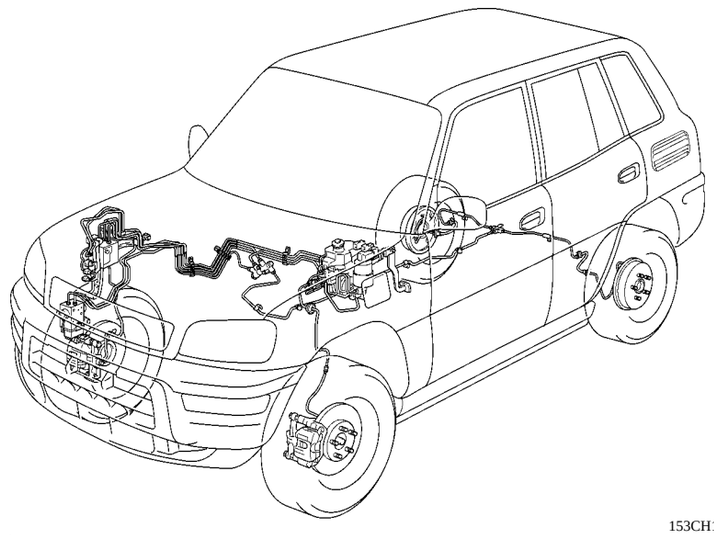
BRAKES

■DESCRIPTION

- An aluminum solid disc brake is used for the front to reduce the weight.
- A leading trailing drum brake is used for the rear.
- The hydraulic brake booster is used.
- Cooperative control of the regenerative brake and hydraulic brake is performed.
- An ABS is a standard equipment.
- The tire pressure warning system is used.



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▶ Specifications ◀

Master Cylinder	Type		Single
	Diameter	mm (in.)	20.64 (0.81)
Brake Booster Type			Hydraulic
Front Brake	Type		Solid Disc
	Pad Area	cm^2 ($in.^2$)	47.9 (7.42)
	Wheel Cylinder Diameter	mm (in.)	54.0 (2.13)
	Rotor Size (D × T)*	mm (in.)	301.7 × 18 (11.88 × 0.71)
Rear Brake	Type		Leading Trailing Drum
	Lining Area	cm^2 ($in.^2$)	85.4 (13.24)
	Wheel Cylinder Diameter	mm (in.)	20.64 (0.81)
	Drum Inner Diameter	mm (in.)	254 (10.00)
Brake Control Valve	Type		P & B Valve
	Deflection Point of Hydraulic Pressure	KPa (kgf/cm^2, psi)	254 (10.00)
	Pressure Reduction Gradient		0.37
Parking Brake	Type		Drum
	Size	mm (in.)	254 (10.00)
	Lever Type		Floor Lever
ABS			STD

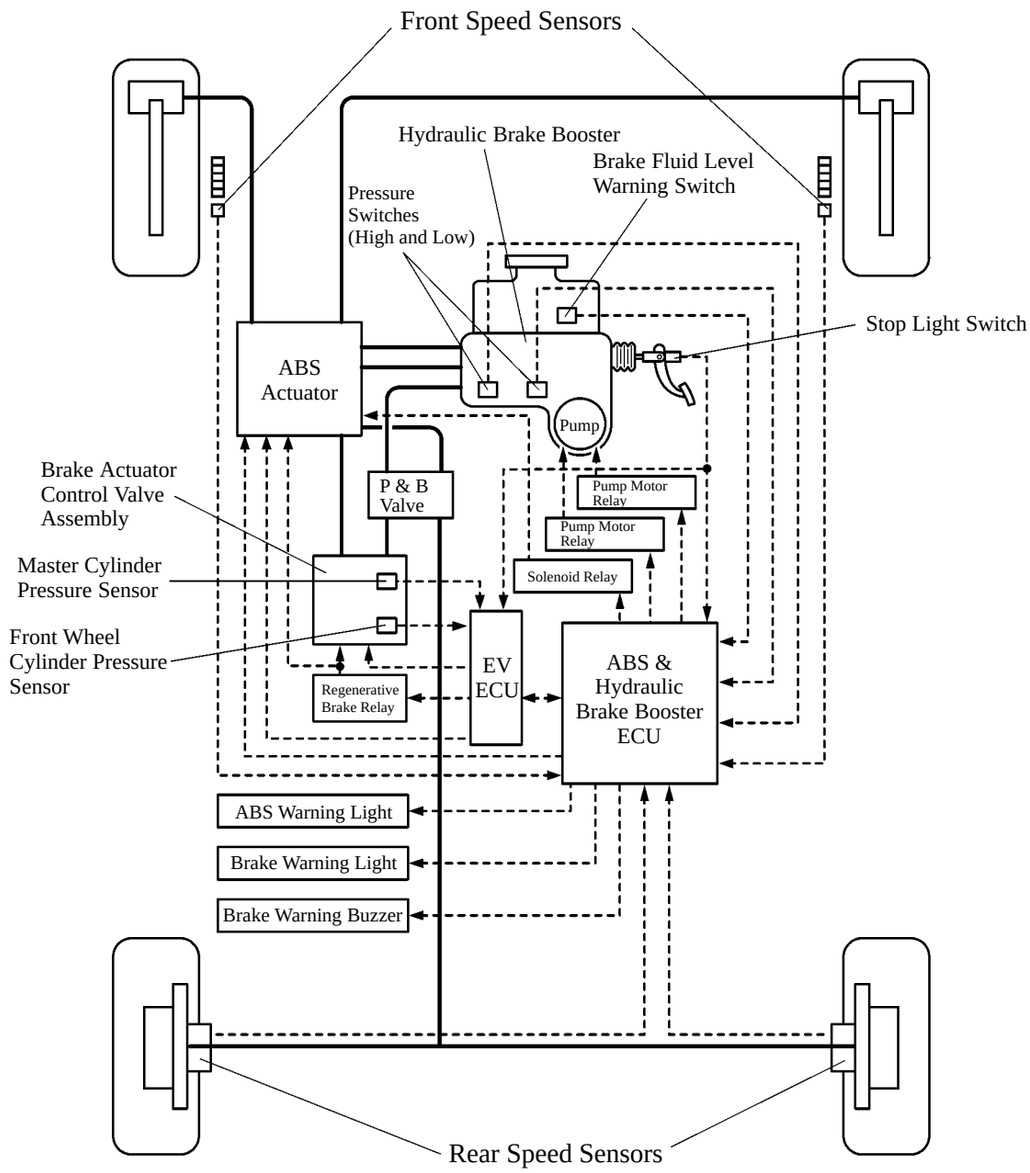
*: D: Outer Diameter, T: Thickness

■BRAKE SYSTEM

1. General

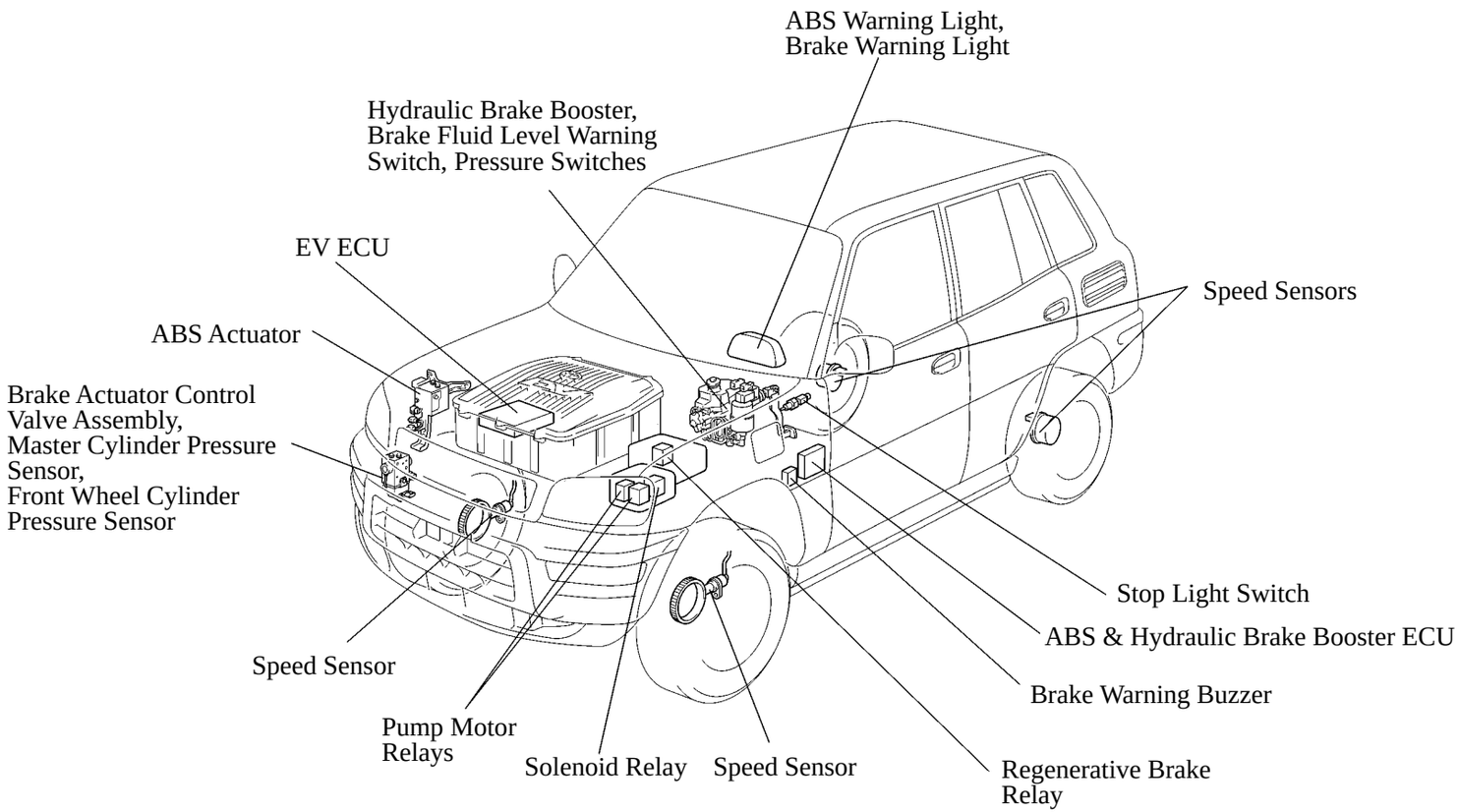
A brake system, which uses brake fluid that is stored under high pressure to assist the brake pedal effort and to operate the ABS and the regenerative brake cooperative control, has been adopted.

2. System Diagram



153CH08

3. Layout of Components



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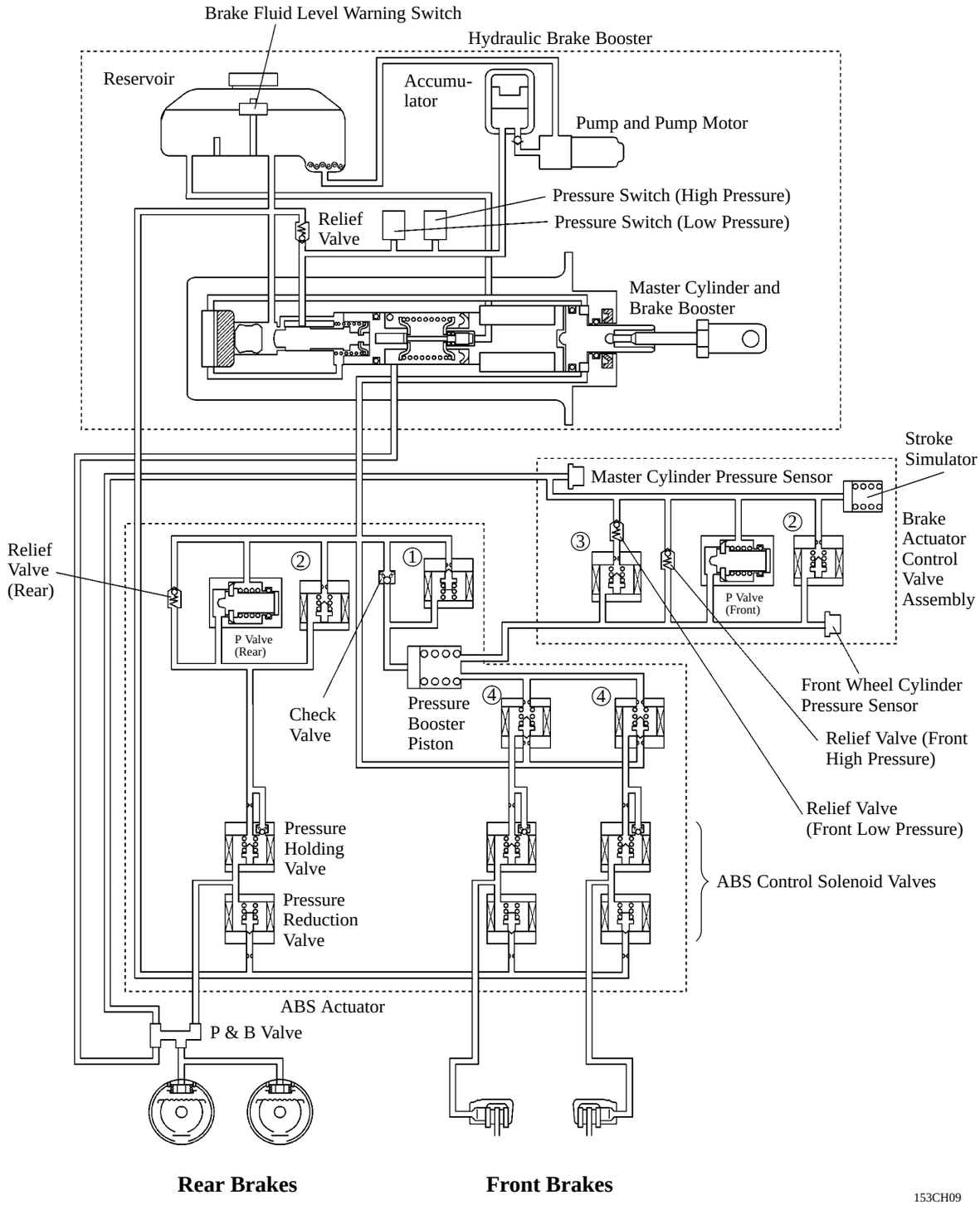
4. Function of Components

Components	Function
Speed Sensors	Detect the wheel speed of each of four wheels.
ABS & Hydraulic Brake Booster ECU	● Processes the speed sensor signals, regenerative brake signals, etc., to execute control of the ABS brake and hydraulic brake booster. ● Communicates control data with the EV ECU.
Hydraulic Brake Booster	● Assists with the pedal effort applied to the brake pedal. ● Supplies hydraulic pressure when operating the ABS.
ABS Actuator	Controls the brake fluid pressure to each brake wheel cylinder by signals from the ABS & hydraulic brake booster ECU and EV ECU.
Brake Actuator Control Valve Assembly	Duaring regenerative brake cooperative control, controls the brake fluid pressure to each brake wheel cylinder by signals from the EV ECU.
Brake Fluid Level Warning Switch	Detects the brake fluid level.
Pressure Switches	Assembled in the hydraulic brake booster and monitors the hydraulic pressure of the accumulator and outputs control signals for the pump motor.
Master Cylinder Pressure Sensor	Assembled in the brake actuator control valve assembly and detects the muster cylinder pressure and sends the master cylinder pressure signal to the EV ECU.
Front Wheel Cylinder Pressure Sensor	Assembled in the brake actuator control valve assembly and detects the front wheel cylinder pressure and sends the front wheel cylinder pressure signal to the EV ECU.
EV ECU	Outputs the regenerative brake's ON/OFF signals to the ABS & hydraulic brake booster ECU and controls the regenerative brake's solenoid valves.
Pump Motor Relays	Control the pump motor operation in the hydraulic brake booster.
Solenoid Relay	Supplies power to the ABS's solenoid valves in the ABS actuator.
Regenerative Brake Relay	Supplies power to the regenerative brake's solenoid valves.
ABS Warning Light	Lights up to alert the driver when the ABS and hydraulic brake booster ECU detects the malfunction in the ABS.
Brake Warning Light	Light up to alert the driver when the malfunction occurs in the brake system.
Brake Warning Buzzer	Emits a continuous sound to inform the driver that the ABS and hydraulic brake booster ECU detects the malfunction in the hydraulic brake booster.
Stop Light Switch	Detects the brake signal.

5. Hydraulic Circuit



①: Regenerative Brake Cooperative Control Solenoid Valve
②: Regenerative Brake Cooperative Switching Solenoid Valves
③: Relief Pressure Switching Solenoid Valve
④: ABS Switching Solenoid Valves

6. Construction and Operation

The brake system of RAV4 EV consists of the following components:

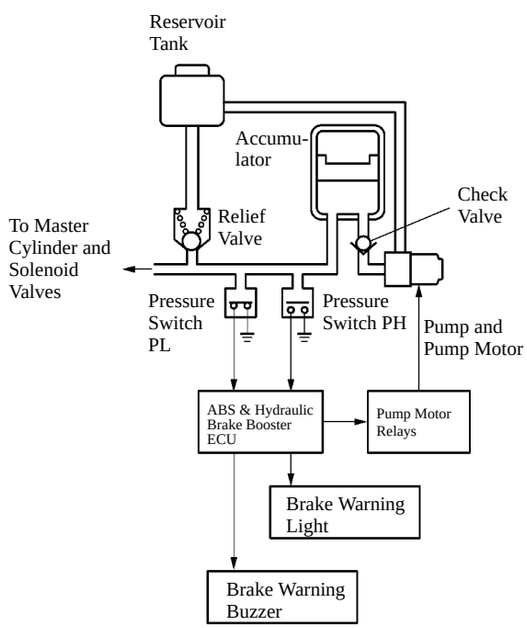
Components		Function
Hydraulic Brake Booster	Pump and Pump Motor	Draws up the brake fluid from the reservoir tank and provides high hydraulic pressure to the accumulator.
	Accumulator	Stores the hydraulic pressure that was generated by the pump. The accumulator is filled with high-pressure nitrogen gas.
	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 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.
Brake Actuator Control Valve Assembly	Master Cylinder Pressure Sensor	Detects the master cylinder pressure.
	Front Wheel Cylinder Pressure Sensor	Detects the front wheel cylinder pressure.
	Proportioning Valve (Front Side)	Introduces hydraulic pressure to the wheel cylinders when the brake pedal is first applied during the operation of the regenerative brake; thereafter, this valve limits the introduction of the hydraulic pressure.
	Relief Valves (Front High Pressure / Front Low Pressure)	Relieves the hydraulic pressure from the master cylinder hydraulic circuit to the wheel cylinder hydraulic circuit to ensure braking force after the regenerative braking force has reached its maximum value. Because the maximum value of the regenerative braking force varies by vehicle speed, 2 types of relief valves are provided and they are switched according to circumstances.
	Regenerative Brake Cooperative Switching Solenoid Valve	Switches the hydraulic path depending on whether or not the brakes are undergoing cooperative regenerative braking.
	Relief Pressure Switching Solenoid Valve	Switches the relief pressure from the master cylinder side to the front wheel cylinder side.
	Stroke Simulator	While the introduction of the hydraulic pressure from the master cylinder to the front wheel cylinders is being limited during a regenerative brake operation, the stroke simulator consumes the fluid flow from the master cylinder by causing the brake pedal to generate a a stroking movement.

Components		Function
ABS Actuator	Proportioning Valve (Rear Side)	Introduces hydraulic pressure to the wheel cylinders when the brake pedal is first applied during the operation of the regenerative brake; thereafter, this valve limits the introduction of the hydraulic pressure.
	Relief Valve (Rear Side)	Relieves the hydraulic pressure from the master cylinder hydraulic circuit to the wheel cylinder hydraulic circuit to ensure braking force after the regenerative braking force has reached its maximum value.
	Regenerative Brake Cooperative Switching Solenoid Valve	Switches the hydraulic path depending on whether or not the brakes are undergoing cooperative regenerative braking.
	Regenerative Brake Cooperative Control Solenoid Valve	Switches the hydraulic path to the pressure booster piston for introducing the hydraulic pressure that is generated in the brake booster to the front wheel cylinders.
	Pressure Booster Piston	Transmits the hydraulic pressure that is generated in the brake booster to the front wheel cylinders.
	ABS Switching Solenoid Valves	Switches the hydraulic path between normal braking and braking under ABS control.
	ABS Control Solenoid Valves (Pressure Holding Valves, Pressure Reduction Valves)	Controls the hydraulic pressure that is applied to the wheel cylinders during ABS control.

Hydraulic Brake Booster

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, for operating the ABS, and for regenerative brake cooperative controling.
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.
At this time, the ABS is prohibited from operating.



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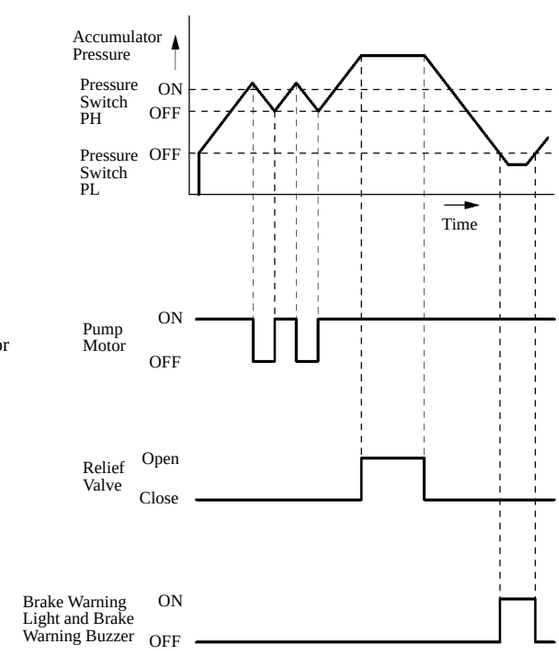


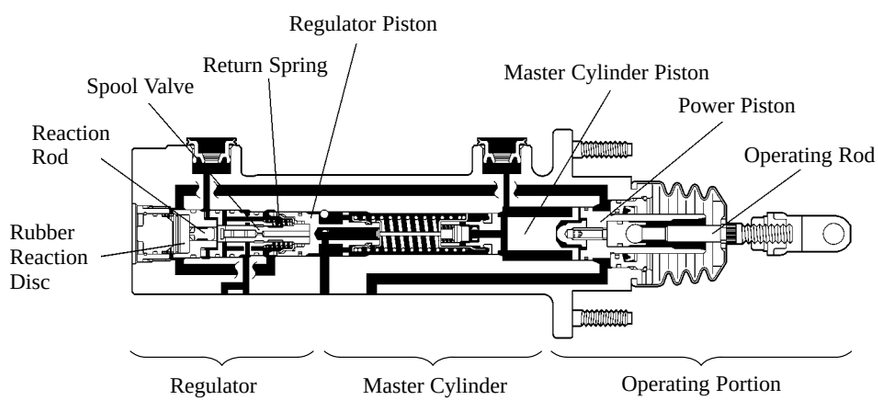
152CH17

2) Master Cylinder and Brake Booster

a. Construction

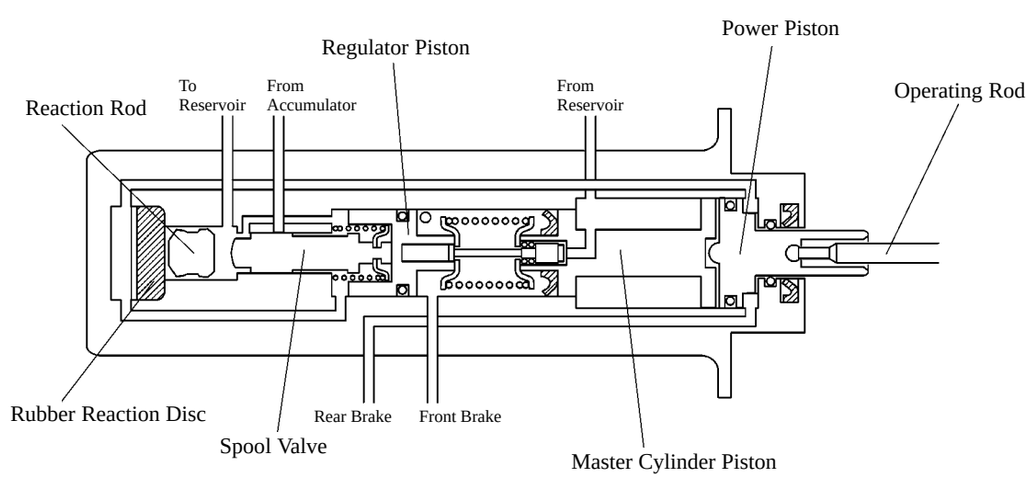
- This construction enables the hydraulic pressure that is generated by the brake booster to be applied directly to the rear brakes.
- The master cylinder is the center port type single master cylinder, which is used for the front brakes only.
- The brake booster is integrated with the master cylinder. The operating portion, master cylinder, and regulator are positioned coaxially to achieve a simple and compact construction.
- The 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.

▶ Cross-Sectional Drawing ◀



153CH20

▶ Simplified Drawing ◀



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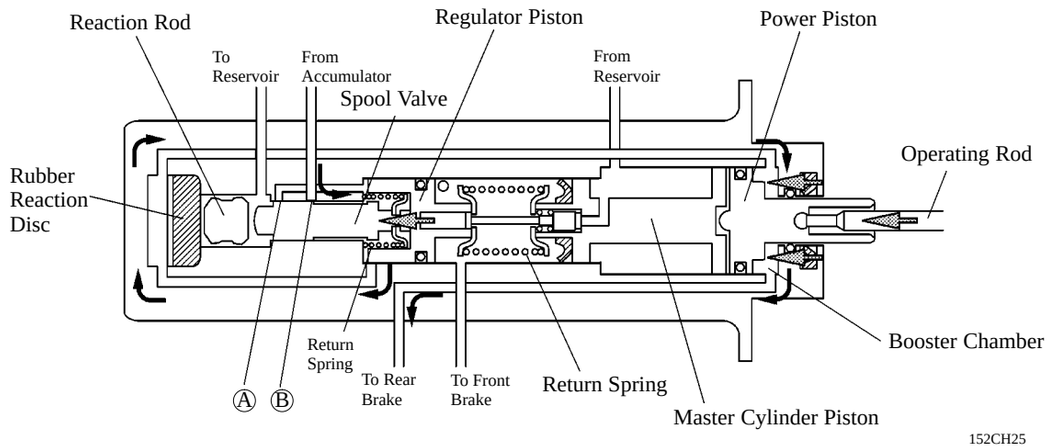
b. Operation

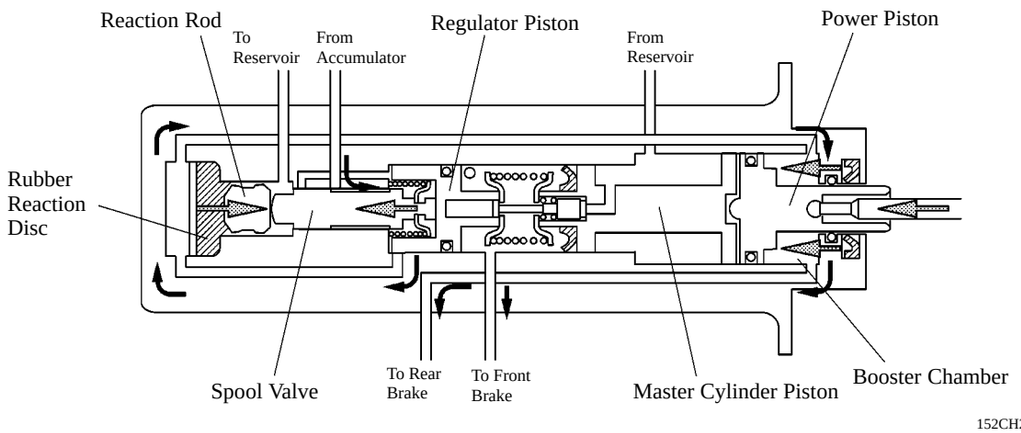
i) Pressure Increase (Low Pressure)

The pedal effort that is applied to the brake pedal is transmitted via the operating rod, power piston, and master cylinder 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)

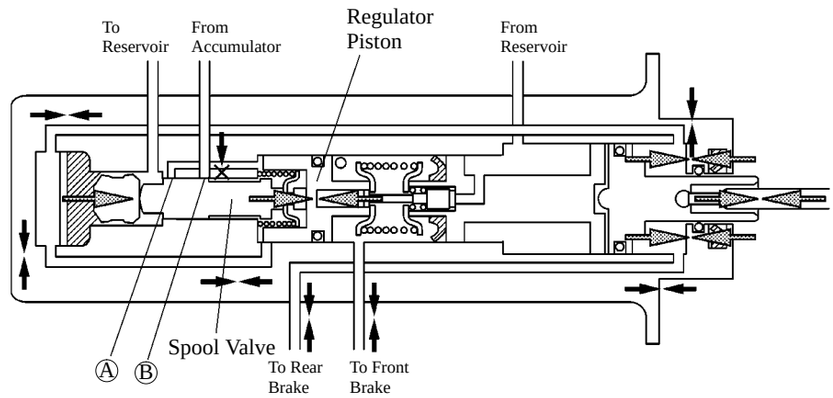
In contrast to the time when the pressure is low, when the pressure is high, the booster pressure that is applied to the rubber reaction disc increases. Accordingly, the rubber reaction disc deforms and causes a return force in the rightward direction to be applied to the spool valve via the reaction 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.

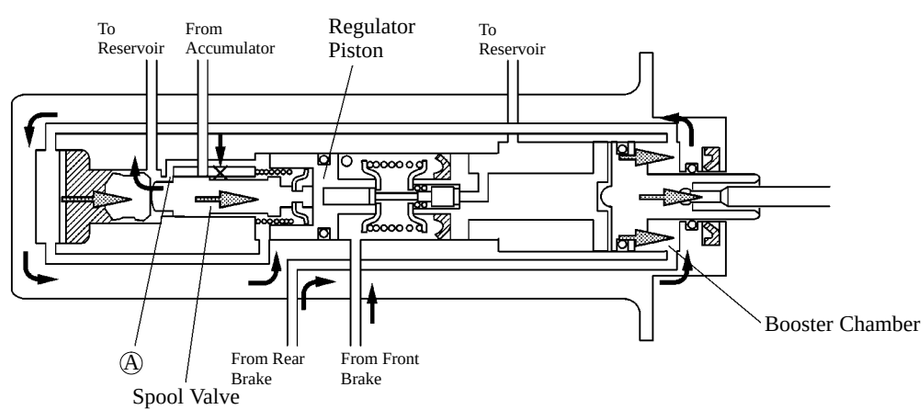


152CH27

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.

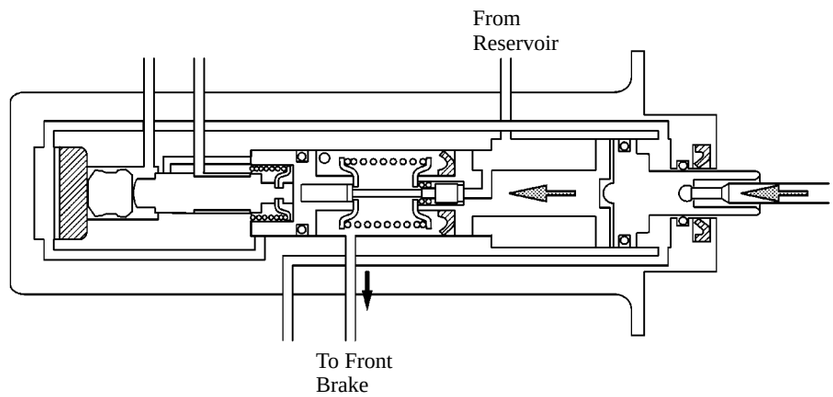
The booster pressure becomes reduced in this state, creating a balance that corresponds to the force that is newly applied via the brake pedal. This process is performed repetitively to reduce the booster pressure and the master cylinder pressure in accordance with the force that is applied via the brake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



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Brake System Operation

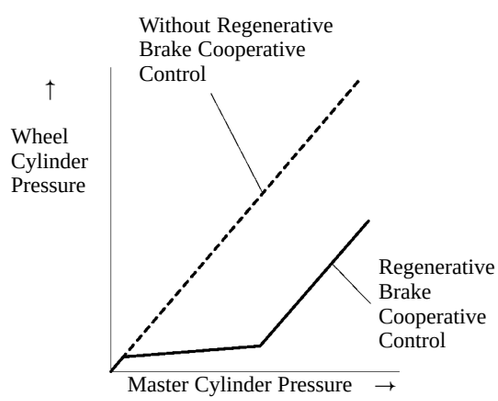
1) Regenerative Brake Cooperative Control

a. General

The regenerative brake cooperative control uses the proportioning valve and the relief valve to regulate the hydraulic pressure that is supplied to the wheel cylinders. It also operates cooperatively with the regenerative braking force that is generated in the traction motor in accordance with the master cylinder pressure.
In addition, functions are provided to switch the front relief pressure and to introduce the hydraulic pressure that is generated in the brake booster via the pressure booster piston to the front wheel cylinders. Thus, a stable braking force is ensured regardless of whether the regenerative braking force during braking is insufficient or reduced.

b. Basic Operation

Regenerative brake cooperative control is executed when the vehicle is driven with the shift lever in position “D” or “B”.
The master cylinder pressure that is generated when the driver presses on the brake pedal is detected by the master cylinder pressure sensor. According to that pressure, the EV ECU outputs a command to the inverter to cause the traction motor to generate a regenerative braking force.
Under the command of the EV ECU, ECU turns ON (closes) the regenerative brake cooperative switching solenoid valve, and operates the proportioning valve to limit the hydraulic pressure that is introduced to the front and rear wheel cylinders.
At this time, the fluid from the master cylinder is consumed by the stroke simulator, thus preventing the brake pedal from becoming stiff, even when the flow of the hydraulic pressure to the wheel cylinders is being limited. Thus, the brake pedal can achieve a proper stroke.
A regenerative braking force is generated up to the maximum of about 1.96 m/s² (0.2G) in deceleration rate. The remaining braking force is secured by introducing hydraulic pressure from the front and rear relief valves to the respective wheel cylinders.
When a regenerative braking force is not generated, such as during a malfunction of the regenerative brake cooperative control system or the drive system, or when the shift lever is in a position other than “D” or “B”, the regenerative brake cooperative switching solenoid valve is turned OFF (open). As a result, the hydraulic circuits of the master cylinder and the wheel cylinders are joined so that the brakes operate only under the hydraulic braking force.



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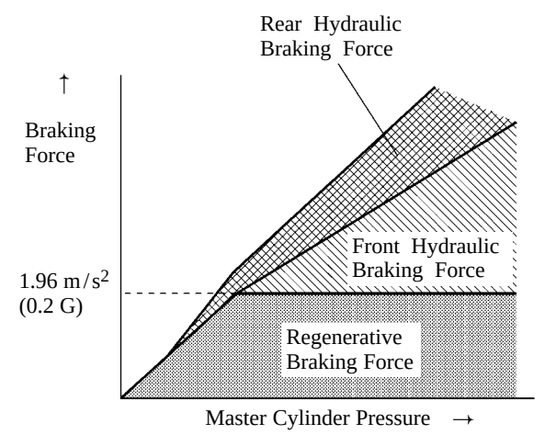
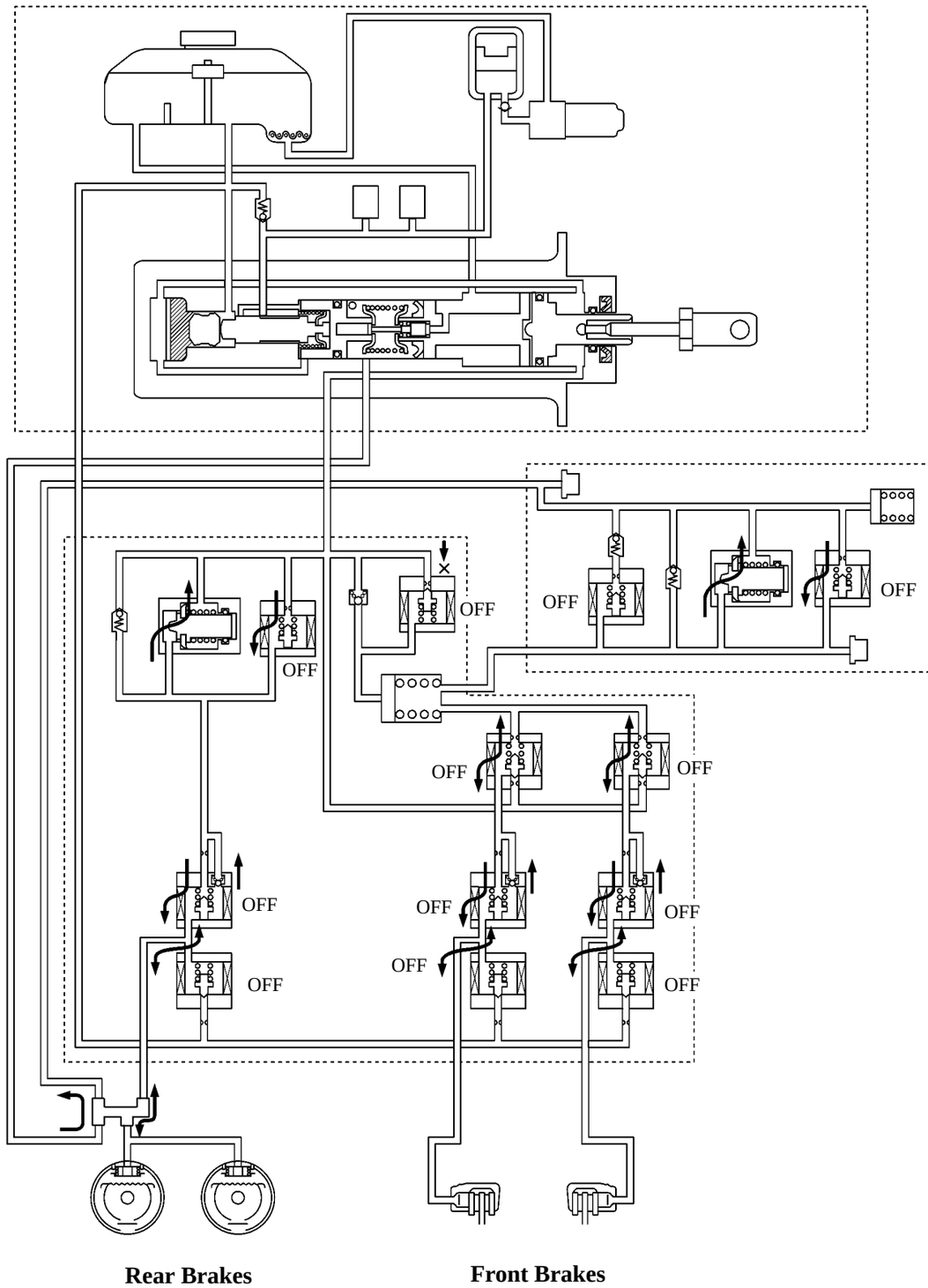


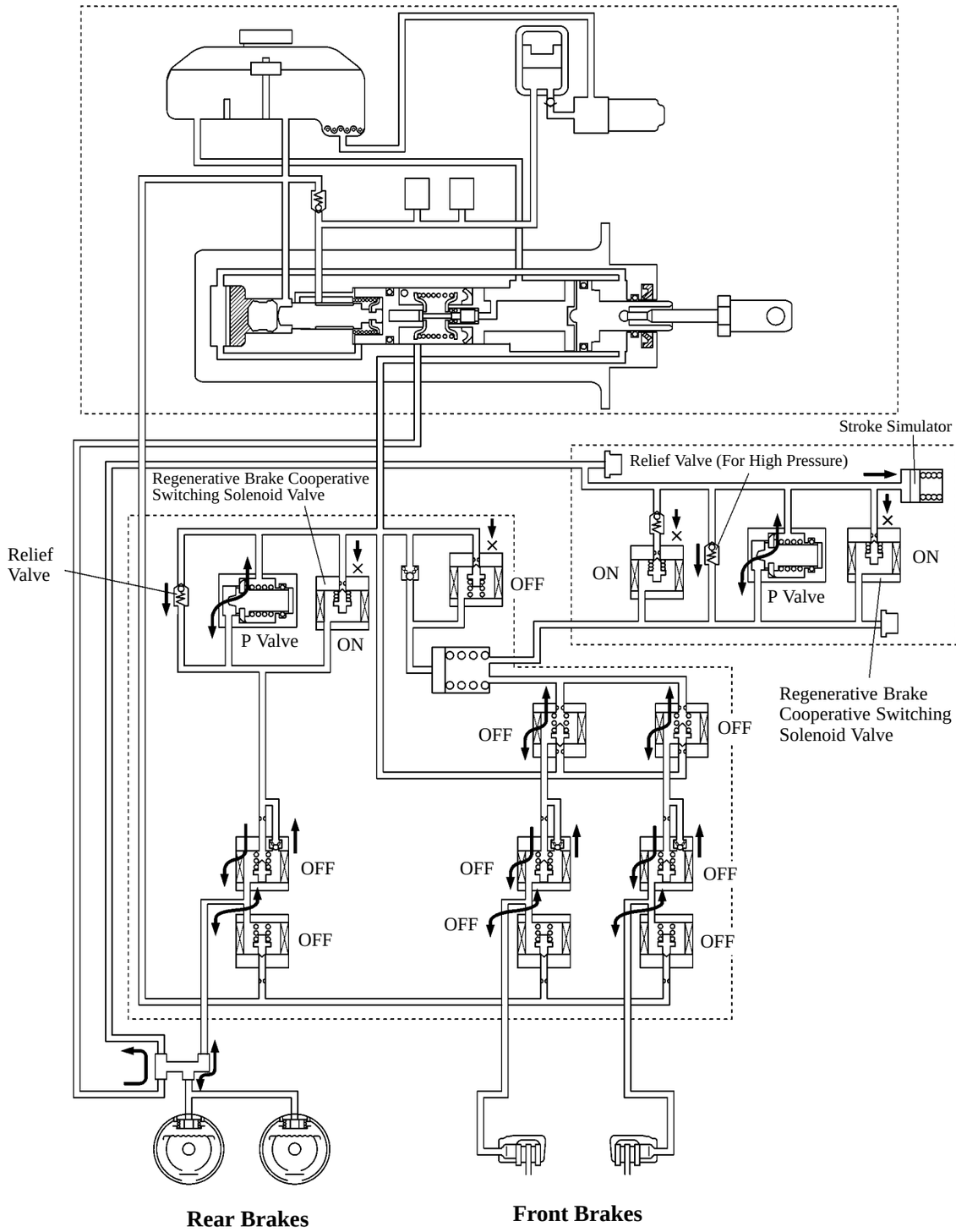
153CH16

i) Without Regenerative Brake Cooperative Control (Hydraulic Brake Only)



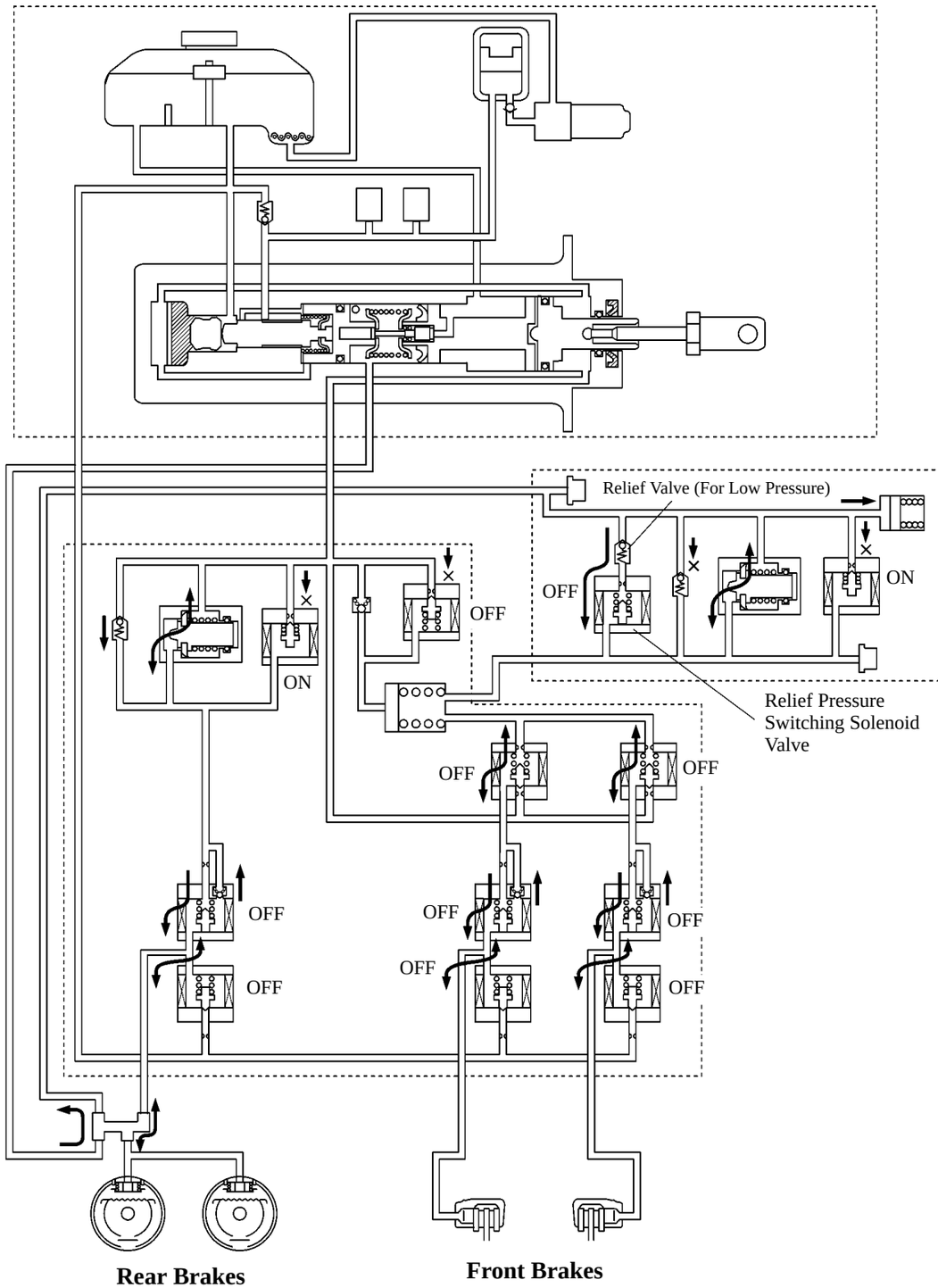
153CH11

ii) Regenerative Brake Cooperative Control (High Pressure Relief)



153CH12

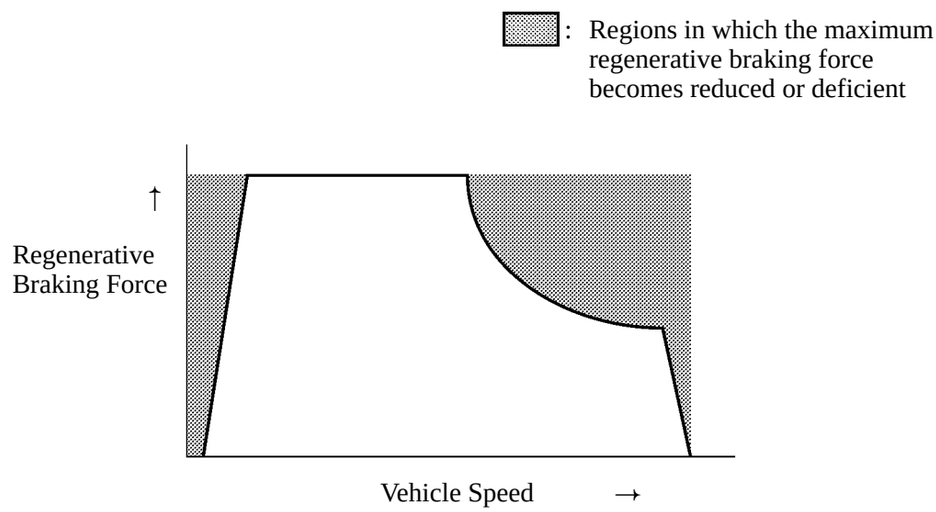
iii) Regenerative Brake Cooperative Control (Low Pressure Relief)



153CH13

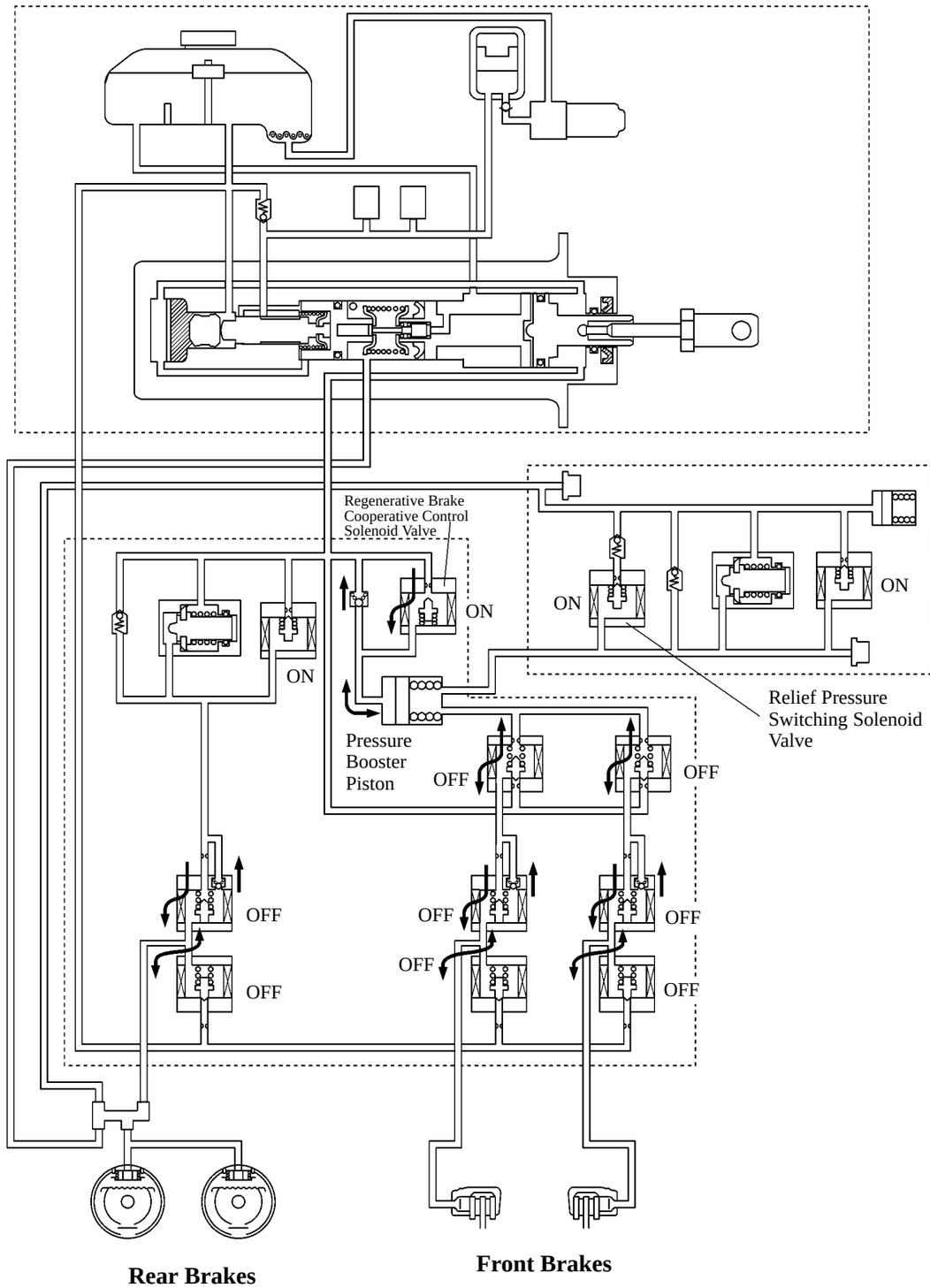
c. Addressing the fluctuation of the maximum regenerative braking force

The maximum regenerative braking force that is generated by the traction motor is not constant; it fluctuates with the vehicle speed and the state of the traction batteries.
If the regenerative braking force is reduced during braking, the EV ECU commands to turn ON (open) the regenerative brake cooperative control solenoid valve.
Accordingly, the hydraulic pressure that is generated in the brake booster is introduced (only in the amount that corresponds to the reduction of the regenerative braking force) from the rear brake hydraulic circuit via the pressure booster piston to the front brakes. As a result, a reduction in the overall braking force is prevented.
The front brake hydraulic circuit and the rear brake hydraulic circuit are separated by the pressure booster piston. Thus, the hydraulic circuits are designed so that in the event that one of the circuits fails, the other circuit remains in an operating state.
Furthermore, if it is predetermined before applying the brakes that the regenerative braking force would be insufficient (during high-speed operation), the EV ECU commands to turn OFF (open) the relief pressure switching solenoid valve to reduce the front relief pressure. By advancing the application of the front hydraulic braking force in this manner, the braking force is prevented from becoming deficient.



153CH17

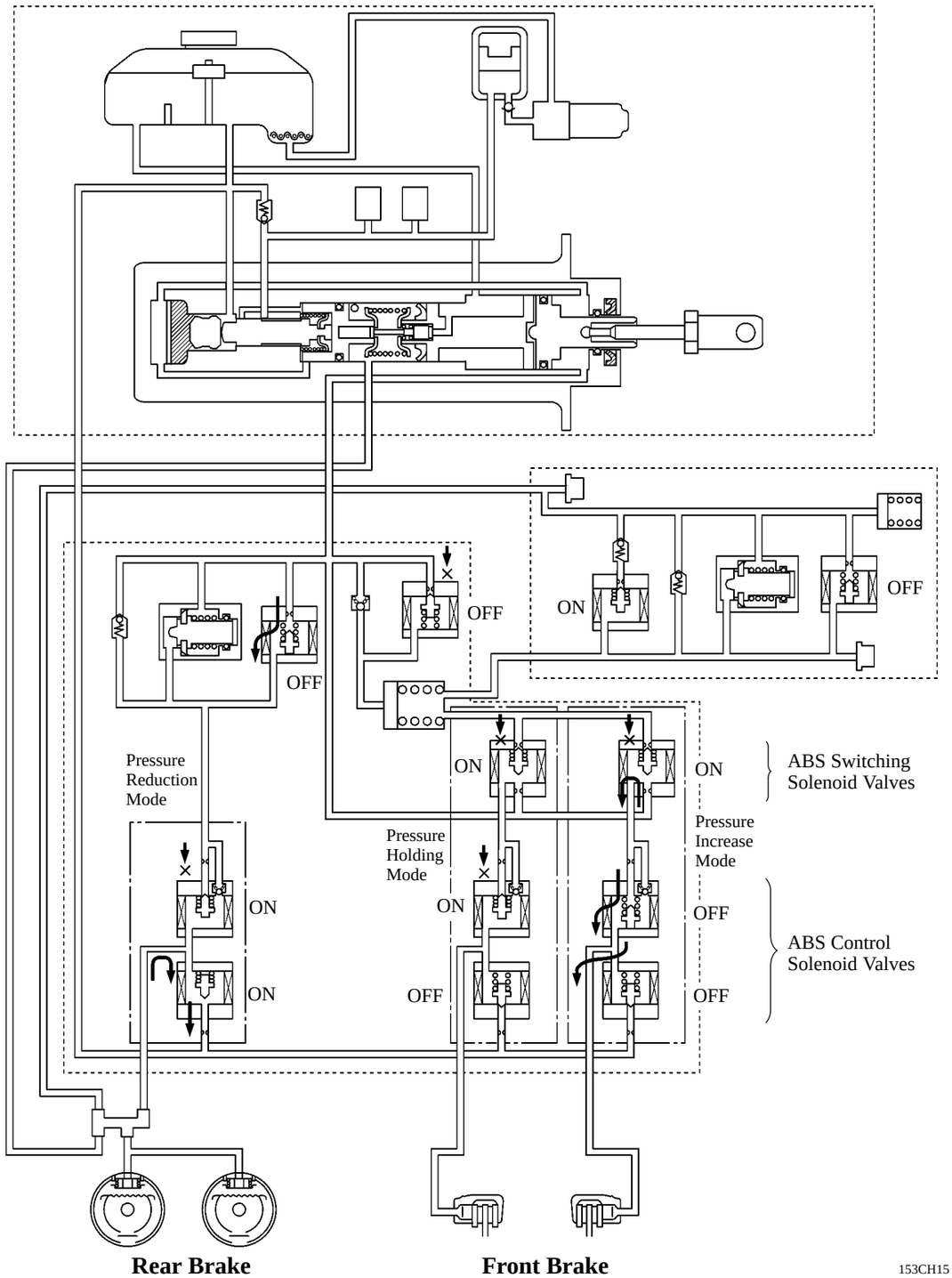
- **High Relief Pressure**



153CH14

2) ABS Control

ABS control is performed through the use of the hyraulic pressure that is generated in the brake booster, by operating the ABS switching solenoid valves and the ABS control solenoid valves to switch the hydraulic paths.
At this time, the hydraulic path between the master cylinder and wheel cylinder is shut off to prevent the brake pedal from vibrating and to improve the feeling during brake application.



ABS & Hydraulic Brake Booster ECU

1) Initial Check

After the motor switch is turned on, the ABS & hydraulic brake booster ECU performs an initial check. The function of each solenoid valve in the actuator is checked in order.

2) Self-Diagnosis

If the ABS & hydraulic brake booster ECU detects a malfunction in the brake system, the ABS warning light and brake warning light will light up and alert the driver that a malfunction has occured. The ECU will also store the codes of malfunctions. See the 2002 RAV4 EV Repair Manual (Pub. No. RM892U) for the diagnostic code check method, diagnostic code and diagnostic code clearance.

3) Speed Sensor Check Function

The ABS & hydraulic brake booster ECU has a speed sensor check function. The output voltage level and output voltage fluctuation of the speed sensor can thus be checked. The results of each check are indicated by the ABS warning light blinking the appropriate code. For the check procedure and diagnostic code of speed sensor check function, see the 2002 RAV4 EV Repair Manual (Pub. No. RM892U).

NOTE: The ABS does not function when the ECU is in the speed sensor check function.

4) ABS Warning Light Check Function

The ABS warning light turns on for about 3 seconds after the motor switch is turned on to check the circuit.

5) Fail-Safe

If the ABS & hydraulic brake booster ECU detects a malfunction in the brake system, the ECU cuts off its current to the actuators. As a result, the brake system operates in the same way as in a vehicle without ABS.

■TIRE PRESSURE WARNING SYSTEM

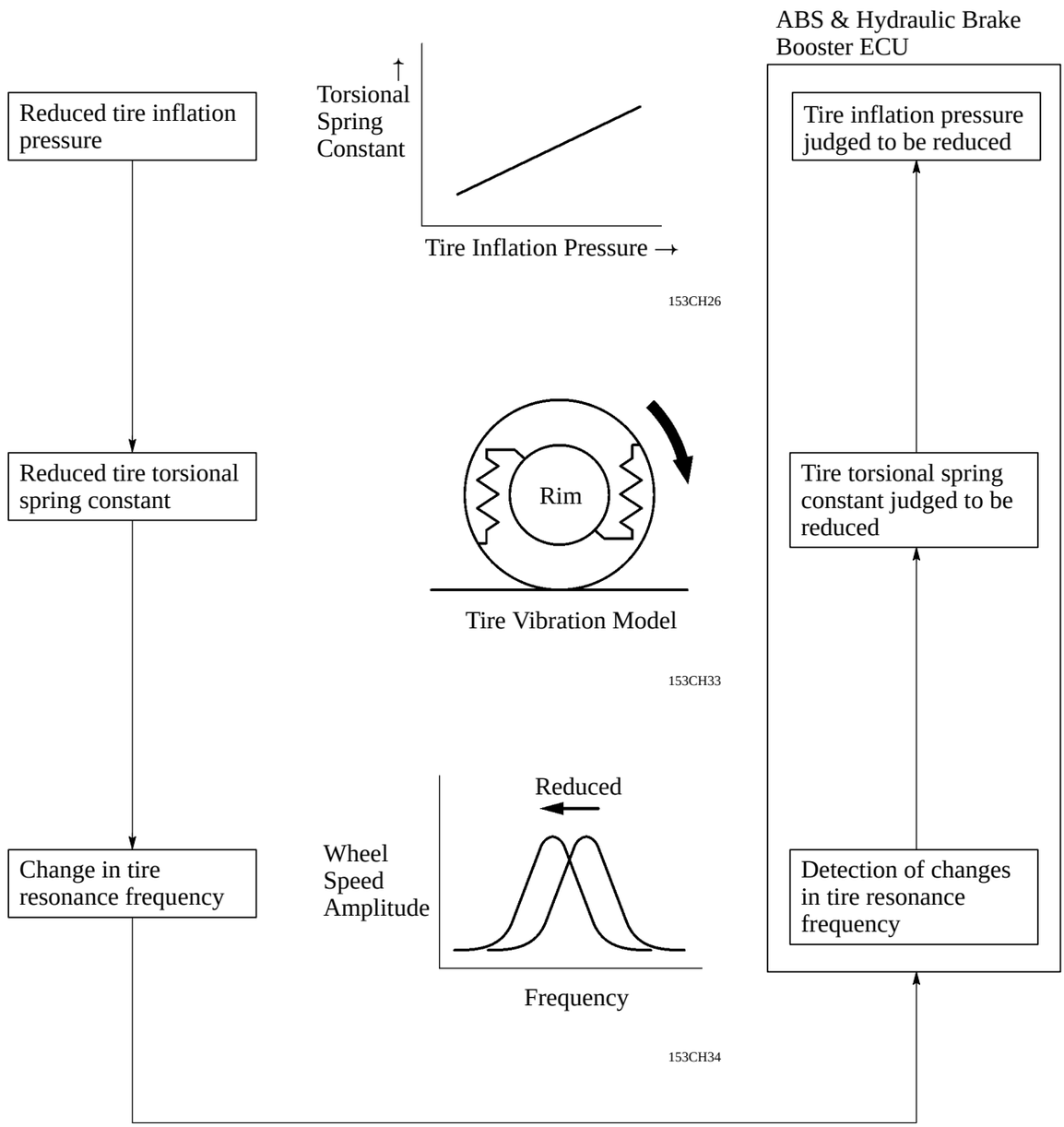
1. General

- This system does not use a pressure sensor to detect a reduction in the tire inflation pressure. Instead, it uses the fluctuation of the ABS wheel speed signal that varies with the ground surface input while the vehicle is being driven, from which the torsional spring constant is estimated. The reduction in the spring constant is then rendered as the reduction in the tires' inflation pressure.
- If the vehicle is driven with a low tire pressure that could impede driving, this system illuminates the tire pressure warning light in the combination meter to alert the driver of the reduction in the tire inflation pressure.
- This system is provided merely as a means of helping the driver to inspect the tire pressure, which is one of the do-it-yourself maintenance items.
- This system can reduce the effects of reduced tire inflation pressure as described below.
  - Poor electrical power consumption rate due to the increase in rolling resistance.
  - Abnormal wear of the tires due to an uneven distribution of tire-to-ground contact.
  - Poor stability and controllability due to the reduction in tire performance.
  - Possibility of the tire becoming separated from its rim due to the reduction in the bead securing force.
  - Possibility of damaging the tire due to the reduction in tire rigidity.

NOTES:
- This system cannot detect the tire pressure when the vehicle is stationary because the tire pressure detection is based on the rotating condition of the tires when the vehicle is in motion.
- If the warning light turns ON, the tire pressure must be checked and adjusted.
- This system may not operate properly under the conditions given below.
  - The tires of a size that is not specified are used, or different sizes and types of tires are combined.
  - The extent of the wear of one tire is considerably different from that of other tires.
  - A temporary use of spare tire, snow tire, or tire chain.
  - The tires are inflated excessively higher than the specified air pressure or the tire pressure drops suddenly due to a flat tire that is caused during driving.
  - The vehicle is driven on an extremely rough surface or on a slippery surface such as an icy road.

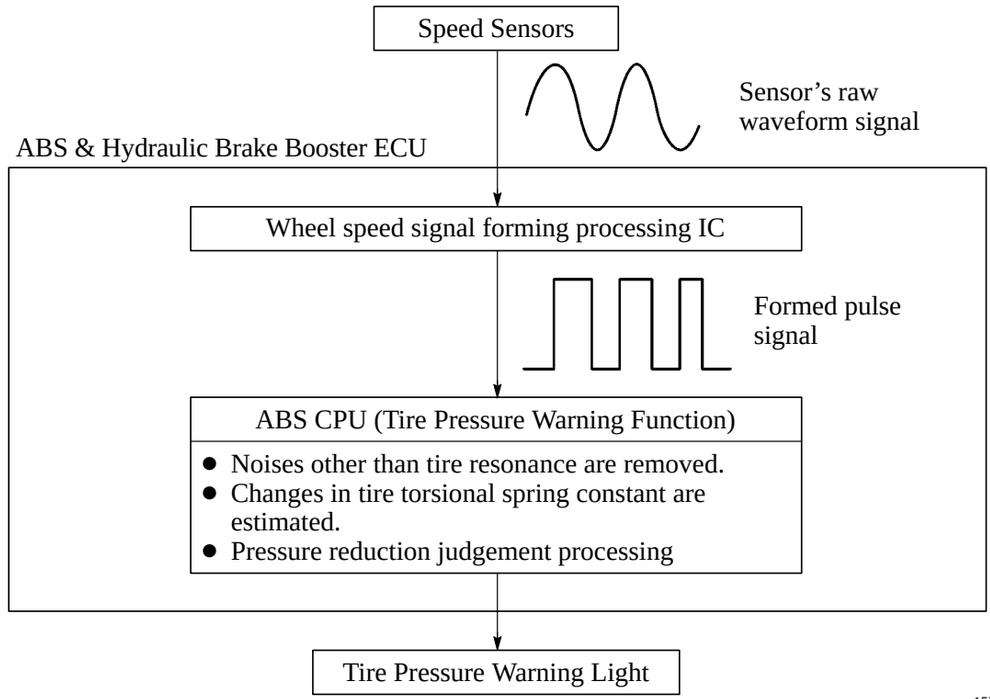
2. Operation Principle

The tire's torsional spring constant changes due to the change in tire inflation pressure.
Based on the wheel speed signal that is detected while the vehicle is in motion, the changes in the tire's resonance frequency are estimated as the changes in the spring constant, thus detecting as the changes in the tire inflation pressure.



3. Detection Method

Based on the signals from the speed sensors, as described below, the under-inflated condition is detected by the CPU of the tire pressure warning system located inside the ABS & hydraulic brake booster ECU, and is output to the warning light.



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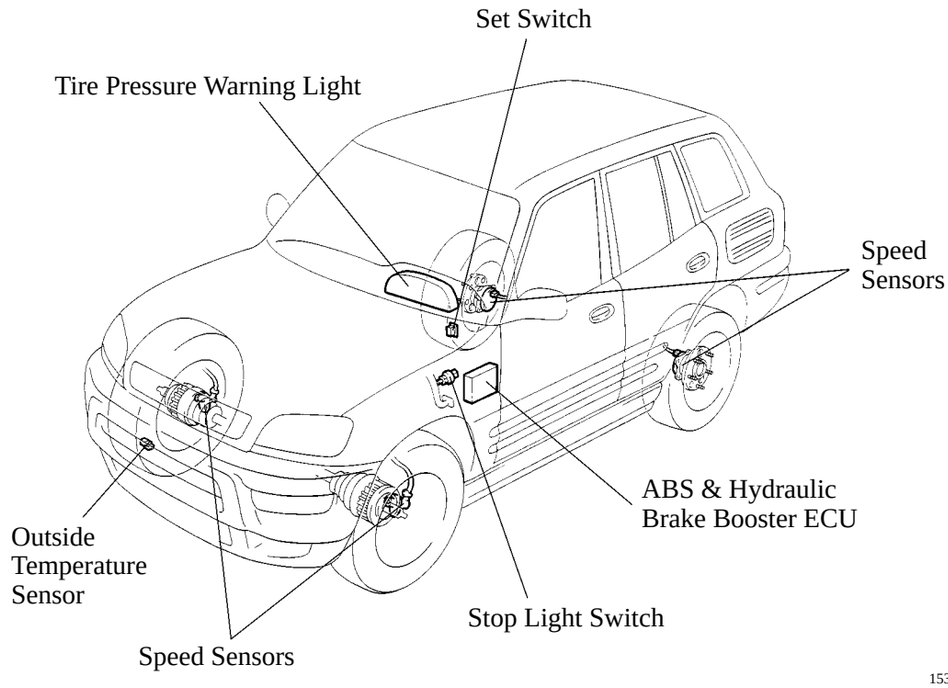
4. Layout of Components



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5. Function of Components

Components	Function
ABS & Hydraulic Brake Booster ECU	Based on the wheel speed signals and etc., it detects the tire inflation pressure and sends signal to the tire pressure warning light.
Speed Sensors	Detect the wheel speed of each wheel.
Tire Pressure Warning Light	Lights up to alert the driver when the ECU detects the tire inflation pressure and the malfunction in the tire pressure warning system.
Outside Temperature Sensor	Detects temperature data for correcting the estimated value of the tire inflation pressure.
Stop Light Switch	Sends a signal to the ECU to prohibit the estimation of the tire inflation pressure during braking.
Set Switch	Used for inspecting the tire pressure warning system.