

2. Brake Control System (ABS with EBD, Brake Assist, TRC and VSC)

General

- This model uses the CAN (Controller Area Network) communication system for communication between the skid control ECU, steering angle sensor and yaw rate & deceleration sensor.
- The “skid control ECU and brake actuator”, and the “yaw rate sensor and deceleration sensor”, are integrated units, respectively.
- A trochoid gear type pump has been adopted for the pump in the brake actuator.
- A pressure regulator valve has been adopted to regulate the pressure of the fluid that is supplied to the pump.

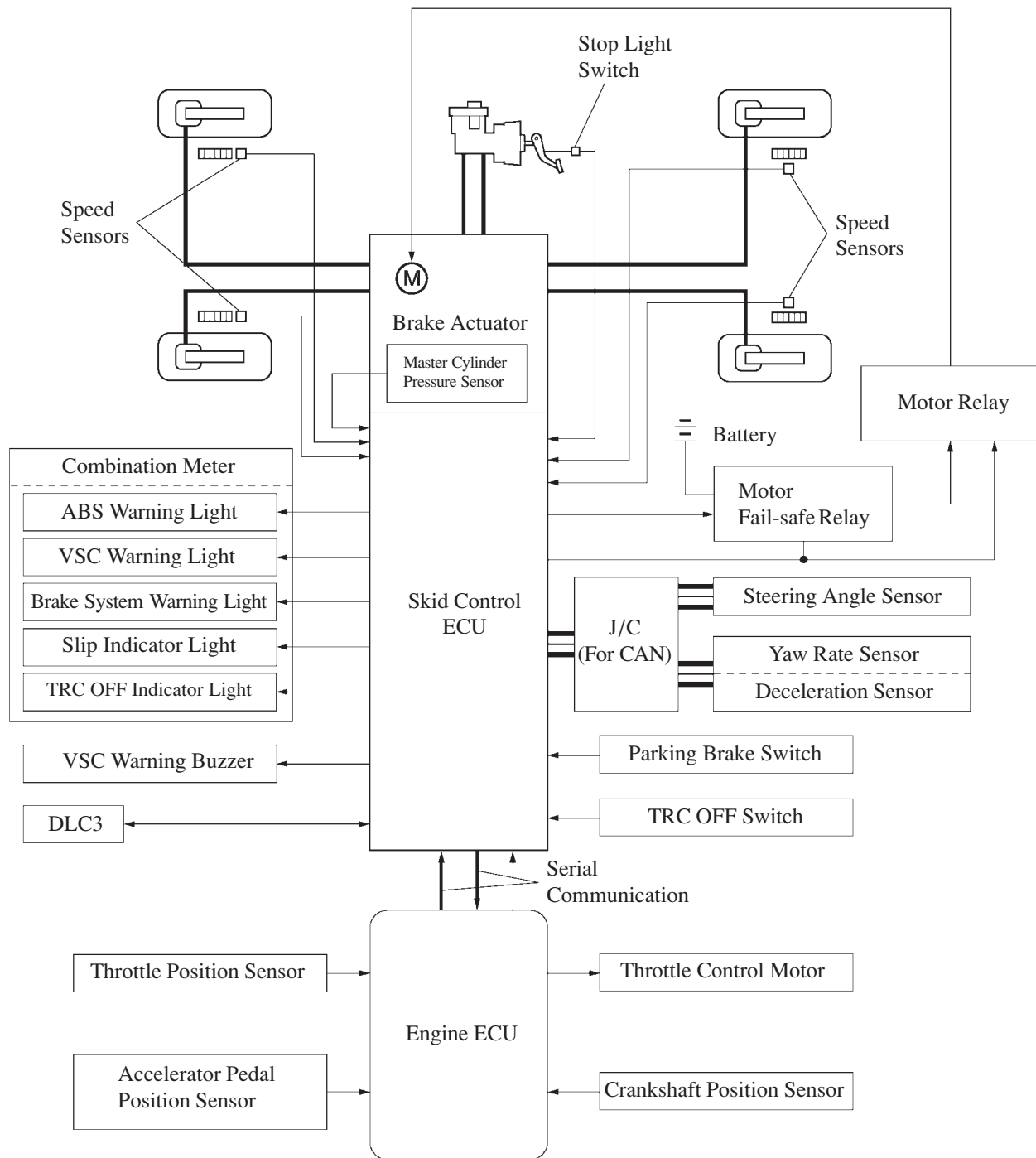
The brake control system (ABS with EBD, brake assist, TRC and VSC) has a following function:

Function	Outline
ABS (Anti-lock Brake System)	The ABS helps prevent the wheels from locking when the brakes are applied firmly or when braking on a slippery surface.
EBD (Electronic Brake force Distribution)	The EBD control utilizes ABS, realizing the proper brake force distribution between front and rear wheels in accordance with the driving conditions. In addition, during cornering braking, it also controls the brake forces of right and left wheels, helping to maintain the vehicle behavior.
Brake Assist	If the skid control ECU determines that the driver intends the emergency braking, the system activates the brake actuator to increase the brake fluid pressure, which increases the braking force.
TRC (Traction Control)	The TRC system helps prevent the drive wheels from slipping if the driver presses the accelerator pedal excessively when starting off or accelerating on a slippery surface.
VSC (Vehicle Stability Control)	The VSC system helps prevent the vehicle from slipping sideways as a result of strong front wheel skid or strong rear wheel skid during cornering.

Service Tip

When brake control system (ABS with EBD) is activated, the brake pedal could shudder, which is a normal occurrence of the system in operation and should not be considered a malfunction.

► System Diagram ◀



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: CAN (Controller Area Network)

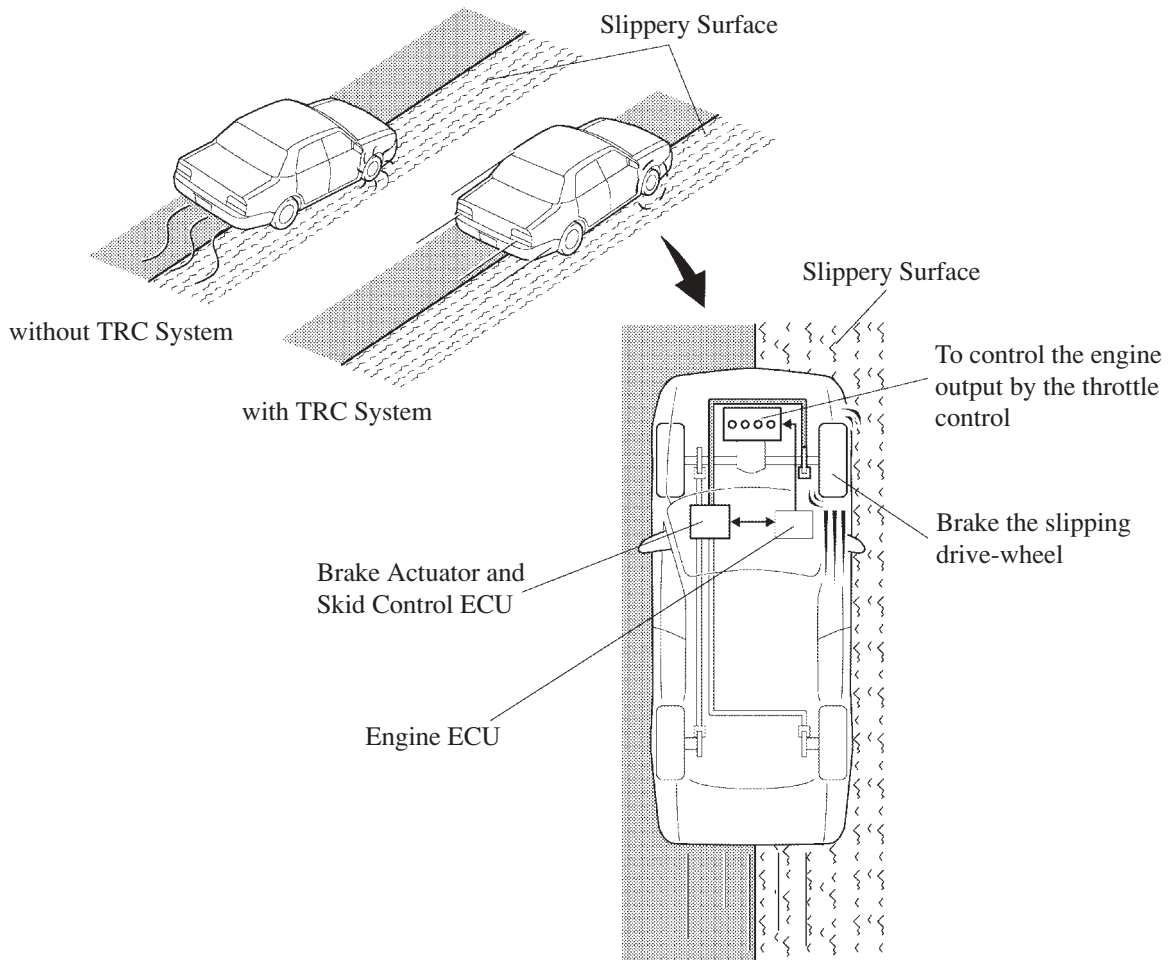
Outline of TRC System

- If the driver presses the accelerator pedal aggressively when starting off or accelerating on a slippery surface, the drive wheel could slip due to the excessive amount of torque that is generated. By applying hydraulic brake control to the drive wheels and regulating the throttle to control the engine output, the TRC system helps minimize the slippage of the drive wheels, thus generating the drive force that is appropriate for the road surface conditions.
- For example, a comparison may be made between two vehicles, one with the TRC system and the other without. If the driver of each vehicle operates the accelerator pedal in a rough manner while driving over a surface with different surface friction characteristics, the drive wheel on the slippery surface could slip as illustrated. As a result, the vehicle cannot start smoothly.

However, when the vehicle is equipped with the TRC system, the skid control ECU instantly determines the state of the vehicle and operates the brake actuator in order to apply the brake of the slipping drive wheel. Furthermore, the engine ECU receives the signals from the skid control ECU and regulates the throttle in order to control the engine output. Thus, the system can help maintain a stable driving force.

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► Driving Condition on Road with Different Surface Friction Characteristics ◀



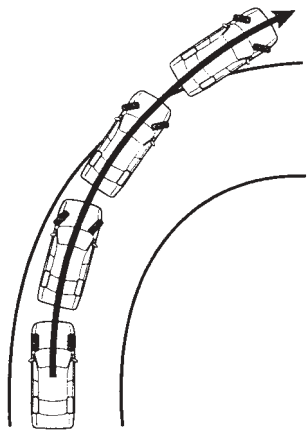
Outline of VSC System

1) General

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

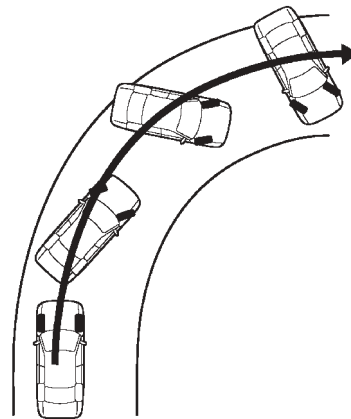
The VSC system is designed to help control the vehicle behavior by controlling the engine output and the brakes at each wheel when the vehicle is under one of the conditions indicated below.

- When the front wheels lose grip in relation to the rear wheels (front wheel skid tendency).
- When the rear wheels lose grip in relation to the front wheels (rear wheel skid tendency).



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Front Wheel Skid Tendency



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Rear Wheel Skid Tendency

2) Method for Determining the Vehicle Condition

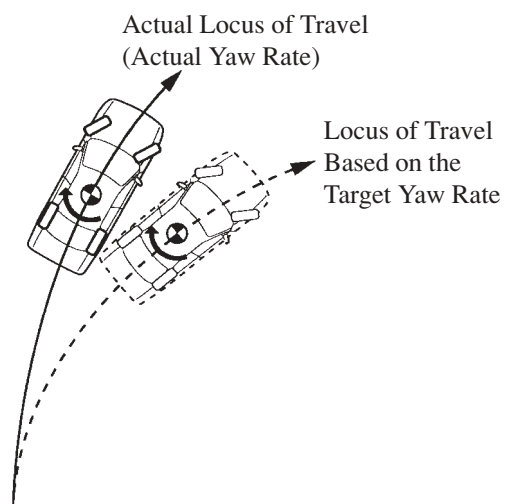
To determine the condition of the vehicle, sensors detect the steering angle, vehicle speed, vehicle's yaw rate, and the vehicle's lateral acceleration, which are then calculated by the skid control ECU.

Determining Front Wheel Skid

Whether or not the vehicle is in the state of front wheel skid is determined by the difference between the target yaw rate and the vehicle's actual yaw rate.

When 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 the vehicle is making a turn at a greater angle than the locus of travel.

Thus, the skid control ECU determines that there is a large tendency to front wheel skid.

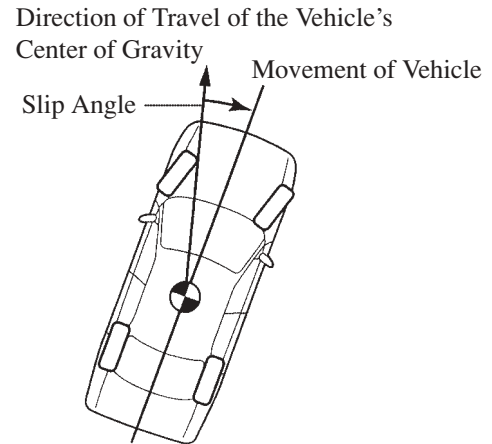


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Determining Rear Wheel Skid

Whether or not the vehicle is in the state of rear wheel skid 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 skid control ECU determines that the vehicle has a large rear wheel skid tendency.



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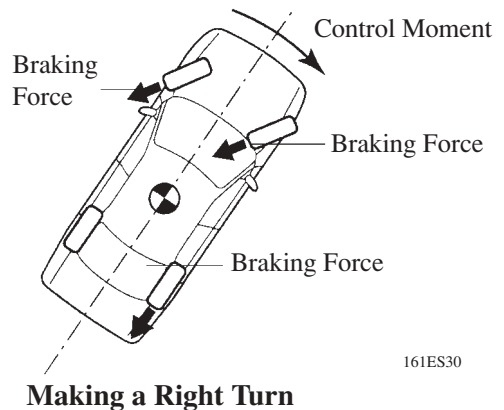
3) Method for VSC Operation

When the skid control ECU determines that the vehicle exhibits a tendency to front wheel skid or rear wheel skid, it decreases the engine output and applies the brake of a front or rear wheel to control the vehicle's yaw moment.

The basic operation of the VSC is described below. However, the control method differs depending on the vehicle's characteristics and driving conditions.

Dampening a Strong Front Wheel Skid

When the skid control ECU determines that there is a large front wheel skid tendency, it counteracts in accordance with the extent of that tendency. The skid control ECU controls the engine power output and applies the brakes of the front wheels and rear wheel of the inner circle of the turn in order to help restrain the front wheel skid tendency.



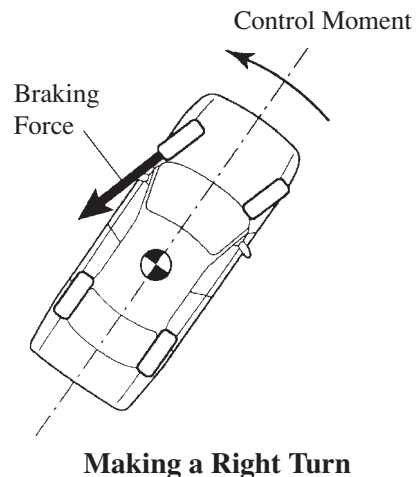
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Making a Right Turn

Dampening a Strong Rear Wheel Skid

When the skid control ECU determines that there is a large rear wheel skid tendency, it counteracts in accordance with the extent of that tendency. It applies the brakes of the front wheel of the outer circle of the turn, and generates an outward moment of inertia in the vehicle, in order to help restrain the rear wheel skid tendency. Along with the reduction in the vehicle speed caused by the braking force, which helps dampen a strong rear wheel skid tendency.

In some cases, the skid control ECU applies the brake of the rear wheels, as necessary.



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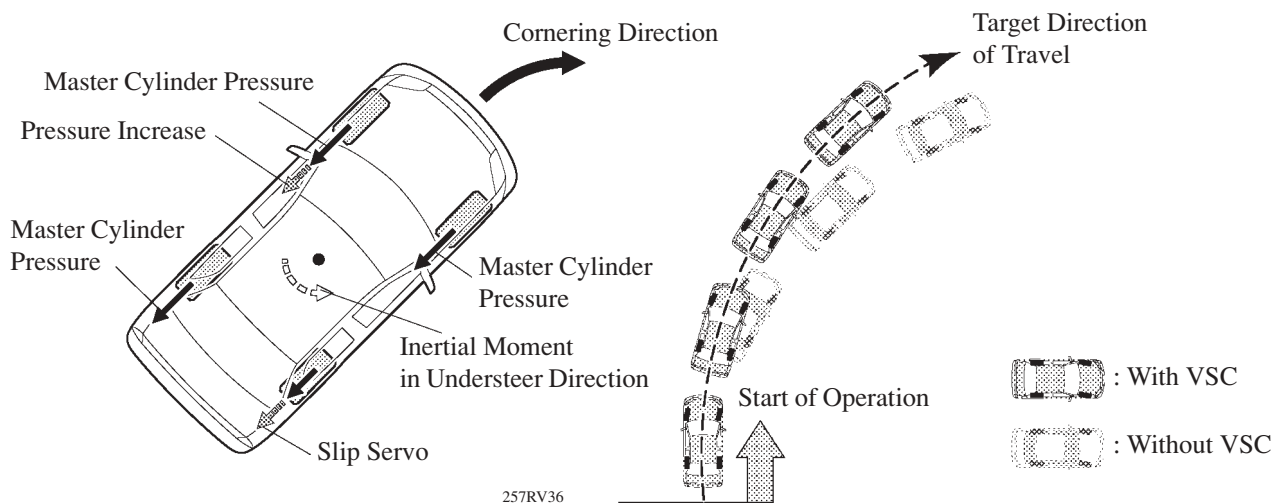
Making a Right Turn

Braking Control Under the Conditions in Which the Tires Do Not Exceed the Lateral Limitations of the Vehicle

1) During Cornering Braking

The VSC system determines the cornering conditions of the vehicle in accordance with the signals provided by the yaw rate & deceleration sensor, and the speed sensor. It determines the extent of the brake pedal application by the driver in accordance with the signals provided by the master cylinder pressure sensor.

When the vehicle is braking while cornering, the brake actuator increases the brake fluid pressure to the front outer wheel of the turn, and simultaneously controls the brake fluid pressure to the inner wheel of the turn. This generates a moment of inertia that inhibits the vehicle from veering further inward of the turn. As a result, this system provides the excellent vehicle stability and braking performance.

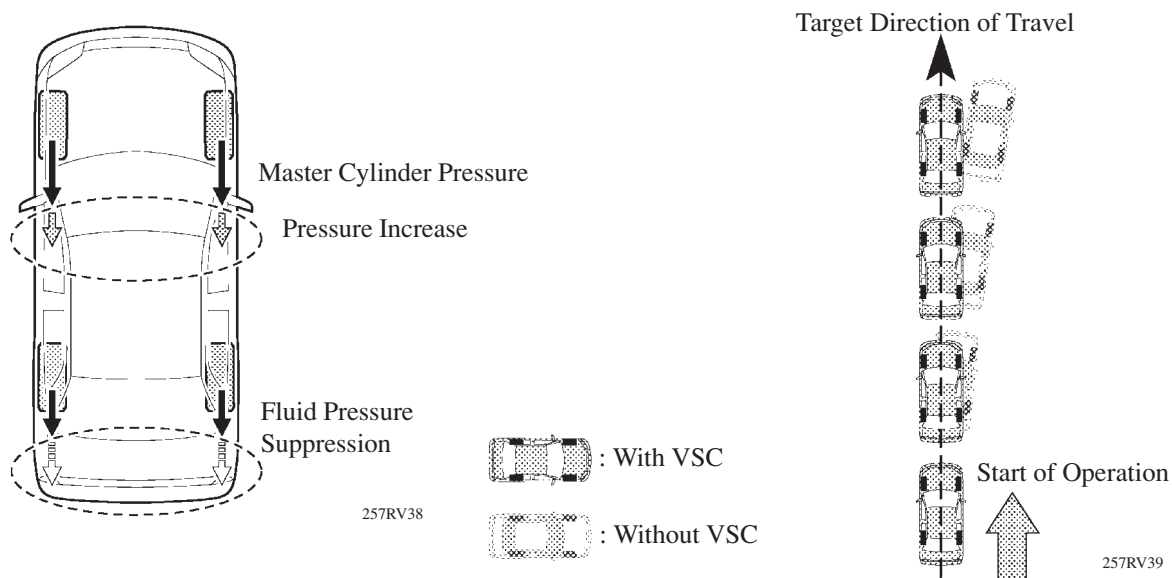


2) During High-Speed Straightline Braking

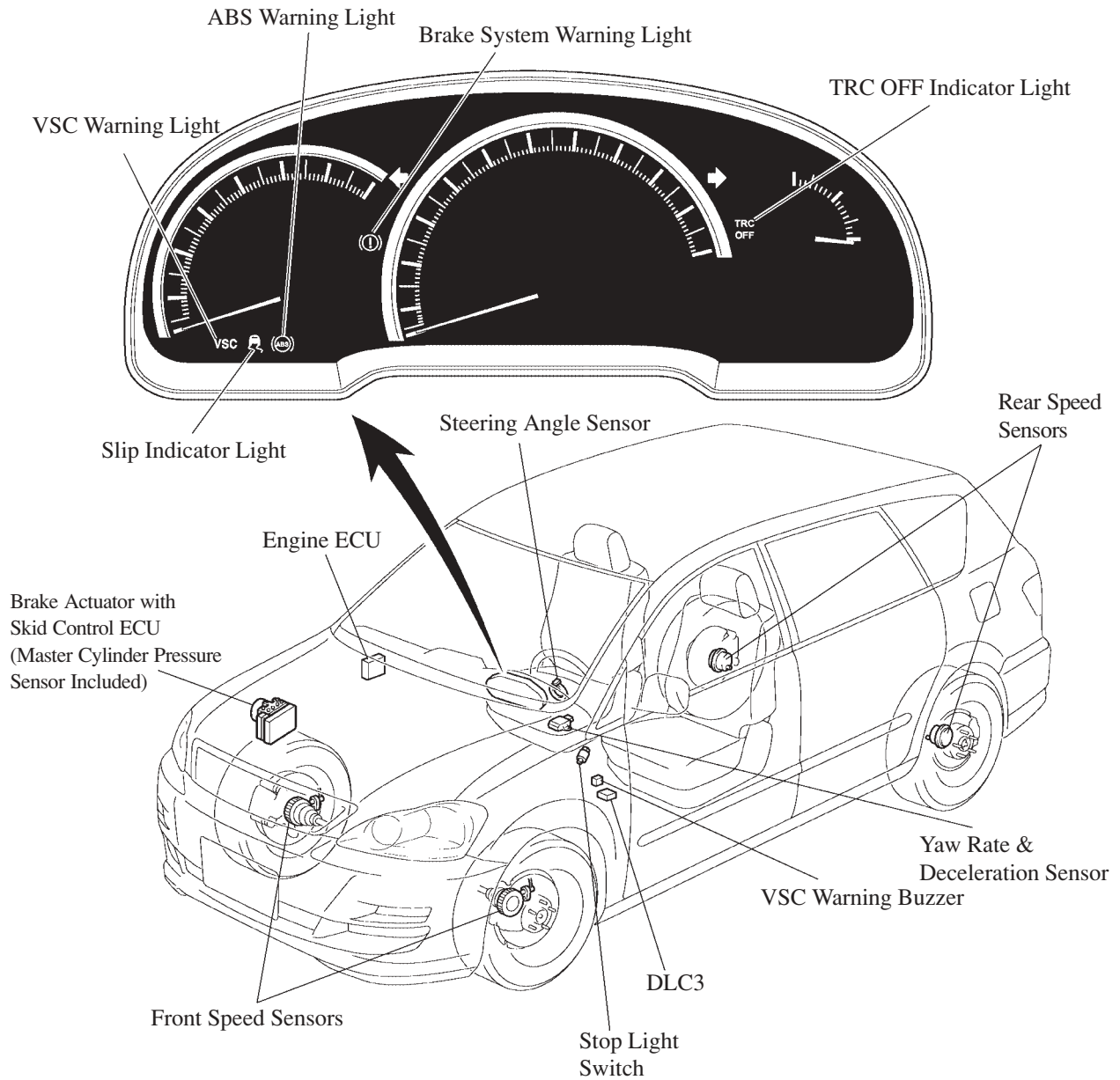
The VSC system determines the extent of the brake pedal application by the driver in accordance with the signals provided by the master cylinder pressure sensor and the high-speed driving conditions in accordance with the signals provided by the speed sensor.

When the fluid pressure in the master cylinder reaches a predetermined value while the vehicle is braking at a predetermined speed or higher, the system controls the brake fluid pressure applied to the rear wheels as a result of the driver's further application of the brake pedal. This helps suppress the slippage of the rear tires and provides the excellent stability of the vehicle.

To compensate for the reduction in the braking force due to the suppression of the fluid pressure to the rear brakes, the brake actuator increases the fluid pressure to the front wheel brakes, in order to provide the proper braking force required by the driver.



Layout of Main Components



Function of Main Components

Components		Function
Brake Actuator		Changes the fluid path based on the signals from the skid control ECU during the operation of the ABS with EBD & Brake Assist & TRC & VSC system, in order to control the fluid pressure that is applied to the wheel cylinders.
	Skid Control ECU	Judges the vehicle driving condition based on signals from each sensor, and sends brake control signals to the brake actuator.
	Master Cylinder Pressure sensor	Assembled in the brake actuator and detects the master cylinder pressure.
Combination Meter	Brake System Warning Light	<ul style="list-style-type: none"> ● Lights up to alert the driver when a malfunction occurs in the brake system. ● Lights up to alert the driver when the skid control ECU detects a malfunction in the EBD control. ● Light up to inform the driver when the parking brake pedal depressed. ● Light up to alert the driver when the brake fluid level decreased.
	ABS Warning Light	Lights up to alert the driver when the skid control ECU detects a malfunction in the ABS, EBD, or Brake Assist system.
	VSC Warning Light	Lights up to alert the driver when the skid control ECU detects a malfunction in the TRC and VSC.
	TRC OFF Indicator Light	<ul style="list-style-type: none"> ● Lights up to inform the driver when the TRC system is turned OFF by the TRC OFF switch. ● Lights up to alert the driver when the skid control ECU detects a malfunction in the TRC or VSC.
	Slip Indicator Light	Blinks to inform the driver when the TRC and VSC is operated.
Speed Sensor (FL, FR, RL, RR)		Detects the wheel speed of each wheels.
Steering Angle Sensor		Detects the steering direction and angle of the steering wheel.
Yaw Rate & Deceleration Sensor		<ul style="list-style-type: none"> ● Detects the vehicle's yaw rate. ● Detects the vehicle's longitudinal and lateral acceleration.
Stop Light Switch		Detects the brake pedal depressing signal.
TRC OFF Switch		Cancels the TRC operation only: it does not apply to other systems.
VSC Warning Buzzer		This buzzer sounds intermittently to inform the driver that the VSC is actives.
Engine ECU		Controls the throttle valve opening angle based on the signals receives from the skid control ECU, in order to control the engine output. Also, sends the throttle valve opening angle signal, accelerator pedal position signal, and engine speed signal to the skid control ECU.
Throttle Position Sensor		<ul style="list-style-type: none"> ● Detects the opening of the throttle valve and inputs it into the engine ECU. ● This sensor is used to control the engine output when the TRC or VSC is operated.
Accelerator Pedal Position Sensor		<ul style="list-style-type: none"> ● Detects the depressing of the accelerator pedal and inputs it into the engine ECU. ● This sensor is used to control the engine output when the TRC or VSC is operated.
Crankshaft Position Sensor		<ul style="list-style-type: none"> ● Detects the engine speed, and sends it via the engine ECU to the skid control ECU. ● This sensor is used to control the engine output when the TRC or VSC is operated.
Throttle Control Motor		Controls the opening of the throttle valve in accordance with the signals received from the engine ECU.

Construction

1) Brake Actuator

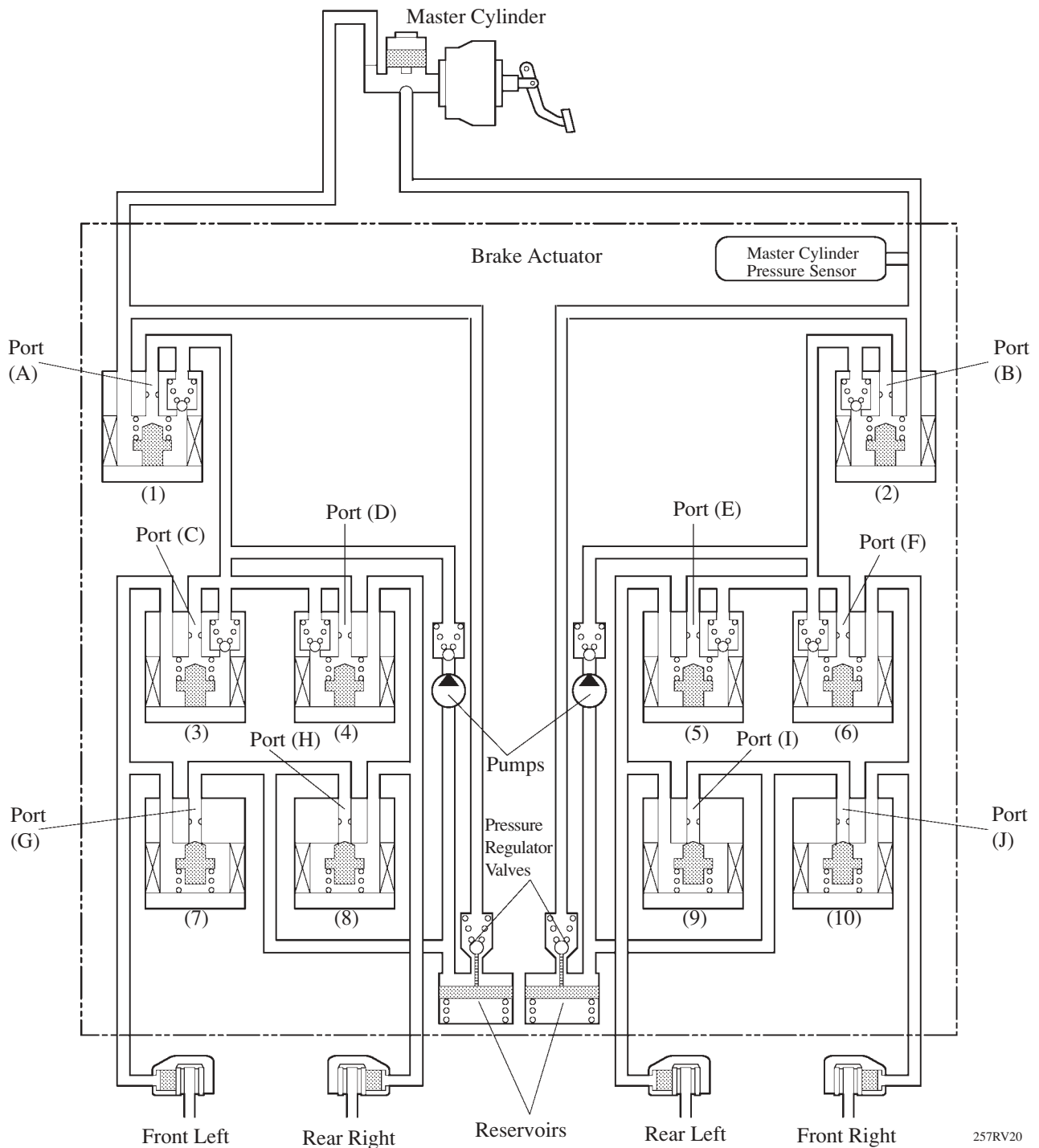
a. General

- The brake actuator consists of 10 two-position solenoid valves, 2 pressure regulator valves, 1 pump motor, 2 trochoid gear type pump, 2 reservoirs, and master cylinder pressure sensor.

The 10 two-position solenoid valves consist of the following:

- 2 master cylinder cut solenoid valves (linear type) [(1), (2)]
- 4 pressure holding solenoid valves [(3), (4), (5), (6)]
- 4 pressure reduction solenoid valves [(7), (8), (9), (10)]

► Hydraulic Circuit ◀

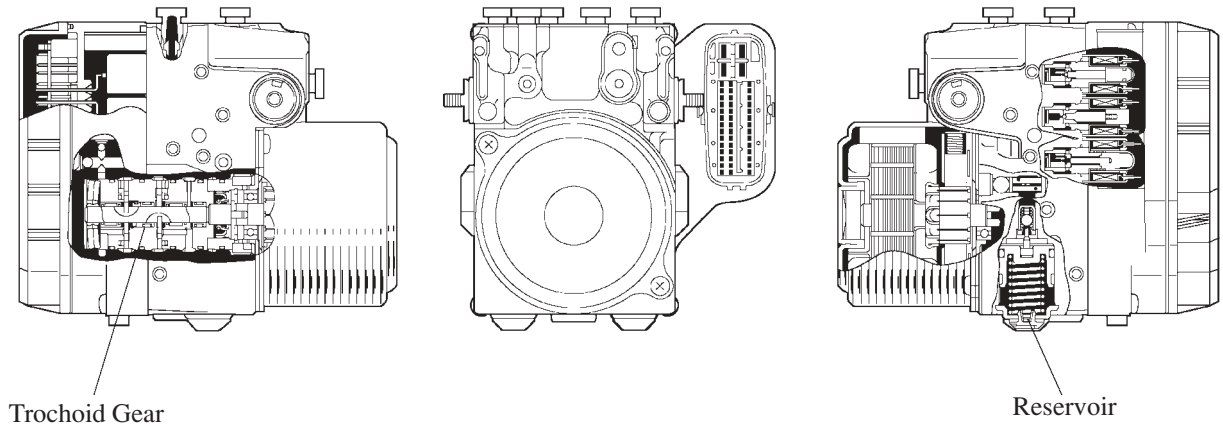


► **Function of Main Components** ◀

Component		Function
(1), (2)	Master Cylinder Cut Solenoid Valve (Linear Type)	To effect the respective brake controls of the brake assist, TRC, and VSC system, a combination of the ON/OFF conditions of the master cylinder cut solenoid valve is used to appropriately vary the fluid pressure.
(3), (4), (5), (6)	Pressure Holding Valve	Each wheel cylinder contains a pressure holding solenoid valve and a pressure reduction solenoid valve. A combination of the ON/OFF conditions of the respective valves is used in order to change the increase mode, holding mode, or the reduction mode during the operation of the ABS, TRC, and VSC system.
(7), (8), (9), (10)	Pressure Reduction Valve	
Master Cylinder Pressure Sensor		The master cylinder pressure sensor converts the brake fluid pressure that the master cylinder applies to the brake actuator into an electrical signal and sends it to the skid control ECU. The skid control ECU can thus monitor the brake fluid pressure that is applied to the brake actuator in accordance with this signal.
Reservoir		While effecting the reduction mode during the operation of the ABS, TRC, and VSC system, the reservoir stores the brake fluid that has returned from the wheel cylinders. It also functions as an accumulator.
Pump		Pumps the brake fluid that is stored in the reservoir and returns it to the master cylinder. While effecting the increase mode during the operating of the brake assist, TRC and VSC system, the pump operates in order to apply brake fluid pressure to the wheel cylinders.
Pressure Regulator Valve		Regulates the pressure of the fluid supplied to the pump, and closes the pressure passage between the master cylinder and the pump when the brake pedal is depressed.

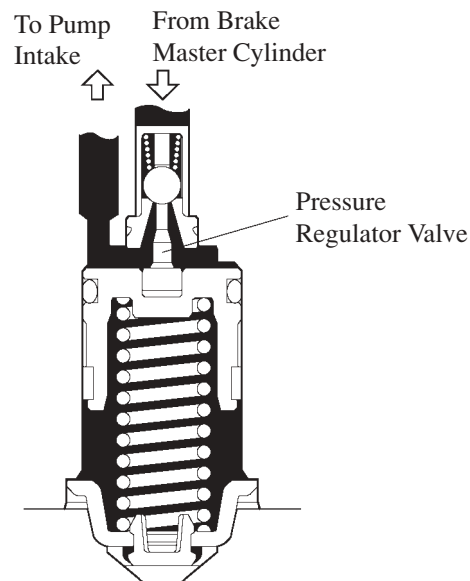
b. Pump and Reservoir

- The trochoid gear type pump has been newly adopted to reduce operating noise.



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- The pressure regulator valve has been adopted in the reservoir for the purpose of regulating the pressure of the fluid to be supplied to the pump and to close the passage between the pump and the master cylinder during braking.



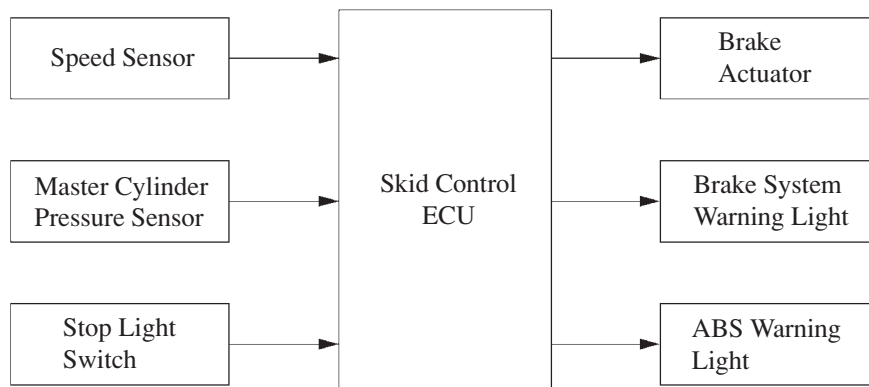
Reservoir Cross Section

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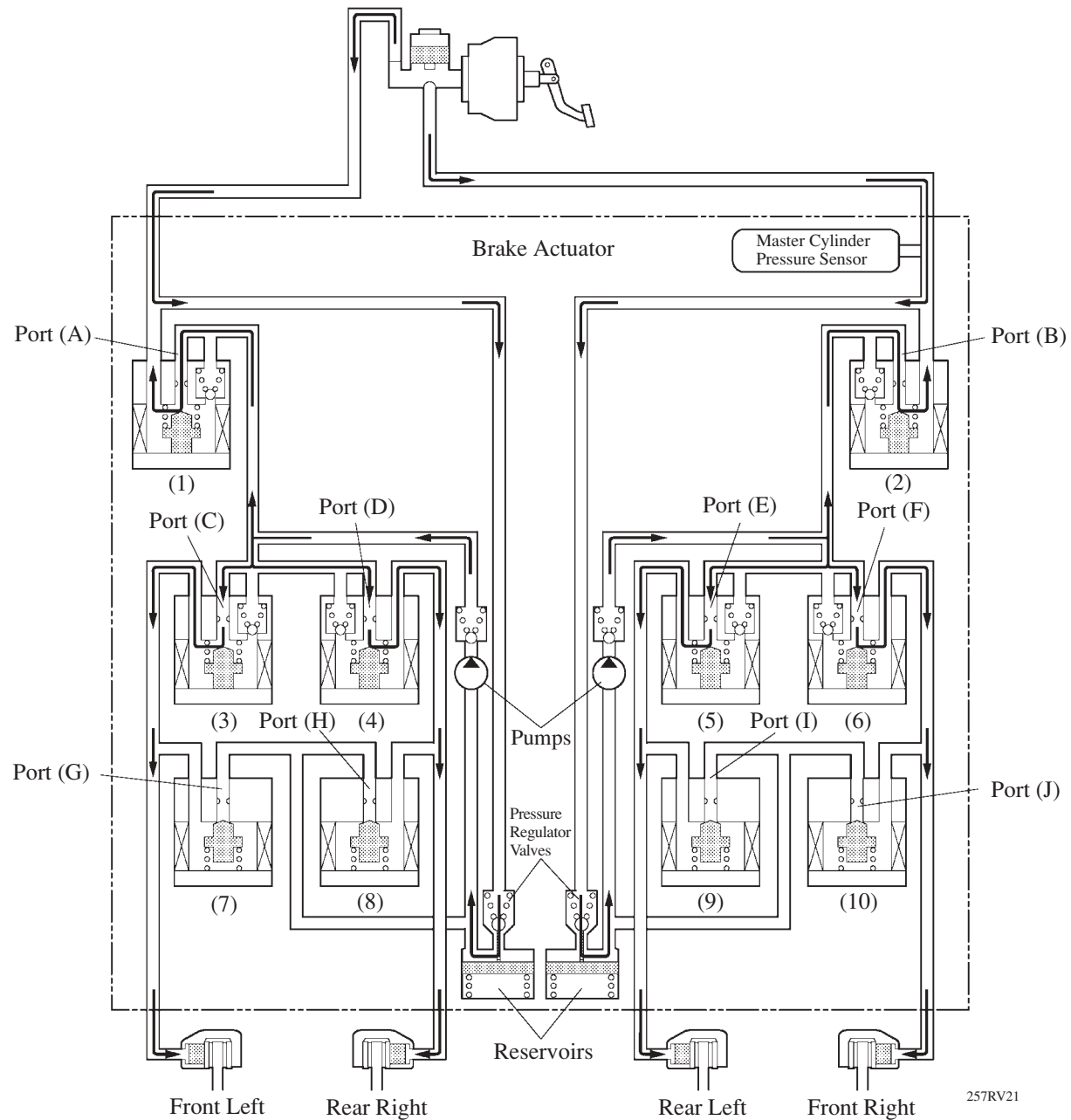
Brake Assist Operation

In the event of emergency braking, the skid control ECU detects the driver's intention based on the speed of the pressure increase in the master cylinder determined by the pressure sensor signal. If the ECU judges the need for the additional brake assist, the fluid pressure is generated by the pump in the actuator and directed to the wheel cylinder to apply a greater fluid pressure than the master cylinder.

► System Diagram ◄



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Brake Assist Activated

Item		Brake Assist Not Activated	Brake Assist Activated
(1), (2)	Master Cylinder Cut Solenoid Valve	OFF (Open)	ON*
	Port: (A), (B)		
(3), (4), (5), (6)	Pressure Holding Solenoid Valve	OFF (Open)	OFF (Open)
	Port: (C), (D), (E), (F)		
(7), (8), (9), (10)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)
	Port: (G), (H), (I), (J)		

*: The solenoid valve controls the hydraulic pressure between “open” and “close” according to the operating condition by adjusting continually.

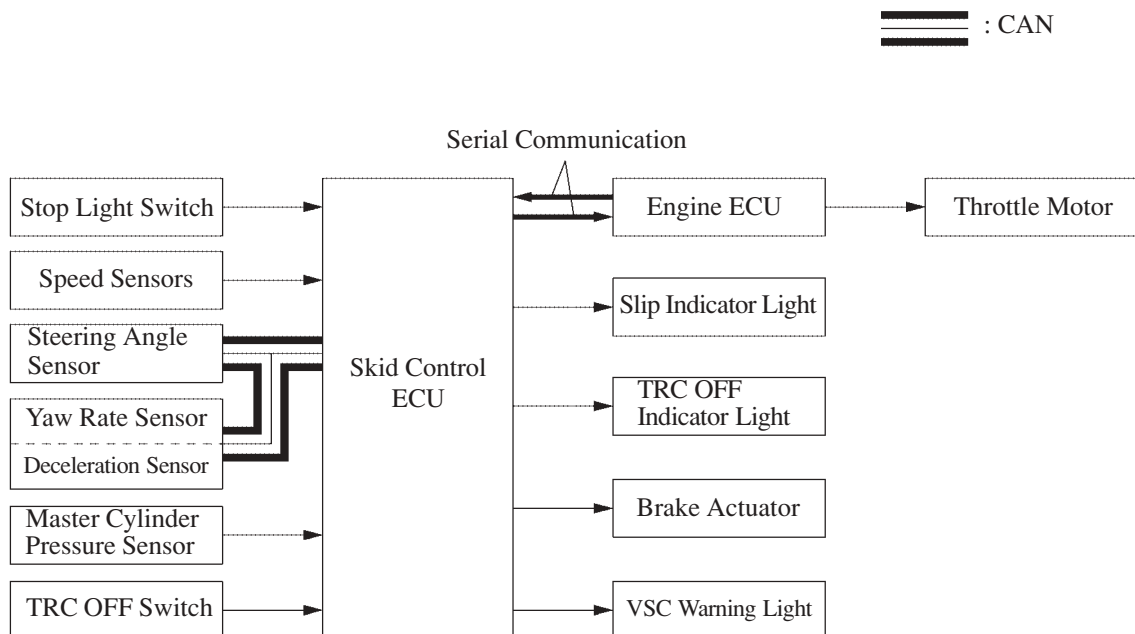
TRC Operation

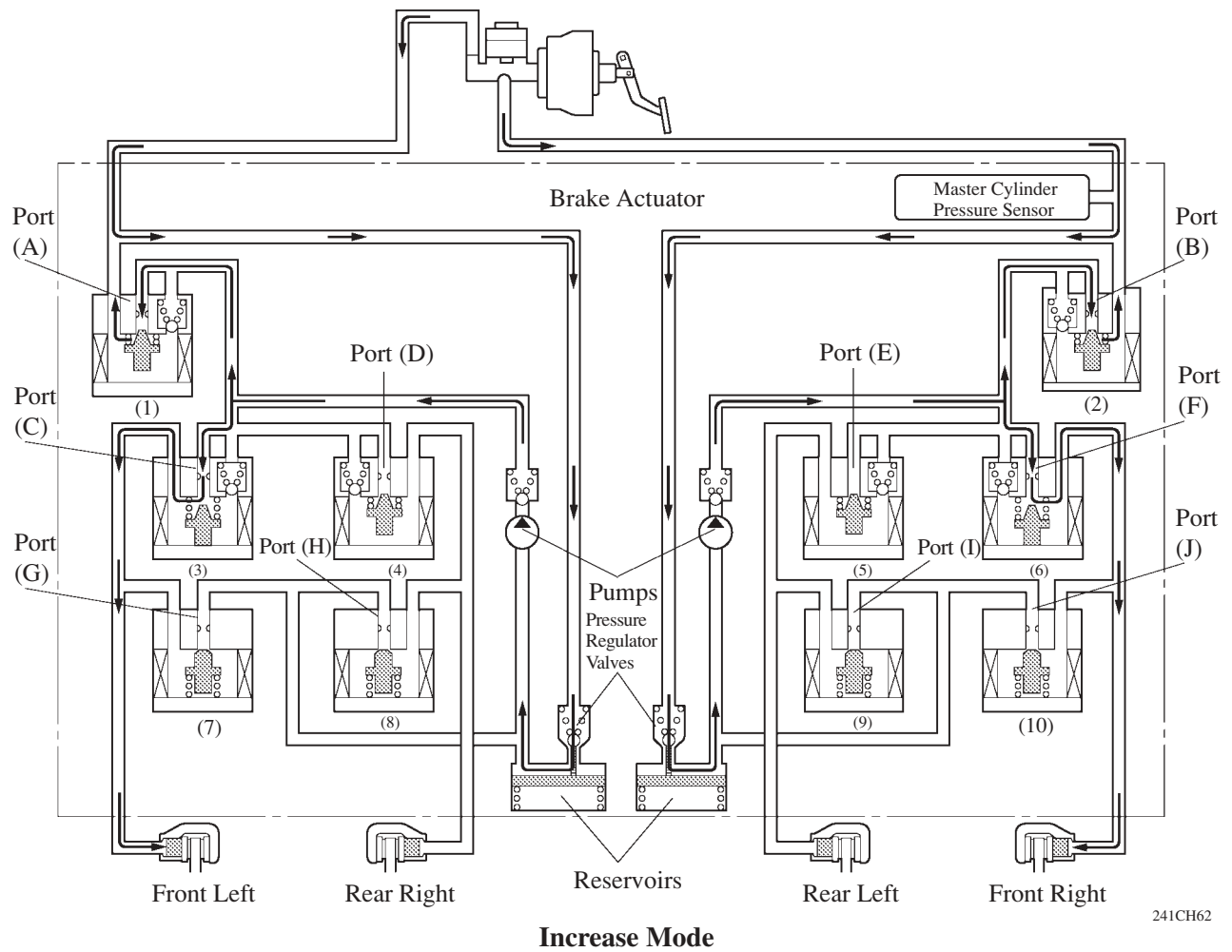
The fluid pressure generated by the pump is regulated by the master cylinder cut solenoid valve to the required pressure. Thus, the wheel cylinders of the drive wheels are controlled in the following 3 modes: pressure reduction, pressure holding, and pressure increase modes, to control the slippage of the drive wheels.

The diagram below shows the hydraulic circuit in the pressure increase mode when the TRC system is activated.

The pressure holding solenoid valve and the pressure reduction solenoid valve are turned ON/OFF according to the ABS operation pattern described on the previous page.

► System Diagram ◀





Item			TRC not Activated	TRC Activated		
				Increase Mode	Holding Mode	Reduction Mode
(1), (2)	Master Cylinder Cut Solenoid Valve		OFF (Open)	ON*	ON*	ON*
	Port: (A), (B)					
Front Brake	(3), (6)	Pressure Holding Valve	OFF (Open)	OFF (Open)	ON (Close)	ON (Close)
		Port: (C), (F)				
	(7), (10)	Pressure Reduction Valve	OFF (Close)	OFF (Close)	OFF (Close)	ON (Open)
		Port: (G), (J)				
	Wheel Cylinder Pressure		—	Increase	Holding	Reduce
Rear Brake	(4), (5)	Pressure Holding Valve	OFF (Open)	ON (Close)	ON (Close)	ON (Close)
		Port: (D), (E)				
	(8), (9)	Pressure Reduction Valve	OFF (Close)	OFF (Close)	OFF (Close)	OFF (Close)
		Port: (H), (I)				
	Wheel Cylinder Pressure		—	—	—	—

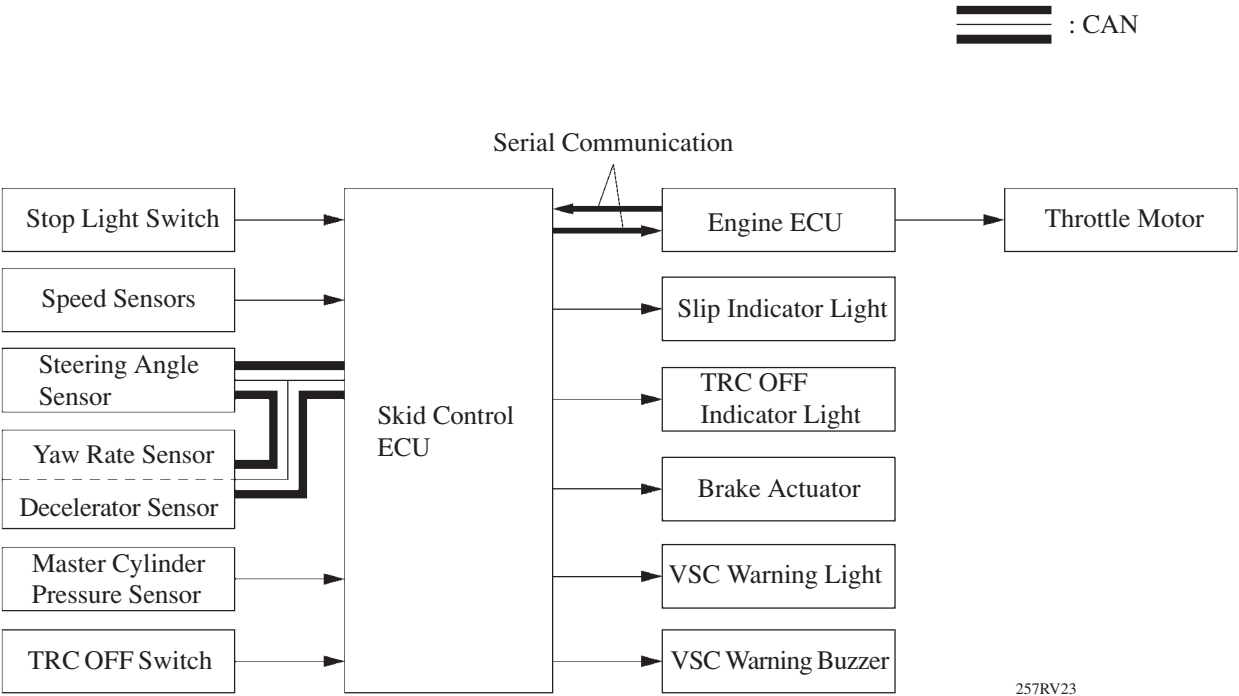
*: The solenoid valve controls the hydraulic pressure between “open” and “close” according to the operating condition by adjusting continually.

VSC Operation

1) General

The VSC system, by way of solenoid valves, controls the fluid pressure that is generated by the pump and applies it to the brake wheel cylinder of each wheel in the following 3 modes: pressure reduction, pressure holding, and pressure increase modes. As a result, the tendency to front wheel skid or rear wheel skid is controlled.

► System Diagram ◀



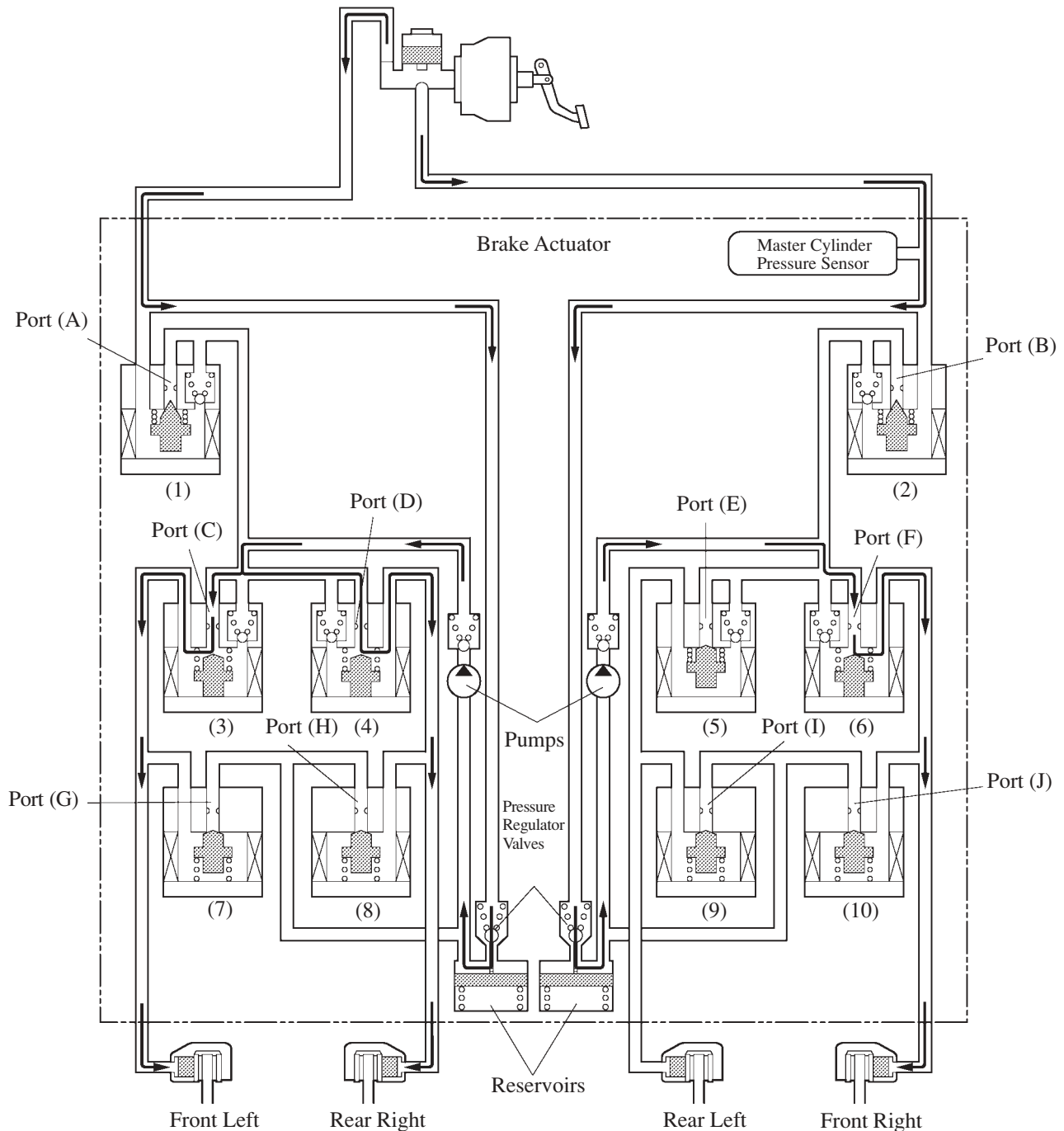
2) Front Wheel Skid Control (Turn to the Right)

In the front wheel skid control, the brakes of the front wheels and the rear wheel of the inner circle of the turn are applied.

Also, depending on whether the brake is ON or OFF and the condition of the vehicle, there are circumstances in which the brake might not be applied to the wheels even if those wheels are targeted for braking.

The diagram below shows the hydraulic circuit in the pressure increase mode, as it controls the front wheel skid condition while the vehicle makes a right turn.

The pressure holding solenoid valve and the pressure reduction solenoid valve are turned ON/OFF according to the ABS operation pattern.



Increase Mode

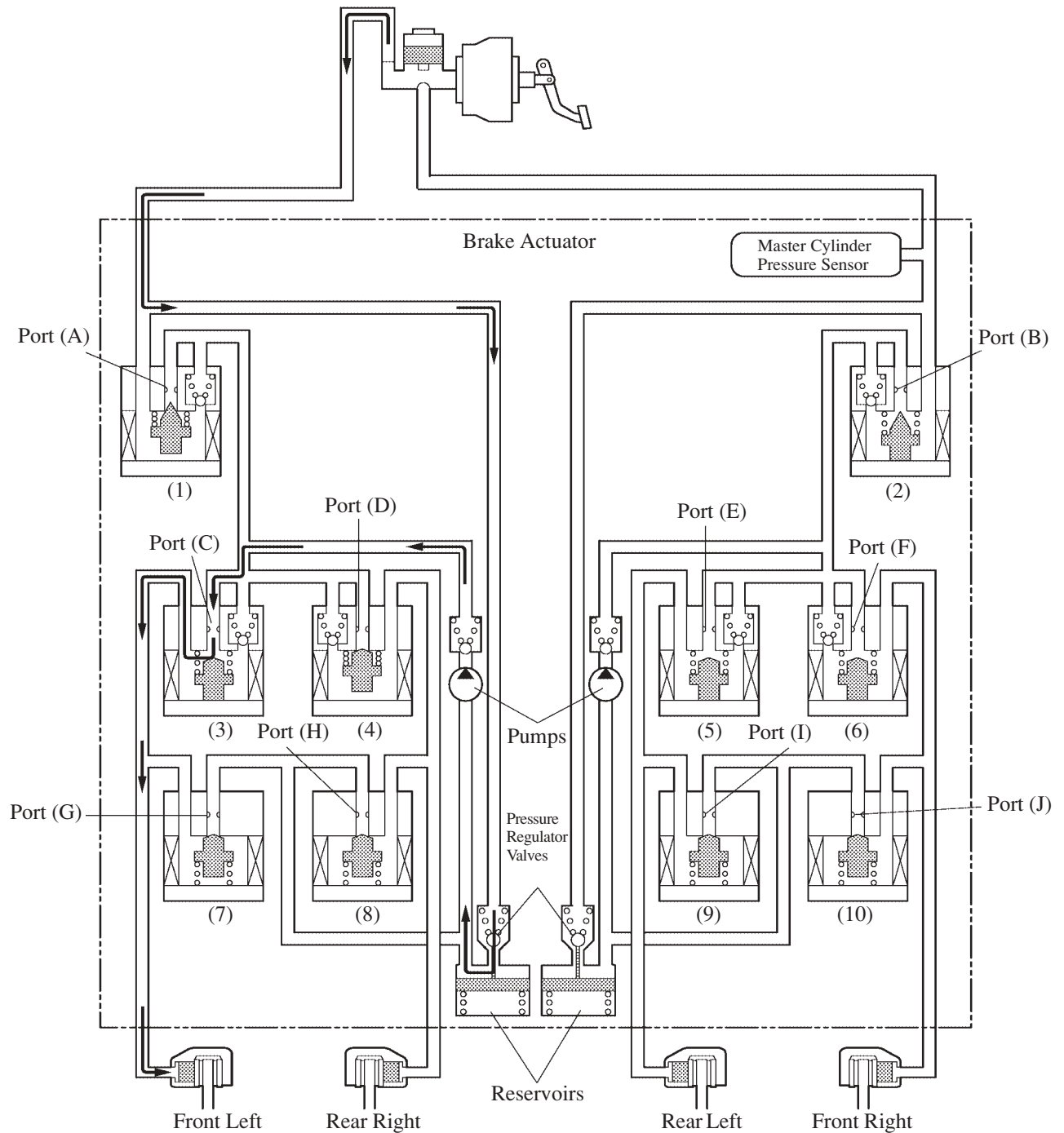
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Item			VSC not Activated	VSC Activated		
				Increase Mode	Holding Mode	Reduction Mode
(1), (2)	Master Cylinder Cut Solenoid Valve		OFF (Open)	ON	ON	ON
	Port: (A), (B)					
Front Brake	(3)	Pressure Holding Solenoid Valve	OFF (Open)	OFF (Open)	ON (Close)	ON (Close)
		Port: (C)				
	(6)	Pressure Holding Solenoid Valve	OFF (Open)	OFF (Open)	ON (Close)	ON (Close)
		Port: (F)				
	(7)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	ON (Open)
		Port: (G)				
	(10)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	ON (Open)
		Port: (J)				
	Wheel Cylinder Pressure	Right	—	Increase	Holding	Reduce
		Left	—	Increase	Holding	Reduce
Rear Brake	(4)	Pressure Holding Solenoid Valve	OFF (Open)	OFF (Open)	ON (Close)	ON (Close)
		Port: (D)				
	(5)	Pressure Holding Solenoid Valve	OFF (Open)	ON (Close)	ON (Close)	ON (Close)
		Port: (E)				
	(8)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	ON (Open)
		Port: (H)				
	(9)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	OFF (Close)
		Port: (I)				
	Wheel Cylinder Pressure	Right	—	Increase	Holding	Reduce
		Left	—	—	—	—

3) Rear Wheel Skid Control (Turn to the Right)

In rear wheel skid control, the brake of the front wheel of the outer circle of the turn is applied. As an example, the diagram below shows the hydraulic circuit in the pressure increase mode, as it controls the rear wheel skid condition while the vehicle make a right turn.

As in front wheel skid control the pressure holding solenoid valve and the pressure reduction solenoid valve are turned ON/OFF according to the ABS operating pattern.



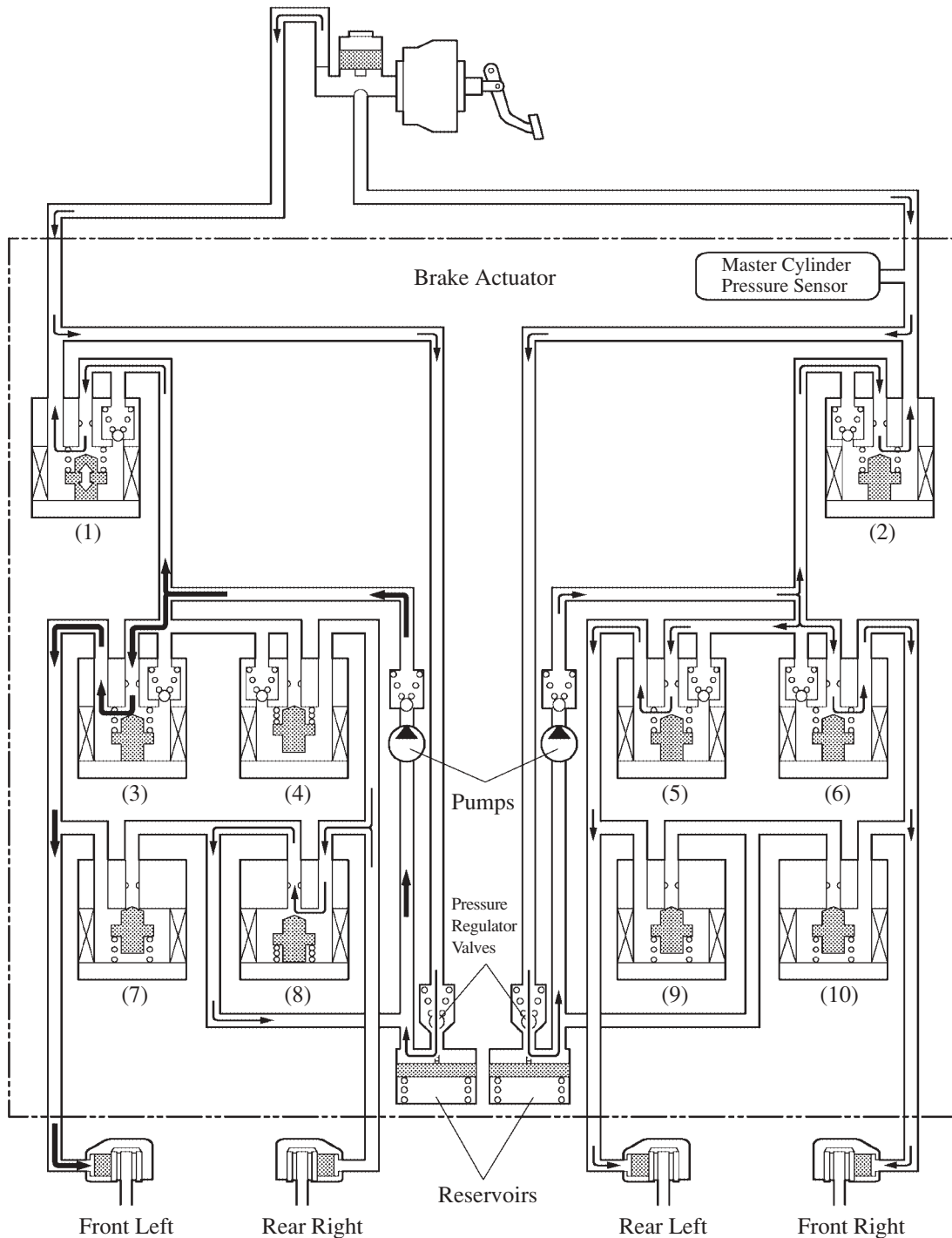
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Item			VSC not Activated	VSC Activated		
				Increase Mode	Holding Mode	Reduction Mode
(1)	Master Cylinder Cut Solenoid Valve		OFF (Open)	ON (Close)	ON (Close)	ON (Close)
	Port: (A)					
(2)	Master Cylinder Cut Solenoid Valve		OFF (Open)	OFF (Open)	OFF (Open)	OFF (Open)
	Port: (B)					
Front Brake	(3)	Pressure Holding Solenoid Valve	OFF (Open)	OFF (Open)	ON (Close)	ON (Close)
		Port: (C)				
	(6)	Pressure Holding Solenoid Valve	OFF (Open)	OFF (Open)	OFF (Open)	OFF (Open)
		Port: (F)				
	(7)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	ON (Open)
		Port: (G)				
	(10)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	OFF (Close)
		Port: (J)				
	Wheel Cylinder Pressure	Right	—	—	—	—
		Left	—	Increase	Holding	Reduce
Rear Brake	(4)	Pressure Holding Solenoid Valve	OFF (Open)	ON (Close)	ON (Close)	ON (Close)
		Port: (D)				
	(5)	Pressure Holding Solenoid Valve	OFF (Open)	ON (Close)	ON (Close)	ON (Close)
		Port: (E)				
	(8)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	OFF (Close)
		Port: (H)				
	(9)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	OFF (Close)	OFF (Close)
		Port: (I)				
	Wheel Cylinder Pressure	Right	—	—	—	—
		Left	—	—	—	—

4) Control During Cornering Braking (Turn to the Right)

During cornering braking, the pressure holding valve (3), and the pressure reduction valve (7) are inactive. However, because the pump is operating, the brake fluid pressure in the left front wheel cylinder increases. At the same time, the pressure holding valve (4) and the pressure reduction valve (8) turn ON and OFF in the pressure increase, pressure holding, and pressure reduction modes, in order to control the brake fluid pressure applied to the right rear wheel cylinder.

The master cylinder cut solenoid valve (2) regulates the master cylinder fluid pressure applied to the right front wheel cylinder and the left rear wheel cylinder. Because the pressure holding valves (5) and (6) and the pressure reduction valves (9) and (10) are inactive at this time, the master cylinder fluid pressure acts on the right front wheel cylinder and the left rear wheel cylinder.



Reduction Mode

Item			VSC Activated		
			Increase Mode	Holding Mode	Reduction Mode
(1)	Master Cylinder Cut Solenoid Valve		ON*1	ON*1	ON*1
(2)	Master Cylinder Cut Solenoid Valve		___*2	___*2	___*2
Front Brake	(3)	Pressure Holding Solenoid Valve	___*2	___	___
	(6)	Pressure Holding Solenoid Valve	___*2	___	___
	(7)	Pressure Reduction Solenoid Valve	___*2	___	___
	(10)	Pressure Reduction Solenoid Valve	___*2	___	___
	Wheel Cylinder Pressure	Right	___*3	___	___
		Left	Increase	___	___
Rear Brake	(4)	Pressure Holding Solenoid Valve	OFF (Open)	ON (Close)	ON (Close)
	(5)	Pressure Holding Solenoid Valve	___*1	___*1	___*1
	(8)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	ON (Open)
	(9)	Pressure Reduction Solenoid Valve	___*1	___*1	___*1
	Wheel Cylinder Pressure	Right	Increase	Holding	Reduce
		Left	___*3	___*3	___*3

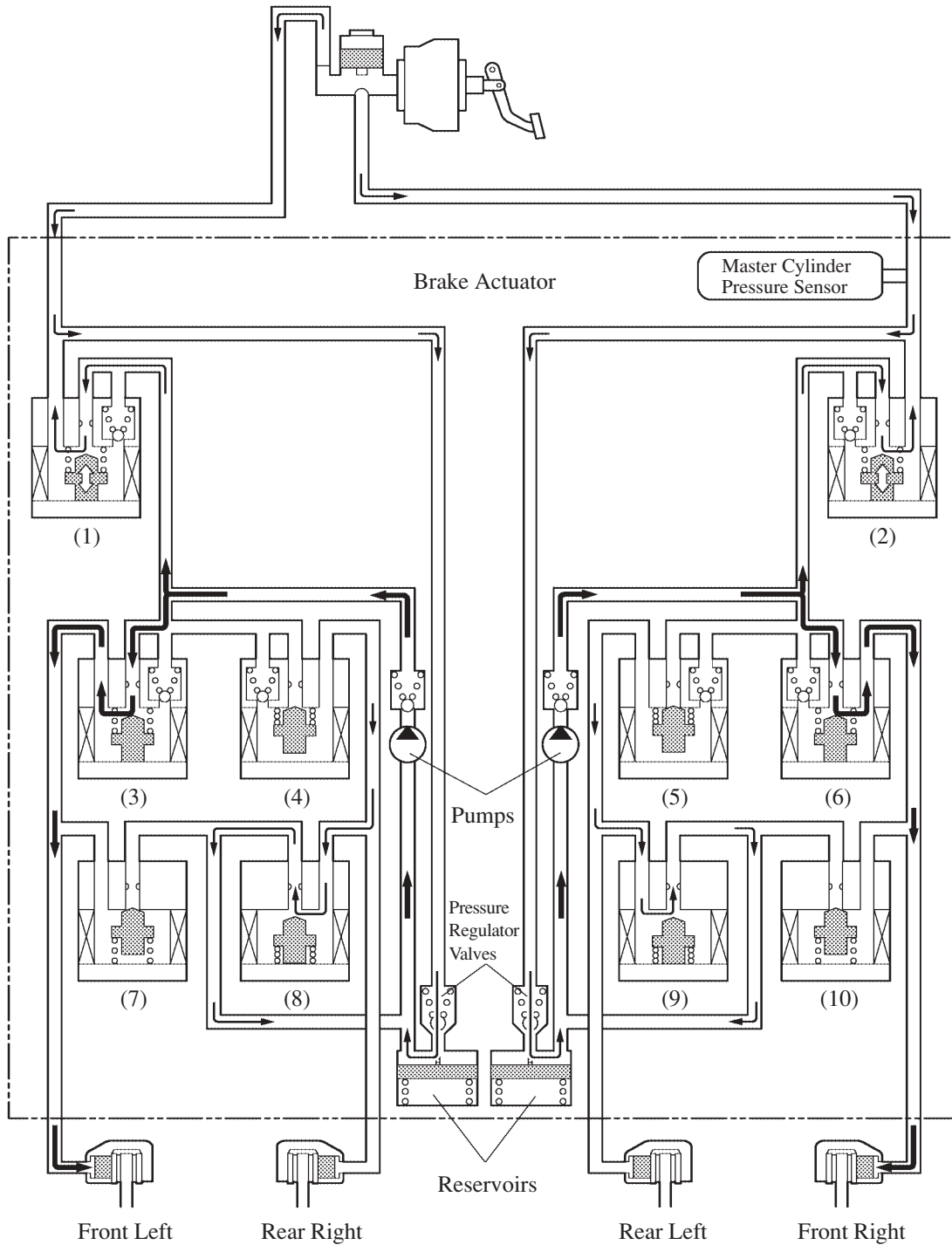
*1: The solenoid valve controls the hydraulic pressure between “open” and “close” according to the operating condition by adjusting continually.

*2: Indicates an inactive condition.

*3: The master cylinder pressure acts on it.

5) Control During High-Speed

During high-speed braking, the system turns ON/OFF (pressurization/depressurization) the pressure holding valves (4) and (5), and the pressure reduction valves (8) and (9) depend on the vehicle condition. Because the pressure holding valves (3) and (6) and the pressure reduction valves (7) and (10) are inactive (the pressure holding valves are ON and the pressure reduction valves are OFF) at this time, the pump increases the fluid pressure of braking force, which is corresponded to the fluid pressure reduced at the rear wheel cylinders, in the front wheel cylinder.



257RV43

Item			VSC Activated		
			Increase Mode	Holding Mode	Reduction Mode
(1)	Master Cylinder Cut Solenoid Valve		ON*1	ON*1	ON*1
(2)	Master Cylinder Cut Solenoid Valve		ON*1	ON*1	ON*1
Front Brake	(3)	Pressure Holding Solenoid Valve	—*2	—	—
	(6)	Pressure Holding Solenoid Valve	—*2	—	—
	(7)	Pressure Reduction Solenoid Valve	—*2	—	—
	(10)	Pressure Reduction Solenoid Valve	—*2	—	—
	Wheel Cylinder Pressure	Right	Increase	—	—
		Left	Increase	—	—
Rear Brake	(4)	Pressure Holding Solenoid Valve	OFF (Open)	ON (Close)	ON (Close)
	(5)	Pressure Holding Solenoid Valve	OFF (Open)	ON (Close)	ON (Close)
	(8)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	ON (Open)
	(9)	Pressure Reduction Solenoid Valve	OFF (Close)	OFF (Close)	ON (Open)
	Wheel Cylinder Pressure	Right	Increase	Holding	Reduce
		Left	Increase	Holding	Reduce

*1: The solenoid valve controls the hydraulic pressure between “open” and “close” according to the operating condition by adjusting continually.

*2: Indicates an inactive condition.