SUBARU

QUALITY DRIVEN®

SERVICE

CERTIFIED SUBARU TECHNICIAN

Technicians Reference Booklet

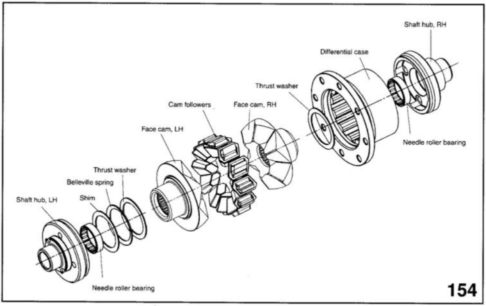
2004 New Model Update

Module 913

MSA5P0301B

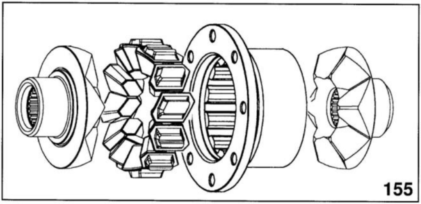
Technical Training

Front Differential



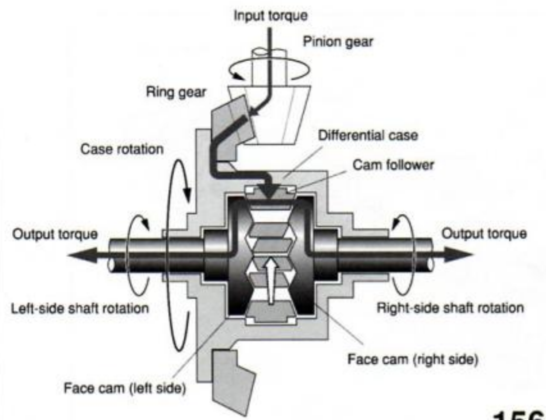
154

The WRX STi front differential is a cam type limited slip differential. It is a sealed unit and must be replaced as an assembly. The main components of the differential are a differential case, cam followers and two face cams. The bottom side of the cam followers is shaped to fit into slots made into the inner diameter of the differential case. These slots allow the cam followers to slide left and right as well as deliver power from the differential case to the left and right face cams. The top side of the cam followers are shaped to work with the shape provided to the cam followers.

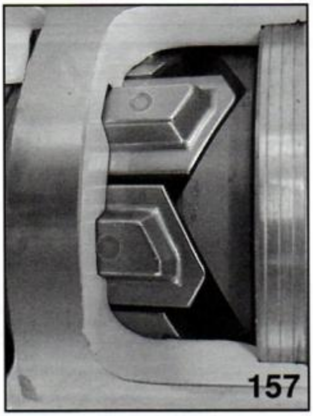


155

The cam followers have two different cam shapes (the shapes of the surfaces in contact with the face cams), which are alternately arranged. Because of this design, the left and right face cams each have 6 teeth.



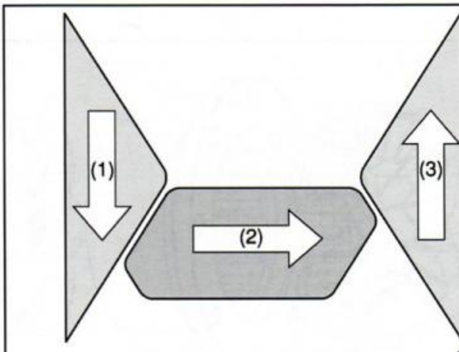
156



157

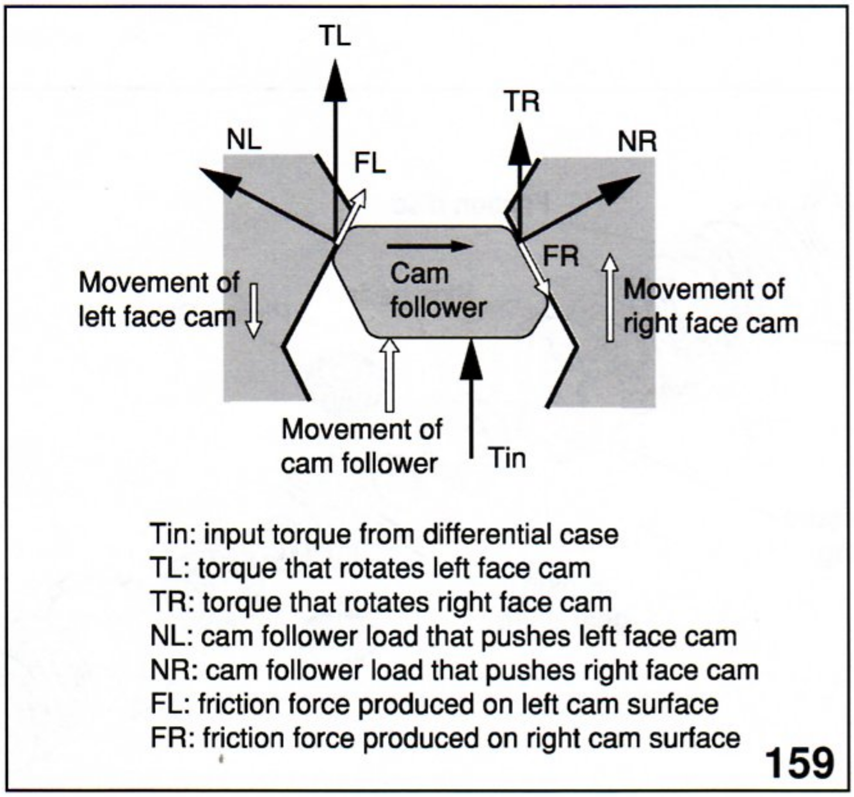
Operation

When the vehicle is driving on a level, uniform road surface, the left and right wheels are turning at the same speed, so there is no difference in the rotational speed of the left and right face cams. The drive force transmitted from the drive pinion gear to the ring gear is transmitted to the 12 cam followers via the slots on the inside of the differential case. The drive force is uniformly transmitted to the left and right face cams by the cam followers in contact with the left and right face cams. This causes all the cam followers and the left and right face cams to rotate together as a single unit.



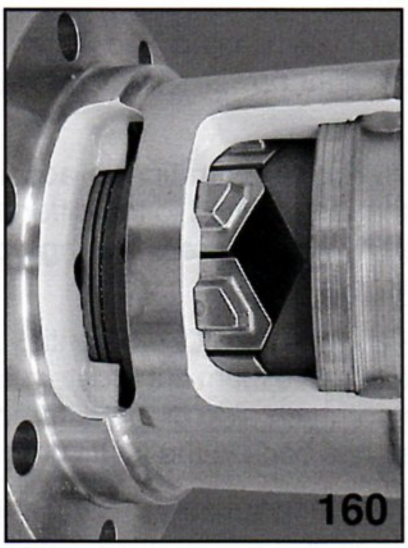
158

When a vehicle turns, producing a difference in rotational speed between the left and right wheels, there is a shift in the relative position of the left and right face cams. When the left face cam moves downward the cam followers are pushed by the left face cam to the right. This pushes the right face cam upward. As a result the upward movement of the right face cam is equal to the downward movement of the left face cam. This operation between the left and right face cams and the cam followers in contact them occurs continuously absorbing the difference in rotational speed between the left and right wheels produced by the turning vehicle.

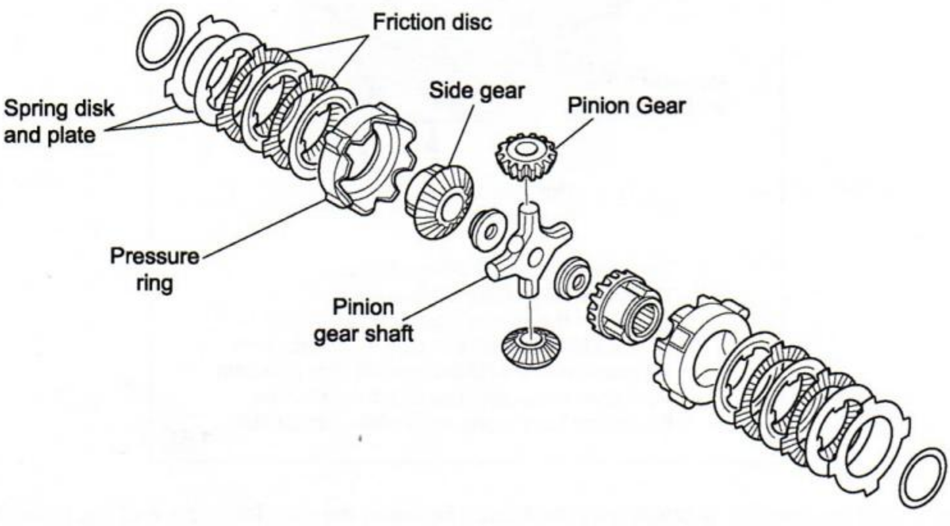


159

The limited slip function is created by the friction between the cam followers and the face cams. When the relative position of the left and right face cams change the cam followers start to move producing forces on the face cams. At the same time frictional forces which counteract the movement of the left and right face cams are produced. Additionally the friction created between the cam followers and the slots in the differential case and the friction between the face cams and the differential case enhance the LSD effect.


160

Rear Differential



162

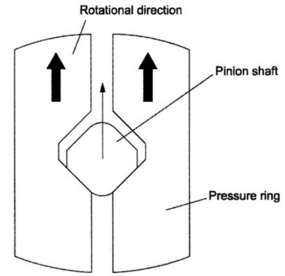
The rear differential of the WRX STi is equipped with a Mechanical Type Limited Slip Differential. The rear differential is non serviceable and must be replaced as an assembly. The Limited Slip Differential functions by slowing down the rear wheel with reduced or low traction and transfers that power to the wheel with traction.

Another feature of the Mechanical Type Limited Slip Differential is the ability to lock the rear differential into a 50% left and 50% right power split of the rear wheels under very high engine output conditions.

Mechanical Type Limited Slip Differential operation is accomplished through the mechanical application of a set friction plates that are splined to the differential side gears and the differential case. The friction plates are applied by a set of pressure rings, one for each side of the differential, which are acted upon by the pinion gear shaft.

The pressure rings are splined to and rotate with differential carrier, but the pressure rings can move in and out. The force required to move them out is determined by the spring tension from a set of spring disks and plates, one set for each side of the differential. It is also this spring force that assists with returning the pressure rings back to the static position.

The outward movement of the pressure rings pushes on and applies the friction plates. The degree of friction plate application is determined by how much outward movement is applied from the pressure rings.



163

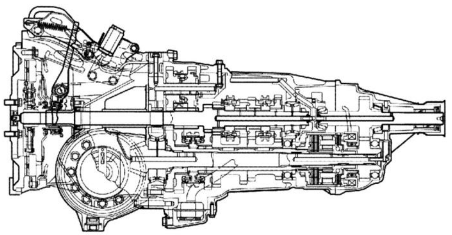
The force that moves the pressure rings outward is generated by the pinion gear shaft. The static position of the pinion gear shaft is in the center of a space created by the pressure rings as they surround the pinion and side gears.

Power from the differential carrier is delivered to the pressure rings and depending on the amount of force created by the movement of the pressure rings into the pinion gear shaft, pulls the pinion gear shaft in the direction of forward movement or uses the pinion gear shaft to split or move the pressure rings outward.

This will apply the friction plates and allow the power to flow partially into the side gears and partially through the differential pinion gears to the side gears and finally to the rear wheels. Higher degrees of friction plate application result in the power flowing from the differential carrier straight to the side gears and to the rear wheels.

Driver Control Central Difference (DCCD)

Outline



165

The DCCD system is comprised of sensors, switches, DCCD central models and planetary gear type center differential with built-in LSD clutch.

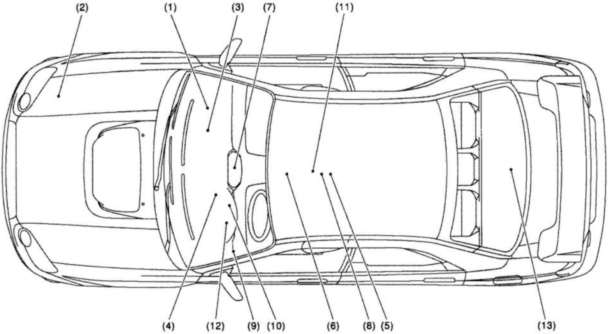
By varying the LSD clutch engagement torque from 0% to 100%, the DCCD control module can vary the drive torque distribution to the front wheels from 35:65 to 50:50 (direct 4WD condition), using the planetary gear type center differential.

Utilizing the DCCD control module to suitably control the drive torque distribution to the front wheels according to the driving conditions, the system improves the running performance over rough roads and reduces tight cornering phenomenon.

Also, the driver can control the LSD clutch engagement torque by adjusting the DCCD control dial equipped beside the parking brake. (Manual Mode)

In the event of a system malfunction, a fail-safe control is activated to release the LSD clutch.

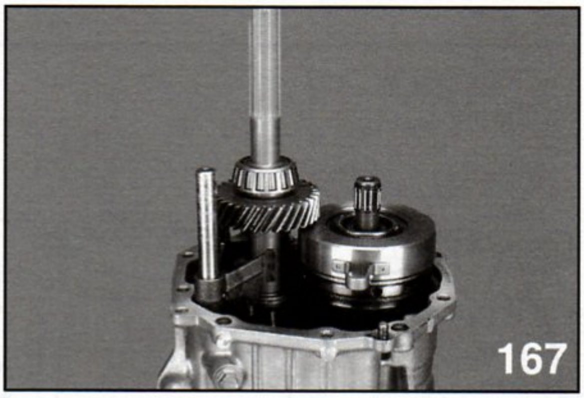
System layout



(1) Engine control module (ECM)
(2) ABS control module & hydraulic control unit (ABSCM & H/U)
(3) Driver's control center differential control module
(4) Accelerator position sensor
(5) Lateral G sensor
(6) Center differential control dial
(7) Center differential
(8) Manual mode switch
(9) Driver's control center differential relay
(10) Driver's control center differential indicator (driver's control center differential diagnostic indicator)
(11) Parking brake switch
(12) Brake Light switch
(13) Rear differential oil temperature switch

166

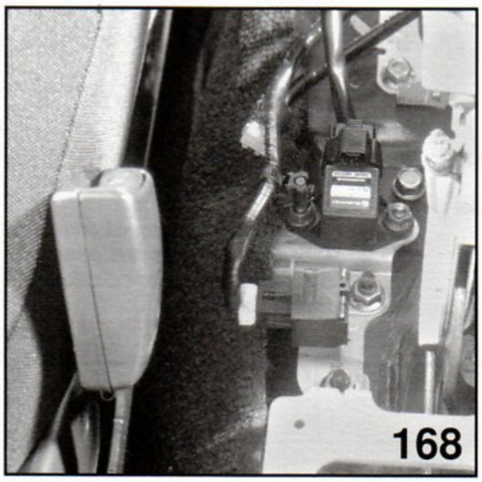
Center Differential



167

The center differential is comprised of the planetary type differential, LSD clutch, pilot clutch, DCCD coil assembly, and other parts. The DCCD coil assembly (electromagnet) is controlled by the DCCD control module duty drive signal, which sets up a magnetic force that the coil assembly uses to vary the LSD clutch engagement force.

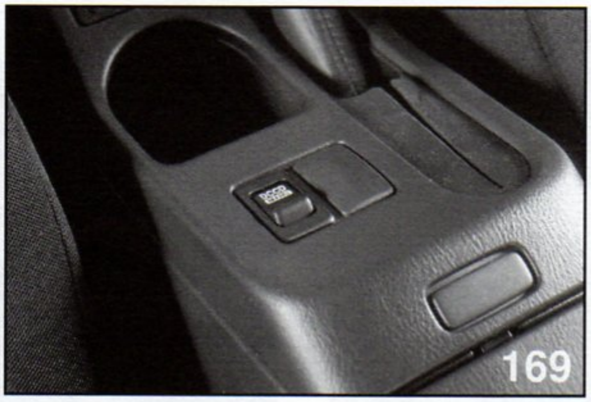
Lateral G Sensor



168

This sensor detects the lateral acceleration of a vehicle while it is cornering. The DCCD control module determines the vehicle cornering conditions based on signals from this sensor and controls the LSD clutch engagement torque accordingly, improving stability when a vehicle is cornering.

Manual Mode



169

The Manual Mode selector switch toggles between Manual Mode and Auto Mode each time it is pressed.

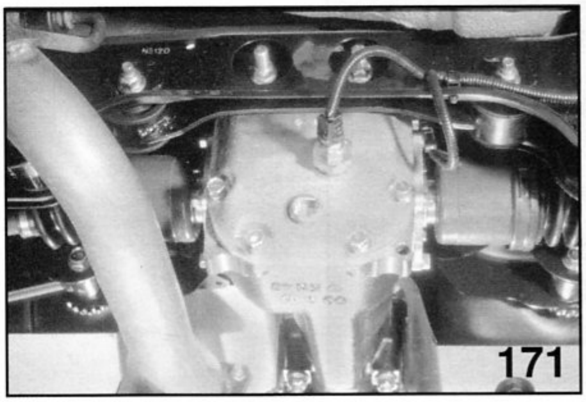
NOTE: WHEN THE ENGINE IS STARTED AUTO MODE IS ALWAYS SELECTED. EVEN IF MANUAL MODE IS SET WHEN THE IGNITION IS TURNED OFF, AUTO MODE WILL AUTOMATICALLY BE SELECTED THE NEXT TIME THE ENGINE IS STARTED.

DCCD Control Dial

170

By operating this dial, the driver can adjust the LSD clutch engagement torque to any desired setting. The DCCD control dial setting will be displayed in the DCCD indicator in the instrument panel when Manual Mode is selected with the Manual Mode switch.

Oil Temperature Switch

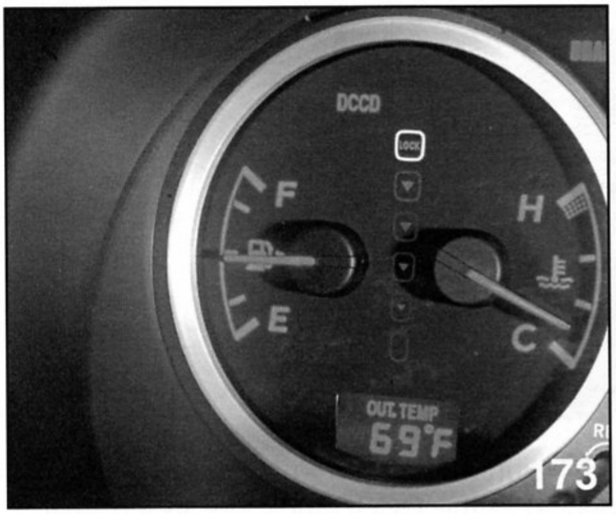


171

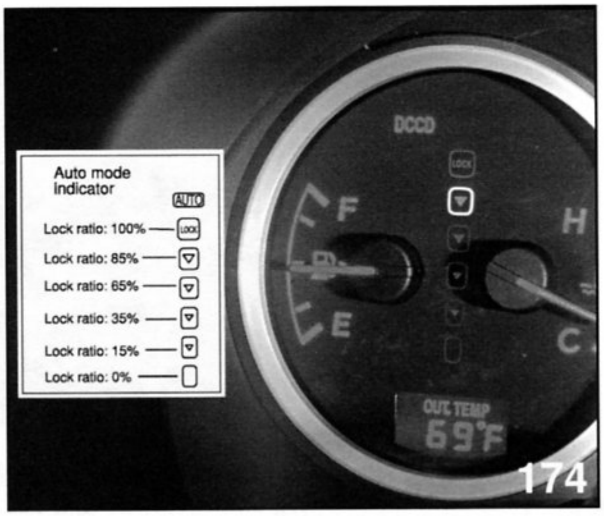
172

This is the temperature switch that is mounted on the rear of the rear differential case. This switch detects the temperature of the lubricating oil inside the case, and it is activated when the oil temperature reaches approximately 150°C. When this happens, a warning light in the instrument panel is illuminated and at the same time an abnormal signal is sent to the DCCD control module.

DCCD Indicator

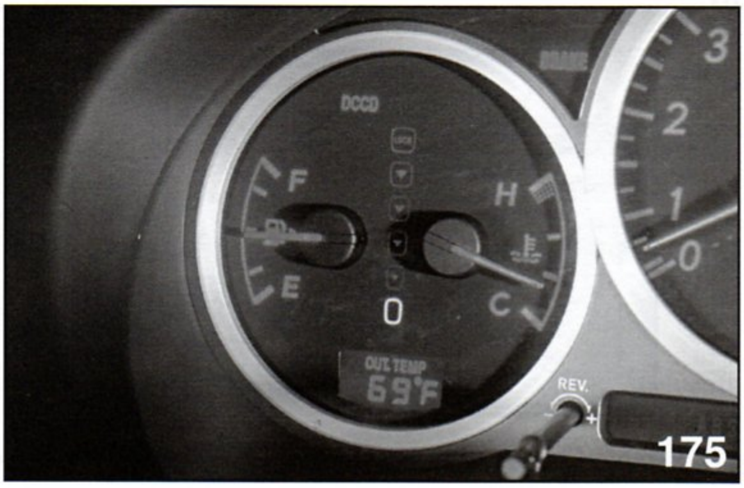


173



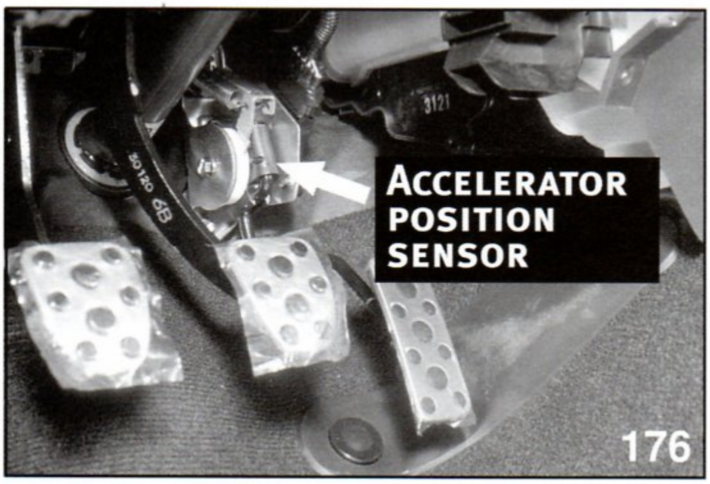
174

In Auto Mode the top DCCD indicator light is illuminated, informing the driver that Auto Mode is activated. In Manual Mode the DCCD control dial setting is displayed.



When trouble occurs, the bottom DCCD indicator light flashes, warning the driver that trouble has occurred. By operating the DCCD control dial and the parking brake lever according to a predetermined procedure, the service technician can read the trouble code stored in the DCCD control module memory from the flashing pattern of the indicator light.

Accelerator Position Sensor



This sensor detects the position of the accelerator pedal as it is depressed by the driver.

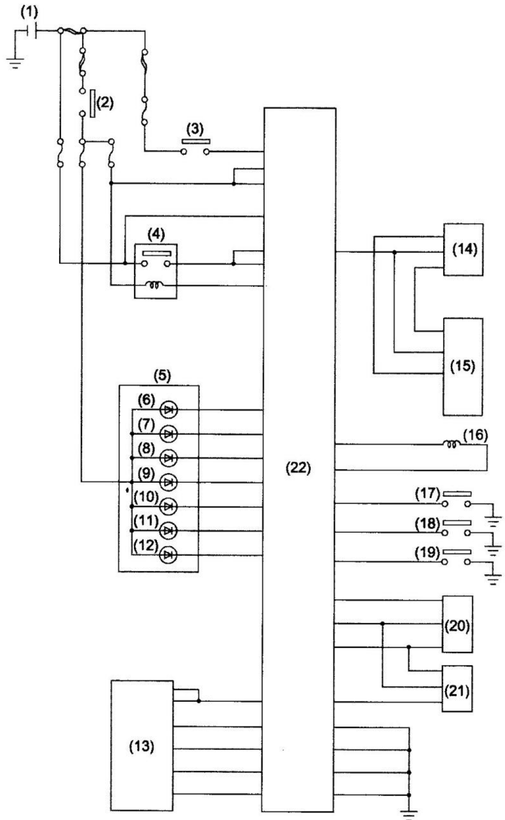
Stop Light Switch

Mounted on the brake pedal bracket, this switch is activated when the driver operates the brake pedal.

Hand Brake Switch

This switch is mounted at the bottom of the parking brake lever and is activated when the driver operates the parking brake lever.

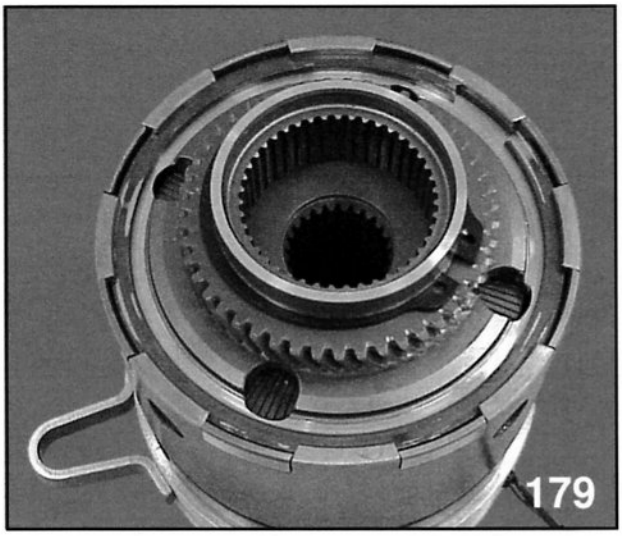
System Circuit



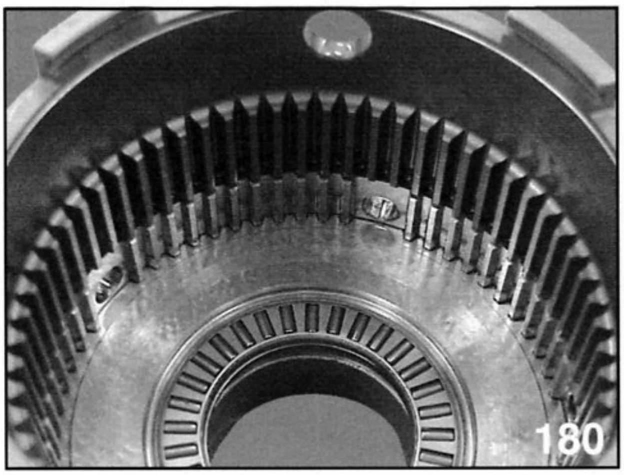
(1) Battery
(2) Ignition relay
(3) Stop light switch
(4) Driver-controllable center differntial relay
(5) Combination meter
(6) Driver-controllable center differential indicator light (0% locked)
(7) Driver-controllable center differential indicator light (15% locked)
(8) Driver-controllable center differential indicator light (35% locked)
(9) Driver-controllable center differential indicator light (65% locked)
(10) Driver-controllable center differential indicator light (85% locked)
(11) Driver-controllable center differential indicator light (100% locked)
(12) Indicator light
(13) ABSCU & HU
(14) Throttle position sensor
(15) Engine control unit
(16) Driver-cotrollable center differential
(17) Parking brake switch
(18) Manual mode switch
(19) Rear differential oil temperature switch
(20) Control dial
(21) Lateral G sensor
(22) Driver-controllable center differential control unit

178

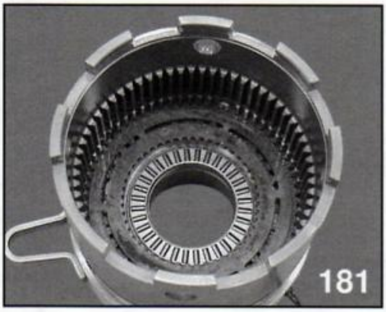
The following 4 pages explaining the DCCD are for general information only. Do not disassemble the DCCD center differential as it is not serviceable.



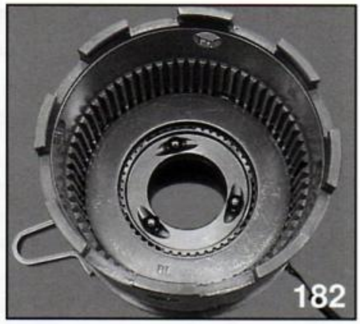
1. Controlled with chopper voltage signal (300 to 2 K HZ).
   Maximum current use is 4 amps.



2. The electronic coil is press fitted to the differential case.
   The lower splines are for the placement of the pilot clutch plates.
   The upper teeth are for delivering power to the planet gears of the planetary assembly.



181



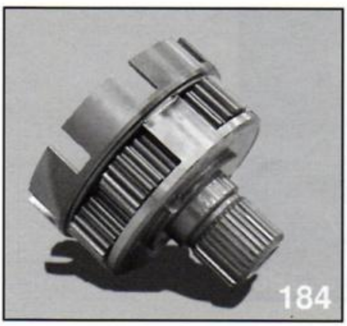
182

3. The needle bearing provides a support for the pilot clutch hub.

The inner splines of the pilot clutch plates engage with the pilot clutch hub.
The armature is located on top of the pilot clutch plates to apply pressure, engaging the pilot clutch hub to the differential case.
The three metal balls are used to push up on the planetary assembly.

183

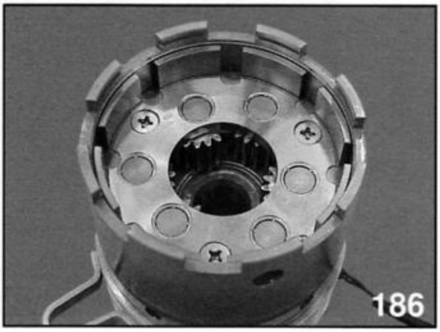
4. The top of the planetary assembly houses the LSD clutch which is used to control the speed of the sun gear and planetary carrier.



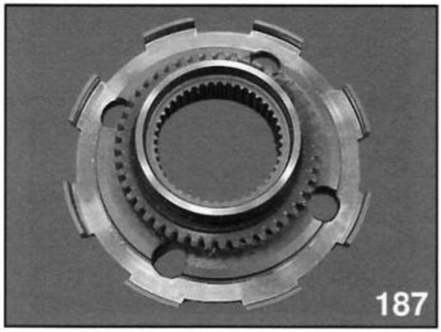
184

185

5. The splines at the bottom of the planetary assembly are used to secure the transfer drive gear.



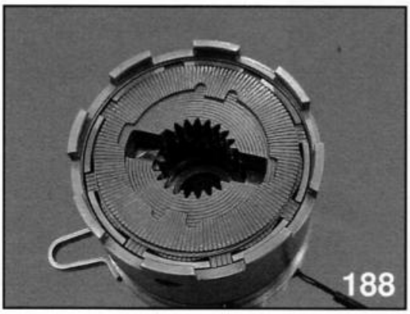
186



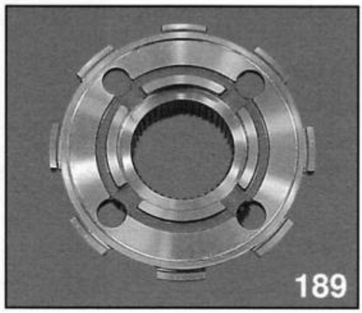
187

6. Power flows into the differential case to the planet gears. Power then splits, the planetary carrier driven by the planet gears power the rear wheels. The sun gear, powered by the planet gears powers the front wheels.

The speed of the sun compared to the speed of the planetary carrier determines the power split of the front and rear wheels.

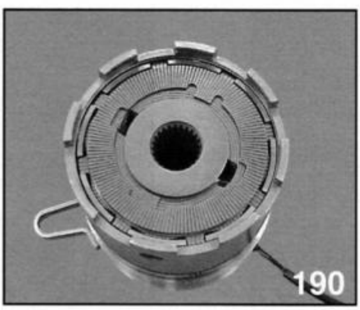


188



189

7. The limited slip differential clutch is used to hold the sun gear and push down on the planetary carrier. This braking action changes the output distribution of power.



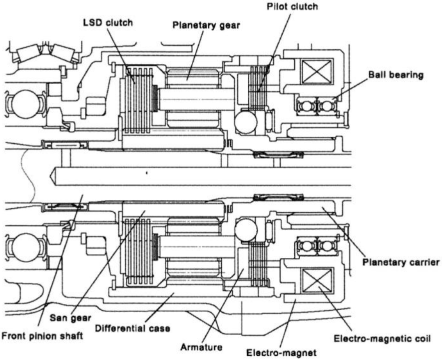
190

8. Case with sun gear installed.

No current applied to the DCCD coil results in a power split of 35% to the front wheels and 65% to the rear wheels.
The more current is applied to the coil, the faster the transfer rate changes towards a 50% front and 50% rear.
The armature pulls down on the pilot clutch in proportion to the amount of current applied to the coil. This results in the pilot clutch hub partially or fully rotating with the differential case.
The differential carrier, rotating in the same direction as the pilot clutch hub is now used as reference of the rear wheel power output. When the planetary carrier rotates faster than the pilot clutch hub the alignment of the three balls to the recesses in the bottom of the planetary carrier changes. This will force the planetary carrier to move into the LSD clutch, slowing down the sun gear and planet carrier. The resulting action removes power from the rear wheels and redirects it to the front wheels.
Power split is determined by the difference in rotation of the sun gear and planetary carrier and the difference in rotation of differential case to the planet gears. If the planetary carrier slows down or stops rotating the power from the differential case passes straight through the planetary assemble as if the planetary assembly was part of the case.

The center differential consists of a planetary gear type differential mechanism, a pilot clutch that is engaged by the DCCD coil assembly, and an LSD clutch placed between the planetary gear unit sun gear and the planetary carrier.

The planetary gear unit sun gear is connected to the front drive pinion shaft, which turns the front wheels, and the planetary carrier is connected to the transfer drive gear, which turns the rear wheels. When the LSD clutch is released, the center differential distributes the drive torque to the front and rear wheels in a 35:65 proportion.

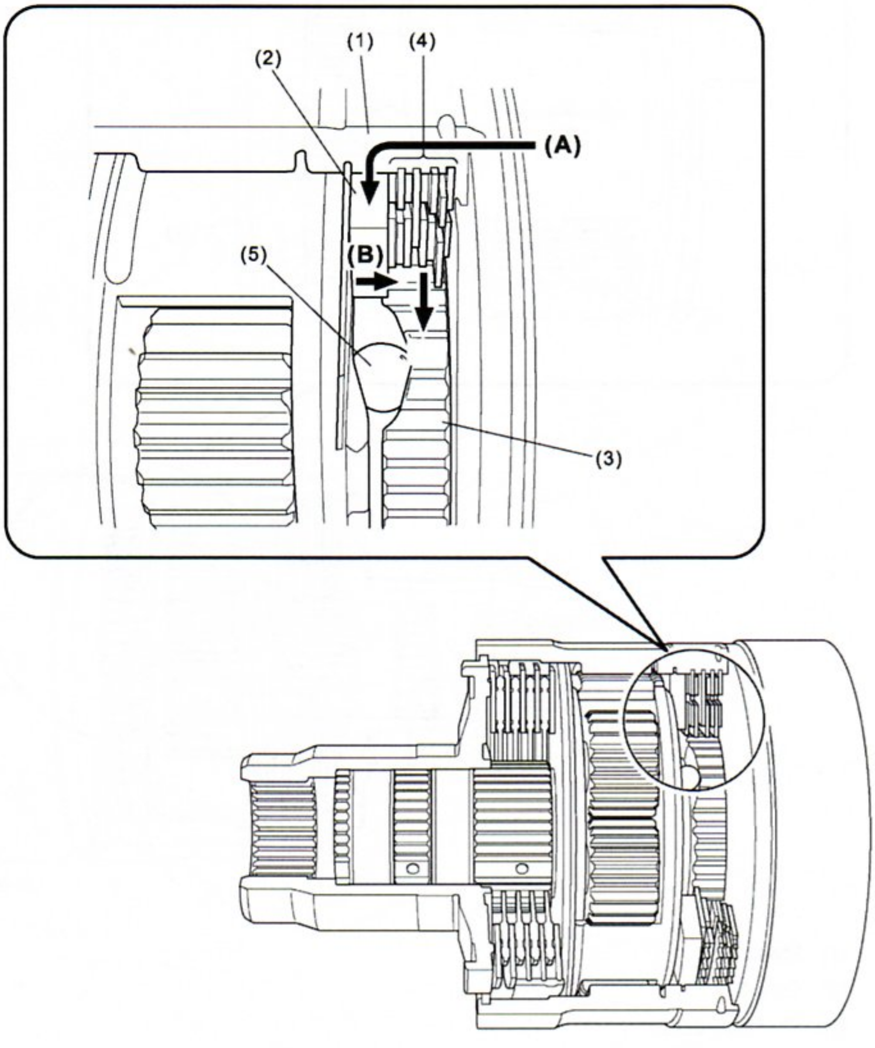


191

Three steel balls are equipped between the pilot clutch hub and planetary carrier inside the center differential case. These steel balls are mounted in hollows in the clutch hub and planetary carrier, and they work to widen the clearance between these parts when their relative position changes. In this explanatory note, the clutch hub hollow is referred to as cam 1 and the planetary carrier hollow as cam 2.

When current flows through the electromagnetic coils, magnetism is generated at components in the following sequence: electromagnet, differential case, armature (A). The armature is moved to the right (B) by this magnetism causing the pilot clutch to engage, and a magnetic field is formed in the area from the electromagnet, differential case, armature, and to the pilot clutch.

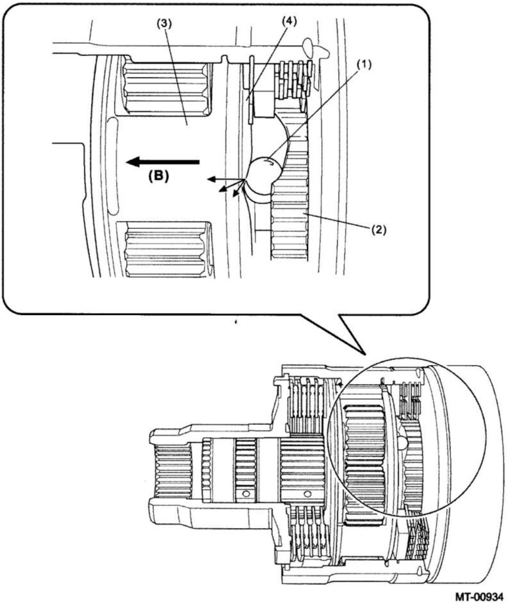
The pilot clutch locks the differential case side and cam 1 side together, thus the rotational speed of the cam 1 and differential case are synchronized. The engagement of the pilot clutch is controlled by adjusting the current flowing through the electromagnetic coils.



(1) Differential case
(2) Armature
(3) Cam 1
(4) Pilot clutch
(5) Steel ball

192

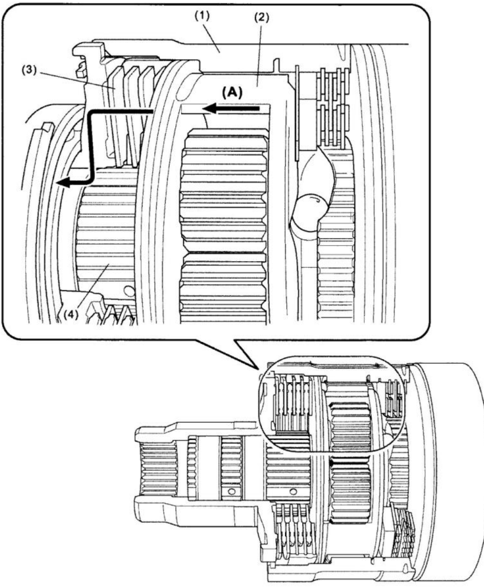
When a speed difference occurs, a force (B) pushing the cam 2 to the left is generated at the steel balls sandwiched between cam 1 and cam 2, pushing the planetary carrier to the left.



(1) Steel ball
(2) Cam 1
(3) Planetary carrier
(4) Cam 2

193

The planetary gears and the sun gear together to generate a differential action restriction torque.



(1) Differential case
(2) Planetary carrier
(3) Main clutch
(4) Sun gear

194

DCCD System Operation

The DCCD system has two modes: Manual Mode and Auto Mode. In Manual Mode, operation of the DCCD control dial (to whatever setting the driver wants) is given priority, and the LSD clutch engagement torque is increased or decreased accordingly. In Auto Mode, on the other hand, the LSD clutch is automatically controlled according to various input signals, such as, the lateral G sensor input signal (turn status signal) and the wheel speed sensor input signal.

The most fundamental control in the DCCD system is the throttle-response engagement-torque control. This control increases or decreases the LSD clutch engagement torque according to the driver's operation of the accelerator pedal (accelerator position sensor signal). (The basic control theory is the same as that of the VTD transfer system.)

Besides the throttle-response engagement-torque control, the DCCD system also executes the following controls.

CONTROL	AUTO MODE	MANUAL MODE
Throttle-response engagement-toque control	O	O
ABS actuation signal input control	O	O
Brake switch signal input control	O	O
Parking brake signal input control	O	O
Tight cornering control	O	O
Slip control	O	X
Cornering control	O	X
DCCD control dial control	X	O
Fail-safe control	O	O
Rear differential oil temperature control	O	O

195

X means not available

ABS Actuation Signal Input Control

Once the ABS Actuation signal has been input into the DCCD control module from the ABS CM & H/U, the DCCD control module decreases the LSD clutch engagement torque.

(Purpose: To reduce the number of factors that will disturb the ABS control.)

Brake Switch Signal Input Control

Once the brake switch signal has been input into the DCCD control module, the module reduces the LSD clutch engagement torque.

(Purpose: To prevent delays in the start of the ABS control and prepare the system for when all the wheels slow down simultaneously.)

Parking Brake Signal Input Control

Once the parking brake switch signal has been input into the DCCD control module, the module releases the LSD clutch.

(Purpose: To enable the vehicle to drift when the rear wheels lock by the operation of parking brake lever.)

Tight Cornering Control

In order to prevent the tight cornering phenomenon, this control determines the vehicle driving conditions from the left and right wheel speed ratios and the vehicle speed, and reduces the LSD clutch engagement torque accordingly.

Slip Control

This control determines the amount of slip for each wheel, based on signals from all four wheels speed sensors, and corrects the LSD clutch engagement torque according to the amount of slip.

Cornering Control

In order to improve stability when a vehicle is cornering, this control determines the cornering conditions on the basis of the throttle position sensor signal, lateral G sensor signal, all four wheel speed sensor signals, and other signals, and optimally controls the LSD clutch engagement torque.

Control Based on Lateral G Sensor Signal

In the DCCD system, the purpose of control based on the lateral G sensor signal is to improve the road handling characteristics of a vehicle. Accordingly, the philosophy behind this control is different than that of the Vehicle Dynamic Control System (which works to maintain vehicle stability when the tires lose their grip).

The DCCD control module varies the LSD clutch engagement conditions as described below, according to the lateral G sensor signal (vehicle cornering conditions). This distributes the drive torque to the front and rear wheels in suitable proportions, according to the cornering conditions.

If the lateral G force is large

LSD clutch engagement strength is reduced —> Drive torque distribution to rear wheels increases —> Pushing force of rear wheels increases —> Vehicle cornering performance is given priority.

If the lateral G force is small

LSD clutch engagement strength is increased —> Drive torque distribution to front wheels increases —> Pushing force of all wheels is equal —> Vehicle acceleration performance is given priority.

Control Based on Accelerator Position Sensor Signal

When the LSD clutch is released completely, 35% of the drive torque is distributed to the front wheels and 65% to the rear wheels. When the LSD clutch operates and distributes 45% of the drive torque to the front wheels and 55% to the rear wheels, it takes 10% of the drive torque from the rear wheels and transfers it to the front wheels.

When the drive torque input into the center differential from the engine increases, the LSD clutch engagement strength must increase to maintain the 45% drive torque distribution to the front wheels and 55% to the rear wheels. Consequently, when the throttle opening is large (the drive torque generated by the engine is large), the LSD clutch engagement strength increases.

Control Based on Wheel Speed Sensors

The difference in speed of the left and right wheels is determined on the basis of signals from four wheel speed sensors. The LSD clutch engagement strength is reduced in order to prevent the tight cornering phenomenon, which occurs in low-speed situations such as when a vehicle is being put into a garage.

DCCD Control Dial Control

The LSD clutch engagement torque increases or decreases according to the DCCD control dial setting selected by the driver. (Manual mode)

Fail-safe Control

When the DCCD control module detects any trouble in the system, it illuminates the bottom DCCD indicator light to inform the driver that trouble has occurred.

When a major malfunction related to the DCCD coil assembly occurs, the DCCD control module will turn the DCCD coil assembly off and fully release the LSD clutch. The DCCD control module will preserve as much of the system operation as it can, provided that the malfunction does not involve a sensor or other critical part.

Rear Differential Oil Temperature Control

If the rear differential oil temperature rises abnormally (to approximately 150°C) because of continued hard driving or for any other reason, the rear differential oil temperature switch will turn on and the rear differential oil temperature warning light in the combination meter will come on. At the same time, the DCCD control module will reduce the LSD clutch engagement torque. (Normal control will automatically be restored once the oil temperature drops.)

LSD Clutch Engagement Torque Control Applied to Cornering Vehicle by DCCD System

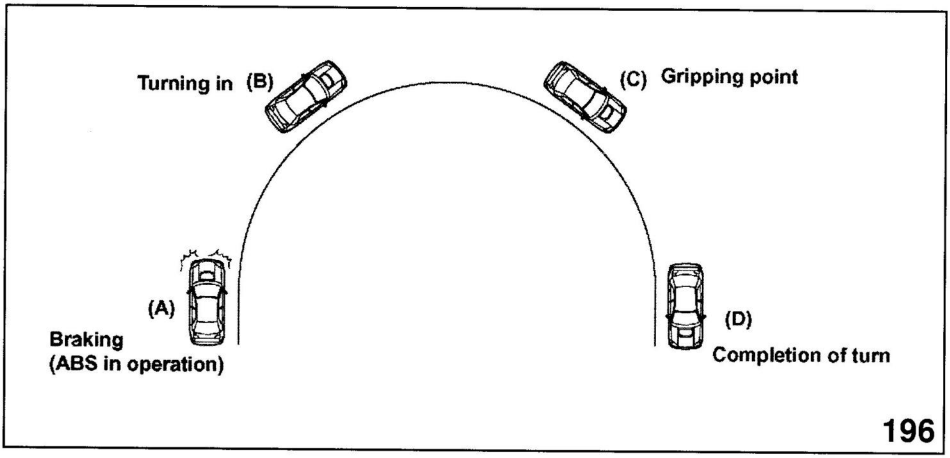
Let's consider the LSD clutch conditions at points A, B, C, and D, using slow-in quick-out cornering as a model.

A: The vehicle is decelerating and has not yet started to turn. Since the brake pedal is depressed and the ABS is working, the system is operating under ABS actuation signal input control conditions and the LSD clutch is practically released.

B: The vehicle is starting to corner, generating a lateral G force. Since the accelerator pedal is not depressed, the system gives cornering performance priority, so the LSD clutch engages weakly.

C: The vehicle has passed the top of the curve and is starting to accelerate. Although the lateral G force is large, the accelerator pedal is depressed, so the LSD clutch engagement strength is increased proportionally to the increasing engine driving force.

D: The vehicle has finished cornering and is traveling straight ahead. Since the lateral G force is small, the system gives priority to acceleration performance, so the LSD clutch engages strongly, approaching direct 4WD conditions.


Turning in (B)
(C) Gripping point
(A)
Braking
(ABS in operation)
(D)
Completion of turn
196

Diagnostics

How To Read the Trouble Code

(1) Engage the parking brake.

(2) Turn the ignition switch to the ON position.

(3) Set the DCCD control dial to the MIN or MAX position.

(4) Fully depress the accelerator pedal.

(5) Turn the DCCD control dial from MIN to MAX and back to MIN, and repeat 10 times.

If no trouble code has been recorded

The bottom indicator light repeatedly flashes at approximately 2Hz.

If a trouble code has been recorded

The trouble code is read from the flashing pattern of the bottom indicator light.

The Bottom DCCD indicator light flashes the code corresponding to faulty part.

The long segment (1.2 sec on) indicates a "ten", and the short segment (0.2 sec on) signifies a "one".

D-Check Procedure

(1) Engage the parking brake.
(2) Set the DCCD control dial to the MIN position.
(3) Start the engine.
(4) Set the DCCD control dial to the MAX position.
(5) Release the parking brake.
(6) Set the DCCD control dial to the MIN position.
(7) Engage the parking brake.
(8) Repeat steps 4 to 7 twice within 30 seconds.

NOTE: THE INDICATOR WILL DISPLAY THE TROUBLE CODE FOR A WHEEL SPEED SENSOR MALFUNCTION.

(9) Operate the parking brake.
(10) Operate the brake pedal.
(11) Operate the Manual Mode switch.
(12) Operate the DCCD control dial and then set it to the MAX position and wait 3 seconds.
(13) Drive the vehicle (above 15km/h for at least 5 seconds) and check the ON/OFF status of the bottom indicator light.

If no trouble code has been recorded

The bottom indicator light repeatedly flashes at approximately 2Hz.

If a trouble code has been recorded

The trouble code is read from the flashing pattern of the bottom indicator light.

NOTE: AFTER THE TROUBLE HAS BEEN REPAIRED, IF A DIAGNOSTIC CHECK IS EXECUTED AND THE SAME TROUBLE IS FOUND NOT TO RECUR, THE RECORDED TROUBLE CODE WILL BE ERASED FROM THE SYSTEM MEMORY THE NEXT TIME THE IGNITION SWITCH IS TURNED ON.

NOTE: ONLY SEVEN TROUBLE CODES STORED IN THE MEMORY APPLY TO TROUBLE DETECTED BY THE DCCD CONTROL MODULE. THESE ARE: CODES 11, 12, 13, 14, 21, 22, AND 23. THE DCCD MODULE WILL CAUSE THE BOTTOM INDICATOR LIGHT TO FLASH AND WARN THE DRIVER OF TROUBLE ONLY WHEN ONE OF THESE SEVEN CODES IS DETECTED.

THERE ARE NO TROUBLE CODES RELATED TO THE REAR DIFFERENTIAL OIL TEMPERATURE SWITCH. IF FOR ANY REASON THE REAR DIFFERENTIAL OIL TEMPERATURE RISES ABNORMALLY AND ACTIVATES THE TEMPERATURE SWITCH, THE REAR DIFFERENTIAL OIL TEMPERATURE WARNING LIGHT IN THE COMBINATION METER WILL COME ON TO WARN THE DRIVER THAT THE OIL TEMPERATURE IS TOO HIGH. AT THE SAME TIME, THE DCCD CONTROL MODULE WILL START THE BOTTOM INDICATOR LIGHT FLASHING. NEVERTHELESS, THE DCCD CONTROL MODULE HAS NO TROUBLE CODES RELATED TO THIS PROBLEM. (NORMAL CONTROL WILL AUTOMATICALLY BE RESTORED ONCE THE OIL TEMPERATURE DROPS.)

Component Parts Test

Lateral G sensor

Measure the sensor output voltage with the sensor connector disconnected.

Between connector terminal No. 1(+) and connector No. 2(-)

In horizontal position: 2.3 - 2.7V

Inclined 90° to the right: 3.5 - 4.1V

Inclined 90° to the left: 0.8 - 1.5V

DCCD coil assembly

Measure the coil resistance.

Resistance value: 1.0 - 2.0 ohms

Check the DCCD control module drive voltage (duty signal).

Voltage value: 6.0 - 7.0V