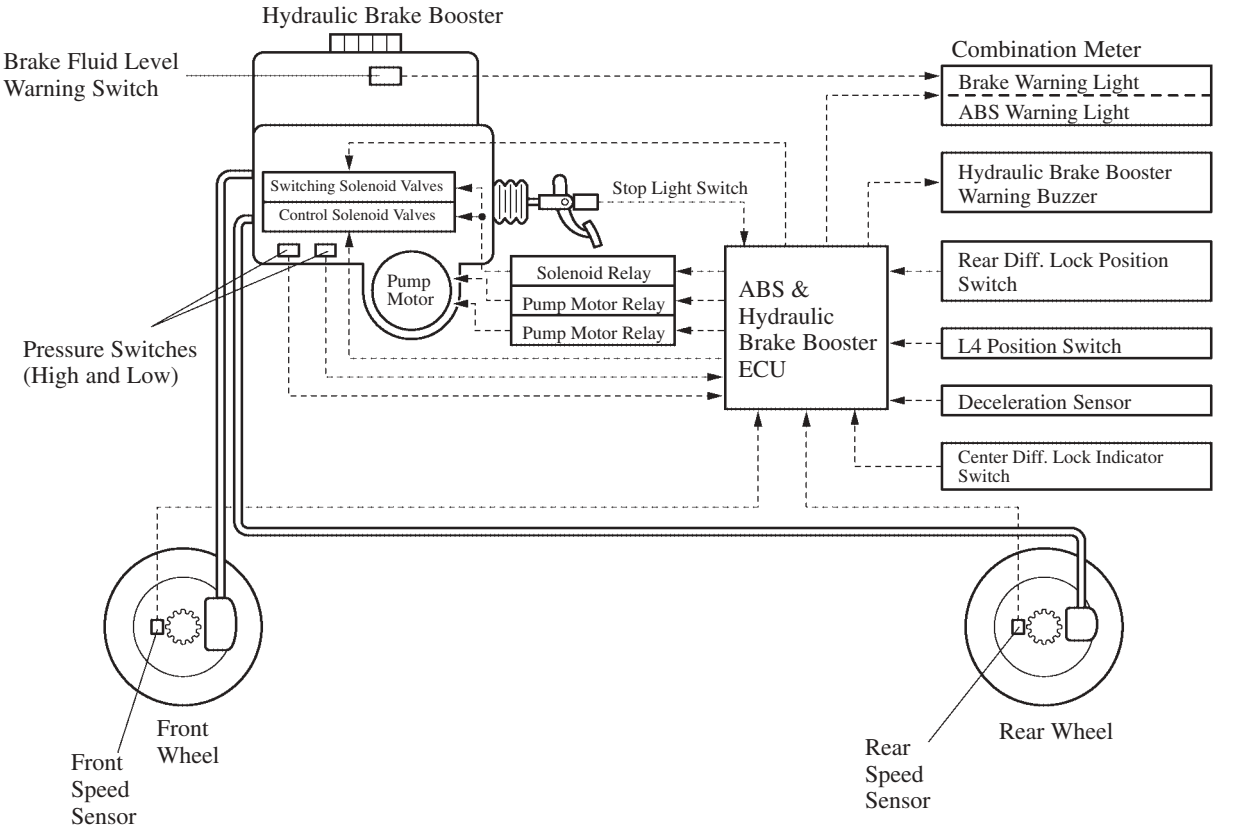
■ ABS

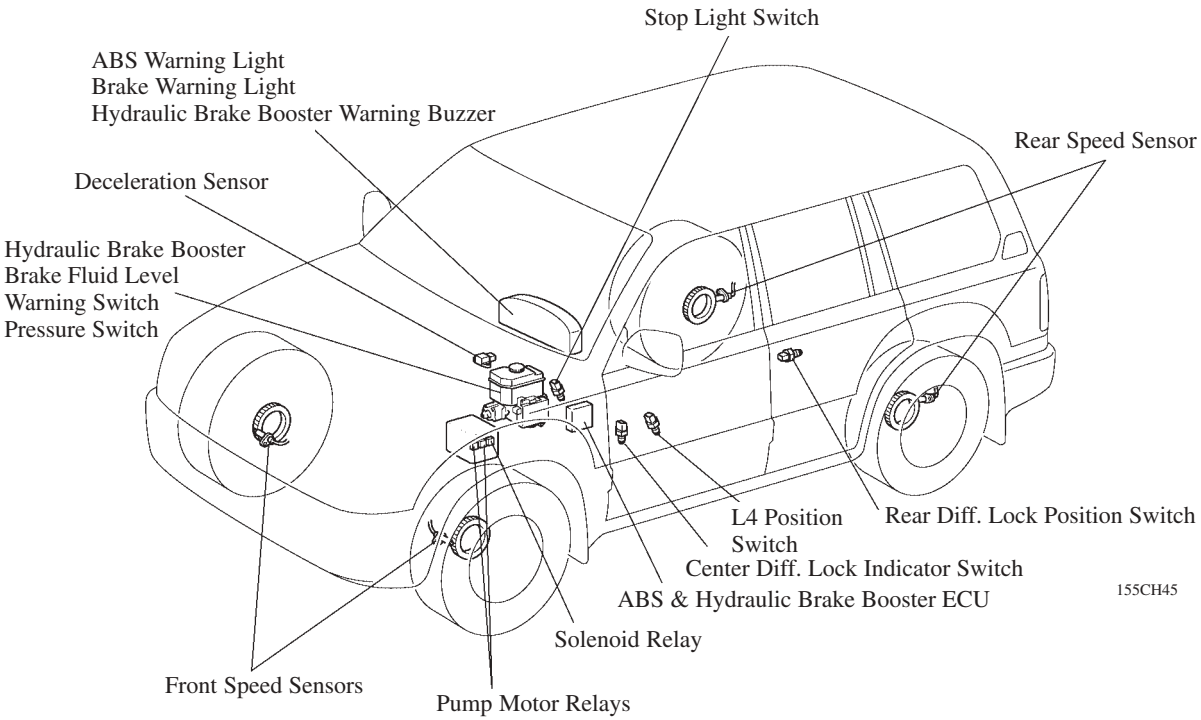
1. General

- The ABS actuator and the hydraulic brake booster have been integrated to form a compact actuator.
- 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.
- The M-OBD (Multiplex On-Board Diagnostic) system is supported.

2. System Diagram



3. Layout of Components



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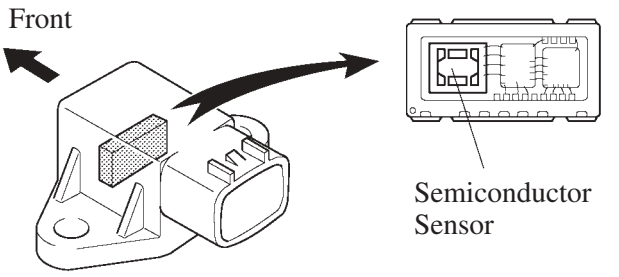
4. Function of Components

Components	Function
Speed Sensors	Detect the wheel speed of each of four wheels.
Deceleration Sensor	Detects the vehicle's acceleration in the longitudinal direction.
ABS & Hydraulic Brake Booster ECU	Controls the operation of the ABS brake and the hydraulic brake booster based on the signals received from the speed sensors, the deceleration sensor, the pressure switches, etc.
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 & hydraulic brake booster ECU during the operation of the ABS, in order to control the fluid pressure that is applied to the wheel cylinders.
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.
Brake Warning Light	Lights up to alert the driver when the ECU detects the malfunction in the brake system.
Hydraulic Brake Booster Warning Buzzer	Emits a continuous sound to inform the driver that the ECU detects a malfunction in the hydraulic brake booster.
Stop Light Switch	Detects the brake signal.
Rear Diff. Lock Position Switch	Detects the condition of the rear differential lock.
L4 Position Switch	Detects the transfer shifted in the low.
Center Diff. Lock Indicator Switch	Detects the condition of the center differential lock.
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.

5. Construction and Operation of Main Components

Deceleration Sensor

A deceleration sensor that uses a semiconductor sensor is provided inside the center console.
When a force is applied to the deceleration sensor, the semiconductor sensor flexes, and this distortion is measured and converted into an electric signal.
This semiconductor sensor is used to detect the acceleration and deceleration rate in the vehicle's longitudinal direction.



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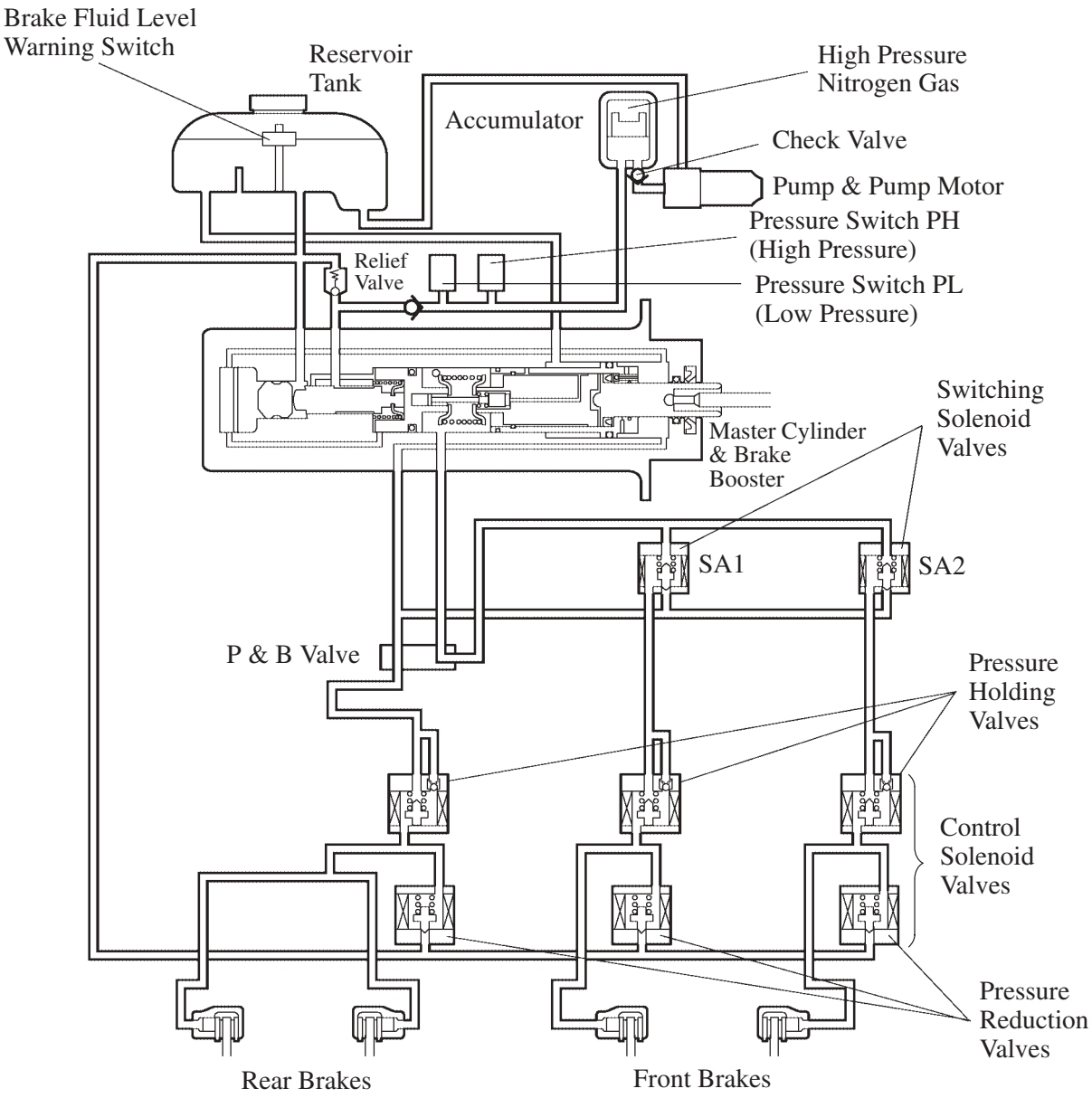
Hydraulic Brake Booster

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, for example.
Reservoir Tank	Stores the brake fluid.
Brake Fluid Level Warning Switch	Detects the low 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.
P & B Valve	Controls the hydraulic pressure of the rear brake system to achieve an appropriate distribution of front/rear braking force. However, if the front brake system fails, the P & B valve does not control the hydraulic pressure of the rear brake system.
Switching Solenoid Valves (SA1, SA2)	Switches the brake hydraulic path when the ABS 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 control.

▶ Hydraulic Circuit ◀



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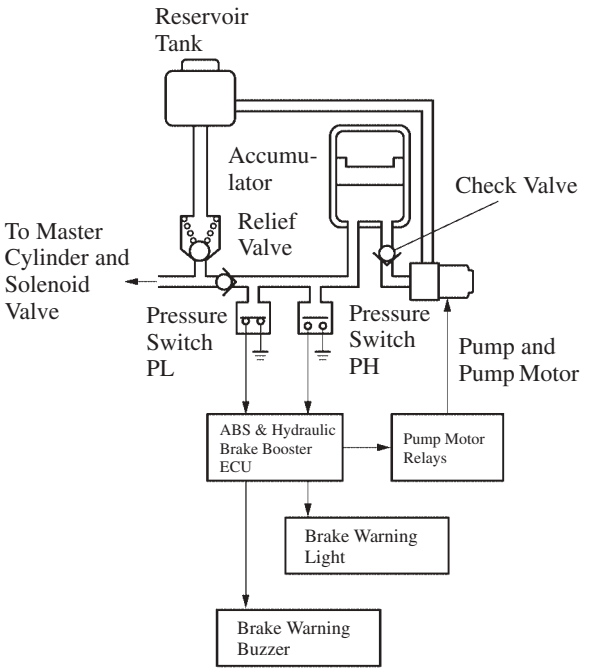
1) Pump, Pump Motor, Accumulator, Pressure Switches and Relief Valve

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 & hydraulic brake booster 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.
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 & hydraulic brake booster 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 brake warning buzzer activates.
As this time, the ABS is prohibited from operating.



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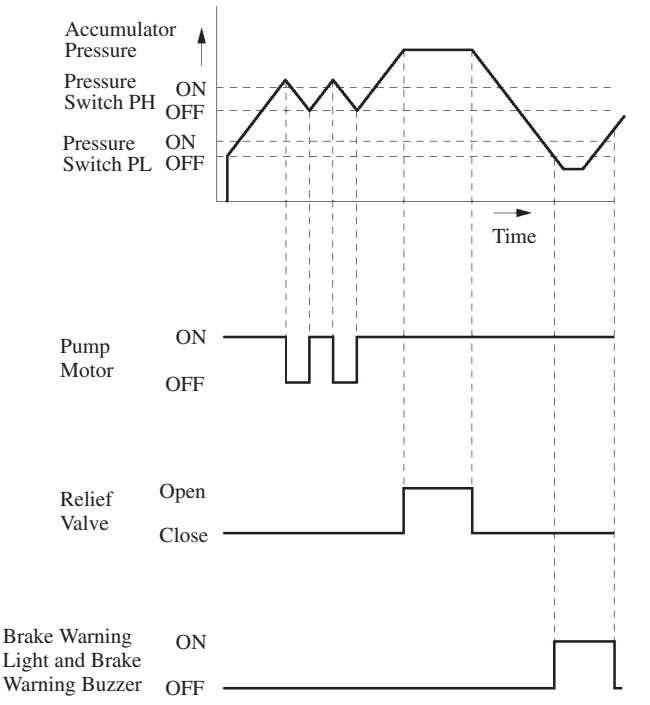

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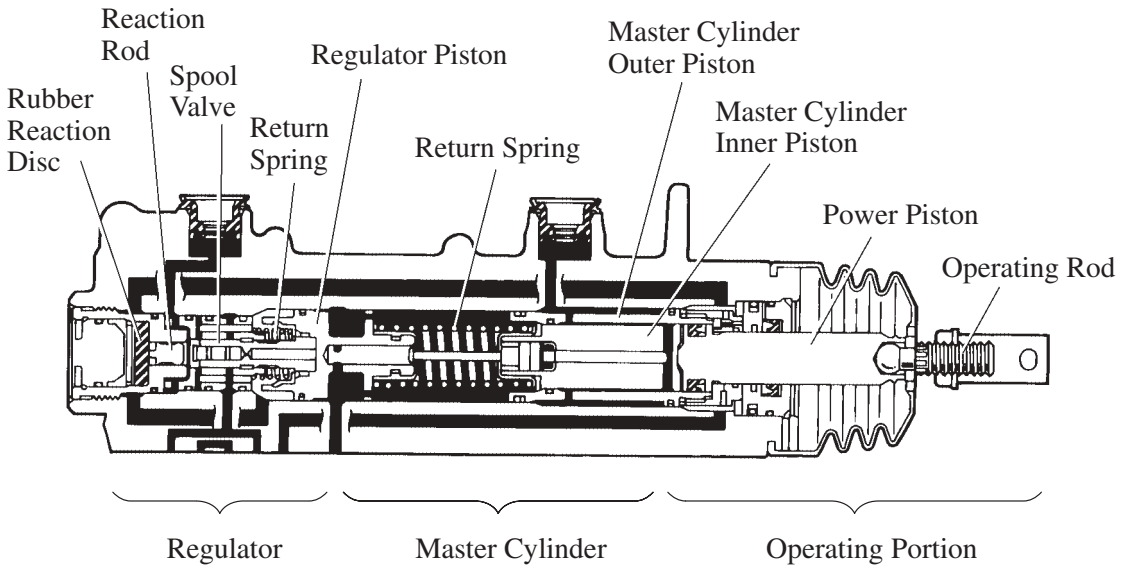
2) Master Cylinder and Brake Booster

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, master cylinder pistons, 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.
- The regulator piston's return spring is provided for the regulator piston to ensure the return of the spool valve.
- The master cylinder pistons have adopted a dual construction consisting of outer and inner pistons. Ordinarily, the outer and inner pistons operate in unison. If the accumulator pressure is not applied, only the inner piston operates to ensure braking force.



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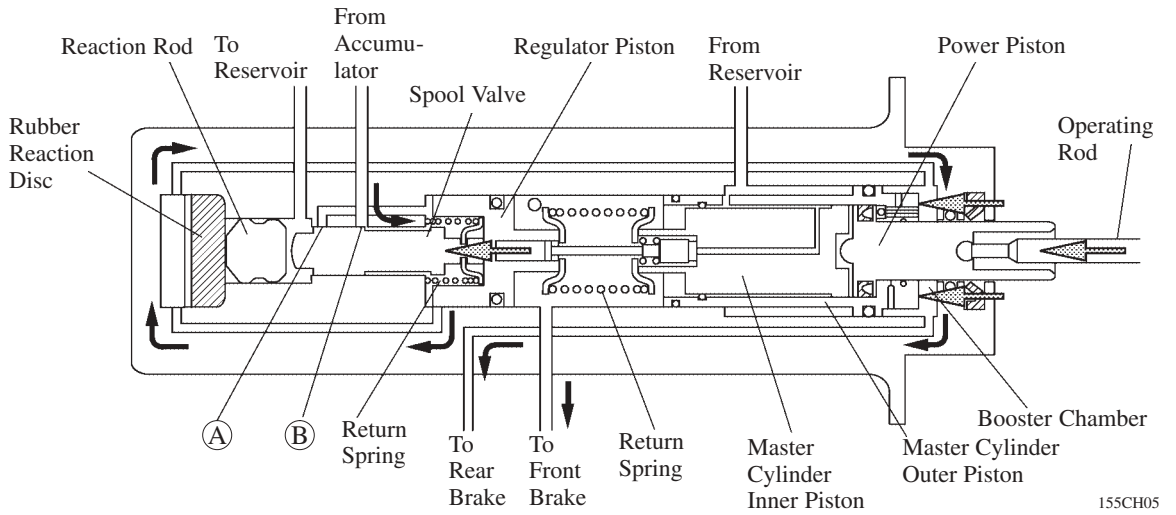
b. Operation

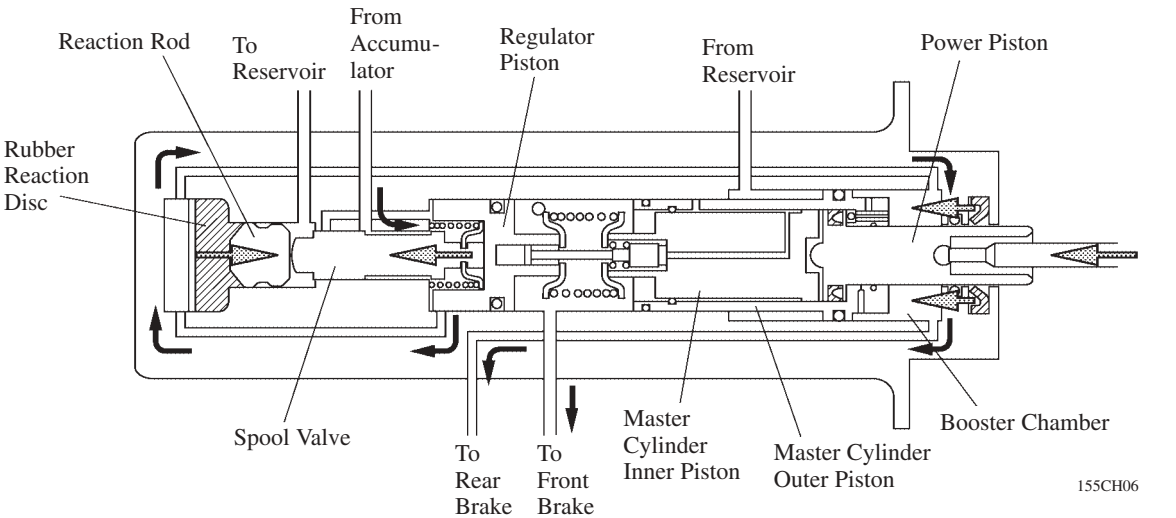
i) Pressure Increase (Low Pressure)

The pedal effort that is applied to the brake pedal is transmitted via the operating rod, power piston, and master cylinder inner piston. However, because the load setting of the master cylinder's return spring is higher 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 Ⓐ between the reservoir and the booster chamber (behind the power piston) and opens the path Ⓑ 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)

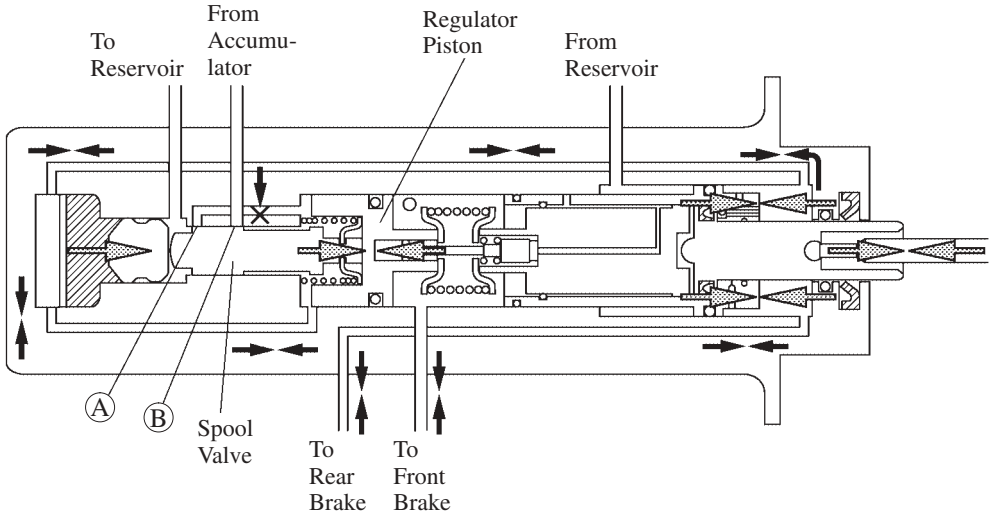
In contrast to the time when the pressure is low, when the pressure is high, the booster pressure that is applied to the rubber reaction disc increases. Accordingly, the rubber reaction disc deforms and causes a return force in the rightward direction to be applied to the spool valve via the reaction 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 Ⓑ from the booster chamber to the accumulator and path Ⓐ to the reservoir. As a result, the brake system is in the holding state.



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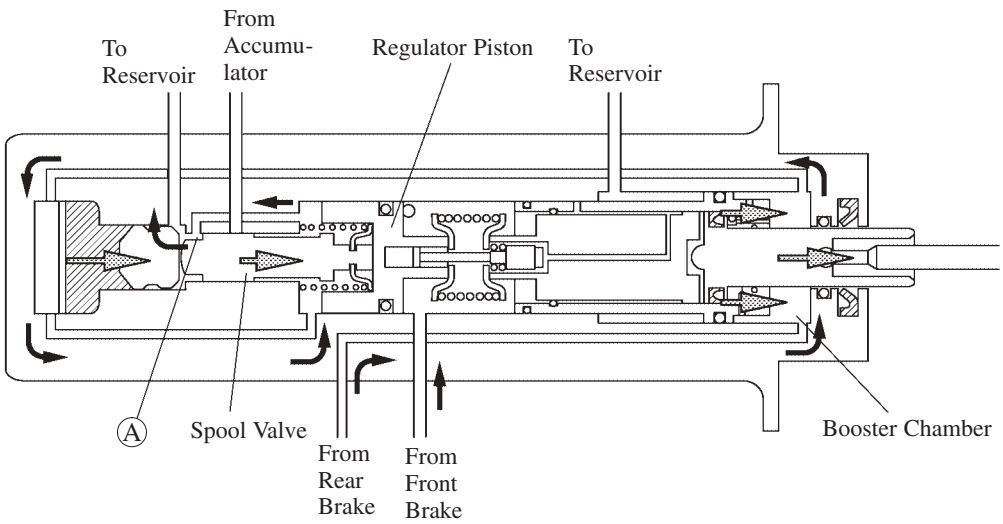
iv) Pressure Reduce

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 Ⓐ 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.



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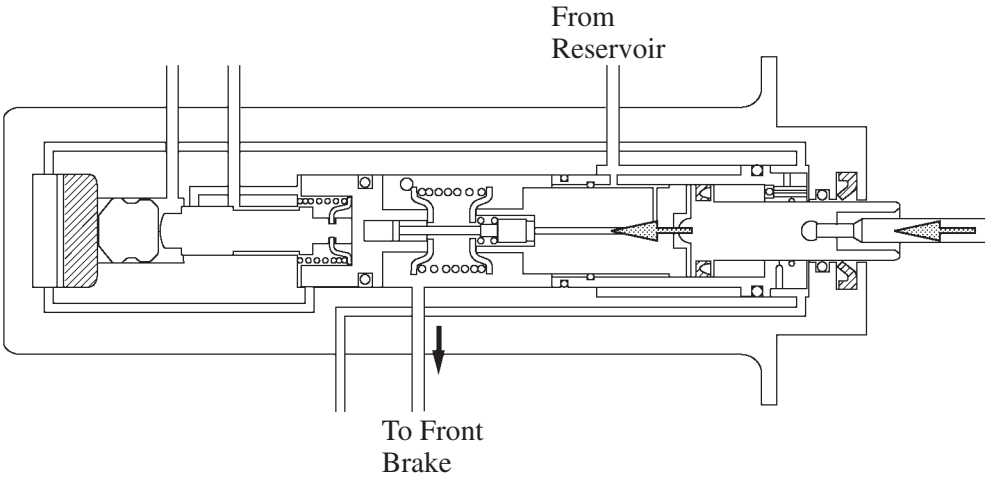
v) During Power Supply Malfunction

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.
Because the power assist is not applied to the master cylinder outer piston, the master cylinder outer piston does not operate and remains in its initial position.
The pressure to the front brakes will be increased by the master cylinder inner piston in accordance with the pedal effort applied to the brake pedal.



3) Solenoid Valves

a. Switching Solenoid Valves

Two switching solenoid valves (SA1 and SA2) are provided.
The control signals from the ABS & hydraulic brake booster 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. During normal braking, the path to the master cylinder side is opened, and the path to the booster chamber side is opened during the activation of the ABS.

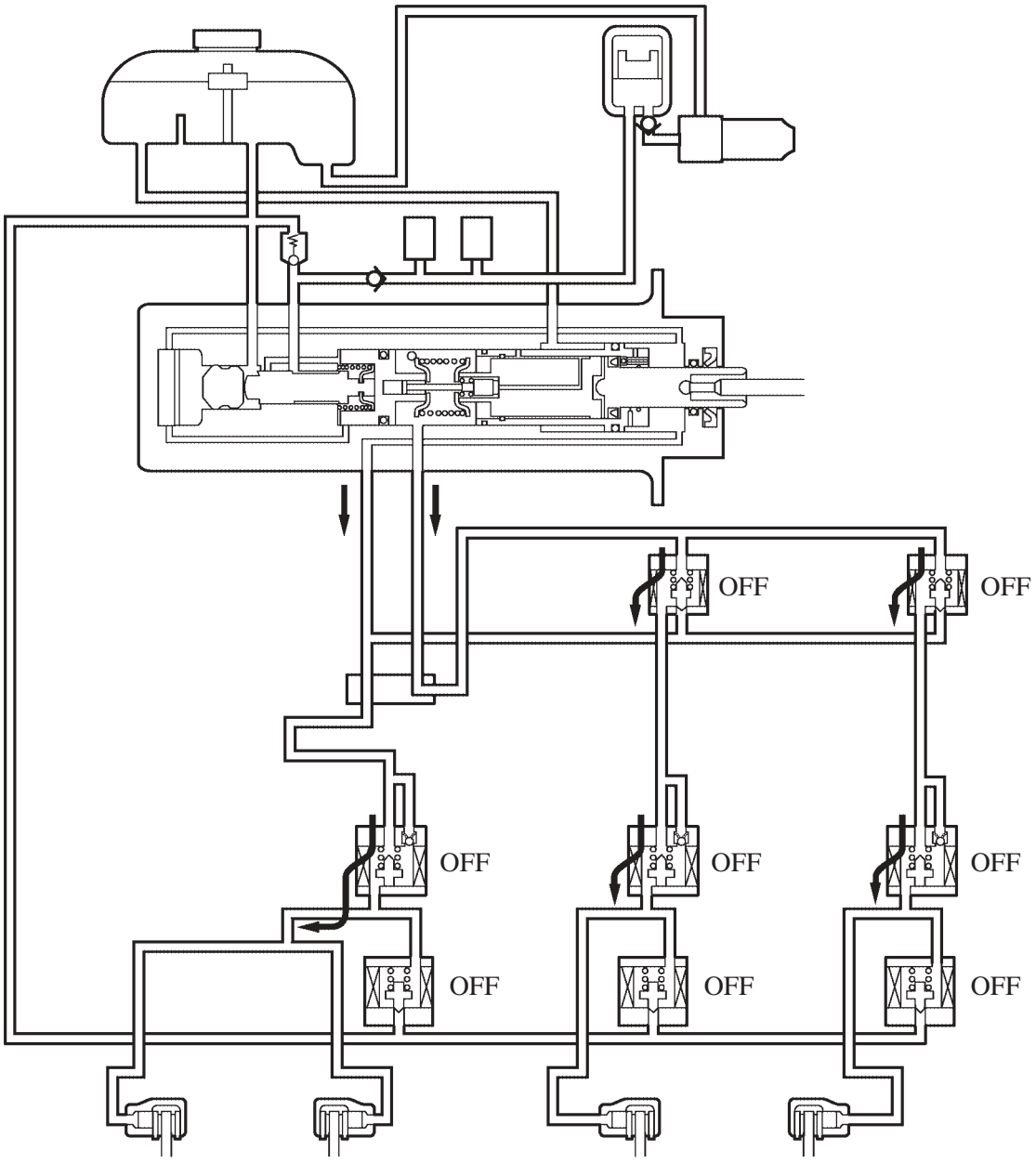
b. Control Solenoid Valves

The control solenoid valve consists of 3 pressure holding valves and 3 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. 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.



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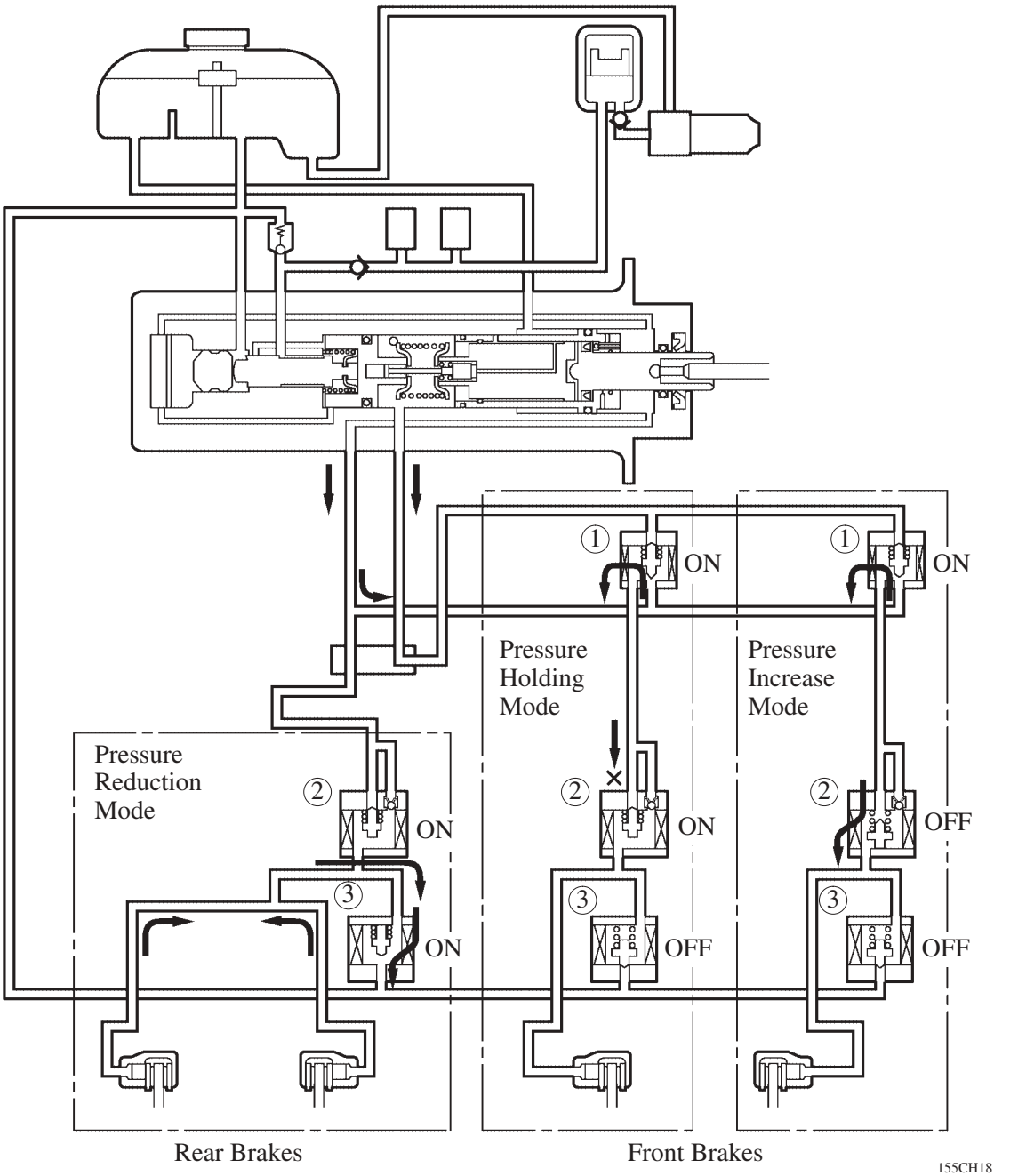
ii) ABS Operation

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.



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Mode / Solenoid Valves		Pressure Reduction Mode	Pressure Holding Mode	Pressure Increase Mode
Front Brake	① Solenoid Valve SA1, SA2	ON	ON	ON
	② Pressure Holding Valve	ON	ON	OFF
	③ Pressure Reduction Valve	ON	OFF	OFF
	Wheel Cylinder Pressure	Reduction	Hold	Increase
Rear Brake	② Pressure Holding Valve	ON	ON	OFF
	③ Pressure Reduction Valve	ON	OFF	OFF
	Wheel Cylinder Pressure	Reduction	Hold	Increase