

Differences within the 4R70W and AODE Family

There are several other items about the transmission worth noting.

Torque Converters and Flexplates

The 4R70W has two different diameter torque converters that are produced in production, a 12" diameter and an 11" diameter. Aside from a higher stall speed, the 11" converter uses a slightly smaller bolt pattern where it bolts to the flexplate. Unlike GM flexplates, the Ford flexplate only has one set of holes, so to change to this smaller torque converter you must also change the flexplate. The smaller torque converter is/was used on all Mark 8's, 1996 to present 4.6L Mustangs, and 1999 to present police cars. Note: The 1999 and newer Mustangs have 8 bolts holding the flexplate on to the crankshaft instead of 6 bolts like the other 4.6L's.

The following chart is for 4.6L and 5.4L engines only.

	12" Torque Converter Pattern	11" Torque Converter Pattern
6 Bolt Crankshaft	F6AZ-6375-BA	F3LY-6375-A
8 Bolt Crankshaft*	F6AZ-6375-DA	XR3Z-6375-EA

**All Cobra and Windsor built engines have 8 bolt crankshafts.*

Remember, since the 11" converter uses a different bolt pattern it needs a different flexplate, and no such flexplate exists for a 3.8L, 4.2L or 5.0L engine. For Reference the 5.0L flexplate part number is below.

5.0L Flexplate -- E2AZ-6375-A

While we are talking about torque converters, there is another advantage of using the 11" converter over a 12" converter. The 12" converter is only good to around 5400 RPM maximum. Beyond this, the torque converter starts to balloon. This is where the converter actually grows out along the axis that it is spinning on. If it balloons enough, a thrust washer will fall out, causing catastrophic failure. This is why most of your rev limiters are set as low as they are, to protect against this problem. The 11" converter is good to 6500 RPM.

There are actually 4 different torque converters that have been used in production. As mentioned above there are two different diameters, but beyond that, there are differences in stall speed and torque multiplication. The chart below shows a brief summary of what torque converters went in what cars.

Application	Size	K Factor	Torque Multiplication
All 4R70W Super Coupes	12"	110K	1.95 T/R
All 3.8L N/A T-Birds & All 4.6L T-Birds	12"	140K	2.25 T/R
All 5.0L and most 3.8L Mustangs	12"	165K	2.40 T/R
All Mark 8's & 1996 to present 4.6L Mustangs	11"	155K	2.40 T/R

The "K" factor is what a torque converter is really rated in, not stall speed. The more torque you put into a torque converter the higher the stall speed. For those who like math, $K = N/\sqrt{T}$, or the K factor is equal to the engine speed over the square root of the torque. Knowing this, you can calculate a new stall speed using one of these converters, if you know the K factor of your current torque converter and it's stall speed. (You must check the stall speed in a forward gear; in reverse the K factor is lower). The torque multiplication is the amount the torque is multiplied when launching the car, not when it's moving, but when you are coming off the line.

For Example, if you have a Super Coupe, you can use the above equation to calculate the torque at stall, if you know the stall speed. Lets say the stall speed is 1500 rpm. Solving for torque, $T = N^2/K^2$, or for this example, $1500^2 / 110^2$ or 186 ft-lb. Assuming the torque is the same at a higher rpm (which it's not, but we know it's higher so the new stall speed will be at least this speed). Now lets say you put in a 165 K converter and want to know your new stall speed. The new stall speed equals K times the square root of the torque, or, $K * \sqrt{T}$, or $165 * 186^{1/2}$ or 2250. With the 750 rpm increase in speed, the torque will go up as well, so the actual stall speed will be even higher.

The following is a table if you want to use a production torque converter.

	Part Number
12" 110K	XL3Z-7902-AARM
12" 140K	F8AZ-7902-AARM
12" 165K	F85Z-7902-AARM
11" 155K	F8LZ-7902-BARM

If you have a transmission built before 11/94, you'll want to update to one of the above torque converters. Early in the 1995 model year the diameter of the friction material inside the torque converter was increased. This increased the clutch capacity from about 290 ft-lbs to around 375 ft-lbs. If you combine this with the changes made in the main control in 1999, the clutch capacity of the 12" torque converter is 400 ft-lbs. The exception are 4R70W equipped Supercoups. All the torque converter clutches in Supercoups were the larger diameter.

If your engine makes more than 400 ft-lbs, and you intend to lock the torque converter clutch at WOT, you'll need an aftermarket torque converter. Pro-Torque makes a torque converter clutch that adds more surface area than the stock clutch, and eliminates the grooves in the friction material. This clutch is good for about 600 ft-lbs if combined with a 1999 main control.

Cases

AODE's and 4R70W's come with two different cases. The only difference is the bellhousing pattern on the case. 3.8L, 4.2L and 5.0L engines use one case and the 4.6L and 5.4L's use a different case. Also, in 1996 the alignment pins for the main control changed diameters, they got smaller, so the holes these line up in the case changed as well. There are no more service main controls of the larger pin size so you'll need the special service kit to install a newer, small pin, main control, in a 1995 or older case. (See TSB #97-16-7)

Beyond the differences in the bellhousing patterns, the case changed during the 1995 model year and the 1997 model year. Several of the passages were reinforced to add strength the case walls during the 1995 model year, and at the start of 1997 model year, all 4.6L and 5.4L cases had the exhaust passage for the forward clutch relocated to provide more consistent exhausting of the forward clutch.

Main Transmission Connector

Beginning with the 1998 model year, a different pin arrangement was used in the main connector on the transmission (the one at the passenger side rear). Even though the connector is the same, and you can plug them in, you cannot put a 1998 and beyond transmission in a 1997 and prior vehicle (or vice versa) without re-arranging all the pins in the connector, the transmission will NOT shift.

Manual Lever Position Sensor (M.L.P.S.)

There also was a change to the sensor on the driver's side of the transmission that senses where you have put the gear selector. All 1997 and beyond Mark 8's and all 4R70W's starting in 1998 went to a totally different sensor. They do not interchange, the hardware in the EEC is different to support the newer sensor. You must keep the sensor that your car came with if you are thinking of swapping in a newer transmission.

Shifter Pattern

AODE's and 4R70W's came with two different shifter patterns. All 1992 AODE's (only built in Town Cars and Crown Vic's) have a P-R-N-OD-D-1 pattern (as well as all AOD's have this) and all 1993 and newer AODE's and 4R70W's have a P-R-N-OD-2-1 and a button. The OD-2-1 shifter allows manual selection of all gears. In addition, it allows the driver to start out in 2nd gear by placing the shifter in the 2 position. The OD-D-1 shifters have a different main control to allow this configuration. They do not have the ability to start and hold in 2nd gear. I will discuss manual shifting the transmission later.

Transmission Operation

(very technical)

Now I want to go over the operation of the transmission.

When you put the car in 1st gear, overdrive of drive range, the forward clutch comes on and the low one-way clutch (located at the front of the planetary gear set) locks, holding the planetary carrier from spinning. Power to the output shaft is transmitted via the following path; with the forward clutch applied, torque is transmitted to the forward sun gear (it is splined to the forward clutch friction plates, so when the clutch is on it has power, when it's off, it does not). This drives the short pinions in the planetary set, the short pinions drive the long pinions (again in the planetary set) and the long pinions drive the ring gear. The ring gear is splined to the output shaft.

When you make a 1-2 shift, the intermediate clutch applies and the intermediate one-way clutch locks, while the low one-way clutch over runs (a one way clutch is just that, it will spin in one direction, but lock in the other direction). One half of the intermediate clutch is splined to the case and the other half to the intermediate one-way clutch, which is attached to the reverse sun gear. When the intermediate clutch applies this locks the reverse sun gear and keeps it from moving. The reverse sun gear drives the long pinions in the planetary. With the forward clutch still driving the long pinions and the reverse sun gear locked, the long pinions still drive the short pinions, but they are forced to roll around the reverse sun gear. Again, the long pinions drive the ring gear, which drive the output shaft. This creates 2nd gear.

When you make a 2-3 shift the direct clutch applies and the intermediate one-way clutch over runs. One side of the direct clutch is attached to the forward clutch cylinder via the short shaft in the middle of the transmission, or stub shaft (this is the input shaft). The other side of the direct clutch is attached to the carrier (or housing) of the planetary carrier. So when the direct clutch applies it forces the planetary carrier to spin input shaft speed. Also, the forward clutch is still applied driving the forward sun gear, and hence the short pinions, at input shaft speed as well. These two elements, when applied, essentially force the gear set to lock up so it can't spin. This then forces the ring gear speed to be the same as the input shaft speed, or a ratio of 1:1.

Finally, on a 3-4 shift the overdrive band applies AND the forward clutch releases. (This will be a long point of discussion later) With the direct clutch still applied and driving the carrier the OD band locks the reverse sun gear (just like in 2nd gear, but this time a band is used rather than a clutch). This forces the direct clutch to roll the long pinions and the carrier around the reverse sun gear, which then drives the ring gear, which drives the output shaft.

There are a few other cases worth talking about. If you recall, a one-way clutch holds in one direction and spins in the other direction. The locking feature of a one-way clutch only works if the input speed is greater than the output speed, or, you are power on (into the throttle). In overdrive or drive range, the low one way clutch holds in 1st gear as long as you are power on. If you were to go to closed throttle, and stay in 1st gear, the engine will return to idle. To allow for coast braking in manual low, the reverse band applies which locks the planetary carrier to the case just like the one-way clutch in overdrive or drive range. In manual 2nd, the OD band applies to lock the reverse sun gear and allow coast braking.

The above explanation on the function of the transmission is pretty technical. Here is a very quick summary.

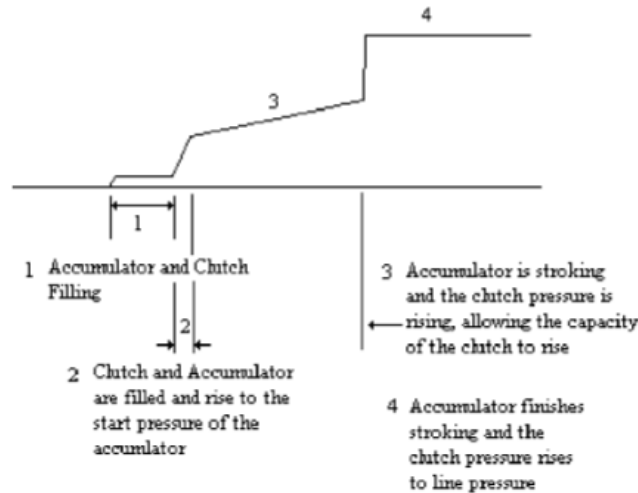
- 1st Gear, the forward clutch is applied
- 2nd Gear, the intermediate clutch applies
- 3rd Gear, the direct clutch applies
- 4th Gear, the OD band applies AND the forward clutch releases.
- Manual 1st Gear, forward clutch and reverse band apply
- Manual 2nd Gear, OD band applies

This is the part you need to know. The rest was for people that really want all the details.

How the Main Control - or Valve Body Works

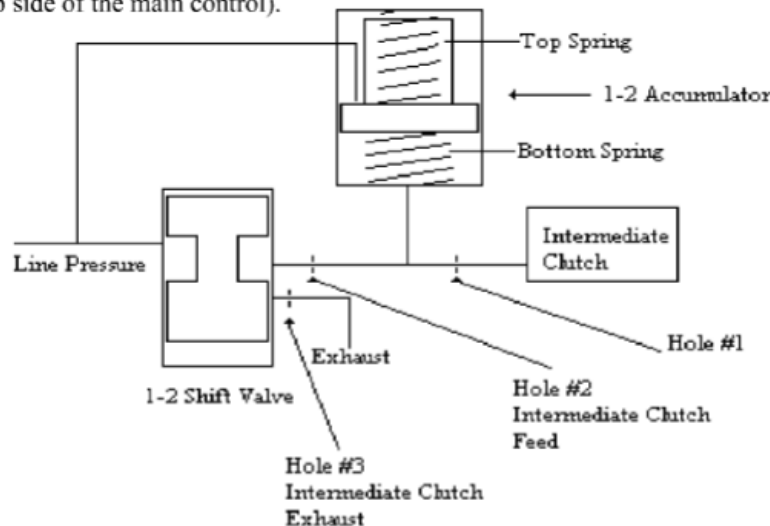
The main control on the 4R70W is very simple compared to other transmissions. It has two shift solenoids that operate on 3 shift valves to achieve 4 forward and one reverse gear. In addition it has one Pulse Width Modulated, or PWM, solenoid that controls the torque converter. I will go through a simple explanation as to how the main control works. Before I do this, first I need to explain how an accumulator works.

An accumulator is a device that controls the pressure to an on coming element. In the case of the 4R70W, there is a 1-2 and a 2-3 accumulator that controls the intermediate and direct clutch pressures respectively. If the oncoming element went directly from 0 psi to line pressure, it would come on very, very firm, eventually causing transmission and driveline failures. What the accumulator and springs do is to allow a lower start pressure and a ramp up of line pressure to the clutch. This softens the apply. The rate at which the accumulator allows pressure to rise is controlled by its springs. The diagram below shows how an accumulator works. At point 1, the clutch and accumulator are filling. When they are filled, the clutch and accumulator pressure rises to the start pressure of the accumulator stroke, point 2. During 3, the accumulator is rising in pressure allowing the clutch to apply softly. And finally, at point 4, the accumulator has finished stroking and the clutch pressure rises to line pressure.



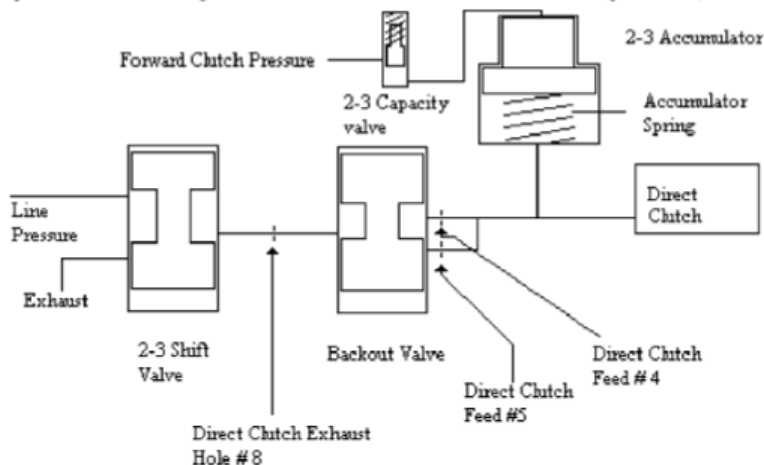
I could get into much more detail, but this is enough for what is being explained.

Now, in 1st gear, shift solenoid #1 (from now on called SS1) is on and SS2 (shift solenoid #2) is off. When a 1-2 shift is commanded SS1 goes off thus moving the 1-2 shift valve to the up position as shown below. This then allows line pressure to feed to the intermediate clutch and its accumulator through a small hole in the separator plate (hole #2), or it's feed orifice (the plate with all the holes on the top side of the main control).



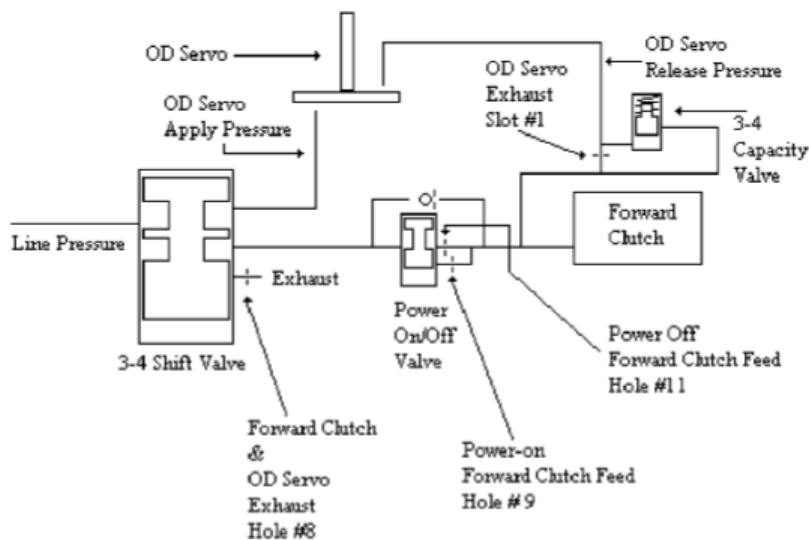
On a 2-1 downshift the 1-2 shift valve moves back down in the picture above, and this blocks the line pressure feed to the clutch and opens the clutch up to exhaust, hole #3.

On a 2-3 shift, SS2 goes on. This moves the 2-3 shift valve and allows the direct clutch and its accumulator to be fed through its feed orifice. There are two feeds to the direct clutch; the one that's used depends on how high TV pressure is. The backout valve shuttles at about 12 TV, switching the feed orifices from #4 to #5. Rather than have a top spring on the 2-3 accumulator, a capacity valve is used. This allows the pressure on the top of the accumulator to rise above line pressure; the amount that it rises depends on the spring load.



For a 3-2 shift, the shift valve shuttles back and then allows the direct clutch to exhaust through hole #8.

The OD band does not have an accumulator like the intermediate and direct clutches. It uses a cushion spring in the servo that has a very high rate to slow down the apply of the band. On the 3-4 shifts, SS1 turns on. Both SS1 and SS2 operate on the 3-4 shift valve and it needs pressure from both solenoids to move the valve. This then allows the OD band to apply and the forward clutch to exhaust.



The apply side of the band is fed through a large hole. The rate at which the servo is applied is controlled by how quickly it is exhausted. The servo exhausts through the 3-4 capacity valve. When pressure is above the spring load in the valve, it exhausts the servo through a hole, when it's below this pressure, the servo exhausts through a slot cut in the gasket, slot #1. The OD servo and forward clutch both exhaust through hole #8.

On a 4-3 shift the forward clutch must come back on, and there is a hole in the separator plate that controls this as well. If you are power on doing a 4-3 shift, you feed through holes #9 and #11. If you are doing a 4-3 coastdown or engagement, you feed through only hole #11.

The above may seem pretty simple but it will help in understanding later when we talk about modifying the main control of the transmission.

Common Problems

Now I want to go over some common problems, causes and solutions. This is by no means a completely comprehensive list of the problems, but I've worked on these transmissions for over 10 years and seen almost everything. I'll do my best to separate the models and model years that could have the problem.

1-2 Accumulator (see TSB# 97-11-11)

I don't think I need to say too much on this since there is a lot of good information out there already. But...

Symptom?

A very late 1-2 shift or no 1-2 shift. A shudder on the 1-2 shift.

What Models?

All AODE's and 4R70W's built until the start of the 1998 model year.

Problem?

All have a cast aluminum 1-2 accumulator with rubber O-rings to seal it. With time, the rubber wears away and creates a leak.

Solution?

Replace with new molded rubber piece with new springs. Don't worry about case scuffing, just buff the case with a Scotch-Brite pad and put in the new accumulator.

Torque Converter Shudder (see TSB# 98-8-7)

There is a lot of information out there on this but not all of it is accurate. Here we go...

Symptom?

While the converter clutch is locking up it feels like you just drove over rumble strips or train tracks. This will start to happen on 3-4 shifts only, then make it's way to 2-3 shifts and when tipping in from closed throttle.

What Models?

All AODE's and 4R70W's. The 1998 and beyond vehicles may still get this, but it would be at much higher mileage's than the 1997 and prior vehicles.

Problem?

No matter what year the vehicle, the problem is caused by a breakdown of the oil/friction material interface. Several different things cause this breakdown. The oil/friction interface getting too hot is the main reason.

Solution?

Depending on the model year of the vehicle the problem is resolved different ways. Any vehicle that has shudder needs an additional transmission oil cooler. This will help keep the temperatures down. In addition, the vehicle needs Mercon V fluid. This is a new fluid that is currently available only at a dealer. Finally, 1996 and 1997 model year vehicles (except Mustang) need a different calibration in the EEC. This is available through a dealer.

Intermediate One Way Clutch

Symptom?

No 1-2 shift or no 3rd and 4th gear. A failing one way clutch will cause a late 1-2 shift that finishes with a big bang, or will allow the engine to run into the rev limiter at WOT.

What Models?

All AODE and 4R70W's built before 1998 model year. (Some of the later years, like 1996 and 1997 were better, but not bullet proof).

Problem?

This design one-way clutch is not suited for this environment.

Solution?

Install the mechanical diode one-way clutch. This part is almost bullet proof.

No 4th Gear (see TSB # 95-5-15)

Problem?

Several different things can cause this. If the car has no 4th gear sometimes, but not all the time, the transmission internals are probably not hurt. This type of no 4th gear is usually caused by bad shift solenoids. A change was made to the solenoids to fix this starting in 1995. A bad range sensor on the side of the trans can also cause this. There is a lot of information out there on the sensor so I won't talk about it here.

Also, when the OD band burns up you'll lose 4th gear.

Solution?

For the intermittent 4th gear install new shift solenoids, but if you've lost it totally time for a rebuild.

No 3rd or 4th Gear

Problem?

The direct clutch is burnt up. This can be caused by a bad intermediate one-way clutch, or could have just burned up.

Solution?

Rebuild.

Slips or Shudders when taking off (see TSB# 94-26-9)

Problem?

Most likely the forward clutch seal rings on the pump stator support are worn and leaking. This may not be the root cause.

Solution?

If the forward clutch seal rings are worn not only must they be replaced, but the stator support must also be replaced. Let me explain. The outer surface of the seal ring seals on the forward clutch cylinder and moves with the cylinder when it spins. If the rings are worn it's because they started to stay attached to the stator support and the forward clutch cylinder spun around them, thus causing them to wear. You'll never get the inside surface of the stator support polished again, get a new one. Also, if you do not clean the cooler after a failure, all the debris will end up here at the seal rings and cause them to stick, thus taking out the seal rings and stator support. This is a common second time failure.

Slips or Neutrals on Right Hand Turns or Stops

Problem?

The oil pump pickup (the filter inlet) sucks air and not oil, happens on right hand turns and stops. Much worse cold rather than hot. Only affects 1995 and prior model year vehicles.

Solution?

In 1996 the pan changed to include a dimple in the bottom, a reservoir if you will, and the filter changed to put the pick up in the dimple. This ensures that the pump will always have oil at the pickup during braking and cornering. This new pan and filter will solve these issues on the older vehicles; see part numbers in build up section.

Noticeable Sag or Hesitation at 3-4 Shifts

Problem?

During the 3-4 shift, as was mentioned before; the OD Band has to apply while the forward clutch has to release. If the clutch releases before the band is applied, the transmission will be in neutral for a short time. This is bad. If the band applies before the clutch releases, then you have a hydraulic park (trying to stop the input shaft from spinning, at least until the clutch releases). The sag feeling is this tie up during the 3-4 shifts.

Solution?

Read later on how to modify valve body to reduce this.

Transmission Do's, Don'ts, and FAQ's

Before we get into this discussion I want to go over what are friction coefficients. The friction coefficient is the element's ability to hold, or slip. The lower the friction coefficient, the lower the torque that element can hold. A clutch or band has two friction coefficients, one is the dynamic friction coefficient and the other is the static friction coefficient. The dynamic friction coefficient controls the element's ability to stop, or apply. The static friction coefficient is that element's ability to hold torque once it has stopped, or applied. The dynamic friction coefficient is primarily controlled by the properties of the friction material and the static is mainly controlled by the properties of the oil.

A lot of shift kits put a blocker ring in the 2-3 accumulators. This limits the amount of travel for the accumulator. And yes, it does result in firmer shifts. But don't do this. What is happening is this; if you remember the accumulator explanation from before, it allows a slower pressure rise in the clutch while it is applying. This accumulator stroke limiter forces the clutch to go to line pressure faster, but the way it does that is by stopping the accumulator from stroking thus ending the ramp. When you allow a shift to finish, meaning the clutch stops, when the accumulator stops stroking, it puts a large shock load into the transmission and driveline which will result in eventual failure of something.

Should I adjust the screw on the back of the EPC solenoid?

Under no circumstances should you EVER adjust the setscrew on the back of the pressure control solenoid. I know several companies recommend this, but this is wrong. It will make the shifts firmer by increasing line pressure, but there is a downside. The maximum line pressure that a 4R70W should ever see is 225 psi in forward and 275 psi in reverse. (Reverse can be higher since the elements that apply in reverse are designed for the higher pressure, the forward elements are NOT designed for higher pressure) If you exceed these values you WILL distort the clutch cylinders and this will eventually cause some type of failure. The failure this causes is subtle and may not be obvious that it was caused by excessive line pressure. I know several cases where people have had chronic forward clutch problems, like slipping when it gets hot, after making this modification. The forward and direct clutch cylinders will distort, resulting in sticking pistons, leakage, and issues like this. The blow off valves that some aftermarket companies offer, do not blow off at a low enough pressure.

In addition to exceeding the maximum amount of line pressure that the transmission should operate at, it causes a few other problems. The higher line pressure generated by turning the screw causes there to be less oil in the transmission pan. The higher the line pressure demanded, the less fluid in the pan. This reduced amount of fluid in the pan can cause the transmission to neutral out more often, especially in turns and accelerations after quick stops.

Another potential problem caused by turning the screw on the EPC solenoid is that the main regulator priority system is in effect more often. See the question about drilling holes in the valve body for more of an explanation about what this is and how it works.

I hear a buzzing from my transmission, what is this?

If you have a 1995 or older valve body, and/or have turned the screw on the back of the EPC solenoid, valve buzz can result. This is when a valve in the valve body goes into resonance and starts to hammer against the valve body casting. This will cause premature wear of the valve. If you have not turned the screw on the back of the EPC solenoid, you need to update to a 1996 or newer main control. If you have turned the screw on the back of your solenoid, read above.

Should I put on an additional transmission cooler?

Almost all clutch friction failures are due to heat. Put on a good external transmission cooler. The best type of cooler to run is the plate design, not the fin and tube type. Have the external cooler plumbed in after the cooler in the radiator. This will allow the radiator cooler to take out as much heat as it can and then the external cooler will take more out. An ideal temperature for the transmission to run is in the 160-180 F range. For every 20 degrees of increase in transmission fluid temperature above 170 F, the life of the fluid is cut in half. A cooler is an easy modification that most people can do themselves. Ford offers coolers and installation kits for all 4R70W and AODE equipped cars. These kits are easy to install (they come with all the fittings and hose needed) and work well for applications making less than 325 HP. Beyond that, you'll need to get a good aftermarket cooler. If you use rubber hose, make sure you use high-pressure hose that's oil resistant. If the manufacturers put good coolers on production cars, they would put most transmission repair shops out of business.

Is there anything else I need to do when my transmission fails?

When you have transmission failure, you need to ensure that the transmission cooler in the radiator is clean. You need to flush the lines and the cooler very well. The factory recommends that if you fail a transmission, you replace the radiator. This is because you usually cannot get all the contamination out of the transmission cooler. For friction material failures, I think you can flush the cooler and it will be clean enough. If you fail any mechanical parts, like a gear set or torque converter, then I think you need to replace the radiator. It is not uncommon to have a repeat failure within 5-10,000 miles after the original failure. This second failure will usually be the forward clutch seal rings leaking, causing the trans to slip coming off the line. If you are going to replace the radiator, get a newer one. Starting in 1996 on T-Birds and 1998 on Mustangs, the internal cooler was changed to a plate type cooler in the radiator. Prior to that a concentric tube type cooler was used. The plate cooler is superior to the concentric tube.

How often should I change the transmission oil?

Change oil and filter often. For regular use I'd recommend oil and filter change every 20,000 miles. If you have a high stall converter, live in a hot climate, or have a heavy foot, I'd change the oil every 12,000 miles. Transmission oil has modifiers in it that alter the friction coefficients of the material. With time and heat, the modifiers get used up and need to be replenished, just like engine oil. The factory recommended transmission fluid change intervals are 30,000 miles for normal use and 21,000 miles for severe use. I recommend changing the fluid more often, just like most of us change our engine oil more often. If you run an auxiliary cooler, you can increase the oil change interval. The cooler it runs, the longer you increase the interval between oil changes. At 170 degrees F, maximum, you only need to change oil every 50,000.

What's the best way to change my transmission fluid?

There are two ways you can change the fluid. One is by removing the pan to drain the oil in the pan, and then remove the drain plug in the torque converter to drain the oil out of the converter. The other way would be to remove a trans cooler line and crank or run the engine until no more oil comes out, you will still need to remove the drain plug from the torque converter to drain the fluid out of the converter. Either method is acceptable.

What transmission fluid should I use?

For all AODE's and 4R70W's, use Mercon V transmission fluid. Contrary to what you may have heard, you can use Mercon V in any AODE or 4R70W transmission. It will not cause any seal problems. **THIS ONLY APPLIES TO THIS TRANSMISSION.** If you put this fluid in an older Taurus, you will eventually have seal problems. For AOD's, I also recommend Mercon V transmission fluid. Do not EVER use Type F fluid in a transmission that has an overdrive gear. The wear properties of Type F will cause premature gear set failure. But if you run a non overdrive transmission, this fluid (type F) has a very high static coefficient and would be the fluid to use in a high output application.

A lot of shift kits, or articles, recommend drilling a hole in the valve body, should I do this?

A lot of shift kits out there have you drill holes through the valve body. What most of these do is bypass the main regulator priority system and allow flow to the torque converter at all time. Let me explain. If the engine was running at low speeds and somewhat hot (>220 F), the pump flow is low. If you ask for high line pressure, via the EPC solenoid, you may not have enough pump flow to keep line pressure up to what is being asked for. Under this condition, the main regulator valve reduces flow to the torque converter circuit, in order to keep line pressure at what is desired. This is not really an issue with the way the transmission is set up in production. This "priority" system only becomes active when at low engine speeds (<1200 rpm), high temperature (>220F), and higher commanded EPC pressure (>65 psi). If you turn the screw on the back of the EPC (which you should NEVER do) then this system becomes active at much easier entry conditions than before and you begin to starve clutches. Don't do this, you are only asking for long-term problems. Even if the priority system activates, there is still a rear lube circuit that keeps the gear set lubed.

Transmission Do's, Don'ts, and FAQ's

Should I use a Kevlar band?

Save the kevlar band for racecars. Kevlar is good stuff. It's almost impossible to burn up in a transmission. It has one problem. Its dynamic friction coefficient is very low so it's very hard to stop the element that the band needs to stop. In the AOD/AODE/4R70W applications it would be the overdrive band. If the band is replaced with a kevlar band, it will have a very difficult time completely stopping the reverse cylinder. It will not slip a lot, it will not be noticeable, but it does slip a small amount, <50 rpm, for a long time. The problem with this the heat it generates. For example; the OD servo has an area of about 5.7 sq.-in. At 100-psi line pressure this is 570 lb. of force on the band slipping, can you imagine the friction and heat that is generated from this? If you modify the main control (valve body) and hardware so that the pressure on the servo rises very, very quickly, then the band can stop the drum. With the right modifications to the main control, the production band is more than adequate for almost all applications.

What is better, a lockup torque converter or a non-lockup?

There have been a lot of questions/view points on torque converter lockup or non-lockup. The answer to this is very simple. At wide-open throttle, a locked torque converter will transmit more power to the rear wheels than an open torque converter. When a torque converter is open, and not multiplying torque, it is about 90-94% efficient (depending on the design of your torque converter). A torque converter only multiplies torque at low engine speeds and vehicles speeds. That means you are losing about 6-10% of the power of the engine through the torque converter. You want your torque converter to lock up at wide-open throttle. When people put the one-piece input shaft in an AOD, they talk about how much better it feels. This is true at part throttle. In an AOD, the torque converter is locked at all times in 3rd and 4th gears. When installing the input shaft that no longer has lockup, you will now get torque converter multiplication in 3rd and 4th gears, at low vehicles speeds. This is a noticeable improvement and does feel better, at these low speeds. But, they did lose rear wheel horsepower at WOT.

Do I need to change the PCM if I change the main control?

There are a lot of questions about keeping valve bodies and PCM's matched. While there is some merit to this, the factory spends a lot of time optimizing shift feel, making the PCM and main control work together. Most of us wouldn't think twice about installing a shift kit. And this is doing the same thing as changing the main control without changing the PCM. The main thing to watch out for when doing this is to make sure the 4-3 or 4-2 downshifts do not flare. Usually, if you are upgrading to a newer model year main control, you can upgrade without worrying about the PCM.

Why does my engine hit the rev limiter when I changed rear end gear ratios?

This is simple but requires a little explanation. A stock AODE/4R70W transmission intermediate clutch takes about 1 second to fill and bring up to pressure to start bringing the engine speed down. In 1st gear the typical acceleration rate of the engine is about 1000 RPM/SEC. So in order for the shift to happen at 5000 rpm, the EEC must command the shift 1 second before it wants the shift to start, or in this example, 4000 rpm. Now, you go ahead and change rear gears and now the engine accelerates at 1500 rpm/sec in 1st gear. All the EEC knows is that it has to command the shift at 4000 rpm. So with the new gears it commands the shift at 4000 rpm, and with a 1 second fill time of the clutch and accelerating at 1500 rpm/sec, the shift will now happen at 5500 rpm (4000 + 1500 rpm). Well, the rev limiter is at 5200 rpm so you just hit it. An easy way to solve this is to increase the size of the feedhole to the intermediate clutch to reduce the fill time of the clutch. If you can reduce the fill time to a ½ second, at this same 1500 rpm/sec acceleration rate, and the EEC commands the shift at 4000 rpm, it will then shift at 4000rpm + ½ second * 1500 rpm/sec, which is 4750 rpm. This works. I will go over what modifications are needed to do this later. This same thing can be done for the 2-3 shifts.

What about synthetic transmission fluid?

I have seen several people, in various BBS's, say to not run synthetic fluid. Their logic, in most cases, was that 12 quarts of synthetic transmission fluid is expensive, and since you have to change it every 20,000 miles or less, it's not worth the investment. This is wrong. If you look above I mentioned that heat is the number one killer of transmission fluid. Synthetic fluid can withstand higher heat before the additives start to get used up, so it will help. Look at it this way, most people don't hesitate to put in synthetic engine oil, and then change it every 3,000 miles. Why would you hesitate to put in synthetic transmission fluid and then change it every 15,000 to 20,000 miles?

Do police cars have better parts in the transmission?

No. The parts inside the transmission are all the same.

Can I put a later model transmission in my car?

Yes, but not without making several changes. The manual levers on the side of the transmission vary from vehicle to vehicle, you need to keep the lever that came with your vehicle. The MLPS on the side changes starting in 1997 or 1998 model year (depending on the model), this would have to be changed. You'll also need to either re-wire the pins on the main connector into the transmission, or switch the new transmission back to wires. (The pinouts of the connectors are shown farther down below) Finally, you need to be aware of how many teeth are on your old output shaft and the new one (in case you have to change speedo gears) and whether or not you have a "long" output shaft (discussed below). If you are going to do this, below are the part numbers for the manual levers needed for the T-Bird/Mark and Mustang.

	Lever Part Number & Stud Part Number
T-Bird and Mark 8 Manual Lever	F4SZ-7A256-A & E9SZ-7B415-A
Mustang Manual Lever	F4ZZ-7A256-A & E43Z-7B415-A

Making these changes to put a later model transmission in your car is not that difficult and it's probably cheaper than buying all the individual parts. I'd recommend starting with a 5.4L truck transmission and start making changes from there. In the next section, you'll see why this is the recommended transmission to start from.

5.4L Truck Transmission Part Number XL3P-7000-LARM (this is a re-man'd transmission)

How much power can a 4R70W withstand?

Built correctly, with the right parts, I have built 4R70W's that are behind the following vehicles without incident; supercharged 5.0L Mustangs making 425 RWHP, twin turbo'd 5.0L Mustangs and T-Birds making 575 RWHP, Blown 4.6L 2V's making up to 450 RWHP, Blown 4.6L 4V's making up to 575 RWHP. All these transmission used a combination of production parts, some modified, and a modified main control. Most had torque converters made by Pro-Torque. No special billet parts were necessary. I will detail the changes necessary to make a transmission like these later.

Will manual shifting hurt my transmission?

Well, the answer is it depends. On any 1996 and newer 4R70W, you can do all the manual 1-2 and 2-1 shifts you want and not hurt anything. If it were older than a 1996, I'd shy away from manual 1-2's unless you've modified the main control. I would stay away from excessive manual 4-2's on all transmissions older than 1998. In 1998 the manual valve changed to allow the direct clutch to exhaust faster, resulting in less wear.

Do I need a custom chip?

It would help, but I have never seen a "tuner" out there that really understands how a transmission works. In addition, the current software that I have seen does not have the capability to properly modify the transmission function. Also, as I stated above, if you make the right changes to the main control, you can make it so the engine will not hit the rev limiter on the wot shift's. If you are going to get a custom chip, I'd make sure that it's changed so the torque converter locks up at WOT, and the chip adds in more pressure to the 2-3 shift. The 2-3 shifts are affected the least by the hydraulic changes I will detail below.

Building a Bullet Proof 4R70W

I am not going to detail how to rebuild a 4R70W. If you want to rebuild your own transmission I'd recommend the Ford Service book below, it is an excellent book, detailing how the transmission works and how to rebuild the transmission, its \$70. If you rebuild your own transmission, this is the best \$70 you'll spend. My plan for this section is to detail what parts should be installed and modified over and above a normal transmission rebuild. Unless otherwise noted, all the parts will interchange with the AOD, AODE and 4R70W transmissions.

AODE/4R70W Service Manual Includes Theory of Operation and Disassembly/Reassembly PTB 606 A&B

The above service manuals are available from
Gage Marketing
Ford Powertrain Publication
101 Union Street
Plymouth, MI 48170
(734) 459-5140

Output Shaft

AODE and 4R70W only

Never use an output shaft from an AODE, they are too weak and cannot handle high torque, they will twist. All 4R70W output shafts are not created equal. To start with there are two different length output shafts. All vehicles except the Town Car and Crown Vic police car use the same length output shaft. The ones in the Town Car and police car are longer. You don't want to use one of these in a high torque application. They have an undercut near the end of the splines where it could break. So, stick with the shorter output shaft. Within this typical length output shaft there are also several differences. The easy difference is the number of teeth on the drive gear for the speedometer. There are 7 and 8 tooth output shafts. If you have to get an output shaft, get a 7-tooth output shaft. It can make speedo accurate up to axle ratios of 3.73 without the special gear (I'll cover that later). The 8-tooth output shaft can only make the speedo accurate to a 3.27 rear axle. The big difference between the 4R70W shafts is the material. Starting in 1998 model year the material the output shaft is made of was upgraded to a stronger material. If you are going to build an engine with a roots type blower with a lot of low-end torque, you'll want this newer output shaft. If you are going to stay naturally aspirated or a centrifugal blower, you can stick with an older 4R70W shaft. Just make sure the seal ring grooves are in good condition. As an additional comment, if you are starting from a 1994 or older transmission, you should get a new shaft, the rear lube feed hole was enlarged during the middle of the 1994 model year.

Make these seal rings one piece teflon, rather than the slit seals used from the factory.

Use the production seal rings here, not teflon.



A "W" output shaft, the stronger ones, have splines all the way up the shaft, "E" shafts have about 2" shorter splines

All Vehicles except Town Cars and Police Cars	Output Shaft Part Number (7-tooth drive gear)
Town Cars and Police Cars	F4SZ-7060-A
	F4UZ-7060-A

Aside from the material of output shaft there are a few other things needed. There are several seal rings on the output shaft. There are 3 seal rings that are larger diameter in the middle of the shaft and then there are two small Teflon rings at the front of the shaft. The small Teflon rings at the front of the output shaft are slit for easy assembly. You just open them up and wrap them around the shaft snout and into the groove. You need to replace these rings with one-piece Teflon rings. These small seal rings are for the direct clutch and the one's with the slit in them tended to leak more than a one-piece ring. You will need to take your time installing the one-piece rings, and once they are installed, you'll need to "set" them. You can do this by lubing up the direct clutch cylinder and slowly sliding the cylinder onto the shaft to "set" the seal rings to their smaller diameter. This is a lot easier than it sounds. The larger seal rings on the output shaft do not need to be upgraded. They work just fine; I'd avoid putting Teflon rings on these since this will cause premature wear to the case bore.

AOD only

Unfortunately, with an AOD since it needs a governor on the output shaft, there is only one choice of output shaft to get. You'll need to find a 1993 Mark 8 transmission and use its output shaft. This shaft had the extra hardening required for the 4R70W gear set and still used the sleeve to block the governor hole. Just use this shaft and add the governor.

Planetary Gear Set

The AOD/AODE gear set cannot handle high torque and high speeds. It will result in a long-term failure. You need the 4R70W gear set. They have caged needle bearings designed for higher speeds. But, once again, not all 4R70W gear sets are created equal. There are basically 3 different gear sets out there. The original gear set that was made from 1993 through 1995 used several aluminum bushings in the gear set. One was in the rear of the planetary carrier and two others in the reverse sun gear. These aluminum bushings have a tendency to gall with speed and torque. From 1996 to date all the planetary bushings were switched to bronze. This fixed the galling problem. This gear set is good enough for most all applications using the 4R70W. The third gear set available comes only in the 5.4L trucks. The pinion gears in this gear set are much stronger than the non-5.4L gear sets. The Planetary carrier and forward sun gears are upgraded in the 5.4L transmission. For high torque applications, this is the only way to go. If you have a gear set with aluminum bushings, I'd upgrade to the 5.4L gear set, the difference in cost is almost nothing.

If you already have a 4R70W, then the only parts needed to upgrade are the following; you need to upgrade if you are going to make more than 450 HP, or use a roots blower with more than 8 psi of boost.

Part	Part Number
5.4L Planetary Carrier	XL3Z-7A398-AA
Forward Sun Gear	XL3Z-7A399-AA

If you are converting to a 4R70W, then you'll need these additional parts;

Part	Part Number
Snap Ring, Ring Gear to Hub	F3LY-7C122-A
Ring Gear	F3LY-7A233-A
Reverse Sun Gear	F4SZ-7A019-A
#5 Needle Bearing	XW7Z-7F244-AA
Output Shaft Hub	F3LY-7D164-B
#8 Needle Bearing	F1AZ-7F240-A
#9 Needle Bearing	F6AZ-7F242-BA

Direct Clutch

Note: if you are building an AOD, you'll need to get a new direct clutch cylinder assembly. The AOD cylinder is made of cast iron and the new plates will not fit in that cylinder.

As far as friction material goes in the direct clutch, you want to stick with the production material that was introduced in the 1998 model year. This is a higher energy material that can withstand a lot of power and torque. Also, when this material was introduced in production, the steel separator plates in the clutch were made thicker, .067" to .077". A thicker steel plate will provide more heat sink than a thinner plate.

The direct clutch friction material you want to use is on the right, the older material is on the left.



All production 4R70W T-Birds (1994-1997) and all Mustangs built through 1997, came with the material on the left. This material will wear out with mileage, the material on the right will not. The material on the right is the direct clutch friction material you want to use.

Except for most 3.8L applications, the production direct clutch has 6 plates in AODE's and 4R70Ws. A 6 plate direct clutch is adequate for most applications. Follow the chart below to determine how many clutch plates your application needs.

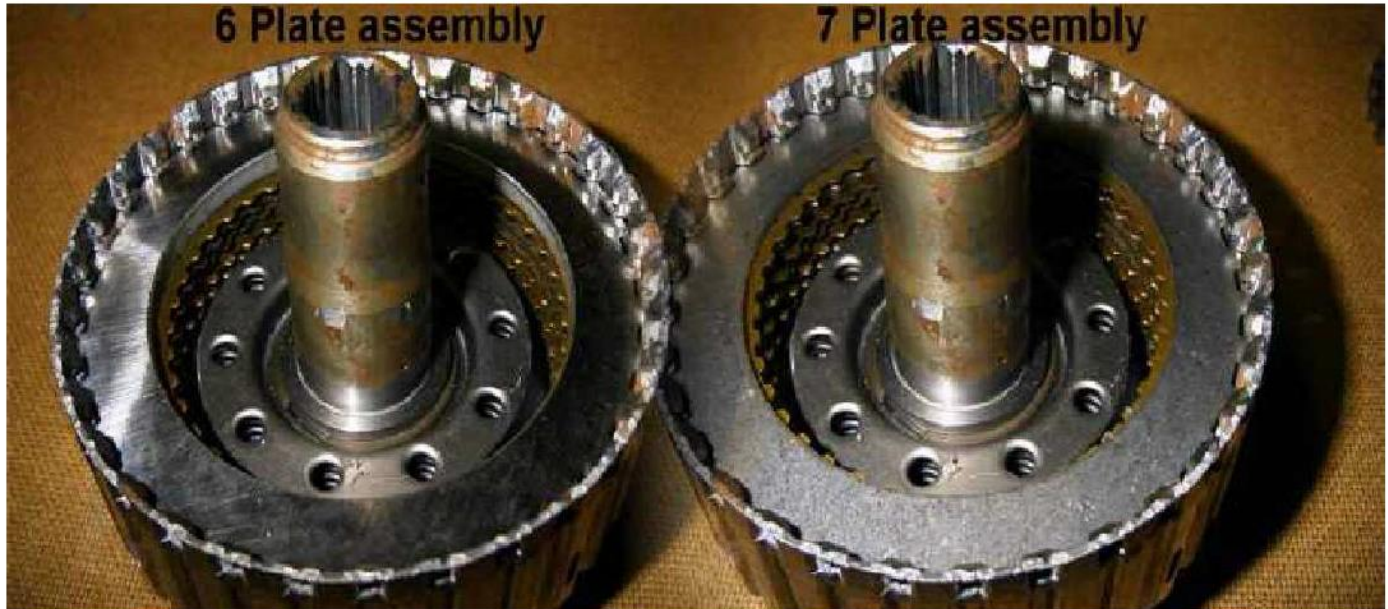


This is correct lay out for a 6 plate direct clutch, 5 steel plates separated by 6 friction plates, with a pressure plate (the thicker plate) on the end. This assembly is installed into the cylinder as shown, from left to right.

As far as end clearance goes, you want the end clearance to be around .080". If you are going to be off, be off on the higher side. You may need different snap rings to get the end clearance you need.

	Number of Direct Clutch Plates	Friction Plate	Steel Plate	Pressure Plate
Up to 500 HP	6	F8AZ-7B164-BA	F6AZ-7B442-AA	F7AZ-7B066-AB
500 - 650 HP	7	F8AZ-7B164-BA	F6AZ-7B442-AA	None
> 650 HP	8	F8AZ-7B164-BA	F6AZ-7B442-AA	None

Direct Clutch Cylinder Part Number F6AZ-7F283-AA



In order to get the right end clearance, below is a list of the snap rings for the direct clutch and their thickness. If you rebuild your own transmission, you can measure the end clearance with the original snap ring, and, knowing this and the desired end clearance, you can determine what snap ring you need.

Snap Ring Part Number	Snap Ring Thickness
F3AZ-7D483-A	.052"
F3AZ-7D483-B	.066"
F3AZ-7D483-C	.080"
F3AZ-7D483-D	.094"

To make an 8 plate direct clutch, the direct clutch piston must be machined down .100" of an inch. Once this is done, 8 plates will fit without a pressure plate. The picture below shows where to machine the direct clutch piston.



Forward Clutch

Note: If you are building an AOD built before 1990, you will have a cast iron cylinder and none of the parts below will fit. You will need to get a newer clutch cylinder.

All AODEs and 4R70Ws were built with 5 plate forward clutch packs. The forward clutch assembly also has a wave spring in the clutch to provide a cushion when the clutch applies. A five plate forward clutch is good enough for engines making up to about 450 hp. After that you'll need to go to a 6 or 7 plate clutch. I'll detail the modifications necessary to make these later in this section.

The production friction material is good enough for any application. This clutch is considered not a shifting clutch. It doesn't see a lot of torque when shifting so the production material is more than adequate. All it has to do is hold torque once the transmission is engaged.

There are 3 different wave plates that have been used in production. The wave plate on the forward clutch acts as an accumulator. It allows the forward clutch to apply at a lower pressure than line pressure. Depending on what your application is, will depend on what wave plate you want to use. All AOD's, AODE's and 4R70W's built up through 1995 model year had one wave plate and all transmissions built since have the other wave plate, except the 5.4L truck transmissions. The wave plate used in the 5.4L transmissions is much stiffer than the other wave plates. This higher load plate allows the forward clutch to gain capacity faster. Any supercharged engine should use the 5.4L wave plate, period. On an engine with a lot of torque, there is a tendency on a 4-3 shift for the engine to flare during the downshift. This is because the forward clutch cannot gain capacity fast enough. This wave plate will prevent this flare. If your engine is going to stay naturally aspirated, then you probably do not need this wave plate.

When should you add more clutch plates to the forward clutch? The forward clutch sees full engine torque in 1st and 2nd gear, and then this is multiplied by the torque converter. So, high low-end torque engines (again, roots type blowers) with higher stall converters will need more forward clutch plates. Most applications can get away with just 5 plates, but, for very extreme applications, you can remove the wave plate and build the clutch as a 6 or 7 plate. If you are going to build a forward clutch with 6 plates or more, you'll need a clutch cylinder from a 1996 or newer vehicle, it was changed to allow more room from the piston to snap ring groove. If you remove the wave plate, the engagements and 4-3 coastdown shifts will become firm.

As far as end clearance goes you want to build this clutch a little tighter for most applications. For a 5-plate forward I'd build it with about .080" end clearance. Again, if you are going to be off, be off higher rather than lower.

	Number of Forward Clutch Plates	Forward Clutch Wave Plate	Pressure Plate
Up to 450 HP	5	See Chart Below	F0SZ-7B066-B
450 - 550 HP	6	None	F0SZ-7B066-B
> 550 HP	7	None	None

Forward Clutch Friction Plate	Forward Clutch Steel Plate
F8AZ-7B164-AA	F0SZ-7B442-A

Forward Clutch Cylinder Part Number F6AZ-7F207-A

Snap Ring Part Number	Letter Stamped on Snap Ring	Thickness
F0SZ-7D483-D	A	.104"
F0SZ-7D483-C	B	.090"
F0SZ-7D483-B	C	.076"
F0SZ-7D483-A	D	.062"



This is the correct layout for a 5 plate forward clutch. It's installed in the cylinder as shown from left to right, a wave plate, then 5 steel plates separated by 5 friction plates and then the pressure plate.



This is the correct layout for a 6 plate forward clutch. It's installed in the cylinder as shown from left to right. No wave plate, then 6 steels separated by 6 friction plates and the pressure plate.



This is the correct layout for a 7 plate forward clutch. It's installed in the cylinder as shown from left to right. No wave plate, 8 steel plates separated by 7 friction plates. You'll need to machine down the piston by .050" and use the thinnest snap ring to make the end clearance correct. The picture below shows where to machine the forward clutch piston.



The arrows here show where to machine the forward clutch piston for a 7 plate forward clutch



The assembly on the left is a 7 plate forward installed in the cylinder.
The assembly on the right is a 5 or 6 plate forward clutch installed in the cylinder.

Forward Clutch Wave Plate

Use the stock forward clutch wave plate unless you meet one of the requirements below

	Wave Plate Part Number
Supercharged or Stroked engine	XL3Z-7E085-A
All Others	F6AZ-7E085-A

If you are not sure which forward clutch wave plate you have, you can use the following table to determine which one you have;

	Thickness	Number of waves
All up through 1995	.039"	5
1996+, except 5.4L	.072"	3
5.4L	.081"	4



Reverse Clutch Cylinder and Intermediate One Way Clutch

This is easy; no matter what you are building you need a reverse cylinder that has the mechanical diode intermediate one-way clutch. This clutch is almost indestructible. The only thing you need to decide is whether you want a 3 plate or 4 plate reverse clutch. All production cars switched from 4 plates to 3 plates starting in 1998. For a totally indestructible transmission, the 4-plate assembly is better. But, unless you like doing reverse stalls, the 3 plates will work fine and provide slightly less drag. (Less clutch plates are less drag when the clutch is off).

Reverse Cylinder Assembly w/mechanical Diode

F8AZ-7A089-AA

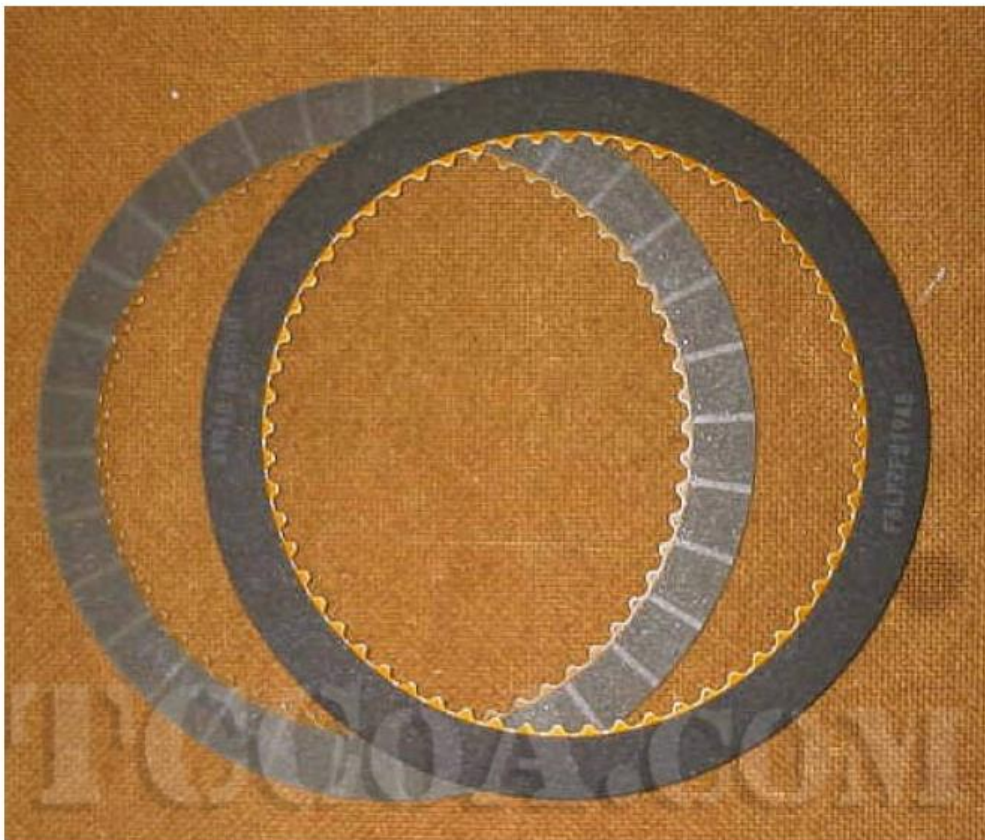
As a side note, most people call this a sprag. This is WRONG. There are basically three types of one-way clutches, roller, sprag and mechanical diode. A sprag is a type of one-way clutch. No production AOD, AODE, or 4R70W, has every used a sprag type one-way clutch.

Intermediate Clutch

All AODE's and 3.8L naturally aspirated transmissions built through 1998 have 3 plate intermediate clutch's, all the rest have 4 plates. No matter what you are building, you want a 4-plate clutch. You can switch to this clutch by just changing the pressure plate. The production material varied depending on the model year, you want to use the current material (it's the same as the direct clutch material that was recommended above). You don't need to upgrade to any thing else. The difference between the two friction materials is the higher HP friction plates do not have any grooves. This increases the surface area of the intermediate clutch, lowering the energy per sq.-in. Do not use these plates unless you make the changes to the accumulator for > 450 HP. If you do not have an aggressive accumulator, the clutch will hydroplane when applying, increasing clutch engagement time, glazing the friction plates, and results in failure.

	Pressure Plate	Friction Plates*	Steel Plates
Up to 450 HP	F7AZ-7B066-AA	F75Z-7B164-CA	XL3Z-7B442-BA
> 450 HP	F7AZ-7B066-AA	F3LY-7B164-A	XL3Z-7B442-BA

* - All applications use 4 intermediate clutch plates



The friction material on the right is what all 4R70W's came with through 1997. In 1998, the material was changed to the one on the left. The grooving pattern on the 1998 material was slightly different, but the thing to notice here is the difference between grooves and no grooves. Follow the chart about to determine what is the best material for your application.



This is the correct layout for a 4 plate intermediate clutch. The pressure plate goes in first, followed by 4 friction plates separated by a steel plate.

Stub Shaft (AODE and 4R70W only)

This is the little shaft that connects the forward clutch cylinder to the direct clutch cylinder. There have been two different stub shafts made in production. You want to use the current shaft; this went into production starting in 1998. Looking at the groove where the splines on the small end, end, you can identify this shaft. The early shafts used a groove cut in at the end of the splines; the current shafts have a taper rather than a groove; the shaft with the taper is much stronger than the shaft with the groove; the shaft with the groove tends to break at the groove.

Stub Shaft Part Number - All Engines

F8AZ-7F351-AA

**This shaft has a taper,
the undercut or taper is right here.**

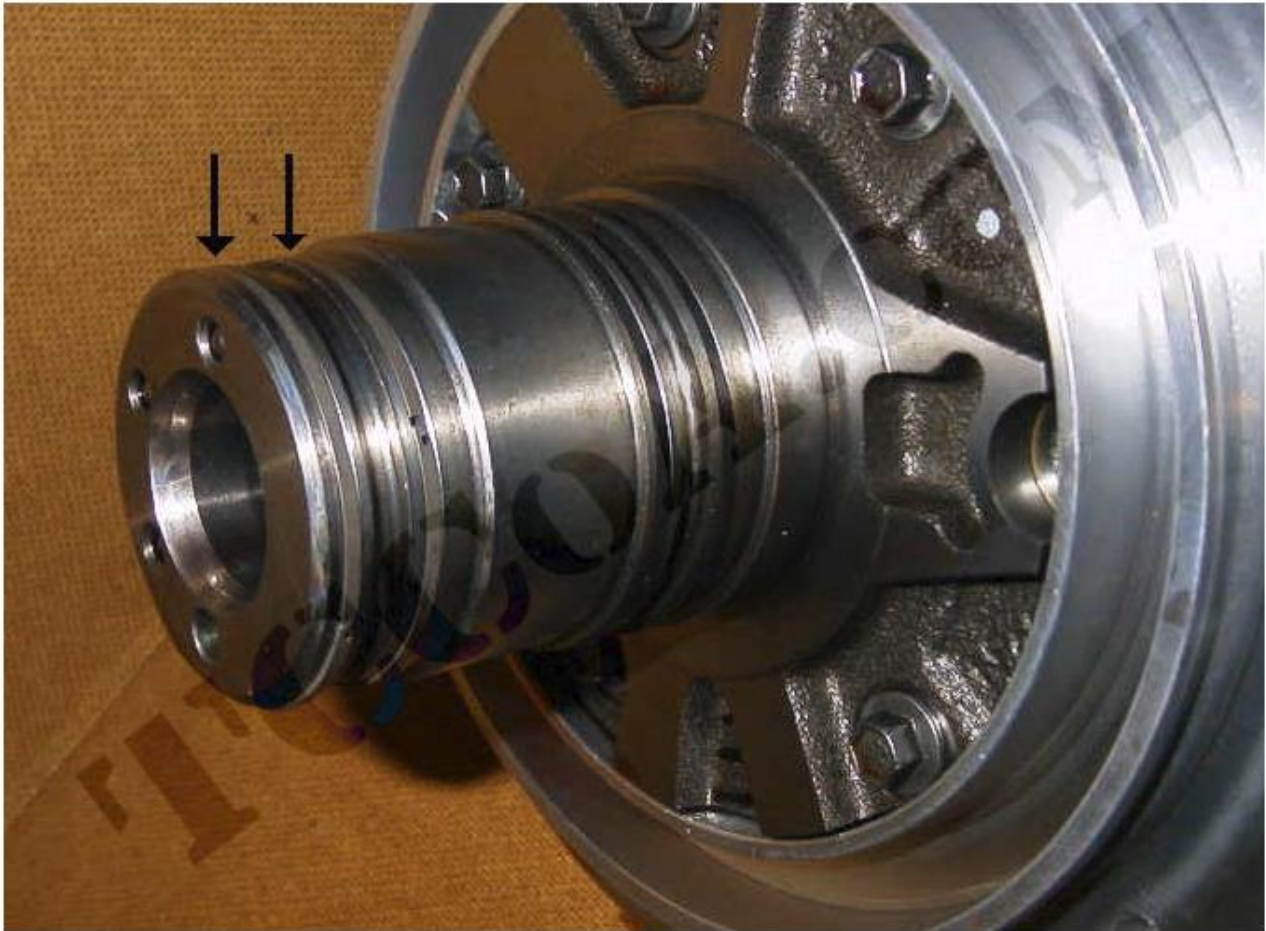


Stator Support

If you are building a performance 4R70W I recommend getting a new stator support. Let me explain. The last two grooves/seal rings on the stator support seal the forward clutch circuit. These grooves are very prone to getting marked up from contamination. If these grooves get too gouged, the seal rings will wear out prematurely. This will result in forward clutch problems. You want to use the production seal rings for the forward clutch, not Teflon. The Teflon rings take too long to start sealing when the transmission is cold. This will cause inconsistent function when warming up.

	Stator Support	Fwd. Cl. Seal Rings	Rev. Cl. Seal Rings
All Engines	F4AZ-7A108-A	F4AZ-7D019-A	E0AZ-7D020-A

The picture below shows the location of the forward clutch seal rings. It is very important to make sure the inside edges of the seal ring grooves are smooth and not gouged with debris. This is very, very important.



Overdrive Servo Assembly (AODE and 4R70W only)

There are two OD servo assemblies available. One is a 2.7" diameter servo and the other is a 2.5" diameter servo. They are easily identified since the 2.5" unit has a sleeve that the servo fits in to reduce the diameter. The larger servo gives more torque capacity in 4th gear. The difference in the two return springs for the 2.7" servo is their load. The higher HP spring has less load, allowing more apply force on the band.

	OD Servo Assembly Part Number	Return Spring
Up to 300 HP	2.5" Servo F7AZ-7H188-AA	F3LY-7F201-A
300 - 450 HP	2.7" Servo F75Z-7H188-AA	F87Z-7F201-AA
< 450 HP	2.7" Servo F75Z-7H188-AA	F2VY-7F201-A



The OD servo on the left is the 2.5" version. The 2.5" OD servo is easily identified by the sleeve it uses to reduce the bore diameter in the case to the smaller diameter. The servo on the right is the 2.7" piece.

Overdrive Band

The production 2" band, with the right valve body changes, is good enough for all applications. Like I mentioned above, unless you have an all out race set up, don't use kevlar.

OD Band Part Number - All Applications F2TZ-7F196-A

Pressure Control Solenoid (AODE and 4R70W only)

For all 1997 model year and prior transmissions, there is only one pressure control solenoid available. This one allows a maximum of 95-psi pressure output, which results in a maximum line pressure of 190-200 psi. For 1998 and beyond transmissions, there are two solenoids. The 5.4L transmission uses a solenoid that allows a maximum pressure of 110 psi, which allows a maximum line pressure of 220 psi. You don't want line pressure in forward to exceed 220 psi. If you are building a 1998 or beyond transmission, I'd get the higher-pressure solenoid.

If you have a 1997 or older transmission and want to use the higher pressure solenoid you can do this. The wire connector will have to be soldered onto the new solenoid.



Don't ever adjust the screw on the back of the solenoid. **Ever.**

Use the data below to determine the best Pressure Control Solenoid (PCS) for your application

	PCS for 1997 & prior years	PCS for 1998 & newer years
Up to 350 HP	F6AZ-7G383-AA	F8AZ-7G383-AA
>350 HP	XL3Z-7G383-AA*	XL3Z-7G383-AA

* - Use a tie strap to hold the connector onto the solenoid

Oil Pan and Filter (AODE and 4R70W only)

This is easy, for any application you have to use the 1996 and beyond transmission pan and filter. This pan has a dimple in the center that ensures the transmission not suck in air at the pump. The filter moves the pickup into the dimple. Anyone with a 1995 and prior AODE or 4R70W should put this piece on their transmission.

Oil Pan Part Number
F6AZ-7A194-A

Filter Part Number
F6AZ-7A098-A

Oil Pan with Drain Plug Part Number
F8UZ-7A194-AA

Accumulators (AODE and 4R70W only)

For the accumulator pistons, the only choice are the new pistons that are rubber bonded onto a steel housing. These provide the best wear and durability. For that matter, the 1-2 accumulator cover also needs to go with the rubber bonded on steel part. I will discuss what to do with the springs in the main control modifying section.

1-2 Accumulator Part Number
F7AZ-7F251-AA

1-2 Accumulator Cover
F4AZ-7F247-A

2-3 Accumulator Part Number
F7AZ-7H292-AA

This is the old 1-2 accumlator, it needs to be replaced with the one next to it.



Extension Housing

There are only two 4R70W extension housings, the difference being the length of the housing depending on which output shaft you use (Only Town Cars and Police cars use the longer shaft). Inspect the bushing in the housing closely. These bushings have a tendency to want to spin due to no forced lubrication to the bushing. If you want to run high numerical gear ratio rear end gears (4.10 or greater) I recommend the following modification to get lube to the bushing; an additional line needs to be added from the line pressure tap on the case to the bushing. If you are going to perform this modification, you'll need to use a new bushing. The line pressure tap (on the drivers side of the case, do NOT use any of the other taps) is 1/8" pipe thread. Get a 1/8" pipe to 3/16" brake line, 90 degree inverted flare fitting and thread it into the line pressure port in the case, putting some good high temperature silicone on the fitting. Press the bushing out of extension housing. Drill and tap the extension housing for 1/8" pipe (this requires an F drill) at the 3 o'clock position as viewed from the front. Get another 1/8" pipe to 3/16" 90 degree inverted flare fitting. Loosely install the fitting into the hole. Grind the fitting on the inside of the extension so that the bushing can be pressed back in without interference. Press the bushing back into the extension housing, using some Loctite on the bushing. Drill a .050" hole through the hole for the fitting and through bushing. Take some crocaus cloth and smooth out any burrs the drill made. Install the 90 degree 1/8" pipe to 3/16 inverted flare fitting into the extension housing using some high temperature silicone. Then connect the two fittings with a 3/16" brake line. This modification will lubricate the bushing and prevent premature bushing failure. It will not hurt line pressure since the hole, .050", is very small.



The picture in the upper left shows the hole drilled and tapped. The upper right picture shows the fitting not sticking into the bushing surface, if it does, you must grind material off the fitting so that it doesn't stick out. The lower left picture shows the bushing back in the extension with the .050" hole drilled through the bushing. The lower right picture shows the fitting installed in the extension housing.

If you are having a custom driveshaft made, I recommend using the longer extension housing. This 1" longer extension housing will make the driveshaft shorter, which will allow a higher driveshaft speed. You still want to use the short output shaft, but use the longer extension housing.

Long Extension Housing	F5UZ-7A039-A
Short Extension Housing	F3LY-7A039-A

Parts needed to add forced lube to extension housing

- 2 1/8" pipe to 3/16" inverted flare fittings
- 3/16" brake line, about 18" long
- F drill
- 1/8" drill
- 1/8" pipe tap
- .050" drill
- Crocus cloth
- Loctite RED
- High temp silicone sealer

Reverse Servo

There are actually 3 different reverse servos made in production. The difference between the 3 is only the length of the rod. There is a long, medium, and short rod. The different rods are used to get the servo stroke to the factory specifications. If you are trying to get every ft-lb out of your vehicle, you can put in the servo with the shortest rod. This provides a very slight improvement drag in the transmission.

Reverse servo with the shortest rod E0AZ-7D189-AVMR

You can determine which servo your transmission already has by looking at it and counting the rings on the servo. The shortest servo has one ring on it. The picture below shows the location of the ring(s).



Case

The main thing to look for in the transmission case is the air bleed hole in the OD servo. There is a very small hole in the top of the servo bore to purge air out of the servo pocket. Since this hole is very small, it is prone to getting plugged, especially if a failure has occurred. During the re-build, blow this hole with high-pressure air from an air compressor.

Other notes

The stock pump is fine as is and needs no changes.

Final Comments/Thoughts

If you are building up a 4.6L engine in an older car (1997 or older), and plan to make a lot of power (>450 HP), you are better off buying a new transmission from a 5.4L truck through a dealer. Try to get a new one, not a remanufactured one, although this may not be possible. You will need to buy a main control from a car (listed below) and not use the one that came on the truck transmission. There are various valves and springs that are different between the two, and the car main control is preferred over the truck one. Unfortunately, the internal parts that are different are not service separately. You may still have to go into the transmission to add more clutches, but it already has most of the parts that were recommended above.

Modifying the Main Control

In this section I will cover how to modify the main control. This will only deal with AODE and 4R70W main controls. If there is enough need, and I have time, I will write a supplement for an AOD main control. I will break down each shift and what to do to modify it to meet your needs. If you are building a transmission for a high-powered engine I recommend starting with a new main control from a 1999 Car. If you get a 1999 main control, which I recommend, you'll have to install your old shift solenoids and converter clutch solenoid. The 1998 and newer transmissions got rid of the wires and went to circuit board type piece. The pin outs of the connectors are different between the two.

The reason a 1999 main control is recommended is that there are several internal changes different in this main control than the previous years, making it a better choice. You cannot just get these different parts since they are not serviced separately, only as an entire main control. These changes include improved flow to the torque converter circuit (which is lube flow), higher 2-3 capacity valve spring, lower 3-4 capacity valve spring, and revised manual valve to allow faster direct clutch exhaust on manual 4-2 shifts.

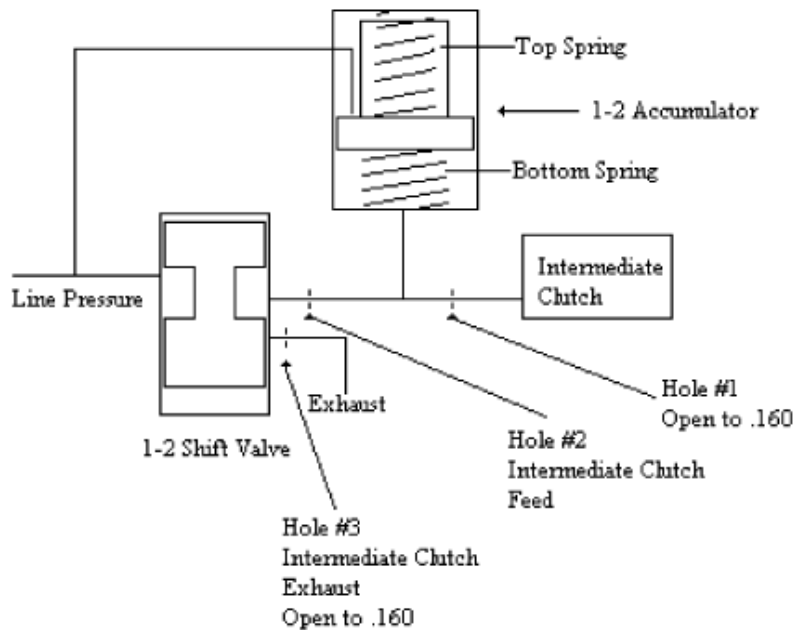
Recommended Part number of Main Control to start with for ALL applications XW7Z-7A100-CA

Also remember that all 1996 and newer vehicles, along with all 1995 Town Cars, Crown Vic's and Grand Marquis, use a different converter clutch solenoid than the previous models. You'll need to keep the solenoid type that your car was designed for to prevent failure of the solenoid.

In addition the pressure control solenoid bracket changes with the 1996 and newer main controls. You'll need to change that if you are going to update to a newer main control. TSB # 97-16-7 details the parts necessary for the change.

1-2 & 2-1 Shifts

There are 3 things to modify with regard to the 1-2 shift; there are two holes that feed the clutch and then the 1-2 accumulator.



All 1995 and prior 4R70W's will need the hole marked #1 opened up to .160" or a number X drill. This eliminates having both feed holes in series and will allow the intermediate clutch to be controlled by a single orifice. This needs to be done on any application.

The main feed orifice for the clutch is marked #2. The larger you open this hole the faster the clutch will fill, thus resulting in firmer shifts. Opening this will lower the WOT 1-2 shift speed since the fill time for the clutch will be reduced to about half of it's original time. This change will eliminate the need for a custom chip when changing rear gear ratios. The steeper you go in gear ratio, the larger you will need to make this hole.

The final part of the 1-2 shift is the accumulator. The accumulator has the capability to have two springs, one on the top and the other on the bottom. (This positioning is as it is installed in the vehicle). The top spring controls the finish pressure of the accumulator and the bottom spring controls the start pressure of the accumulator stroke.

There is only one orifice that controls the 2-1 downshift; this is hole #3 on the diagram above.

The following is the recommended changes to these 3 holes and accumulator springs.

	Hole #1	Hole #2	Hole #3	Top Accumulator Spring*	Bottom Accumulator Spring*
Mild (<300 HP)	.160"	.081"	.180"	F75Z-7F284-AA	F7AZ-7F284-BA
Mild w/gear change	.160"	.100"	.180"	F75Z-7F284-AA	F7AZ-7F284-BA
300-450 HP	.160"	.100"	.180"	F75Z-7F284-BA	None
450 - 625 HP	.160"	.125"	.180"	F75Z-7F284-BA	None

* - **Part numbers are based on new style accumulator piston only**

A #46 drill is .081", a #39 drill is .0995", a #15 drill is .180", and a #20 drill is .160"

Manual 2-1 Downshift

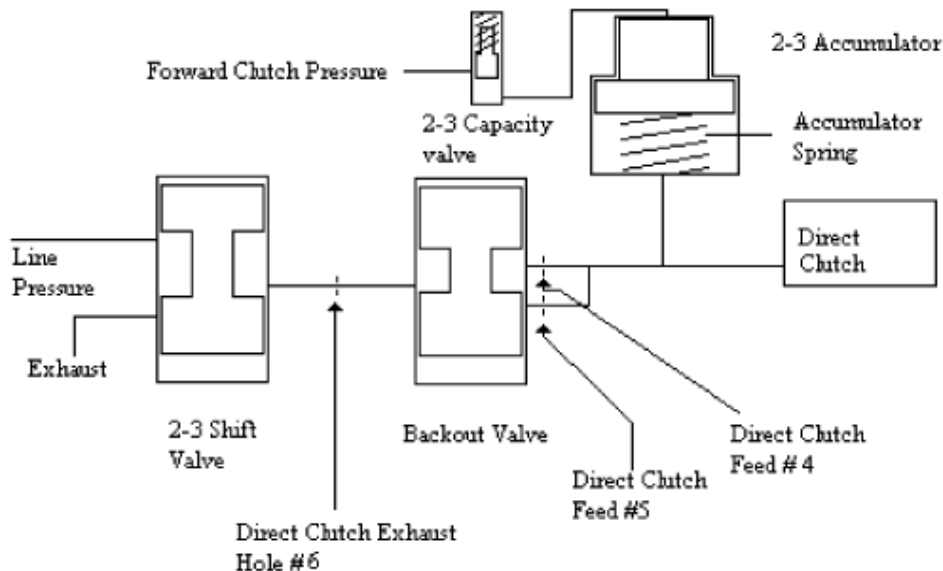
This is for people that get irritated at the "pause" that occurs when you move the manual lever to low. The pause is a delay while the reverse servo is filling. The reverse servo is very large and requires a lot of fluid to fill. You can reduce this delay by opening hole #7 in the separator plate.

Hole #7 - All applications desiring faster manual 2-1's .125"*

* - Note: Making this larger may/will result in momentarily locking the rear wheels.

2-3 & 3-2 shifts

The 2-3 shift is similar to the 1-2 shift. There are two feedholes and an accumulator.



The direct clutch feed holes are marked #4 and #5. Again, the larger the feed to the clutch, the faster the clutch fills, and the firmer the shift.

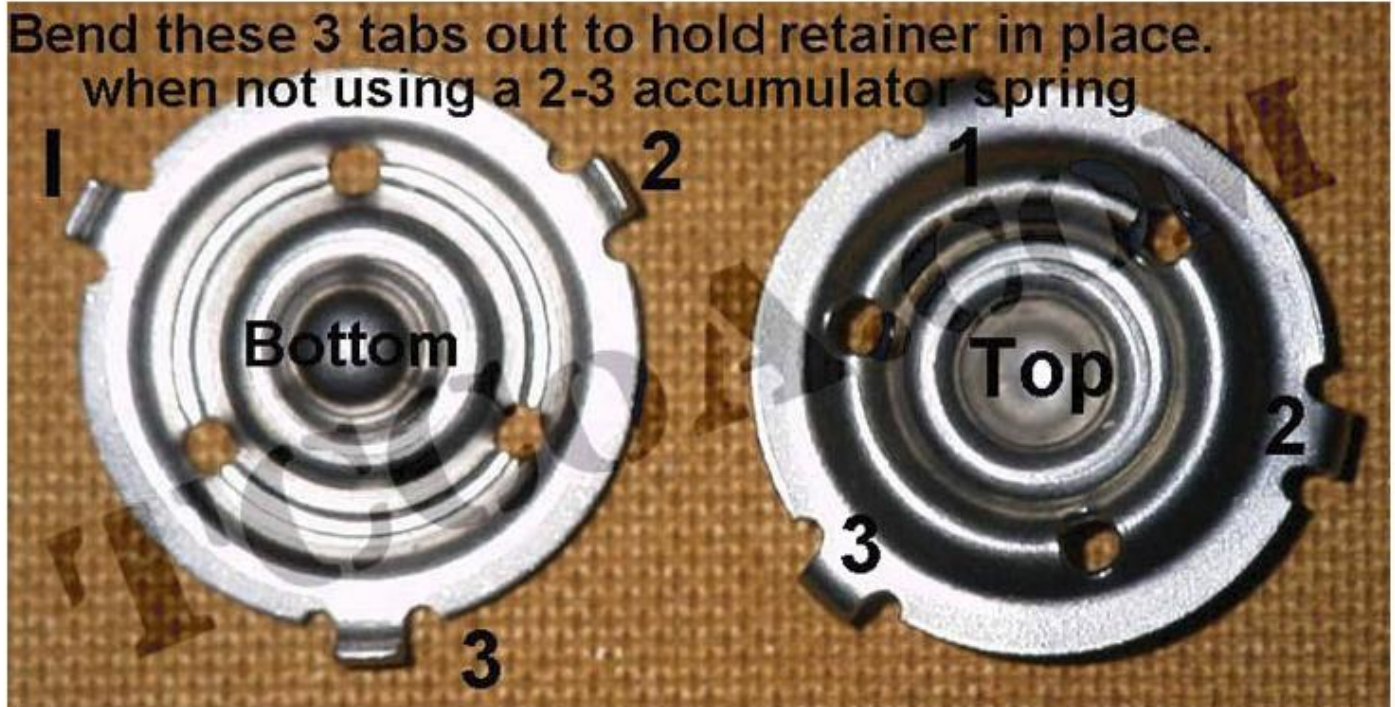
The following table is the recommended changes for the 2-3/3-2 shift.

	Hole #4	Hole #5-1	Hole #6-2	2-3 Accumulator Spring
Mild (<300HP)	.081"	.081"	.125"/.160"	None
300-450HP, or Mild w/gear change	.100"	.100"	.125"/Slot	None
450 - 625 HP	.125"	.125"-3	.160"/Slot	None

A #46 drill is .081" and a #39 drill is .0995", a #20 drill is .161"

- 1 - If you do not have the higher load 2-3 capacity modulator spring, you cannot make this hole bigger than .081". You need a 1998 or newer main control.
- 2 - If the transmission does not have a mechanical diode intermediate one-way clutch, open this hole to .125", if it does have a mechanical diode, open this hole to Slot. Use the gasket as a guide and drill/file this hole open to a slot
- 3 - You must open the gasket up with a razor blade when opening these holes to this size.

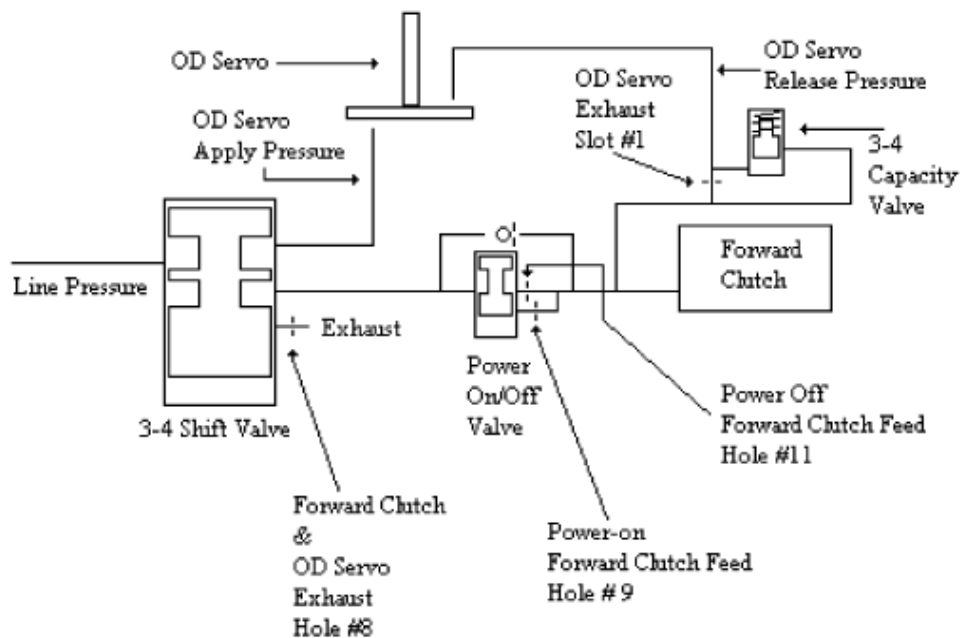
When you remove the 2-3 accumulator spring, if you have the one-piece retainer, you need to bend the 3 tabs on the retainer out slightly so it snaps into place when installing it in the case.



The larger direct clutch exhaust is only recommended for transmissions with the mechanical diode. The larger exhaust puts more stress on the one-way clutch and may cause pre-mature failure.

3-4 Upshift, 4-3 Downshift and Engagements

A lot of AODE's and 4R70W's have noticeable sag during the 3-4 shifts. This is because the OD band is applying before the forward clutch is released. The 3-4 shift has an exhaust orifice for the forward clutch and an exhaust slot for the release side of the OD servo.



If you have a 1996 or newer 4R70W you do not need to modify your forward clutch exhaust orifice. If you have a 1995 or older transmission, you need to open up the forward clutch exhaust orifice to .238", hole #8.

The OD servo release exhaust is a slot in the gasket that goes between the separator plate and the valve body itself. Open this slot up with an Exacto knife or razor blade to .100" wide. This is slot #1 on the diagram.

Note: All 1995 and prior AODE's and 4R70W's have a higher spring load 3-4 capacity valve. This higher load is not desirable and needs the lower load spring of 1996 and newer main controls. In this case, start with a new 1999 main control.

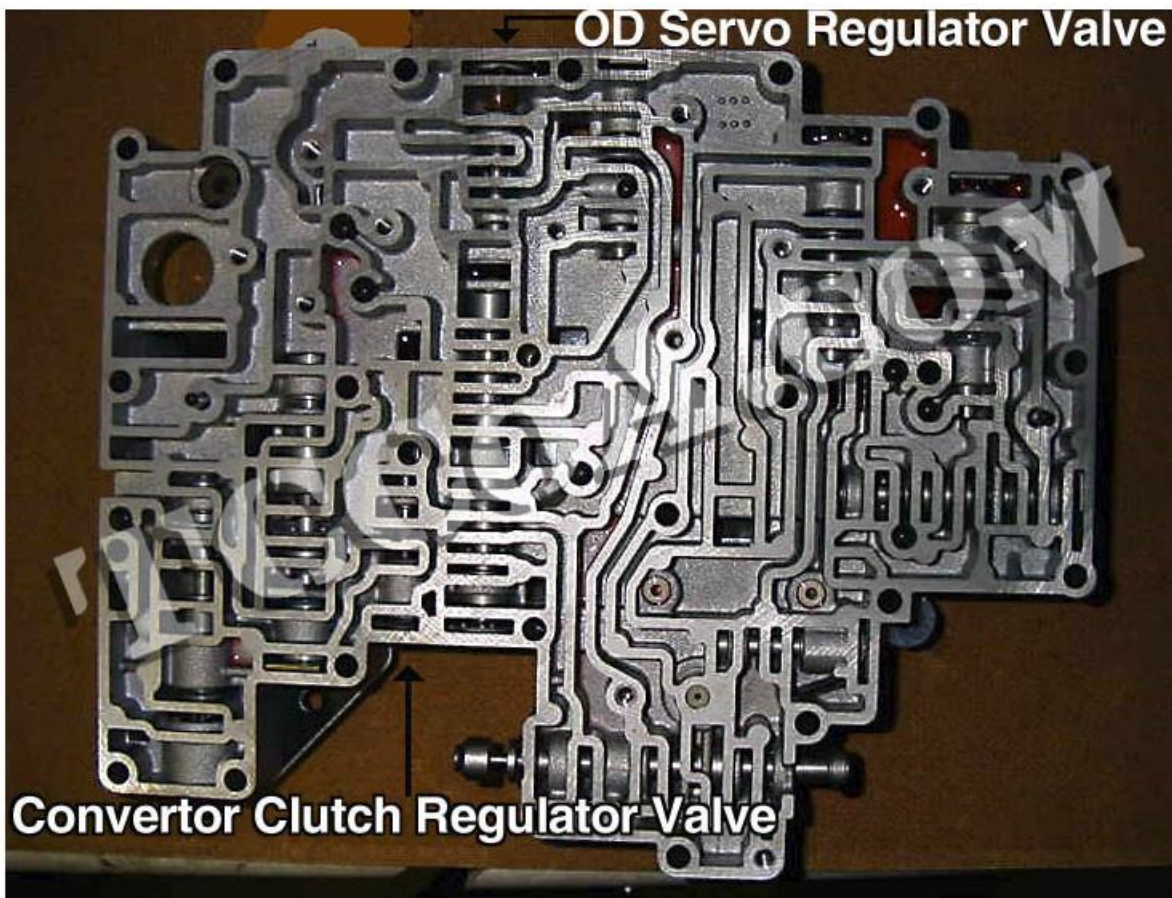
The 4-3 downshift is accomplished by bringing on the forward clutch and bringing off the OD band. This is done through both the #9 and #11 holes when doing a power-on 4-3 and only the # 11 hole when power off (coasting) or doing and engagement. To firm up the 4-3 downshift, you need to open up or add a hole in the separator plate. If you have a 1996 or newer 4R70W you only need to open a hole, if you have a 1995 T-Bird you also only need to open a hole. All others you'll need to add an additional hole (#9)

Use the chart below to determine what changes you need to this circuit.

	Hole #9	Hole #11	Slot #1	Hole #8
Mild (<300 HP)	.081"	.081"	No change	.238"
300 - 450 HP	.089"	.089"	.100"	.238"
450 - 625 HP	.100"	.100"	.100"	.238"

A #46 drill is .081", a #43 drill is .089", a #39 drill is .0995", and a "B" drill is .238"

If you experience a flare, or over rev, on a 4-3 or 4-2 downshift, and you've made the above changes, you have a few choices to correct this. The best way to solve this is to install the 5.4L forward clutch wave spring (mentioned in the above section). Another choice is to switch to a 6 plate forward clutch with no wave spring. Your final choice is to install a higher load OD servo regulator valve spring in the main control. Since the springs are not serviced separately, the best way to get a higher load spring is to find an old main control. If you have access to an old main control, you can remove the spring from the converter clutch pressure regulator valve and install it in the OD servo regulator valve bore of the valve body you are going to use. The spring you want to use is either orange or brown in color. This main control change may not completely fix the flare condition, it depends on how much line pressure is requested and what OD servo regulator spring you started with. The best way is to install the 5.4L wave plate. The picture below shows where the converter clutch regulator valve and OD servo regulator valves are located.



Reverse Engagement

For a faster reverse engagement there is a single hole that can be opened up in the separator plate. The larger the hole, the faster engagement.

	Hole #10
Mild (<300 HP)	.076"
300 -450 HP	.089"
>450 HP	.100"

A #48 drill is .076", a #43 drill is .089" and a #39 drill is .0995".

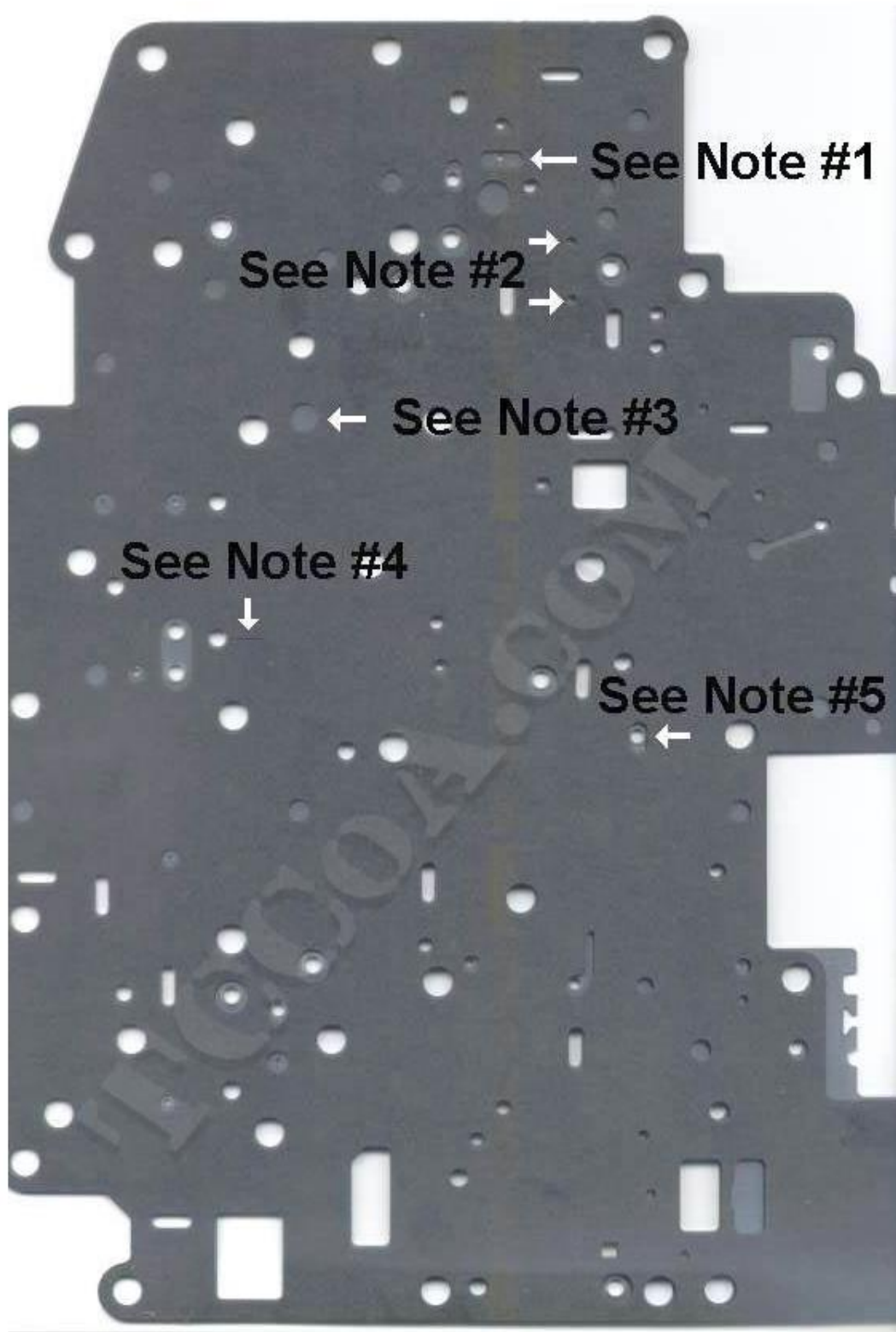
This hole size is not really dependent on horsepower. The above sizes are the minimum for that HP, but if you want faster reverse engagements, you can go to a larger size hole.

Separator Plate Details

The picture below shows the location of the above holes. There are a few exceptions to this. The #8 hole shown below is correct for 1998 and newer separator plates only. The location of the #8 hole for 1997 and older separator plates is shown farther down. Also, some older applications, 1994 and 1995 model years, may be missing the #11 hole. To add the hole, use the hole in gasket (shown farther below) as a guide for where to drill the hole.



The next picture is of the separator plate and valve body to separator plate gasket together. The five marked locations are explained below.



Note #1 This location is where, depending on your original plate, you may have to add the #11 hole. Use the center of the slot in the gasket as a guide for the center of your hole.

Note #2 When opening these holes, #4 and #5, to the 450 - 625 HP level (.125"), you'll need to open these holes in the gasket as well.

Note #3 This is the location of the #8 hole on 1997 and older separator plates. Find this hole to open up on your plate if your valve body was built prior to 1996.

Note #4 There is a very small gasket slot in the gasket at this location. This is Slot #1, as referenced in the 3-4/4-3 shift section. Open this slot to the correct size based the chart.

Note #5 If you have a mechanical diode intermediate one-way clutch, you can open Hole #6 to a slot. Use the slot in the gasket as a template for your slot.

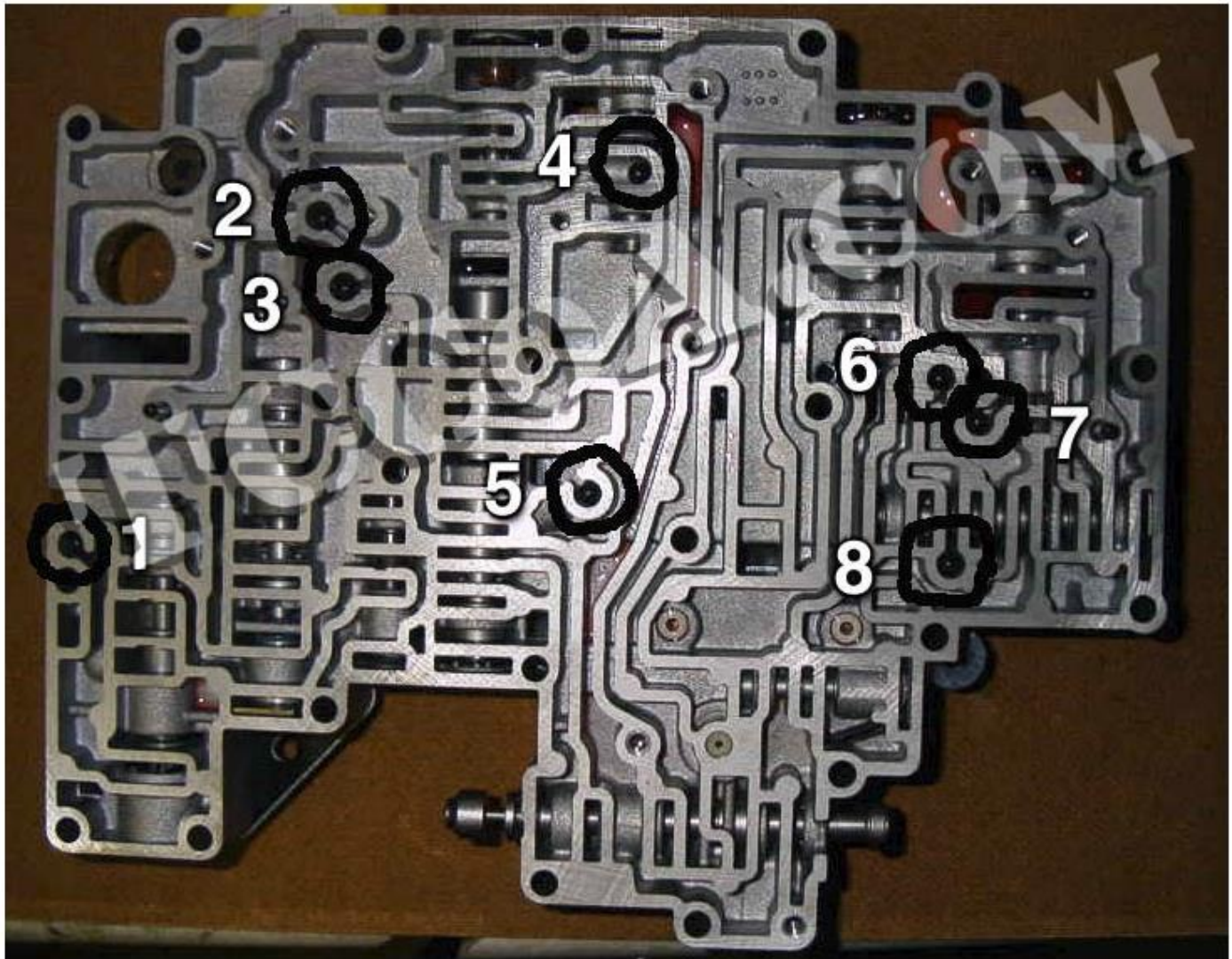
Other Misc. Main Control Items

When drilling holes in the separator plate, make sure you take some sand paper to the back of the plate and sand any burrs off. Do not get any burrs in the transmission or main control.

The bolt torque on the main control to case bolts is 90 in-lbs.

Make sure all the connections for the solenoids are plugged in; some of them are difficult to lock.

There are 8 balls in the main control, don't lose them or take them out.



Diagnosing Transmission Problems

TSB 95-5-15 covers a lot of different things. I would recommend that if you have any problems with shifting in or out of 4th gear, you should go over this TSB.

The first thing to do when trying to diagnose a problem is to check the fluid level. I know this sounds simple but most of the dipsticks in these transmissions are hard to read. If you have to add fluid to the transmission, you'll need to wait at least 5 minutes before you can check it again to be sure to get an accurate reading. Always check the fluid level when the trans is warm and the car is level.

The smell and visual condition of the fluid can tell a lot about the transmission. When checking your transmission fluid, get a clean white rag and wipe the dipstick on the rag. Look at the color of the fluid and look for deposits in the fluid. If the transmission is running hot, the fluid will get a brownish look and smell burnt. In this case you need a fluid change and a transmission cooler. If the color is very dark and smells very, very burnt, this means that a lot of heat was generated in a short time, indicating a failure. Look for small deposits in the oil. There can be several things causing deposits in the oil. Small dark pieces are usually friction material. Some friction material wear is normal in a transmission, but if there are a lot of deposits in the oil, most likely you need a rebuild. Another common thing found in oil is very small pieces of bronze. This could be caused by a bushing failure, but most likely is due to a failed torque converter.

If the transmission slips or shudders when just accelerating away from a light, this is caused by a lack of forward clutch capacity. This is most likely caused by one of 3 things, not enough fluid, the car has the old style (pre 1996) transmission pan, or the forward clutch seal rings are leaking. The pan and fluid level will mainly cause a problem when the transmission is cold, the forward clutch seal ring leakage is much worse at higher temperatures. If a gear set has failed, the significant amount of contamination will cause the main regulator to stick, acting like this problem. But if that happened, you'll have very, very, very, loud gear noise.

If the car has no 1-2 shift, but gets a 2-3 shift, try putting the manual lever in position two (for AOD's and OD-D-1 shifters, put this in the 1 position above 45 mph). If you have second gear in manual two range, most likely the intermediate one-way clutch has failed. This could also mean the intermediate clutch has burned up, but this is not a common failure. Even if the intermediate clutch is burnt and distressed, it will still hold torque at light throttles.

If the car has no 4th gear, but has 1 thru 3, put the shifter in position two at a higher speed like 50 mph. If the engine speed goes up to the second gear speed, and you have engine braking, then the OD band is still good (it comes on in manual 2nd) and the problem is somewhere else, most likely in the main control. If the engine speed drops to idle speed, around 800-1000 rpm, then the band is not holding, meaning that's it's very distressed and time to rebuild.

The following is chart showing the resistances of the various sensors and actuators in the transmission. If you check the resistances you must either perform this at the EEC connector end with the EEC removed from the harness, or you must disconnect the wire where it goes onto the sensor. If you don't remove the electrical device from the EEC you will get incorrect readings.

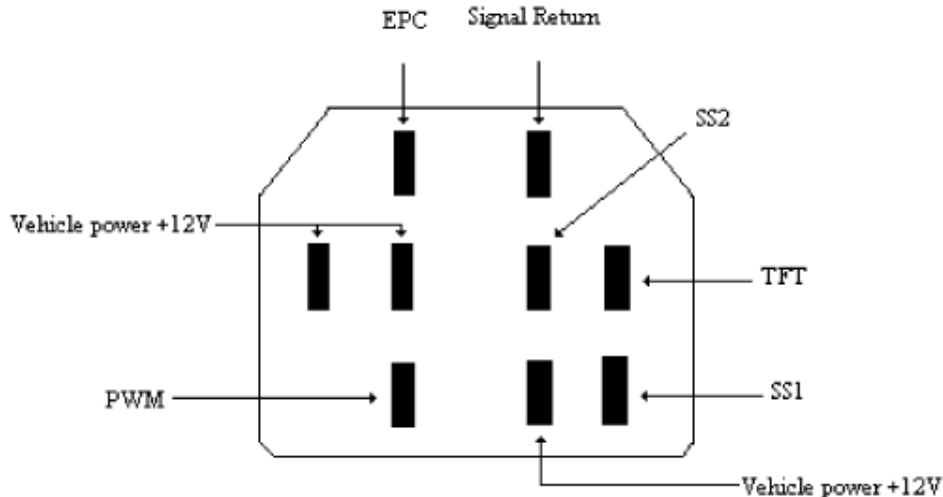
Device	60 pin EEC	104 pin EEC - 1997 and older	104 pin EEC - 1998 and newer	Resistance
SS1 (shift solenoid 1)	51 to 57	27 to 71	6 to 71	24.5 to 29.5
SS2 (shift solenoid 2)	52 to 57	11 to 71	11 to 71	24.5 to 29.5
PWM (torque converter)				
This is for 1995 and older vehicles, except TownCar and Crown Vic, where it is 1994 and older.	53 to 57	54 to 71	54 to 71	1.1 to 1.7
EPC (pressure control)	38 to 57	81 to 71	81 to 71	3.3 to 3.9
TOT (temperature)	49 to 46	37 to 91	37 to 71	28K to 35K
OSS (output shaft speed)	5 to 46	84 to 91	84 to 91	476 to 644

If the resistance is off on the sensors in your vehicle, then you need to replace it.

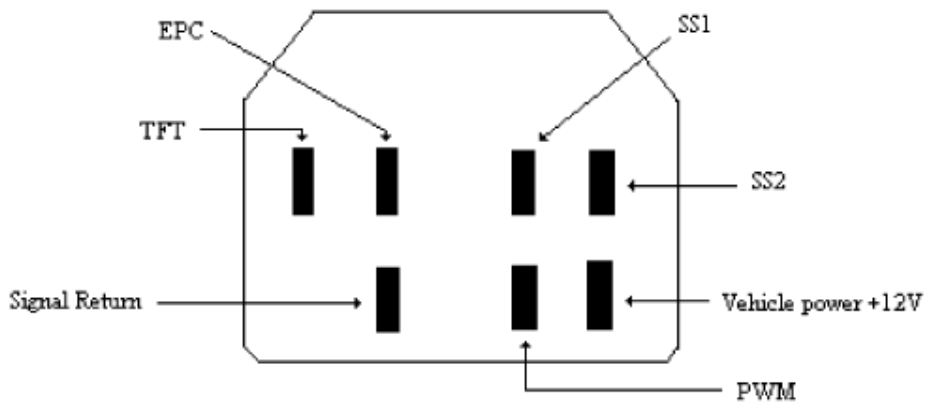
Also locate the wiring diagram for your particular vehicle. The above pins may not be correct for all vehicles, but the resistance is correct for that device. The shift solenoids, PWM, and EPC solenoids are checked between their signal and vehicle power, and the TOT and OSS are checked between their signal and signal return.

Re-Wiring Your Vehicle for A Later Model Transmission

If you want to put a later model transmission in your car you'll have to either re-wire the harness of the main connector or switch the components to go back to wires rather than the circuit board inside the transmission. The following is the pinout for the two different connectors. Note that vehicle power went from having 3 wires into the connector to one wire. This is because the circuit board in the transmission splits the power to the 3 places it needs to go, and in the older transmissions (1997 and prior), vehicle power is split to the 3 places in the harness. You'll need to make sure the two other vehicle power wires are tied off so they cannot short to ground.



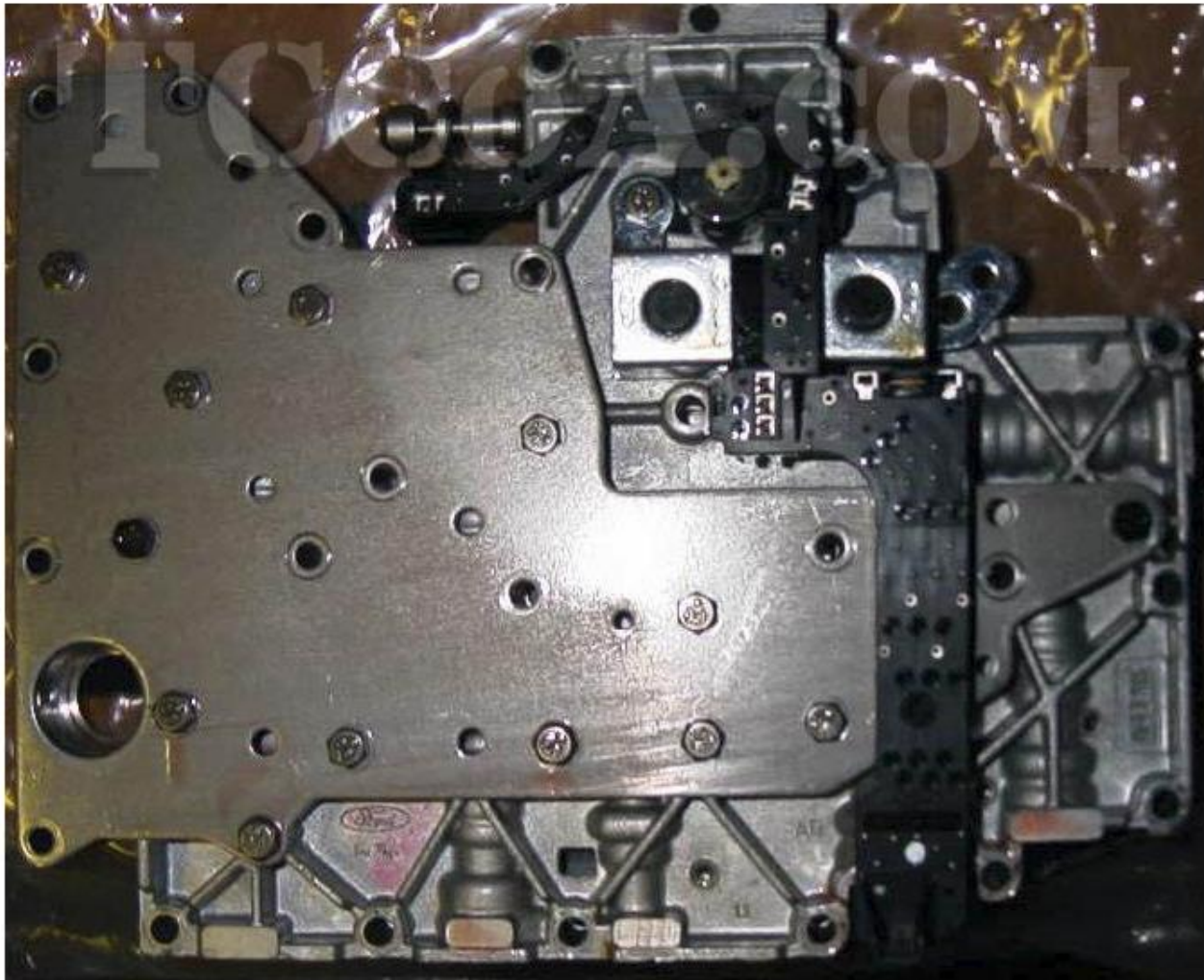
This pinout is looking into the harness connector.
This pinout is for all 1997 and prior transmissions



This pinout is looking into the harness connector.
This pinout is for all 1998 and new transmissions

The picture below shows the circuit board inside the transmission that connects all the solenoids. The wiring pinout above, 1998 and newer, uses this setup. All 1997 and older transmissions use wires rather than this circuit board. The connectors on the solenoids are different, so when switching from one to the other, rather than changing the pinout on the harness, you must change all the internal electronic pieces.

The picture below shows the circuit board inside the transmission that connects all the solenoids. The wiring pinout above, 1998 and newer, uses this setup. All 1997 and older transmissions use wires rather than this circuit board. The connectors on the solenoids are different, so when switching from one to the other, rather than changing the pinout on the harness, you must change all the internal electronic pieces.



Final Thoughts/Wrap-up

If you follow the recipe above, you can build a bulletproof transmission. The main things to remember are to take your time when making the changes and keep everything as clean as possible during the re-build. Don't overbuild the transmission, by this I mean be realistic about the amount of power you are going to make. The additional clutches add drag loss and rotating weight. The larger holes in the main control section will cause very, very firm shifts on a lower powered engine, that will most likely fail items in the driveline.

Some people may think the parts mentioned above, like the 5.4L gear set and the new output shaft, are overkill and not needed. When I build a transmission, I don't expect to ever see the transmission again. A lot of these parts, like the gear set and output shaft, are for high mileage durability. The upgraded parts will handle the torque better and the transmission will last a long time without suffering from high mileage fatigue. If you try to cut corners and save some money, you usually get what you pay for.

Like I said before, if the need arises, and I have enough time, I can add several things to this thesis. I can add the changes necessary to support an all out race transmission. I can go through a similar explanation for the main control on an AOD. And I can detail how to make a transbrake that will still work in OD range so the transmission shifts automatically.

Driveline Critical Speed

What it is -

Every rotating object has a "critical" speed or resonant speed, which is a function of its design, mass and stiffness. This is when the driveshaft is whipping in the middle, rather than spinning on a true centerline. For a driveshaft, this is also called "first bending mode", indicating the shaft actually bows out into a boomerang shape (on a micro-scale). This first mode bending speed is usually referred to in a driveshaft frequency.

What it does -

The energy stored and released through the deflection of the driveshaft through the resonance creates lateral and vertical accelerations of >10g at the problem frequency, which results in broken transmission extension housings, cases and causes moderate to severe vibration at highway speeds (> 70 mph), particularly with axle ratios numerically higher than 3.27:1. This energy release, when compounded by excessive driveshaft imbalance (some is good, too much or too little is not), companion flange run out/imbalance and excessive driveline angles provides the driver with excessive vibration and boom and tortures the driver and driveline components in general.

Because of this, most vehicles have a speed limiter to prevent from entering this mode and causing damage to the driveline.

Some detail -

As mentioned above, the driveshaft rotates at a certain speed based on rear axle ratio; tire size and road speed, but is independent of engine speed (unless you have a vehicle such as a Porsche 944 or C5 Corvette which utilize torque tubes and transaxles, in which case the driveshaft turns at engine speed).

The factors governing driveshaft critical speed include its material properties (i.e., Bulk Modulus of Elasticity which is roughly analogous to material stiffness), diameter, and length and to a lesser degree, wall thickness.

The only factor you can really modify to affect critical speed is material choice. Length is package-dictated, and diameter is usually constrained by driveline tunnel space as well. The answer then becomes a bit simpler - replace your steel shaft with an aluminum or MMC (metal matrix composite) shaft. Both offer reduced weight, which is key in this frequency range. MMC offers the additional bonus of additional damping and stiffness over a typical aluminum alloy.

As mentioned above, at the frequencies in question, a change in rotational mass has a greater impact on resonant frequency than a change in stiffness does, partly since it is easier to reduce mass than increase stiffness (adding stiffness almost invariably means adding mass -- a vicious circle), but particularly since resonant frequency is equal to the sqrt (k/m), where m is mass and k is stiffness. Here m is a stronger function being the in the denominator of a square root. So you can see that as "m" gets smaller, the resonant frequency "f" gets much bigger.

The use of an aluminum shaft provides a dual purpose - increasing critical speed out of the operating range AND directly reduces the rotational forces since those rotational forces are governed by:

$$F = mr \omega^2$$

Where ω is rotation speed, m is the mass and r is the radius at which it is spinning.

This means that a 50% reduction in rotational mass results in 50% less rotational force. So, when a driveshaft rotates out of true, due to run out of the shaft itself or due to trans output shaft or axle companion flange run out, the reduced mass * the radius of gyration (i.e., run out) product is smaller than for the same conditions with a steel shaft.

This becomes important not only at critical speed, but at more normal operational speeds where the effects of run out and mass imbalance are more evident than those of resonance:

For a typical Fox or SN95 Mustang, driveline critical speed is around 95-100 Hz. Using stock tires we have the following:

225-60R15, 225-55R16, 245-45R17 all rotate at 812-820 revs/mile at 60 mph.

This give is 13.5 Hz wheel frequency at 60 mph, and assuming a 3.27 axle, we then have:

$812/60 * 3.27$ or 44.25 Hz , driveline frequency.

So, $100/44.25 * 60$ yields a driveline critical VEHICLE speed of 135 mph. A good rule of thumb states that the objectionable driveline forces will start becoming significant at 70% of resonant frequency, so for the case of the 3.27 axle, the boom and vibration may be felt beginning at 95 mph.

Typically, 3.27 axles don't provide the driver with much to complain about; it is 3.73 and above which create the concerns. Using a 3.73, we find that

$13.53 * 3.73$ gives 50.5 Hz wheel frequency at 60 mph (substantially higher than the 3.27)

And the critical VEHICLE speed then becomes

$100/50.5 * 60$ or 119 mph.

Taking 70% of 119 mph equals 83 mph, certainly a speed at which some Mustang drivers experience occasionally.

For a 4.10 axle, the "70% speed" is 76 mph!

Compounding this problem are factors like transmission output shaft run out, imbalances and run outs from components such as the reverse sun gear, driveshaft, companion flange and pinion pitch line run out (a torque induced run out created when the pinion tries to crawl up the face of the ring gear involutes).

Combine these factors and the already marginal NVH resulting from proximity to 1st bending (critical speed) and the NVH becomes absolutely agricultural.

The aluminum shaft minimizes the contribution from companion flange run out and the driveshaft's own run out, directly due the lower mass. The pinion is free to pitch +/- 20 degrees and adding in any run outs of the companion flange or driveshaft at the pinion end results in the driveshaft mass having a large eccentric path to wobble about. It is this path times the mass of the driveshaft, which gives the characteristic boom and vibration at highway speeds.

Thus, as Newton predicted, as mass decreases so will the forces. That is why an aluminum shaft is your friend when coupled to 3.73s.

One side note: that great big mass on your pinion nose, fondly named by driveline engineers after the appendage on a male moose, is tuned to 45 Hz, the frequency at which the 2nd order forces created by u-joints as they rotate, force the pinion to bounce or pitch up and down and shake you by the seat of your pants and create an uncomfortable boom in the car. Once again run outs and imbalances will modulate this 2nd order driveline phenomenon to make it worse, so the moral is, LEAVE THE MOOSEB-, uh, DAMPER ON the pinion nose!

Another item: you CAN expect more axle noise when using an aluminum shaft however, which does not necessarily mean the pinion depth or side shims are incorrect, or that the gear cutting process is flawed. It just means that the aluminum shaft is more willing to "bend" circumferentially, torsionally and in a double hump (2nd bending) much more easily than a steel shaft.

Recall my prior statements at the very beginning about aluminum stiffness vs. steel? Picture a piece of sheet metal ducting. Bend it and it makes a WA-WA sound. That is pretty much what a driveshaft does, but at a much higher frequency - higher than even the dreaded "critical speed" of 100 Hz.

Axle noise will occur from about 350 Hz all the way through 500 Hz, sometimes even higher than that. The energy comes from the teeth meshing at the pinion/ring gear interface. This energy is transmitted to the driveshaft (and suspension components) and makes them deflect in the same sense as a piece of sheet metal goes WA-WA. Aluminum is less stiff than steel and takes less energy to deflect it, so it is far more inclined to make your axle go WOOOOO as you drive down the road at 45-70 mph.

Assuming again a 3.73 axle ratio, which has 11 teeth on the pinion and 41 on the ring gear, the axle noise frequency is calculated as (at 45-70 mph):

$$815/60 * 3.73 * 11 \text{ or } 557 \text{ Hz at } 60 \text{ mph.}$$

This means the WOOO you hear at 45 mph is about 418 Hz and the WEEEEEE you hear at 70 mph is way up there at 650 Hz. You can't SEE the driveshaft is bending and breathing and twisting, but it is telling you that precisely that is occurring.

So, now armed with this information, you now understand the basics of your vehicle's driveline.

Happy Motoring!