Automatic Transmission Operation

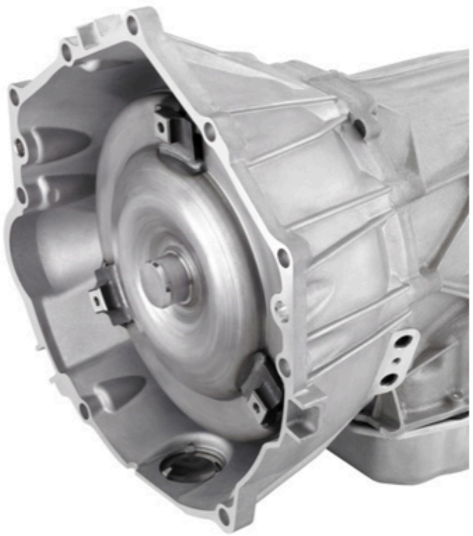

Figure 1: Transmission. Image source: [Link]

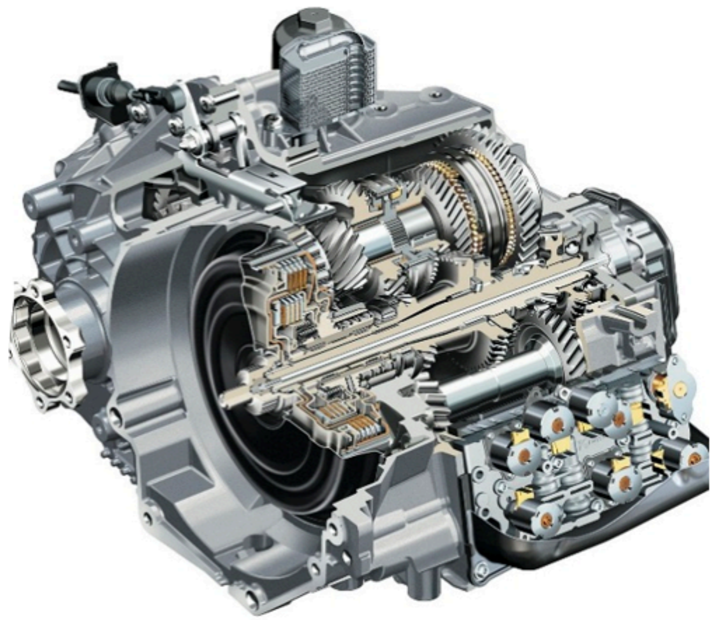

Figure 2: Automatic Transmission. Image source: [Link]

Introduction

Automatic transmissions have an exciting history. One of the main reasons they came about is because consumers wanted to drive without having to manually shift. Planetary gear-based, or traditional automatics were the first transmission designs to offer automatic shifting. Since their creation, automatic transmissions became a component that many automotive service professionals do not feel comfortable working around because they do not understand them. They have more complexity than manual transmissions do. Automatics, however, do offer an advantage, which is higher towing capability and they do so smoothly as compared to manual transmissions. The goal of this chapter is to help you understand planetary gear type automatic transmissions so that you can perform both routine maintenance and complex repairs on them.

The engine and transmission are two major components that work together to propel the vehicle. Today's vehicles are complex, especially when you consider the many vehicle systems that are part of the vehicle's communication network that have been added as various systems have developed. Systems such as anti-lock brakes, stability control, climate control, body controls, and so forth are all networked, including the power train system, all which offer consumers safe and efficient transportation. In regard to diagnostics, what can at times is a problem with one system modules or a sensor has a problem. When such a problem occurs it often impacts another system/module on the network.

With that in mind, one of the first things a service professional needs to understand is that there is a **priority order** regarding diagnostic trouble codes or DTCs. Simply put, whenever a U code is present, it needs to be diagnosed and repaired before any P codes are. For example, if both a U1000-loss of communication code and a P0104-MAP sensor voltage high are found to be present during a code scan, the U code is diagnosed first. Additionally, if ever a drivability code like a P0104 MAP voltage high and a transmission related DTC such as a P0741-torque converter clutch failure code are both found during a scan, the engine performance code is to be repaired before transmission related DTC. Simply stated, transmission DTCs are third in priority if ever a U and drivability DTCs happen to be present alongside a transmission type code.

Chances are likely that once the U code is repaired the others DTCs will no longer be an issue.

Figure 3

Let's explain why transmission related DTCs are third priority.

Network type issues, which create U code DTCs, can make a vehicle operate in strange and sometimes unpredictable ways. A faulty sensor that is shared on the network can also cause irrational outcomes with more than one system and often leads to incorrect diagnosis if the **network issues** are not addressed first. This is why it is necessary to repair all network U codes before any other type of DTC.

As mentioned, engine performance codes are second in priority to U codes because the transmission control module or **TCM** needs to have reliable signals from all the engine's system sensors for the TCM to shift the transmission correctly. For example, when an engine misfire exists due to one cylinder having either low compression or a bad ignition coil, it disrupts intake manifold air pressures which the **MAP** sees as a problem. Inconsistent intake manifold air pressures will confuse the TCM and in turn cause abnormal transmission shift patterns.

In a cylinder with **low compression**, especially one with a bad intake or exhaust valve, intake manifold air pressure values will be abnormal because positive pulses will occur each time the problem cylinder's piston travels up on its compression stroke. When the TCM doesn't receive correct manifold pressure information it gets confused as to when to command a shift and how much fluid pressure to send to the clutches. This often leads to a harsh 1-2 shift.

Fail-safe mode

Transmission modules have a back-up or **default** mode they can operate in when necessary. This is usually referred to as **fail-safe mode**. Fail-safe is when the transmission operates in only one forward gear or range. Reverse may even be possible but fail-safe mode is a result of either of these two things:

1. There is a **power loss** to the TCM. On a large number of automatic transmissions, whenever power is lost to the TCM the transmission will operate in hydraulic mode, which means it will only have one forward gear and maybe reverse. Simply stated, it will not shift from one gear to the next and the engine may seem to have a low power issue. The one forward gear that the transmission will be "stuck" in could be 2^{nd}, 3^{rd}, 4^{th}, or 6^{th} gear; it all depends on what is possible when the transmission was designed and built. Creating a default gear is a challenge to design due to the complexity of the hydraulic control side of an automatic transmission.
2. Sometimes the TCM sees a particular problem and will go into default mode in order to protect the transmission's clutches. These types of problems are what transmission design engineers determine as they work with software engineers in order to predict what types of internal failures or conditions need to occur in order to put the transmission into default mode.

Transmissions are controlled by an electronic control module, the TCM, which in turn controls all of the solenoids that direct hydraulic fluid to the clutches. The transmission's clutches either drive or hold planetary gear set members in order to create evenly stepped gear ratios. For the TCM to perform these actions it needs input information.

The three high priority **INPUTS** a TCM needs in order to control a transmission's shifting actions are the following sensors:

1. The MAP, manifold absolute pressure, or the MAF, mass air flow or volume. Some vehicles have only one of these two sensors while others have both of these. Either way, the TCM needs to determine intake manifold pressure and air flow which helps it to determine engine load. For your benefit keep this in mind since many transmission publications use the term load in place of the phrase "intake manifold pressure."
2. The **VSS** or vehicle speed sensor. This sensor reports to the network how fast the vehicle is moving. It is located on the transmission's housing where an axle shaft exits the transmission. Please don't confuse this sensor with a wheel speed sensor. Wheel speed sensors are located at each wheel, a VSS tells the TCM about vehicle speed, not wheel speed.
3. **TPS**, or throttle position sensor. This input signal tells the TCM and other modules what the throttle angle is so the TCM can determine how much hydraulic pressure to send to the clutches. Additionally, when there is a sudden change of throttle angle the TCM the rest of the modules on the network knows that the driver is accelerating. The TCM responds by downshifting the transmission to a gear which it calculates is best in order to increase power to maximize engine performance. The TPS, or the APP, accelerator pedal position sensor, is also an input to help determine when to apply or to disengage the TCC, torque converter clutch, inside the converter.

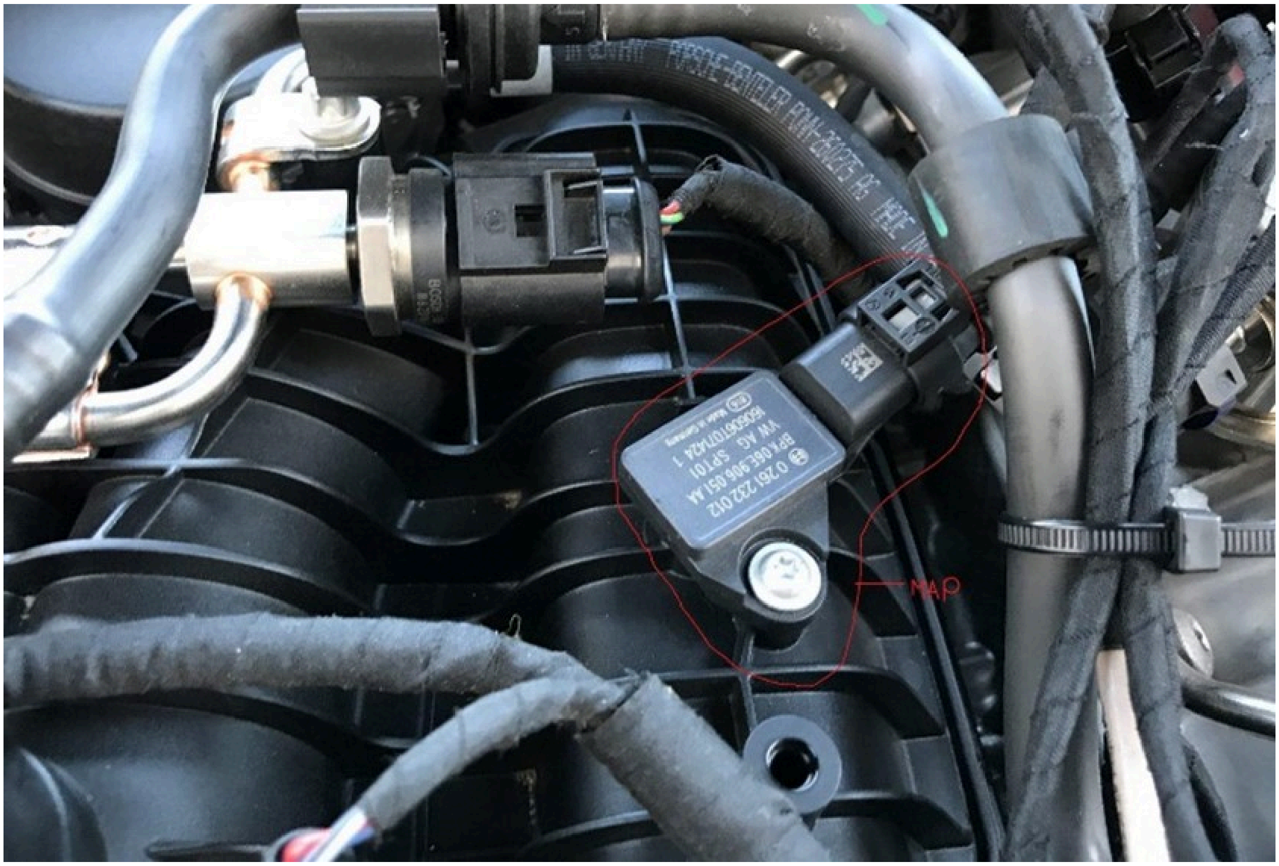

Figure 4

Again, the MAP/MAF, VSS and the TPS sensors are the major inputs for transmission shifting to occur.

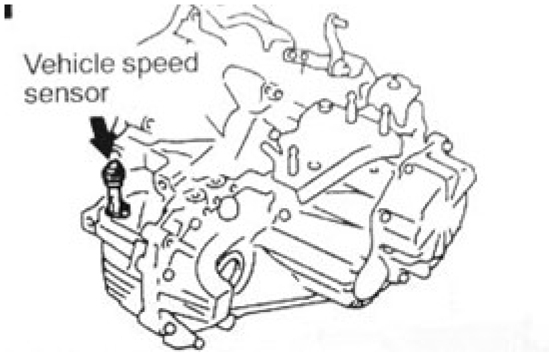

Figure 5

Shift Inputs

Transmission shift timing is much like riding a bicycle. Cyclists do not shift to a higher gear until they feel that they are going fast enough and that the load on their legs is light enough. Hence the need for the TCM to monitor vehicle speed and engine load.

Other inputs are considered **secondary** in that the TCM doesn't need them to actually determine shift timing mut it does use them to modify exactly when shifts will occur. For example, when engine coolant and transmission fluid is cold shift timing will be delayed a bit and the TCC will not engage. Secondary inputs are:

- **CkP** – crank position. This information is part of the shift timing calculation and when to apply and release the TCC. This answers the question of whether engine RPM is high enough for a shift to occur.
- **ECT** and **IAT** – engine coolant temperature and intake air temperature. The TCM will not allow the TCC to engage and it will delay transmission shift timing until the engine is warm enough, as determined by manufacturer programming.
- **TFT** - transmission fluid temperature. This information is for TCC application and shift timing as well. Best engine performance and shift timing occur once transmission fluid is warm enough.

TCMs also have an **adapt function**. This means that as apply components, such as the clutches, wear down somewhat due to normal use shift timing can be maintained by boosting hydraulic pressure a bit in order to keep “shift feel” consistent and optimal. This improves both transmission life and retains shift quality.

Figure 6

To help understand more about transmission inputs, listed below are details from two different manufacturers technical training publications. The first statement is from the *Hydra-Matic 6 Speed RWD Technician’s Guide*, produced by General Motors.

“Electrical signals from various sensors provide information to the TCM about vehicle speed, throttle position, engine coolant temperature, transmission fluid temperature, gear range selector position, engine speed, converter turbine speed, engine load and operating mode.”

In other words, the TCM uses this information to determine the precise moment to either upshift or downshift and how much fluid pressure to send to the hydraulic clutches. These inputs are also used to determine when to apply and when to release the TCC – torque converter clutch.

This next statement is from a Mercedes transmission publication, Mercedes 722.9 or NAG2 (New Automatic Gearbox gen 2).

“Primary transmission inputs are:

- Engine RPM
- Engine load
- Throttle position
- Vehicle speed
- Coolant temperature
- Shift mode or shift lever position”

These two statements from two different manufacturers help us understand more of how automatic transmissions operate. They all use much the same sensors, regardless of manufacturer.

To review, both manufacturers require the input of engine load (either a **MAP** or **MAF**), VSS - vehicle speed, **TP** - throttle position, engine rpm - **CKP**, transmission **range selector** position, and **fluid temperatures** to operate their automatic transmissions.

TRS

The input from the **TRS** or the transmission range switch is necessary because this switch is what allows the starter motor to engage only when in P-park or N-neutral. Additionally, when R-reverse is selected it turns on the reverse lights as well as signaling the TCM that R has been selected so that the solenoids that enable R-reverse send hydraulic fluid to the clutches that allow reverse to occur. When D-drive is selected, power is sent to the clutches that will provide 1st gear as well as 2nd, 3rd and so forth for shifting to occur automatically as conditions are reached.

When “manual 1st” is selected, power will only be allowed to the solenoids to maintain clutch application for 1st gear, unless engine rpms are high enough that the TCM will take over and command a shift to 2nd gear in order to protect the engine. Being able to manually shift to 1st, 2nd, 3rd, and so on, allows the driver to descend hills without having to apply the brakes nearly as often as compared to the selector being left in D-drive. This is a convenient safety feature.

Other names that other car manufacturers use instead of **TRS**-a term used by Ford-are these:

- MPLS – multi lever position switch a term used by General Motors.
- Inhibitor switch - a Term Subaru uses.
- Manual Shift Shaft Position Switch – a term by General Motors
- Toyota uses two switches, a Park Neutral Switch – on the transmission – and a **Transmission Control Switch** – located at the shift lever. These switches work together to accomplish what a TRS does. (See Toyota’s A750F Transmission manual.)

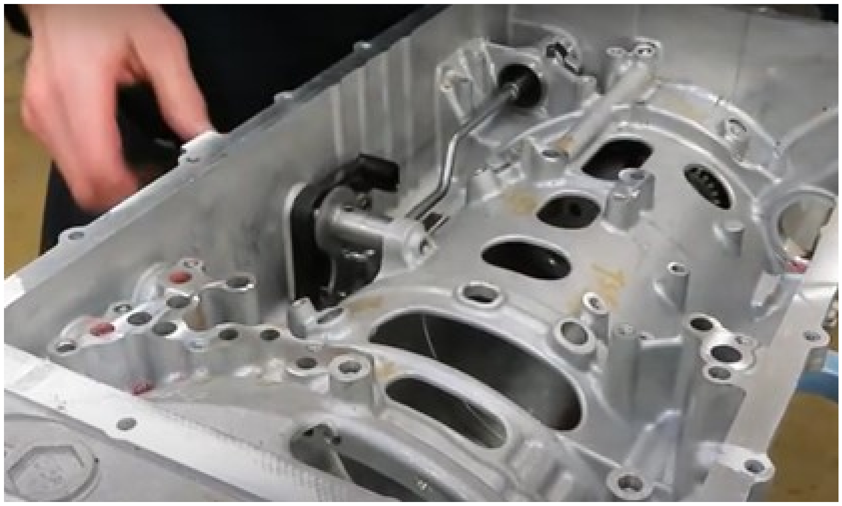

Figure 7

Another TRS type term that Ford uses on its 10R80 is a MLP – Multi lever position switch. It's located inside the transmission but performs the same tasks as a TRS.

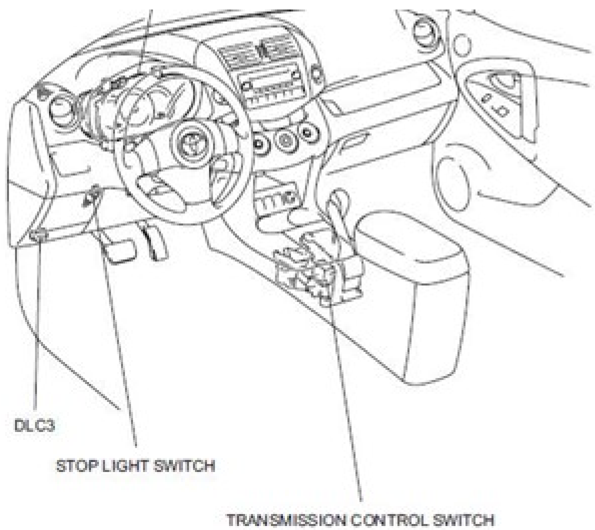

Figure 8

Models

Automatic transmissions and transaxles are identified by model. For example, a 6-speed General Motors Turbo Hyro-Matic **6L90** model number means that the transmission has 6 forward speeds, L is for longitudinal platform/rear wheel drive design, and the 90 is an abbreviation for 900 newton meters of torque capacity. This is the amount of torque the transmission can handle from the engine it is mated with. Additionally, 900 newton meters equates to about 660 lb. ft. of torque.

A popular transaxle model by Ford is their **8F35**. This is an 8 speed, front wheel drive unit that can handle 350 newton meters of torque.

A popular transmission made by ZF and is used by many car manufacturers is their **8HP**. Chrysler, Ram, Jaguar, Jeep, BMW, Audi, Volkswagen, Land Rover, and other manufacturers use this transmission. 8HP stands for 8 speed, Hydraulic converter and Planetary gear set based. ZF stands for *Zahnradfabrik Friedrichshafen*. It is German, and it means *Cogwheel Factory*.

Since 2016, the standard for automatic transmissions in the automotive industry has become 8, 9, and 10 speeds. The reason for this many speeds is to keep the engine operating at lower/efficient RPMs which enables best fuel economy. All transmission and engine design improvements are about improving vehicle *performance, fuel efficiency*, and reducing tailpipe *emissions*. Transmissions play an important role in this effort. More forward gears allow the engine to operate at its most efficient rpm range more often. In fact, this is what CVT, constantly variable transmissions do, and they do it better than traditional automatic transmissions can. CVTs offer numerous gear ratios, however, they don't have the towing capacity that automatics do.

To use the bicycle analogy again, more transmission forward ranges is just like having more speeds on a bicycle. The rider can select the most efficient gear according to the speed and load as he desires, according to the given terrain.

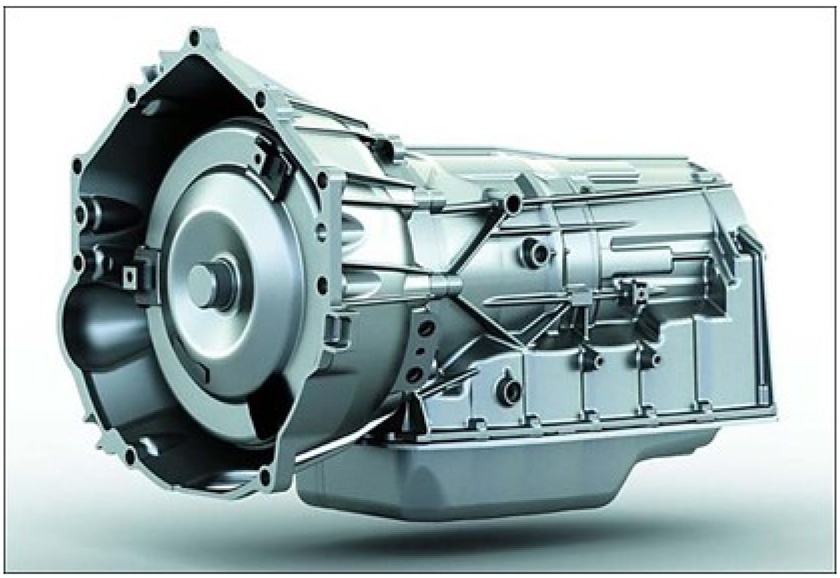

Figure 9

Here's one more transmission model description. Chrysler (Dodge / Ram) developed what is known as their 68RFE. It has 6 forward speeds, has a relative torque rating of 8 (the scale 0-9 and the actual torque capacity of the relative torque rating number is not published extensively), R is for rear wheel drive, and it is Fully Electronic-FE. This transmission typically sits behind the 6.7L diesel in their 2500 (3/4 ton) pick-up trucks made from 2007 – 2021.

Vehicle Platform

Let's explain what the transmission/vehicle **platform** is. Front wheel drive or **FWD** is a configuration platform where the drivetrain sits in the vehicle transverse or side-ways. These transmissions are actually a ***transaxle***. Transaxles are compact, designed for mid-size and small vehicles and are a combination of both a transmission and differential in one housing. In recent years CVT – constantly varying transaxles – have been making their way into the market as well as DCT or dual clutch transaxles. The terms transmission and transaxle are often used interchangeably, but technically, a transaxle is a unit that is comprised of a transmission and differential and sits transverse or sideways in the vehicle.

RWD – rear wheel drive platform vehicles – are what light duty pick-up trucks are. Their transmissions are said to be **longitudinal**, or in line with the vehicle's drive wheels. This platform is where the transmission and the differential are separate units.

A common and incorrect notion is that transmissions produce power. *Engines* produce the power that propels a vehicle, while *transmissions* provide the means for engine torque to reach the drive wheels in a manner that enables the engine to move the vehicle efficiently. Transmission gear ratios are used to modify engine power so that correct speed and torque reach the drive wheels in an effective manner.

Good acceleration requires good torque while high vehicle speeds do not. In regard to ratios, we'll use numbers from a GM 6L90. Low gears, such as 1st and 2nd are high in ratio. For example, a common 1st-gear ratio is 6:1. The higher gears such as 4th, 5th and 6th are low in ratio, 1.15:1, .85:1 and .667:1 respectively. Transmissions do not produce additional power in combination with the engine, they alter engine torque. In reality they consume a small percent of the engine's power due to friction between gears and how power flows from gear to gear inside a transmission.

One last word about transmission/vehicle platforms. The transmission pictured below allows us to see what **transfer gears** are. The three gears and the rear of this transmission are all transfer gears. These gears are necessary in order for power change direction in order to reach the large final drive gears. The yellow-colored arrows portray the flow of power through this transmission.

Note that the top gear is connected to the main shaft of the transmission. The middle transfer gear transmits or sends power to the bottom gear. Lastly the bottom gear is what sends power to the final drive unit of this transmission so that power can be sent to the drive wheels. Transfer gears perform the job of redirecting power flow.

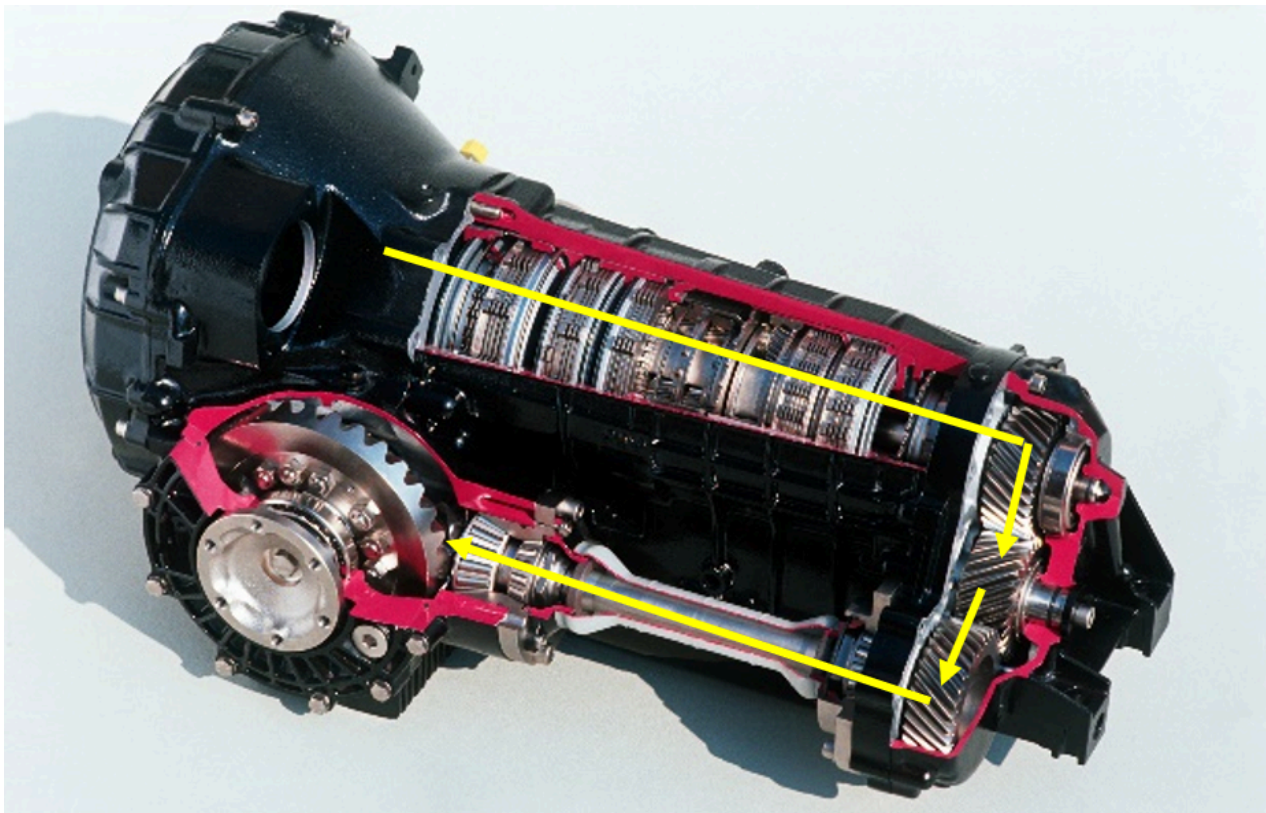

Figure 10

Components of an Automatic Transmission

Let's begin with the **torque converter**. It is located between the transmission and the engine inside an area called the bell housing. A torque converter is a fluid coupling (not a mechanical connection) and contains four main elements: an **impeller**, **turbine**, **stator**, and **clutch** – see Figure 11. A torque converter is the coupling device that engages and disengages engine power to the transmission based upon engine rpm. It delivers engine power to the transmission effectively and smoothly.

A torque converter operates like Figure 12 simulates. Note that the two fans look alike, yet one fan is powered, and the other fan spins as a result of air that is coming from the first fan that is plugged into electrical power.

The fan that is powered represents the half of a torque converter that is bolted directly to an engine's crankshaft, which is the impeller. The fan that is not powered by electricity represents the turbine. The turbine receives fluid force from the impeller. The turbine is connected to the transmission input shaft, which powers the transmission.

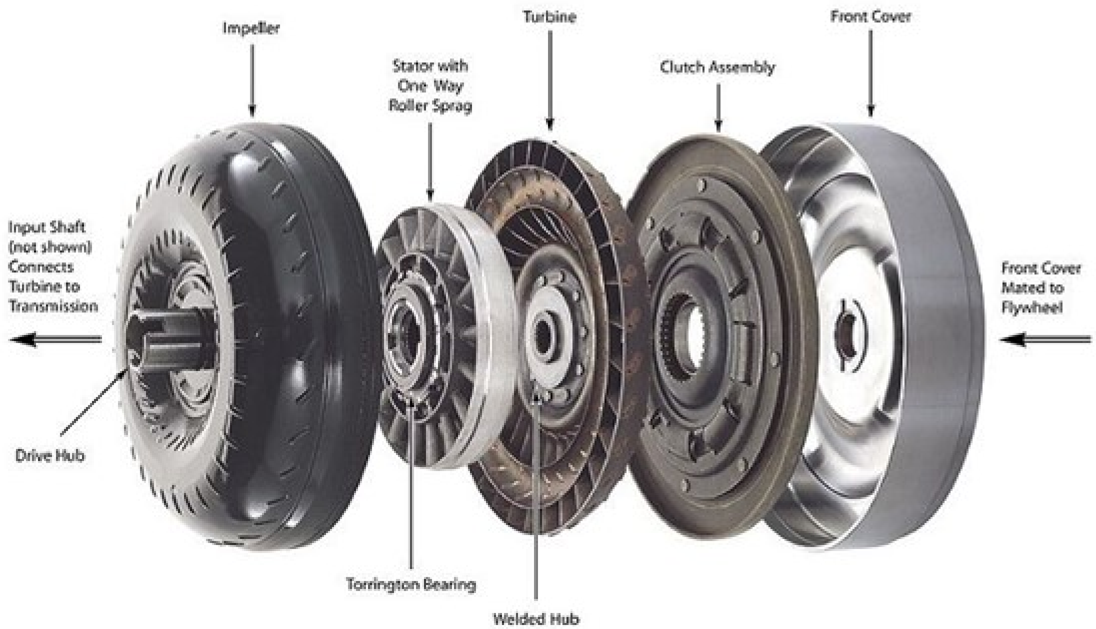

Figure 11

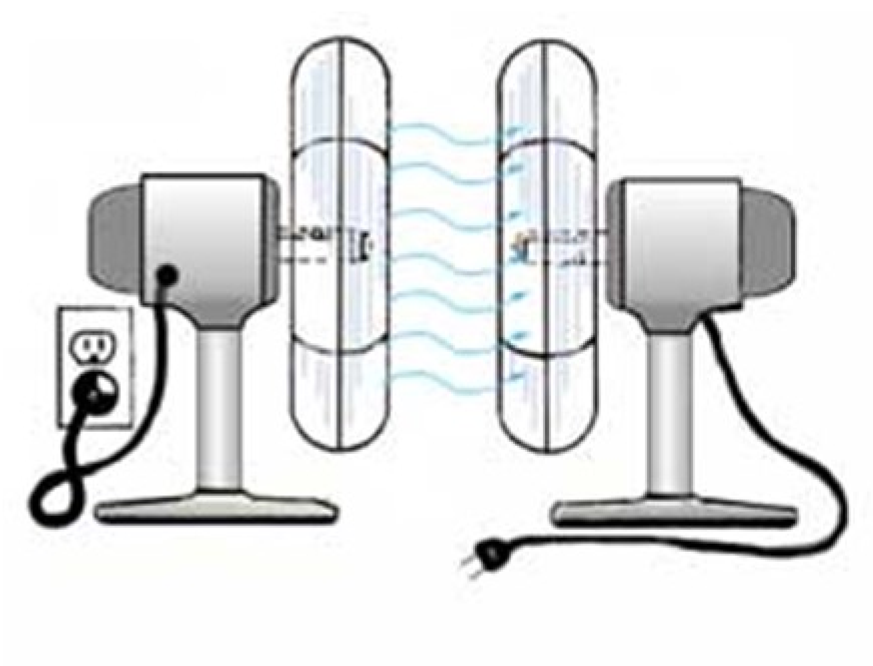

Figure 12

Transmission case – this house all the gears, clutches, a valve body, some of the hydraulic passages of a transmission. It is usually made of aluminum and includes the bell housing where the torque converter resides.

Figure 13

Transmission pump – the pump pressurizes transmission fluid which is used to both propel and operate the transmission. It provides pressurized fluid to the torque converter, to the valve body, to the lubrication circuit, and to the multi-disc clutches.

Figure 14

Figure 15

Valve body – This is a complex component as it contains passages, valves, springs, a pressure control solenoid and the shift and clutch control solenoids. It directs fluid to many of the areas of the transmission. It takes the pressurized fluid from the pump and distributes the fluid, by use of the solenoids and valves, to the clutches, bands, gear sets, torque converter, and so forth. It is the control center of the transmission and is controlled in turn by the TCM.

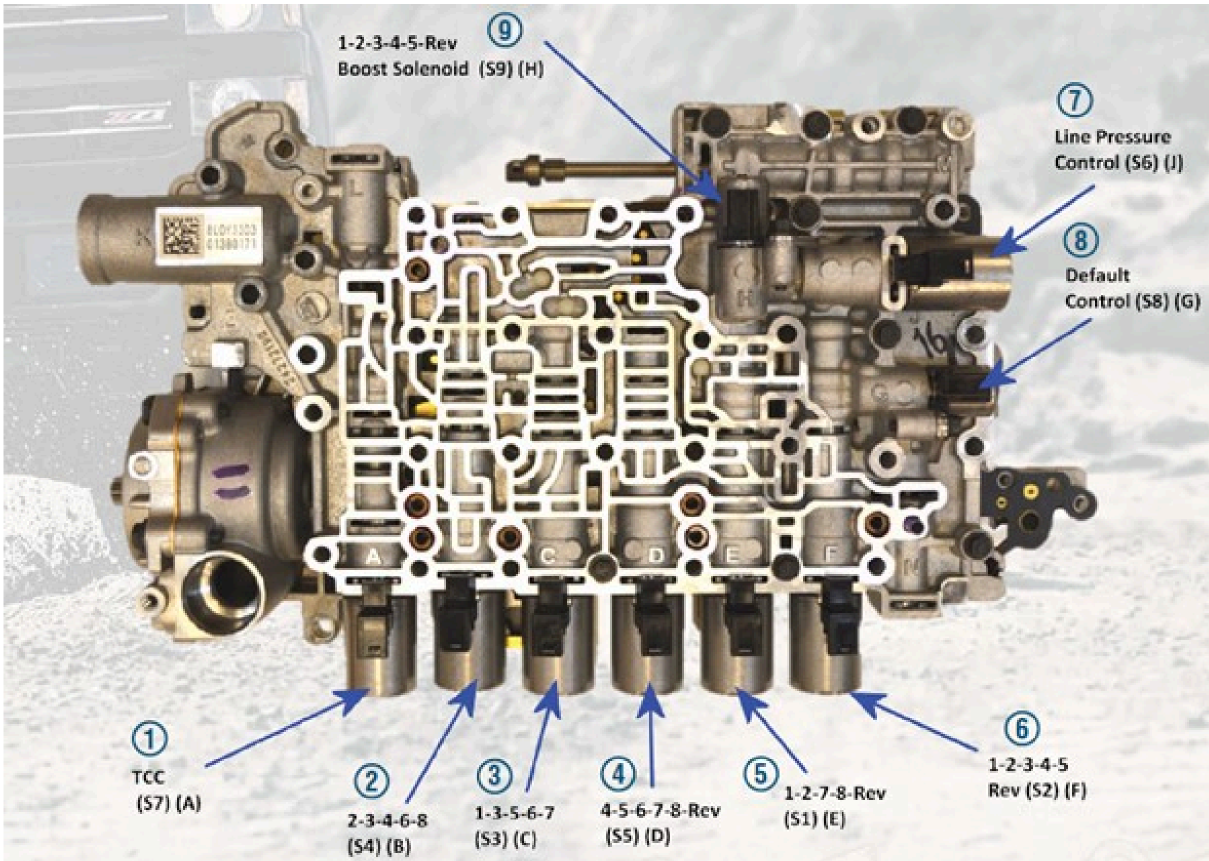

Figure 16

Gears / gear sets – as you are already aware, the gears inside an automatic transmission are of planetary design and are always in mesh with each other. This is why it is not possible to "grind the gears" of an automatic transmission; the gears never come out of mesh/ from being in contact with each other.

A planetary gear set is an amazing configuration of gears where several outcomes can occur from one gear set. All automatic transmissions that have three speeds or more use at least two planetary gear sets. Many of today's (6, 8, 9 and 10 speed) automatic transmissions have three or four gear sets.

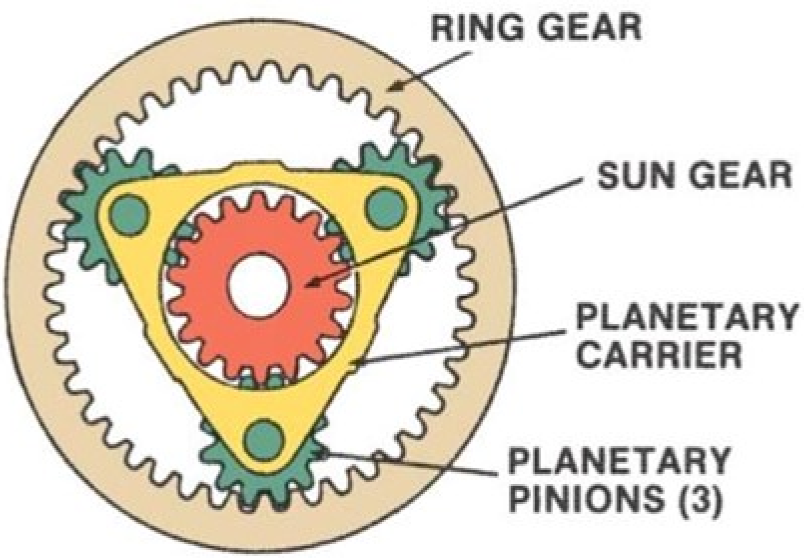

Figure 17

Figure 18

Clutches and bands are the mechanical means by which various gear ratios/speeds are achieved. Figure 19 shows what a band and a clutch drum are, and Figure 20 is what a set of multi-disc clutch plates look like. Both of these drums serve two purposes, they house the clutch plates and piston, and they have a surface for a band to apply against.

For example, in regard to Figure 19, this is from a 4L60E. When this drum is held stationary by the band, with the clutch plates released, 4th gear is the outcome. When the clutch pack is applied and the band released, reverse is the outcome.

Modern transmissions (6-speed and higher) generally do not use bands as they did in the past, therefore their shifting is called “clutch to clutch” shifting, which is easier for programming, plus clutches assemblies tend to be more durable than bands.

Bands are holding or brake type of device, meaning bands are used to hold a planetary gear member stationary. Clutches, on the other hand, can do two things: drive a planetary gear member or hold it stationary.

In order for a planetary gear set to produce an outcome two things must occur. One gear member of a gear set needs to be the input or *driving* member while one of the other gears needs to be *held*. This results in a third gearset member to be the output member. This is how gear ratios or outcomes are achieved.

Figure 19

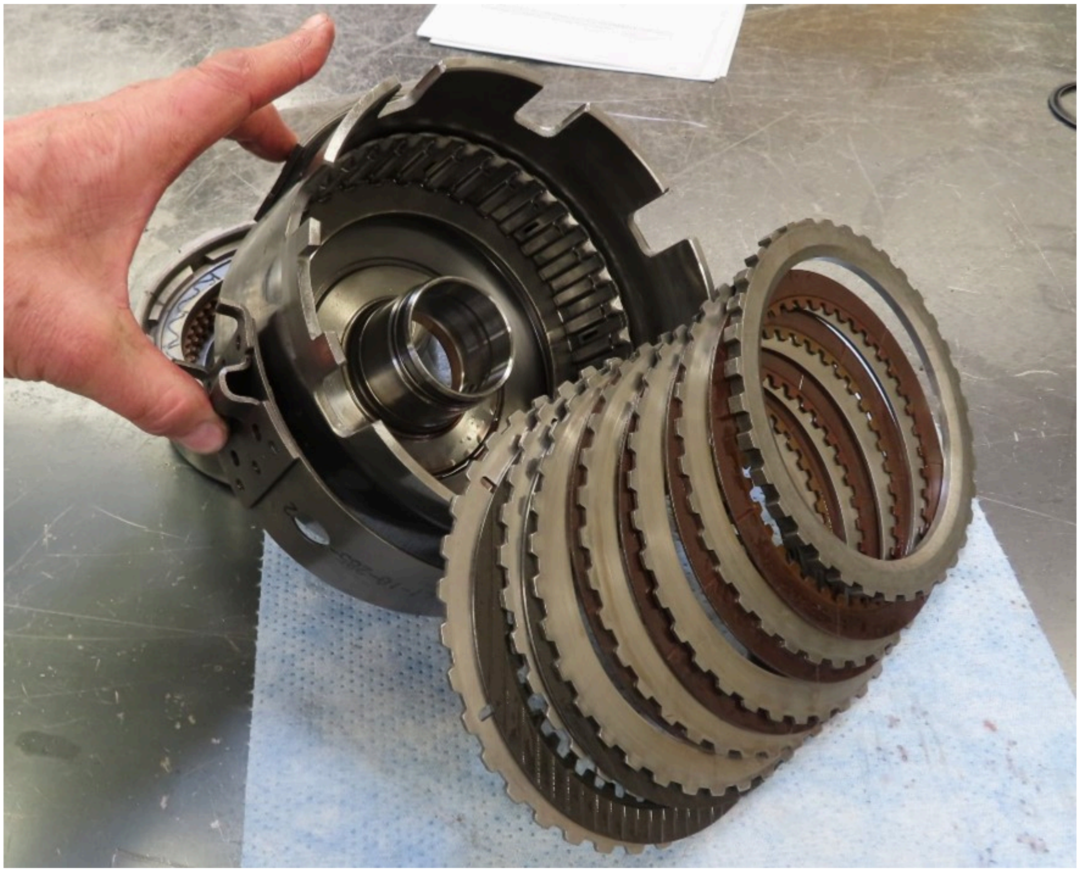

Figure 20

Gear Ratio Terms

Gear ratios were explained in a previous chapter, but let's dive deeper into some gear ratio terminology. The first term is ***underdrive***. Underdrive gear ratios are low gear/high ratio and are used to help get the vehicle moving from a stop or from a slow speed. The next gear term is ***direct drive***. This is simply a ratio of 1:1. Keep in mind that as a transmission shifts from a lower gear to the next higher gear, vehicle speed increases, but as speed increases torque to the wheels decreases. This is a key principle: as vehicle speed increases, less torque is available to the drive wheels, because the drive and the driven gears in the transmission become more similar in size, thus, less leverage is needed to keep the vehicle in motion once it is in motion.

As higher gears are selected, gear ratios are reduced. Referring to Figure 21, first gear has the **highest ratio** of 4.02:1. Third gear on the other hand is a higher gear but is low ratio – 1.53:1. In the case of direct, the drive and driven gears would be identical in size and the ratio would be 1:1. Quite often the 4^{th} gear in many six speed transmissions is direct drive. Figure 21 doesn't offer a true direct drive ratio, but 1.15:1 is very close.

Overdrive is the third term to describe. It means output speed is more than input speed. This six-speed transmission offers two overdrive gears, .85:1 and .67:1 respectively.

To rephrase, low gears have high ratios. They offer good leverage and produce good torque, which helps the vehicle move effectively at low speeds. High gears are of low ratio, but they enable speed increase, which results in less torque, as vehicle speeds increase.

Figure 21

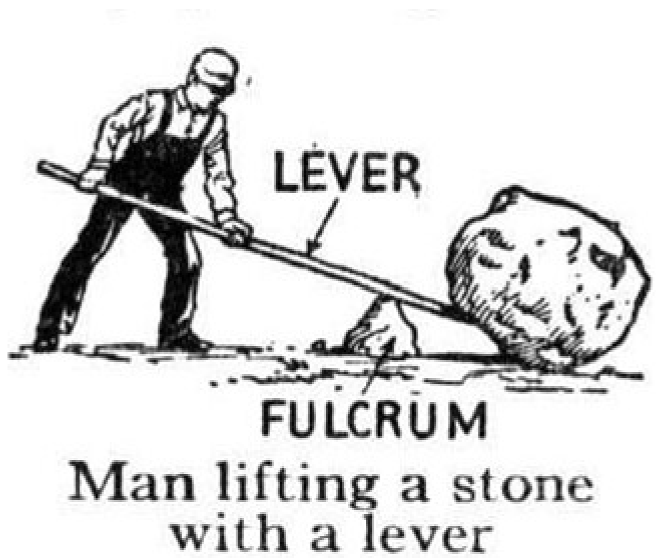

Figure 22

Planetary Gears

Planetary gears are in many ways the heart of a *traditional* automatic transmission. The three gears that make up each planetary gear set inside a transmission are the sun, ring, and planetary pinion gears. The yellow triangle piece in Figure 23 is known as the **planet carrier** or carrier. The carrier supports the gears as a group as they are either held, driven or are the driving input member.

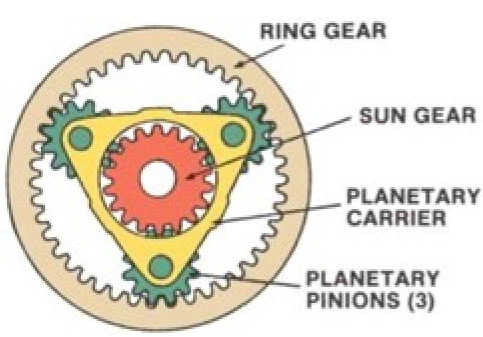

Figure 23

A primary operating principle with planetary gear sets is that in order to have power outcome from the gear set, one gear has to be a drive/input member, a second member has to be held in place (a reactionary member) while the third gearset member is the power output gear.

There are eight possible outcomes relating to planetary gear set operation. The outcomes are:

1. **Neutral**. This is when only one of the principles stated above occurs. In other words, one gear is a driving member but there is not a gear that is held stationary. Therefore, there is no power output.
2. **Reverse**. This occurs whenever the carrier is held stationary and either the sun or the ring is a power input member. Regardless of car manufacturer, the key to achieving reverse is when the carrier is held and when one of the other gears is the power input gear. This forces the third gearset member to act as the power output. There are two possible reverse ratios but only one is a realistic outcome. Here's why:

Let's suggest that the sun gear has 39 teeth, and the ring gear has 71 teeth. The gears/teeth on the planetary carrier do not have to be counted because they will simply function as power transfer gears. Reverse is calculated as if two gears are in mesh with each other, much like what occurs in a manual transmission. The formula to count R-reverse is:

Driven / Drive = ratio

When the sun is the drive gear and the ring is driven: 71 / 39 = 1.82:1 ratio which is a realistic speed reduction ratio.

Let's calculate the opposite possible outcome where the ring gear is the drive gear, and the sun gear is the driven gear. Remember for reverse to occur the **carrier** is held and the planetary gears act as power transfer gears and are not part of the calculation.

Using the same formula: Ratio = Driven / Drive: 39 / 71 = **.55:1** ratio

A ratio of .55:1 is an overdrive ratio and is not useful in a real-world application since moving a vehicle from a stop requires good torque—not high speed.

The point is there are two different reverse possibilities. but only one is realistic.

3. Underdrive. These gear ratios produce good torque but not high speed. As stated earlier, LOW gears like 1st, 2nd, and 3rd gear are higher ratio in ratio. However, to calculate underdrive ratios with planetary gear sets, a different formula is used:

Underdrive = # of teeth on the SUN gear + # of teeth on RING gear

# of teeth on DRIVE gear

Again, let's use 39 and 71 teeth respectively. The planetary gear tooth count is handled in a different manner when it comes to calculating underdrive and overdrive ratios. Just like any planetary gear ratio outcome, there is an input gear and a held gear. The key to underdrive is that the carrier is the output member. To achieve this, we'll use in our example where the sun gear as the drive member, the ring as the held member and the carrier is the output.

Using the above formula, 39 + 71 = 110 / 39 = **2.82:1**

There is another possible underdrive gear ratio. This is when the ring gear is the drive member, and the sun is the held member. Again, the key is that the carrier is the output member. Using the same formula:

Underdrive = # teeth on SUN gear + # teeth on ring

# of teeth on drive gear

39 + 71 = 110 / 71 = **1.55:1 ratio**

Try this video:

If this is all a bit difficult to understand, try this video. It explains these principles visually:
[Planetary Gear Calculation and Operation]

Both of these calculations (2.82:1 and 1.55:1) are realistic ratios, but please consider that by using other ratios the steps or shifts from one gear to the next can be refined thus enabling better outcomes as compared to using only one gear set. This is why transmissions have three or four gear sets, so that all of the sets work together in order to achieve better shifting events.

4. **Direct drive**. This one is easy. Direct drive is achieved when any two of the three gears become locked together. Locking any two of the three gearset member together so long as one of the members is the power input member. With direct drive no one member is held since a locked up gearset causes the entire assembly to rotate as a whole unit thus achieving a ratio of 1:1.

5. **Overdrive**. As with reverse and underdrive, there are two possible overdrive outcomes. The key to overdrive is that the carrier is the **power input** member. Overdrive also has a formula that is quite similar to the underdrive formula:

Overdrive = ________#of teeth on DRIVEN gear______

# of teeth on SUN gear + # of teeth on RING

When the carrier is the input member and when the sun is held, the RING is the driven member. Let's calculate:

71 / 110 = **.65:1 ratio**

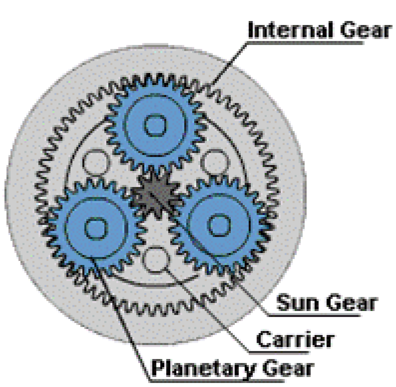

Figure 25

The other overdrive possibility is where the ring is held the carrier is power input, and the sun is the driven member. The calculation is: 39 / 110 = **.35:1 ratio**

In regard to these two overdrive ratios, .65:1 is realistic but .35:1 is not. As stated earlier, this is why more than one gear set is necessary in order to work together to achieve reasonable gear ratios. What will be shown next is how two or more planetary gear sets interact with each other in order achieve useful gear-ratio outcomes. If you didn't watch this video on a previous slide, here is the link once again. It will help you visualize a bit more how gearsets interact with each other in order to achieve final outcomes.

Planetary Gears, Principles of Operation - Part II - Multiple Sets

To recap the eight planetary outcomes just described, consider the following:

- **Neutral** is when no gear is held, but there is a power input gear OR vice versa.
- **Reverse** occurs whenever the **carrier is held** and when either of the other two gears is the power input gear. Also, there are two possible outcome ratios, but only one of these ratios is realistic.
- **Underdrive** also has two possible outcomes. The key to underdrive ratios is to have the carrier as the output member.
- **Direct drive** has one outcome possibility which occurs when any two of the three gears are locked together.
- **Overdrive** is the result whenever the carrier–which is considered the largest of the three gears, is the **power input** gear. It also has two possible outcomes.

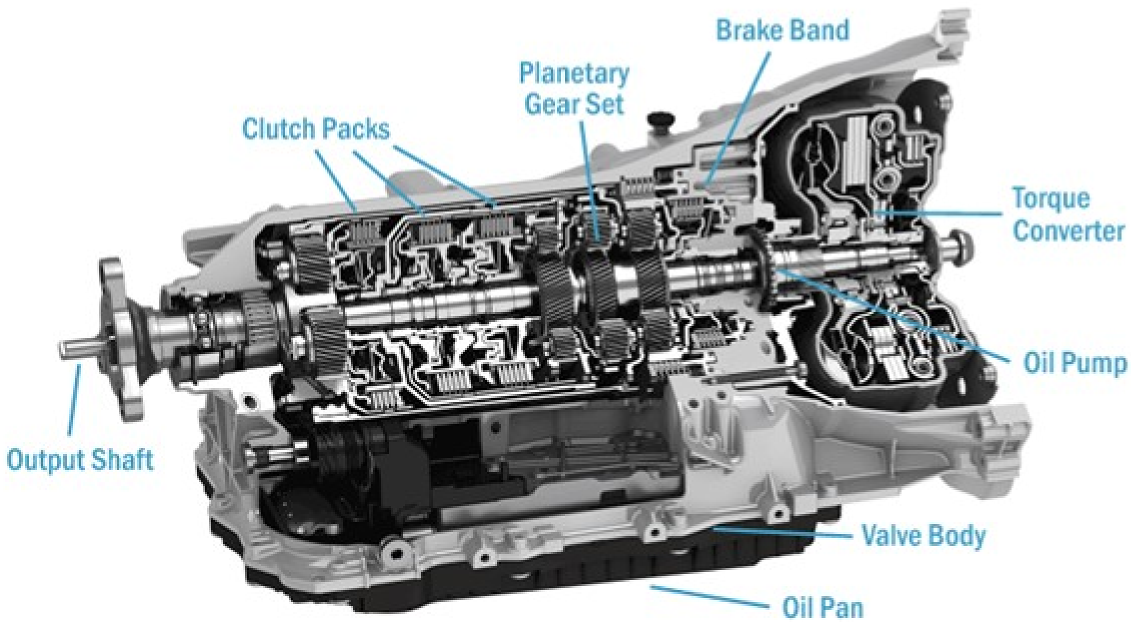

Figure 26

One last thing about gearsets is that there are various configurations. In the automotive world, the following are the most common gearset designs used.

- **Simple**. As figure 27 shows, there is one sun, one set of planets, and one ring gear. This design is commonly used in 8, 9 and 10-speed transmissions.

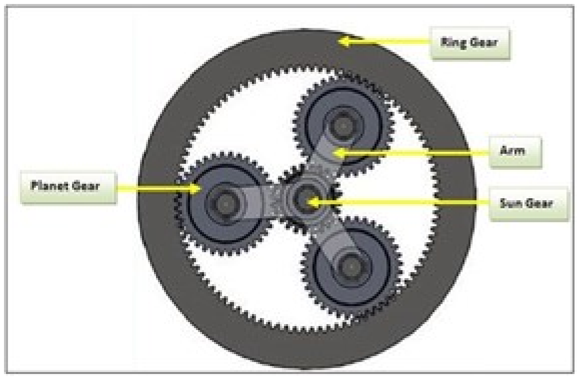

Figure 27

- **Simpson**. As shown in Figure 28, there is one common sun gear, two sets of planets, and two ring gears. This type was used in the three-speed transmission era.

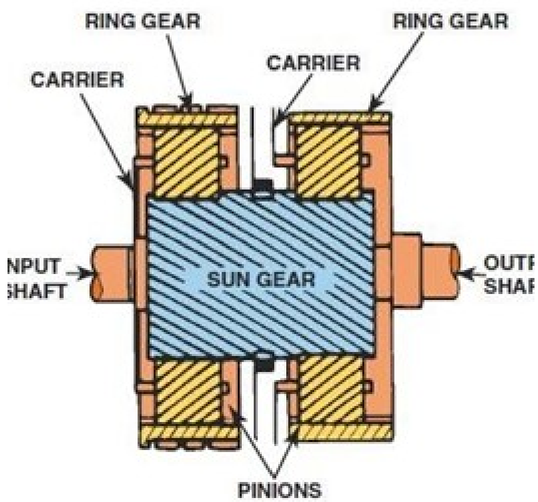

Figure 28

- **Ravigneaux**. As displayed in Figure 29, this design has two planet sets that mesh with each other, two sun gears of different sizes, and one common ring gear. Ravigneaux gearsets are found in some 4-speed but are quite prevalent in 6-speed transmissions.

Figure 29

- **Lepelletier**. As shown in figure 30, Lepelletier gear designs are a combination of both Simple and Ravigneaux. They are used in many 6-speed units.

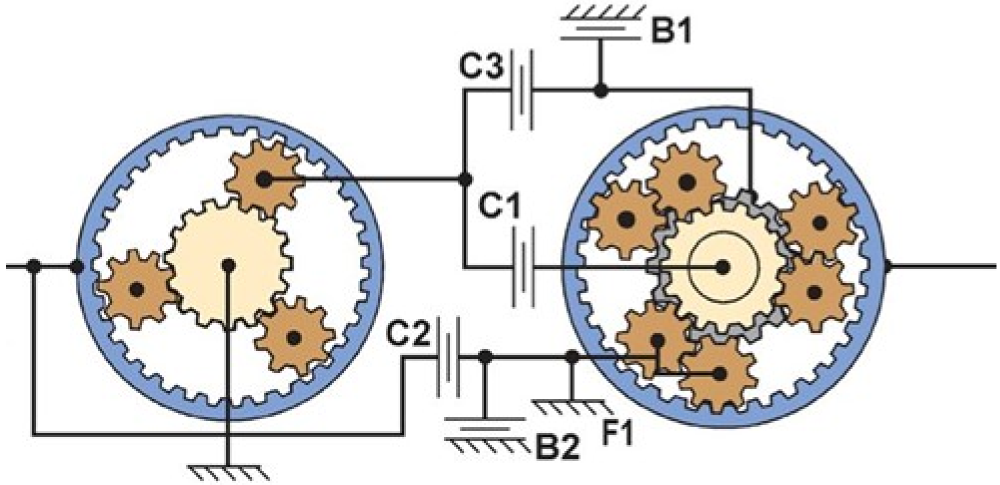

Figure 30

Gear set design enables transmission engineers to obtain desired gear ratio results. Simpson gear sets were popular in 3-speed transmissions several years ago. Today 6, 8, 9 and 10-speed transmissions utilize Simple, Ravigneaux and Lapellitier.

So, how is it that a planetary gear member is either a DRIVING or a HOLDING member? This depends on the clutch assembly's design. This video explains how clutches are used to either **DRIVE** or **HOLD** a gear set member.

Video: AT Clutches and Bands

To recap the video, clutches can be used to either drive or hold a gear, while a band can only be used to hold a gear set member.

Transmission Fluid

Let's now focus on transmission fluid. Why the term transmission "fluid" instead of oil? Transmission oil is considered to be a hydraulic fluid because it is used to propel the vehicle. Transmission fluid serves several purposes. It is used to **hydraulically** apply clutches and bands, **lubricate** gears and bearings, and **cool** or remove heat. Plus, it propels the vehicle due to how it is used inside the torque converter, which is to convey **fluid force** from the impeller to the turbine.

Automotive service professionals need to be keenly aware that there are several different types of automatic transmission fluid. The primary factor in determining what specific transmission fluid is used in a particular transmission is the materials that the clutch linings are made of.

Transmission fluid is engineered to be compatible with certain clutch lining materials so that the friction material will grip the steel plates appropriately. The friction coefficient of both the steel plates and the friction or plates with lining are BIG factors, along with the fluid's characteristics in how contributes to smooth transmission shifting. Manufacturers engineer new or improved lining materials quite often and this, at times, requires a change in fluid viscosity and additives.

Another consideration for smooth shifting is how the shift solenoids pulse width modulate (PWM) fluid to the clutch assemblies.

Figure 31

Automatic transmissions operate according to three principles: **mechanical, hydraulic,** and **electrical**. Clutch assemblies are applied hydraulically by electronic control and the gears are mechanical. The fluid that is inside a transmission is pressurized by the transmission's pump. The pressurized fluid is then directed through small passages to engage the various clutches in order to provide specified gear ratios.

When a transmission's fluid level becomes low, hydraulic components such as clutches and bands will not be able to apply adequately. Another unfortunate result of low fluid is insufficient lubrication for the planetary gears since they get cooled by the same fluid that engages the hydraulic components of a transmission. How this fluid becomes pressurized and used to engage the various clutches and servos is explained in the chapter that describes hydraulic operation.

Whenever transmission fluid levels are low, the transmission can't operate properly. Low fluid levels cause damage to clutches, gears, and the fluid itself. Excessive temperatures cause the fluid to break down and the additives in the fluid to deteriorate. When fluid becomes *thermally damaged* it can't apply the clutches smoothly due to reasons just stated. This can lead to expensive transmission repairs or replacement.

One more insight about transmission fluid is that transmission fluid levels need to be within ½ quart (which is 1 pint or 0.48 liter) of the full line when it is checked. Otherwise, something known as aeration can occur whenever transmission fluid levels are too LOW. Aeration is something to avoid.

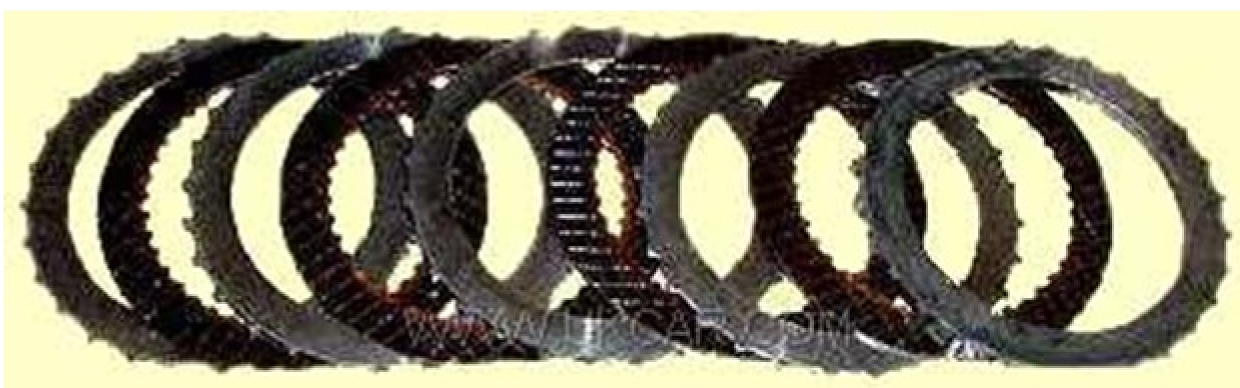

Figure 32

Aeration means the fluid has become mixed with some air. This makes the fluid foamy. This is a problem because air is compressible. This causes the clutches to slip and burn because they can't apply with full force/properly.

Something else to know about aeration is that it can also occur when transmission fluid levels are **too high**. This happens when the gears and other rotating components come in contact with the fluid because there is too much fluid in the transmission. The rotating drums whip air into the fluid, thus aerating it.

It cannot be emphasized enough *that a transmission needs to be filled with the correct **type*** and to the ***correct level** of transmission fluid* in order to function properly. Aerated fluid becomes hot due to the friction that occurs when the clutches slip. The fluid gets hot enough that it turns dark. The fluid can get hot enough that it foams, therefore it can't lubricate, carry away heat from components, etc. Just know that it can be just as harmful to **over-fill** a transmission as it is to allow fluid levels to become **too low**.

Exchanging the old transmission fluid with new or performing a '**flush**' is a topic of debate. For years a common practice was to replace or flush out the old fluid about every 30,000 – 50,000 miles. Many service professionals still believe that the 30,000 – 50,000 flush is still a good practice.

What makes this confusing is that many manufactures state that their transmissions are **sealed** or "filled for life." This isn't altogether true. All transmission fluid levels can be checked and serviced. Please consider the following before taking a position on this issue.

1. Today's fluids are better than the fluids of the past and can last a long time if the vehicle is not driven harshly or is used for heavy towing.
2. Whenever transmission fluid has been overheated it loses some of its properties and color, which impacts its ability to lubricate and to apply clutches appropriately.
3. When fluid gets dirty or overheated, the clutch lining deteriorates causing particulates or debris to be present in the fluid. The fluid then has abrasive material in it which causes wear with transmission components as fluid circulates throughout the transmission.

Figure 33

Clutches and Diagnostics

A few of today's automatic transmissions utilize both hydraulic multi-disc and mechanical clutches. This page will explain the THREE types of mechanical one-way clutches, or OWCs. A fourth type of mechanical clutch, known as a "dog clutch" will also be explored.

There is typically at least one OWC in every automatic transmission. One reason for the use of OWCs is that they take up little space but more importantly they enable the vehicle to coast during deceleration.

The various types of OWCs are **roller, sprag**, and **diode**. The **dog** clutch is of another design. At this point in time, the only transmission model to use a dog clutch is the ZF 9HP. As far as OWC, the three different types that are used are explained in this video.

One Way Clutches

Dog Clutch Demo

As for diagnosis, a fundamental tool to be aware of when diagnosing a transmission problem are application charts. Figure 34 is one such chart, a **clutch application chart**. A chart such as this exists for about every transmission model. This particular clutch application chart is for a General Motors 8L90. For instance, if the 2-3-4-6-8 clutch happened to fail, by deduction we can see that only 1st and reverse would work. Also, there would likely be "engine flare," or engine revving, when the transmission would try to shift into 2nd gear while driving. As you might guess, during an engine flare, there would be no vehicle propulsion. Some folks describe this condition as a "neutraling out," since the shift event failed to occur. Additionally, a 'gear ratio error' related DTC would be stored in the control module. This kind of chart helps service professionals deduce which clutch may be at fault.

Range	Gear	1-3-5-6-7 Clutch	4-5-6-7-8 Reverse Clutch	2-3-4-6-8 Clutch	1-2-7-8 Reverse Clutch	1-2-3-4-5 Reverse Clutch
Park	P				Applied**	Applied**
Reverse	R		Applied		Applied	Applied
Neutral	N				Applied**	Applied**
Drive	1st	Applied			Applied	Applied
	2nd			Applied	Applied	Applied
	3rd	Applied		Applied		Applied
	4th		Applied	Applied		Applied
	5th	Applied	Applied			Applied
	6th	Applied	Applied	Applied		
	7th	Applied	Applied		Applied	
	8th		Applied	Applied	Applied	

**= Applied with no output load.

Figure 34

Something else to notice is, both the 1-2-7-8-Reverse and the 1-2-3-4-5-Reverse clutches are applied when in **Park**. These clutches are applied during Park in preparation for a third clutch to apply depending on whether the driver selects **Drive** or **Reverse**. If Reverse is selected, the 4-5-6-7-8-Reverse clutch will also apply in order to create the desired range of Reverse.

If you study this clutch chart, you will note that every gear requires three clutches to apply. For example, when Drive is selected, the third clutch to apply is the 1-3-5-6-7 clutch. If reverse is selected the 4-5-6-7-8-Reverse clutch will apply along with the 1-2-7-8-Reverse and the 1-2-3-4-5-Reverse clutches.

To clarify, every gear range requires three different clutches to apply in order for vehicle propulsion to occur. If any one of the clutch assemblies happen to fail, particular gears will not work.

Using the clutch apply chart in Figure 34 again, let's try another example. If the 1-2-7-8 Reverse clutch were to fail, the symptoms would be no vehicle movement in either Drive or Reverse, plus there would likely be related DTCs stored in the control module. Using a clutch application chart can be of help to service professionals in determining the cause of a transmission problem. Diagnosis isn't always this easy, but as explained a chart like this is a good place to start.

Consider one last example. In order for 3rd gear to work all of the clutches that have a 3 in their description need to be operational. This includes the 1-3-5-6-7, the 2-3-4-6-8 and the 1-2-3-4-5 Reverse clutches.

There is a second type of diagnostic chart known as a **solenoid application chart (Figure 35**). If the symptoms of a transmission problem don't match up with a clutch application chart, try using a solenoid chart. These charts work just like a clutch application chart. As with any diagnostic situation, performing a visual inspection, looking for DTCs, and TSBs (technical service bulletins), as well as using these charts is a great approach when trying to understand the real cause of a transmission issue.

Let's consider two different examples of using this 8L90 solenoid chart. First, if **S9** (or solenoid 9) on the valve body failed, the driving symptom would be no 6th, 7th and 8th gears. All other gear ranges, including reverse, would operate. Second, if **S5** failed, the vehicle would not have reverse and only 1st, 2nd and 3rd would work.

Range	Gear	S1 (NH) 1-2-7-8 Reverse	S2 (NL) 1-2-3-4-5 Reverse	S3 (NL) 1-3-5-6-7	S4 (NH) 2-3-4-6-8	S5 (NH) 4-5-6-7-8 Reverse	S7 (NL) TCC	S8 (NC) Default Control	S9 (NC) 1-2-3-4-5
Park	P	On	On	Off	Off	Off	Off	Off	Off
Reverse	R	On	On	Off	Off	On	Off	Off	Off
Neutral	N	On	On	Off	Off	Off	Off	Off	Off
Drive	1st	On	On	On	Off	Off	On°	Off/On	Off
	2nd	On	On	Off	On	Off	On°	Off/On	Off
	3rd	Off	On	On	On	Off	On°	Off*	Off
	4th	Off	On	Off	On	On	On°	Off*	Off
	5th	Off	On	On	Off	On	On°	Off*	Off
	6th	Off	Off	On	On	On	On°	Off*	On
	7th	On	Off	On	Off	On	On°	Off*	On
	8th	On	Off	Off	On	On	On°	Off*	On

NOTE: On = Solenoid control port pressurized.

NOTE: Off = Solenoid control port not pressurized.

Off/On = soleinoid control port is not pressurized at low speed in 1st gear, solenoid control port is pressurized at high speed in 1st gear.

On/Off = soleinoid control port is pressurized at low speed in 2nd gear, solenoid control port is not pressurized at high speed in 2nd gear.

* = Default valve is hydraulically latched in the stroked position in this state, default solenoid can be commanded on for lube override.

° = The TCC may apply from 1st through 8th gear depending upon shift condition determined by the TCM

Figure 35

In regard to "**failsafe**" mode, you may remember that this is a mode of operation where there may be only one forward gear and reverse. The GM 8L90 failsafe or default gear is 2nd gear. You will know that you are in failsafe mode whenever the transmission will not upshift, in other words it will stay in one gear and reverse will be available.

Clutch application and solenoid charts, DTCs, TSBs all are part of the SEVEN STEP diagnostic process when diagnosing transmission problems. Failsafe mode occurs when the TCM recognizes a problem serious enough that it goes into a self-protection mode OR when there is a power loss problem to the TCM. Here are a few more examples of various manufacturer failsafe operating modes by transmission model.

- Dodge Ram's **68RFE**. Dodge refers to their failsafe mode as "**Limp-in**" mode. When the transmission shift lever is in "Drive" position, the transmission will default to 4th gear when in Limp-in mode. If the shift lever is moved to "2" or "L" position while in default mode, the transmission will go into and stay in 2nd gear. This allows the driver to manually shift the transmission from 2nd to 4th in order to get home with good speed.
- Ford's **10R80** & GM's **10L80** transmissions do NOT have a failsafe mode. In other words, when there is a serious transmission problem there is no default gear, not even reverse. The vehicle will have to be towed. There are a few TSB's that describe some of the reasons that this transmission may not engage but once again, there is no default gear with these transmissions.
- **ZF's 8HP** is a bit more complicated. When there is a power loss to the transmission control module, the unit enters a default mode dependent on the current state of the vehicle. When no power can reach the solenoids, hydraulic line pressure defaults to high. If the vehicle is in Drive when the error occurred, it defaults into 6th gear. If the power loss occurs when the vehicle is in Park, Reverse or Neutral, the vehicle will default to Park and stay in Park.

As just presented, various transmission models have their own default mode limits.

Leaks

Leaks are a big concern with transmissions, as they are with engines. The most common leak areas with transmissions are the pan, axle seals or a drive line seal, and cooler lines—the lines that carry transmission fluid to the transmission cooler.

Avoid using stop leak additives. These additives do not fix leaks. They instead add debris to the fluid, which can shorten transmission life since the debris clogs critical passageways. Stop leak products for radiators have no lasting value. When there is a leak, get it fixed right and soon. Preventative maintenance is always cheaper in the end as compared to putting off a need repair. In fact, the primary reason for transmission and engine failure is often due to leaks that were neglected.

Over tightening transmission pan bolts is one possible reason for a leaking pan gasket. Know the proper bolt torque when replacing the pan bolts. Over-tightening will bend the areas of the pan around the bolt holes. Additionally, never use two gaskets (double gasket) on a pan when trying to stop a leak. This doesn't work. Ensure that the pan rail (where the bolt holes are) is flat or replace the pan, then tighten these bolts to specification.

Cork gaskets are low quality and should be avoided. Many transmissions today utilize "**reusable**" gaskets **(Figure 36)**. These have proven to be quite reliable over the years and they can be reused as their names indicate. They have raised rubber rib and steel collars around the bolt holes.

Figure 36

Figure 37

Conclusion

Not everyone in the automotive industry understands automatic transmissions, especially their operating principles. Those who do understand them have an advantage in that they can better comprehend the entire vehicle and how all vehicle systems operate together.

Having a foundation of planetary gear set outcomes is valuable to those learning about transmissions. It is also important to know that automatic shifting is reliant on three primary sensors or inputs. Sensors that can determine engine load (MAP or a MAF), vehicle speed (VSS) and throttle angle (TPS).

One foundational diagnostic practice that was explained is that transmission related DTCs are third in priority if U codes, and engine performance codes are present. This is an important concept because U codes/network codes are to be addressed first in most every diagnostic scenario.

Both clutch and solenoid application charts are valuable to service technicians whenever dealing with a transmission concern. Additionally, automatic transmissions have a default option, or **failsafe mode**, in the event the TCM either loses power or the TCM thinks there is a serious enough issue that it needs to enter such a mode.

The importance of maintaining correct fluid level and using the correct fluid is essential for good transmission operation and service life. Experienced automotive professionals need to become familiar with fluid level inspection procedures. These procedures will be emphasized in a future chapter as well as in the laboratory segment of this class.

Lastly, torque converters were introduced. They were not covered in depth, but they are a major component to consider since they transfer engine torque to the transmission in an effective way. Many do not understand how they operate. Their make-up and operating principles are addressed in another chapter. For a review of torque converter operation, watch from 1:00-5:00 of the video in Figure 39, Enjoy.

Torque Converter Explained

Chapter Review:

Read through the following bullet points to check your understanding of the concepts that were introduced in this chapter.

- What kind of gears are the base of a traditional automatic transmission?
- What does TCM stand for? What does it do? Where is it located?
- When do you address transmission DTCs? Which codes do you address first?
- Can you list the three primary inputs or sensors that enable transmission shifting?
- Can you list three sensors that are secondary to the transmission shift schedule?
- Can you define these transmission model designations: 8F35 & 10R80?
- What four elements are inside a torque converter?
- Where is most of the heat of an automatic transmission generated?
- Define the following terms: longitudinal transmission, transaxle, and transfer gears.
- What main transmission component is the Control Center of the transmission?
- In order for a planetary gearset to create an output or ratio, what two things need to happen?
- What is used to either hold or drive a planetary gearset member?
- When are clutch application and solenoid application charts valuable?
- Why are there so many types of transmission fluid types?