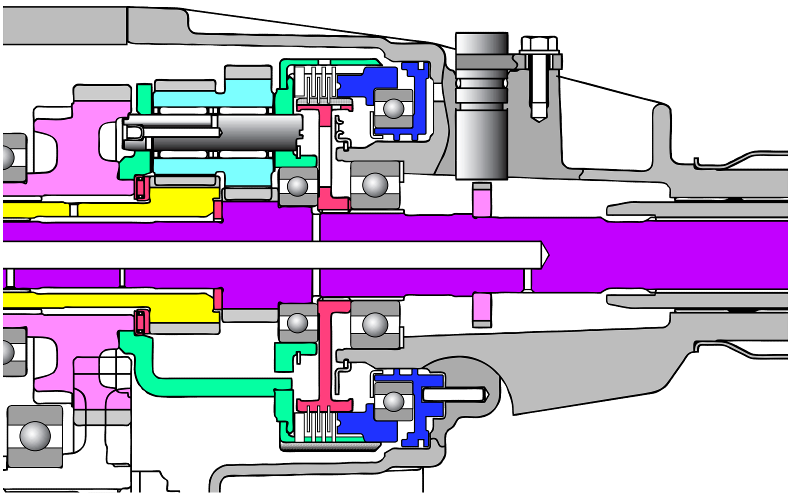
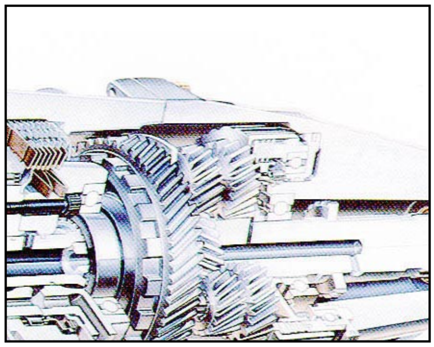
AT Vehicle with VTD

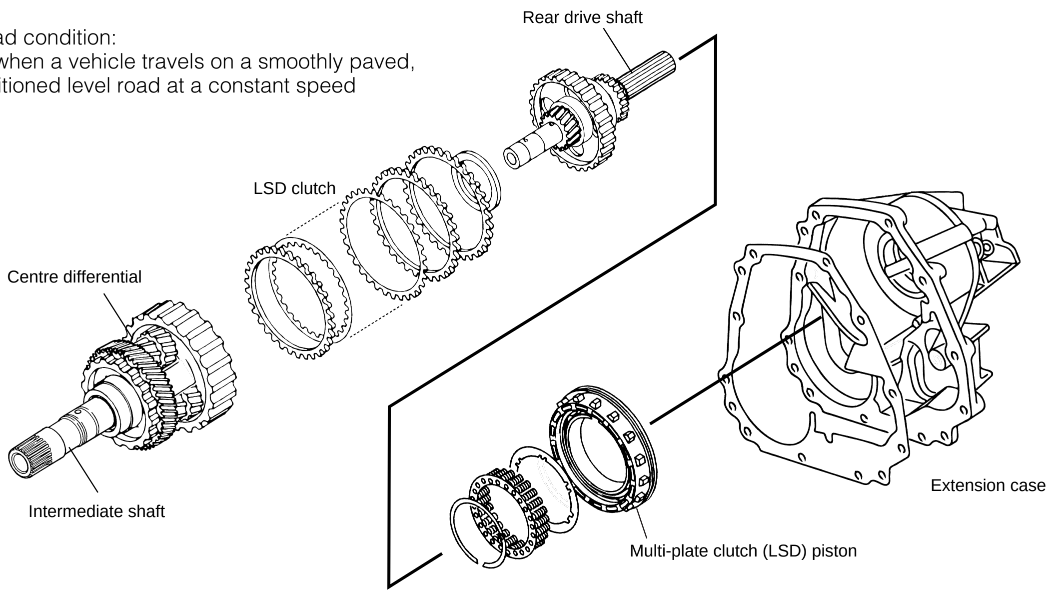
This system has the center differential made up of composite planetary gears inside the transfer to compensate for the rotational speed difference between the front and rear axles as well as provide uneven torque distribution between front and rear axles (45:55). As described before, it is not necessary to use the frictional force of the tires exclusively for transferring the driving force during normal travel (the road load condition*). Therefore, the numbers of teeth of the planetary gears are set to insure that the torque is distributed to the front and rear axles in an unequal proportion in order to make the traction of the rear wheels greater than that of the front wheels.
This is to obtain driveability similar to that of a RWD vehicle by giving a push to the vehicle from the rear in order to improve cornering.





A center differential made up of composite planetary gear sets is installed among the intermediate shaft,which is the output shaft of the transmission, and the rear drive shaft connected to the propeller shaft. Also, at the rear end of the center differential, a multi-plate clutch (LSD clutch) which limits the operation of the center differential is installed.
The LSD clutch is in an almost released position during normal traveling (the road load condition), with the center differential distributing the torque in a 45: 55 proportion to the front and rear axles respectively.
As the throttle opening is increased when a driving force higher than that for the road load condition is required, engagement of the LSD clutch is tightened in proportion to the throttle position so that the proportion of torque distributed to the front and rear axles becomes close to that of a rigid AWD system.

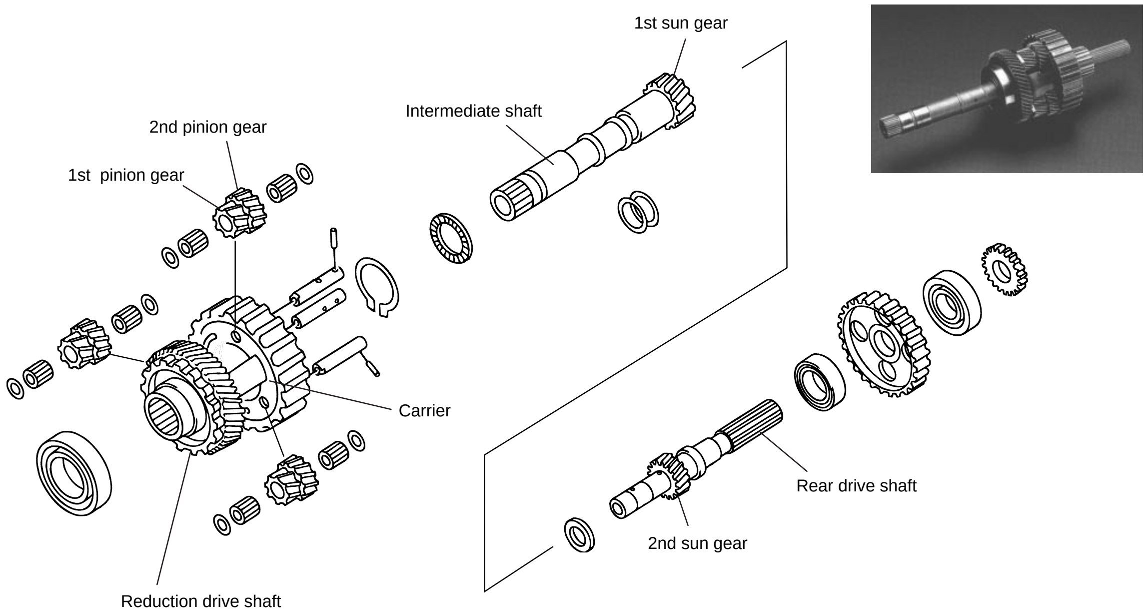
* Road load condition:
The load when a vehicle travels on a smoothly paved, well-conditioned level road at a constant speed



Center Differential

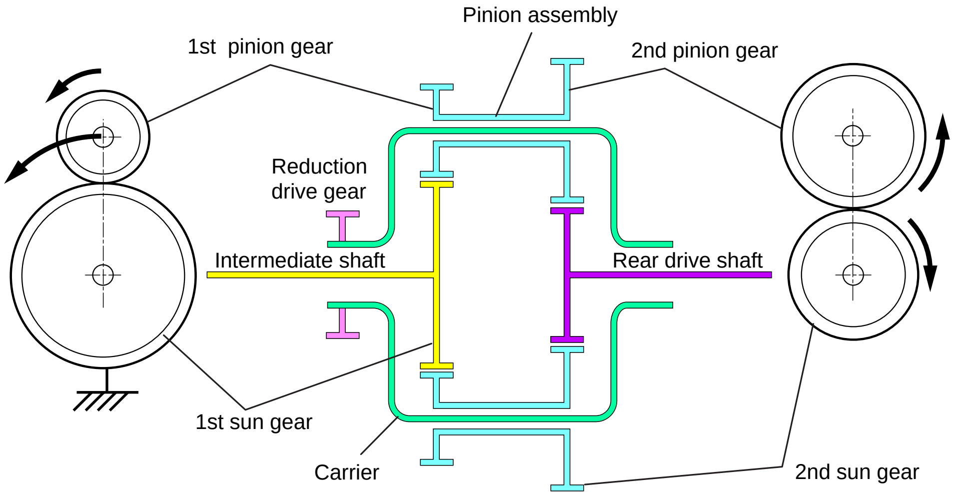
A center differential comprises two sets of planetary gears installed to one planetary carrier. The two sets of planetary gears are called the 1st and 2nd planetary gear set. The 1st and 2nd sun gears are installed to the intermediate shaft and rear drive shaft respectively. The three pinion gear assemblies installed to the carrier have a unit construction, which consists of the 1st and 2nd pinion gears.

The power transmitted to the intermediate shaft from the transmission is output to the rear wheels through the rear drive shaft and to the front wheels through the reduction drive gear installed to the carrier.



Suppose we fixed the 1st sun gear in position and then, rotated the 2nd sun gear clockwise. The rotation of the 2nd sun gear turns the 2nd pinion gear counterclockwise. Since the pinion assembly is unit construction of the 1st and 2nd pinion gears, the 1st pinion gear also rotates counterclockwise at the same rotational speed as the 2nd pinion gear. At this time, since the 1st sun gear has been fixed, the 1st pinion gear starts to revolve along the 1st sun gear counterclockwise. As a result, the carrier, which the pinion gear assemblies are installed, turns counterclockwise.

This means that, with the input shaft fixed, when the 2nd sun gear functions as the output shaft to the rear wheels rotates, the carrier functions as an output member for the front wheels turns in the opposite direction. Thus, this shows that the planetary gear sets can be used as the differential gears between the front and rear axles.



Next, let's look at how the torque is distributed by the center differential to the front and rear axles.

This time, let us assume that we are going to lift up the vehicle body, make the front wheels not rotate, and input the driving force to the intermediate shaft. In this condition the 1st sun gear will be turned while the carrier is fixed. If the gears composing the planetary gear set have the following number of teeth, the rotation number of the 2nd sun gear at per rotation of the 1st sun gear can be calculated as below:

1st sun gear: 33 teeth

2nd sun gear: 18 teeth

Both pinion gears: 21 teeth

Since the carrier has been fixed, the rotation number of the 1st pinion gear while the 1st sun gear is rotated once is:

33/21 (= 11/7)

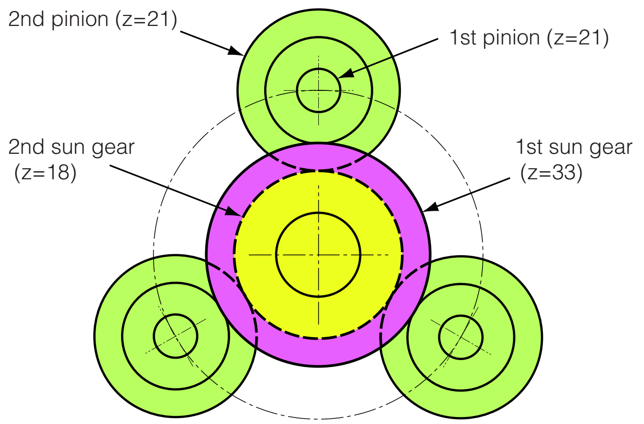
As the 2nd pinion and 1st pinion are unit construction, the 2nd pinion also turns 11/7 turns.

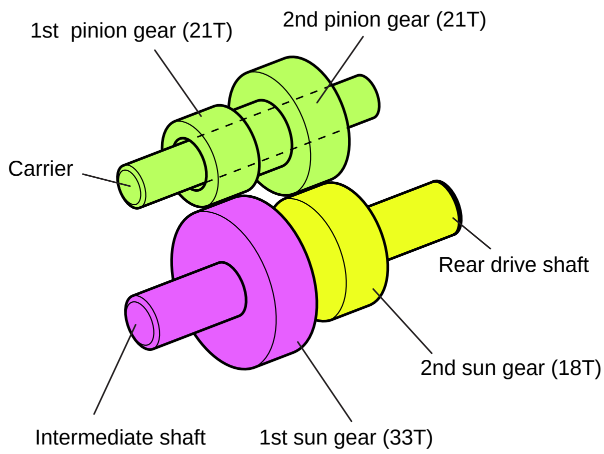
While the 2nd pinion turns 11/7 turns, the 2nd sun gear rotates:

11/7 x 21/18 = 11/6 (approx. 1.83)

From the above, we can see that the 2nd sun gear rotates approximately 1.83 turns while the 1st sun gear turns once.

Because the planetary gear sets function as a simple overdrive gear under this condition, the torque transmitted to the 2nd sun gear (rear wheel axle) is decreased to 6/11 (approx. 55%) of the input torque. The force required to fix the carrier at this time is the torque distributed to the front wheel axle, which is 5/11 (approx. 45%) of the torque being input into the 1st sun gear, the remainder of the torque which is transmitted to the 2nd sun gear.



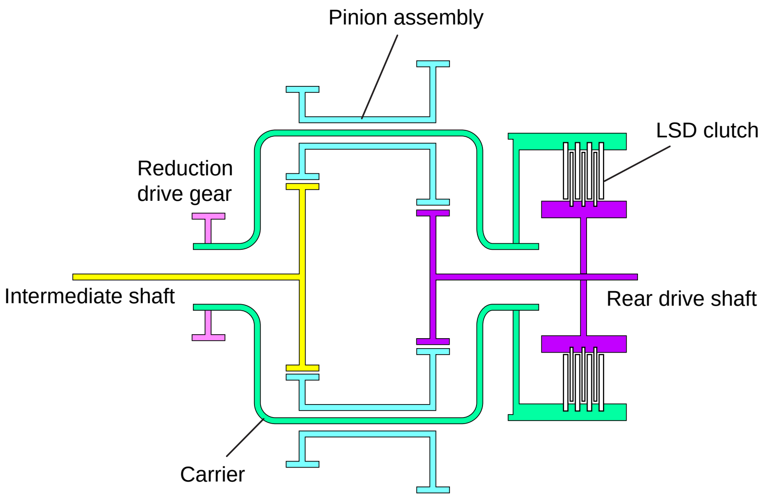


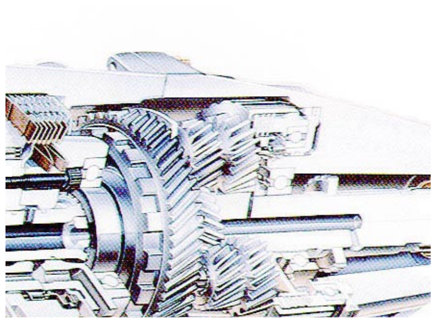
Functions of LSD

The center differential works to compensate for rotational speed differences between the front and rear wheel axles generated during turning etc. However, if one of the four tires loses its grip and keeps slipping, the center differential, because of its structural characteristics, will not be able to transmit the traction to the rest of the tires gripping the road surface. (Those tires will stop their rotation.)

To countermeasure this, it is necessary for an AWD system with a center differential to have some means to limit the rotational differences between the front and rear axles created by the center differential. The device that limits these rotational differences in the center differential is the LSD.

For the VTD system, the hydraulic multi-plate clutch (LSD clutch) is installed at the rear of the center differential. The drive plates and the driven plates of the LSD clutch are incorporated between the carrier working as an output member for the front axle, and the rear drive shaft working as an output member for the rear axle. The engagement of the LSD clutch limits the speed differences created by the center differential.



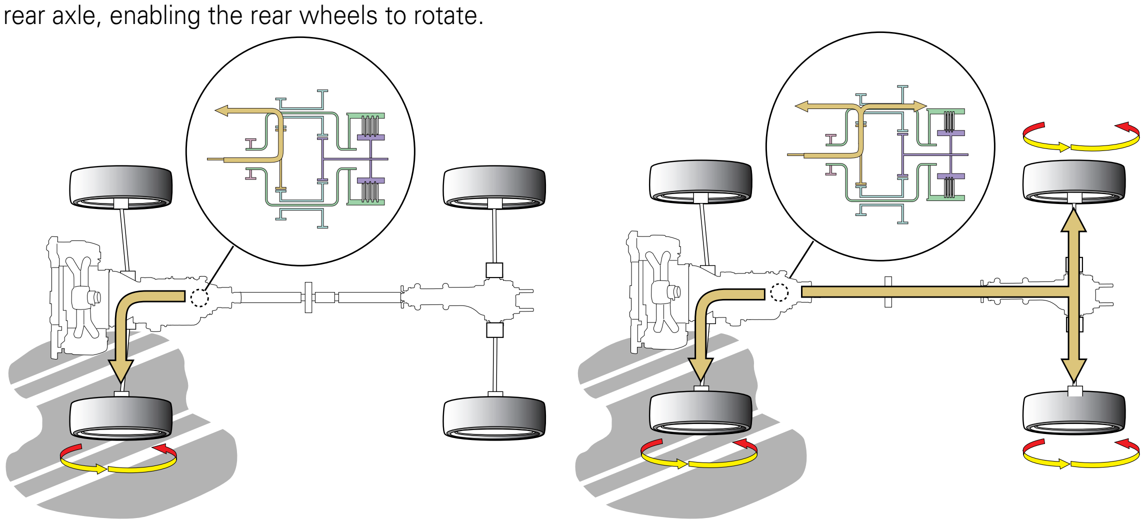


During normal driving, the LSD clutch is in released position, allowing the center differential to compensate for the rotational differences between the front and rear axles and to distribute the driving force transmitted from the engine to the front and rear axles in 45: 55 proportions.

But, if one of the tires starts slipping, the LSD clutch is engaged to connect the carrier and the drive shaft. This means that the front and rear axles are directly connected and a rigid AWD condition is produced.

For example, when either of the front tires slips with the LSD clutch in released position, the rear drive shaft output rotation to the rear axle is stopped because of the differential compensating function of the center differential, and the full traction transmitted via the carrier and output to the front axle makes the tires keep slipping.

Yet, once the LSD clutch is engaged, the carrier and the rear drive shaft are connected to transmit the power even to the rear axle, enabling the rear wheels to rotate.

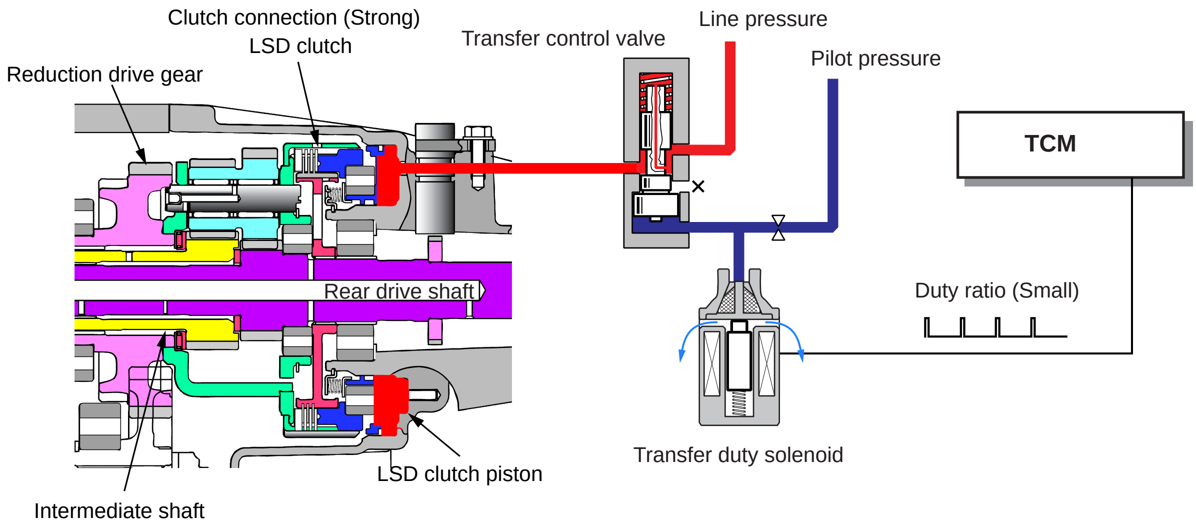


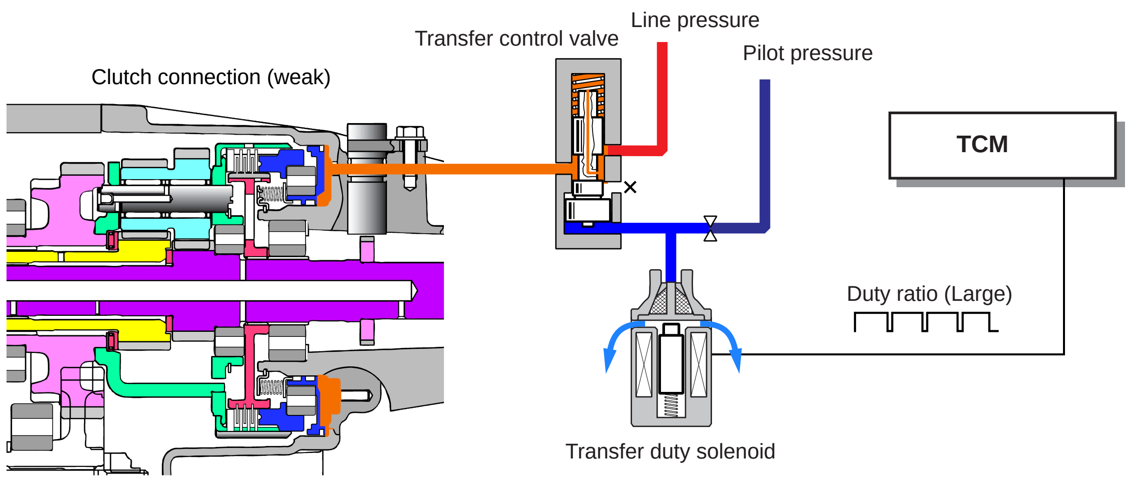
The hydraulic system of the VTD AWD is basically the same as that of the MP-T AWD, consist of a transfer duty solenoid, transfer control valve, and LSD clutch. The transfer duty solenoid is operated by the duty signal sent from the TCM.

When the duty ratio of the driving signal from the TCM is small, the drain amount of the transfer duty solenoid decreases, and the duty pressure working on the lower side of the transfer control valve increases. Subsequently, the pressure controlling point* of the transfer control valve rises to increase the pressure on the transfer clutch piston. Thus the LSD clutch is strongly engaged.

When the duty ratio of the driving signal from the TCM becomes larger, the drain amount of the transfer duty solenoid increases and decrease the duty pressure working to push the transfer control valve upward from its lower side. Then, the pressure controlling point* of the transfer control valve lowers and decrease the pressure on the transfer clutch piston. Consequently, the LSD clutch engages less strongly.

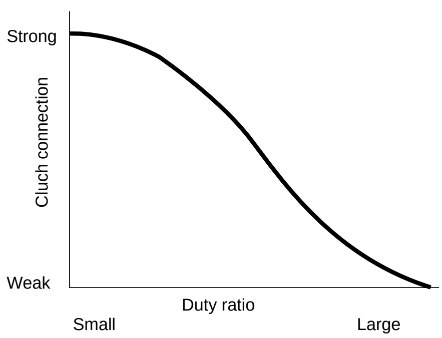
(*For more information on the pressure controlling point, refer to page 31.)





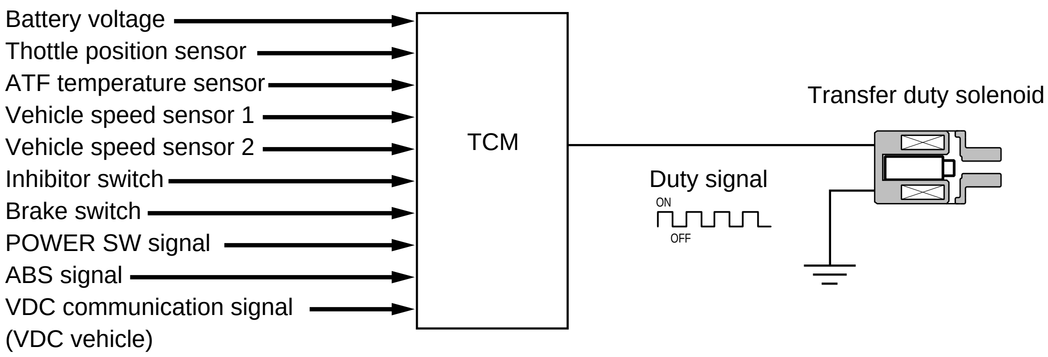
The relationship between the duty ratio of the driving signal from TCM and the condition of the LSD clutch engagement is shown in the table below.

Duty ratio	Condition of LSD clutch
Small	Strongly engaged
Large	Weakly engaged



The transmission control module (TCM) that controls the entire system judges the operating condition of the vehicle with various sensor signals including throttle position sensor, vehicle speed sensors and, etc. The TCM controls the duty ratio of the signal driving the transfer duty solenoid in order to control the strength of engagement of the LSD clutch.

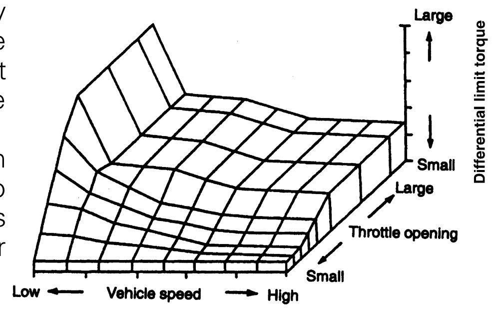
The basic input signals are the same as those for the MT-P AWD system, however, the vehicles equipped with the Vehicle Dynamic Control (VDC), the communication links between the TCM and VDCCM are provided.



ORDINARY CONTROL

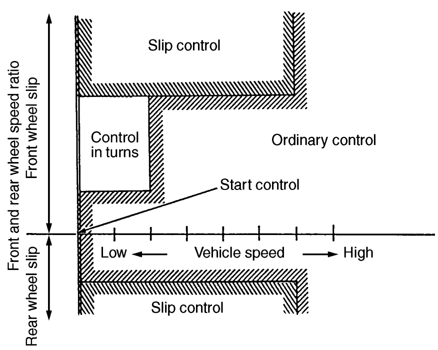
Each gear from 1st to 4th gear and reverse has a map for ordinary control which controls the LSD clutch torque appropriately for the driving conditions. The differential limit torque is set so it decreases when the throttle valve opening is small and vehicle speed is high.

The control is designed to reduce internal circulation torque. In addition, improved turning behavior has been designed to incorporate the advantages of AWD stability and driveability as well as provide stabilized vehicle response when the accelerator pedal is released or when a downshift is performed.



START CONTROL

When the vehicle speed is 0 km/h, the TCM makes control to generate differential action limiting torque that is proportional to the throttle opening. This enables the vehicle to start smoothly without swerving even on a slippery road.



TURNING CONTROL

When the front and rear wheel rotation ratio is within the standard range below set vehicle speed, control is performed to decrease the differential limit torque according to the rotation ratio and vehicle speed.

SLIP CONTROL

When front or rear wheels start slipping with the vehicle running slower than the predetermined speed, the TCM makes control to increase the differential limit torque. This function maintains traction and improves driving stability.

ABS CONTROL

When the TCM receives an ABS operation signal from the ABS unit, it adjusts the differential limit torque to the predetermined level and selects the 3rd gear. This function improves ABS control.

NORMAL BRAKE CONTROL

When the brake switch is ON and the throttle valve is fully closed, the TCM makes control to decrease the differential limit torque. This function improves stability during braking. (The ABS control has priority over this control.)

1 RANGE CONTROL

When the 1 range is selected, the TCM makes control to increase the differential limit torque. This function improves driving performance and traction when the road condition is worse.