

# Diagnosing Transmission Control

**How do you begin to diagnose any problem today's complex transmissions could throw at you? It might not be as hard as you think.**

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Automotive transmission shifting problems have been around for many years. In early automobiles, the transmission was shifted manually from one gear step to the next using cogwheels or gears. In most modern automobiles this is accomplished automatically. The automatic transmission started as a hydro-mechanical unit where hydraulic pressure acting on different valve areas allows hydraulic pressure to be channeled in order to lock or unlock epicyclic gear sets (planetary gears). This allows gear step changes to occur without manually shifting the transmission. In these types of transmissions, shifting problems would be located within the transmission itself or the shifting linkage.

The transmission is a device that changes the rotational speed from the input to the output thus adapting speed to torque. This speed change from the input to the output in the automobile is where the input speed from the internal combustion engine is high in comparison to the wheel speed of the vehicle. The engine speed ranging from 600 rpm to around 6,000 rpm must be adapted to the rotational speed of the wheel, which could be zero rpm to around 2,000 rpm. The transmission accomplishes this with the use of gear changes. These gears use mechanical advantage or leverage to multiply torque. Torque is the twisting action on an object and is the product of the applied force, the lever arm length and the angle between the force and the lever arm. The gears allow the engine to produce horsepower (the rate at which work is done) that is produced at higher rpms and converts this into torque or the twisting action which is produced at lower rpms. In order for the engine's rpm band to be correctly converted into torque multiple gear ratios must be used.

With the introduction of electronic control to the modern automobile the gear step changes are now controlled with a microprocessor. The microprocessor gathers data from input sensors and then commands solenoids on or off to control hydraulic pressure in order to accomplish gear step changes. If a shifting issue occurs in a hydro-mechanical unit the problem is in the transmission, throttle valve adjustment or shift linkage. However, with the modern computer controlled transmission this is not the case, shifting issues have become far more complicated and might be in the transmission or in the electronic control system. It will be important to separate the electronic control system from the mechanical transmission in order to properly diagnose these units.

The question at hand is how does one diagnose these modern transmissions? When looking at a wiring diagram there are so many components and wires it first appears to be over whelming. This is actually much easier than the wiring diagram would indicate. The first thing to do is to locate the shift control solenoids in the wiring diagram and the wiring color for each of the solenoids; additionally the wiring diagram will give the location of the transmission components. You also will need a shift solenoid command chart that indicates which solenoids are on and which solenoids are off for each gear application (Figure 1).

In order to check the operation of the electronic control transmission solenoids, it will be necessary to use an oscilloscope. You may ask why you should use an oscilloscope when a scan tool allows the shift solenoid data to be displayed? There are several very important reasons to use an oscilloscope. One problem with the scan tool is how the data is transmitted from the vehicle to the scan tool. With all data bus systems, there is a delay between when the scan tool requests the data and when the data is actually received and displayed on the scan tool. No scan tool data is ever live, there is always a delay. This delay will vary depending on which communications bus type is used and how much traffic (data transmissions) is currently on the bus. This delay can be large and will create real problems when trying to diagnosing electronic systems. These electronic systems can fail in a millisecond (1/1,000 of a second); however the scan tools loop read speed can be greater than 250 milliseconds (1/4 of a second). If you are using a scan tool to diagnose the transmission, you might feel the transmission fail but be unable to determine what caused the failure.

It is also imperative to understand that the scan tool data is only as good as the engineering of the Transmission Control Module (TCM). When monitoring the transmission shift solenoids, the scan tool display will indicate the

command status of each solenoid. This will indicate whether the solenoid is on or off so you can determine what gear step is commanded.

The problem with a command status on the scan tool is this is exactly what this is: a command. This command does not mean that the solenoid was actually turned on or off. The command is accomplished by an algorithm running in the microprocessor. This base shift algorithm will equate the engine load, engine rpm, engine temperature, transmission temperature, transmission pressure and vehicle speed in order to select the correct gear for the current operating conditions for the vehicle. This algorithm will then command the solenoids on or off, which will be enabled by the TCM's hardware.

The TCM hardware incorporates a driver that will complete an electrical circuit. This completed circuit will allow current to flow through the solenoid windings, which in turn creates a magnetic field that will overcome the mechanical spring pressure and move the shift solenoid. Depending on the application of the TCM, the engineer will determine if a circuit will be installed on the TCM's hardware layer to monitor the shift solenoid current; one such circuit is shown in Figure 2.

In this diagnostic circuit, a shunt is used. A shunt is a very small resistor that drops millivolts when current is flowing through the circuit. This voltage drop across the shunt is equal to the current flowing through the circuit. This small voltage drop will need to be amplified by an operational amplifier. Once amplified this larger voltage output produced from the op amp will be read and converted by an analog to digital converter. This will convert the analog voltage (voltage changing over time) to a binary code (1's and 0's) that the microprocessor can read. This type of monitoring circuit will incur a monetary cost. When the manufacture is producing large numbers of vehicles this cost adds up quickly.

In order to limit the production cost of the vehicle, each component of the vehicle will need to be examined for the application. If there is a less expensive means to accomplish the same goal, then this may be used.

Another way to check the shift solenoid's operation is to use the outcome method. What this means is if the transmission solenoid actually functioned the gear step took place. Because the engine Crankshaft Position Sensor (CKP) can provide the engine rpm and the Vehicle Speed Sensor (VSS) can provide the vehicle speed, then a simple algorithm can be used to check the gear step change. If a 1-2 gear step is commanded and the gear ratio changes from a 4:1 (first gear) to a 3:1 (second gear), then the rpm divided by the VSS would give the gear ratio that was obtained.

Additionally if a clock is incorporated during the shift command the microprocessor can determine the amount of transmission slip that occurred during the gear step change. When the outcome method is used an electric circuit solenoid Diagnostic Trouble Code (DTC) will not be used. Because the solenoid is not actually being monitored the microprocessor cannot determine if it worked electrically or not, so the DTC will be set for a gear ratio error. When the outcome method is utilized, the vehicle already has the CKP and VSS sensors so this method can reduce the manufacturing cost of the vehicle.

Now that it is clear that the data the scan tool provides is limited, it will be necessary to use an oscilloscope in order to properly diagnose these systems. To connect the oscilloscope it will be necessary to check the wiring diagram for the location of the TCM. In most cases the transmission wiring at the transmission will be very hard to access, so it will be quicker to find the TCM and back probe the solenoid control wires at the control module. When back probing these solenoids, it is best to connect channel 1 to sol A, channel 2 to sol B and so on. This will allow you to easily match the shift solenoid command chart to the oscilloscope channels.

Because you will be testing at the module, it will also be important to check the current with an amp clamp. In Figure 3 the oscilloscope is connected to the shift solenoids 1-5 and the solenoid control wires are all put in the same amp clamp. As can be seen when the solenoids on channel 1 and channel 3 turn on, by pulling them to ground, the current is increased on channel 7. Then the solenoid on channel 2 is turned on, again a current increase is seen. This shows which solenoids are turned on or off and the current that was applied to each solenoid. Now it will be important to check the shift solenoid command chart to see which solenoids are applied for each gear.

As you drive the vehicle, you will record the oscilloscope data. When a shift error occurs check that each of the shift solenoids were applied correctly. If the shift solenoids were correctly applied and a shift error occurred the problem is inside the transmission. If a shift error occurs and the shift solenoids did not correctly, apply the problem is in the control system. It will be important to understand that some transmissions use timing solenoids whose operation may not correctly be shown in the shift charts. If this occurs you will need to find a good vehicle to test the solenoid operation and compare this to the vehicle with the shifting problem.

If the TCM uses pressure switches to check solenoid commands and a pressure switch is activated at the wrong time the transmission will default (Figure 4). The yellow trace is the L/R pressure switch and the blue trace is the L/R and TCC solenoid. When the shift for L/R is completed the solenoid will now become the TCC solenoid. When the TCC solenoid is applied the L/R switch should not change, the voltage should stay high. Figure 4 shows that the TCC solenoid (blue trace) pulses several times and L/R pressure switch (yellow trace) follows the solenoid's operation. If the L/R switch is grounded, then pressure is there to apply the L/R clutch.

When the TCC is turned on and causes the low reverse clutch to drag, this pressure will then burn up the transmission so that the microprocessor defaults the transmission. In default mode the transmission will not shift and will start in either 2nd or 3rd gear. If the L/R pressure switch is applied with the TCC solenoid application, and the vehicle is at high speed, the microprocessor will stop applying the TCC but may not default the transmission until the vehicle speed is reduced. This might mean that the TCC failed on the highway but actually defaulted 10 miles later when the vehicle came off of the highway to a stop. These pressure switches may cause a shift error that you can feel, but many times this will just create a default condition.

Additionally if the TCM hardware is designed with a circuit to monitor the shift solenoids, a diagnostic key on TCM test may be run. What this does is cycle the transmission solenoids when the ignition key is first turned on to test each of the shift solenoid circuits. In Figure 5, the key is turned on and the oscilloscope is used to monitor the TCM key-on solenoid circuit test. The test turns each solenoid on and off in sequence, if the circuits pass no further test is done. If the circuit fails then each solenoid is cycled on and off several times in order to fully test each solenoid circuit. If a solenoid circuit fails the transmission is put in a default mode. In Figure 5 it can be seen that the solenoid A circuit (yellow trace) is not working properly. This is caused by resistance in the shift solenoid circuit. In figure 6 the wiring as been repaired and the key-on solenoid circuit test now passes.

Many years ago transmission diagnoses was much less complicated. However, when diagnosing shifting problems in computer controlled transmissions with an understanding of the equipment you are using and an understanding of the system it will be quite easy to determine if the problem is in the transmission control or the transmission.