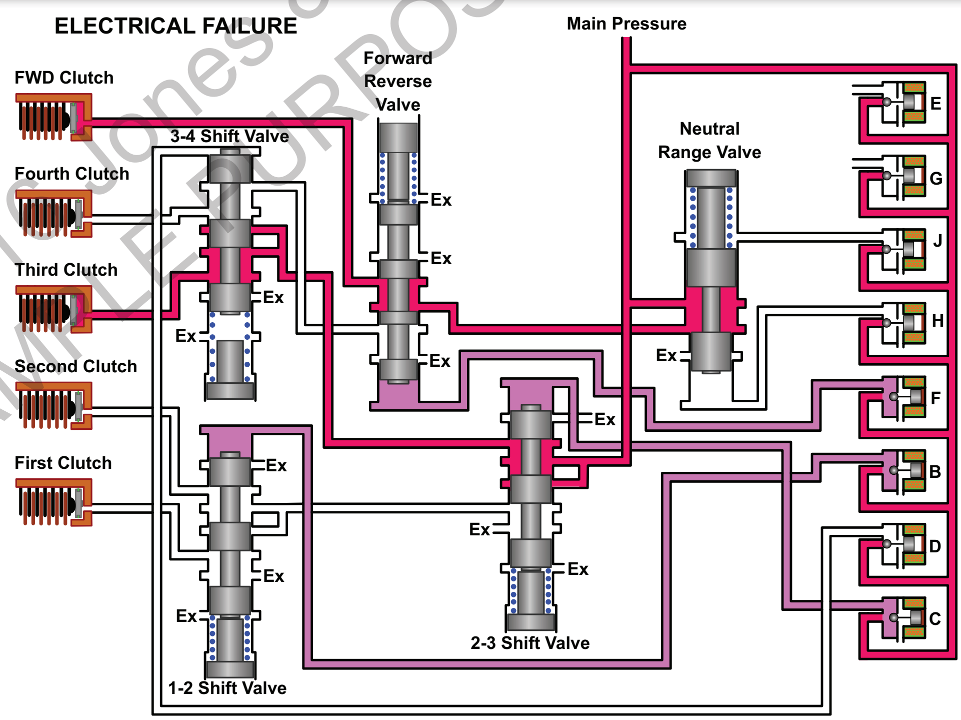


FIGURE 46-22 During electrical failure all latching solenoids remain in their positions so the transmission will stay in the range it is in until the engine is turned off.

World Transmission

In 1991, Allison launched its World Transmission into the marketplace FIGURE 46-23. The World Transmission was a completely new design comprised of six forward speeds including two overdrives. In addition to the six-speed design, Allison offers a seven-speed model that incorporates a "low" gear into the six-speed model. The seven-speed transmission has one extra planetary gear set and one extra stationary clutch. The "low" gear is obtained by passing the output of the traditional six-speed model through the fourth planetary set.

All designs of the World Transmission are equipped with what has come to be known as adaptive logic control. That means that the transmission ECU is capable of adapting shift strategies based on drive-cycle experience. The transmission ECU constantly monitors and adjusts shift points and processes to maintain optimum shift quality, fuel economy, and driver comfort. Eventually, Allison dropped the World Transmission moniker and began referring to the model line by its series numbers (e.g., the 3000, 4000, and B series). In the truck and coach market, however, the name World Transmission is still widely used. In an attempt to align model functionality with the needs of particular markets, Allison has recently created a long list of market-specific names—the Highway Series, the Rugged-Duty Series, the Motor Home Series, Transport/Shuttle Series, and several others. Despite the name changes, the transmission model numbers remain basically the same.

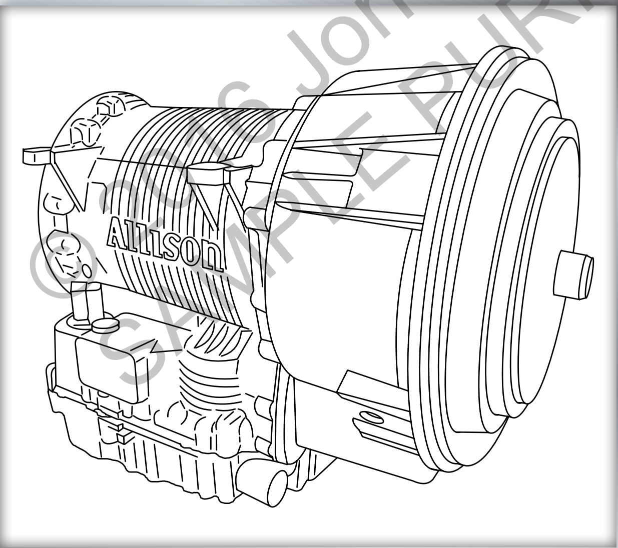


FIGURE 46-23 The World Transmission was introduced by Allison in 1991.

The World Transmissions came in three general series:

- MD series for medium duty
- HD series for heavy duty applications
- B series for Bus and Coach applications

Specifications for model number MD-3060-PR are in TABLE 46-2 and Allison's specifications for bus model number B500 PR are in TABLE 46-3.

In 1999, Allison introduced the 1000, 2000, and 2400 series transmissions. These lighter duty transmissions shared the same powerflow and geartrain design as the World Transmission. A key difference, however, was in the control system. In the lighter series of transmissions, the control system uses a quite different design than the original **World Transmission Electronic Control (WTEC)** systems—WTEC, WTEC 11, and WTEC 111.

The addition of the 1000, 2000, and 2400 series transmissions enabled Allison to match transmissions to a variety of engines that produce between 165 and 565 horsepower (121–421 kW) and generate from 420 to 1,850 pound-feet of torque (568–2,508 Nm). TABLE 46-4 lists the models in Allison's Highway series and the transmission capacity rating of each.

World Transmissions—3000, 4000, and B series

The six-speed World Transmission uses three planetary gear sets. They are named P1, P2, and P3 and are numbered from front to back. The transmission also uses five hydraulic clutches, again numbered from front to back. C-1 and C-2 are rotating clutches contained in the rotating clutch module, which can be used to provide input to the transmission. Clutches C-3, C-4, and C-5 are stationary clutches.

The 4000 series transmission is also available in a seven-speed model, which features an extra planetary gear set and an additional stationary clutch C-6. The seventh speed is an extra low gear for starting out. The 3000 series transmissions are available with a transfer case (drop box) for four-wheel drive operation. These transmissions also feature an extra planetary gear set in the transfer case and two more clutches (C-6 and C-7). The C-6 clutch provides an extra low forward speed through the transfer case when applied. The C-7 clutch locks the front and rear wheel drives together for low-traction situations.

TABLE 46-2: Specifications for Allison's MD-3060-PR Medium-Duty Transmission

MD	3	0	6	0	P	R
Medium duty or HD for Heavy Duty	#3 is medium duty #4 is heavy duty	0 is close ratio 5 is wide ratio	Number of forward speeds 6 or 7	Major revisions	Power take off provision	R is Retarder T is for drop box or transfer case

TABLE 46-3: Specifications for Allison's Bus Model Number B500 PR Transmission

B	5	0	0	P	R
Bus	Series 300, 400 or 500 higher # series can handle can handle more input torque	0 is close ratio 5 is wide ratio	Major revisions	Power take off provision	Retarder

TABLE 46-4: Allison's Highway Series Transmissions and Their Capacity Ratings

RATINGS								
Model	**Ratio**	**Park Pawl**	**Max Input Power[1] hp (kW)**	**Max input Torque[1] lb-ft (N m)**	**Max Inport Torque w/ SEM or Torque Limiting[1,2] lb-ft (N m)**	**Max Turbine Torque[3] lb-ft (N m)**	**Max GVW bs (kg)**	**Max GCW lbs (kg)**
1000 HS	Close	Yes	340 [4,7] (254) [4,7]	575 (780)	660 [4,7] (895) [4,7]	950 [4] (1288) [4]	19,500 (8,845)	26,001 (11,800)
2100 HS	Close	No	340 [4,7] (254) [4,7]	575 (780)	660 [4,7] (895) [4,7]	950 [4] (1288) [4]	26,000 (11,800)	26,000 (11,800)
2200 HS	Close	Yes	340 [4,7] (254) [4,7]	575 (780)	660 [4,7] (895) [4,7]	950 [4] (1288) [4]	26,000 (11,800)	26,001 (11,800)
2300 HS [5]	Close	No	325 (242)	n/a	450 (610)	950 [4] (1288) [4]	33,000 (15,000)	33,000 (15,000)
2350 HS [7]	Close	Yes	340 [4] (254) [4]	575 (780)	660 [4] (895) [4]	950 [4] (1288) [4]	30,000 (13,600)	30,000 (13,600)
2500 HS	Wide	No	340 [4,7] (254) [4,7]	575 (780)	660 [4,7] (895) [4,7]	950 [4] (1288) [4]	33,000 (15,000)	33,000 (15,000)
2550 HS [7]	Wide	Yes	340 (254)	575 (780)	660 [4] (895) [4]	950 [4] (1288) [4]	30,000 (13,600)	30,000 (13,600)
3000 HS	Close	n/a	370 (276)	1100 (1491)	1250 [6] (1695) [6]	1600 [4] (2169)	80,000 (36,288)	80,000 (36,288)
4000 HS	Close	n/a	565 (421)	1770 (2400)	1850 [8] (2508) [8]	2600 (3525)	--	--
4500 HS	Wide	n/a	565 (421)	1650 (2237)	1850 [8] (2508) [8]	2600 (3525)	--	--

[1] Gross ratings as defined by ISO 1585 or SAE J1995. [2] SEM = engine controls with Shift Energy Management. [3] Turbine torque limit based on iSCAAN standard deductions. [4] SEM and torque limiting are required to obtain this rating. [5] Only available with VORTEC 8.1L gasoline-powered engine applications. [6] Requires Allison Transmission engine-transmission combination approval. Only available in gears three through six. [7] Check with your OEM to ensure offerings. [8] Only available in gears three through six.

Source: Information from Allison International, Inc. Permission requested.

The World Transmission design is divided into modules or major component groups FIGURE 46-24. The modules are as follows:

- Torque converter module
- Torque converter housing module
- Control module
- Front support/charging pump module
- Rotating clutch module
- Rear cover module
- Main shaft module
- P1 planetary module
- P2 planetary module
- Main housing module

Modules

Torque Converter Module

The torque converter module is a typical lock-up torque converter. The lock-up clutch incorporates a torsional damper to reduce shock on lock-up engagement and reduce the impact of engine torsional vibrations on the rest of the driveline. The torque converter hub drives the front charging pump directly on 3000, 4000, and B series without power take-off (PTO) provision. With PTO provision, the input converter drive hub drives the PTO gear which, in turn, drives the charging pump. The input torque converter has raised ribs on it. The engine speed sensor uses those ribs to sense engine RPM.

Torque Converter Housing Module

The torque converter housing module bolts the transmission to the rear of the engine flywheel housing. Likewise, the torque converter housing is also bolted to the transmission main housing. A gasket seals the connection between the torque converter housing and the main housing. The torque converter housing module also has access plates for power take-offs on the left and right side on models with PTO provision FIGURE 46-25.

Control Module

The control module is an electro-hydraulic valve body attached to the bottom of the main housing module. The module houses the electric solenoids and the various valves necessary to control the transmission operation. Also contained in the control module are the lube and main pressure filters and the pressure taps for main pressure as well as for each of the clutch-apply passages. Finally, the control module also includes the internal solenoid and switch harness and the pass-through connector that attach the module to the vehicle harness.

A gasket seals the control module to the bottom of the main housing module. Care must be taken when separating the module. First, remove all of the attaching bolts. Then, break the gasket seal only at the specified pry points.

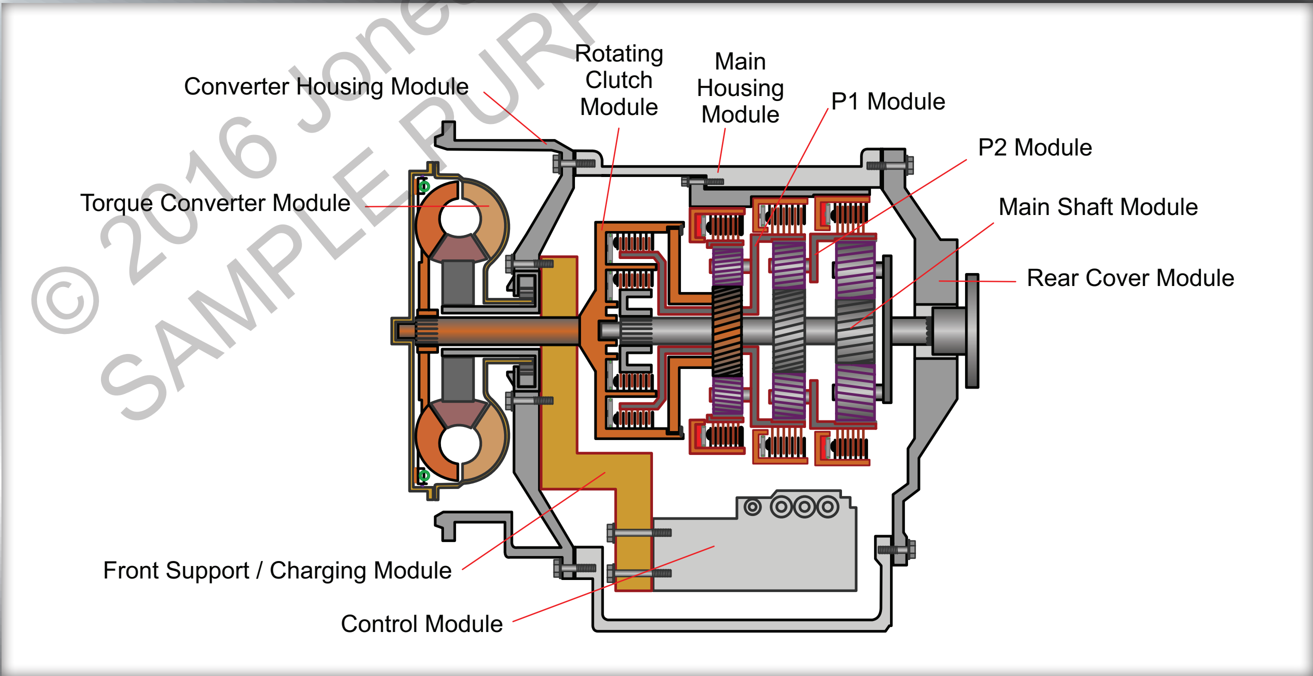


FIGURE 46-24 The World Transmission is modular in design.

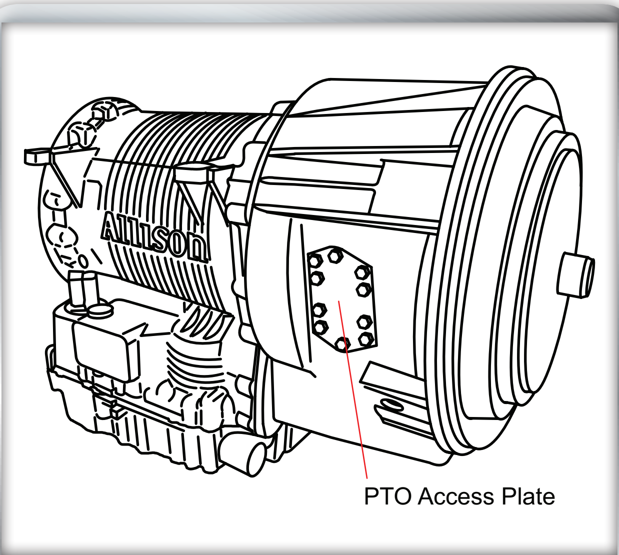


FIGURE 46-25 World Transmission models with power take-off provision have PTO access plates on both sides of the torque converter housing module.

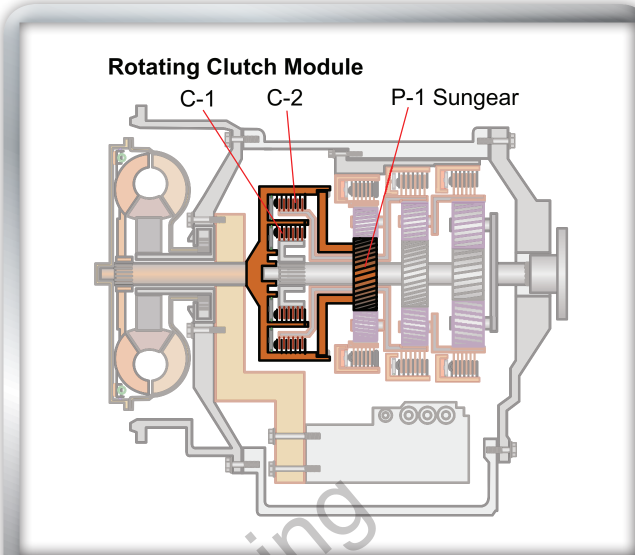


FIGURE 46-26 The rotating clutch module contains clutches C-1 and C-2 (the rotating input clutches), and the P-1 sun gear is splined to the module.

Front Support/Charging Pump Module

The front support/charging pump module includes the gerotor-style charging pump assembly, the front support bushings and bearings, and the stator support shaft. The module bolts to the main housing module and is sealed with a gasket.

Main Housing Module

The main housing module contains all of the transmission's internal components. When all other modules are removed from the housing, the C-5 clutch plates, the C-3 and C-4 clutch assemblies, and the P-1 ring gear remain in the housing.

Rotating Clutch Module

The rotating clutch module is attached to the turbine shaft and contains the two rotating clutches C-1 and C-2 FIGURE 46-26. When applied, C-1 transfers rotational power from the turbine shaft to the main shaft module. When C-2 is applied, it transfers rotational power to the P-2 carrier. There is a third piston inside the rotating clutch module called the balance piston; it is located between the C-1 piston return spring assembly and the C-1 pressure plate. The balance piston traps lubrication pressure between itself and the C1 piston. This trapped lubrication pressure is balanced against exhaust backfill pressure behind the C1 piston. The balance of pressures enhances control of exhausting and applying rotating clutches. The balance piston also provides a base for the C1 spring assembly to work against when returning the C1 piston to its seat.

Another component of the rotation clutch module is the P-1 planetary sun gear. Input torque is available at the P-1 sun gear whenever the module is rotating.

Main Shaft Module

The P-2 and P-3 sun gears are splined to the main shaft module, so rotating power is transferred to the sun gears when C-1 clutch is applied and the turbine shaft is turning.

Planetary Modules

The P-1 planetary module consists of the P-1 carrier and the P-2 ring gear. They are splined to each other and held together by a snap ring. The P-2 planetary module consists of the P-2 carrier and the P-3 ring gear. They, too, are splined to each other and held together by a snap ring.

Rear Cover Module

The rear cover module is bolted to the rear of the main housing module and sealed with a gasket. The function of the rear cover module is to contain and provide support to the output shaft. The P-3 carrier is splined to the output shaft and is part of the rear cover module. Also included as part of the rear cover module is the C-5 clutch piston. On models with an output retarder, the output cover module is replaced with a retarder module. A **retarder** is any system used to slow a vehicle's momentum and augment the service brake.

Powerflows

The operation of the torque converter and basic planetary gearing concepts were covered in earlier chapters and will not be repeated here. Please review those chapters as necessary.

To anchor our discussion of powerflows, we will use FIGURE 46-27, which shows a cutaway view of a typical 6-speed World Transmission. As mentioned previously, the World Transmission has three sets of interconnected planetary gears numbered P-1, P-2, and P-3 (in order from front to back). The P-1 sun gear is part of the rotating clutch module and turns whenever the module does. The P-1 ring gear is not attached to any other component. It is, however, splined to the C-3 clutch plates, so when C-3 is applied, the plate holds the P-1 ring gear stationary. The P-1 carrier is splined to the P-2 ring gear and turns with it. The P-2 sun gear is splined to the main shaft. The P-2 carrier is splined to the P-3 ring gear. The P-3 sun gear is splined to the main shaft, and the P-3 carrier is splined to the output shaft. All powerflows, therefore, must go through the P-3 carrier to reach the output shaft.

As shown in FIGURE 46-28, there are five clutches in the transmission numbered, front to back, C-1, C-2, C-3, C-4, and C-5. Three of the clutches are stationary—C-3, C-4, and C-5—and are splined to the transmission case when applied. In addition, each stationary clutch has a specific function:

- C-3 holds the P-1 ring gear stationary.
- C-4 holds the P-2 ring gear stationary when applied. This also holds the P-1 carrier stationary as it is splined to P-2s ring gear.
- When C-5 is applied, it holds the P-3 ring gear and, therefore, the P-2 carrier stationary.

The two remaining clutches, C-1 and C-2, are rotating clutches. Both are contained in the rotating clutch module, which is splined to the turbine shaft. Both clutches enable rotational power to enter the gear train. When C-1 is applied, it brings rotational power from the turbine shaft to the main shaft and, therefore, to the P-2 and P-3 sun gears. When C-2 is applied, it brings rotational power from the turbine shaft to the P-2 carrier and, therefore, to the P-3 ring gear which is splined to it. The P-1 sun gear also enables rotational power to enter the gear train. Because the P-1 sun gear is splined to the rotating clutch module, there is always rotational power at the P-1 sun gear whenever the turbine shaft turns.

Clutch Application Chart

Even though the World Transmission (WT) has multiple clutches, not all clutches are applied in all gears. If the

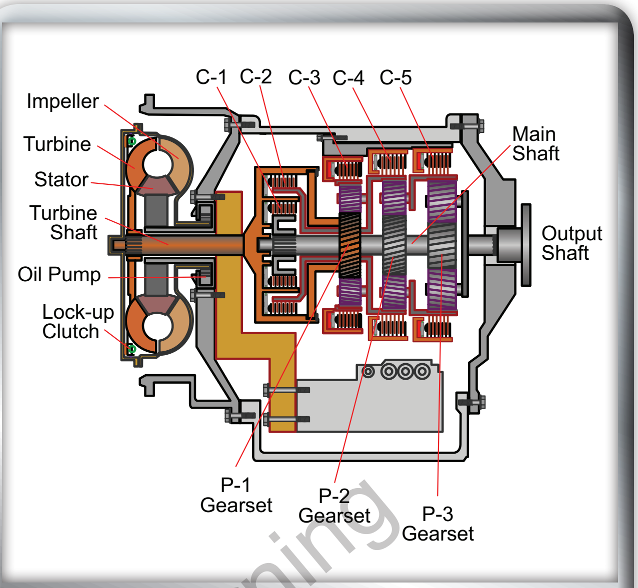
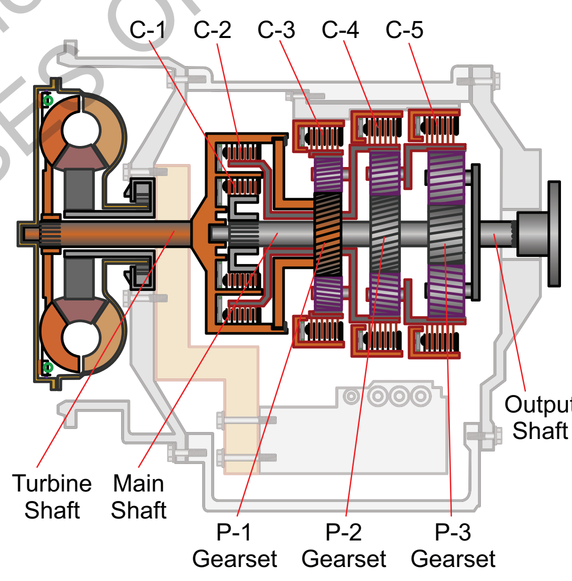


FIGURE 46-27 Cutaway view of a typical 6-speed World Transmission.



	R	N	1st	2nd	3rd	4th	5th	6th
C1			X	X	X	X		
C2						X	X	X
C3	X				X		X	
C4				X				X
C5	X	X	X					

FIGURE 46-28 Simplified schematic illustrating the powerflows of the World Transmission. All 6-speed models share the same powerflows.

vehicle is moving while in neutral range, the transmission will attain neutral 1, 2, 3, or 4 depending on the speed of the vehicle. This capability minimizes the rotational speed of the transmission's internal components while moving in neutral and readies the transmission for shifting into gear at that particular speed. This means that when the transmission is eventually put into a forward range, the transmission ECU only has to control one applying clutch to achieve the correct range for that speed. TABLE 46-5 illustrates how each clutch in a World Transmission is applied in each gear. As the table shows, only one clutch at a time is applied when the transmission is in neutral. Which clutch is applied depends on whether the vehicle is moving.

WT Neutral Powerflow

The transmission can obtain four different neutral powerflows based on vehicle speed.

As shown in FIGURE 46-29, in neutral the C-5 clutch is applied holding the P-3 ring gear stationary. No other clutch is applied, so rotational power does not go any further than the rotating clutch module and the P-1 sun gear. Since only one clutch is applied, the transmission is in neutral. If the vehicle is moving, the applied clutch will change based on vehicle speed. As speed increases, the transmission will release and apply clutches in the following sequence:

1. Release C-5 and apply C-4.
2. Release C-4 and apply C-3.
3. Release C-3 and apply C-4 again.

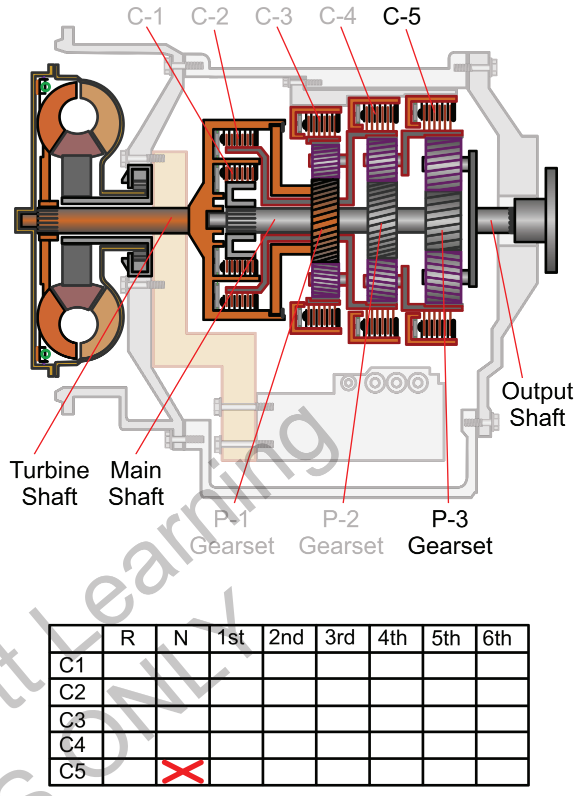


FIGURE 46-29 When the vehicle is in neutral, only one clutch is applied—C-5, C-4, or C-3—depending on whether the vehicle is moving.

TABLE 46-5: Clutch Application Chart for Allison World Transmissions

Range	C-1	C-2	C-3	C-4	C-5
Neutral 1					Applied
Neutral 2				Applied	
Neutral 3			Applied		
Neutral 4				Applied	
First	Applied				Applied
Second	Applied			Applied	
Third	Applied		Applied		
Fourth	Applied	Applied			
Fifth		Applied	Applied		
Sixth		Applied		Applied	
Reverse			Applied		Applied

*Note this chart covers all Allison World Transmissions except the seven-speed models, which have an extra clutch.

This shifting controls the rotational speed of the transmission components and prepares the transmission to shift into range at that speed. Only one clutch is applied at any one time, however, so the transmission remains in neutral.

WT First Range

When any forward range is selected, the transmission shifts into first range. First range is a simple planetary gear powerflow involving only the P-3 planetary gear set. In first range, the C-5 clutch is still applied, holding the P-3 ring gear stationary. The C-1 clutch is applied, which brings rotational power to the main shaft and the P-3 sun gear. The P-3 sun gear is input, the P-3 ring gear is held, and the P-3 carrier becomes output. The P-3 carrier is splined to the output shaft, so first range is obtained **FIGURE 46-30**.

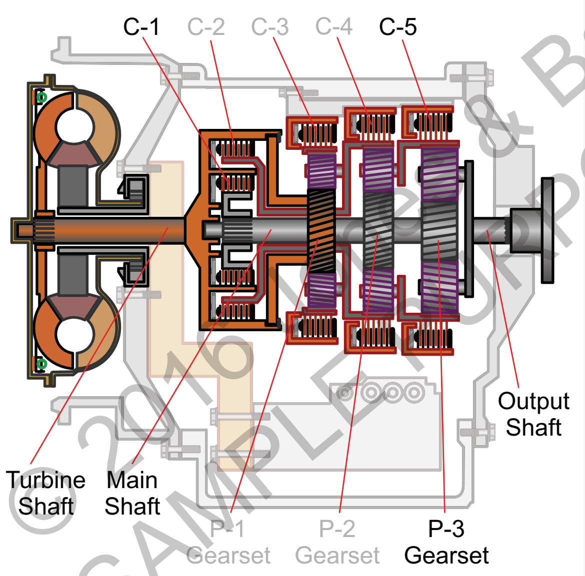
WT Second Range

As the vehicle accelerates, it will automatically shift to second range if any range higher than first has been selected. Second range is a compound planetary gear powerflow involving P-3 and P-2 planetary gear sets **FIGURE 46-31**.

As the shift to second is made:

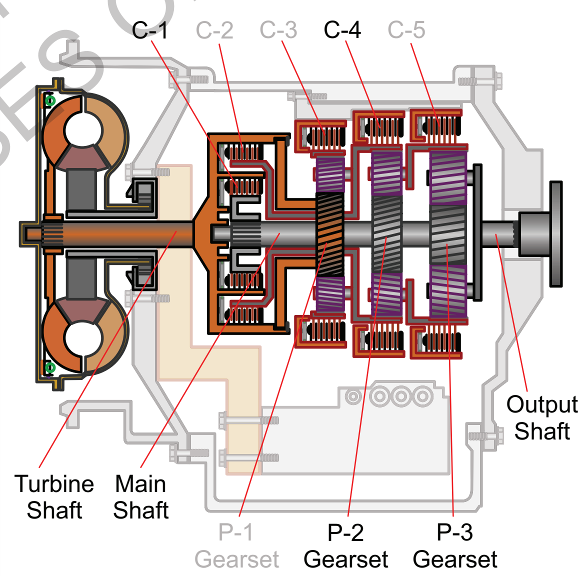
- C-5 clutch is released.
- C-4 clutch is applied.
- C-1 clutch remains applied.
- C-4 clutch holds the P-2 ring gear stationary.

Those transitions bring rotational power to the main shaft and, therefore, to the P-2 and the P-3 sun gears. The P-2 sun gear becomes input to the P-2 planetary gear set, and C-4 holds the P-2 ring gear stationary. As a result, the P-2 carrier becomes output. The P-2 carrier is splined to the P-3 ring gear, so the P-3 ring gear is turning as well. The P-3 sun gear is splined to the main shaft and so still acts as an input to the P-3 planetary gear set. This means the P-3 planetary gear set has two inputs: the P-3 sun gear and the P-3 ring gear—which are not turning at the same rate. The P-3 ring gear is turning slower than the P-3 sun gear. This makes the P-3 ring gear act as a



	R	N	1st	2nd	3rd	4th	5th	6th
C1			X					
C2								
C3								
C4								
C5			X					

FIGURE 46-30 In first range, clutches C-1 and C-5 are applied, and only the P-3 planetary gear set is involved in the powerflow.



	R	N	1st	2nd	3rd	4th	5th	6th
C1				X				
C2								
C3								
C4				X				
C5								

FIGURE 46-31 In second range, clutches C-1 and C-4 are applied, and the P-2 and P-3 planetary work together to produce the powerflow.

held member. In this configuration, the P-3 sun gear is input, the P-3 ring gear acts as a held member, and the P-3 carrier becomes the final output and is splined to the output shaft.

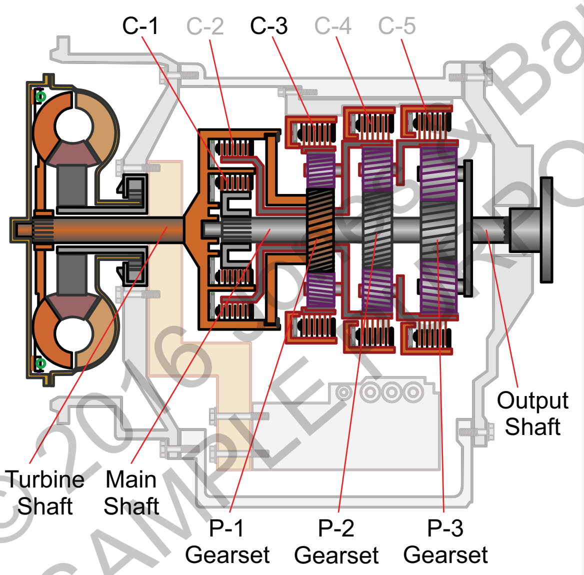
In this powerflow, the only change to the output speed over first range comes from the rotation of the P-3 ring gear. Its movement adds to the rotation of the P-3 carrier.

WT Third Range

As long as the selected range is higher than second, the transmission will automatically shift to third range when conditions are correct. Third range is a compound powerflow that uses all three planetary gear sets **FIGURE 46-32**.

When the shift to third range is made:

- C-4 clutch is released.
- C-3 clutch is applied.
- C-3 holds the P-1 planetary ring gear stationary.
- C-1 clutch remains applied.



	R	N	1st	2nd	3rd	4th	5th	6th
C1					X			
C2								
C3					X			
C4								
C5								

FIGURE 46-32 In third range, clutches C-1 and C-3 are applied, and all three planetary gear sets work together to produce the powerflow.

Here's how the powerflow occurs in the shift to third range. The P-1 sun gear is part of the rotating clutch module and therefore rotates with it. That makes the P-1 sun gear an input to the P-1 planetary gear set. The P-1 ring gear is held by C-3, and the P-1 carrier becomes output. The P-1 carrier is splined to the P-2 ring gear, so both P-1 and P-2 rotate together. Because the C-1 clutch is still applied, the P-2 planetary gear set now has two inputs: the P-2 sun gear and the P-2 ring gear. The P-2 ring gear, however, is turning slower than the P-2 sun gear, and so the P-2 ring gear acts as a held member. The P-2 carrier, then, becomes output of the P-2 planetary gear set, and the P-2 carrier is turning faster than it did in second range because of the rotation of the P-2 ring gear. The P-2 carrier is splined to the P-3 ring gear, so it is turning also.

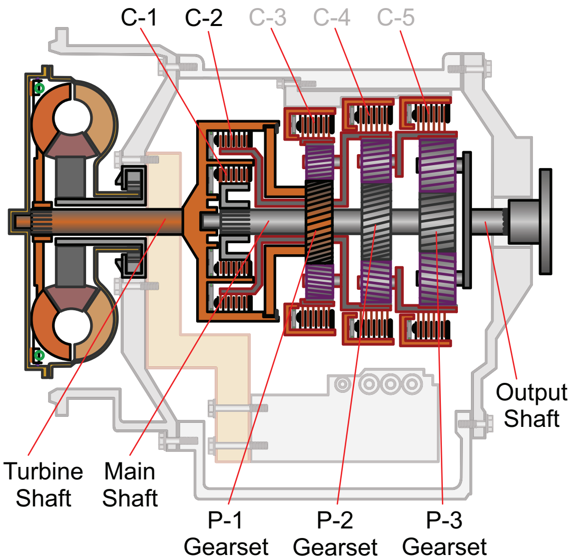
As in the second range, the P-2 carrier provides a second input into the P-3 planetary gear set, but now the P-2 carrier is turning at increased speed. The P-3 sun gear is still being driven by the C-1 clutch and the main shaft, so the P-3 sun gear still turns faster than the P-3 ring gear. The P-3 carrier becomes the final output, and it is splined to the output shaft. The ratio in third range is created by P-1 adding speed to P-2 and then P-2 adding speed to P-3.

WT Fourth Range

As long as the selected range is higher than third, the transmission will automatically shift to fourth range when conditions are correct. Fourth range is a simple planetary powerflow that involves only the P-3 planetary gear set **FIGURE 46-33**.

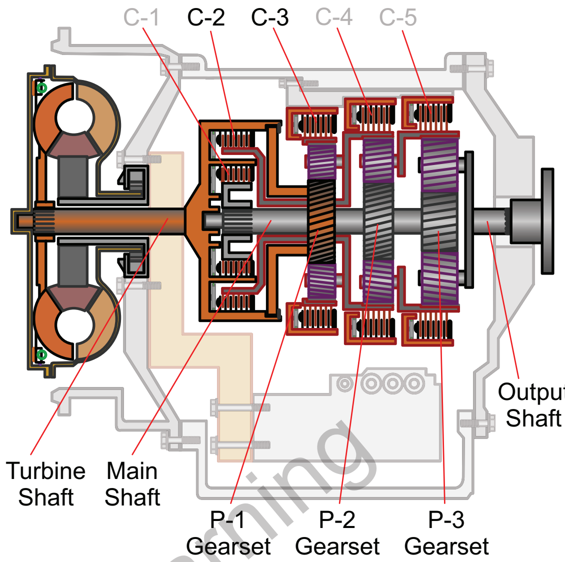
In fourth range, C-3 clutch is released, C-2 clutch applies, and C-1 clutch remains applied. The powerflow is achieved in the following sequence: C-1 clutch delivers rotational power to the main shaft and the P-3 sun gear; and C-2 cutch delivers rotational power through the P-2 carrier to the P-3 ring gear, which is splined to it. This gives the P-3 planetary gear set two inputs rotating at the same speed. The P-3 carrier must then also rotate at the same speed, as it is splined to the output shaft. This provides a direct or a one-to-one ratio.

In fourth range, even though the powerflow is through the P-3 planetary gear set, the interconnections of the drive train components means that they all turn as one unit at the same speed x. Remember that the P-2 planetary has two inputs as well: the P-2 planetary carrier and the P-2 sun gear (from the main shaft). That double input makes the P-2 ring gear turn at the same speed x. The P-2 ring gear is splined to the P-1 carrier, and the P-1 sun gear is part of the rotating clutch module. That means the P-1 planetary gear set also has two inputs, and



	R	N	1st	2nd	3rd	4th	5th	6th
C1						X		
C2						X		
C3								
C4								
C5								

FIGURE 46-33 In fourth range, clutches C-1 and C-2 are applied, and all three planetary gear sets rotate together at the same speed even though the powerflow is through the P-3 planetary gear set.



	R	N	1st	2nd	3rd	4th	5th	6th
C1								
C2							X	
C3							X	
C4								
C5								

FIGURE 46-34 In fifth range, clutches C-2 and C-3 are applied, and all three planetary gear sets work together to produce the powerflow.

therefore its ring gear must also turn at the same speed x. So, in fourth range, the rotating clutch module and all three planetary gear sets are all turning as one unit at the same speed as the turbine shaft.

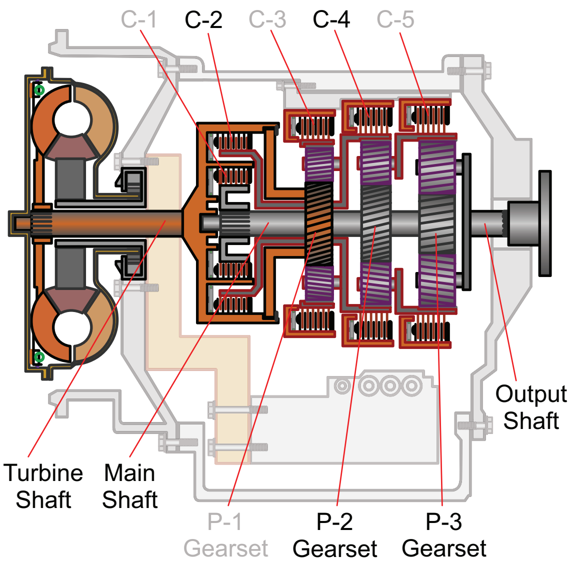
WT Fifth Range

As long the selected range is higher than fourth, the transmission will automatically shift into fifth range when conditions are correct. Fifth range is the first of two overdrive ranges and is a compound planetary gear flow that uses all three planetary gear sets to achieve the final ratio **FIGURE 46-34**.

In fifth range, C-2 and C-3 are applied and produce the following powerflow. The P-1 sun gear is part of the rotating clutch module and therefore always provides rotational input to P-1. C-3 is holding the P-1 ring gear stationary, and so the P-1 carrier becomes output. The P-1 carrier is splined to the P-2 ring gear, and so it becomes one of two inputs to the P-2 planetary gear set. C-2 clutch is applied and supplies rotational input to the P-2 carrier, which is the second input to the P-2 planetary gear set. This causes the P-2 sun gear to become output as it turns clockwise at a higher speed than the P-2 carrier. The P-2 sun gear is splined to the main shaft as is the P-3 sun gear. The interaction of the P-2 and P-3 sun gears produce an overdrive input to the P-3 planetary gear set. The P-3 planetary gear set also has an input from the P-3 ring gear, which is splined to the P-2 carrier that, in turn, is being driven by the P-2 clutch. Because the P-3 ring gear is turning slower (at turbine shaft speed) than the P-3 sun gear, the P-3 ring gear acts as a held member. The P-3 carrier becomes the final output and is splined to the output shaft.

WT Sixth Range

As long as the selected range is higher than fifth, the transmission will automatically shift into sixth range when conditions are correct. Sixth range is the highest overdrive range and is a compound ratio that uses the P-2 and P-3 planetary gear sets to achieve the ratio **FIGURE 46-35**.



	R	N	1st	2nd	3rd	4th	5th	6th
C1								
C2								X
C3								
C4								X
C5								

FIGURE 46-35 In sixth range, clutches C-2 and C-4 are applied, and the P-2 and P-3 planetary gear sets work together to produce the powerflow.

In sixth range C-2 and C-4 are applied, C-2 supplies rotational input to the P-2 carrier, and C-4 holds the P-2 ring gear stationary. That flow makes the P-2 sun gear output at an even faster overdrive than it did in fifth range. Why is it faster? Because when (a) the P-2 carrier is the input member and (b) the P-2 sun gear is the output the carrier, the pinion gears use the ring gear as a reaction member to push against in order to drive the sun gear. In fifth range, the reaction member (the P-2 ring gear) is moving away from the input member (the carrier), so the sun gear is not pushed as much. In sixth range, the ring gear is held stationary, and that allows the full reaction, or push, and allows the sun gear to have a higher speed output. The P-2 sun gear is splined to the main shaft, as is the P-3 sun gear, so the P-3 planetary gear set again has two inputs: the P-3 sun gear and the P-3 ring gear. The P-3 ring gear is splined to the P-2 carrier and, therefore, driven by the C-2 clutch. The P-3 ring gear, however, is rotating slower (at turbine speed) than the P-3 sun gear (overdrive), and so the P-3 ring gear acts as a held member. That causes the P-3 carrier to become final output, as it is splined to the output shaft.

WT Reverse

In reverse, all three planetary gear sets work together to create the powerflow. Reverse range will always start from neutral gear. Recall that, in neutral, C-5 is the only clutch applied, and it holds the P-3 ring gear stationary. As the operator selects reverse, the C-3 clutch is applied and in turn holds the P-1 ring gear stationary. Neither of the rotating clutches C-1 or C-2 is applied, so the rotational input in reverse must come from the P-1 sun gear. Recall that the P-1 sun gear is attached to the rotating clutch module and turns with it at all times.

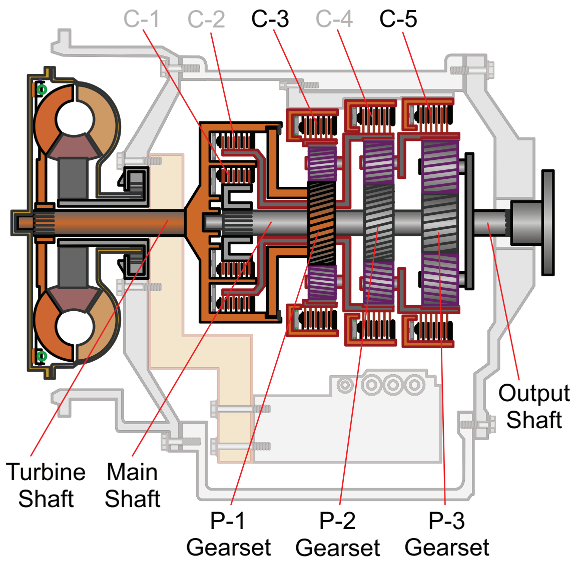
So the powerflow in reverse is as follows. The P-1 sun gear is input, and the P-1 ring gear is being held by the C-3 clutch. As a result, the P-1 carrier becomes output. The P-1 carrier is splined to the P-2 ring gear, making the P-2 ring gear input to the P-2 planetary set. The P-2 carrier is splined to the P-3 ring gear, which is being held stationary by the C-5 clutch, so the P-2 carrier is the held member in the P-2 gear set. Because the carrier is held, the P-2 sun gear becomes output in reverse. The P-2 sun gear is splined to the main shaft, as is the P-3 sun gear, so the P-3 sun gear becomes reverse input for the P-3 gear set. The P-3 ring gear is being held by the C-5 clutch and the P-3 carrier becomes the final output and it is splined to the output shaft. The reverse powerflow is illustrated in **FIGURE 46-36**.

Electro-Hydraulic Control—WTEC II and WTEC III

Allison's electronic control system was originally called World Transmission Electronic Control (WTEC). Since the original model was launched, WTEC has gone through three revisions, including WTEC11 and WTEC111. Each revision incorporated several improvements over its predecessor. The third revision was simply known as fourth generation electronic control, and the fourth and current revision is known as fifth generation electronic control. In the fourth generation, the electro-hydraulic valve body and the control strategies were altered in major ways. For that reason, we will discuss the earlier WTEC controls separately from the fourth and the current fifth generation electronic controls. Let's start by examining the WTEC 11 and WTEC 111 versions in greater detail.

Electronic Control Unit

As with earlier Allison transmissions, in the WTEC controls system, the Allison transmission Electronic Control



	R	N	1st	2nd	3rd	4th	5th	6th
C1								
C2								
C3	X							
C4								
C5	X							

FIGURE 46-36 In reverse, clutches C-3 and C-5 are applied, meaning that rotational input comes from the always rotating P-1 sun gear. All three planetary gear sets are involved in the reverse powerflow.

Unit, or ECU, is completely drive by wire. That is, the driver has no mechanical input to the transmission.

The transmission ECU receives input information from a number of sources. Feedback information comes from the transmission itself in the form of output speed, input speed, engine speed, transmission temperature, transmission oil level, and the solenoids. The ECU also receives input from the driver's interface via the shift selector. Input from various optional input functions come through the vehicle interface wiring (VIW) or through the vehicle interface module (VIM). Finally, the ECU receives input from the electronic engine, namely from the throttle position sensor.

The transmission ECU then uses all of that information to control shifting, diagnose transmission operation, and control output and input functions that control the numerous available features of the transmission, such as shift interlocks, remote shift selectors, and power take-off operation.

The transmission control also has various self-preservation strategies to protect the transmission from abuse. The controller will inhibit neutral to range shifts if input RPM is too high and will also prevent high-speed direction changes. If the driver tries to shift from reverse to forward while the vehicle is in motion, the controller will wait until the vehicle speed is near zero before allowing the change. If the driver selects a lower range than the current road speed requires, the transmission will not downshift until a safe speed has been reached. Transmission oil temperature is also closely monitored, and the controller will modify shift capabilities based on temperature to protect the transmission.

Solenoids and Solenoid Control

The WTEC 11 and 111 transmission ECUs use solenoids in the control module to control the shifting process. The World Transmission ECU electro-hydraulic control uses two general types of solenoids:

- **Normally open solenoids** that close when energized
- **Normally closed solenoids** that open when energized

Normally open solenoids allow fluid flow while de-energized and stop flow when energized; normally closed solenoids allow fluid flow when energized and stop fluid flow when energized.

In general, the solenoids redirect solenoid regulator pressure, which is used to control the position of the solenoid regulator valves below them. When solenoid regulator pressure is directed to the top of the solenoid regulator valve, the valve is positioned down in its bore and directs control main pressure to the appropriate clutch applying it. This process is illustrated in **FIGURE 46-37** under solenoid E. Main pressure that was dead-heading at the solenoid regulator valve is thereby able to flow into the clutch apply passage.

Solenoids A and B are normally open (N/O) solenoids. Solenoids C, D, E, and F are normally closed (N/C) solenoids. Solenoid A controls C-1 clutch; solenoid B controls C-2 clutch; solenoid C controls C-3 clutch; solenoid D controls C-4 clutch; solenoid E controls C-5 clutch; and solenoid F controls the torque converter lock-up clutch. All models of the Allison WTEC 11 and 111 transmission contain an additional solenoid—solenoid G. Solenoid G is a normally closed solenoid that controls the position of the C-1 and C-2 latch valves. (We will cover the latch valves in greater detail later in the chapter).

The solenoids used with the WTEC controlled transmission are controlled by the transmission ECU using a pulse-width-modulated circuit. **Pulse-width modulation** means that the control command to the solenoid is pulsed on and off at a set frequency. There are two levels

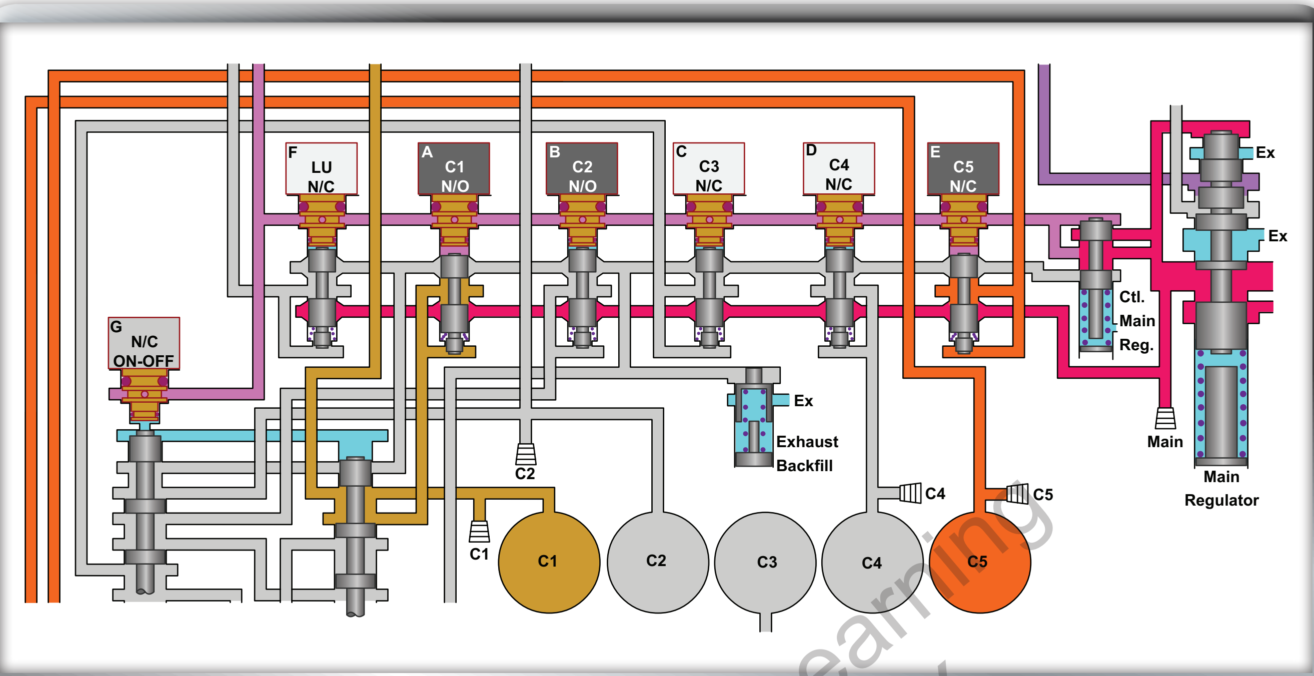


FIGURE 46-37 The WTEC II and III electro-hydraulic valve body uses two general types of solenoids: normally open and normally closed. When they are open, they cause the valves they control to move.

of pulse-width modulation used—primary modulation and secondary modulation.

Primary modulation is the control used to actually open the solenoid to allow fluid flow to control the clutch application. The primary modulation control is set at 63 hertz meaning that the control current to the solenoid is turned on and off 63 times a second. The computer alters the duty cycle of the solenoid current to precisely control the speed of the clutch application. The **duty cycle** is the amount of time during each 1/63 of a second that the current is allowed to flow to the solenoid.

Secondary or (sub-modulation), means that the control current being modulated at 63 hertz and controlling the solenoids is itself being modulated at 7,812 hertz. This sub-modulation allows the transmission ECU to provide a constant average current to the solenoids. The secondary or sub-modulation is too fast to interfere with primary modulation controlling the solenoid opening but allows the ECU to increase or decrease the current to the solenoids to account for differences in operating temperature, voltage fluctuations, and solenoid degradation. The secondary modulation leads to more consistent solenoid response.

Shift Control Logic

The WTEC is programmed to adapt to provide optimum shift characteristics regardless of changes in vehicle load, terrain, and transmission component wear (e.g., solenoid degradation or clutch wear). The control has a flash memory that is programmed with the optimal shift calibrations for a given vocation. The transmission inputs—engine speed, turbine speed, output shaft speed, throttle percentage, engine and transmission temperature, and so on—allow the transmission to compare actual shifts to the pre-programmed optimal shifts **FIGURE 46-38**.

The controller compares each shift in progress to a set of pre-programmed values. Then the next time a shift of that kind is made, the controller adjusts the control signal of the solenoid such that the actual shift profile matches the desired shift profile.

The transmission has two adaptive modes—fast adaptive and slow adaptive. **Fast adaptive** is used when the transmission is new and makes large changes to bring the shift close to the optimal profile quickly. After the shift is close to the profile in memory (this is called convergence), the transmission switches to slow adaptive mode. In **slow adaptive** mode, the transmission makes small changes to the shifts. These small changes are designed to make up for transmission clutch wear and solenoid drift or degradation. After a transmission has been rebuilt, or if a new transmission is being installed, the controller should be reset to fast adaptive, using the Allison DOC electronic service tool or a similar device, so the shifts will reach convergence as soon as possible.

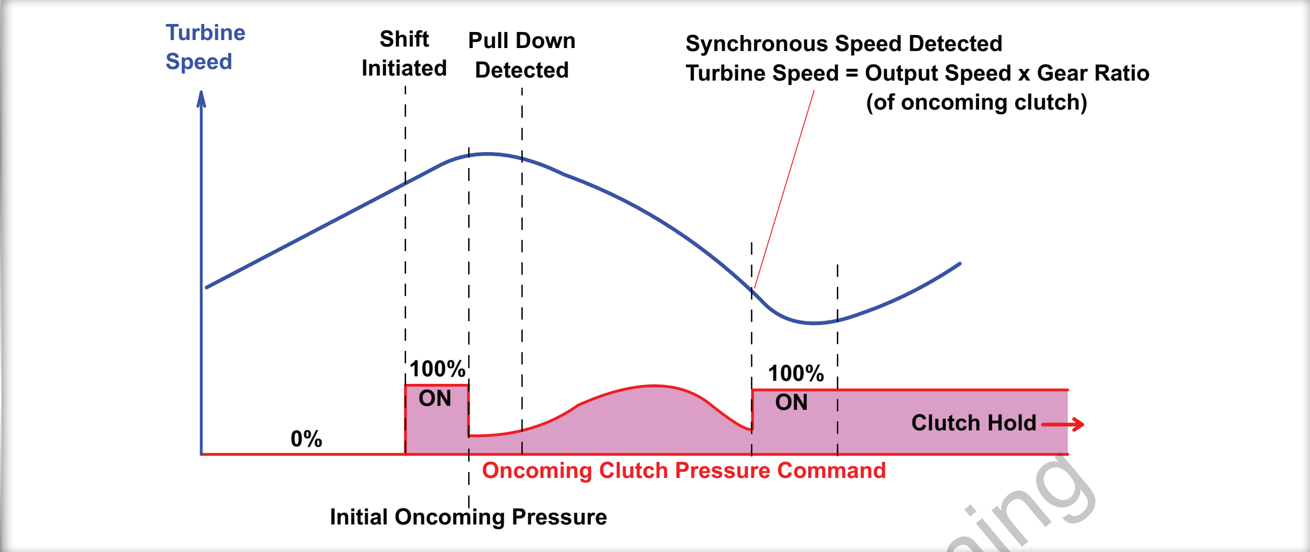


FIGURE 46-38 The Transmission ECU monitors shifts in progress and tries to get them to match ideal shift characteristics programmed into the ECU memory by actively controlling clutch application pressures during a shift.

Shift Sequence

The transmission monitors turbine speed to determine when a shift should be initiated. **FIGURE 46-39** illustrates the shift sequence. As the turbine speed increases to the shift initiation point, the transmission controller commands the solenoid that controls the on-coming clutch to full pressure for a short time so that the clutch piston starts moving. This process is known as clutch fill or volume ratio. (Volume Ratio is an important diagnostic tool, for the transmission delays during this period can signal problems with specific clutches).

At the same time, the off-going clutch control solenoid is being commanded to reduce the pressure on its clutch piston. After clutch fill, the transmission applies pressure to the oncoming clutch piston at what is known as the fixed ramp rate, or **open-loop ramp rate** (meaning that the clutch pressure is being increased at a fixed rate). The off-going clutch pressure drops at a fixed **ramp-off rate** as well (meaning that the off-going clutch pressure is being reduced at a preset rate). This continues until the transmission controller detects turbine pull down. **Turbine pull down** is the reduction in turbine speed as the on-coming clutch starts to squeeze its clutch plates and the transmission is starting to attain the next range.

At this point, the off-going clutch is commanded to zero pressure, and the controller starts closed-loop control of the shift in progress. During closed loop, the controller is monitoring the decrease in turbine speed and trying to get the rate of decrease to match the ideal shift profile in its calibration. The controller constantly monitors engine speed, input shaft speed, and output shaft speed. The period of this monitoring and adjusting during a shift in progress on a World Transmission is known as **closed-loop control**.

The transmission ECU is actively adjusting oncoming clutch application pressure using pulse-width modulation to control shift quality. Closed-loop control continues until **synchronous speed** is detected. Synchronous speed occurs when the output shaft speed times the gear ratio of the oncoming range equals the input shaft speed. Synchronous speed signifies that the transmission has now attained the on-coming ratio and clutch slip is no longer occurring. At this point the controller commands the on-coming clutch solenoid to 100% duty cycle to fully clamp the piston and the clutch plates with full main pressure. This period is called **time to full apply (TFA)**. After TFA, the solenoid duty cycle is reduced to clutch hold. Full main pressure will be maintained in the clutch with less current actually flowing through the solenoid.

Range Verification and Ratio Tests

The transmission controller initiates a series of tests at each stage of a shift in progress—and even when no shifts are in progress. When no shifts are in progress, the transmission controller initiates a **range verification test** to ensure that the transmission is in a selected range **FIGURE 46-40**. This enables the transmission controller to compare output speed times the gear ratio to the turbine speed and determine if the clutch is slipping. For

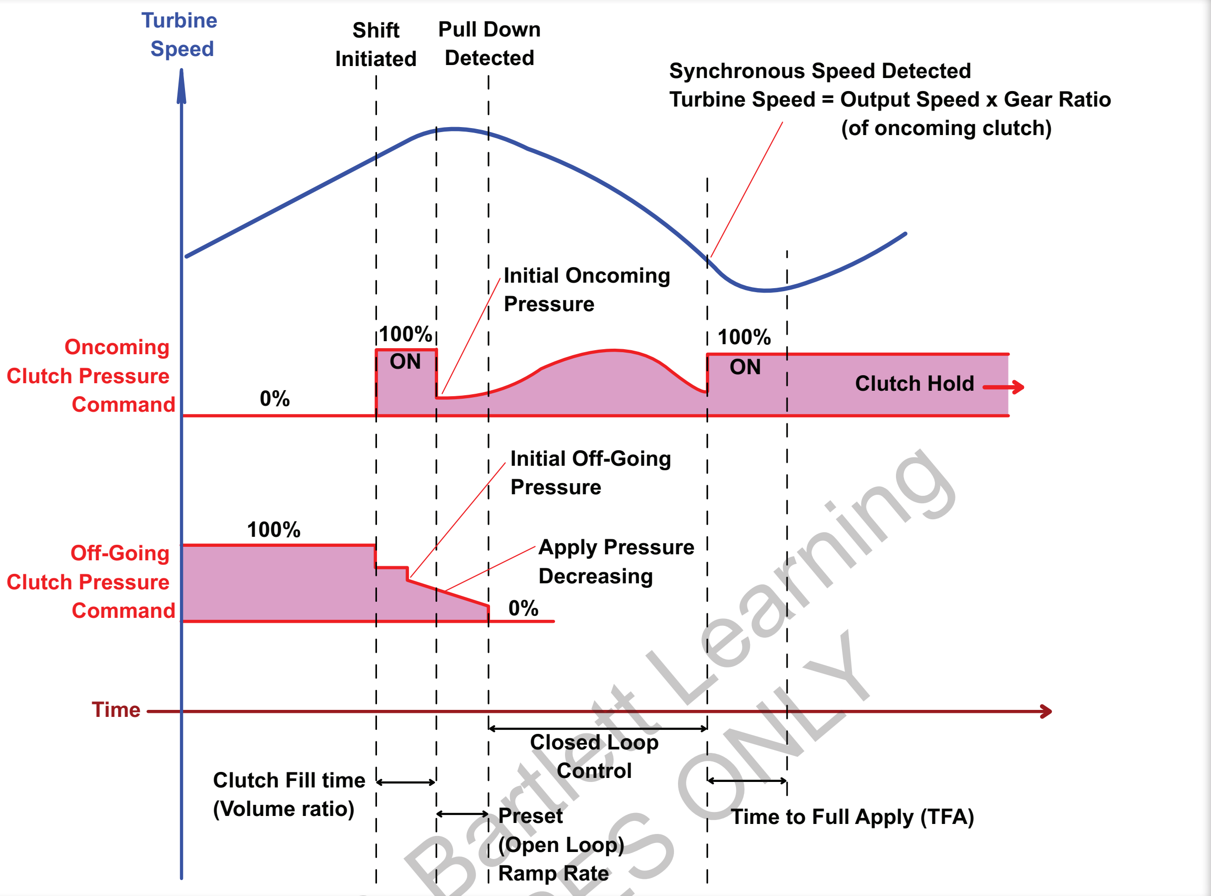


FIGURE 46-39 The transmission ECU sends signals to on-coming and off-going clutch solenoids to control the shift in progress.

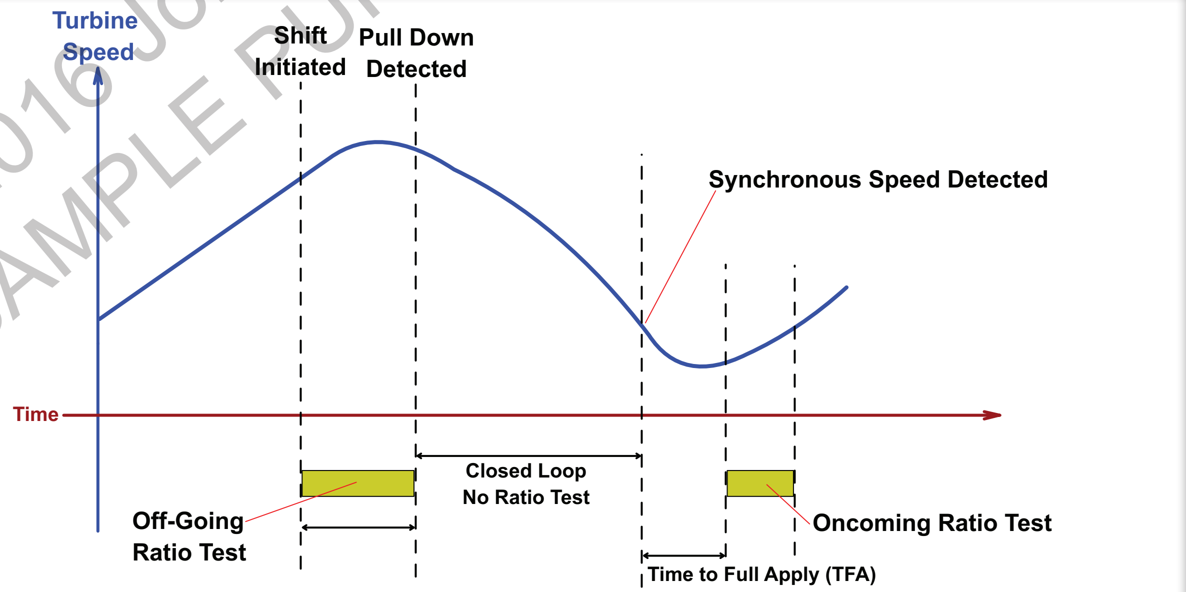


FIGURE 46-40 The controller performs range verification tests to ensure the transmission is in the correct range and not slipping.

example, if the output speed is 250 RPM and the gear ratio is 4:1, then the turbine speed should be 1,000 RPM. If it is higher, that means the clutch is slipping. If the range verification test fails for any reason, the controller will command the transmission to down shift to the last known attained range.

Ratio tests are performed at the beginning and end of a shift in process. The **off-going ratio test** is performed during the beginning of a shift in progress and assures that the off-going clutch actually released. If this test fails, the transmission is once again commanded to the previous range. The **on-coming ratio test** is performed at the end of a shift in progress after synchronous speed has been detected and assures that the transmission attained the desired range. As with the range verification and off-going ratio tests, if the on-coming ratio test fails, the transmission is commanded to the last known attained range.

Hydraulic Control

The World Transmission (WT) electro-hydraulic control system is a complex system including multiple elements. A schematic of the system in neutral gear is depicted in **FIGURE 46-41**.

Recall from the chapter on Hydraulically Controlled Automatics that the electro-hydraulic control system starts with the hydraulic charging pump. The gerotor-style charging pump is driven by the torque converter pump drive hub and therefore turns at engine speed. The charging pump draws fluid from the sump and

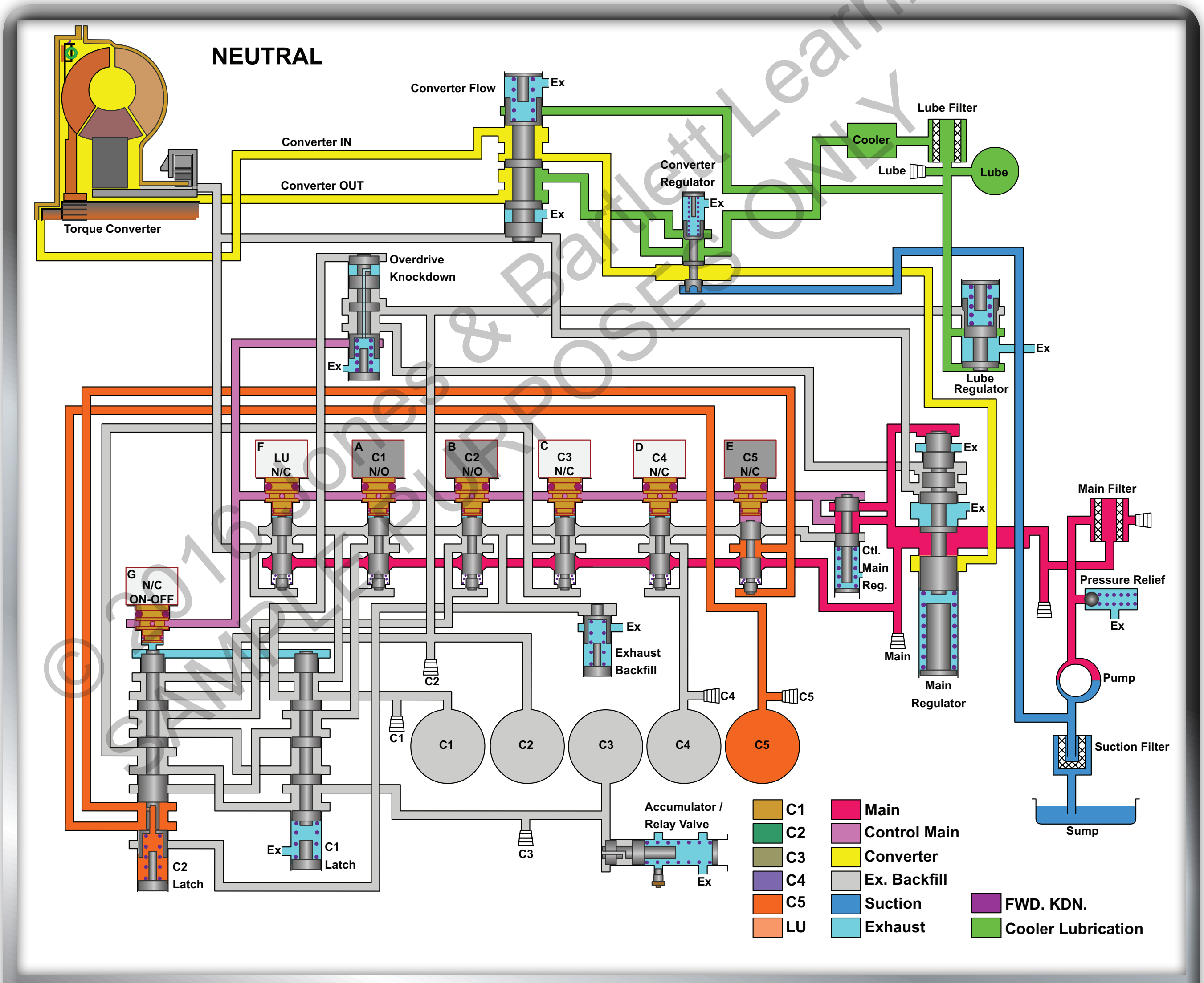


FIGURE 46-41 Hydraulic schematic of the World Transmission WTEC III.

delivers it through the main filter and onto the main pressure regulator valve (MPRV), which is a normally closed spring-loaded valve. The fluid then flows through the MPRV and onto the solenoid regulator valves. Fluid pressure is also directed to the top of the MPRV, and as pressure increases, fluid forces the valve down in its bore. In moving down, the valve opens a passage to the torque converter. Further movement of the MPRV opens a passage to the exhaust hydraulic circuit (to the oil sump), and then the valve becomes balanced between spring force at the bottom and fluid pressure at the top.

This process sets main pressure for the transmission. In neutral and reverse, main pressure is at its highest—between 275 and 320 psi depending on transmission model. Main pressure also varies depending on the transmission range and operating mode. The circuit to the MPRV contains a pressure relief valve this valve is set to exhaust main pressure at 600 psi. TABLE 46-6 shows the ranges for main and lube pressure for each gear.

Fluid going to the MPRV is also directed to the top of the solenoid regulator valve. As pressure moves this valve down in its bore, the pressure opens a passage to the solenoids. The valve will become balanced at 100 psi. This new pressure is known as control main pressure and is the pressure that transmission solenoids will redirect to control the position of the solenoid regulator valves at the bottom of each shift control solenoid (solenoids A, B, C, D, E and the converter control solenoid F).

TECHNICIAN TIP

Main pressure varies slightly from model to model up to WTEC III.

The Allison Fourth Generation Electronic control has more complete control of main pressure due to the modulated main solenoid.

TABLE 46-6: Main Pressure and Lube Pressure for Each Gear

MAIN PRESSURE		
Gear	**Lock-Up**	**Pressure**
Neutral and Reverse	Lock-up not applied	275-320 psi
Forward with converter active	Lock-up not applied	239- 285 psi
2, 3, 4	Lock-up applied	165-205 psi
5, 6	Lock-up applied	155-175 psi

LUBE PRESSURE	
Gear	**Pressure**
Neutral, Reverse, 1, 2, 3	22 psi
4, 5, 6	17 psi

Solenoid Fluid Flows

The solenoids control the flow of pressurized hydraulic fluid to apply the clutches necessary to attain each range. Solenoids are operated both to apply on-coming clutches and release off-going clutches as a shift occurs. Let's examine more closely the solenoid operation and fluid flows for each range.

WTEC Neutral Fluid Flow

As was illustrated in FIGURE 46-41, solenoids A, B, and E are energized when the transmission is in neutral. Because solenoids A and B are normally open, they stop fluid from flowing to their solenoid regulator valves and thereby prevent their respective clutches from being applied. Solenoid E is normally closed, so, when it is energized, its solenoid regulator valve is positioned down. That downward position acts to direct control main pressure to the C-5 clutch. The result is that the C-5 clutch is applied, and because it is the only applied clutch, neutral is obtained. This is the process for a transmission in neutral when the vehicle is not in motion.

If, however, the transmission is in neutral while the vehicle is moving, the transmission ECU will energize solenoid E then D then C then D again, depending on the rotational speed of the transmission's components. These solenoids will correspond to clutch C-5, C-4, C-3, and C-4 again. By energizing those solenoids in that particular sequence, the ECU can control the rotational speed of the internal transmission components. Because only one of those solenoids is energized at any time, the transmission remains in neutral.

WTEC First Range

Solenoids B and E are energized in first range. As the driver selects first range, solenoid A is de-energized. Recall that solenoid A is normally open, so when it is de-energized, it directs solenoid regulator pressure to the top of its solenoid regulator valve, causing the valve to move down in its bore. This action directs control main pressure to the C-1 clutch applying it. Solenoid B remains energized, so C-2 clutch is not applied. Solenoid E remains energized, so C-5 also remains applied. Since C-1 and C-5 are applied, the transmission attains first range. This process is illustrated in FIGURE 46-42.

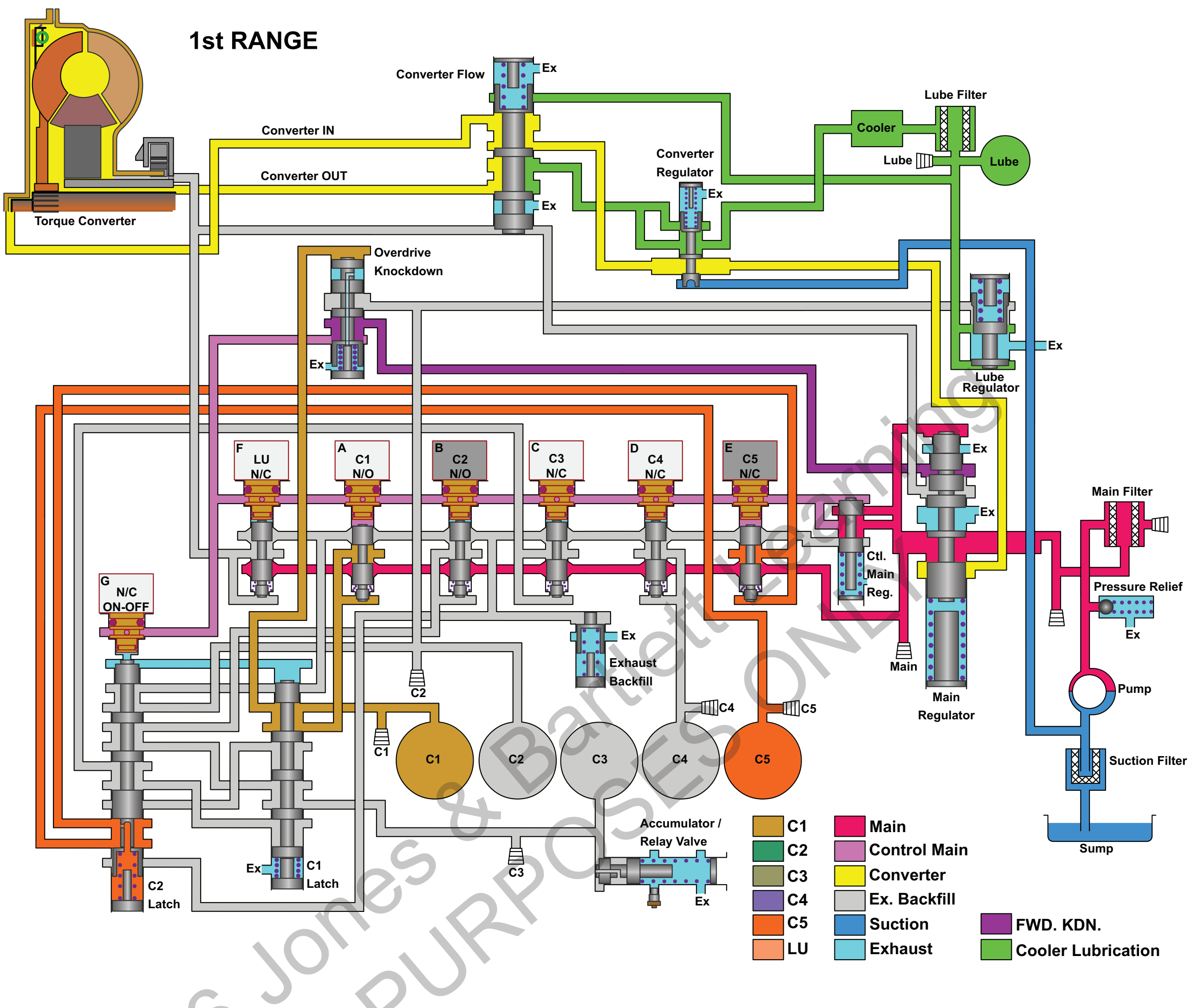


FIGURE 46-42 Hydraulic flow in a WTEC III in first range.

WTEC Second Range

In second range, the solenoids B, D, and F are energized. As the transmission shifts to second range, solenoid E is de-energized, and solenoid D is energized. That action exhausts C-5 clutch and applies C-4 clutch. Solenoid A remains de-energized, so C-1 remains applied. Solenoid B remains energized, so C-2 clutch is not applied. Because C-1 and C-4 are applied, the transmission attains second range as is shown in FIGURE 46-43. At this point, solenoid F is energized and applies the torque converter lock-up clutch.

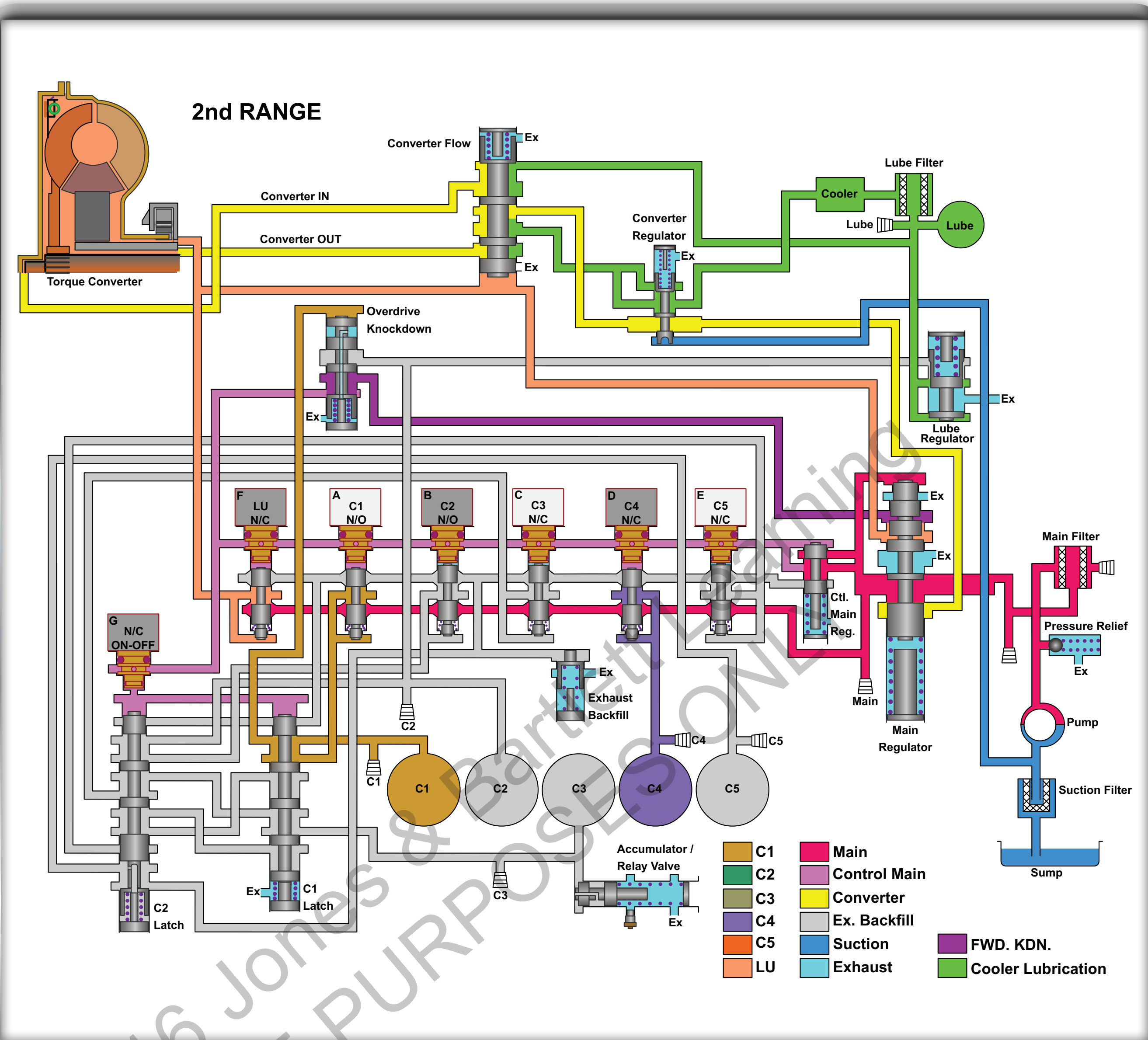


FIGURE 46-43 Hydraulic flow in a WTEC III in second range.

WTEC Third Range

In third range, solenoids B, C, and F are energized. As the transmission shifts to third range, solenoid D is de-energized, and solenoid C is energized. This process exhausts C-4 clutch and applies C-3 clutch. Solenoid A remains de-energized, so C-1 clutch remains applied. Solenoid B remains energized, so C-2 clutch is not applied. Because C-1 and C-3 are applied, the transmission attains third range, as is illustrated in FIGURE 46-44. Solenoid F remains energized applying the torque converter lock-up clutch.

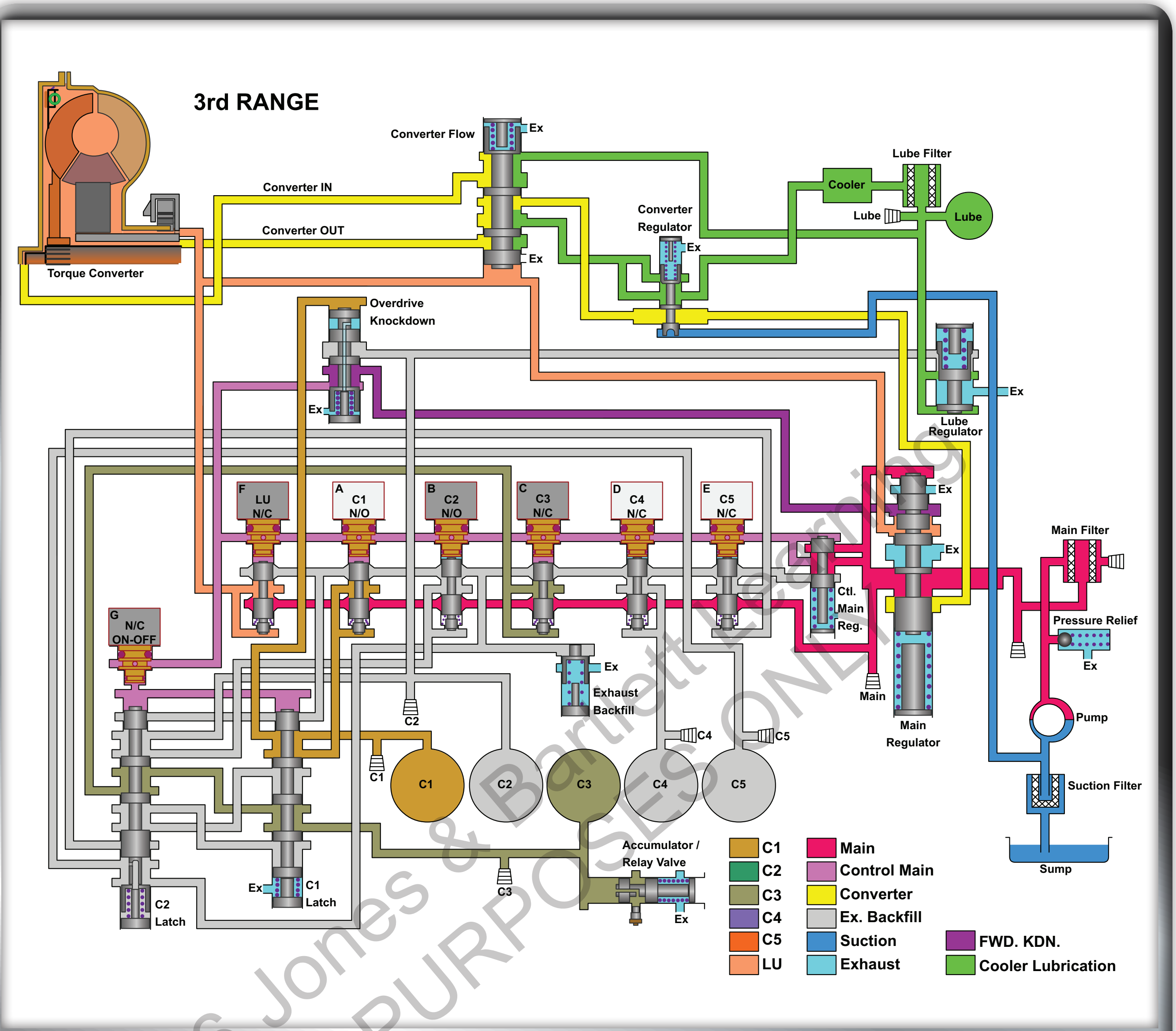


FIGURE 46-44 Hydraulic flow in a WTEC III in third range.

WTEC Fourth Range

When the transmission is in fourth range, solenoid F is the only energized solenoid.

As the transmission shifts to fourth range, solenoids B and C are de-energized. De-energizing solenoid C exhausts the C-3 clutch. De-energizing normally open solenoid B causes its solenoid regulator valve to move down in its bore. That process sends control main pressure to the C-2 clutch and applies it. Since C-1 and C-2 are both applied, the transmission attains fourth range. FIGURE 46-45 illustrates the system in fourth range. Notice that solenoid F remains energized applying the torque converter lock-up clutch.

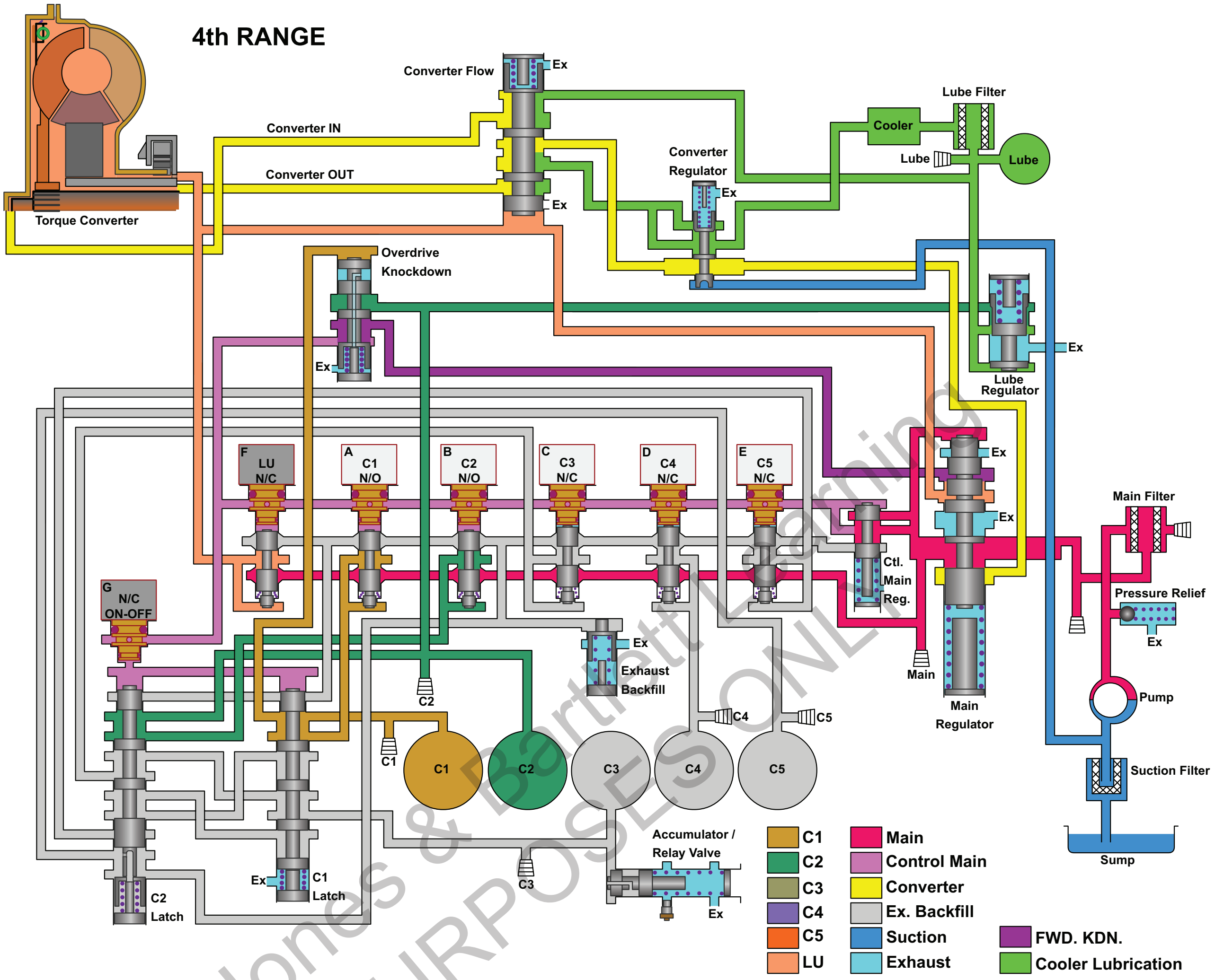


FIGURE 46-45 Hydraulic flow in a WTEC III in fourth range.

WTEC Fifth Range

In fifth range, solenoids A, C, and F are energized. As the transmission shifts to fifth range, solenoid A is energized, which exhausts the C-1 clutch. Solenoid B remains de-energized, keeping the C-2 clutch applied. Solenoid C is energized, and that applies the C-3 clutch. Since C-2 and C-3 are applied, the transmission attains fifth range, as is shown in FIGURE 46-46. Solenoid F again remains energized applying the torque converter lock-up clutch.

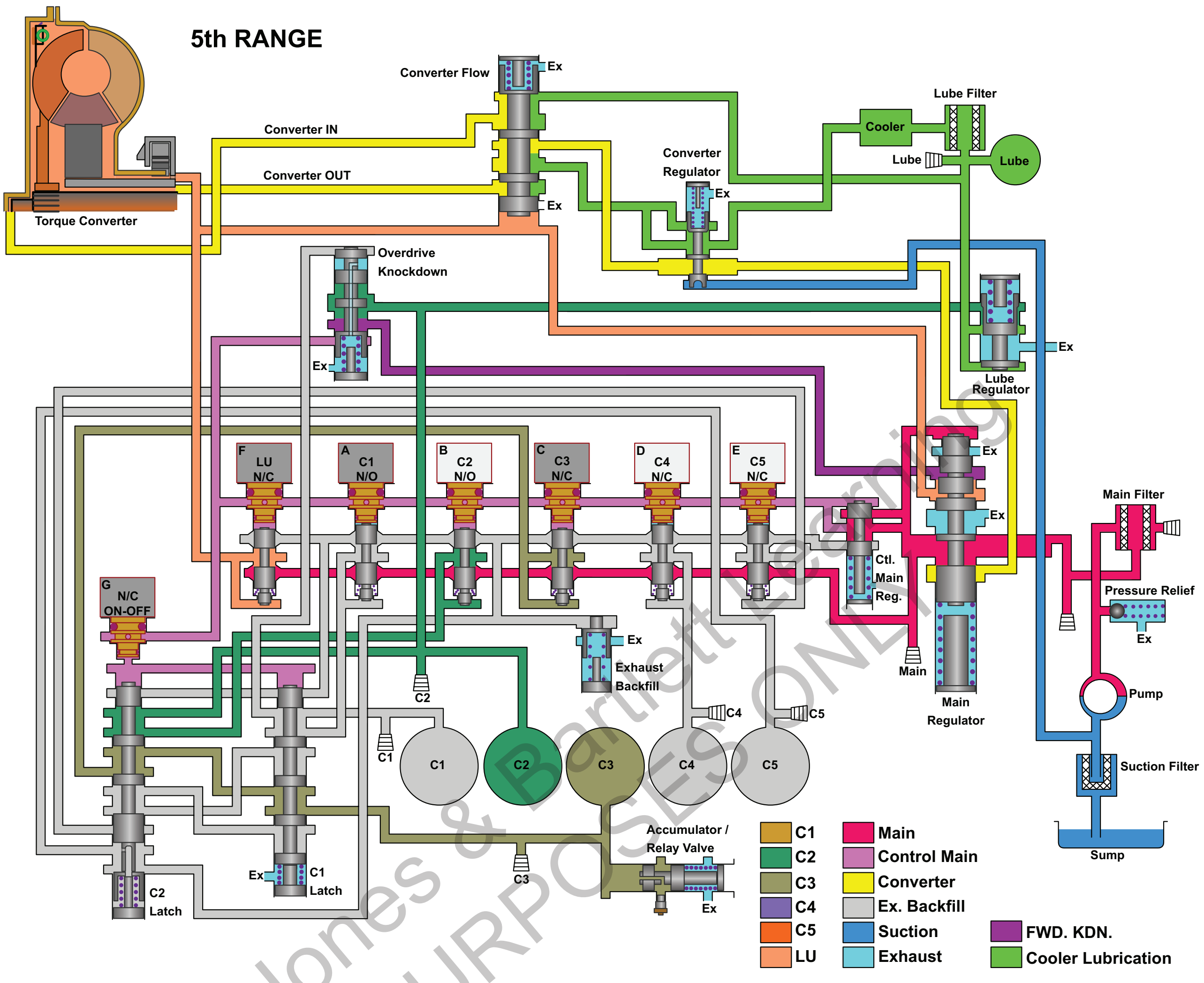


FIGURE 46-46 Hydraulic flow in a WTEC III in fifth range.

WTEC Sixth Range

In sixth range, solenoids A, D, and F are applied. Solenoid A remains energized keeping C-1 clutch unapplied. Solenoid B is de-energized, so C-2 remains applied. Solenoid C is de-energized, exhausting C-3 clutch. Solenoid D is energized, applying C-4 clutch. Since C-2 and C-4 are applied, the transmission attains sixth range. This is shown in FIGURE 46-47. Solenoid F again remains energized applying the torque converter lock-up clutch.

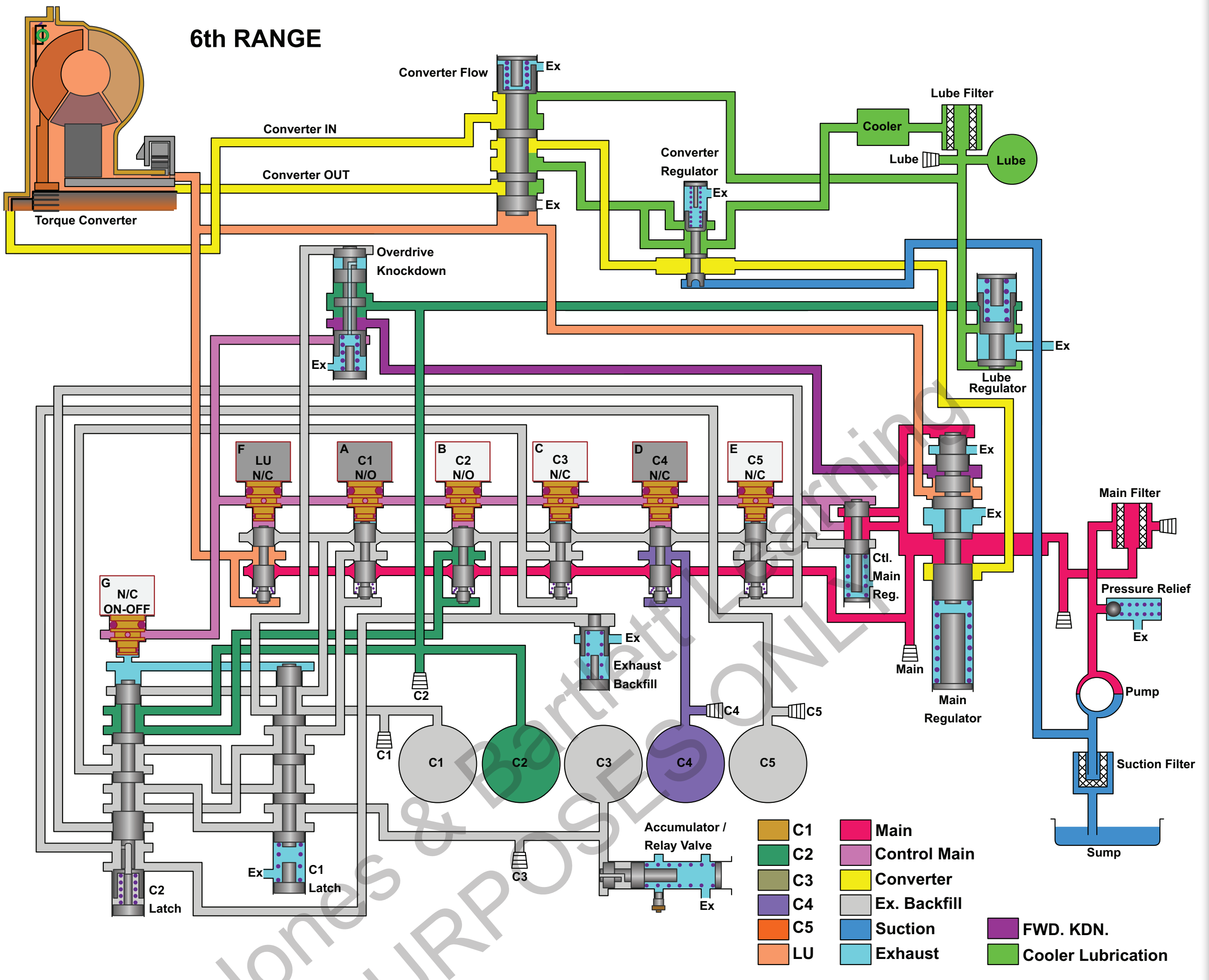


FIGURE 46-47 Hydraulic flow in a WTEC 111 in sixth range.

WTEC Reverse

In reverse, solenoids A, B, C, and E are energized. Reverse will start from a neutral position. Recall that in neutral, solenoids A, B, and E are energized. Energizing normally open solenoid A means that C-1 clutch is not applied. Energizing normally open solenoid B means that C-2 clutch is not applied. Normally closed solenoid E is energized, and that applies C-5 clutch. As the driver selects reverse, normally closed solenoid C is energized, which applies the C-3 clutch. Since C-5 and C-3 are applied, the transmission attains reverse. FIGURE 46-48 illustrates the WTEC 111 transmission in reverse.

As a review for the section on solenoid fluid flows, TABLE 46-7 shows the position of each solenoid in each range.

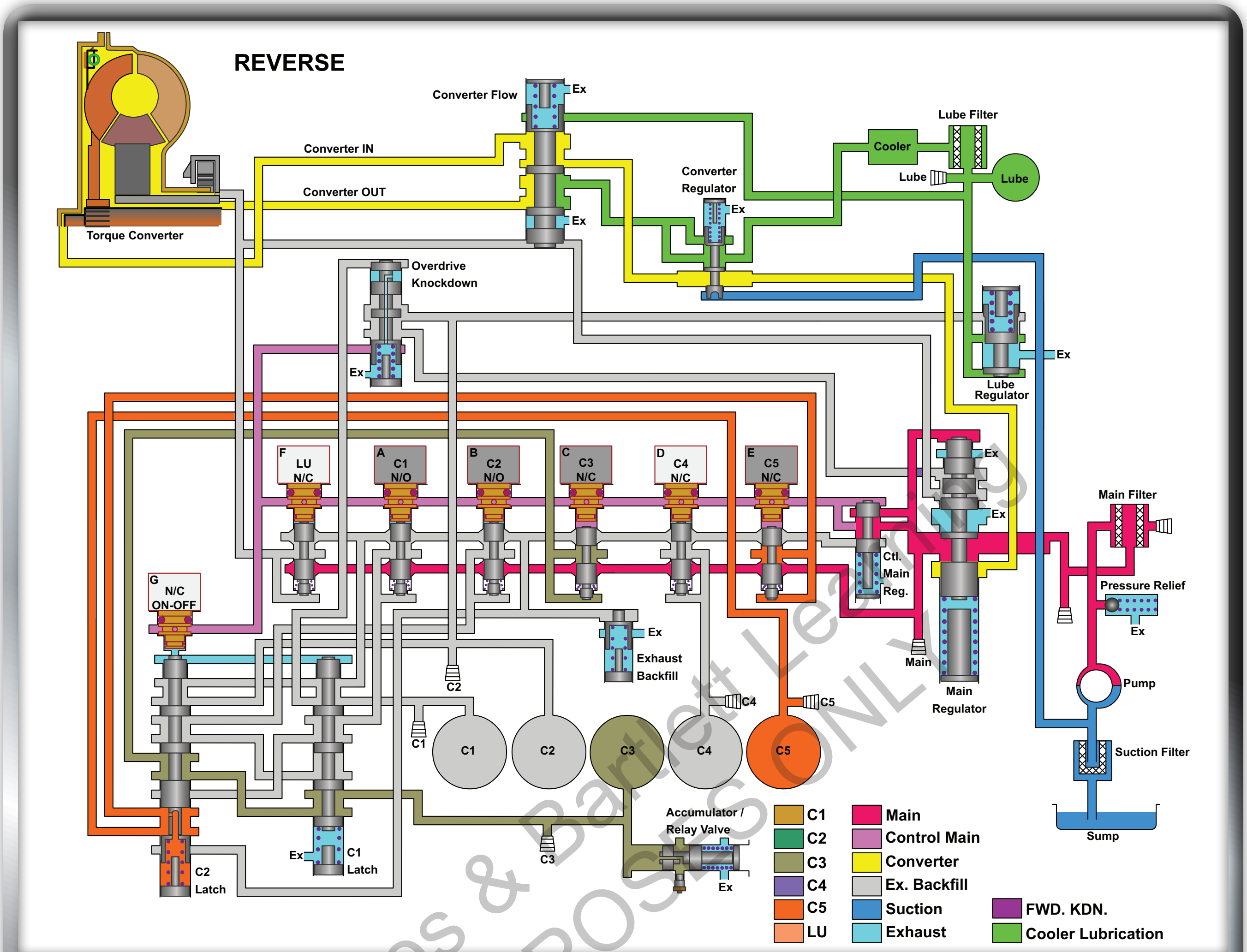


FIGURE 46-48 Hydraulic flow in WTEC III in reverse range.

TABLE 46-7: Solenoid Position in Each Range

Range	A (N/O)	B (N/O)	C (N/C)	D (N/C)	E (N/C)	F (N/C)	G (N/C)	Applied Clutches
Neutral 1	ON	ON			ON			C-5
Neutral 2	ON	ON		ON				C-4
Neutral 3	ON	ON	ON					C-3
Neutral 4	ON	ON		ON				C-4
Reverse	ON	ON	ON		ON			C-3 / C-5
First		ON			ON			C-1 / C-5
Second		ON		ON		ON*	ON	C-1 / C-4
Third		ON	ON			ON*	ON	C-1 / C-3
Fourth						ON*	ON	C-1 / C-2
Fifth	**ON**		**ON**			**ON***	**ON**	**C-2 / C-3**
Sixth	ON			ON		ON*		C-2 / C-4

* Solenoid F controls the lock-up and is normally energized in all ranges above first. Under certain operating conditions, however, solenoid F may be de-energized.

Latch Valves

The WTEC transmission utilizes two latch valves, C-1 latch and C-2 latch, to assure failsafe operation during electrical failure FIGURE 46-49. **Failsafe operation** occurs when the transmission control system is not operating due to electrical failure. The transmission's hydraulics are designed to allow minimal function so that the vehicle can be moved. The C-1 and C-2 latch play the main role in failsafe operation. The two latch valves are spring-loaded spool valves, and during normal operation, their position is controlled by normally closed solenoid G. The fluid is directed in such a way to apply clutches C-1, C-2, C-3, and C-5 from solenoids A, B, C, and E. That fluid must flow through one or both latch valves on the way to the clutches. Solenoids D (C-4) and F (lock-up clutch) are the only solenoids that send fluid directly to the clutches they control.

When solenoid G is energized, it directs solenoid regulator pressure to the top of both latch valves. That application of pressure tries to move the valves down in their bore against spring pressure. The valves may or may not move, however, depending on the fluid flow through them. Fluid flow through the valves may keep them in a closed position—even though the G solenoid is energized.

Latch Valve Fluid Flows

The design of the latch valves and their fluid flows allows for the following electrical failure failsafe operational modes in each gear.

- If the transmission is in neutral or reverse when electrical failure occurs, the transmission will fail to neutral with no clutches applied (NNC).
- First range will fail to third range.
- Second, third, fourth, and fifth will fail to fourth range.
- Sixth range will fail to fifth range.

These failsafe modes allow limited (limp home) operation of the transmission during electrical failure. Refer to the hydraulic flow schematic in FIGURE 46-50 as you read the following sections on latch valve fluid flows during electrical failure.

WTEC Neutral Range Failsafe

When a WTEC transmission is in neutral, solenoids A, B, and E are energized. Fluid flow from solenoid E flows through the C-2 latch valve and into the C-5 clutch. Only C-5 is applied when the transmission is in neutral.

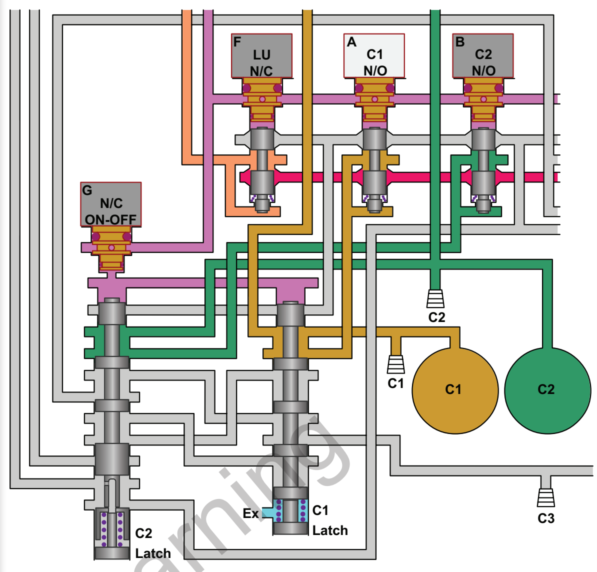


FIGURE 46-49 The C-1 and C-2 latch valves assure failsafe operation in the event of electrical failure.

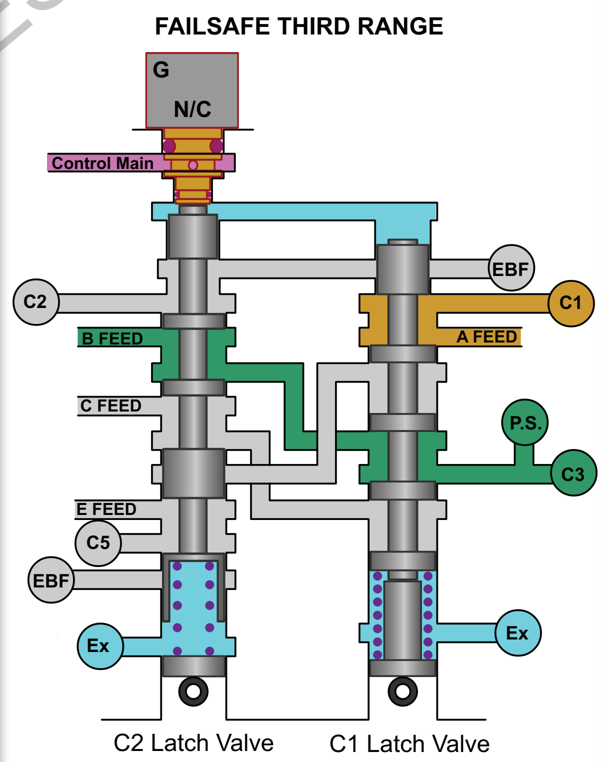


FIGURE 46-50 Detail of the C-1 and C-2 latch valves.

Electrical failure in neutral de-energizes normally open solenoids A and B and normally closed solenoid E. The latch valves are positioned up in their bores. Fluid from solenoid A flows through the C-1 latch valve and deadheads at the C-2 latch valve. Fluid from solenoid B flows through the C-2 latch valve and deadheads at the C-1 latch valve. Fluid flow from solenoid E stops, so C-5 is no longer applied. Because the transmission is in neutral, no clutches are applied. This situation is called **neutral no clutches (NCC)**.

WTEC First Range Failsafe

When the transmission is in first range, solenoids B and E are energized. Solenoid E keeps the C-5 clutch applied. Normally closed solenoid G is energized during the N-1 shift, sending solenoid regulator pressure to the top of the latch valves. That pressure causes the C-1 latch valve to move down in its bore against spring pressure. The C-2 latch valve remains up because the C-5 clutch apply pressure flowing through the valve will not let the valve move down. Normally open solenoid A directs control main pressure through the C-1 latch valve and into C-1 clutch. C-1 and C-5 are applied, so the transmission attains first range. After the shift, solenoid G is de-energized, but the fluid flow from solenoid A through the C-1 latch valve to C-1 clutch keeps the valve in a down-stroked position.

During electrical failure in first range, all solenoids are de-energized. Fluid no longer flows from solenoid E, so the C-5 clutch is exhausted. Fluid flow from the normally open solenoid A through the C-1 latch valve keeps the valve positioned down because of differential land sizes in the valve. Fluid flows from normally open solenoid B through the C-2 latch valve which is positioned up. Fluid continues to flow through the C-1 latch valve and into the C-3 clutch circuit. The C-3 circuit is then applied.

Because C-1 and C-3 are applied, the transmission attains third range. If the vehicle is shut down during electrical failure, on restart the normally open solenoids A and B will still allow fluid to flow. The C-1 latch valve will have moved up in its bore, however, causing the fluid to deadhead at the latch valves. The result will be neutral no clutches (NCC).

WTEC Second Range Failsafe

In second range, solenoids B, D, F, and G are energized. As the shift from first to second occurs, normally closed solenoid G is de-energized. Nonetheless, the flow to C-5 through latch valve C-2 holds the latch valve up it its bore. Fluid flowing through normally open solenoid A flows through the C-1 latch valve (holding it down in its bore) and continues on to C-1 clutch. Solenoid D directly applies the C-4 clutch—the only clutch control solenoid that does not flow through the latch valves.

As the shift is being made, normally closed solenoid E is de-energized and cuts off the flow to the C-5 clutch. After the shift has been made, solenoid G is energized, sending fluid to the top of the latch valves. As a result, latch valve C-2 will move down in its bore, and latch valve C-1 will remain down in its bore. Solenoid F is energized to apply the lock-up clutch. Because C-1 clutch and C-4 clutch are applied, the transmission attains second range.

During electrical failure in second range, all solenoids are de-energized. Normally closed solenoid D closes and stops the flow of fluid to the C-4 clutch. The fluid flow from solenoid A keeps the C-1 latch valve down in its bore and continues to supply the C-1 clutch. Fluid immediately flows from the de-energized normally open solenoid B to the C-2 latch valve, keeping it down in its bore—even though there is no pressure at the top of the valve. This fluid flows through the C-2 latch valve and on to the C-2 clutch. At that point, the C-2 clutch is applied. Normally closed solenoid F exhausts the lock-up clutch. Because C-1 and C-2 clutches are applied, the transmission attains fourth range. If the transmission is shut down, both latch valves will move back up in their bores. Upon restart, both latch valves will block the flow of fluid from normally open solenoid A and B. The result will be neutral no clutches (NCC).

WTEC Third Range Failsafe

Solenoids B, C, G, and F are energized in third range. Solenoid G keeps both latch valves down in their bores. Solenoid F applies the lock-up clutch. Normally closed solenoid C is energized. This directs fluid through the C-2 and the C-1 latch valves and into the C-3 clutch, applying it. Fluid flows from normally open solenoid A through the C-1 latch valve and into the C-1 clutch, applying it. Because C-1 and C-3 are applied, the transmission attains third range.

During electrical failure in third range, all solenoids are de-energized. Solenoid F exhausts the lock-up clutch. Solenoid C exhausts the C-3 clutch. Solenoid G exhausts the pressure from the top of the latch valves. Fluid begins to flow immediately from normally open solenoid B through the C-2 latch valve. The valve is held down in its bore. Continuation of the fluid flow applies the C-2 clutch. Fluid flow through the C-1 latch valve keeps it down in its bore and supplies C-1 clutch. Because C-1 and C-2 are applied, the transmission attains fourth range. If the vehicle is shut down, upon restart the latch valves will have moved up in their bores due to spring pressure. Flow through normally open solenoids A and

B will simply deadhead at the valves. The transmission will attain neutral no clutches (NCC).

WTEC Fourth Range Failsafe

In fourth range, solenoids G and F are energized. Solenoid G delivers pressure to the top of the latch valves, which holds them down in their bore. Fluid flows from normally open solenoid A through the C-1 latch valve and into C-1 clutch. Fluid from normally open solenoid B flows through the C-2 latch valve and into the C-2 clutch. Because the C-1 and the C-2 clutches are applied, the transmission attains fourth range. Solenoid F applies the lock-up clutch.

During electrical failure in fourth range, solenoid F exhausts the lock-up clutch. Solenoid G exhausts the pressure from the top of the latch valves, but the fluid flowing through them to C-1 and C-2 clutch keeps the valves down in their bore. Since C-1 and C-2 clutches are applied, the transmission stays in fourth range. If the vehicle is shut down, upon restart the latch valves will have moved up in their bores due to spring pressure. Flow through normally open solenoids A and B will simply deadhead at the valves, and the transmission will attain neutral no clutches (NCC).

WTEC Fifth Range Failsafe

In fifth range, solenoids A, C, G, and F are energized. Solenoid G keeps both latch valves down in their bores. Solenoid F applies the lock-up clutch. Normally closed solenoid C is energized. The energized solenoid C directs fluid through the C-2 and the C-1 latch valves and into the C-3 clutch, applying it. Fluid flows from normally open solenoid B through the C-2 latch valve and into the C-2 clutch, applying it. Because C-2 and C-3 are applied, the transmission attains fifth range.

During electrical failure in fifth range, all solenoids become de-energized. Solenoid F exhausts the lock-up clutch, and solenoid G exhausts the fluid from the top of the latch valves. Fluid flowing from normally open solenoid B through the C-2 latch valve and into the C-2 clutch keeps the valve down in its bore and the C-2 clutch applied. Fluid immediately flows from normally open solenoid A through the C-1 latch valve, keeping the valve down in its bore. Fluid flows onto the C-1 clutch, applying it. Because clutches C-1 and C-2 are applied, the transmission attains fourth range. If the vehicle is shut down, upon restart, the latch valves will have moved up in their bores due to spring pressure and flow through normally open solenoid A. Fluid flow through solenoid B will simply deadhead at the valves, and the transmission will attain neutral no clutches (NCC).

WTEC Sixth Range Failsafe

In sixth range, solenoids A, D, and F are energized. Solenoid G is de-energized. This exhausts the fluid from the top of the latch valves, and latch valve C-1 moves up in its bore. Latch valve C-2 stays down, however, because of the fluid from normally open solenoid B flowing through it and into the C-2 clutch. Solenoid F applies the lock-up clutch. Solenoid D applies the C-4 clutch. Because C-2 and C-4 are applied, the transmission attains sixth range.

During electrical failure in sixth range, all solenoids are de-energized. Solenoid F exhausts the lock-up clutch, and solenoid D exhausts the C-4 clutch. Fluid continues to flow from normally open solenoid B through the C-2 latch valve and into the C-2 clutch. Fluid immediately begins to flow from normally open solenoid A through the C-1 latch valve, which is positioned up. This fluid flows to the C-2 latch valve and through it back to another port on the C-1 latch valve. Fluid flows through this port in the C-1 latch valve and into the C-3 clutch, applying it. Because C-2 and C-3 are applied, the transmission attains fifth range. If the vehicle is shut down, upon restart the latch valves will have moved up in their bores due to spring pressure. Fluid flow through normally open solenoid A and B will simply deadhead at the valves, and the transmission will attain neutral no clutches (NCC).

WTEC Reverse Range Failsafe

When the transmission is in reverse, solenoids A, B, C, and E are energized. Solenoids A and B are normally open, so energizing them stops fluid flow. Solenoid C sends fluid pressure through the C-2 and the C-1 latch valves and into the C-3 clutch. Solenoid E sends fluid pressure through the C-2 latch valve to the C-5 clutch. Both latch valves are positioned up in their bores. Because C-3 and C-5 clutches are applied, the transmission attains reverse.

TECHNICIAN TIP

These failsafe strategies activate a limp-home mode to allow the vehicle to be driven to a repair depot during an electrical failure. Note that, although the vehicle can be moved during electrical failure, as soon as the engine is shut off and the transmission oil pressure drops, the transmission will then revert to neutral no clutches and the vehicle can no longer be driven.

During electrical failure in reverse, all solenoids are de-energized. Solenoid C exhausts the C-3 clutch. Solenoid E exhausts the C-5 clutch. Fluid immediately begins to flow from normally open solenoid A through the C-1 latch valve and deadheads at the C-2 latch valve. Fluid also immediately begins to flow from normally open solenoid B through the C-2 latch valve and deadheads at the C-1 latch valve. No clutches are applied, and the transmission attains neutral no clutches (NCC).

Allison Fourth Generation Electro-Hydraulic Control Valve Body

The next revision of the Allison electronic control is simply called Allison Fourth Generation Electronic Control. Fourth generation was released in the 2004–2005 model year and introduced several changes to the electro-hydraulic valve body and control strategy. For example, the solenoids used in fourth-generation systems have different functioning and locations compared to the solenoids in the WTEC 11 and WTEC 111 transmissions.

The transmission ECU is renamed **transmission control module (TCM)** FIGURE 46-51 and the clutch control solenoids have been renamed **pressure control solenoids (PCS)**. PCS1 replaces solenoid A; PCS2 replaces solenoid B; PCS3 replaces solenoids C and E; and PCS4 replaces solenoid D. Solenoid E as a standalone part has been eliminated altogether. Solenoid F has been renamed **torque converter control (TCC)**, and Solenoid G, which controls the position of the C-1 and C-2 latch valves, has been renamed **shift solenoid 1 (SS1)**. A new solenoid has been introduced called the **modulated main solenoid (Mod Main)**. The TCM uses the Mod Main to reduce main pressure when desired.

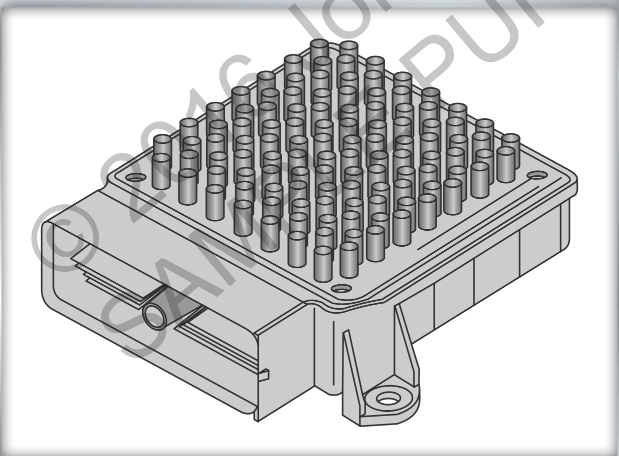


FIGURE 46-51 The fourth generation transmission control module is common to all 1000, 2000, 3000 and 4000 product families.

The pressure-control solenoids and the Mod Main solenoid are very different internally from their predecessors in the WTEC 11 and WTEC 111 controlled transmissions. The WTEC 11 and WTEC 111 solenoids had an inlet port, an outlet port, and an exhaust port. The flow of fluid was controlled by the transmission ECU using pulse-width modulation to control the opening and closing of a check ball in the solenoid. That process would direct fluid either to the outlet port or to exhaust.

In contrast, the fourth-generation control system uses variable-bleed solenoids (VBS). **Variable-bleed solenoids** control application by allowing some of the pressure going to a device to bleed off to exhaust. Variable-bleed solenoids have three ports:

- A supply port that is fed control main pressure
- A control port that sends that pressure to the solenoid regulator valve
- An exhaust port

Each pressure-control solenoid is connected to an accumulator, which absorbs pressure pulsations that can be caused by the pulse-width modulation of the solenoid. FIGURE 46-52 shows a variable-bleed solenoid in high-pressure state and in a controlling pressure state.

The TCM (formerly the transmission ECU) precisely controls the current being applied to the solenoids by changing the duty cycle of the pulse-width-modulated control circuit. Changing the duty cycle controls the size of the bleed orifice. The sizing of the bleed orifice is what allows the transmission to control precisely the speed of application of the clutch. Variable bleed solenoids are called either normally high (maximum pressure is supplied to the control circuit) or normally low (minimum pressure supplied to the control circuit).

The SS1 solenoid is not a variable-bleed solenoid. Rather, it is an on/off solenoid. PCS3 controls clutch C-5 when the C-1 and C-2 latch valves are in the up or un-stroked position. PCS3 also controls clutch C-3 when the C-1 latch valve is in the down or stroked position. TABLE 46-8 is the Fourth Generation solenoid application chart for six-speed transmissions without a retarder.

The Mod Main solenoid directs pressure to a land on the main pressure regulator valve, and this reduces main pressure. The Mod Main is only used in reverse when throttle is less than 18%. Reducing main pressure when possible lowers the parasitic load the transmission hydraulic pump places on the engine.

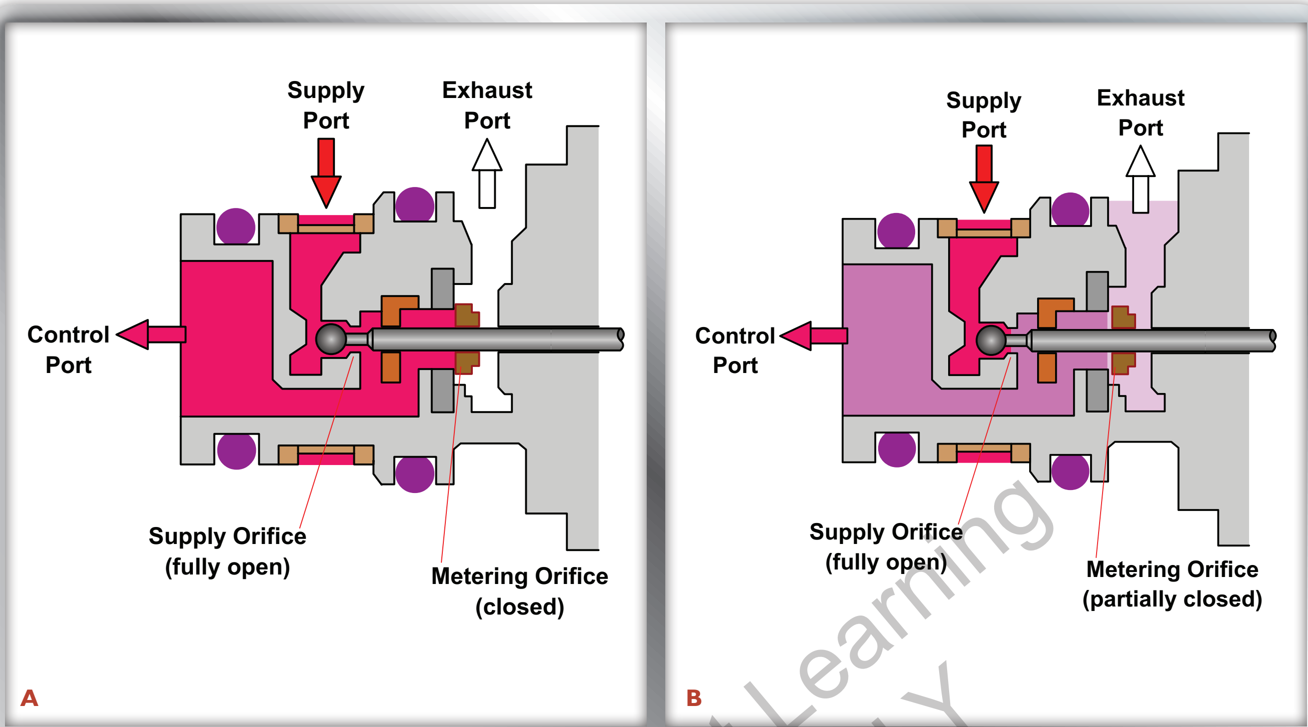


FIGURE 46-52 The new variable-bleed solenoids (VBS) used with fourth generation control allow more accurate control of clutch application. **A.** VBS in high-pressure state. **B.** VBS in controlling pressure state.

TABLE 46-8: Fourth Generation Solenoid Application Chart

Range	PSC1 N/O	PCS2 N/O	PCS3 N/C	PC4 N/C	SS1 N/C	Mod Main N/C
Neutral **	ON	ON	ON			Optional*
Reverse	ON		ON			Optional*
First		ON	ON			Optional*
Second		ON		ON	ON	Optional*
Third		ON	ON		ON	Optional*
Fourth					ON	Optional*
Fifth	ON		ON		ON	Optional*
Sixth	ON			ON		Optional*

* The modulated main solenoid may be energized by the TCM when lower main pressure is desired in any operating range.

** Four different neutral configurations can be attained if the vehicle is moving in neutral range.

As with the WTEC 11 and WTEC 111 control systems, the fourth-generation transmission can attain four different neutral configurations if the vehicle is moving while in neutral. The clutch applications depend on component rotational speed. Check the OEM manual for applications. Note that the clutch application chart and powerflows for the fourth generation transmissions are identical to those for the earlier World Transmission models.

Fourth Generation Fluid Flows

Fourth Generation Neutral

Normally open solenoids PCS1 and PCS2 and normally closed PCS3 solenoid are energized. Main pressure deadheads at the PCS1 and PCS2 solenoids. Main pressure flows through the open PCS3 solenoid through the C-2 latch valve and applies the C-5 clutch. Normally closed Mod Main solenoid is energized to lower main pressure FIGURE 46-53.

Fourth Generation First Range

During the shift to first, normally closed solenoid SS1 is energized briefly to position the C-1 latch valve down. The C-2 latch valve remains up because of the fluid pressure flowing to C-5 clutch. Normally open solenoid PCS2 and normally closed solenoid PCS3 remain energized, but normally open solenoid PCS1 is de-energized. Main pressure flows through PCS1 and the C-1 latch valve and applies the C-1 clutch. The normally closed Mod Main solenoid may be energized to reduce main pressure if desired by the TCM FIGURE 46-54.

Fourth Generation Second Range

During the shift to second range, normally closed solenoid PCS3 is de-energized, thereby exhausting C-5. Normally closed solenoid PCS4 is energized, causing main pressure to flow through its solenoid regulator valve to C-4. The normally closed Mod Main solenoid is de-energized to increase main pressure if the situation warrants. Normally open solenoid PCS2 remains energized. When second range is attained, normally closed solenoid SS1 is energized, positioning the C-2 latch valve down. The C-1 latch valve remains down. The TCM may again lower main pressure by energizing the normally closed main modulator solenoid. Normally closed solenoid TCC (torque converter clutch) is energized, applying the lock-up clutch FIGURE 46-55.

Fourth Generation Third Range

In third range, normally closed solenoid PCS4 is de-energized to exhaust C-4 clutch, and the Mod Main solenoid is de-energized to increase main pressure. Normally closed solenoid PCS3 is energized, and main pressure flows

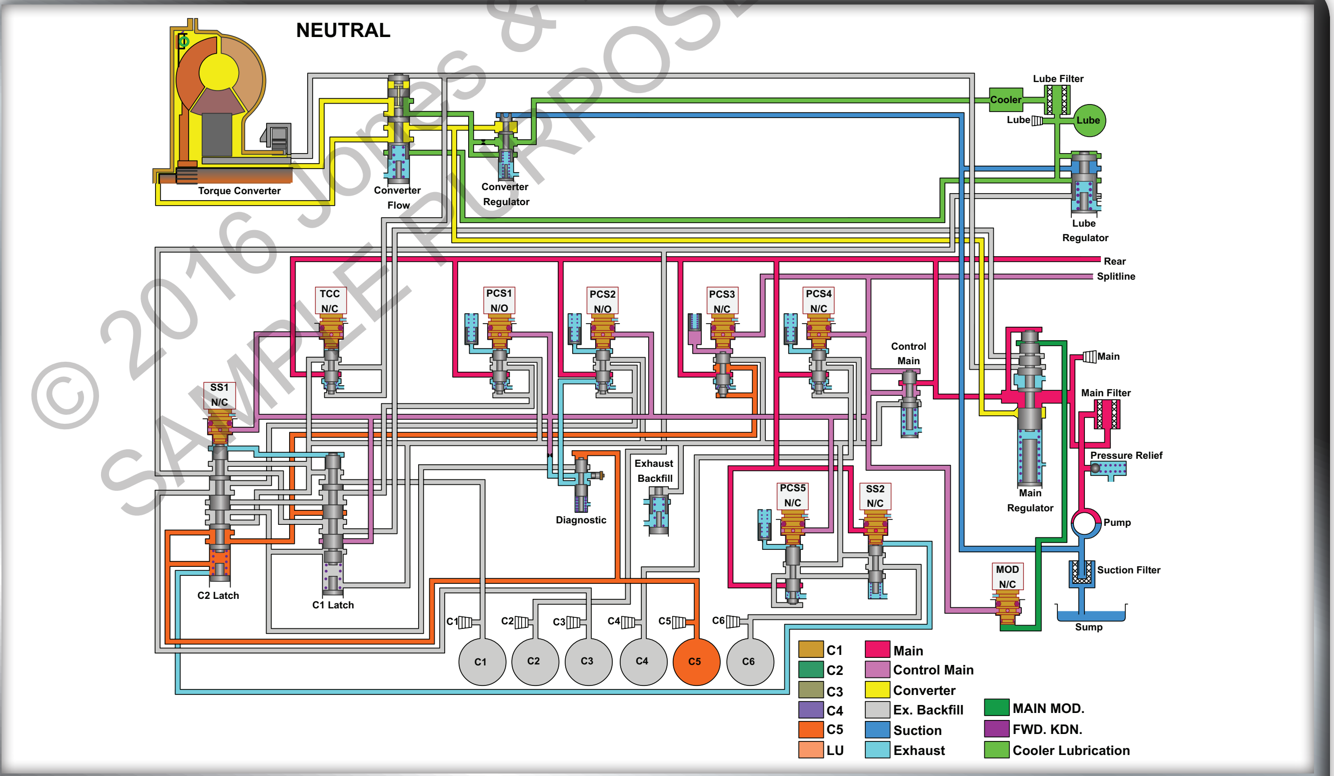


FIGURE 46-53 Neutral hydraulic flow for World Transmission fourth generation control.

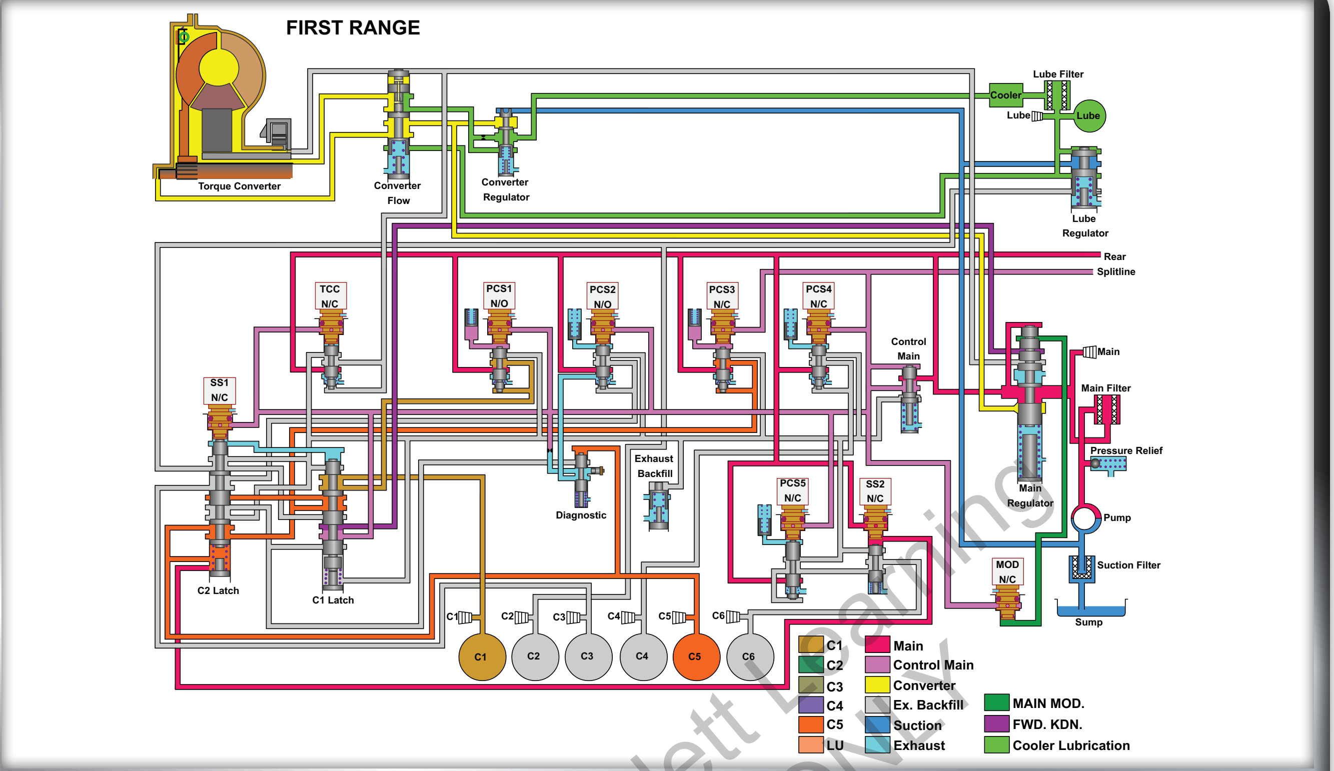


FIGURE 46-54 First Range hydraulic flow for World Transmission fourth generation control.

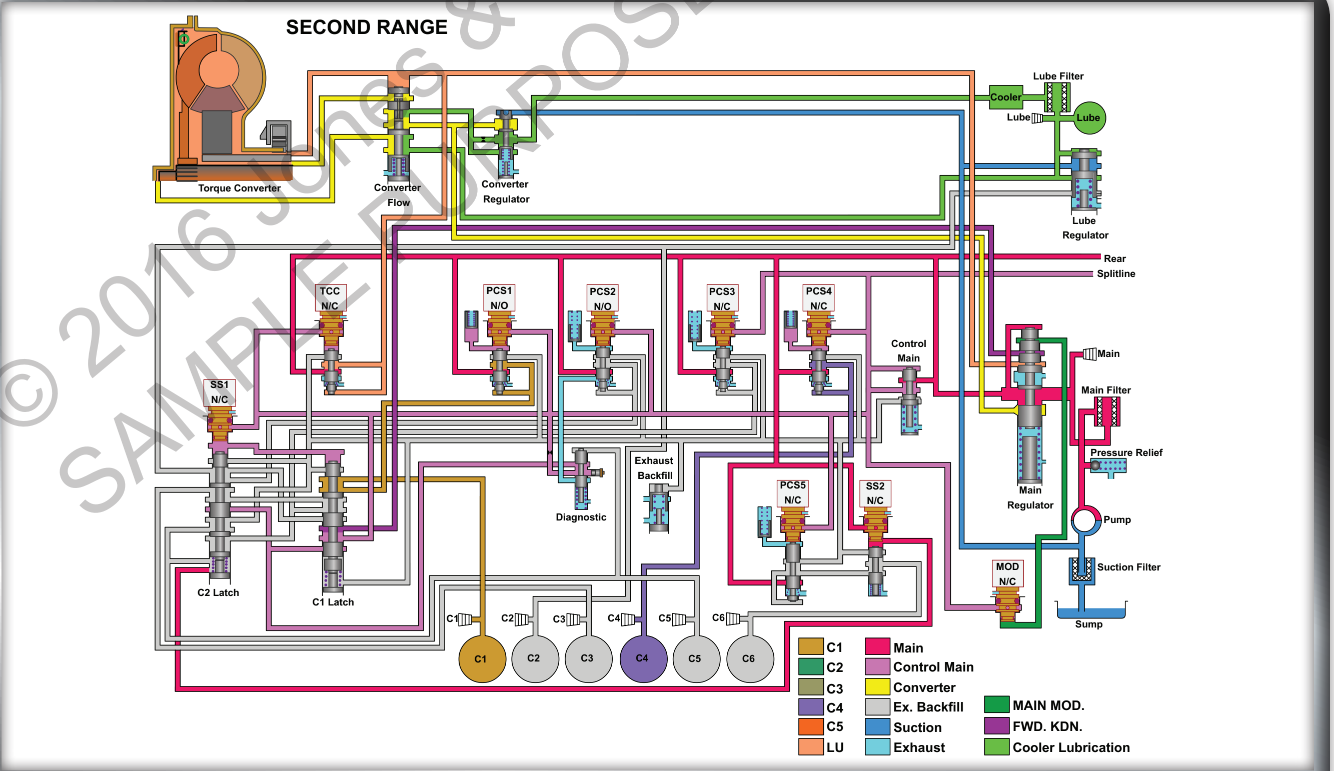


FIGURE 46-55 Second Range hydraulic flow for World Transmission fourth generation control.

through its solenoid regulator valve and the C-1 and C-2 latch valves. That flow applies the C-3 clutch. Normally open PCS2 solenoid remains energized. Normally closed solenoid SS-1 remains energized. Normally closed solenoid TCC (torque converter clutch) is energized, thereby applying the lock-up clutch FIGURE 46-56.

Fourth Generation Fourth Range

In fourth gear, normally closed solenoid PCS3 is de-energized, exhausting C-3 clutch, and normally open solenoid PCS2 is de-energized. That allows main pressure to flow through its solenoid regulator valve and the C-2 latch valve to apply the C-2 clutch. Normally closed solenoid SS-1 remains energized. Normally closed solenoid TCC (torque converter clutch) is energized, applying the lock-up clutch FIGURE 46-57.

Fourth Generation Fifth Range

Normally open PCS1 solenoid is energized, exhausting the C-1 clutch. Normally open solenoid PCS2 remains de-energized, and main pressure still flows through its solenoid regulator valve and the C-2 latch valve to apply C-2 clutch. Normally closed solenoid PCS3 is energized, allowing main pressure to flow through its solenoid regulator valve to apply the C-3 clutch. Normally closed solenoid TCC (torque converter clutch) is energized, applying the lock-up clutch. Normally closed solenoid SS-1 remains energized FIGURE 46-58.

Fourth Generation Sixth Range

Normally open solenoid PCS2 remains de-energized, allowing main pressure to continue to flow through the C-2 latch valve to apply the C-2 clutch. Normally closed solenoid PCS3 is de-energized, exhausting the C-3 clutch. Normally closed solenoid PCS4 is energized, and main pressure now flows through its solenoid regulator valve to apply the C-4 clutch. Normally closed solenoid SS-1 is de-energized, and spring pressure positions the C-1 latch valve up in its bore. The C-2 latch valve remains down, however, because of the pressure flowing to the C-2 clutch. Normally closed solenoid TCC (torque converter clutch) is energized, applying the lock-up clutch FIGURE 46-59.

Fourth Generation Reverse

The shift to reverse starts in the neutral position. Normally open solenoids PCS1 and PCS2 and normally closed PCS3 solenoid are energized. Main pressure dead-heads at the PCS1 and PCS2 solenoids. Main pressure flows through the open PCS3 solenoid through the C-2 latch

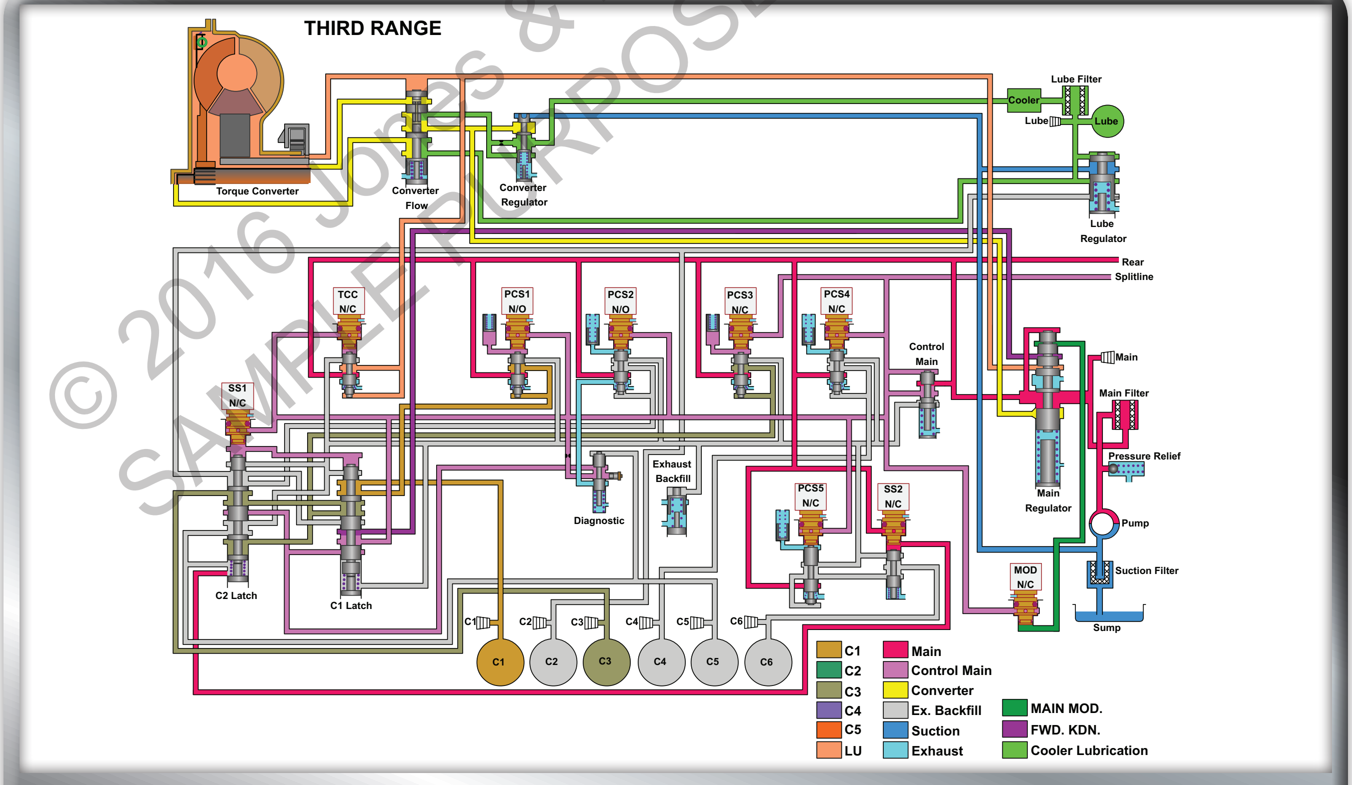


FIGURE 46-56 Third Range hydraulic flow for World Transmission fourth generation control.

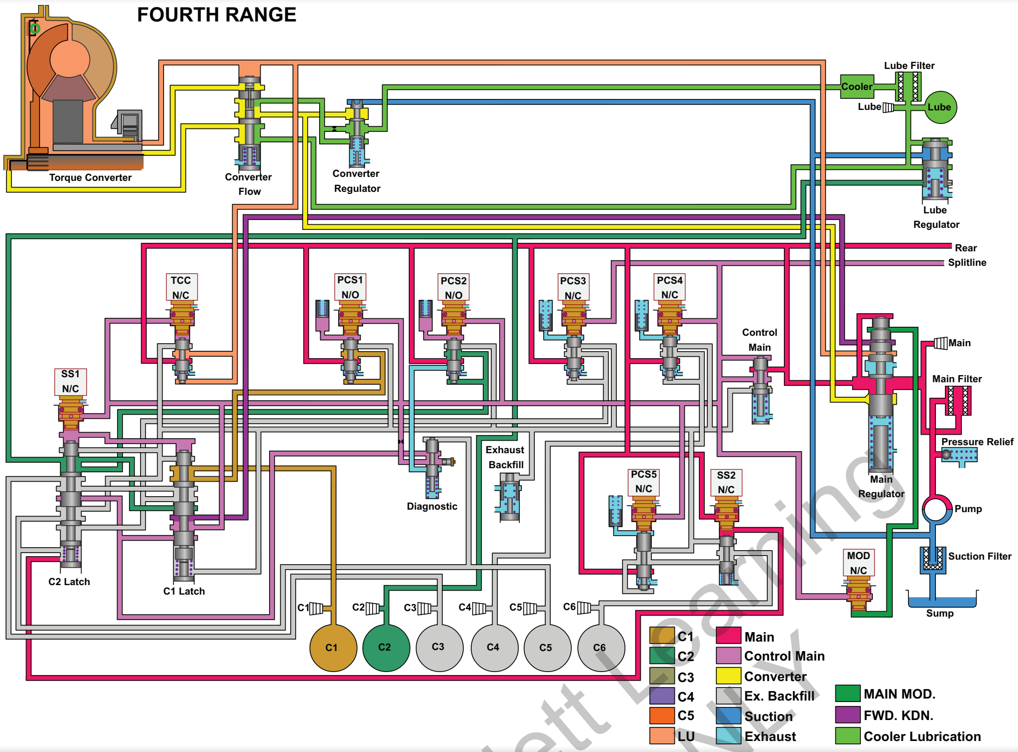


FIGURE 46-57 Fourth Range hydraulic flow for World Transmission fourth generation control.

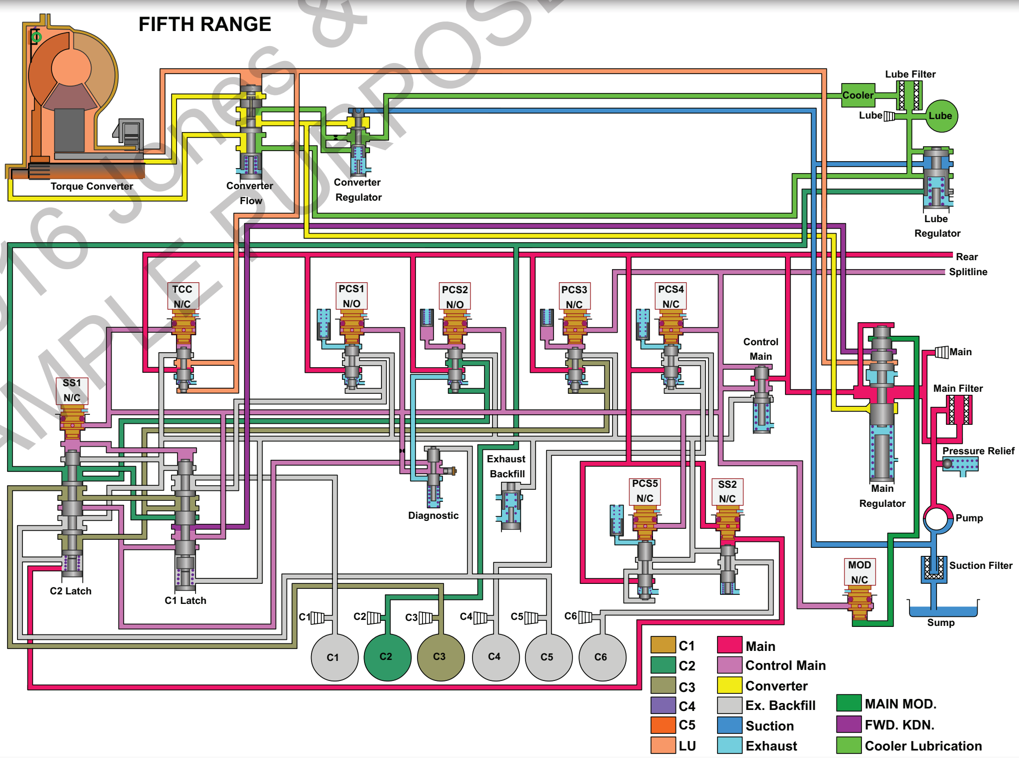


FIGURE 46-58 Fifth Range hydraulic flow for World Transmission fourth generation control.

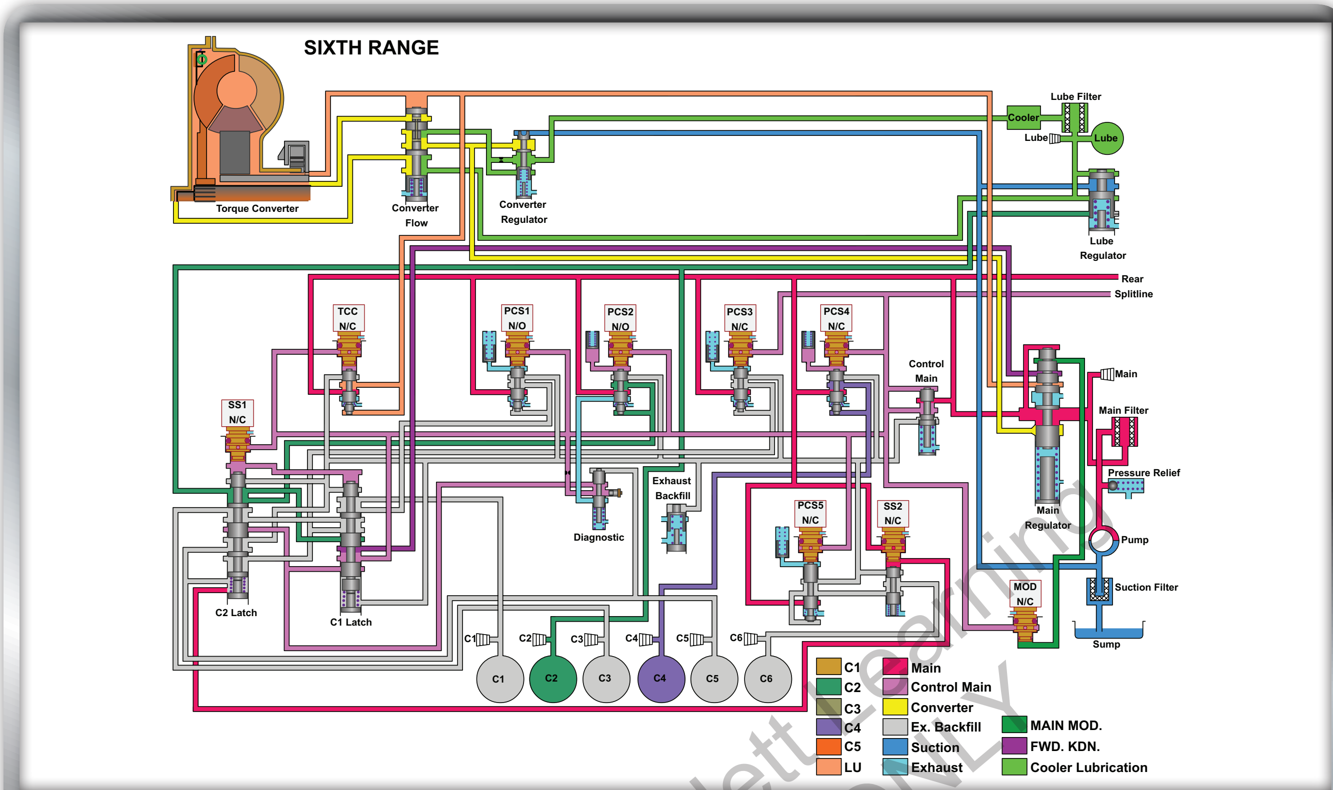


FIGURE 46-59 Sixth Range hydraulic flow for World Transmission fourth generation control.

valve and applies the C-5 clutch. Normally closed Mod Main solenoid is energized to lower main pressure.

In shifting into reverse, normally open solenoid PCS2 is de-energized and main pressure flows through both its solenoid regulator valve and the C-2 latch valve. The C-3 clutch is then applied. The normally closed Mod Main solenoid may or may not be energized FIGURE 46-60.

Other Valves Used in the Electro-Hydraulic Valve Body

There are several other valves in the control valve body of the World Transmission including the converter regulator valve, the converter flow valve, the lube regulator valve, the overdrive knock-down valve, and the exhaust backfill valve. These valves are illustrated in FIGURE 46-61.

Converter Regulator Valve

The converter regulator valve controls maximum torque converter working pressure and oil flow by controlling the convertor in-circuit. As fluid flows to the torque converter, it passes through the converter regulator valve, then through the converter flow valve into the converter, and back out to the converter flow valve.

From here, the returning fluid can take two separate paths. It can either flow into the lubrication circuit, or it may return to the charging pump intake. One path flows through a restriction and then around the center land area of the converter regulator valve into the lube circuit. The oil in the lube circuit passes through the transmission oil cooler, the lube filter, and the lubrication circuit and then is directed back to the converter flow valve where it deadheads.

When converter in pressure is lower than desired, the converter regulator valve is in the down position, and there is no restriction to the converter in-flow. The converter out-flow is directed at the valve in two locations. The converter out-flow deadheads at the upper land of the converter regulator valve, and all of the flow must enter the lube circuit through the restriction and the lower land of the converter regulator valve. As converter pressure rises to 130 psi, the converter regulator will move up in its bore, and some of the return flow that was dead heading at the upper land will flow by it and into the lube circuit. This action starts to restrict converter in flow as well.

The second path the returning fluid can take returns it to the charging pump. The converter regulator valve exhausts some of the converter in-flow to the pump intake. When converter pressure rises above 130 psi, the converter regulator valve moves further up in its

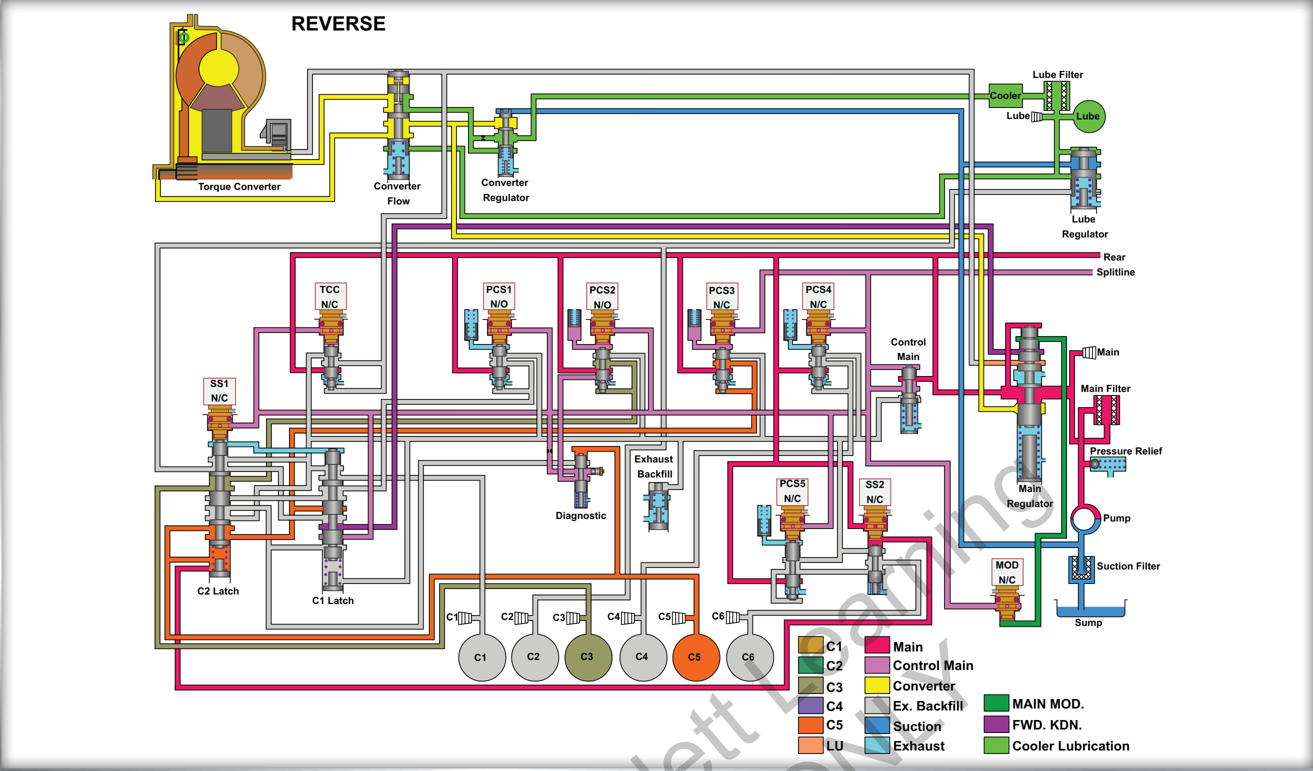


FIGURE 46-60 Reverse Range hydraulic flow for World Transmission fourth generation control.

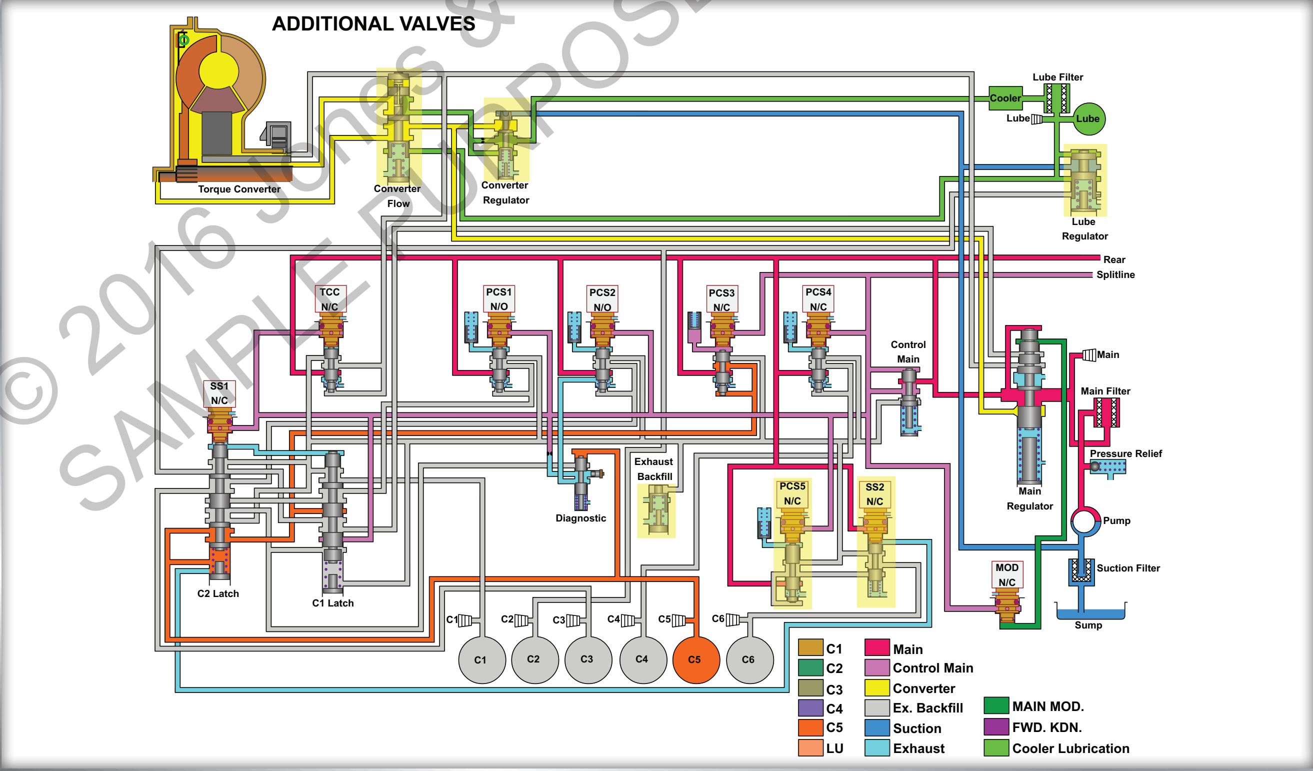


FIGURE 46-61 Additional valves in a fourth generation World Transmission.

bore and allows some of the converter in-circuit to flow directly into the lubrication circuit.

Lubrication Pressure Regulator Valve

The lube pressure regulator is connected to the lubrication circuit and will regulate lubrication pressure at either 17 or 22 psi depending on the gear range. The lube pressure regulator also returns excess fluid to the pump intake directly rather than to the sump, thereby minimizing oil churning in the sump.

Converter Flow Valve

When the TCC solenoid (the equivalent of WTEC solenoid F) is energized, it applies the lock-up clutch. The clutch apply circuit is also directed to the bottom of the converter flow valve. This moves the valve up in its bore and blocks the flow of fluid from the converter regulator valve to the converter in-circuit. The flow from the converter regulator valve now flows directly to the lube circuit. The fluid returning from the lube circuit that normally deadheads at the converter flow valve is now directed through a central drilling in the flow control valve and into the torque converter. This greatly reduces the flow through the torque converter when the torque converter is in lock up. (Recall that high fluid flow is not needed during lock-up but we must keep the converter full of fluid). Reducing the flow through the torque converter removes some parasitic load from the engine. Parasitic loss is further reduced because the lock-up clutch apply circuit is directed to the main pressure regulator valve to reduce main pressure when in lock-up.

Overdrive Knock-Down Valve

The overdrive knock-down valve actually reduces main pressure in all ranges except reverse. The valve has control main pressure directed to it at all times. This valve is not present in the fourth-generation control. Instead, the fourth-generation control uses the main modulator solenoid to lower main pressure when required. When C-1 clutch is engaged, the knock-down valve directs control main pressure (100 psi) to a land on the main pressure regulator valve. The valve moves down, reducing main pressure. When the C-2 clutch is applied, the valve stays up in its bore, and apply pressure from the C-2 clutch circuit is delivered to the main pressure regulator valve. The effect is to further decrease main pressure.

In neutral and reverse ranges, no pressure is delivered to this land on the main pressure regulator. Therefore, main pressure is at its highest in these ranges. C-2 clutch apply pressure from the overdrive knock-down valve is also directed to a land on the lube regulator valve. That application of pressure helps move the valve off its seat. The result is a reduction in lubrication pressure whenever the C-2 clutch is applied. Lube pressure is 22 psi in first, second, and third ranges and 17 psi in fourth, fifth, and sixth ranges.

> **TECHNICIAN TIP**
>
> Because so much power is needed to drive the transmission's hydraulic pump, most transmission manufacturers use pressure-reducing strategies, such as the ones mentioned above, to minimize parasitic losses from the engine.

Since 2010, the fourth generation electro-hydraulic valve body uses a pulse-width-modulated main modulator solenoid designated as open-ended, normally high (OE NH) **FIGURE 46-62**. That means the solenoid is normally closed and pressure is normally HIGH. This solenoid controls the flow of control main pressure to the bottom of the MPRV to control actual main pressure. Increasing pressure at the bottom of the MPRV causes main pressure to increase. This gives the TCM much greater control over main pressure.

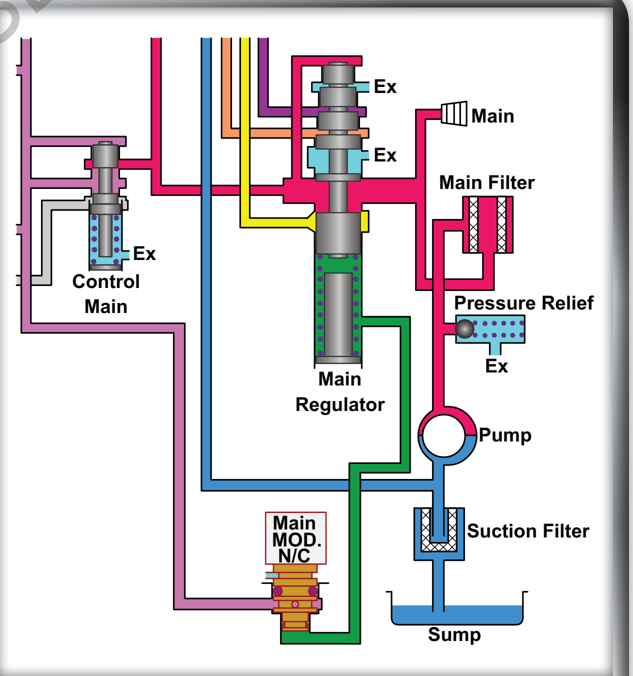


FIGURE 46-62 From 2010 model year onwards, a pulse-width-modulated main modulator solenoid, is used to have greater control over transmission main pressure by changing the pressure present at the MPRV.

Exhaust Backfill Valve

The exhaust backfill valve maintains a very low pressure in the exhaust passages for the clutch packs. This minimal pressure of 2 to 3 psi is not sufficient to apply or delay release of the clutches. Minimal pressure does, however, keep the cavity behind the clutch piston full of fluid to ensure quick response during shifts.

Accumulator Relay Valve

Recall from FIGURE 46-47, in the WTEC11- and WTEC 111-controlled transmissions, the accumulator relay valve delays activation of the C-3 pressure switch until the clutch apply pressure is high. Without the accumulator, the pulse-width-modulated apply signal would cause fluctuations in the apply pressure which, in turn, would cause the switch to turn on and off rapidly. As clutch pressure builds, the accumulator is moved in its bore until the center-drilled hole in the valve communicates apply pressure to the C-3 switch. The C-3 pressure switch informs the controller whether the C-3 clutch is engaged. That is, the C-3 pressure switch signals the controller whether the transmission is in reverse, third range, fifth range, or not.

The fourth-generation valve body does not use an accumulator relay valve. Instead, fourth-generation transmissions use a valve called the diagnostic valve to control the PS1 pressure switch. As was illustrated in FIGURE 46-59, the position of the diagnostic valve is controlled by the latch valves position. The PS1 switch relays information to the transmission controller regarding the position of the PCS2 solenoid when the vehicle is second, third, fourth, and fifth range. The PS1 switch also relays information the C-5 clutch is applied in reverse.

Allison Fifth Generation Electronic Control

In 2013, Allison introduced the Fifth Generation electronic control of the World Transmission. In terms of prognostics, there are very few physical differences between the fourth and fifth generations. In the fifth-generation controls, Allison mostly added sophistication and functionality to the transmission-control software. Another difference is that filter life is actually measured by pressure differential across the filter. As pressure builds in front of the filter, the PS-2, or pressure switch valve, moves to turn off the PS-2 switch. This makes the filter life prognostics much more accurate. Pulse-width modulation of the pressure control solenoids and the open-ended solenoid (OE) is controlled at a frequency between 12,000 and 19,000 hertz.

Fifth-generation transmission controllers are common across the Allison product line but offer different software versions depending on the vocation of the vehicle. The fifth-generation controllers include an integral **inclinometer/accelerometer** to allow further refinement of transmission shifting based on topography and operating conditions such as load and road grade. Fifth-generation controllers also have other software enhancements, such as greater control over programming in/out functions and the ability to integrate and control diverse optional equipment functionality.

Retarders

Allison World Transmissions can be equipped with an optional hydraulic output retarder. As shown in FIGURE 46-63, the output retarder is mounted at the rear of the transmission in place of the rear cover.

The **hydraulic retarder** is used as a supplement to the vehicle braking system and is completely electronically controlled. The use of a retarder can increase service brake life by more than double. In addition, having a retarder on a transmission can increase braking efficiency, especially on long grades where service-brake fade can be a serious issue. Hydraulic retarders help to minimize service-brake use and keep brake temperatures down. (Lower brake temperatures result in less fade). In some instances the retarder can handle 90% of the braking effort or more.

The retarder is an assembly consisting of the following component parts:

- The rotor, which is splined to the output shaft of the transmission

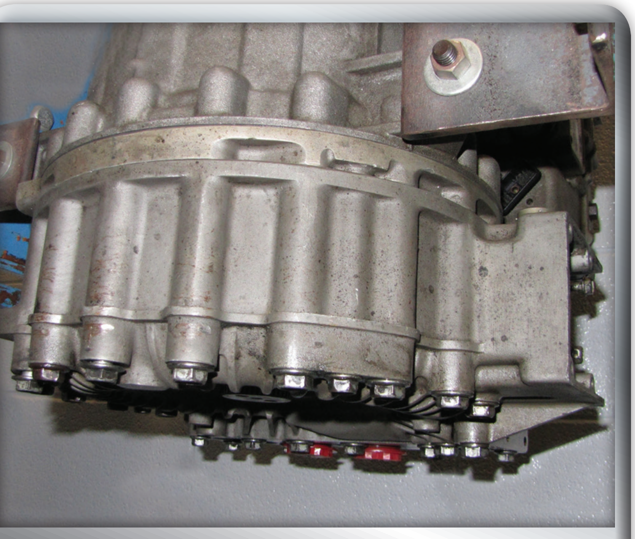


FIGURE 46-63 The retarder is part of the transmission output module.

- A stationary housing
- A retarder accumulator, which is maintained full of transmission fluid
- A control valve assembly

The rotor's cast-iron components include cupped vanes formed into each side face FIGURE 46-64. The rotor sits in the middle of the stationary housing, which also has cupped vanes on its inside surfaces. The cupped surfaces of the stationary housing, however, are in the opposite direction of those on the rotor. During normal driving, the space between the rotor and the stationary cupped vanes of the housing is empty.

In order to control retarder operations, the transmission controller receives inputs from a number of sources. The controller usually receives the vehicle speed directly from the vehicle speed sensor (VSS), which is mounted on the output module of the transmission. The controller also gathers information about the arrangement of braking from the vehicle CAN BUS. (The CAN BUS is the controller area network connection on the vehicle. All of the vehicle's electronic controllers are connected together through the CAN BUS and communicate with each other). The braking information or request can be generated from multiple sources:

- A lever operated by the driver
- A separate foot pedal not connected to the vehicle brake pedal
- A variable force switch connected to the foot pedal output
- An auto-retard schedule managed by the transmission controller
- A combination of the above

FIGURE 46-64 The hydraulic retarder consists of a vaned rotor splined to the transmission output shaft and two stationary vaned elements in the housing.

In addition to speed and braking information, the dash switch sends input to the controller retarder enable switch.

When retardation is required, the controller uses pulse-width modulation to control a solenoid which in turn controls the retarder inlet valve. This valve controls transmission fluid under pressure in the accumulator that is directed to the space between the rotor and the stationary vanes. Retarder capacity is directly related to the amount and pressure of the fluid in this space. The rotor drives the fluid against the stationary cupped vanes. The friction of the fluid causes the forward momentum of the vehicle to change into heat energy. The fluid is constantly replenished by the transmissions hydraulic circuit it flows through the retarder to the outlet and on to the transmission cooler.

By increasing fluid pressure, more energy can be absorbed, but the temperature of the fluid must be closely monitored. The transmission controller monitors brake request, retarder fluid temperature, transmission sump temperature, transmission range, and output shaft speed. If any parameter is out of range, the transmission controller will disable the retardation. Specifically, the controller stops retardation when output shaft speed approaches the vehicle's calibrated minimum 165 to 450 revolutions per minute (rpm) to provide a smooth transition to the service brakes only FIGURE 46-65. Hydraulic retarders are capable of retardation equivalent to 600 horsepower (447 kW)—and more.

Most OEM hydraulic retarders function in a similar fashion, but some include extra features. For example, retarders that include a friction braking feature use a multiple-disc hydraulic clutch inside the retarder to provide even more braking effort. Hydraulic retarders generate enormous amounts of heat, so the transmission heat exchanger system (cooler) and the engine cooling system must be in good working order for them to function correctly.

Prognostics

Since 2009, Allison fourth-generation controlled transmissions have come with an optional feature called **prognostics**, which can be enabled or disabled by the operator. Fifth-generation controllers even come standard with prognostics installed in the software. The prognostics feature is software programmed into the transmission TCM that monitors and alerts the operator when the transmission fluid or filter needs changing or when the transmission clutches need servicing. The transmission controller calculates the need for service through drive cycle data and by monitoring shifts in progress.

The prognostics are accessed through the two digit display on the shift selector and the driver is alerted by a wrench symbol or the service transmission light. If the

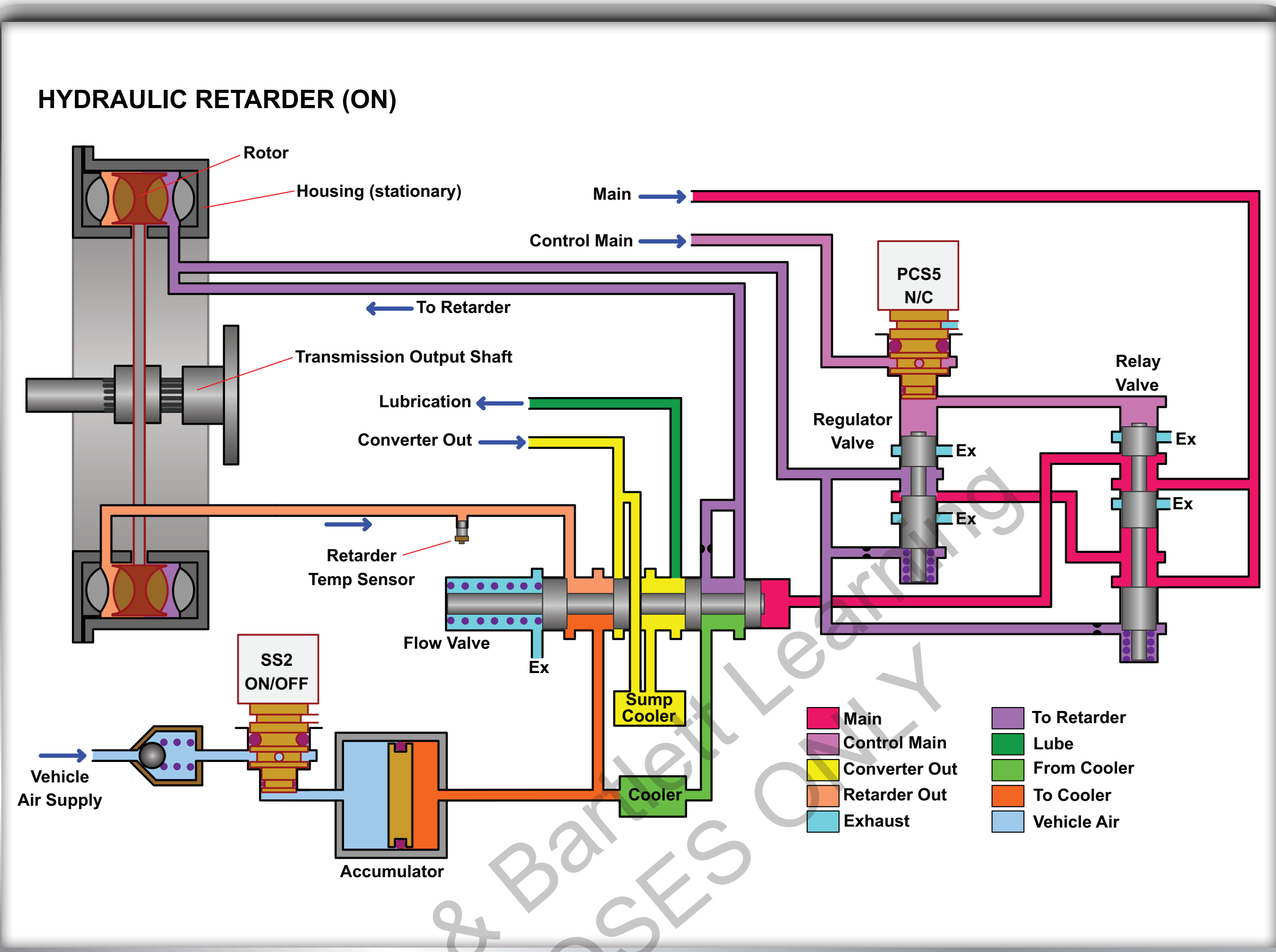


FIGURE 46-65 Retardation is controlled by filling the space the rotor occupies with transmission fluid under pressure.

wrench symbol or the service light illuminates for two minutes after drive is selected, that indicates an issue with the transmission fluid. If the wrench or the light flashes on and off for two minutes after drive is selected, it indicates an issue with the filter. Finally, if the wrench or light comes on and stays on in all ranges, it indicates that there is a problem with the transmission clutches. Understanding the warning lights allows the operator to schedule maintenance when required and before a problem gets worse.

Shift Selectors

World Transmission shift controllers perform a diagnostic function when a transmission diagnostic trouble code is set or when maintenance is required.

WTEC 11 and WTEC 111 transmissions have self-diagnostic capability only. When a problem is discovered, the transmission ECU will set a diagnostic trouble code (DTC). The codes can be accessed using the push button controller FIGURE 46-66A. To enter the diagnostic mode, press the up and down arrow buttons simultaneously with the key on but the engine off. The codes are set as a two-digit main code and a two-digit sub-code and are displayed in sequence on the two-digit selector display.

To display the codes for a transmission with a lever shift, press the diagnostic button (the button with the Allison logo) momentarily with key on but the engine off. If the transmission is fitted with an oil lever sensor, the oil level will be displayed first, as shown in FIGURE 46-66B.

After displaying the oL code to indicate “oil level,” the display will show an additional code. For example, the display will read oL/ok, if the oil level is good. If oil level is low, oL/Lo will be displayed, followed by a number to indicate how low the oil is. For example, oL/Lo/2 means the oil is low by 2 quarts. If the oil level is high, the display will show oL/Hi, followed by a number indicating how much excess oil is in the system. For example, a display reading of the following ‘oL’ then ‘Hi’ then ‘1’ indicates there is one excess quart of oil in the system. If the conditions are not correct to check the oil level, the display will flash oL, followed by a number, for example, 70, as shown in FIGURE 46-66C.

Each number indicates a specific issue needs to be addressed:

- X and a number between 1 and 8 indicate that the oil needs to settle for a longer period before the level can be displayed.
- 50 indicates that engine speed is too low.
- 59 indicates engine speed is too high.
- 65 indicates neutral is not selected.
- 70 indicates transmission oil temperature is too low.
- 79 indicates oil temperature is too high.
- 89 indicates that the output shaft is rotating the vehicle must be stopped.
- 95 indicates a failed sensor.

On vehicles equipped with an oil-level sensor, pushing the up and down button together twice will cause the display to enter the diagnostic mode. (On lever selectors, push the diagnostic button twice). Up to five codes can be stored, and the code for most recent issue will be flashed out in the following format: d1, followed by two digits followed by two more digits. For example d1,25,11 FIGURE 46-66D.

The system will repeat the first code again and again. To switch to the second code, momentarily push the mode button. The second code will be flashed out in the same format. During the diagnostic procedure, the LED in the mode button will light if the code is active. Active codes indicate an issue happening with the transmission at that actual moment. If the code is inactive (historic), the LED will not be lit. Record all codes. Any of the five code positions that does not have a stored code will flash "—". From the fifth code position, pushing the mode button momentarily will return the display to the first code position again.

The following is an example of two codes after entering the diagnostic mode code "d1," "13," "12," and "d2," "21," "12" are displayed. Code 13 indicates a problem with the ECU and 12 indicates low voltage. Code 21 12, 21 indicates a problem with the TPS and 12 again indicates low voltage. There are well over 100 diagnostic codes and sub-codes that can be displayed, and the troubleshooting manual will guide the technician in the proper diagnostic routine to correct the problem.

Clearing Codes on WTEC II and III

Disconnecting the TCM power will clear all active code indicators and keep them in the code queue as inactive. Code indicators can be removed manually. While in the diagnostic mode, push and hold the mode button for three seconds until the mode LED flashes. That indicates that all active indicators are removed. Inactive codes can also be removed. While still in the diagnostic mode, press and hold the mode button again for 10 seconds until it

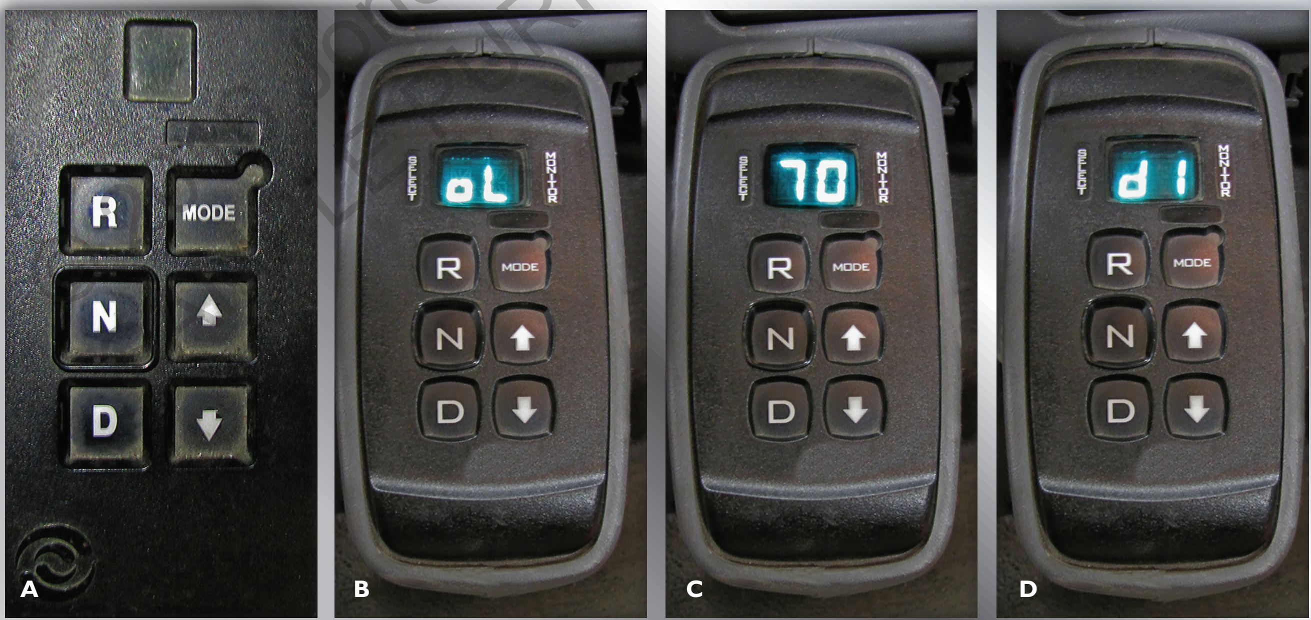


FIGURE 46-66 **A.** Older WTEC II and III controller. **B.** oL indicates oil level is being shown. **C.** Code number (70 indicates that transmission oil temperature is too low to read the oil level). **D.** Display shows first of five code positions: d1, d2, d3, d4, d5.

flashes again. All inactive indicators will be cleared when the TCM is powered down.

To exit the diagnostic mode on a push-button shifter, press any range button. On lever-type selectors, push the diagnostic button once, or move the lever to any other position.

The fourth- and fifth-generation control systems use SAE J-2012 codes that are OBD 11 (on-board diagnostics) compliant. These codes contain one letter followed by four digits. Codes can be read from the Allison shift selector, with an aftermarket diagnostic reader, or using the Allison DOC software along with a computer.

The letter in a J-2012 code signifies the general component or system.

- B = Body systems
- C = Chassis systems
- P = Power train systems
- U = Network systems

The first digit after the letter code indicates DTC groupings.

- 0 = SAE/ISO controlled
- 1 = Manufacturer controlled
- 2 = SAE/ISO controlled in powertrain manufacturer controlled in any other system
- 3 = Reserved for SAE/ISO or manufacturer controlled

The second digit after a powertrain DTC refers to which system is affected. For example, 7, 8, and 9 indicate transmission issues. Some examples include P-07XX, P-08XX, and P-09XX. The XX will be the actual two-digit fault code. P-00XX, P-01XX, and P-02XX pertain to the fuel system. P-03XX is ignition systems.

The fourth-generation Allison shift selectors have a two-digit display similar to the WTEC 11 and WTEC 111, and the codes are accessed in the same way in all three models. To read the fourth-generation diagnostic codes, turn the key on, but keep the engine off. Push the up and down arrows together twice or the diagnostic button twice on lever shifters.

The order in which the codes appear is dictated by the recency of the problem (more recent troubles are indicated first). The first code to be displayed will be the position of the code (d1). The last code set will always be d1 and will be followed by a single letter (c, p, or u) and then by a sequence of two two-digit codes. For example, d1, followed by p, followed by 07, followed by 27 tells us the following information: first code position d1 is code p0727; the "p" indicates an issue with the powertrain. Code p0727 means engine speed sensor input to the transmission no signal.

To determine if a second code is present, push the mode button momentarily. You can toggle through up to five codes before the display returns to the first code. To clear the codes on a fourth generation system, press and hold the mode button for ten seconds while in diagnostic mode. This clears both active and inactive codes. Before clearing codes, always record them for future reference.

TABLE 46-9 contains a few of the fourth-generation WT control DTCs. It is by no means a comprehensive list, as there well over a hundred DTCs that can be set. Always consult the OEM manual for troubleshooting.

TABLE 46-9: Main Pressure and Lube Pressure for Each Gear

Diagnostic Code	Code Indicator
P063F	Auto Configuration Engine Coolant Temp Input Not Present
P0658	Actuator Supply Voltage 1 Low
P0659	Actuator Supply Voltage 1 High
P0701	Transmission Control System Performance
P0702	Transmission Control System Electrical
P0703	Brake Switch Circuit Malfunction
P0708	Transmission Range Sensor Circuit High Input
P070C	Transmission Fluid Level Sensor Circuit—Low Input
P070D	Transmission Fluid Level Sensor Circuit—High Input
P0711	Transmission Fluid Temperature Sensor Circuit Performance
P0712	Transmission Fluid Temperature Sensor Circuit Low Input
P0713	Transmission Fluid Temperature Sensor Circuit High Input
P0716	Turbine Speed Sensor Circuit Performance
P0717	Turbine Speed Sensor Circuit No Signal
P0719	Brake Switch ABS Input Low
P071D	General Purpose Input Fault
P0721	Output Speed Sensor Circuit Performance
P0722	Output Speed Sensor Circuit No Signal
P0726	Engine Speed Sensor Circuit Performance
P0727	Engine Speed Sensor Circuit No Signal

A high-quality or factory scan tool can be an invaluable asset while diagnosing an electronically controlled transmission. A generic scan tool can read codes, but a factory scan tool can also view live data from the sensors and actuators inside the transmission. To scan the TCM, follow the guidelines in SKILL DRILL 46-1.

To inspect, adjust, repair or replace electronic shift controls, electronic control unit, wiring harnesses, sensors, control module, vehicle interface module, and related components, follow the guidelines in SKILL DRILL 46-2.

Post-2009 Fourth-Generation Transmission Controls with Prognostics

The process for reading the codes is slightly different when the vehicle is equipped with fourth-generation controls and prognostic are enabled. On vehicles equipped with prognostics, a small wrench icon will momentarily be displayed between the two digits on the fourth-generation shift selector when the vehicle is started. The wrench icon should then go out. If, however, the icon remains illuminated, it indicates that maintenance is required. When the oil should be changed the wrench will illuminate for two minutes after drive range is selected and then go out. When the filter is due for a change the wrench icon will flash on and off for two minutes after drive range is selected and then go out. When clutch maintenance is required the wrench icon will come on and remain on for the entire operating time of the vehicle.

The shift controller can access the oil level, prognostic features, and the diagnostic codes by following this procedure. All of these actions are done with Key On and Engine Off with the vehicle stopped. Push the up and down arrows together once on a push type lever or the Allison diagnostic button once on a lever shifter; the display will show the oil level. Pushing the button twice displays the remaining oil life with the oM code followed by a number from 0 to 99. The number indicates the percentage oil life remaining.

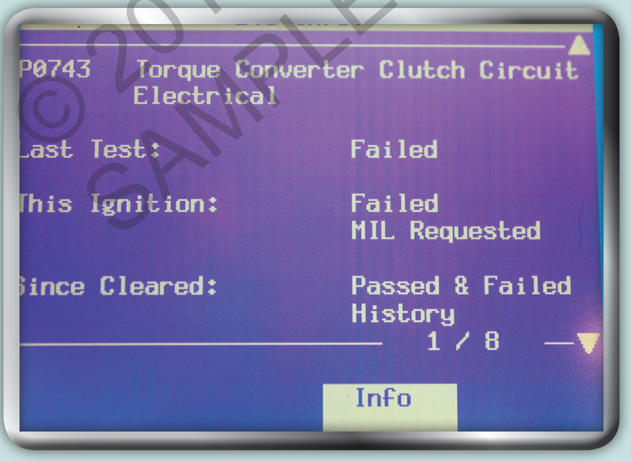
Pushing the buttons three times puts the display into filter life mode. The display will then show FM followed by either "oK" if the filter is good or "Lo" if the filter should be changed.

Pushing the buttons four times puts the system into clutch life, or transmission maintenance, mode. If internal transmission maintenance is required, the display will read TM followed by either "oK" or "Lo."

While the display is in oil-life-monitor mode, pushing the mode button for ten seconds will reset that monitor. (The same is true when the display is in filter-life-monitor mode). The oil life monitor will reset to 99 and the filter monitor will reset to "oK." Note that, after model year 2010, the oil filter is monitored by pressure differential, so the filter life monitor will go back to "Lo" if the filter is clogged.

To access the diagnostic codes on fourth-generation systems with prognostics, press the up and down buttons

SKILL DRILL 46-1 Scanning the TCM



1. Install a scan tool onto the vehicle's data link connector (DLC). For the location of the DLC, consult the service information.
2. Retrieve any diagnostic trouble codes (DTCs) from the vehicle. Record the codes.
3. Using the service information, research the diagnostic procedure for any codes found.
4. If there are multiple codes, evaluate the service information to see if codes are related to each other.
5. Follow the diagnostic procedure step by step until you have completed the diagnostic procedure and found the cause of the DTC.
6. Consult with the customer before completing any repair.

five times together on the push button selector. For level selectors, push the diagnostic button five times. The diagnostic codes will be displayed in the same format as for fourth-generation systems without prognostics described previously. To clear codes while in the diagnostic mode, push and hold the mode button for ten seconds. That clears both active and inactive codes. Be sure to record all of the codes before clearing them.

Fifth-Generation Shift Selectors

The fifth-generation Allison shift selectors are capable of displaying two digits for gear selection. These selectors also have multi-character graphic-display capabilities. That means that fifth-generation shift selectors can display prognostic information, full codes, and code descriptions, making it easier for technicians to diagnosis problems.

The process for using the shift selector to check transmission function is essentially the same as for the fourth generation with prognostics. Press the up and down arrows together on a push button selector (or push the diagnostic button once) to obtain information about transmission oil level. Push twice for the oil-life monitor, three times for the filter-life monitor, and four times for the transmission-life monitor. Although the basic process

SKILL DRILL 46-2 Inspecting, Adjusting, Repairing or Replacing Electronic Shift Controls, Electronic Control Unit, Wiring Harnesses, Sensors, Control Module, Vehicle Interface Module, and Related Components

1. Locate and follow the appropriate procedure in the service manual.
2. Complete a job sheet or work order with all pertinent information.
3. Move vehicle into workshop, apply parking brakes and chock the vehicle wheels. Observe lockout/tagout procedures.
4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral". Note: Some vehicles with automatic transmissions do not have "park".
5. Test operation and retrieve diagnostic codes as outlined in the service manual.
6. Use service manual procedures to inspect and repair or replace external/internal wiring harnesses.
7. Use service manual procedures to test, repair or replace the following components:
   - **a.** Electronic control unit (ECU)
   - **b.** Vehicle interface module (VIM)
   - **c.** Vehicle interface wiring (VIW)
   - **d.** Engine speed sensor
   - **e.** Turbine speed sensor
   - **f.** Output speed sensor
   - **g.** Throttle position sensor
   - **h.** Control module
8. Use service manual procedures to test, repair, or replace electronic shift selector(s).
9. List the test results and/or recommendations on the job sheet or work order, clean the work area, and return tools and materials to proper storage.

is the same, however, what the technician will see on the fifth-generation shift selector is more sophisticated. The fifth-generation selector will display a message rather than a simple code. For example, TRANS OIL 3 QUARTS HI, or, TRANS OIL LEVEL OK **FIGURE 46-67**.

To access diagnostic codes, push the buttons once. The display will cycle through showing the oil level function, followed by prognostics, followed by the diagnostic codes. The display will show both the code and whether it is active or not, for example, P0730 ACTIVE.

Resetting the maintenance flags and the codes is the same procedure as for the fourth generation with prognostics described previously.

Allison introduced a comprehensive dedicated diagnostic software package in 2002 called Allison DOC **FIGURE 46-68**. The software is capable of diagnosing faults and monitoring transmission operation and adaptations. Allison DOC software version 12.0 is the current package available from authorized Allison dealers. The software enables technicians to diagnose transmission operation and record operational data for all of Allison's electronically controlled transmissions— from the ATEC/CEC through all versions of the World Transmission— and is also capable of diagnosing the Allison TC-10-TS. As described in the next section, the Allison TC-10-TS is a ten-speed, twin-countershaft, fully automatic transmission designed for on-highway Class 8 tractors. Allison has offices all over the world and hundreds of qualified dealers in North America.

TC-10-TS

In late 2012, Allison released a new transmission model called the TC-10-TS, which stands for twin-countershaft (TC), ten-speed (10), tractor series (TS) **FIGURE 46-69A**. The TC-10-TS employs the blended architecture of a traditional, twin-countershaft main box, a planetary two-speed range section, and electronically controlled hydraulic clutches for shifting. With ten forward speeds and two reverse speeds, plus the comfort and ease of

FIGURE 46-67 Fifth-generation shift selectors have a graphical display capable of displaying a message rather than a simple code.

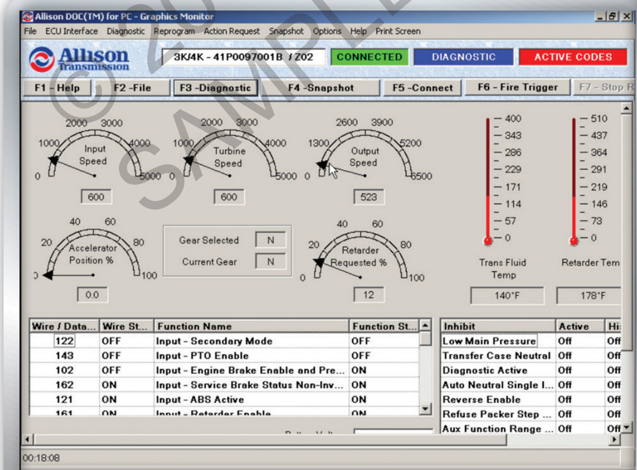
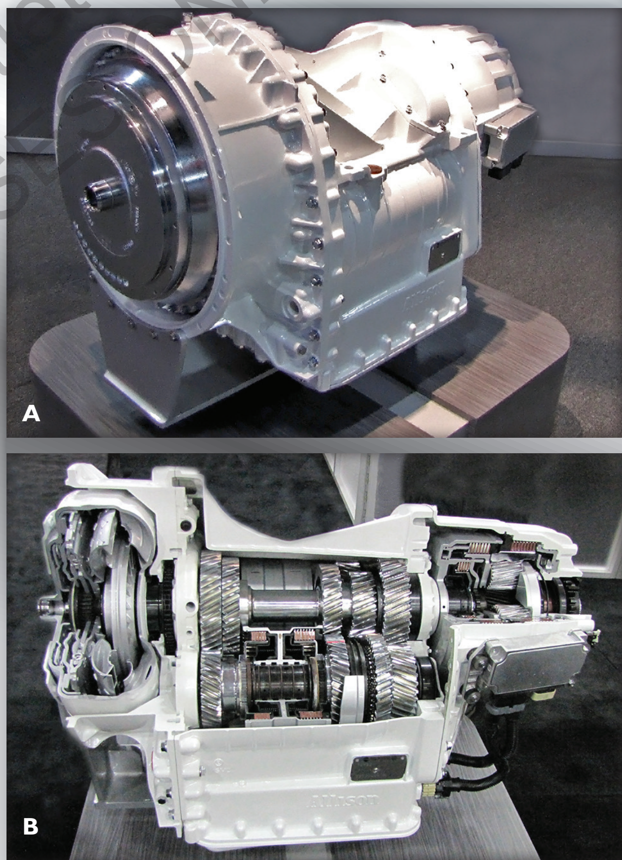


FIGURE 46-68 Screen from Allison DOC diagnostic software.



© Allison Transmission

FIGURE 46-69 **A.** The Allison TC-10 TS is specifically targeted at the Class 8 on highway tractor market. **B.** The TC-10 has two countershafts, only one of which is used for any particular range.

operation of an automatic transmission, this unit was designed to carve out a niche in the Class 8 on-highway tractor market. To date, sales of this unit have been relatively low, and it seems to appeal mainly to the markets using less-than-truck-load and around-town delivery vehicles. At the moment only Navistar (International), currently offers the TC-10-TS as an option in its trucks.

The TC-10-TS model is a completely new design that incorporates the following features:

- Torque converter input module with lock-up clutch
- Twin countershaft five-speed main gear box with five wet clutches FIGURE 46-69B
- A two-speed planetary range rear section controlled by two additional wet clutches

As shown in FIGURE 46-70, the TC-10-TS has five wet clutches in the main box. With a clutch for every gear, shifting takes place under power with no efficiency losses required when torque is broken to make a shift. The power is reduced slightly during shifts to soften the shift and, unlike in automated manual transmissions, it is unnecessary to completely break torque for a shift to occur.

Allison has historically made transmissions for use in Class 8 on-highway tractors, but the TC-10-TS is the first Allison transmission targeted specifically to the on-highway tractor market. After conducting extensive field testing of the TC-10, Allison claims the transmission can produce a 3% to 5% better fuel economy than current automated manual transmissions. Acceleration is also improved with the TC-10-TS because the transmission's clutches are basically handing off power from one to another. Under power during fleet testing, this transmission produces 20% faster acceleration. Plus, the transmission controller is adaptive. The shift can be tailored to the load and the terrain without driver input, further improving fuel economy. The TC-10-TS is available for engines with up to 600 horsepower (447 kW) and 1,700 foot-pounds (2,304 Nm) of torque. (The company states the TC-10-TS transmission is capable of handling 1,850 foot-pounds (2,508 Nm) of torque, but for now it recommends a maximum torque

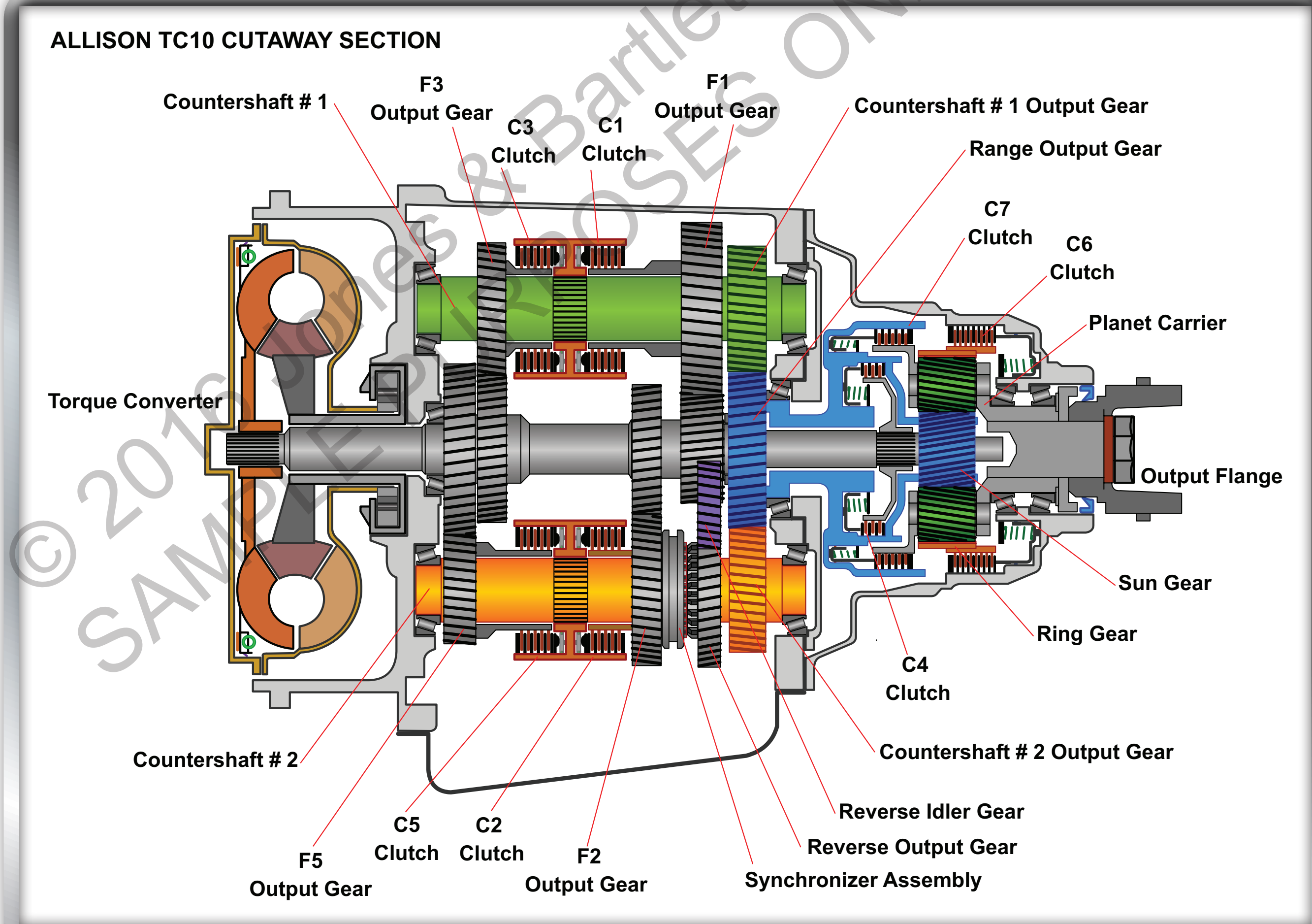


FIGURE 46-70 Cutaway schematic of the TC-10 transmission.

of 1,700 foot-pounds (2,304 Nm)). TABLE 46-10 shows the TC-10-TS clutch application.

TC-10-TS Powerflows

TC-10-TS Neutral

In neutral, the C-6 clutch is applied and holds the ring gear of the planetary gear set stationary and the synchronizer is rearward. The input shaft only will rotate with the torque converter turbine FIGURE 46-71.

TC-10-TS First Range

As shown in FIGURE 46-72, in first range, the C-1 clutch applies, and the synchronizer moves forward. C-1 clutch locks the F-1 output gear to the right-side counter shaft, and the synchro position unlocks the reverse gear. Power flows from the input shaft to the right-side countershaft through C-1. Then power flows back to the range output gear through the right-side countershaft output gear. The range output gear turns the sun gear of the planetary range section. C-6 is holding the ring gear, so the range carrier is output. That means the range planetary gear set is in low range.

TC-10-TS Second Range

The powerflow for second is the same as first with the exception that C-1 is released and C-2 is applied FIGURE 46-73. C-2 locks the F2 output gear to the left-side counter shaft through the synchronizer, which is in the forward position. Note that the C-2 clutch can connect either the reverse output gear or F-2 output gear to the left-side countershaft depending on the position of the synchronizer. If the synchronizer is forward, the F-2 gear is connected by C-2. If the synchronizer is rearward, then the reverse gear is connected to the countershaft. In the second range, power is delivered to the range output gear through the left countershaft from the F-2 output gear. C-6 is still applied and holding the ring gear of the planetary range gear set. The planetary gear set, therefore, remains the same as for first gear—in low range.

TC-10-TS Third Range

In third range, the powerflow switches back to the right-side countershaft FIGURE 46-74. C-2 is released, and C-3 is applied. That brings power from the input shaft to the range output gear through the F-3 output gear at the front of the right countershaft. Again, the planetary range section remains the same.

TC-10-TS Fourth Range

In fourth range, the countershafts are not used FIGURE 46-75. C-3 clutch is released and C-4 clutch is applied. Rotational power is brought directly from the input shaft to the sun gear in the planetary range section.

TABLE 46-10: TC-10 Clutch Application Chart

RANGE	RATIO	STEP	C1	C2	C3	C4	C5	C6	C7	SF*	SR*
N	-	-						X			X
1	7.40	-	X					X		X	
2	5.44	1.36		X				X		X	
3	4.25	1.28			X			X		X	
4	3.43	1.24				X		X		X	
5	2.94	1.17					X	X		X	
6	2.16	1.36	X						X	X	
7	1.59	1.36		X					X	X	
8	1.24	1.28			X				X	X	
9	1.00	1.24				X			X	X	
10	0.86	1.17					X		X	X	
R1	6.71	-		X				X			X
R2	1.96	-		X					X		X

* The SF and SR categories refer to the synchronizer forward or rearward.

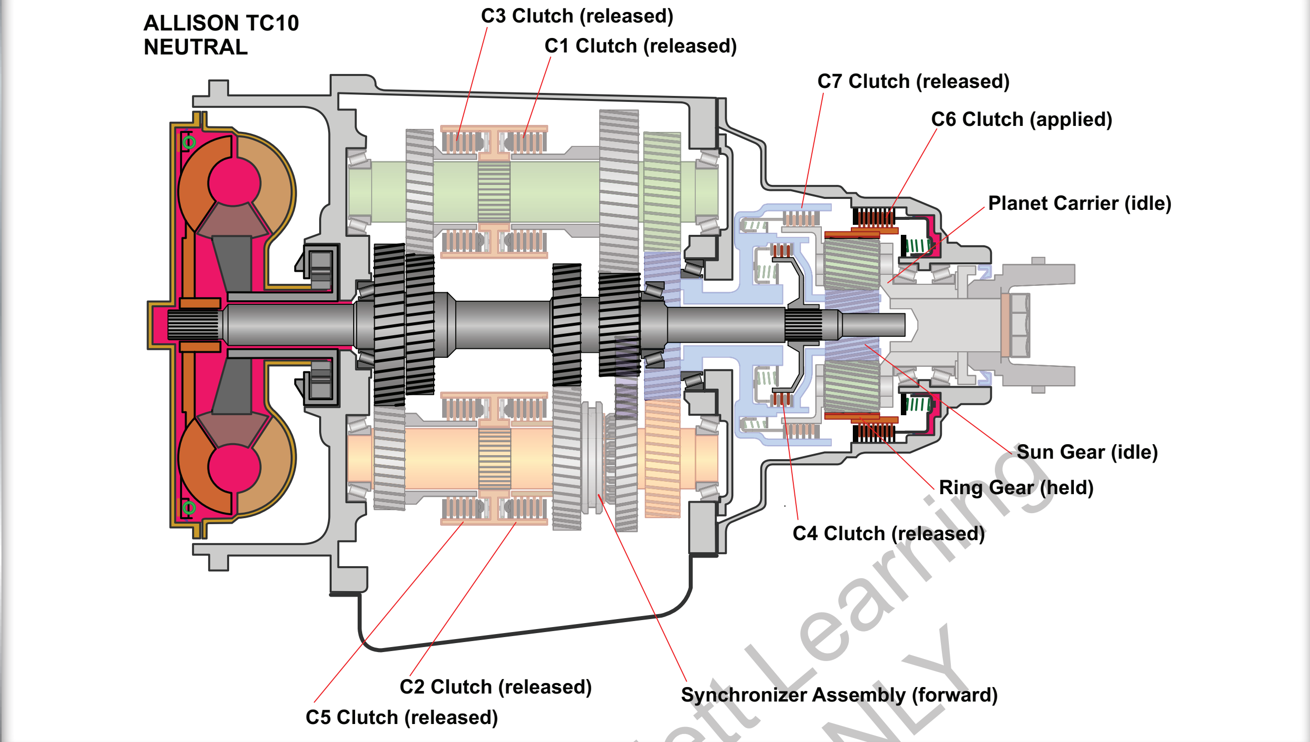


FIGURE 46-71 In neutral, no power is transmitted beyond the input shaft.

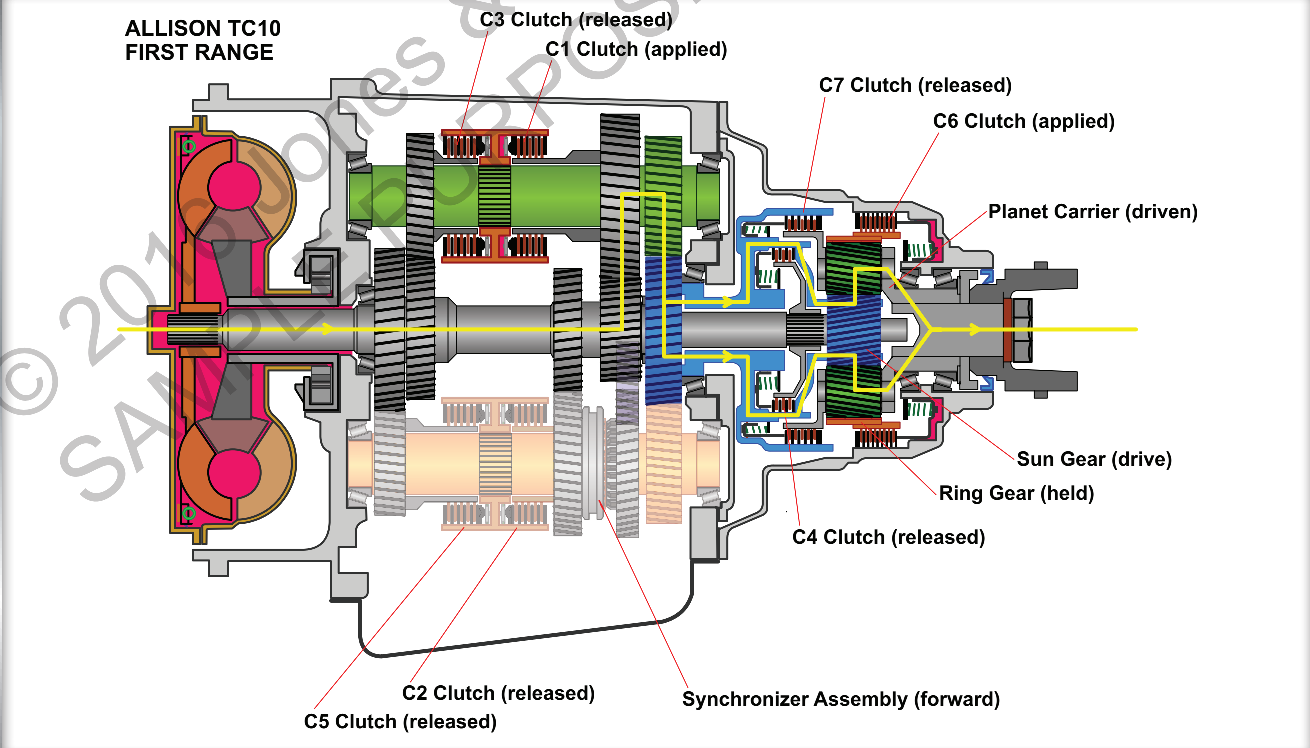


FIGURE 46-72 First range.

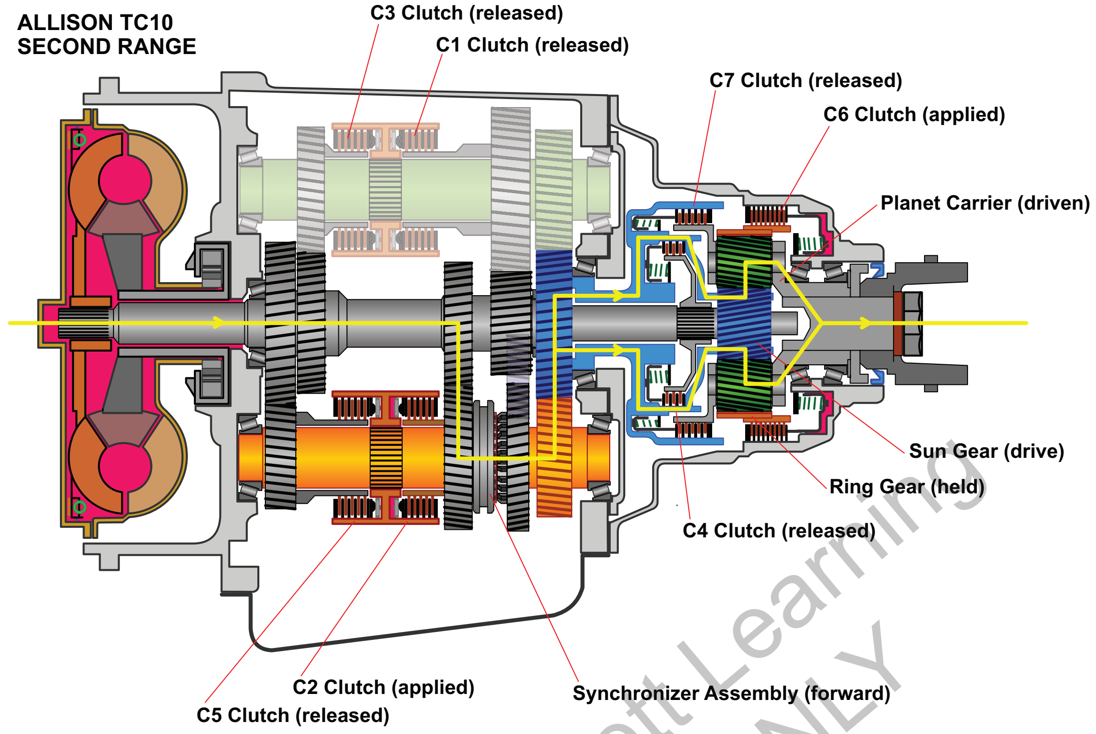


FIGURE 46-73 Second range.

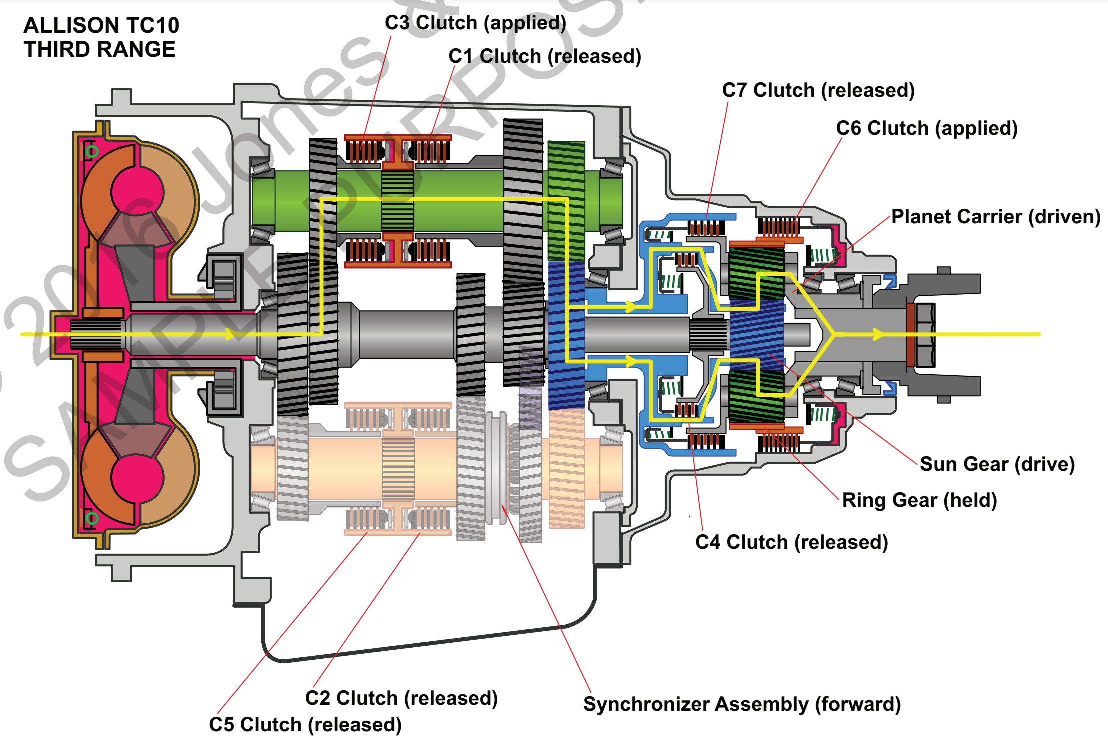


FIGURE 46-74 Third range.

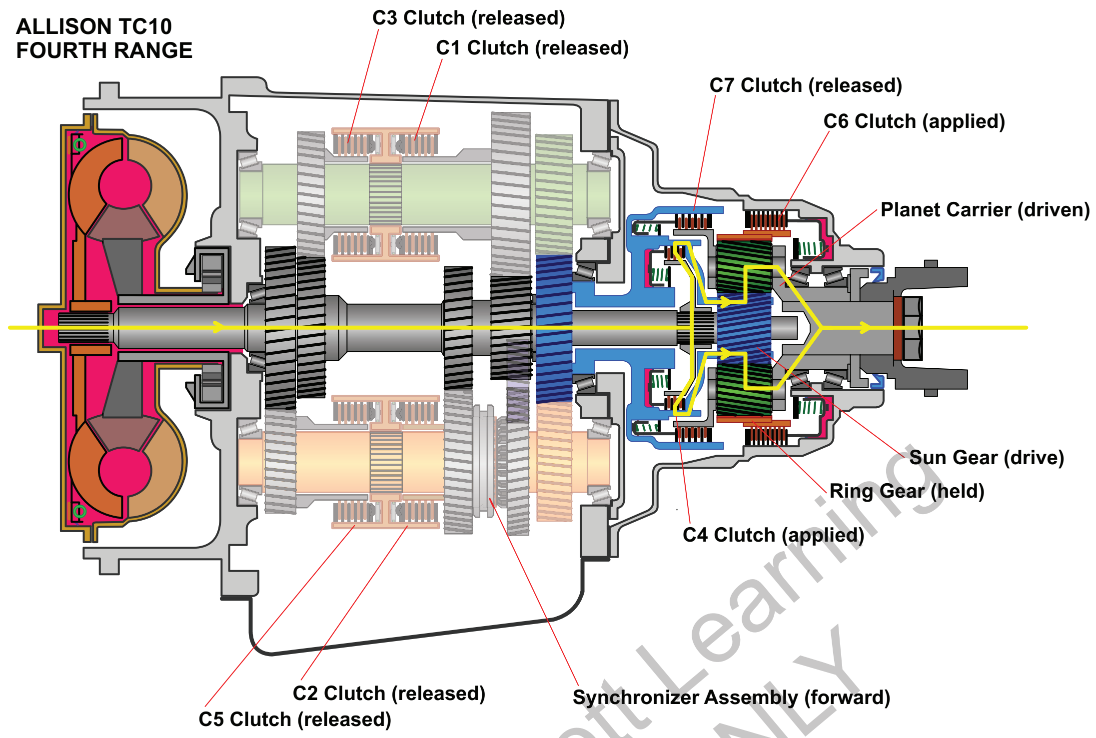


FIGURE 46-75 Fourth range.

C-6 is still holding the planetary range section ring gear, and the range planetary carrier remains the output.

TC-10-TS Fifth Range

In fifth range, C-4 is released, C-5 is applied, and C-6 remains applied. C-5 locks the F-5 output gear to the left-side countershaft. Power flows from the input shaft to the left-side countershaft through F-5 and then to the range output gear. The planetary range section remains unchanged, and the planetary carrier is still the output FIGURE 46-76.

TC-10-TS Sixth Range

In sixth range, the planetary range section changes to high range or direct (straight through operation). C-6 is released, and C-7 is applied. C-7 will remain applied for ranges six through ten. C-6 releases the planetary ring gear, and C-7 locks the planetary carrier to the range output gear and, therefore, to the planetary sun gear. This causes all three members of the range planetary to lock together and turn as one unit FIGURE 46-77.

For ranges six through ten, the first five powerflows are repeated with one important exception. Instead of being reduced through the planetary range section, powerflows pass straight through it unchanged. In the sixth range, then, C-1 is applied and locks the F-1 output gear to the right-side countershaft. Power flows from the input shaft through F-1 and back to the range output gear. From there, power flows directly to the output shaft through the locked together range planetary gear set.

TC-10-TS Seventh Range

In seventh range, C-7 remains applied, C-1 is released, and C-2 is applied. That sequence locks the F-2 output gear to the left-side countershaft through the synchronizer, which is in the forward position. Power flows from the input shaft to the left-side countershaft through F-2 and then to the range output gear. From there, power flows directly to the output shaft through the locked together range planetary set FIGURE 46-78.

TC-10-TS Eighth Range

In eighth range, C-7 is still applied, C-2 is released, and C-3 applies. C-3 locks the F-3 output gear to the right-side counter shaft. Power flows from the input shaft through F-3 to the range output gear and, from there, directly to the output shaft through the range planetary gear set which is locked together FIGURE 46-79.

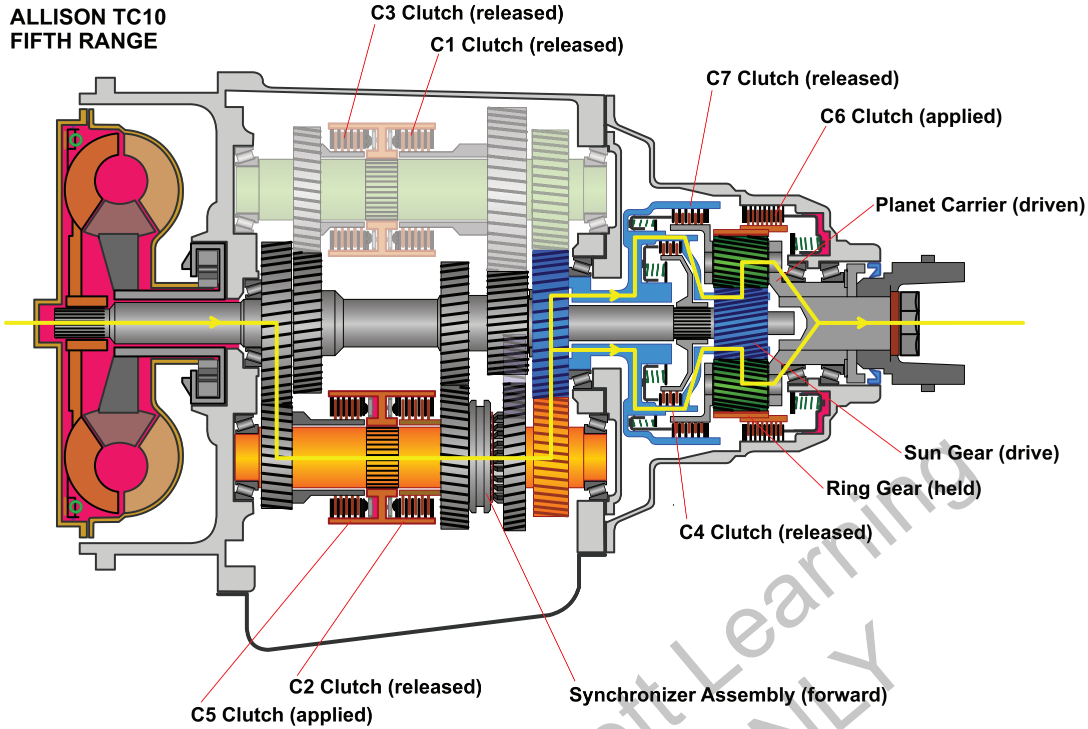


FIGURE 46-76 Fifth range.

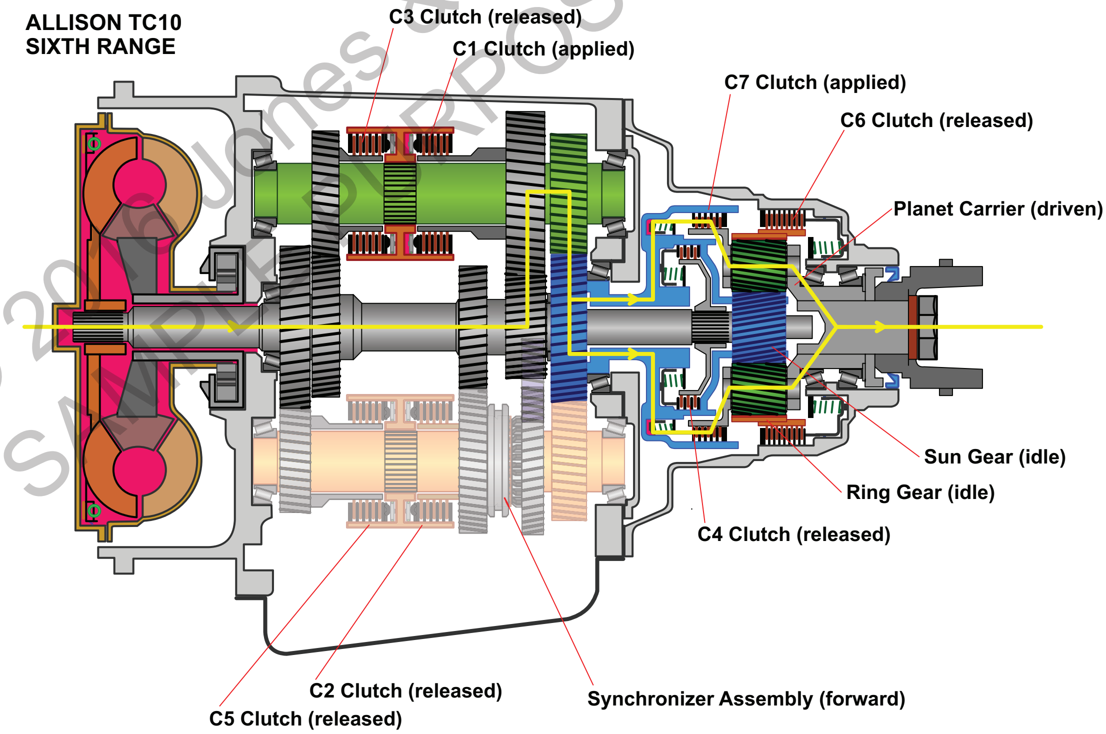


FIGURE 46-77 Sixth range.

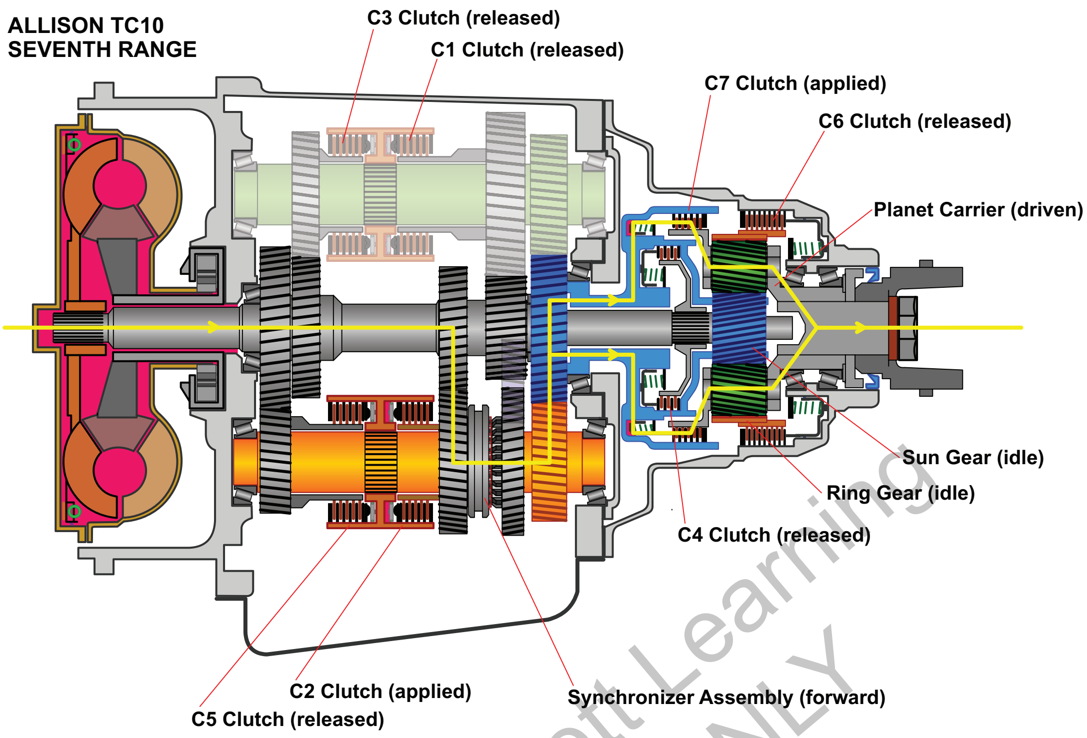


FIGURE 46-78 Seventh range.

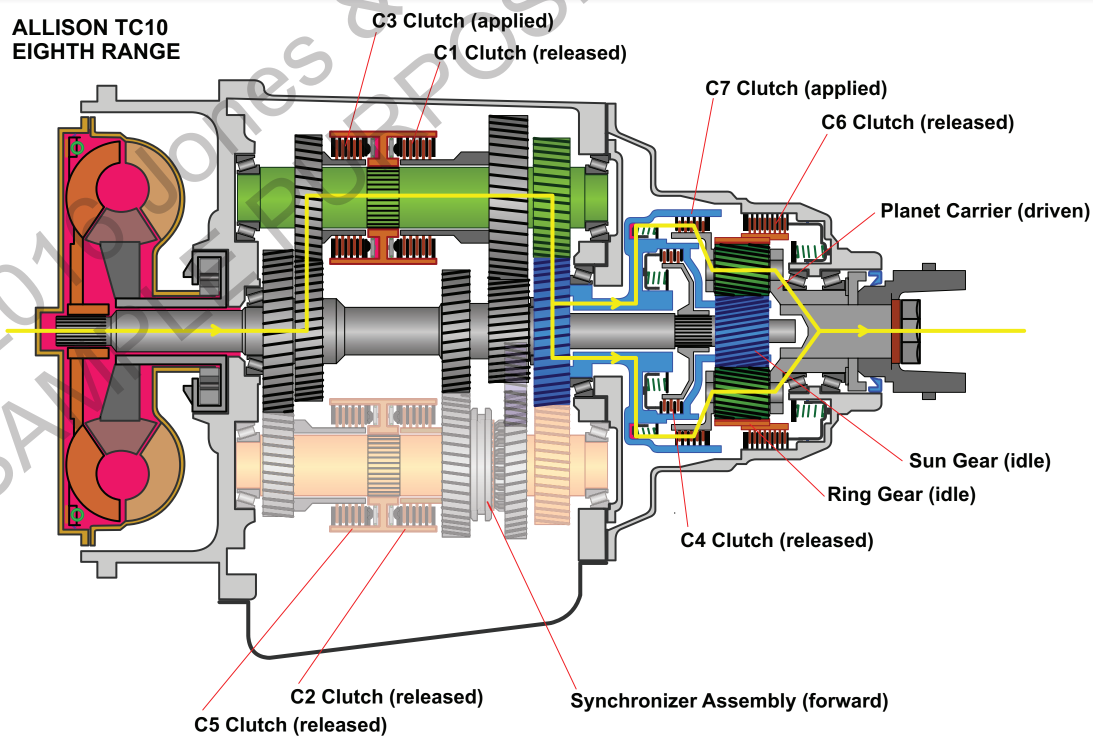


FIGURE 46-79 Eighth range.

TC-10-TS Ninth Range

In the TC-10-TS, ninth range is direct. That means that power flows straight through from the engine to the output shaft. In ninth range, C-3 is released, and C-4 is applied. The counter shafts are not used as in fourth range. C-4 locks the input shaft to the sun gear of the range planetary. C-7 is still applied, so the carrier of the range planetary is also locked to the sun gear. As a result, the planetary gear set turns as one unit, and power passes straight through from the input shaft to the output shaft FIGURE 46-80.

TC-10-TS Tenth Range

Tenth range is an overdrive range in the TC-10-TS. In tenth, C-4 is released, and C-5 applies. C-7 remains applied. C-5 locks the F-5 output gear to the left-side countershaft. Power flows from the input shaft to the left-side countershaft through F-5 and then to the range output gear. From the range output gear, power flows directly to the output shaft through the locked together planetary range section FIGURE 46-81.

TC-10-TS Reverse

The TC-10-TS has two reverse ranges: one low range and one high range. In reverse low, C-6 and C-2 are applied, and the synchronizer is rearward. C-6 holds the ring gear of the planetary range section. Because the synchronizer is in the rearward position, C-2 locks the reverse output gear to the left-side countershaft. Power then flows from the input shaft to the reverse idler gear. Power continues to flow to the reverse output gear and the left-side countershaft. From there, power flows to the range output gear to the sun gear of the planetary range gear set. C-6 is holding the ring gear of the range planetary, so the range planetary carrier is the final output and is connected to the output shaft FIGURE 46-82.

In reverse high range, the powerflow is exactly the same as for reverse low range except that C-6 is released and C-7 applies. C-7 locks the range planetary carrier to the range planetary sun gear. The three members of the planetary are locked together, so reverse gear moves into high range (or direct). Power flows straight through the planetary gear set unchanged. C-2 is still applied, and the synchronizer is still in the rearward position. C-2 still locks the reverse output gear to the left-side countershaft. Power flows from the input shaft through the reverse idler to the reverse output gear to the left countershaft. From there, it flows to the planetary range sun gear through the range output gear. Because the range planetary is locked together, however, power flows from there directly to the output shaft FIGURE 46-83.

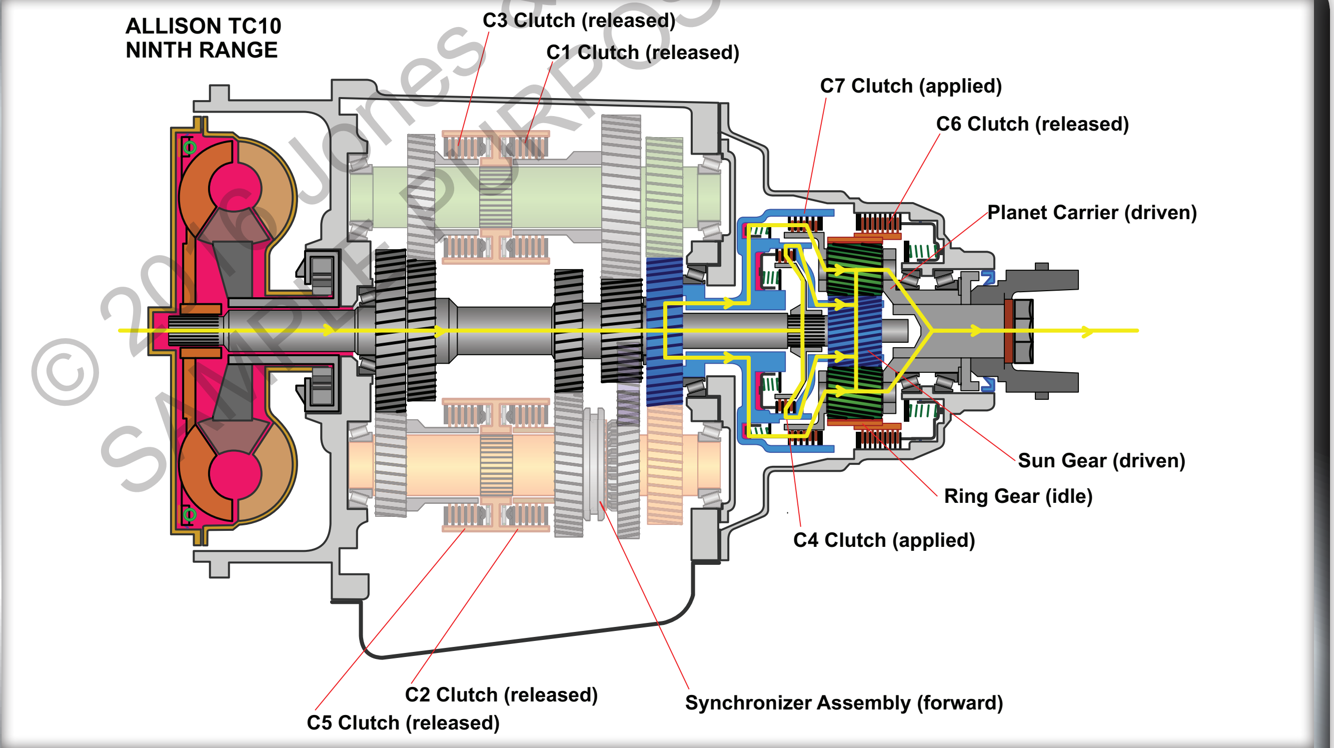


FIGURE 46-80 Ninth range.

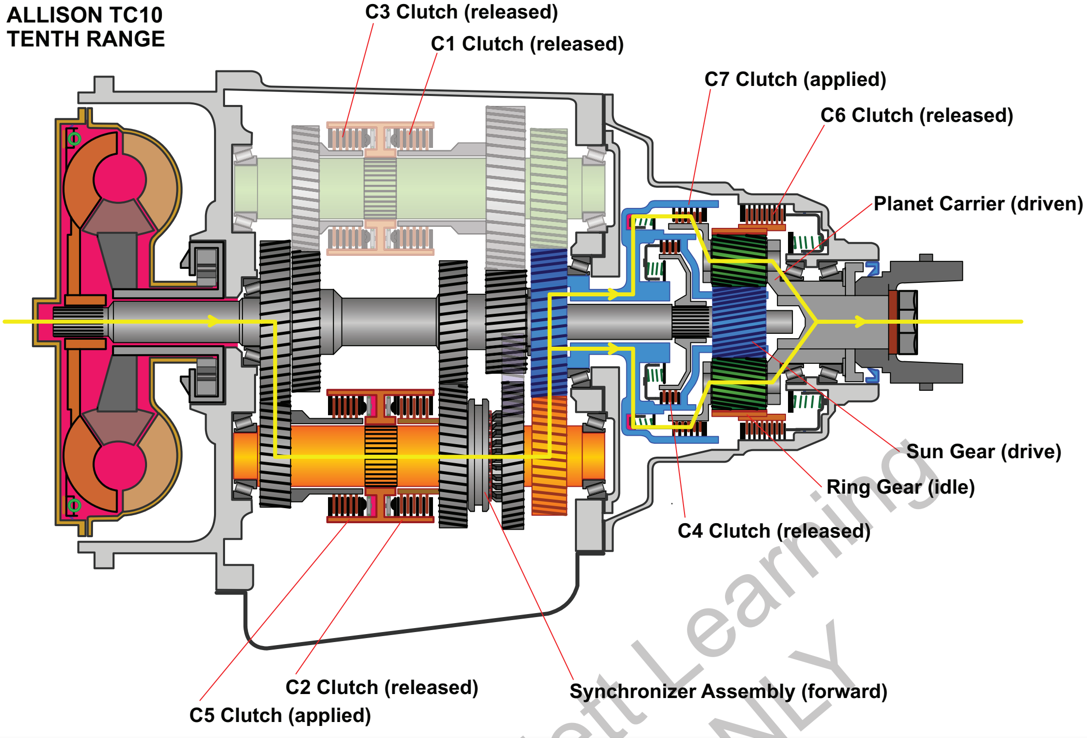


FIGURE 46-81 Tenth range.

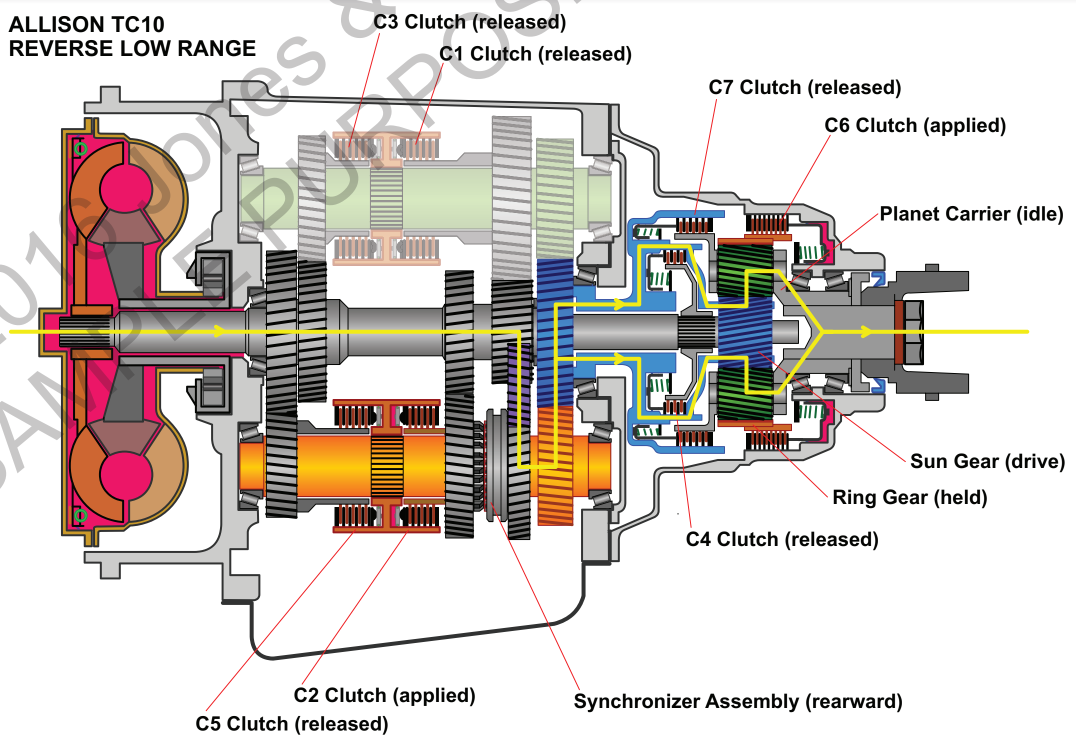


FIGURE 46-82 Reverse 1, also called reverse low range.

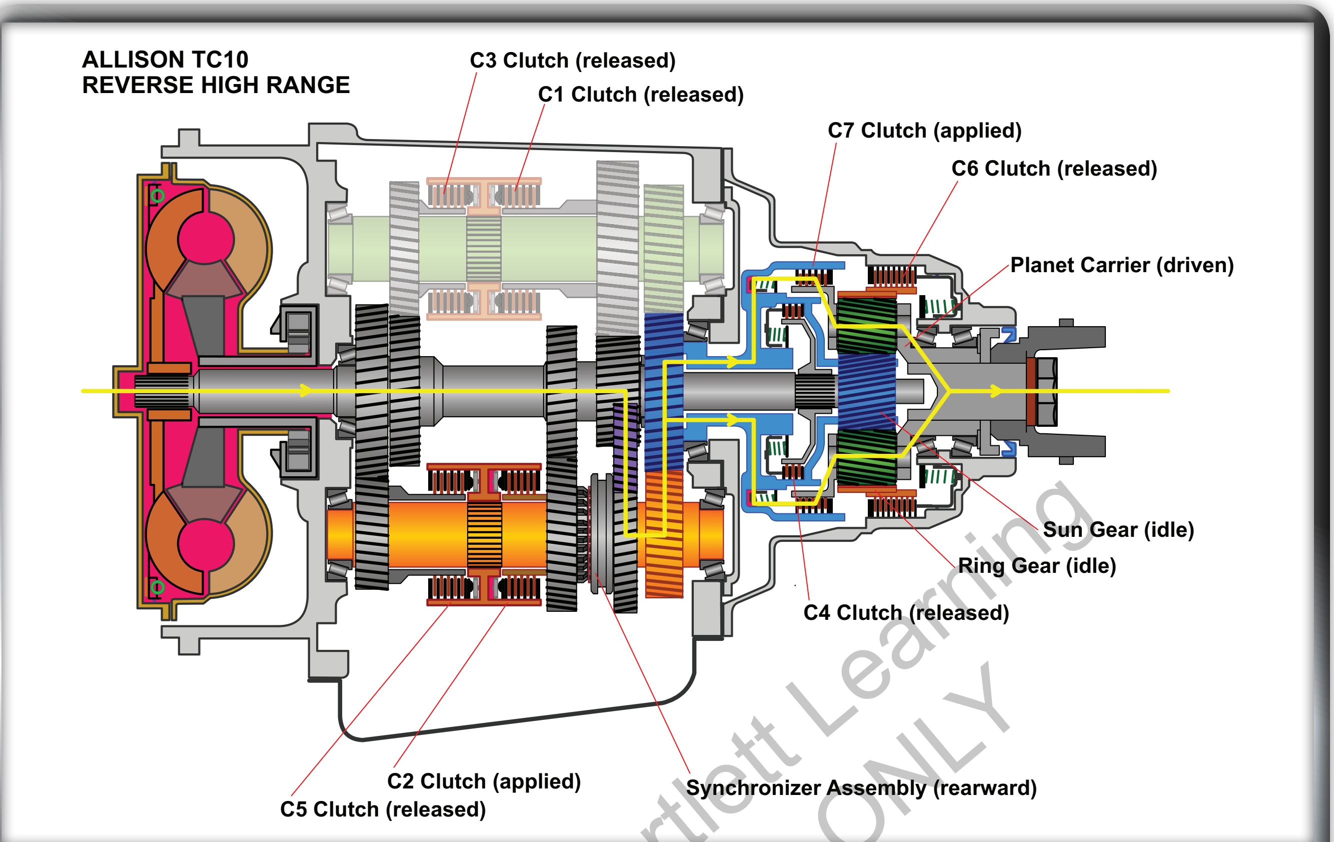


FIGURE 46-83 Reverse 2, also called reverse high range.

Voith DIWA Transmissions

The Voith Turbo Company makes transmission systems for a variety of applications worldwide. Its systems are in use in rail, marine, and trucking applications. The transit bus market, however, is the company's largest market for transmissions in terms of numbers. The Voith DIWA transmission is used in over 200,000 buses and coaches worldwide and increasingly in North America.

This transmission has a unique design with a differential torque converter drive principal called DIfferential-WAndler, giving the DIWA its name FIGURE 46-84. (Wandler is the German word for a torque converter). Differential drive with wandler means that the input torque during DIWA operation is split between mechanical and torque-converter operation. The DIWA transmission, therefore, has a much greater range of operation in first gear.

The DIWA transmission will use first gear to accelerate to speeds that would normally require a conventional automatic transmission to shift at least once and sometimes twice. That capability is particularly beneficial in bus applications. In stop-and-go traffic, the DIWA usually does not need to shift at all, yet it is just as capable of high-speed operation as a vehicle that does shift. Reduced shifting adds to passenger comfort and means less wear and tear on the transmission itself. Low-speed operation appears seamless.

DIWA Transmission Operation

The counter-rotating torque converter is the heart of the DIWA transmission's operation. The converter is mounted in the middle of the transmission and doubles as a fully functional hydraulic retarder on deceleration in all gears except first. The DIWA system torque converter is different from the standard converters that we looked at in the chapter on Torque Converters. The DIWA system converter has the same three components as other torque converters, but their arrangement is different. The impeller, or pump, is at the front of the transmission, but it is counter-rotating. In other words, the impeller at the front of the converter turns in a counter-clockwise direction when viewed from the front.

Another difference between DIWA and other transmissions is the position of the stator. Instead of the turbine being opposite the impeller, the stator is positioned

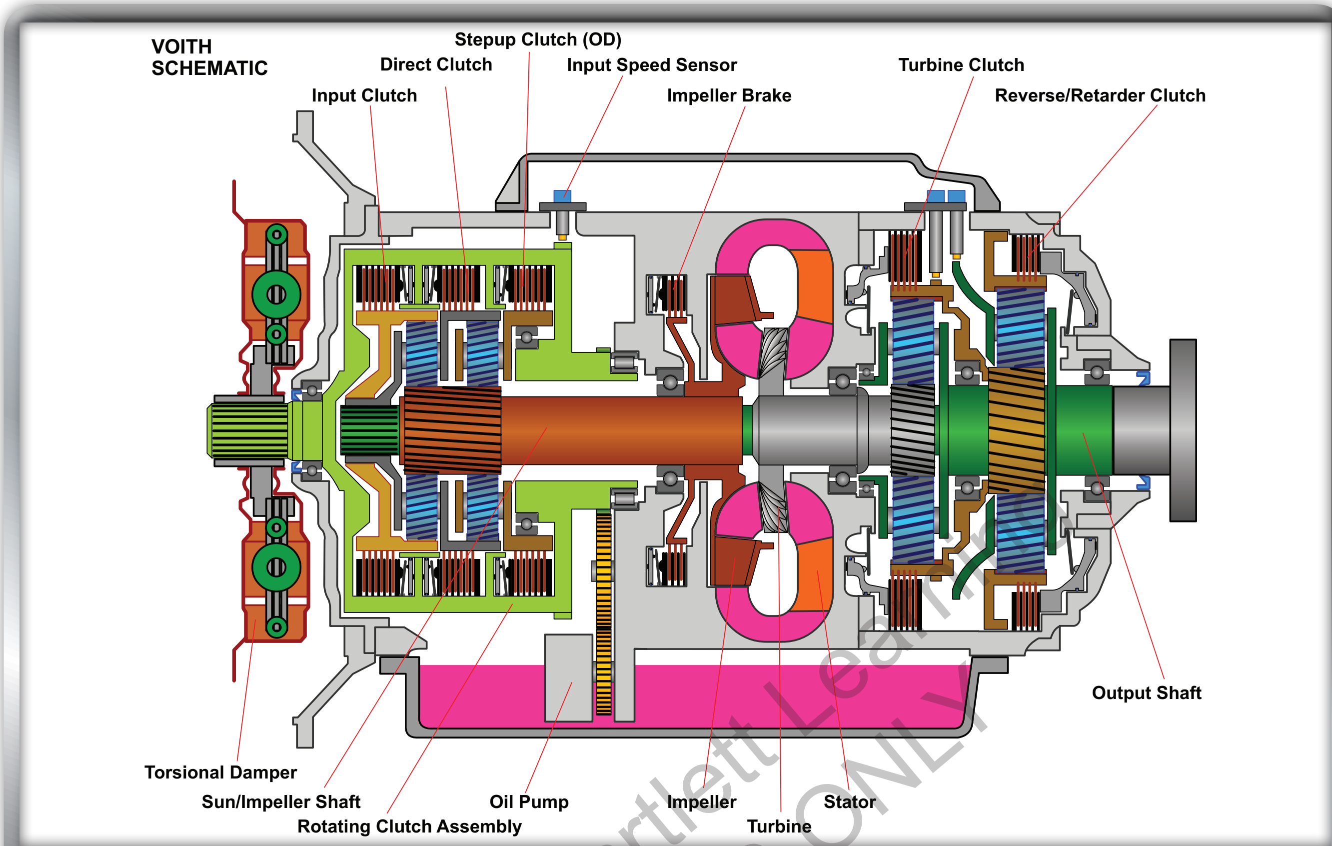


FIGURE 46-84 The Voith DIWA drive transmission.

at the rear. DIWA operation is the same regardless of whether the transmission is a three-speed or four-speed overdrive model.

DIWA Torque Converter Oil Flow

The DIWA torque converter is responsible for the hydrodynamic input to the transmission gearing. The mechanical portion of the differential input system will be covered later in the chapter. The following is a description of the torque converter fluid flow and operation.

As the counter clockwise-rotating impeller (or pump) throws the transmission fluid outward by centrifugal force and rearward because of the housing shape, the fluid contacts the stator first—not the turbine, as is the case in most torque converters. Recall that in the DIWA system, the stator is at the rear of the torque converter. The stator re-directs the fluid flow and sends it back towards the impeller in a direction opposite to the impeller's rotation. The fluid then strikes the smaller, center-mounted turbine. The fluid striking the turbine causes the turbine to turn clockwise. The fluid then exits the turbine and enters the impeller in the same direction that it is turning, multiplying the torque. The rotating turbine provides input to the sun gear of the planetary gear set immediately behind the torque converter.

DIWA Transmission Components

All power enters the transmission through a torsional damper attached to the engine flywheel. In the front section of the overdrive transmission, a single, rotating clutch drum attached to the transmission input shaft contains three clutches:

- The input clutch
- The third gear clutch, also called the lock-up clutch as it provides 1:1 operation
- The step-up clutch (overdrive or fourth gear clutch)

Those three clutches control the operation of two planetary gears. The front planetary carrier is splined to the output shaft, and the second planetary ring gear is splined to the front carrier. The first clutch (the input clutch) in the rotating clutch module drives the front planetary ring gear when applied. The second clutch (the lock-up clutch) drives the second planetary ring gear and, by connection, the front carrier when it is applied. The third clutch (the overdrive clutch) drives the second planetary carrier when it is applied. There is also a stationary clutch that, when applied, locks the converter's impeller to the transmission housing for second, third, and fourth gears and retarder operation.

The torque converter of the DIWA transmission is in the middle of the transmission and provides input to the gearing in the rear of the transmission. The rear section of the transmission has two planetary gear sets and two stationary clutches. The planetary gear immediately behind the torque converter receives the hydro-dynamic input from the torque converter during first gear and reverse operation. The ring gear of this planetary gear set is splined to the sun gear of the rear (reverse and braking) planetary gear set. The carrier of the first planetary ring gear set in the rear of the transmission is splined to the output shaft. The rear (reverse and braking) planetary gear set sits at the very back of the transmission, and its carrier is also splined to the output shaft. So, three of the four planetary gear sets in this transmission have their carriers splined to the output shaft. Only the second planetary gear in the front section does not.

There are two clutches in the rear section. The first is the turbine clutch, which applies during DIWA operation in first gear (when torque converter operation is necessary). The first clutch holds the first planetary ring gear in this section stationary. The rear planetary gear clutch applies for reverse and for retarder operation and holds the rear planetary ring gear stationary.

DIWA Powerflows

DIWA Neutral

In neutral, no clutches are applied, and torque flows only to the rotating clutch housing. The rest of the transmission is disconnected from the powerflow FIGURE 46-85.

DIWA Automatic Neutral at Standstill

Automatic neutral at standstill is an optional feature. When the vehicle is at a standstill with the service or parking brake applied, the reverse clutch and the turbine clutch are applied at the same time. This results in the vehicle being held stationary, as two elements of the planetary gear set behind the turbine (the ring gear and the carrier) are held. This system automatically releases the front input clutch at a standstill. Doing so takes the load off the engine and applies the two rear clutches to hold the vehicle stationary. The engine load is automatically reduced, thereby increasing fuel economy in stop-and-go operation.

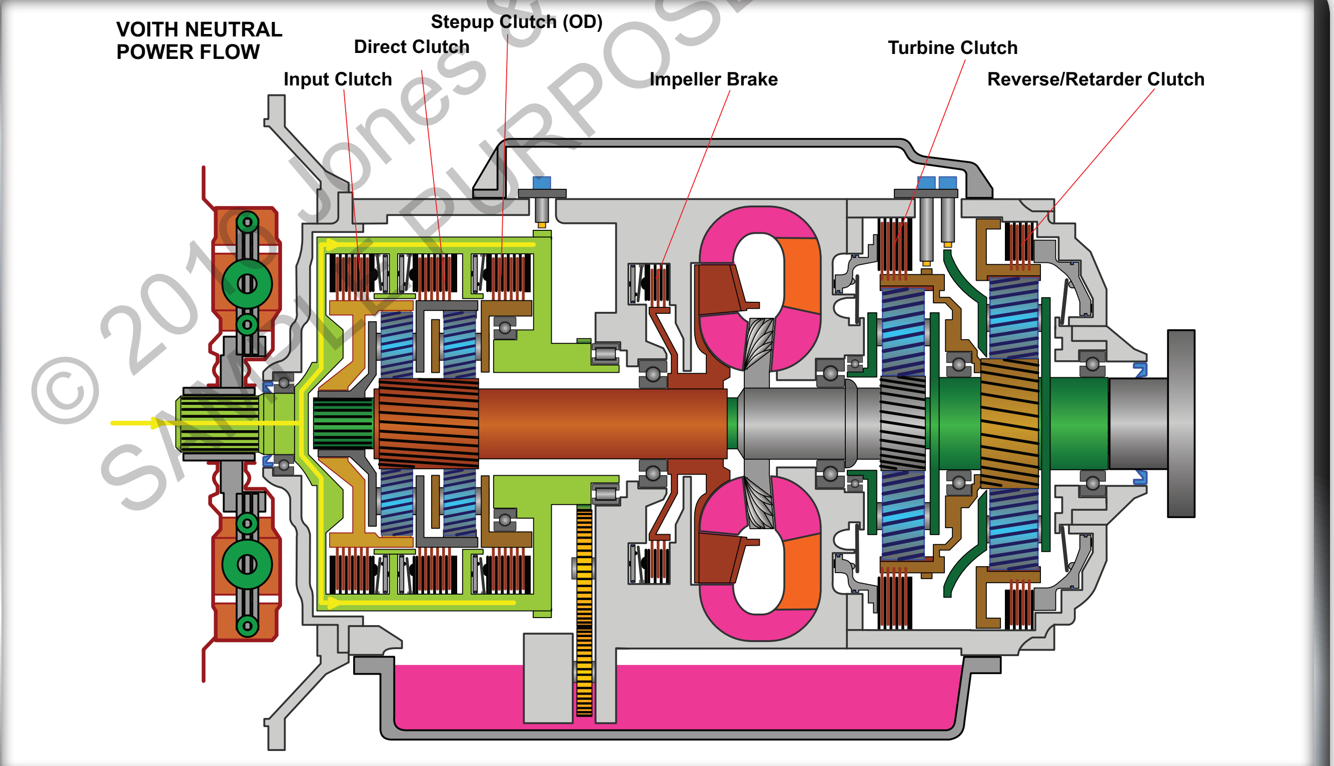


FIGURE 46-85 Voith power flows in neutral.

DIWA First Gear

In first gear, as the vehicle accelerates, the input clutch and the turbine clutch are applied, and engine torque is split between mechanical input and hydro-dynamic input FIGURE 46-86. The mechanical input comes from the front planetary gear set. The hydro-dynamic input comes from the planetary gear set directly behind the torque converter.

In the front planetary gear set, the ring gear is input by the input clutch, and the front carrier is splined to the output shaft. As such, the front carrier acts as a held member, causing the sun gear to rotate in the opposite direction. The sun gear drives the impeller of the torque converter counter-clockwise, and the torque converter turbine drives the sun gear of the planetary gear set behind the turbine in a clockwise direction. The ring gear of this planetary set is held stationary by its clutch, and its carrier becomes output. The carrier is splined to the output shaft, so this is the hydro-dynamic drive.

As the vehicle starts to move, the load becomes heavier on the sun gear driving the impeller. As a result, the sun gear starts to act as a held member in the front planetary set. The front carrier becomes output because it is splined directly to the output shaft. The load becomes stronger on the sun gear in the front planetary gear, and it acts more and more as a held member. The output from the front carrier increases as the vehicle's speed increases.

The output is a combination of the drive through the gear set behind the torque converter and the ever-increasing drive through the front planetary carrier. As the vehicle accelerates, more of the powerflow is transferred from the hydro-dynamic side behind the torque converter to the mechanical side at the front planetary carrier.

DIWA Second Gear

The shift to second is controlled electronically and is essentially the same as first FIGURE 46-87. A key difference, however, is that the torque converter's operation is completely stopped. The turbine clutch is released, and the impeller clutch (brake) is applied. This holds the front planetary sun gear stationary. The front ring gear is still input, the sun gear is held, and the carrier (splined to the output shaft) is output. The result is a pure mechanical powerflow.

DIWA Third Gear

In third gear, the input clutch is released, and the third, or lock-up, clutch applies FIGURE 46-88. That combination drives the second planetary ring gear, which is splined to the front carrier. In turn, the front carrier is splined directly to the output shaft, so the output shaft is driven

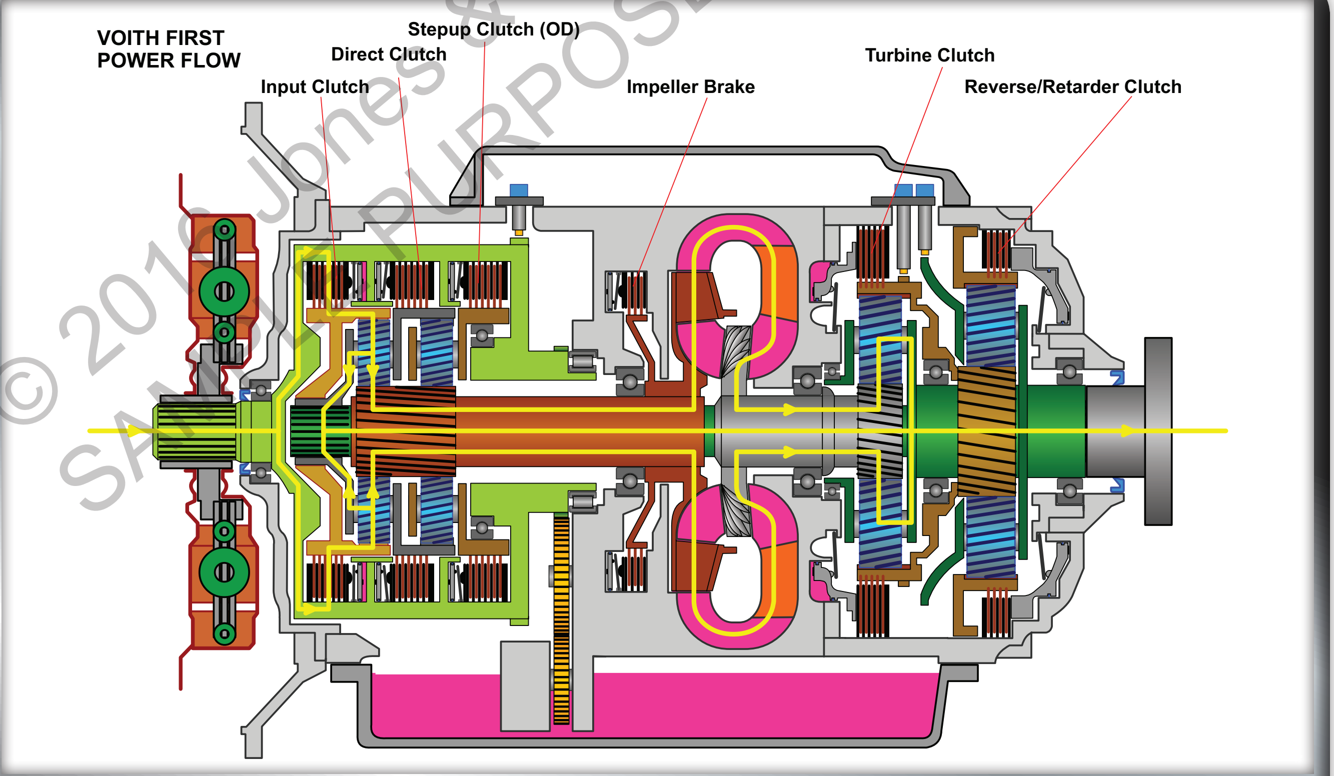


FIGURE 46-86 Voith power flows in first DIWA drive.

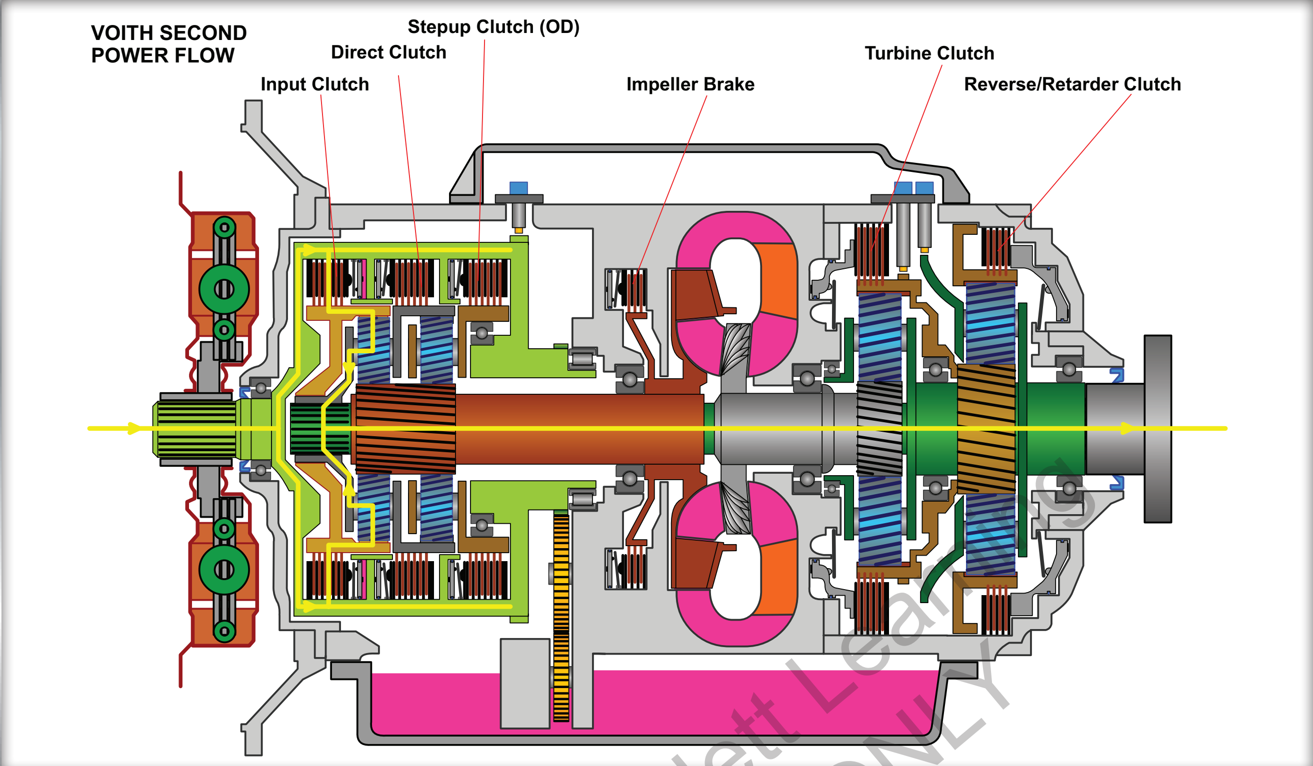


FIGURE 46-87 Voith power flows in second.

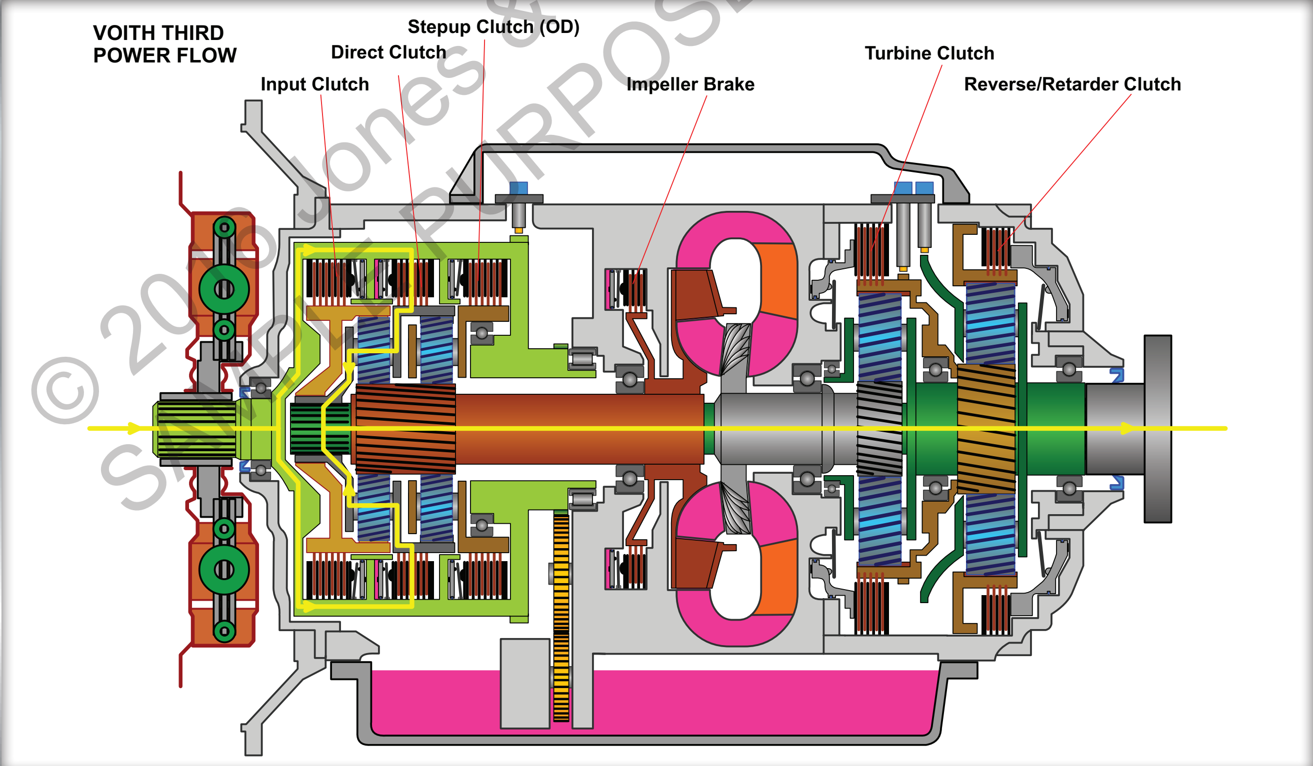


FIGURE 46-88 Voith power flows in third.

directly by the rotating clutch assembly. A one-to-one ratio results.

DIWA Fourth Gear

In fourth gear, the fourth clutch applies. This inputs the carrier of the second planetary gear set. The sun gear in the second set is held by the impeller brake (clutch). With the carrier input and the sun gear held, the result is overdrive output on the second planetary ring gear. The second planetary ring gear is splined to the front carrier which is, in turn, splined to the output shaft. The result is fourth range overdrive FIGURE 46-89.

DIWA Reverse

In reverse the input is the same as for first gear FIGURE 46-90. The input clutch is applied, and that drives the forward ring gear. The turbine clutch is not applied, but the reverse/retarder clutch is applied. That combination holds the ring gear of the rear planetary gear stationary.

The powerflow proceeds as follows. The front planetary ring gear is input. The front carrier has the load of the output shaft and the vehicle weight holding it stationary. That causes the sun gear to turn in reverse and inputs the impeller of the torque converter counter-clockwise. As the vehicle accelerates, the impeller begins to turn faster, driving the turbine and the sun gear of the planetary set behind the torque converter clockwise. The carrier in this set is loaded by vehicle weight, so its ring gear turns in reverse. The ring gear of this planetary set is connected to the sun gear of the rear planetary set, so its sun gear becomes reverse input to the rear planetary. The rear planetary ring gear is held by the reverse clutch, so its carrier becomes output (still in reverse), and the rear carrier is splined to the output shaft.

Retarder Operation

Retardation in first range is accomplished by lightly applying the reverse clutch with a pressure of approximately 17 to 18 pounds per square inch (1.2 bar) to slow down the output shaft FIGURE 46-91. In second, third, and fourth gears, retarder operation uses the torque converter as a hydraulic retarder. The reverse clutch, the impeller clutch (i.e., brake), and the input clutch associated with the particular range are all applied for retardation. The reverse clutch drives the turbine, which throws oil against the stationary impeller in the torque converter. The resultant retarding force slows the output shaft. The

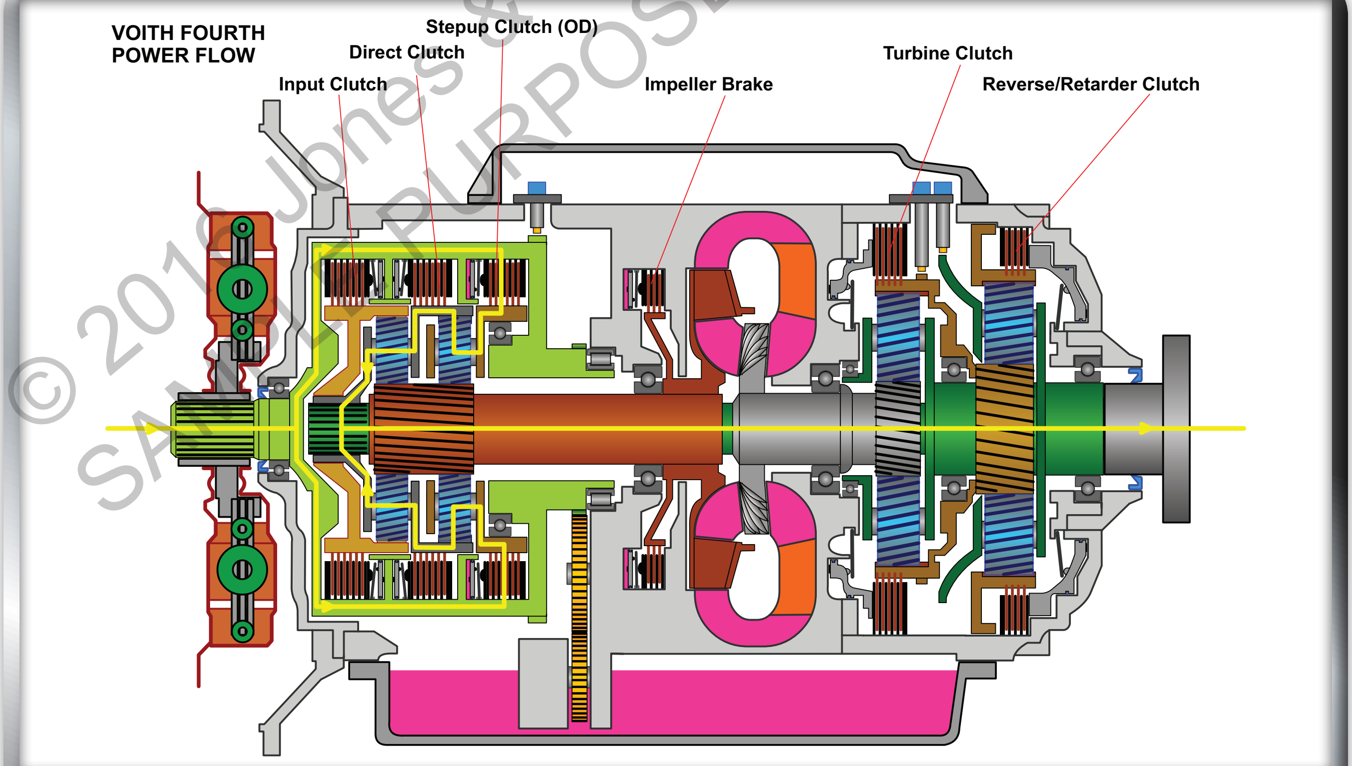


FIGURE 46-89 Voith operations for fourth gear.

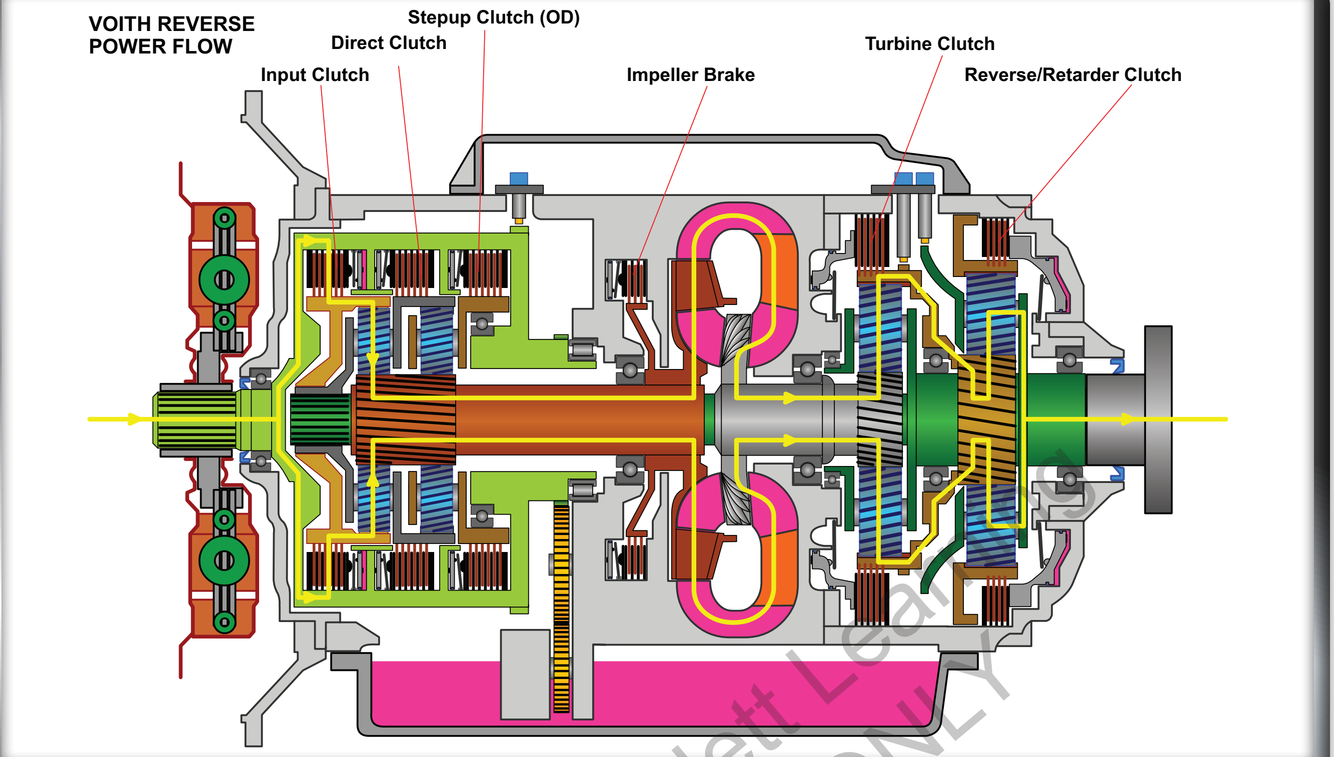


FIGURE 46-90 Voith operations for reverse.

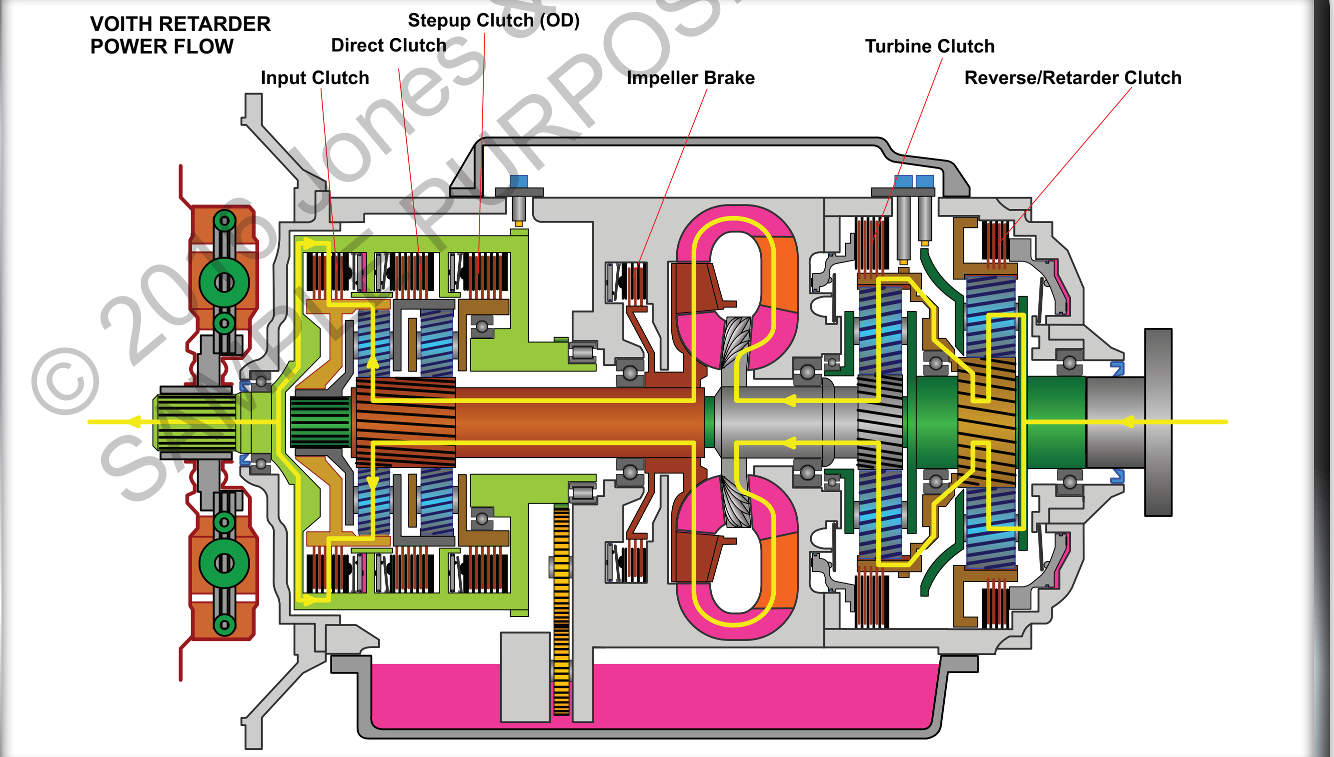


FIGURE 46-91 Voith operations for retarder power flow.

braking effort is controlled by the torque converter fluid pressure. Increased operating pressure provides greater retardation; decreased operating pressure provides less. The heat generated by the retardation is dissipated in the transmission integral heat exchanger.

Control System

The DIWA.5 Transmission with the Intelligent Control Unit E-300 comes equipped with **SensoTop**, an **adaptive control** feature that senses topography and vehicle load and adjusts shift control to obtain maximum economy and comfort. As with other transmission control systems, adaptive control allows the transmission ECU to "learn" and adapt shifts based on any number of input data. Most systems will include inclinometers or a similar component to sense road grade and gather information on load factors, fuel, rates, and more. As with most information in the system, the information collected by SensoTop travels through the controller area network (CAN) from the engine ECU.

To diagnose transmission problems and record operating events, the DIWA transmission uses a dedicated software diagnostic program called Aladin with a user friendly interface. Voith also offers a satellite monitoring system than can remotely diagnose problems with the transmission and relay them to the nearest service depot. Voith headquarters are in Hiedenheim, Germany, and the company also has offices in York, Pennsylvania and Sacramento, California.

ZF Friedrichshafen AG EcoMat and EcoLife Transmissions

ZF is a leading transmission manufacturer and has been designing and producing transmissions for various world markets for well over 50 years. ZF produces two automatic transmissions for the truck and coach market—the EcoMat and the EcoLife. The EcoMat is available in five- and six-speed models and can accept up to approximately 1,300 foot-pounds (1,762 Nm) of input torque. EcoMat is used in both trucks and buses FIGURE 46-92.

The EcoLife is ZF's latest six-speed transmission model that can handle up to 1,475 foot-pounds (2,000 Nm) of input torque. Both EcoMat and EcoLife transmissions utilize three planetary gears, six hydraulic clutches, and an integrated retarder for braking assist. ZF's proprietary TopoDyn software allows the transmission controller to learn load and road grade conditions and optimize shift profiles to suit the terrain and drive cycle. That capability leads to more efficient operation and greater driver and passenger comfort. Until 2009, ZF was in partnership with Arvin Meritor in North America, and the company still has a network of U.S. dealers marketing and servicing these transmissions.

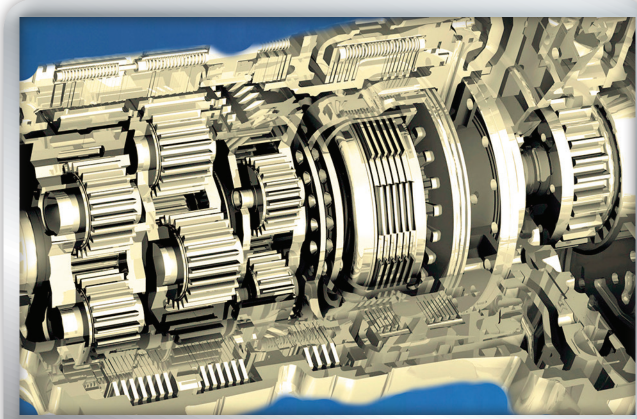


FIGURE 46-92 ZF transmissions are sold all over the world.

Caterpillar Automatic Transmissions

Caterpillar has made electronically controlled transmissions for the off-road market for years. In 2006, the company launched its first line of automatic truck transmissions for the on-highway market. The on-highway line consists of three models:

- CX28 is a medium-duty, six-speed transmission rated for 400 horsepower (300 kW) with input torque of 1250 foot-pounds (1,770 Nm) FIGURE 46-93.
- CX31 is a six-speed model for medium-duty applications rated for up to 525 horsepower (391 kW), and 1,770 foot-pounds (2,400 Nm) of input torque.

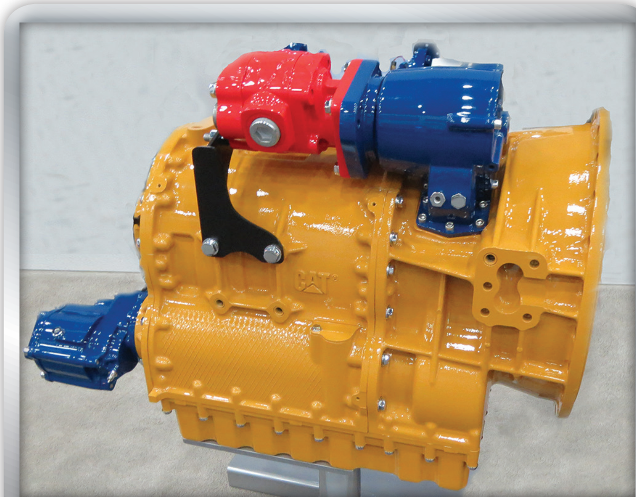


FIGURE 46-93 Caterpillar's CX-28 Transmission.

- CX35 is a heavy-duty, eight-speed model rated for up to 625 horsepower (466 kW) and 2,150 foot-pounds (2,915 Nm) of input torque.

The CX28 and CX31 on-highway models have three planetary gear sets, five hydraulic clutches, and are capable of six forward speeds.

In all models, the clutches are numbered C-1 to C-5, and the clutch application chart and the powerflows are the same as the Allison World Transmission **FIGURE 46-94**. The heavy-duty CX35 model has four planetary gear sets and six hydraulic clutches and is capable of eight forward speeds. The CX transmissions are completely drive by wire. In other words, they are solely electronically controlled. The transmission ECU has adaptive control built in so that it can optimize shifting for any operating cycle and load configuration.

The CX line of transmissions uses electronic clutch-pressure control units (ECPCs) to control clutch application. The ECPCs consist of a pulse-width-modulated solenoid that in turn controls a modulating spool valve that directs main pressure of 350 pounds per square inch (24 bars) to the clutches. When making a shift, the transmission ECU will first send a full-duty cycle signal to the ECPC solenoid. The signal tells the transmission to initiate clutch application and then will vary the duty cycle to control the quality of the shift in progress. Each clutch uses its own ECPC to control its application, and all of the ECPCs are identical **FIGURE 46-95**.

The transmissions are equipped with a lock-up converter, which locks up as the vehicle approaches maximum speed in second range. The lock-up converter is applied for all forward ranges above second. CX transmissions have two selectable operational modes:

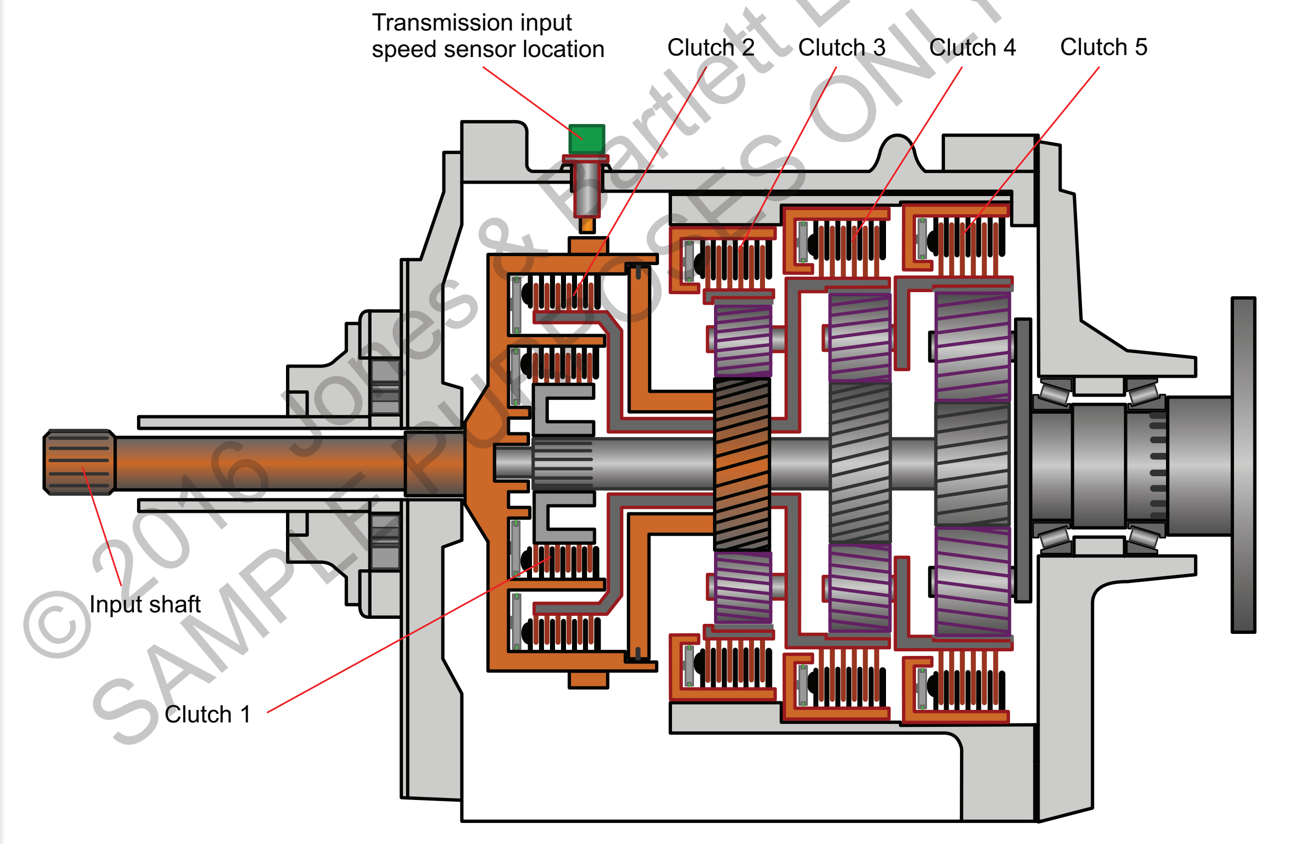


FIGURE 46-94 The clutches and planetary gear arrangement in the Cat CX-28 and CX-31 transmissions are the same as in the Allison World Transmission. The clutches are numbered 1 to 5 in this diagram.

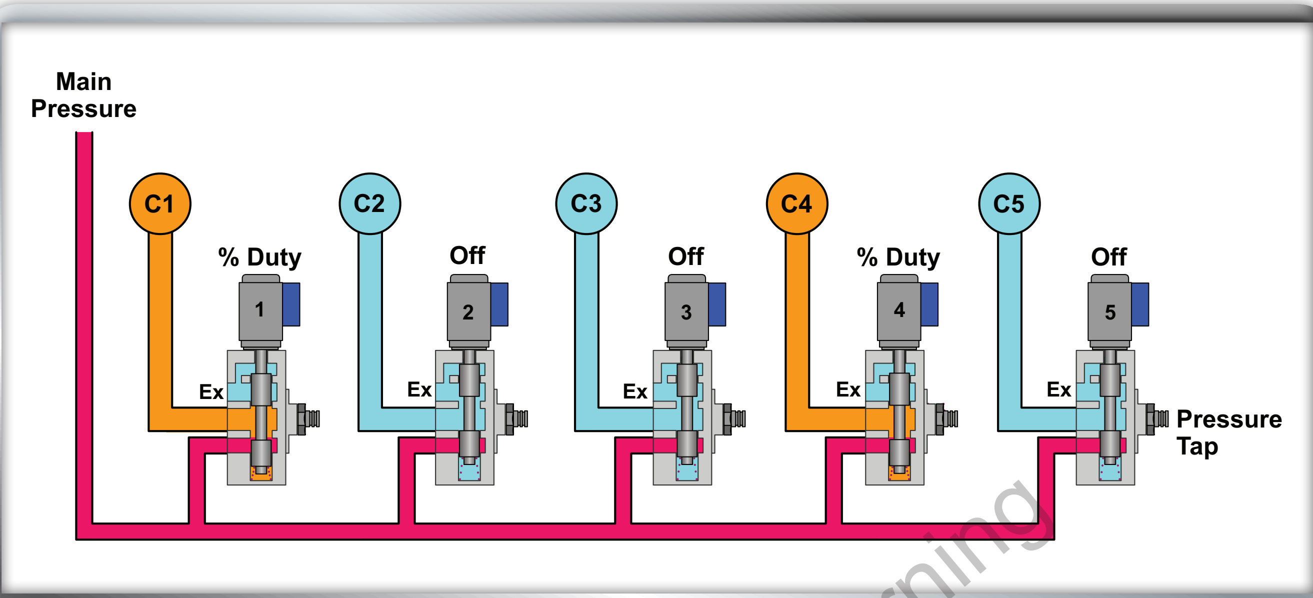


FIGURE 46-95 Each clutch in a CX transmission is controlled by its own individual ECPC.

economy mode and performance mode. In economy mode, shifting occurs at lower road speeds to save fuel. In performance modes, shifts will occur at close to the rated revolutions per minute (rpm) to allow for greater acceleration.

CX transmissions have self-diagnostic capability and will set a diagnostic trouble code (DTC) in the ECU memory and turn on an amber or red warning lamp when a problem exists. Cat Electronic Technician (ET) software is a proprietary diagnostic software program that can be utilized to access DTC information.

The ECU adaptive control on CX transmissions continuously monitors and adjusts the shifting process to make up for transmission wear and system degradation. After transmission overhaul or replacement, the adaptive control must be reset. Caterpillar calls this resetting of adaptive control "the transmission calibration procedure." It basically entails incorporating the learned adjustments to the shift process. Recalibration can only be accomplished with the Cat ET service program.

The CX series transmissions have not yet made a big impact on the North American automatic transmission market due, in part, to Caterpillar's decision to drop out of the on-highway truck engine market back in 2010. Despite reduced activity in the on-highway truck engine market, Caterpillar now produces its own line of on-highway trucks (the CT 660 and the CT 681) in which the CX31 transmission is standard equipment when an automatic is specified. These trucks currently use Navistar engines and are strictly for vocational applications—mostly dump and cement trucks. Although Cat does have a visible presence on North American highways with the CT 660 and CT 681trucks, the company has not yet garnered significant market share. As a result, the CX series of transmissions are mostly serviced only at Caterpillar dealerships.

Wrap-up

Ready for Review

- Electronic control of transmissions has been in place in the light-duty market since the early 1980s and the truck market since the late 1980s.
- In general, transmissions require at least three inputs to function: input from the driver, a road speed input, and a load factor input.
- In electronic transmission control systems, a lever selector or a push button controller provides the drivers input; a vehicle speed sensor (VSS) provides the speed input; and a throttle position sensor (TPS) provides the load factor input.
- Most electronically controlled transmissions will use inputs from a variety of other sources—such as pressure switches, temperature switches, and oil pressure sensors—to fine tune transmission shift control.
- All electronic controlled transmissions are connected to the vehicle by a multiple wiring harnesses and connectors.
- Electronically controlled transmissions use a variety of computer controlled solenoids to control shifting.
- Allison is by far the world-leading manufacturer of electronically controlled automatic transmissions.
- Allison electronic control systems have undergone several advancements through the years, starting with the Allison ATEC/CEC system, which offered minimal electronic control, through the five software versions of the Allison World Transmission series, which offers increasingly sophisticated electronic control.
- The driving force behind electronic control advancements is fuel economy.
- The careful system monitoring characteristic of electronic control results in better control of the shift timing and process leads to increased fuel economy and greatly increased transmission durability.
- Lock-up torque converters are computer controlled and lead to even better fuel economy.
- The Allison World Transmission (WT) is modular in design, so individual modules can be serviced independently if necessary to decrease down time.
- The Allison World Transmission (WT) has six forward ranges with two overdrives, a design that increases fuel economy.
- The Allison World Transmission (WT) has three speed sensors, which allow it to compare input speed, turbine speed, and output speed. That comparison tells the transmission controller if a transmission clutch is slipping, so it can protect the transmission.
- The Allison World Transmission (WT) has several protection strategies built in, such as range inhibitors when input speeds are too high, high-speed direction-change inhibitors, and temperature-based inhibitors.
- The Allison World Transmission (WT) has built-in failsafe operation that provides minimal transmission function should electrical power be lost. Failsafe operation ensures that the vehicle is not stuck on the side of the road.
- Electronically controlled transmissions have varying levels of adaptive control. That is, the transmission controller can adapt shifting to different operating conditions, load levels, and other conditions.
- The Allison TC-10-TS transmission is a fully wet-clutch-controlled electronic transmission with ten forward ranges and twin countershafts. The TC-10-TS is specifically designed for the Class 8 on-highway truck market.
- The TC-10-TS also has fully electronically controlled shifting and adaptive control.
- Allison DOC software can be used to diagnose and monitor all of Allison's electronically controlled transmissions.

- The Voith DIWA drive transmission is primarily used in transit and coach applications, as its differential inputs (mechanical and hydrodynamic) allow it to operate in first range over a wide speed range without shifting.
- The Voith DIWA is more popular in the rest of the world but is making significant inroads in North America.
- The Voith DIWA has its own dedicated software diagnostic program, known as Aladin, which can read diagnostic trouble codes and monitor transmission operation.
- ZF electronically controlled transmissions are primarily used in transit and coach operations and have yet to make a significant dent in the North American market. ZF is a huge global marketer of transmissions, and its presence in in North America is likely to grow.
- Caterpillar's CX series of electronically controlled transmissions has not yet made a significant impact on the North American market, but, with CAT poised to re-enter the on-highway engine market soon, the company may see its sales of these transmissions increase.

Vocabulary Builder

adaptive control A feature that senses topography and vehicle load and adjusts shift control to obtain maximum economy and comfort.

Allison Transmission Electronic Control (ATEC) The original version of Allison's electronic control systems which evolved into Commercial Electronic Control (CEC).

cab harness The harness that connects the shift selector to the electronic control unit.

chassis wiring harness The wiring that connects the transmission, the TPS, and the variable speed sensor to the transmission electronic control unit.

closed-loop control The time during a shift in progress on a World Transmission that the transmission ECU is actively adjusting on-coming clutch application pressure using pulse-width modulation to control shift quality.

Commercial Electronic Control (CEC) The second iteration of Allison's electronically controlled transmission.

counts The unit that Allison uses to describe throttle position based on the variable voltage signal from a TPS, Throttle Position Sensor.

diagnostic data link (DDL) connector The diagnostic data link connector is the location on the vehicle where the technician can plug in diagnostic software.

duty cycle The amount of time during each 1/63rd of a second that the current is allowed to flow to the solenoid.

electro-hydraulic control (electro-hydraulic valve body) The valve body used to control electronically controlled transmssions and consisting of solenoids, spool valves, and, usually, pressure switches.

failsafe operation The minimal transmission function that occurs when electrical power is lost.

fast adaptive A type of adaptive control used when the transmission is new and makes large changes to bring the shift close to the optimal shift profile quickly.

hydraulic retarder Retarder systems that pump transmission fluid between a turning cupped rotor and stationary cupped housing, thereby creating fluid pressure and fluid friction that slow the vehicle.

inclinometer/accelerometer Sensors included in the transmission control system that allow it to adapt to topography and operating conditions.

latching solenoids Solenoids that need only a short burst of electricity to move to an open or closed position and they remain in that state until they are energized again.

modulated main solenoid A pulse-width-modulated solenoid that controls main pressure in fourth generation and later World Transmissions (WT).

neutral with no clutches (NCC) The status of a vehicle in neutral gear when no clutches are applied and an indicaton of a possible failure mode for Allison World Transmission (WT).

non-latching solenoid A solenoid that requires constant electric power to remain in the open position.

normally closed solenoid A solenoid that blocks the flow of fluid when it is not electrically energized.

normally open solenoid A solenoid that is open when not electrically energized.

off-going ratio test A test performed at the beginning of a shift in progress in the World Transmission (WT) to ensure that the off-going clutch has released.

on-coming ratio test A test performed near the end of a shift in progress in the World Transmission (WT) to ensure that the on-coming clutch has applied.

open-loop ramp rate A predictable increase in clutch apply pressure; the open-loop ramp rate is controlled by the transmission ECU.

pressure control solenoid (PCS) The term to denote clutch control solenoids in an Allison Fourth Generation Electro-Hydraulic Control transmission.

primary modulation The pulse-modulated signal sent to a solenoid to intiate fluid flow.

prognostics A self-diagnostic maintenance schedule that informs the driver when the oil, filters, or the transmission itself requires service. Prognostics are offered on the Allison World Transmissions (WTs) since 2009 and can be turned on or off by the vehicle owner if desired.

programmable read-only memory (PROM) chip A memory chip particular to the application of the vehicle in which it is found.

pulse-width modulation The ability of a solenoid electric circuit to control pressure buildup in a clutch by turning on and off the flow of current at a fixed frequency.

ramp-off rate The specific reduction in clutch apply pressure for the clutch that is being released during a shift in the World Transmission (WT).

range verification tests Tests constantly being performed by the Allison World Transmission (WT) control system whenever there is no shift in progress the test compares turbine times the gear ratio to the output speed to ensure the transmission is not slipping.

ratio test A test performed at the beginning and end of a shift in process.

retarder Any system used to slow a vehicle's momentum and augment the service brake.

secondary modulation (sub-modulation) A very high-frequency pulse-width modulation of the current flowing through the primary modulated circuit of a World Transmission (WT) solenoid. The secondary modulation occurs at between 12000 and 19000 Htz and is used to fine tune the solenoid function.

SensoTop A system used by Voith that senses topography and adapts the shifting schedule accordingly.

shift logic The logical process created by the transmission controller using data gained from the vehicle to determine when and how shifting should occur.

shift solenoid 1 (SS1) The solenoid used in fourth-generation and later World Transmissions (WTs) to control the position of the C-1 and C-2 latch valves.

slow adaptive A type of adaptive control that involves making small changes to the shifts as a way to mitigate the effects of clutch wear and solenoid drive and degradation.

synchronous speed The point at which the on-coming clutch has applied and there is no more slippage. Turbine shaft seed times the gear ratio equals output shaft speed.

time to full apply (TFA) The point after synchronous speed has been detected at which the solenoid controlling the on-coming clutch in a World Transmission (WT) is commanded to full pressure (that is, to fully apply the clutch).

torque converter control (TCC) A control solenoid used in fourth-generation and later World Transmissions (WTs).

transmission control module (TCM) The electronic controller that issues commands to the solenoids inside the transmission to obtain the desired range. Also known as the transmission electronic control unit (ECU).

transmission electronic control unit (ECU) The electronic controller that issues commands to the solenoids inside the transmission to obtain the desired range. Also called the transmission control unit (TCU).

trimmer An accumulator used in the ATEC/CEC systems to smoothen out the shift process.

turbine pull down A decrease in turbine speed as a shift is in progress that results from the on-coming clutch starting to control its gear train component; the signal for the transmission to enter closed-loop control of the shift in progress.

variable-bleed solenoid (VBS) Hydraulic solenoids used in late-model Allison World Transmissions (WTs), which control application by allowing some of the pressure going to a device to bleed off to exhaust.

vehicle speed sensor (VSS) An inductive pick-up sensor that reads the speed of the transmission output shaft.

World Transmission Electronic Control (WTEC) Allison's original electronic transmission control system for the World Transmission.

Review Questions

1. In the Allison ATEC/CEC transmission, solenoids are used to do which of the following?
   a. Send fluid directly to clutches.
   b. Act as system pressure-modulation devices.
   c. Control the flow of transmission fluid to valves.
   d. Replace the function of the load- and speed-sensing devices.

2. What is the purpose of the transmission temperature and oil level sensors?
   a. They act as system-protection devices.
   b. They act as additional flow-control devices.
   c. They are used only as troubleshooting tools.
   d. They are installed to assist in stall testing.

3. When the fluid in an Allison ATEC/CEC transmission is extremely cold (below -25 degrees Fahrenheit), the transmission controller allows which of the following?
   a. No shifting
   b. Shifts from neutral to first or reverse only
   c. All range shifts to occur
   d. Weather does not affect the transmission shifts.

4. In Allison ATEC/CEC transmissions, what replaces the modulator valve used in hydraulically controlled transmissions?
   a. The vehicle speed sensor
   b. The transmission oil pressure control valve
   c. The throttle position sensor
   d. The transmission temperature sensor

5. What happens if you are driving a vehicle with an ATEC/CEC transmission in fourth range and electrical power to the transmission TCU is lost?
   a. The transmission immediately shifts to neutral.
   b. The transmission downshifts until it reaches first range.
   c. The transmission will shift to the next lower range (third).
   d. The transmission will remain in fourth range until the vehicle is shut off.

6. What is meant by synchronous speed as it relates to the Allison World Transmission TCU?
   a. The output shaft speed times the gear ratio equals the engine speed.
   b. The turbine speed equals the output shaft speed.
   c. The engine speed times the gear ratio equals the turbine speed.
   d. Turbine shaft speed equals output shaft speed times the gear ratio of the oncoming clutch.

7. During a shift, the World Transmission enters closed-loop control between which of the following points?
   a. Turbine pull down detected and synchronous speed.
   b. Shift initiation and turbine pull down.
   c. Synchronous speed and shift initiation.
   d. The WT has closed loop control during the entire shift.

8. During closed-loop control, the TCU is controlling shift quality by doing which of the following?
   a. Using the fixed ramp rate
   b. Applying full-line pressure to the on-coming clutch.
   c. Varying the on-coming clutch application pressure using pulse-width modulation.
   d. None of the above is correct.

9. Which of the following is NOT one of three ways that the engine's rotational power can be transmitted to the gear train in a World Transmission?
   a. Through the P-2 and P-3 sun gears.
   b. Through the P-1 sun gear.
   c. Through the P-2 carrier.
   d. Through the P-2 ring gear

10. When a World Transmission (WT) is in reverse, the input power from the engine enters the gear train through which of the following?
    a. P-1 sun gear.
    b. P-1 carrier.
    c. P-2 carrier.
    d. P-2 and P-3 sun gears.

ASE-Type Questions

1. Technician A says that the Allison transmission's TCU switches to slow adaptive mode after optimum shift quality has been attained. Technician B says that the TCU must be switched to fast adaptive mode after transmission replacement. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and B are correct.
   d. Neither Technician A nor B is correct.

2. Technician A says that the Allison World Transmission series is a true "drive by wire" transmission. Technician B says that the World Transmission series still has a mechanical gear-shift linkage. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and B are correct.
   d. Neither Technician A nor B is correct.

3. Technician A says the Allison World Transmission is capable of inhibiting neutral to range shifts if the engine RPM is too high. Technician B says that the TCU is capable of inhibiting downshifts if the road speed is too high. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and B are correct.
   d. Neither Technician A nor B is correct.

4. Technician A says that the Voith DIWA drive transmission has two inputs to the transmission gear train: mechanical and hydrodynamic. Technician B says in the Voith DIWA drive transmission, torque converter doubles as a retarder. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and B are correct.
   d. Neither Technician A nor B is correct.

5. Technician A says that the Allison TC-10 has two countershafts. Technician B says that the Allison TC-10 uses both countershafts for each powerflow like the Eaton Fuller Twin countershaft transmission does. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and B are correct.
   d. Neither Technician A nor B is correct.

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SAMPLE CHAPTER
ELECTRONICALLY CONTROLLED AUTOMATIC TRANSMISSIONS

Fundamentals of
Medium-Heavy Duty Commercial Vehicle Systems

Owen C. Duffy
Gus Wright

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