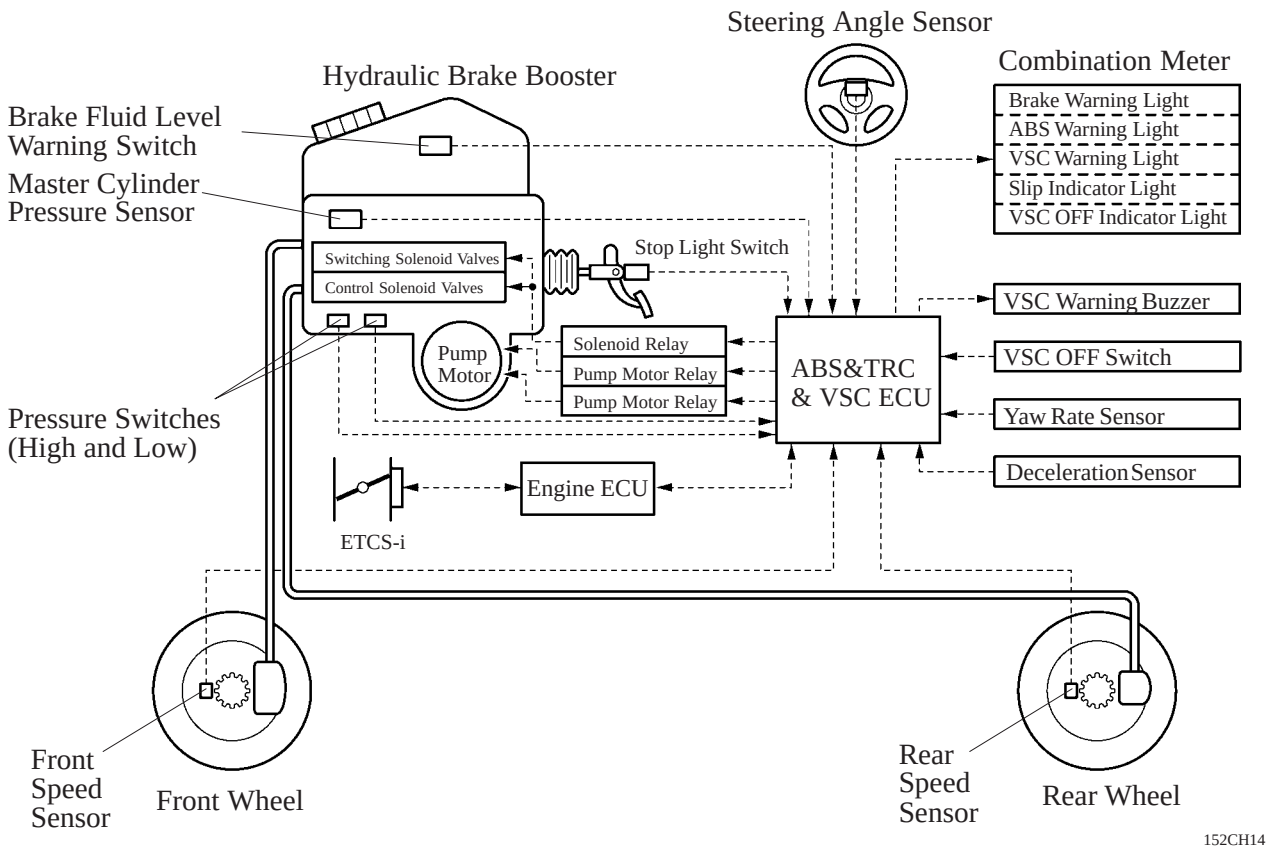
■VSC SYSTEM

1. General

- In addition to the ABS and TRC systems, the VSC system has been adopted on all models.
- The hydraulic brake booster is adopted on all models.
- The brake actuator (ABS, TRC and VSC) and the hydraulic brake boosters have been integrated to form a compact actuator.
- In case the vehicle's behavior becomes unstable during an emergency avoidance maneuver, the VSC system generates a yaw moment that applies a braking force to the appropriate wheel in order to stabilize the vehicle.
- The hydraulic brake booster uses the brake fluid that has been stored under high pressure to provide a power assist to the pedal effort that is applied to the brake pedal. Furthermore, the brake fluid that has been stored under high pressure is also used as the hydraulic pressure for controlling the ABS, TRC and VSC systems.

2. System Diagram

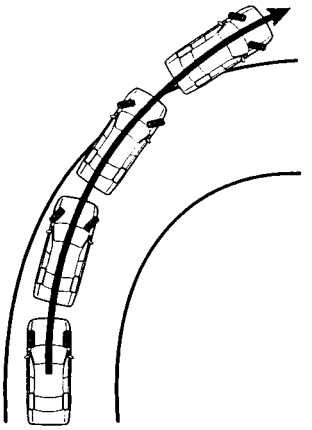


3. Outline of Control Performance

General

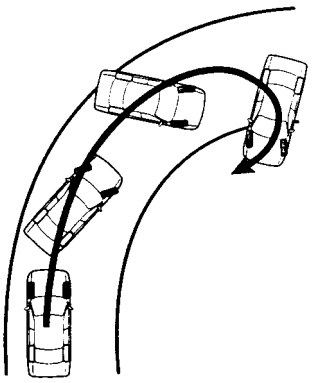
The followings are two examples that can be considered as circumstances in which the tires overcome their lateral grip limit.

- When the front wheels lose grip in relation to the rear wheels (strong understeer tendency).
- When the rear wheels lose grip in relation to the front wheels (strong oversteer tendency).



Strong Understeer Tendency

151CH17



Strong Oversteer Tendency

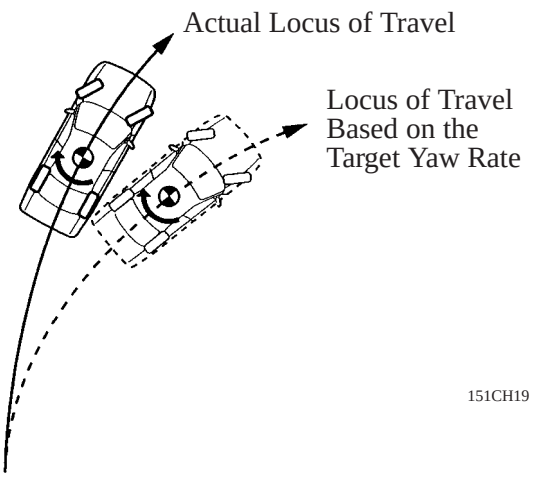
151CH16

Method for Determining the Vehicle Condition

To determine the condition of the vehicle, sensors detect the steering angle, vehicle speed, vehicle's yaw rate, and the vehicle's lateral acceleration, which are then calculated by the ABS & TRC & VSC ECU.

1) Determining Understeer

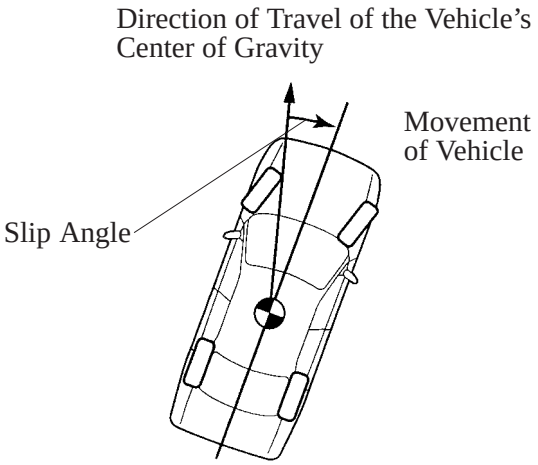
Whether or not the vehicle is in the state of understeer is determined by the difference between the target yaw rate and the vehicle's actual yaw rate. If the vehicle's actual yaw rate is smaller than the yaw rate (a target yaw rate that is determined by the vehicle speed and steering angle) that should be rightfully generated when the driver operates the steering wheel, it means that the vehicle is making a smaller turn. Thus, the ECU determines that there is a large tendency to understeer.



151CH19

2) Determining Oversteer

Whether or not the vehicle is in the state of oversteer is determined by the values of the vehicle's slip angle and the vehicle's slip angular velocity (time-dependent changes in the vehicle's slip angle). When the vehicle's slip angle is large, and the slip angular velocity is also large, the ECU determines that the vehicle has a large oversteer tendency.



151CH18

Method of VSC Operation

When the ABS & TRC & VSC ECU determines that the vehicle exhibits a strong tendency to understeer or oversteer, it decreases the engine output and applies the brake of a front or rear wheel to control the vehicle's yaw moment, thus dampening the effects that are not desirable for the vehicle.

CH

1) Dampening a Strong Understeer

When the ABS & TRC & VSC ECU determines that the vehicle exhibits a strong tendency to understeer, depending on the extent of that tendency, it controls the engine output and applies the brakes of the rear wheels, thus providing the vehicle with an understeer control moment, which helps dampen its tendency to understeer.

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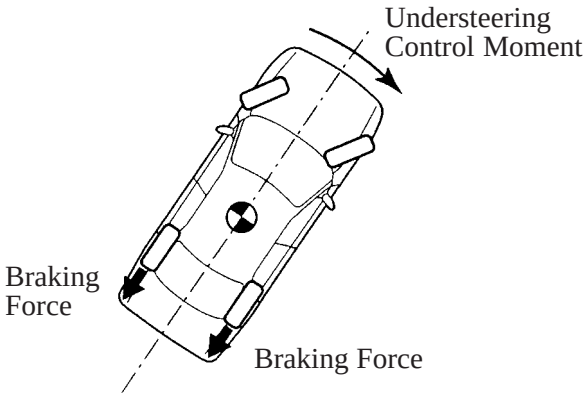
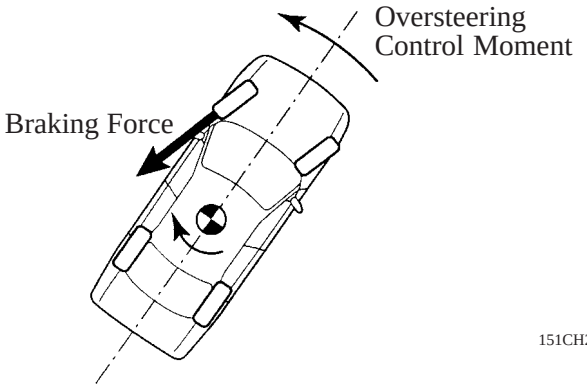


Making a Right Turn

151CH21

2) Dampening a Strong Oversteer

When the ABS & TRC & VSC ECU determines that the vehicle exhibits a strong tendency to oversteer, depending on the extent of that tendency, it controls the engine output and applies the brake of the front wheel of the outside of the turn, thus generating an inertial moment in the vehicle's outward direction, which helps dampen its tendency to oversteer. Also, there are instances in which the brake is applied to the rear wheels.



151CH20

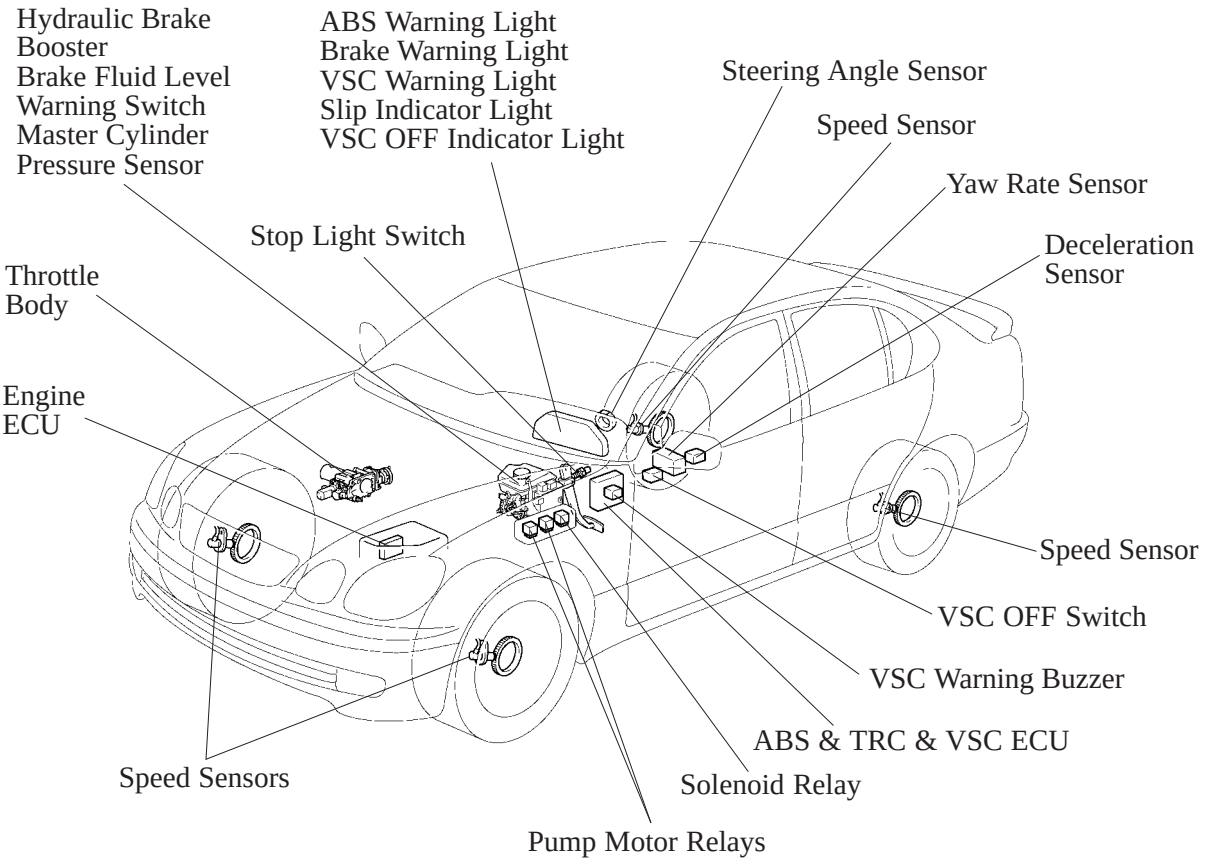
Making a Right Turn

System Cooperative Control

In order to bring the effectiveness of the VSC system control into full play, the methods for controlling other control systems are changed when the VSC is active.

System	Description of Control
Throttle Valve Control	Controls the throttle valve opening angle and the engine output so that the engine drive force and the braking force of the VSC system do not interfere with each other.
ABS Control	Gives priority to VSC control.
TRC Control	

4. Layout of Components



LHD Model

152CH45

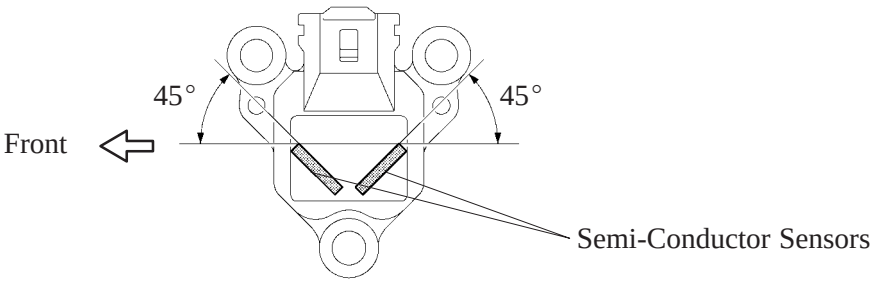
5. Function of Components

Components	Function
Speed Sensors	Detect the wheel speed of each of four wheels.
Yaw Rate Sensor	Detects the vehicle's yaw rate.
Deceleration Sensor	Detects the vehicle's acceleration in the longitudinal and lateral directions.
Steering Angle Sensor	Detects the steering direction and angle of the steering wheel.
ABS & TRC & VSC ECU	Judges the vehicle driving condition based on signals from each sensor, and sends brake control signal to the hydraulic brake booster. Also, sends the throttle opening angle demand signal and other control signals to the engine ECU.
Brake Fluid Level Warning Switch	Detects the brake fluid level.
Hydraulic Brake Booster	● Assists with the pedal effort applied to the brake pedal. ● Changes the fluid path based on the signals from the ABS & TRC & VSC ECU during the operation of the ABS & TRC & VSC system, in order to control the fluid pressure that is applied to the wheel cylinders.
Master Cylinder Pressure Sensor	Assembled in the hydraulic brake booster and detects the master cylinder pressure.
Pump Motor Relays	Control the pump motor operation in the hydraulic brake booster.
Solenoid Relay	Supply power to the solenoid valves in the hydraulic brake booster.
ABS Warning Light	Lights up to alert the driver when the ECU detects the malfunction in the ABS.
VSC Warning Light	Alert the driver when the ECU detects the malfunction in the TRC system and VSC system.
Slip Indicator Light	Blinks to inform the driver when the TRC system or the VSC system, is operated.
Brake Warning Light	Lights up to alert the driver when the accumulator pressure is low.
VSC Warning Buzzer	● Emits an intermittent sound to inform the driver that the ECU detects a strong understeer or oversteer tendency. ● Emits a continuous sound to inform the driver that the ECU detects a malfunction in the hydraulic brake booster.
Engine ECU	Controls the throttle valve opening angle based on the signals received from the ABS & TRC & VSC ECU, in order to control the engine output. Also, sends the throttle valve opening angle signal, accelerator pedal position signal, etc., to the ABS & TRC & VSC ECU.
Throttle Body	Controls the throttle valve to control the engine output.
VSC OFF Switch	Turns the TRC and VSC system inoperative.
VSC OFF Indicator Light	Lights to inform the driver when the TRC and VSC system is turned OFF by the VSC OFF switch.
Stop Light Switch	Detects the brake signal.

6. Construction and Operation of Components

Deceleration Sensor

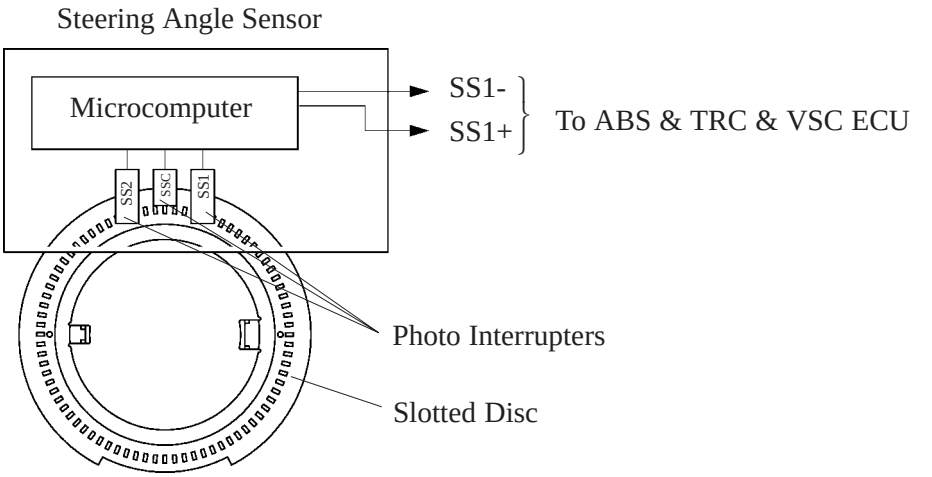
Located behind the shift lever, the deceleration sensor detects the acceleration, and sends this signal to the ABS & TRC & VSC ECU. The deceleration sensor consists of 2 semi-conductor sensors. These semi-conductor sensors are opposed 90° to each other, and installed so that each has an angle of 45° in the longitudinal direction. Each semi-conductor sensor is provided with a weight which is moved by the deceleration force applied to the vehicle. The semi-conductor sensor itself converts the weight's movement into electronic signals, and outputs them to the ABS & TRC & VSC ECU.
These electronic signals have linear output characteristics; and the ABS & TRC & VSC ECU combines the signals received from both of these semi-conductor sensors to calculate the acceleration of all horizontal movements. This makes it possible to provide detailed each control in accordance with various road surface conditions.



151CH25

Steering Angle Sensor

To accommodate the VSC, a high-precision steering angle sensor has been adopted.
The steering angle sensor consists of a microcomputer and three photo interrupters (SS1, SS2 and SSC). The slotted disc passes the dent of the photo interrupters.
The signals that are detected by the SS1 and SS2 photo interrupters are converted by the micro computer into serial signals that are output to the ABS & TRC & VSC ECU.
The SSC photo interrupters are used for detecting the neutral position of the steering wheel and for performing a self-check of the steering angle sensor.



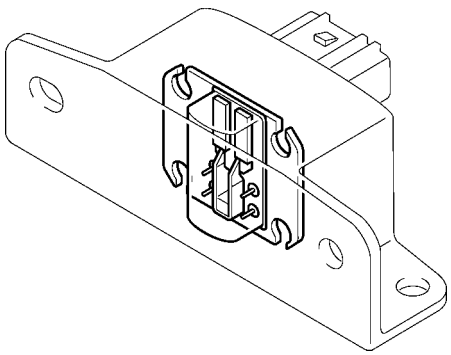
151CH24

Yaw Rate Sensor

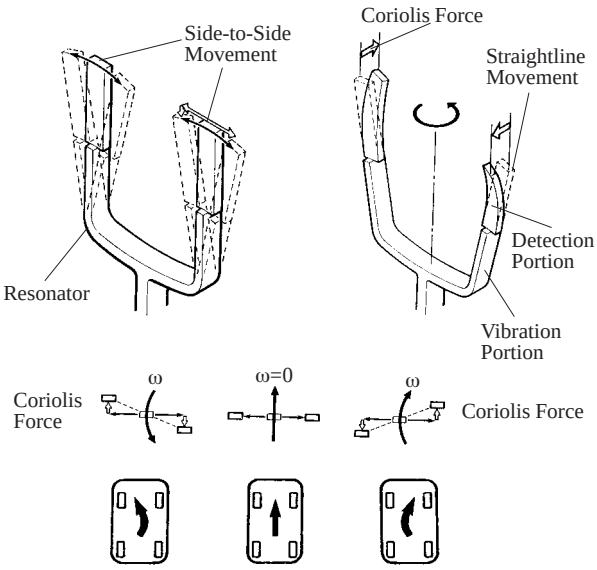
The yaw rate sensor is mounted behind the shift lever.

The yaw rate sensor uses a tuning-fork shaped vibration type rate gyro. Each resonator consists of a vibrating portion and a detecting portion that are shifted 90 degrees to form one unit. A piezoelectric ceramic piece is affixed to both the vibration and detection portions. The characteristic of the piezoelectric ceramic piece is to become distorted when voltage is applied to it, and to generate voltage when an external force is applied to distort the ceramic piece.

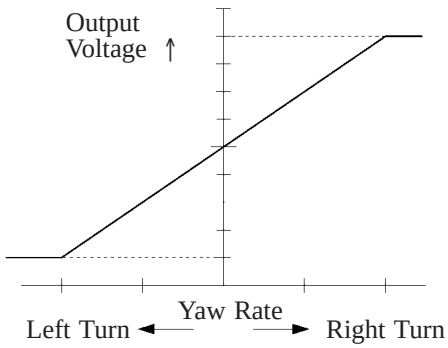
To detect the yaw rate, alternating current voltage is applied to the vibration portion, which causes it to vibrate. Then, the yaw rate is detected from the detection portion according to the amount and direction of distortion of the piezoelectric ceramic piece, which is caused by the coriolis force that is generated around the resonator.



151CH22



151CH48



151CH49

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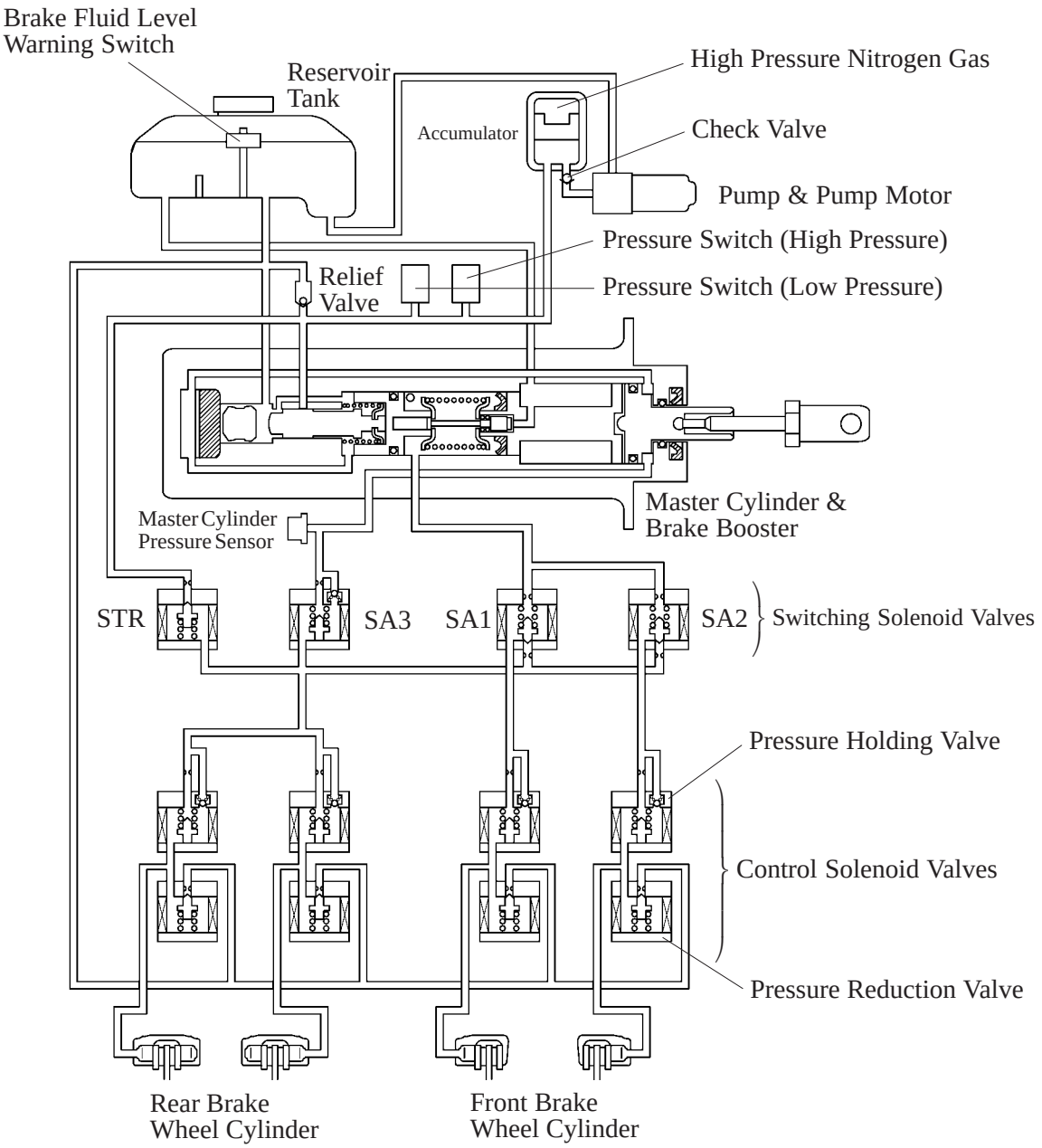
Hydraulic Brake Booster

The hydraulic brake booster consists of the following components:

Components	Function
Pump and Pump Motor	Draws up the brake fluid from the reservoir tank and provides high hydraulic pressure to the accumulator.
Accumulator	Stores the hydraulic pressure that was generated by the pump. The accumulator is filled with high-pressure nitrogen gas.
Pressure Switches	Monitors the hydraulic pressure of the accumulator and outputs control signals for the pump motor. There are two types: the pressure switch PH for controlling the pump, and the pressure switch PL for giving a warning when the pressure is low.
Relief Valve	Returns the brake fluid to the reservoir tank to prevent excessive pressure if the pump operates continuously due to a malfunction of the pressure switch.
Reservoir Tank	Stores the brake fluid.
Brake Fluid Level Warning Switch	Detects the brake fluid level.
Master Cylinder	Generates the hydraulic pressure that is provided to the wheel cylinders during normal braking.
Brake Booster	Regulates the accumulator pressure in accordance with the pedal effort that is applied to the brake pedal and introduces this pressure to the booster chamber in order to provide a power assist to the brakes.
Master Cylinder Pressure Sensor	Detects the hydraulic pressure that is generated in accordance with the pedal effort applied to the brake pedal and outputs the signals to the ABS & TRC & VSC ECU.
Switching Solenoid Valves (SA1, SA2, SA3, STR)	Switches the brake hydraulic path when the ABS, TRC or VSC is activated, or normal braking is applied.
Control Solenoid Valves (Pressure Holding Valves Pressure Reduction Valves)	Controls the hydraulic pressure that is applied to the wheel cylinders during ABS, TRC and VSC control.

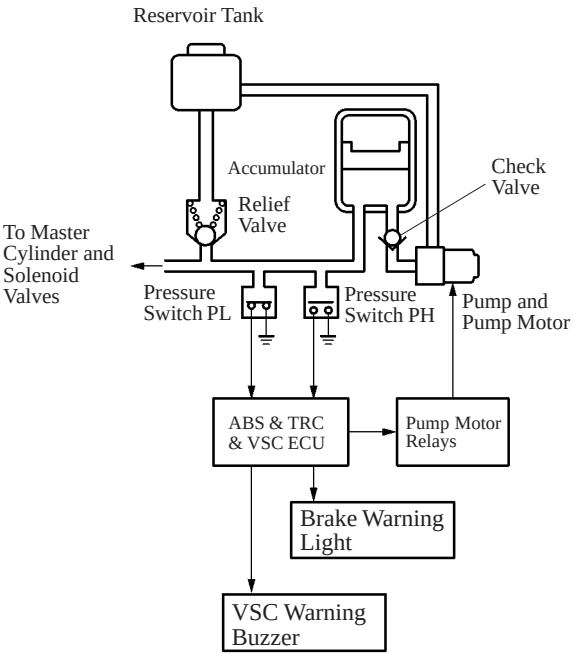


Hydraulic Circuit

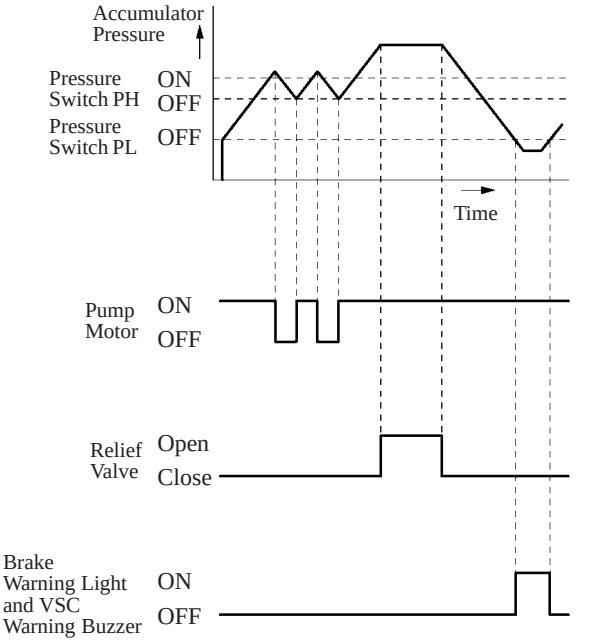
CH

1) Pump, Pump Motor, Accumulator, Pressure Switches and Relief Valve

If the accumulator pressure becomes lower than the pressure that is specified in the pressure switch PH, which is used for detecting high pressure, the pressure switch PH turns OFF. Then, the ABS & TRC & VSC ECU turns ON the pump motor relays to operate the pump motor and the pump.
The brake fluid that is discharged by the pump passes through the check valve and is stored in the accumulator. The hydraulic pressure that is stored in the accumulator is used for providing the hydraulic pressure that is needed for normal braking and for operating the ABS, TRC and VSC systems.
If the accumulator pressure becomes higher than the pressure that is specified in the pressure switch PH, the pressure switch PH turns ON. Then, after several seconds, the ABS & TRC & VSC ECU turns OFF the pump.
At this time, if the pressure switch PH malfunctions and causes the pump to operate continuously, the relief valve opens to prevent excessive pressure from being generated.
Moreover, if the accumulator pressure becomes lower than the pressure that is specified in the pressure switch PL, which is used for detecting low pressure, the pressure switch PL turns OFF. As a result, the brake warning light turns ON and the VSC warning buzzer activates.
At this time, the ABS, TRC and VSC systems are prohibited from operating.



152CH16



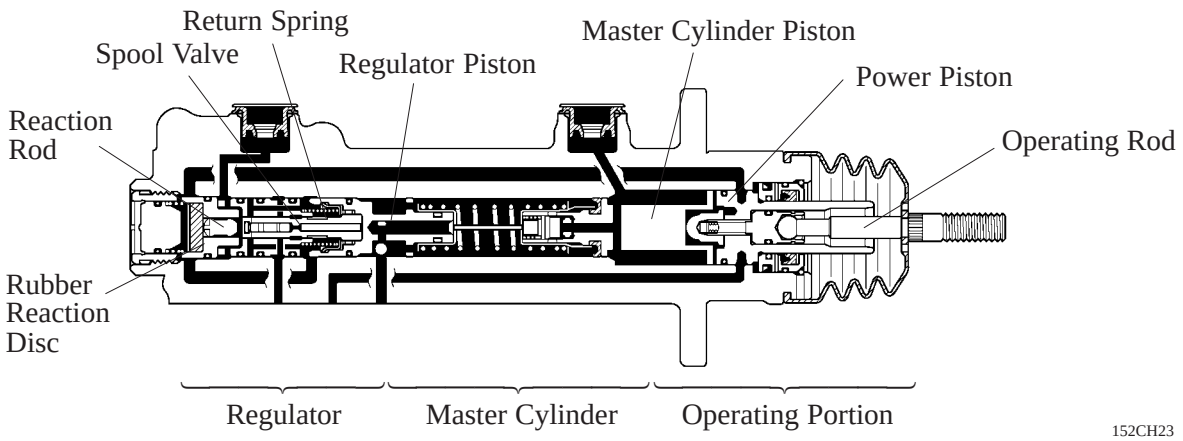
152CH17

2) Master Cylinder and Brake Booster

a. Construction

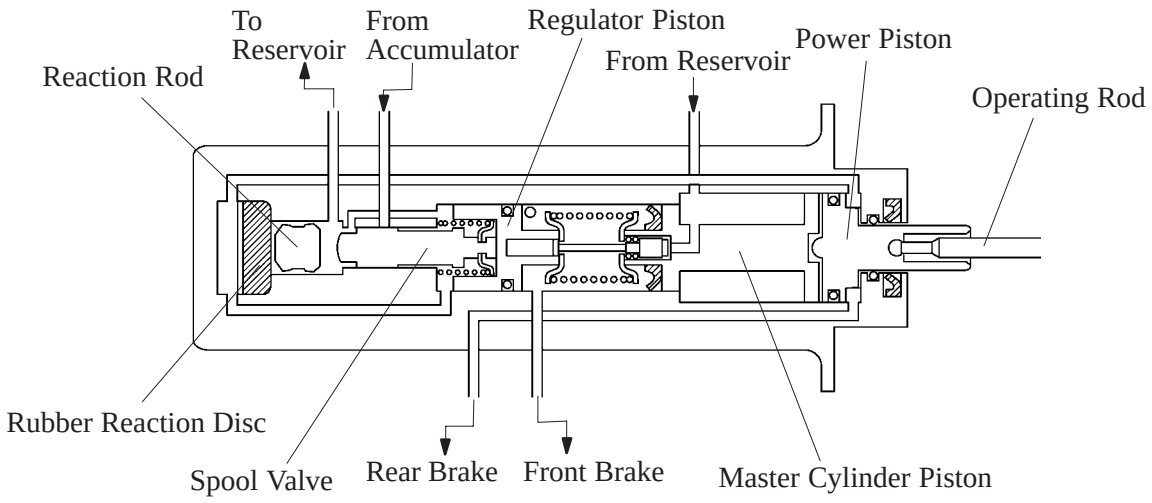
- This construction enables the hydraulic pressure that is generated by the brake booster to be applied directly to the rear brakes.
- The master cylinder is the center port type single master cylinder, which is used for the front brakes only.
- The brake booster is integrated with the master cylinder. The operating portion, master cylinder, and regulator are positioned coaxially to achieve a simple and compact construction.
- The master cylinder and brake booster consists of an operating rod, a power piston, a master cylinder piston, a regulator piston, a spool valve, a reaction rod and a rubber reaction disc.
- The operating rod and the power piston are linked directly to transmit the pedal effort that is applied to the brake pedal.
- The regulator piston and the spool valve are linked directly. A forward (leftward) force generated by the master cylinder pressure and a rearward (rightward) force generated by the power assist of the booster are applied to the regulator piston. Both forces maintain a balance.
- A return spring is provided for the regulator piston to ensure the return of the spool valve in case there is no pressure.

▶ Cross-Sectional Drawing ◀



152CH23

▶ Simplified Drawing ◀

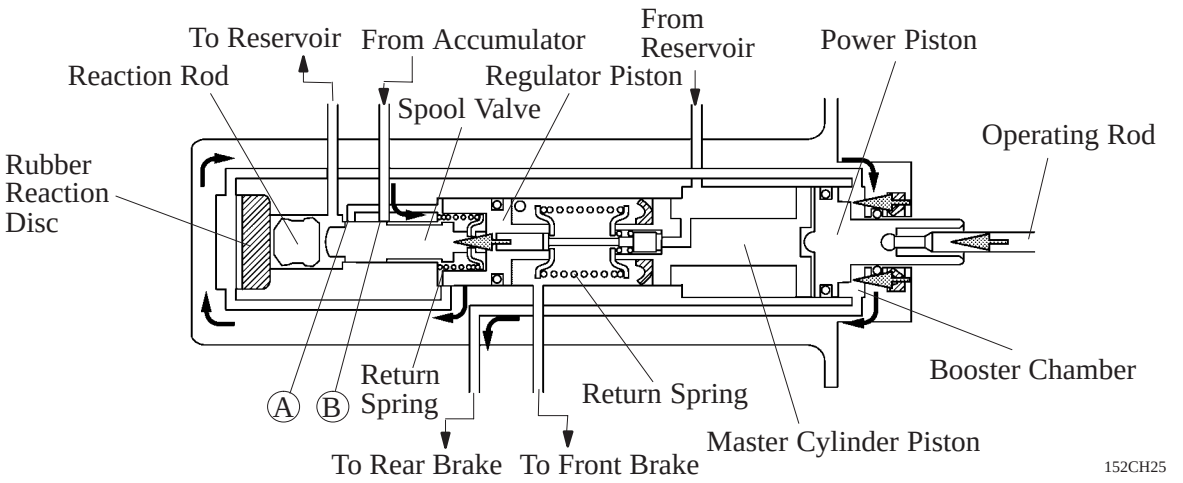


152CH24

b. Operation

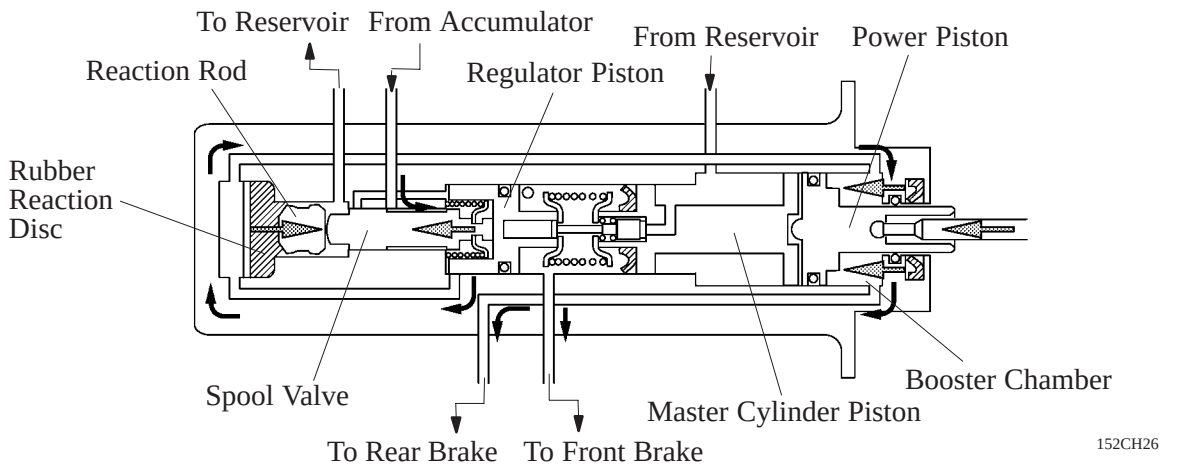
i) Pressure Increase (Low Pressure)

The pedal effort that is applied to the brake pedal is transmitted via the operating rod, power piston, and master cylinder piston. However, because the load setting of the master cylinder's return spring is lower than that of the regulator piston's return spring, the regulator piston gets pushed before the volume in the master cylinder becomes compressed. As a result, the spool valve moves forward.
The spool valve closes the path (A) between the reservoir and the booster chamber (behind the power piston) and opens the path (B) between the accumulator and the booster chamber. Then, the pressurized brake fluid is introduced into the booster chamber to provide a power assist to the pedal effort.
When the pressure is introduced into the booster chamber, the power assist overcomes the force of the master cylinder's return spring. This causes the volume in the master cylinder to become compressed and increases the pressure that is applied to the front brakes. At the same time, the pressure in the booster chamber increases the pressure that is applied to the rear brakes.
During the initial stage of the brake operation, the booster pressure that is applied to the rubber reaction disc is small. Therefore, a return force in the rightward direction does not apply to the spool valve via the reaction rod.



ii) Pressure Increase (High Pressure)

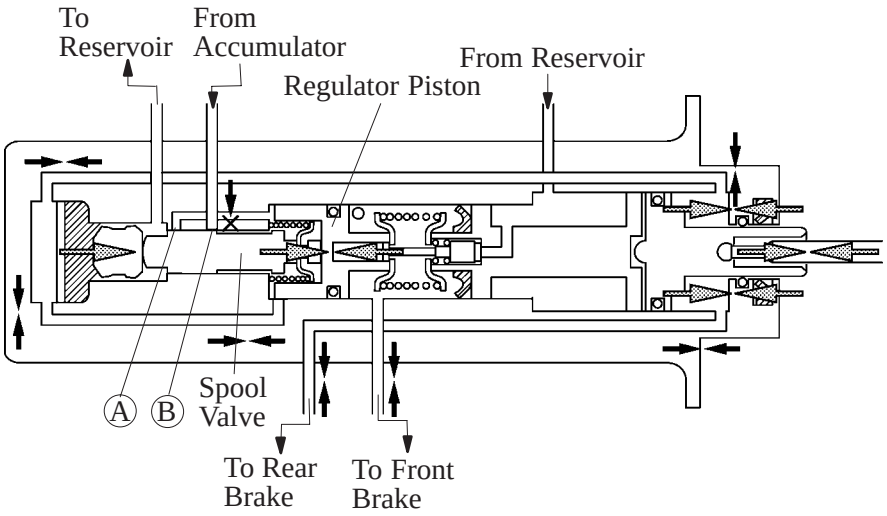
In contrast to the time when the pressure is low, when the pressure is high, the booster pressure that is applied to the rubber reaction disc increases. Accordingly, the rubber reaction disc deforms and causes a return force in the rightward direction to be applied to the spool valve via the reaction rod. Therefore, in contrast to the time when the pressure is low, a greater reaction force is transmitted to the brake pedal.
As a result, a variable servo mechanism is realized, in which the servo ratio is lower during high pressure than during low pressure.



iii) Holding

This is a state in which the force that is applied via the brake pedal and the master cylinder pressure are in balance.

The forces that are applied to the front and the rear of the regulator piston, in other words, forces that are generated by the master cylinder pressure and the regulator pressure become balanced. This causes the spool valve to close both path (B) from the booster chamber to the accumulator and path (A) to the reservoir. As a result, the brake system is in the holding state.

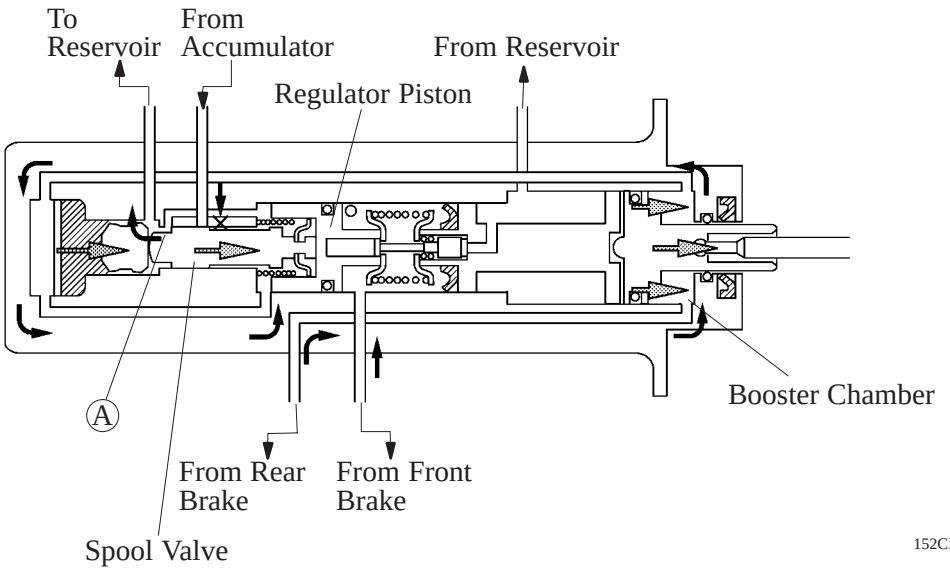


152CH27

iv) Pressure Reduce

When the pressure that is applied to the brake pedal is relaxed, the master cylinder pressure decreases. Then, the regulator piston's return (rightward) force becomes relatively greater, causing the regulator piston to retract and the spool valve to also retract. As a result, the path (A) between the reservoir and the booster chamber opens.

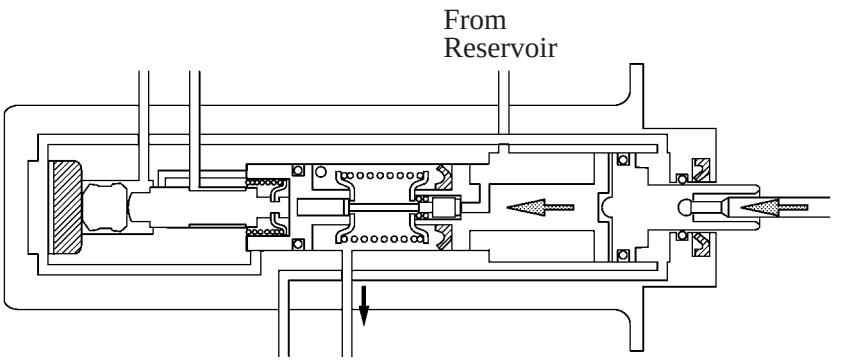
The booster pressure becomes reduced in this state, creating a balance that corresponds to the force that is newly applied via the brake pedal. This process is performed repetitively to reduce the booster pressure and the master cylinder pressure in accordance with the force that is applied via the brake pedal.



152CH28

v) During Power Supply Malfunction

If the accumulator pressure is affected due to some type of malfunction, no pressure will be supplied by the regulator. Then, a power assist cannot be provided to the force that is applied via the brake pedal and the pressure to the rear brakes cannot be increased.
The pressure to the front brakes will be increased by the master cylinder in accordance with the pedal effort applied to the brake pedal.



152CH29

3) Solenoid Valves

a. Switching Solenoid Valves

Four switching solenoid valves (SA1, SA2, SA3, and STR) are provided.
The control signals from the ABS & TRC & VSC ECU open and close the switching solenoid valves to switch the brake fluid paths.
The solenoid valves SA1 and SA2 switch during normal braking of the front brakes and during the activation of the ABS and VSC. During normal braking, the path to the master cylinder side is opened, and the path to the hydraulic pressure supply side is opened during the activation of the ABS and VSC.
The solenoid valve SA3 is switched during normal braking of the rear brakes, during the activation of the ABS, and during the activation of the TRC and VSC. The path to the booster side is opened during normal braking and during the activation of the ABS, and the path is closed during the activation of the TRC and VSC.
The solenoid valve STR opens the path to the accumulator side during the activation of the TRC and VSC.

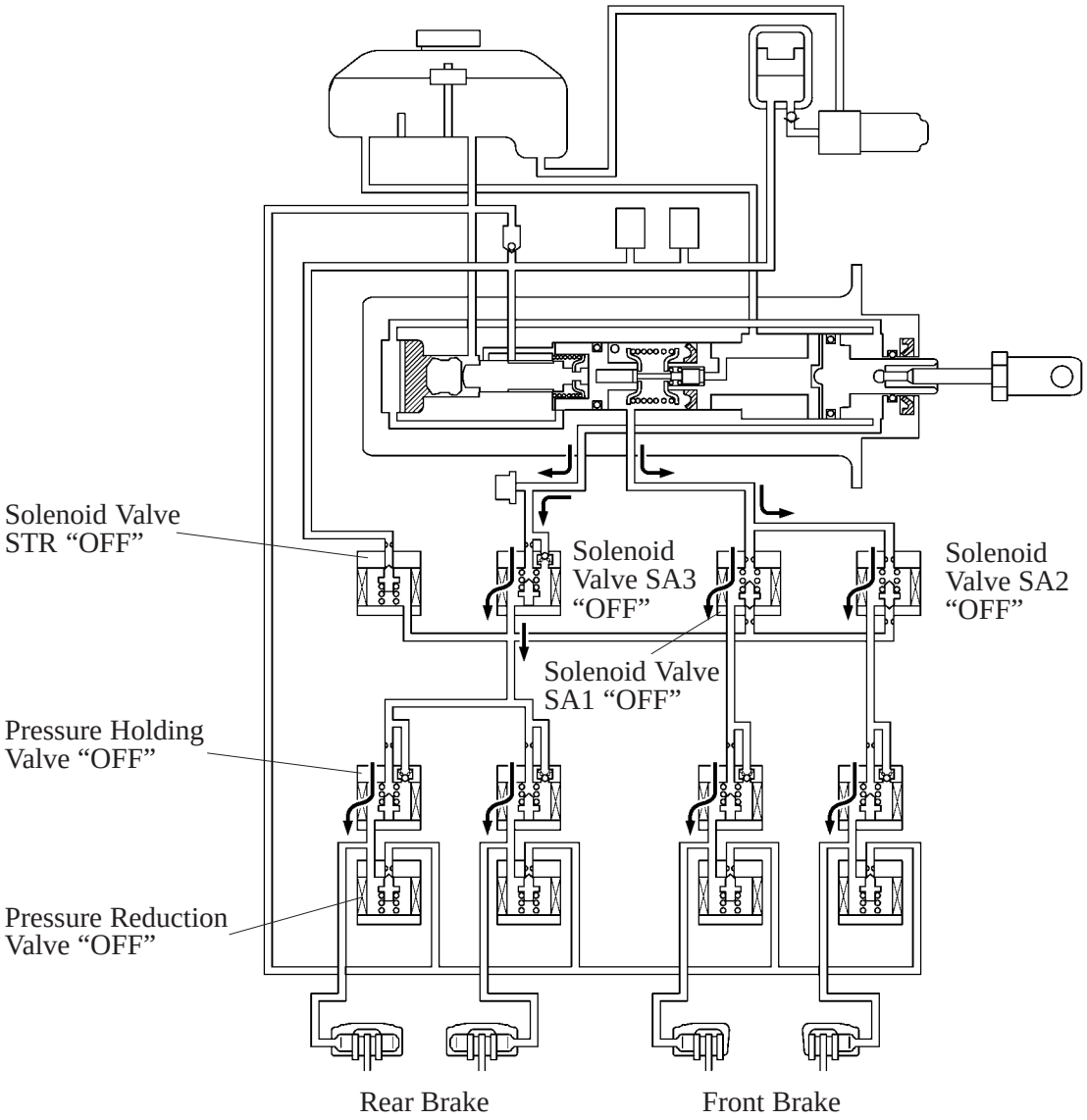
b. Control Solenoid Valves

The control solenoid valve consists of 4 pressure holding valves and 4 pressure reduction valves.
Each of the brake circuits consists of a pressure holding valve and a pressure reduction valve. The valves are turned ON and OFF during the activation of the ABS, TRC, and VSC. The pressure increase mode, the pressure holding mode, and the pressure reduction mode are effected based on the combination of these valves that are turned ON and OFF, in order to control the hydraulic pressure that is applied to each of the wheel cylinders.

c. System Operation

i) Normal Braking

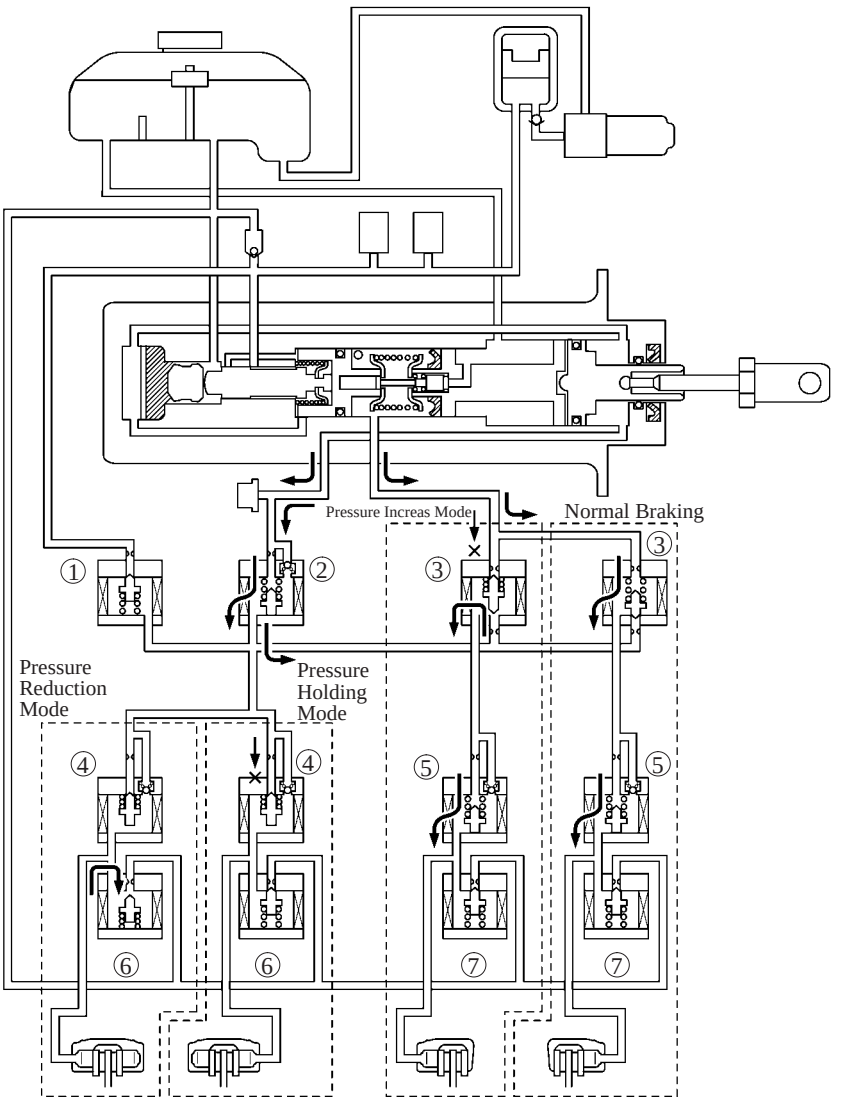
During normal braking, all solenoid valves are turned OFF.



152CH32

ii) ABS Operation

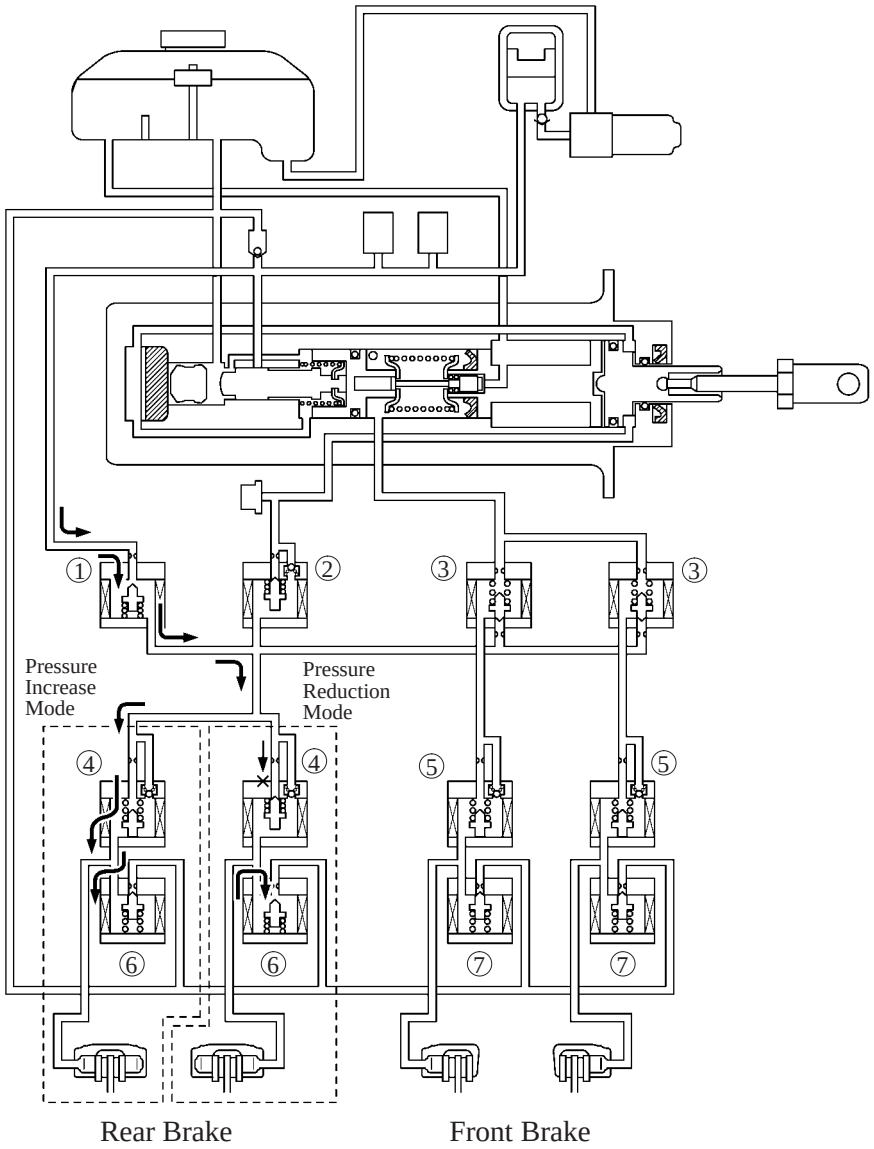
The solenoid valves are turned ON and OFF as described below to switch the fluid paths in order to control the brakes.
At this time, the hydraulic path between the master cylinder and the front brakes is shut off to prevent the brake pedal from vibrating and to improve the feeling during brake application.



Mode / Solenoid Valves		Normal Braking	ABS Activated		
			Pressure Increase Mode	Pressure Holding Mode	Pressure Reduction Mode
① Solenoid Valve STR		OFF	OFF	OFF	OFF
Front Brake	③ Solenoid Valves SA1 and SA2	OFF	ON	ON	ON
	⑤ Pressure Holding Valve	OFF	OFF	ON	ON
	⑦ Pressure Reduction Valve	OFF	OFF	OFF	ON
	Wheel Cylinder Pressure	Increase	Increase	Hold	Reduction
Rear Brake	② Solenoid Valve SA3	OFF	OFF	OFF	OFF
	④ Pressure Holding Valve	OFF	OFF	ON	ON
	⑥ Pressure Reduction Valve	OFF	OFF	OFF	ON
	Wheel Cylinder Pressure	Increase	Increase	Hold	Reduction

iii) TRC Operation

The TRC system control consists of an engine output control and a brake hydraulic control. As described below, this system turns the solenoid valves ON and OFF to switch the fluid paths in order to control the rear brakes.

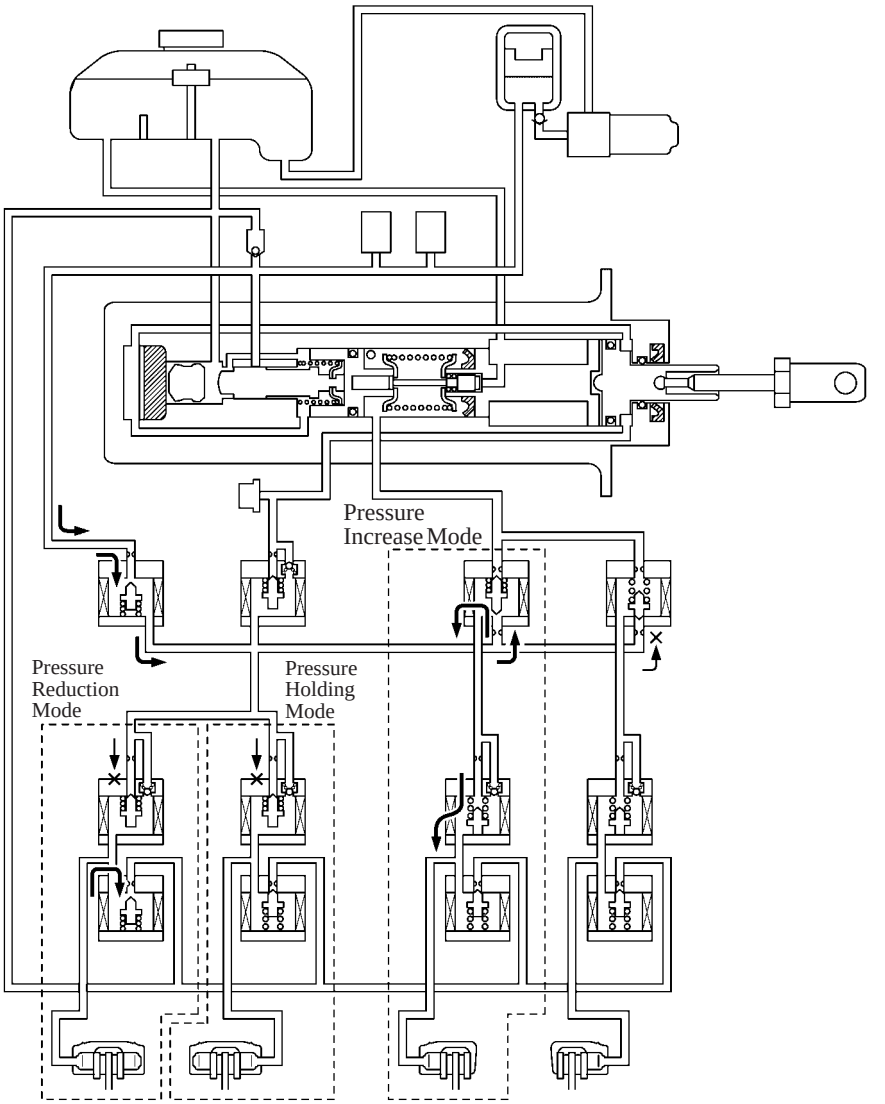


152CH34

Mode / Solenoid Valves		TRC Not Activated	TRC Activated		
			Pressure Increase Mode	Pressure Holding Mode	Pressure Reduction Mode
① Solenoid Valve STR		OFF	ON	ON	ON
Front Brake	③ Solenoid Valves SA1 and SA2	OFF	OFF	OFF	OFF
	⑤ Pressure Holding Valve	OFF	OFF	OFF	OFF
	⑦ Pressure Reduction Valve	OFF	OFF	OFF	OFF
	Wheel Cylinder Pressure	—	—	—	—
Rear Brake	② Solenoid Valve SA3	OFF	ON	ON	ON
	④ Pressure Holding Valve	OFF	OFF	ON	ON
	⑥ Pressure Reduction Valve	OFF	OFF	OFF	ON
	Wheel Cylinder Pressure	—	Increase	Hold	Reduction

iv) VSC Operation

- The VSC system control consists of an engine output control and a brake hydraulic control.
- When the system activates to restrain oversteer, it controls the front brake of the outer wheel in the turn. It also regulates the rear brakes as needed.
- When the system activates to restrain understeer, it controls the rear brakes.



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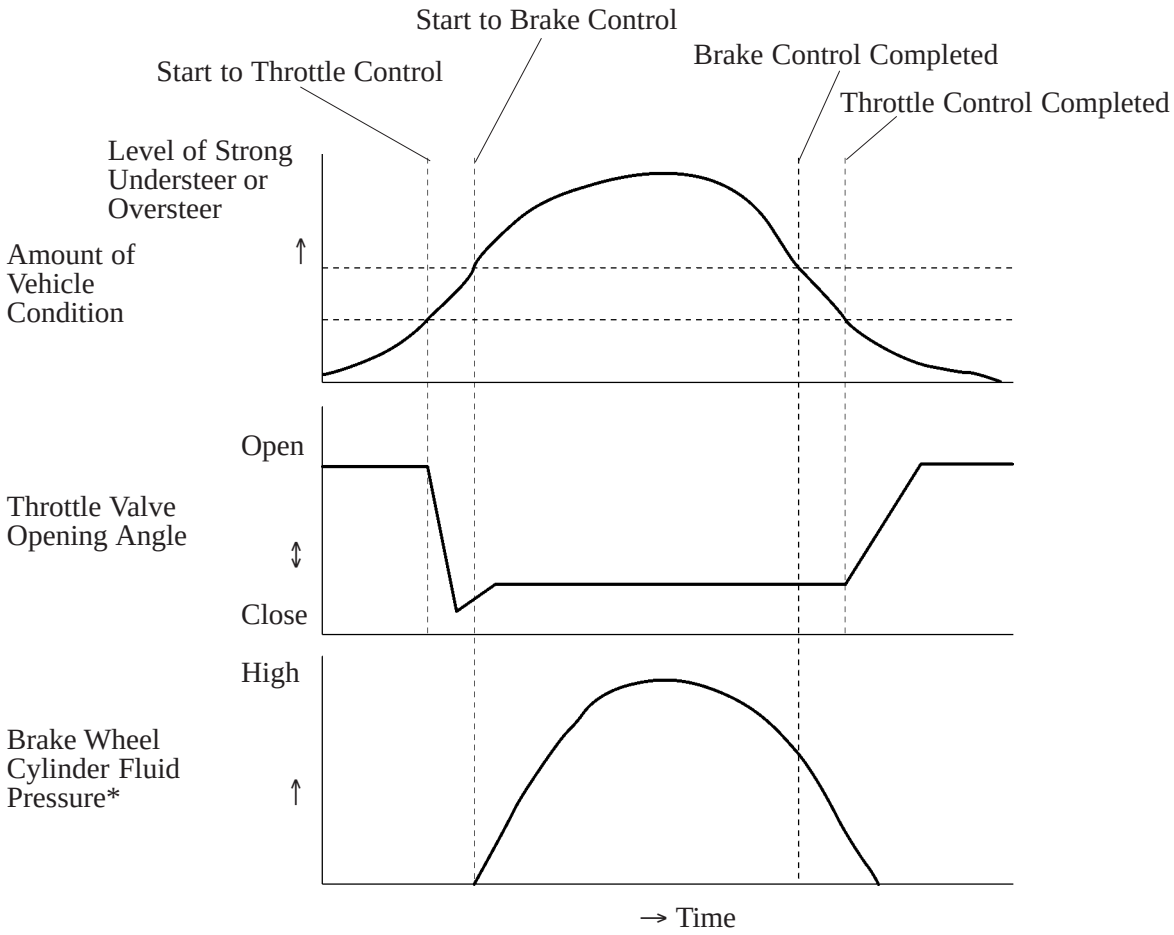
Mode / Solenoid Valves		VSC Not Activated	VSC Activated		
			Pressure Increase Mode	Pressure Holding Mode	Pressure Reduction Mode
	① Solenoid Valve STR	OFF	ON	ON	ON
Front Brake	③ Solenoid Valves SA1 and SA2	OFF	ON	ON	ON
	⑤ Pressure Holding Valve	OFF	OFF	ON	ON
	⑦ Pressure Reduction Valve	OFF	OFF	OFF	ON
	Wheel Cylinder Pressure	—	Increase	Hold	Reduction
Rear Brake	② Solenoid Valve SA3	OFF	ON	ON	ON
	④ Pressure Holding Valve	OFF	OFF	ON	ON
	⑥ Pressure Reduction Valve	OFF	OFF	OFF	ON
	Wheel Cylinder Pressure	—	Increase	Hold	Reduction

ABS & TRC & VSC ECU

1) Vehicle Stability Control

Based on the 4 types of sensor signals received from the speed sensors, yaw rate sensor, deceleration sensor, and steering angle sensor, the ABS & TRC & VSC ECU calculates the amount of vehicle condition.

If a strong understeer or oversteer tendency is created during an emergency avoidance maneuver or cornering, and the ABS & TRC & VSC ECU determines that the amount of vehicle condition exceeds a prescribed value, it controls the throttle valve opening angle and the brake fluid pressure according to the amount of the vehicle condition.



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*: The wheel cylinder that activates varies depending on the condition of the vehicle.

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2) Initial Check

After the ignition is turned ON and only at the initial time, ABS & TRC & VSC ECU performs an initial check when the vehicle attains an approximate speed of 6 km/h (4 mph) and more or when the stop light switch is turned OFF from ON.
The functions of each solenoid valve in the hydrulic brake booster are checked in order.

3) Self-Diagnosis

If the ABS & TRC & VSC ECU detects a malfunction in the hydraulic brake booster, ABS, TRC and/or VSC system, it turns on the ABS warning light and the VSC warning light to alert the driver the malfunction. The ECU will also store the codes of the malfunctions. The diagnostic code can be accessed from the ABS warning light and the VSC warning light. A hand-held tester can be used to access the diagnostic code and to perform an active test. See the GS300 Repair Manual (Pub. No. RM588E) for the diagnostic code check method, diagnostic code and diagnostic code clearance.

4) Fail Safe

In the event of a malfunction in the ABS, TRC or VSC system, the ABS & TRC & VSC ECU prohibits the ABS, TRC and VSC system.
Thus, the brake and throttle valve opening angle control will be operated in the same conditions as those without the ABS, TRC and VSC system.