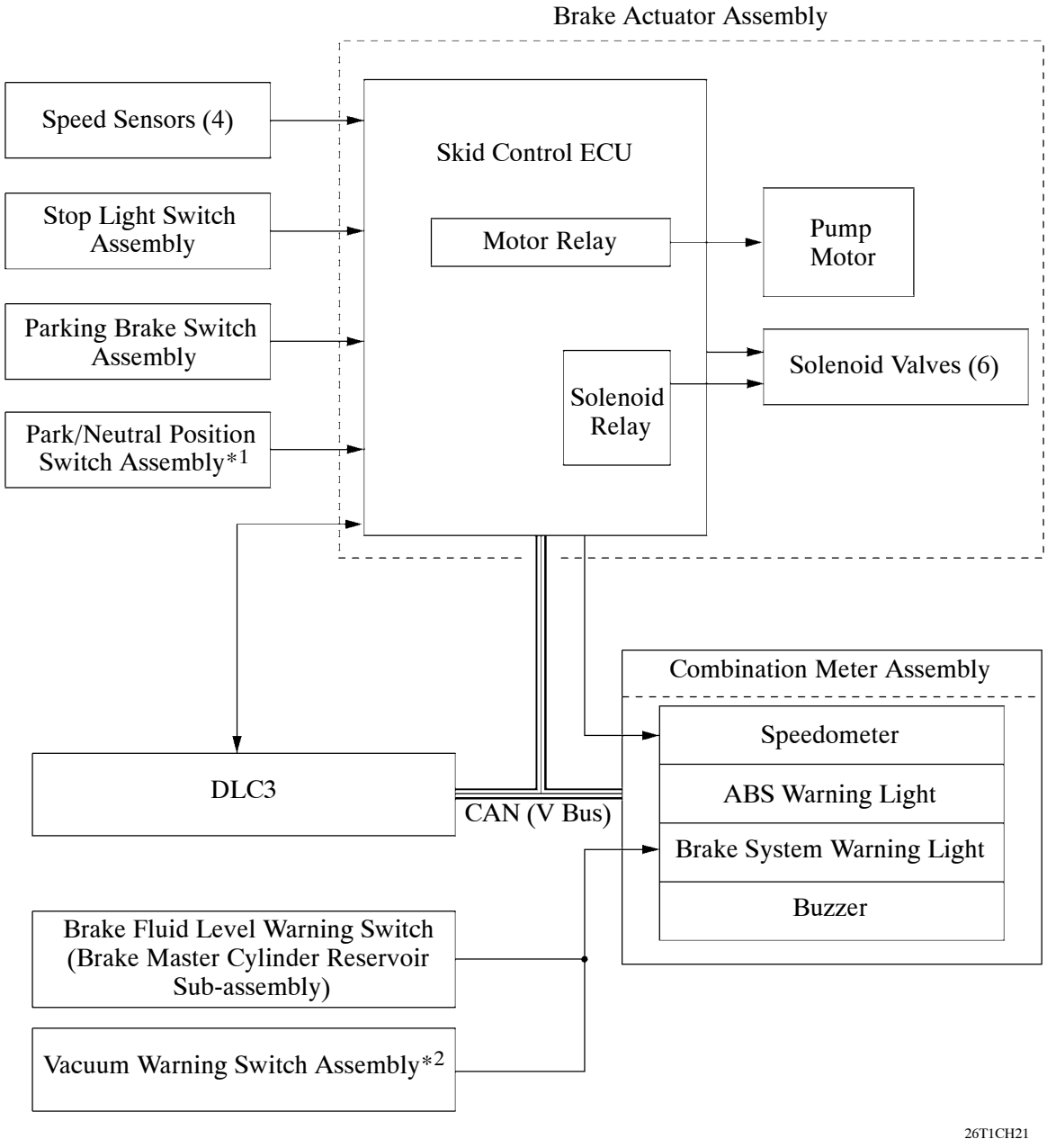
■ BRAKE CONTROL SYSTEM

1. General

- The brake control functions (ABS, EBD, Brake Assist, TRC, VSC, Hill-start Assist Control) have been provided to ensure excellent brake performance and vehicle stability.
- The VSC OFF switch is provided to enable the driver to select the “Normal Mode”, “TRC-OFF Mode”, or “VSC-OFF Mode”.
- A CAN communication compatible brake actuator assembly has been adopted for the models equipped with ABS.
- The passive type front and rear speed sensors have been altered to an active type.

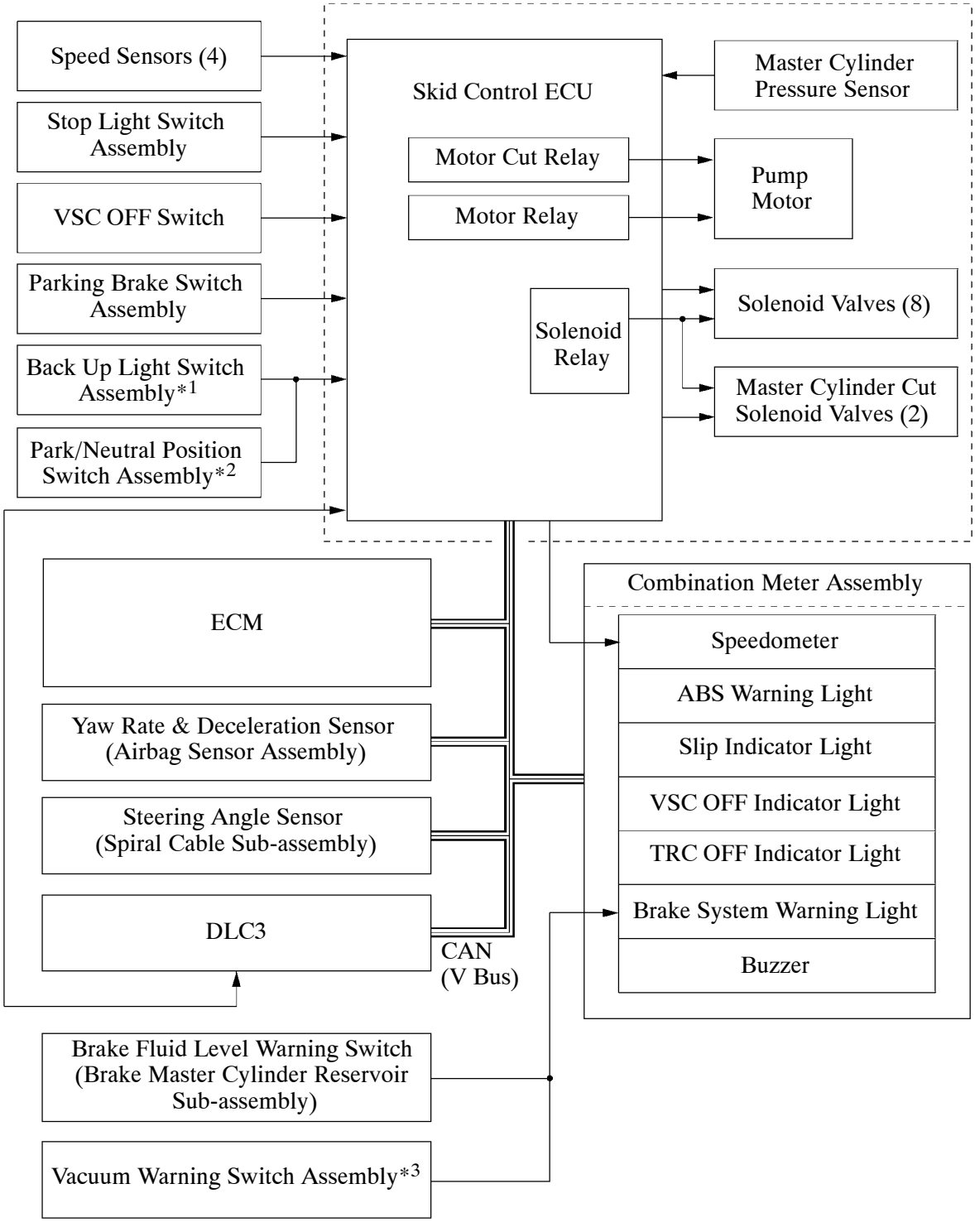
2. System Diagram

▶ Models with ABS ◀



*1: Models with A/T
*2: Models with 1KD-FTV, 2KD-FTV, 5L-E

▶ Models with VSC ◀



*1: Models with M/T
*2: Models with A/T
*3: Models with 1KD-FTV, 2KD-FTV

3. Outline of Brake Control Functions

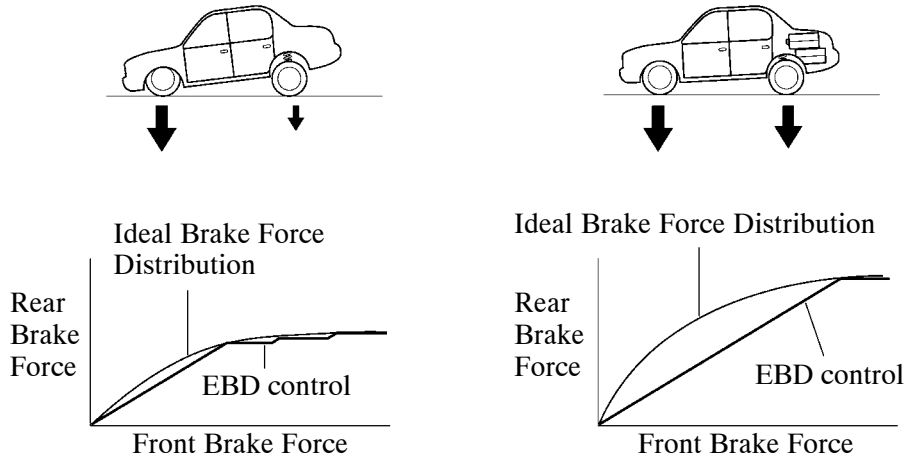
EBD Control

The distribution of the brake force, which was performed mechanically in the past, is now performed under electrical control of the skid control ECU, which precisely controls the braking force in accordance with the vehicle's driving conditions.

Front/Rear Wheel Brake Force Distribution

If the brakes are applied while the vehicle is moving straight forward, the transfer of load due to braking reduces the load that is applied to the rear wheels. The skid control ECU determines this condition by way of the signals from the speed sensor, and the brake actuator regulates the distribution of the brake force of the rear wheels to optimally control brake balance.
For example, the amount of the brake force that can be applied to the rear wheels during braking varies depending on whether the vehicle is carrying a load. The amount of the brake force that is applied to the rear wheels also varies in accordance with the extent of the deceleration.
Thus, the distribution of brake force to the rear is optimally controlled in order to effectively utilize the braking force of the rear wheels under these conditions.

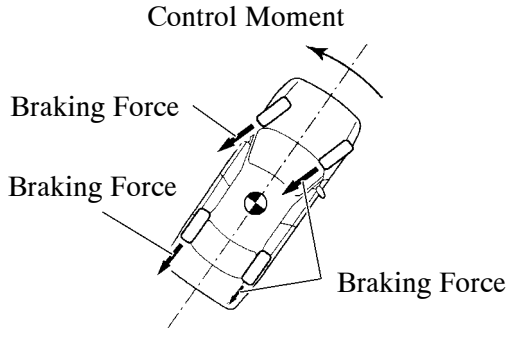
▶ EBD Control Concept ◀



182CH56

Right/Left Wheel Brake Force Distribution (During Cornering Braking)

During braking while cornering, this function controls the brake force that acts on the left and right wheels in accordance with the vehicle conditions at that time. This ensures vehicle stability and excellent braking performance.

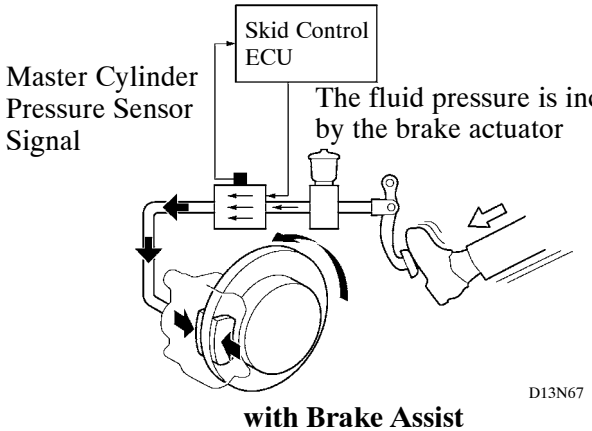


26T1CH11

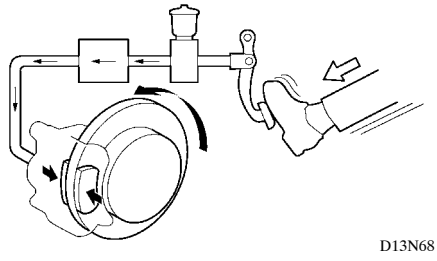
Brake Assist

- The brake assist in combination with ABS helping improves the vehicle's brake performance.
- The brake assist interprets a quick push of the brake pedal as emergency braking and supplements the brake power applied if the driver has not stepped hard enough on the brake pedal. In emergencies, drivers, especially inexperienced ones, often panic and do not apply sufficient pressure to the brake pedal.
- A key feature of brake assist is that the timing and the degree of braking assistance are designed to help ensure that the driver does not discern anything unusual about the braking operation. When the driver intentionally eases up on the brake pedal, the brake assist reduces the amount of assistance it provides.
- Based on the signals from the master cylinder pressure sensor, the skid control ECU calculates the speed and the amount of the brake pedal application and then determines the intention of the driver to perform emergency braking. If the skid control ECU determines that the driver intends emergency braking, the system activates the brake actuator to increase the brake fluid pressure, which increases the braking force.

▶ In case that the driver's pedal application force is small when applying emergency braking ◀

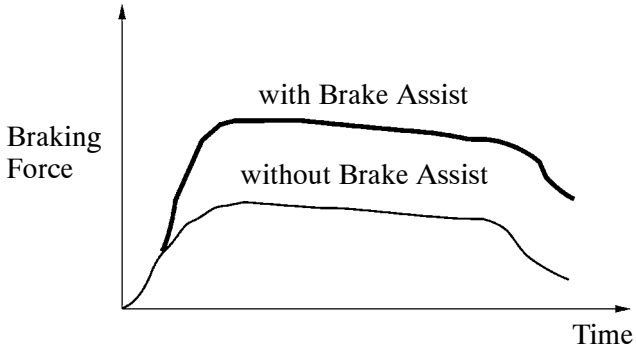


with Brake Assist



without Brake Assist*

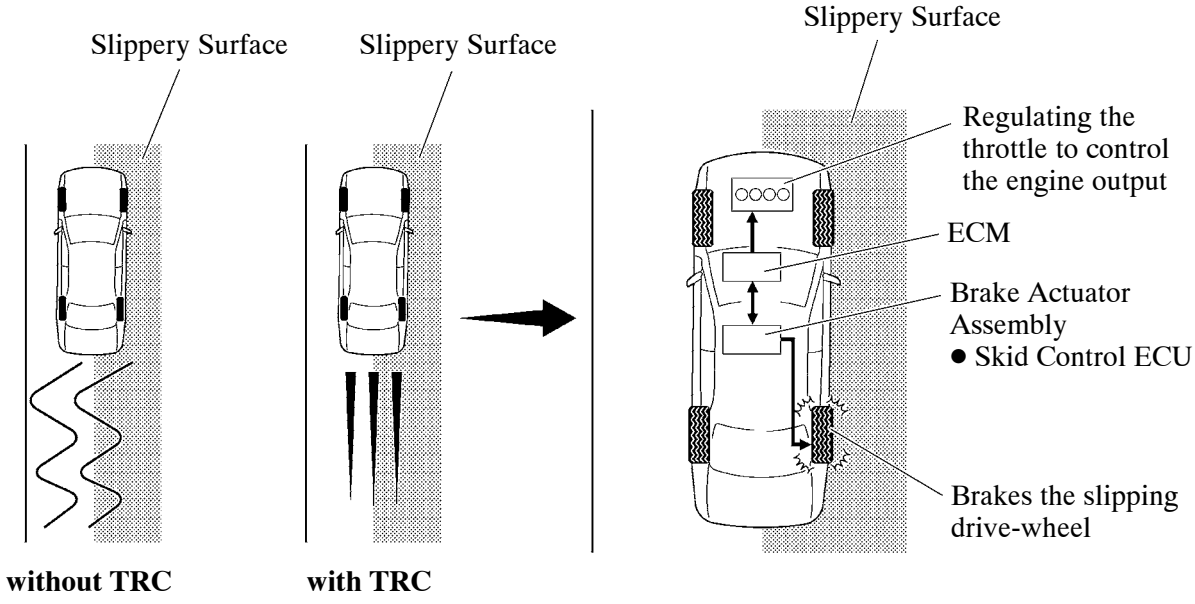
*: The basic performance of the brakes is the same as the model with the Brake Assist.



TRC (Traction Control)

- If the driver presses the accelerator pedal aggressively when initially acceleration or when accelerating on a slippery surface, the drive wheels 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 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 2 vehicles, one with the TRC 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 can not start accelerating smoothly.
  However, when the vehicle is equipped with the TRC, the skid control ECU instantly determines the state of the vehicle and operates the brake actuator in order to apply the brakes to the slipping drive wheel. Furthermore, the ECM receives the signals from the skid control ECU and regulates the throttle in order to control the engine output. Thus, the TRC can constantly help the driver to maintain stability while accelerating.

▶ Driving condition on road with different surface friction characteristics ◀

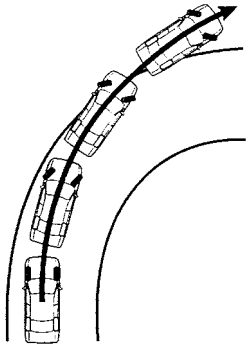


26T1CH78

VSC (Vehicle Stability Control)

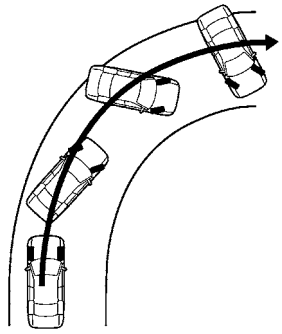
The followings are 2 examples that can be considered as circumstances in which the tires exceed their lateral grip limit.
The VSC is designed to help control the vehicle behavior by controlling the engine output and the brakes at each wheel when the vehicle experiences one of the conditions indicated below.

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



Front Wheel Skid Tendency

151CH17



Rear Wheel Skid Tendency

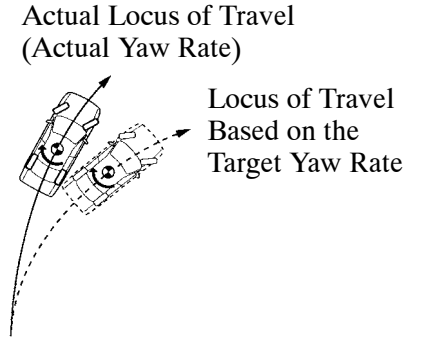
189CH100

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.

1) Determining a Front Wheel Skid

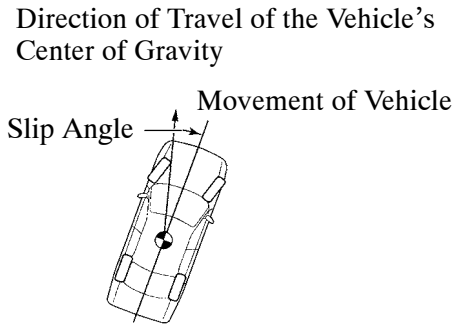
Whether or not the vehicle is experiencing a front wheel skid is determined by the difference between the target yaw rate and the vehicle's actual yaw rate.
When the vehicle's actual yaw rate is smaller than the target yaw rate (a target yaw rate that is determined by the vehicle speed and steering angle) 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 target locus of travel.
Thus, the skid control ECU determines that there is a large front wheel skid tendency.



151CH19

2) Determining a Rear Wheel Skid

Whether or not the vehicle is experiencing a 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.



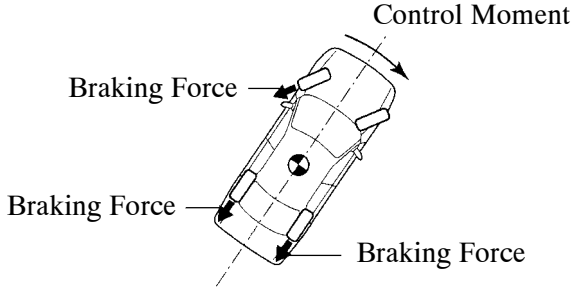
151CH18

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 to 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 may differ depending on the vehicle's characteristics and driving conditions.

1) Dampening a Strong Front Wheel Skid

When the skid control ECU determines that there is a large front wheel skid tendency, it attempts to counteract the tendency based on the extent of that tendency. The skid control ECU controls the engine power output and applies the brakes of the front wheel of the outer circle in the turn and rear wheels in order to restrain the front wheel skid tendency.

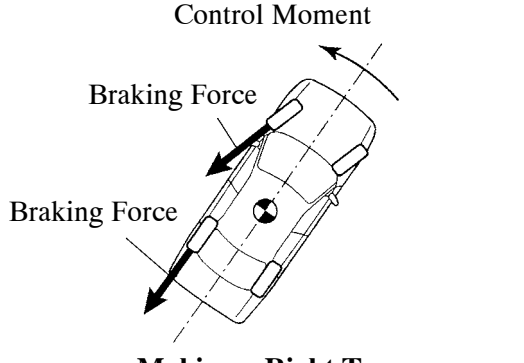


Making a Right Turn

189CH101

2) Dampening a Strong Rear Wheel Skid

When the skid control ECU determines that there is a large rear wheel skid tendency, it attempts to counteract the tendency based on the extent of that tendency. It applies the brakes of the front and rear wheels of the outer circle of the turn, and generates an outward moment of inertia in the vehicle, in order to restrain the rear wheel skid tendency. Along with the reduction in the vehicle speed caused by the braking force, excellent vehicle stability is ensured.
In some cases, the skid control ECU applies the brake of the rear wheels, as necessary.

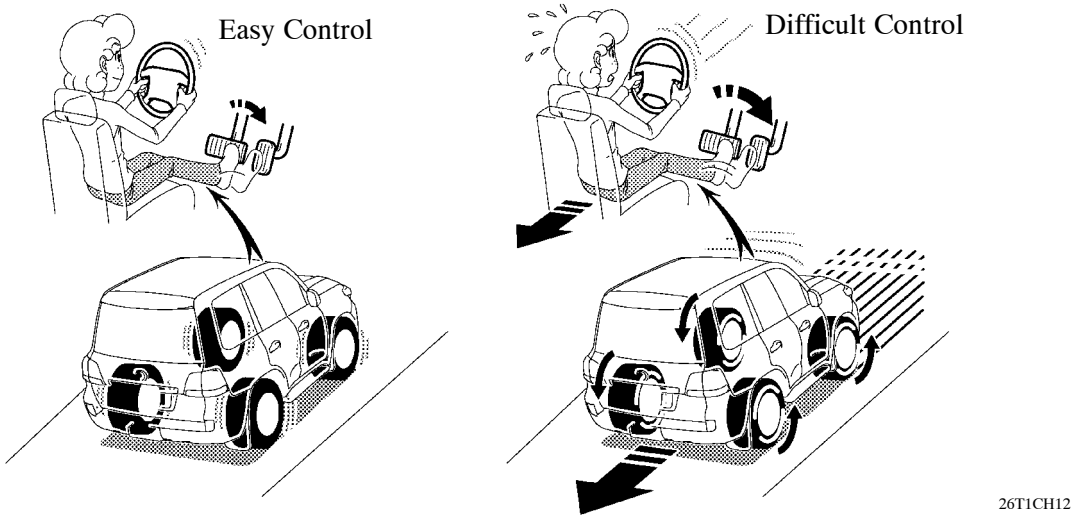


Making a Right Turn

204CH15

Hill-start Assist Control

- When the vehicle starts off on a steep or slippery hill, it could descend backward while the driver switches from the brake pedal to the accelerator pedal, making it difficult for the vehicle to start off. To prevent this from occurring, the hill-start assist control temporarily (approximately 2 seconds at the maximum) applies the brakes to all the wheels in order to prevent the vehicle from descending backward.
- Without the hill-start assist control, the driver must quickly and precisely switch from the brake pedal to the accelerator pedal. With the hill-start assist control, however, the driver can start off easily and operate the pedal in a relaxed manner because the hill-start assist control prevents the vehicle from descending backward.



Prevents backward descent of vehicle

with Hill-start Assist Control

Increases backward speed of vehicle

without Hill-start Assist Control

Hill-start Assist Control Start Operation

The hill-start assist control operates when all of the following conditions have been met:

▶ Models with automatic transmission ◀

- When on an uphill: The shift lever is in a position other than P , R and N.
- When on a downhill: The shift lever is in a position R.
- The vehicle is at a standstill.
- The accelerator pedal is not depressed.
- The parking brake is not applied.

▶ Models with manual transmission ◀

- When on an uphill: The shift lever is in a position other than R.
- When on a downhill: The shift lever is in a position R.
- The vehicle is at a standstill.
- The accelerator pedal is not depressed.
- The parking brake is not applied.

Hill-start Assist Control Cancelation Operation

If any one of the below conditions is met during hill-start assist control operation, hill-start assist control will be canceled.

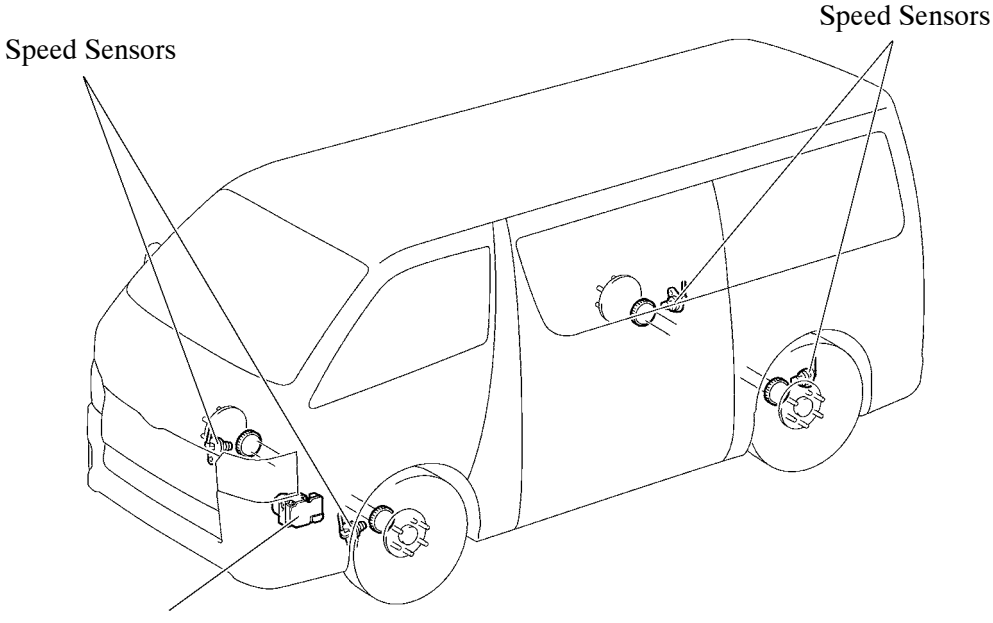
▶ Models with automatic transmission ◀

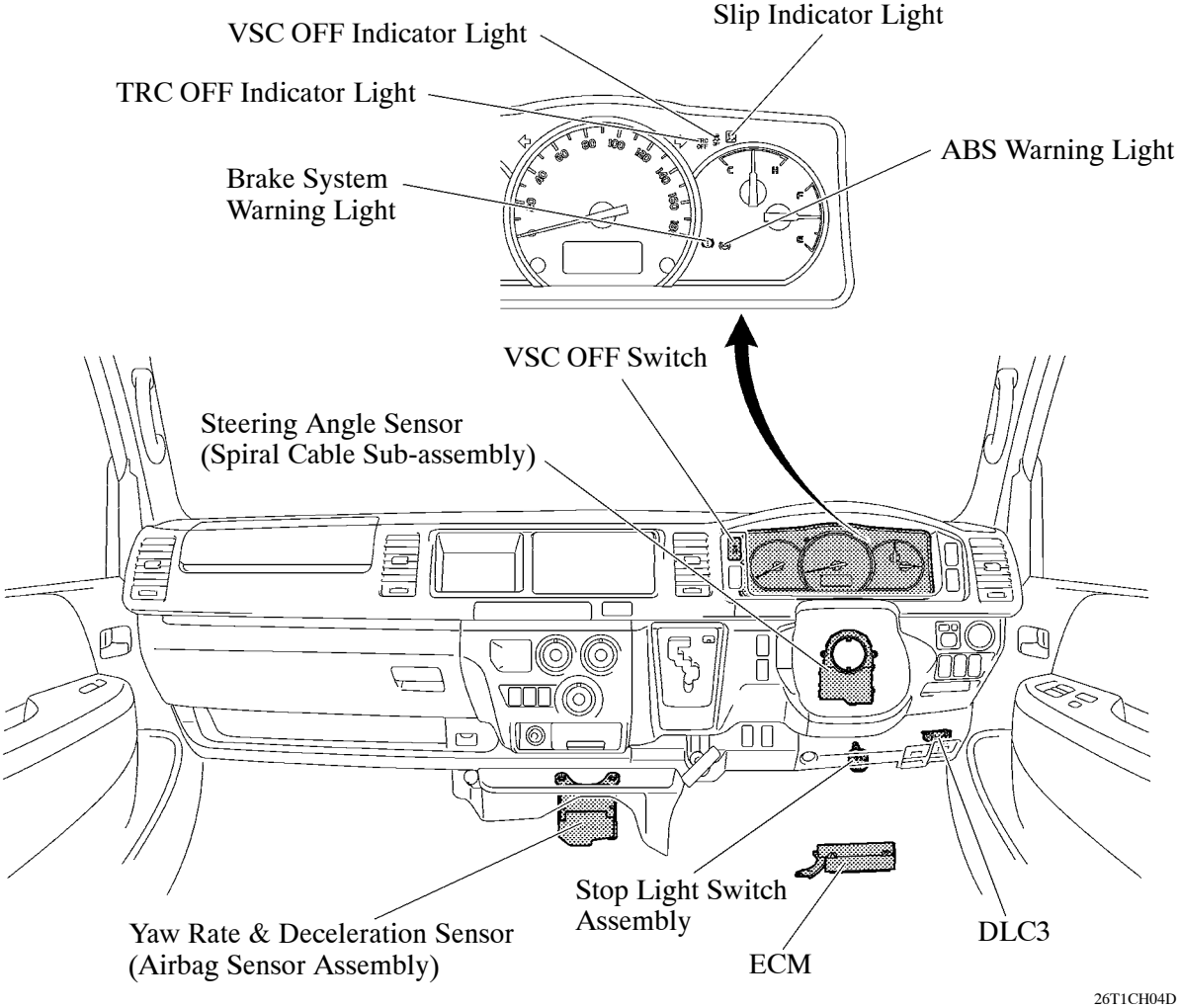
- When on an uphill: The shift lever is in a position P , R and N.
- When on a downhill: The shift lever is in a position other than R.
- The driver depresses the accelerator pedal.
- The parking brake is applied.
- 2 seconds have elapsed since the hill-start assist control operated.

▶ Models with manual transmission ◀

- When on an uphill: The shift lever is in a position R.
- When on a downhill: The shift lever is in a position other than R.
- The driver depresses the accelerator pedal.
- The parking brake is applied.
- 2 seconds have elapsed since the hill-start assist control operated.

4. Layout of Main Components





5. Function of Main Components

Component		Function
Combination Meter Assembly	Brake System Warning Light	● Illuminates to alert the driver when the skid control ECU detects a malfunction in the EBD or brake system. ● Illuminates to alert the driver when the brake fluid level is low. ● Illuminates to inform the driver when the parking brake lever is pulled up.
	ABS Warning Light	Illuminates to alert the driver when the skid control ECU detects a malfunction in the ABS or brake assist.
	Slip Indicator Light	● Blinks to inform the driver when the TRC or VSC is operational. ● Illuminates to alert the driver when the skid control ECU detects a malfunction in the TRC or VSC.
	VSC OFF Indicator Light	Illuminates to inform the driver of the VSC-OFF mode.
	TRC OFF Indicator Light	Illuminates to inform the driver of the TRC-OFF mode.
	Buzzer	● Emits a warning sound to alert the driver if the vehicle is driven with the parking brake lever engaged, and the vehicle speed is over 5 km/h. ● Emits a warning sound to alert the driver when the brake fluid level is low.
Steering Angle Sensor (Spiral Cable Sub-assembly)		Detects the direction and angle of the steering wheel.
Yaw Rate & Deceleration Sensor (Airbag Sensor Assembly)		● Detects the vehicle's longitudinal and lateral acceleration and deceleration. ● Detects the vehicle's yaw rate.
Speed Sensors		Detect the wheel speed of each of 4 wheels.
Stop Light Switch Assembly		Detects the brake pedal depressing signal.
Back Up Light Switch Assembly*1		Detects the reverse position.
Park/Neutral Position Switch Assembly*2		Detects the shift lever position.
Parking Brake Switch Assembly		Detects when the parking brake lever is pulled up.
Brake Fluid Level Warning Switch (Brake Master Cylinder Reservoir Sub-assembly)		Detects the brake fluid level.
VSC OFF Switch		Enables the driver to select the "Normal Mode", "TRC-OFF Mode", or "VSC-OFF Mode".
Brake Booster Assembly		Increases the brake pedal effort.
Brake Actuator Assembly	Solenoid Valves	Changes the fluid path based on the signals from the skid control ECU during the operation of the brake control system functions, in order to control the fluid pressure that is applied to the wheel cylinders.
	Solenoid Relay	Supplies power to the solenoid valves.
	Motor Relay	Supplies power to the pump motor.
	Motor Cut Relay	Cuts the power to the pump motor in the brake actuator.
	Master Cylinder Pressure Sensor	Assembled in the brake actuator, detects the master cylinder pressure.

(Continued)

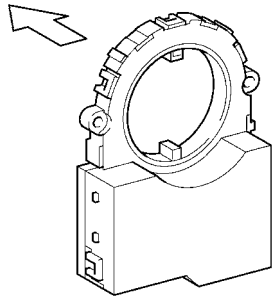
Component		Function
Brake Actuator Assembly	Skid Control ECU	Judges the vehicle driving condition based on the signals from each sensor, and sends the brake control signals to the brake actuator.
	Pump Motor	Drivers the pumps inside the brake actuator.
ECM		● Sends the throttle position signal, accelerator pedal position signal, engine speed signal etc., to the skid control ECU. ● Based on the signals received from the skid control ECU, controls the engine output.

*1: Models with M/T
*2: Models with A/T

6. Construction and Operation of Main Components

Steering Angle Sensor

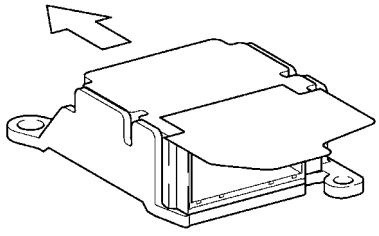
The steering angle sensor detects the steering direction and angle, and sends this signal to the skid control ECU.



26T1CH05D

Yaw Rate and Deceleration Sensor

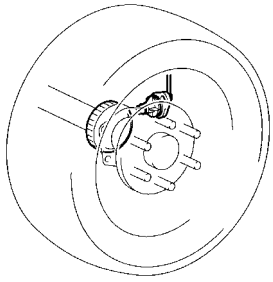
- The yaw rate sensor detects the vehicle's yaw rate.
- The deceleration sensor detects the vehicle's longitudinal and lateral acceleration and deceleration.



26T1CH06D

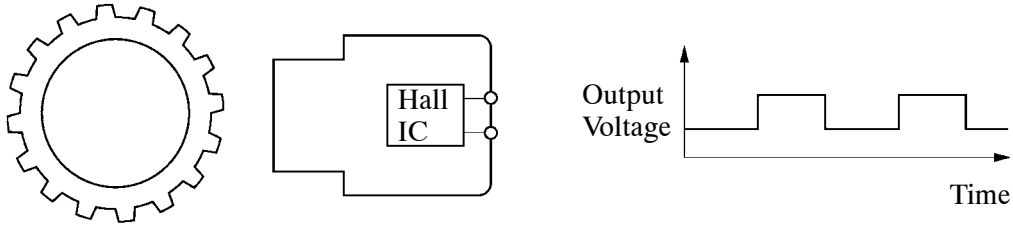
Speed Sensor

The speed sensor detects the wheel speed.



26T1CH02D

▶ Active Type Speed Sensor ◀



Sensor Rotor
(Drive Shaft or Axle Shaft)

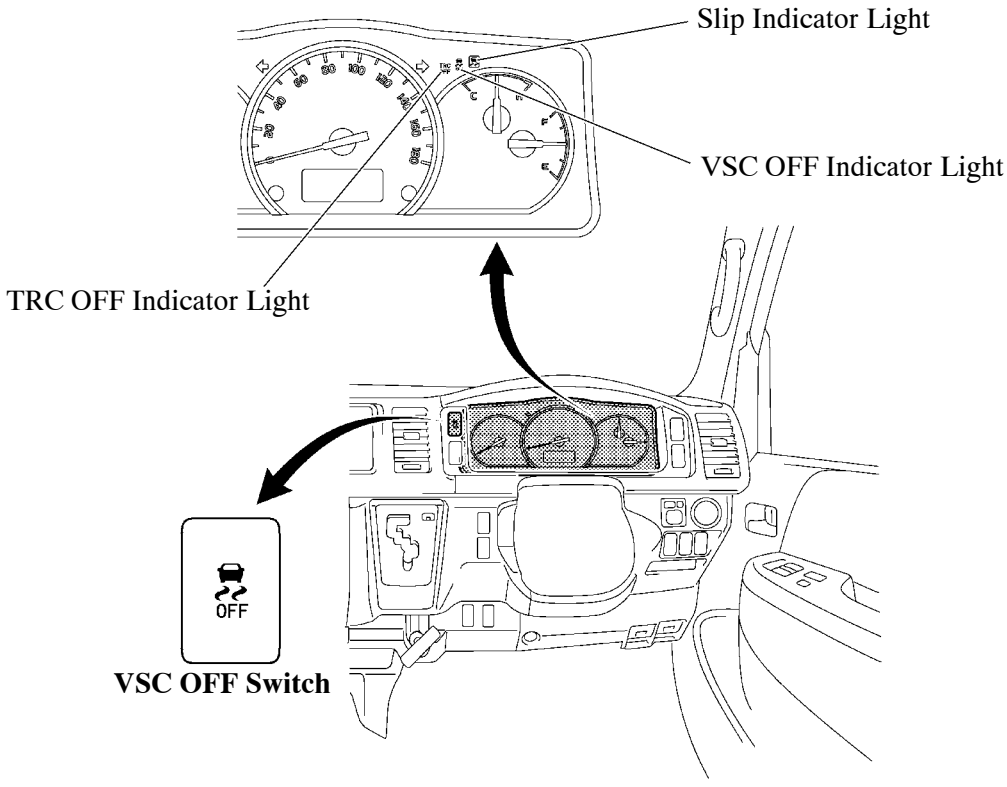
Digital Output

26T1CH20

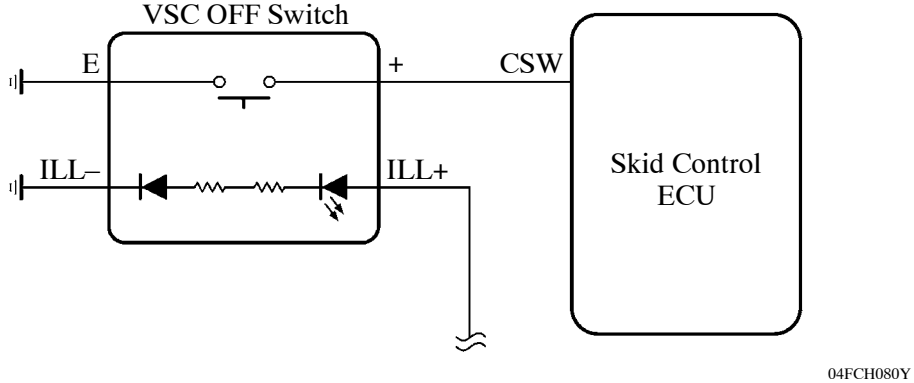
VSC OFF Switch

1) General

The VSC OFF switch has been provided.
The operation of the VSC and TRC functions can be stopped by the VSC OFF switch. While the vehicle is running off the shoulder of the road or running on the dirt road, the engine output control is stopped to maintain drive torque.

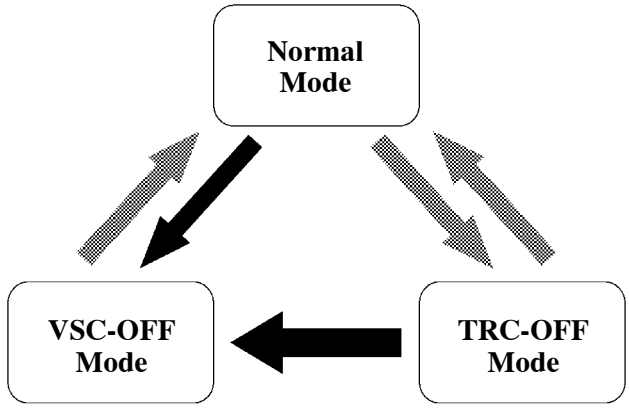


▶ Wiring Diagram ◀



2) Function of VSC OFF Switch

- The VSC OFF switch can select the 3 modes (Normal mode, TRC-OFF mode, VSC-OFF mode).
- After the ignition switch is turned OFF in the TRC-OFF mode or VSC-OFF mode, turning the ignition switch ON (IG) again selects the Normal mode.



: Switch Operation (Press shortly.)

: Switch Operation
(Keep pressing for 3 seconds with the vehicle at a standstill.)

04FCH153Y

- The operations of the brake control functions in each mode are as follows:

○: Controllable ×: Not Controllable

Item	Brake Control Function		Slip Indicator Light	VSC OFF Indicator Light	TRC OFF Indicator Light
	TRC	VSC	 02W6CH24	 02W6CH14	 02W6CH15
Normal Mode	○	○	Light Off	Light Off	Light Off
TRC-OFF Mode	×	○	Light Off	Light Off	Light On
VSC-OFF Mode	×	×*	Light Off	Light On	Light On

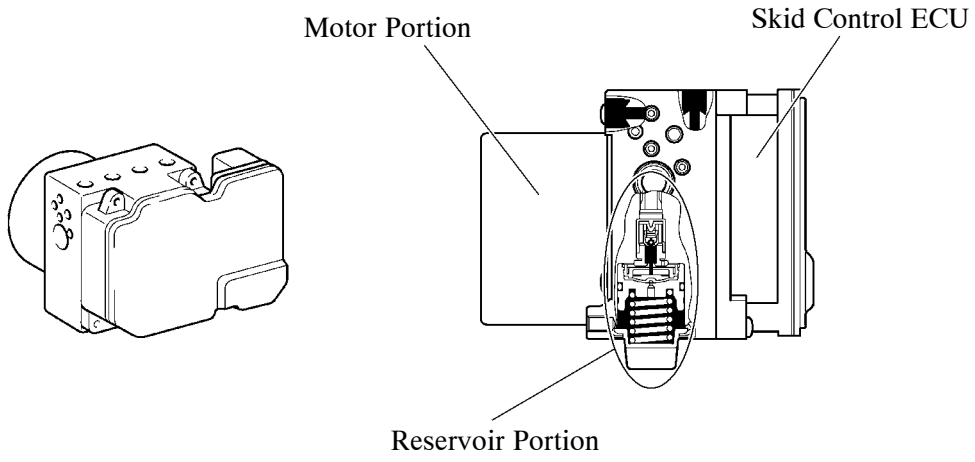
*: The control is effected during braking or while the yaw rate is large.

NOTE

The TRC and VSC functions control brake hydraulic pressure and engine output to ensure vehicle stability.
Therefore, operate the VSC OFF switch (stop the operation of the TRC and VSC functions) only when it is necessary.

Brake Actuator

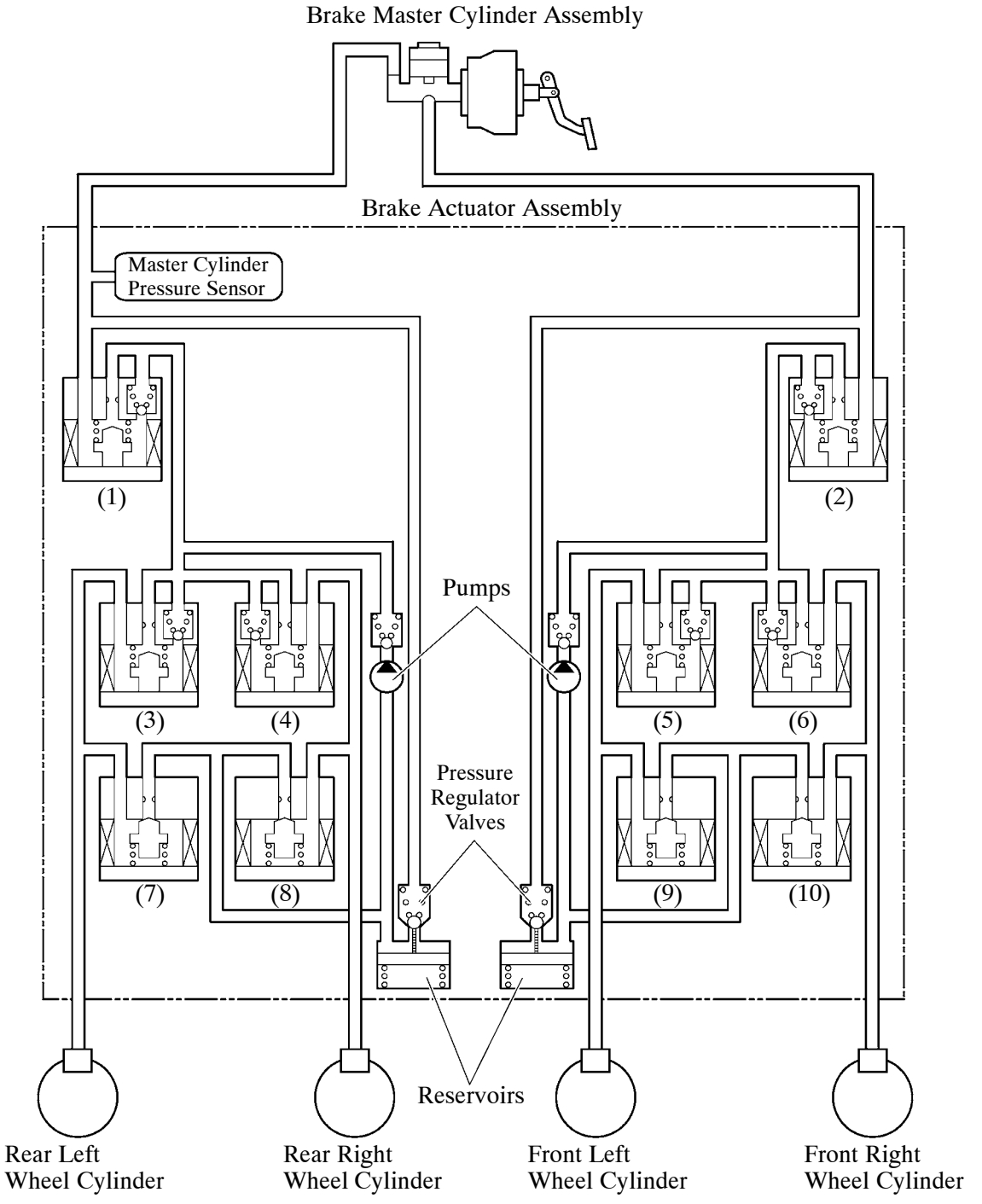
The brake actuator assembly consists of the actuator, skid control ECU, solenoid relay, pump motor, and master cylinder pressure sensor.



26T1CH08D

- The actuator portion consists of 10 solenoid valves, 2 pressure regulator valves, 2 pump, 2 reservoirs, and master cylinder pressure sensor.
- The 10 solenoid valves consist of 2 master cylinder cut solenoid valves [(1), (2)], 4 pressure holding solenoid valves [(3), (4), (5), (6)], and 4 pressure reduction solenoid valves [(7), (8), (9), (10)].

▶ Hydraulic Circuit ◀

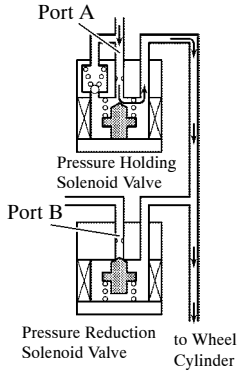
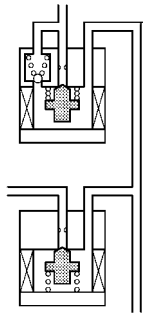
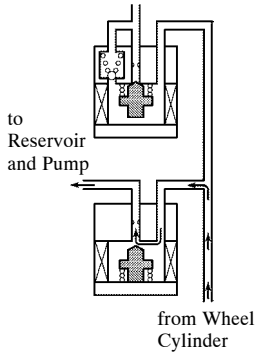


26T1CH13

7. System Operation

ABS with EBD Operation

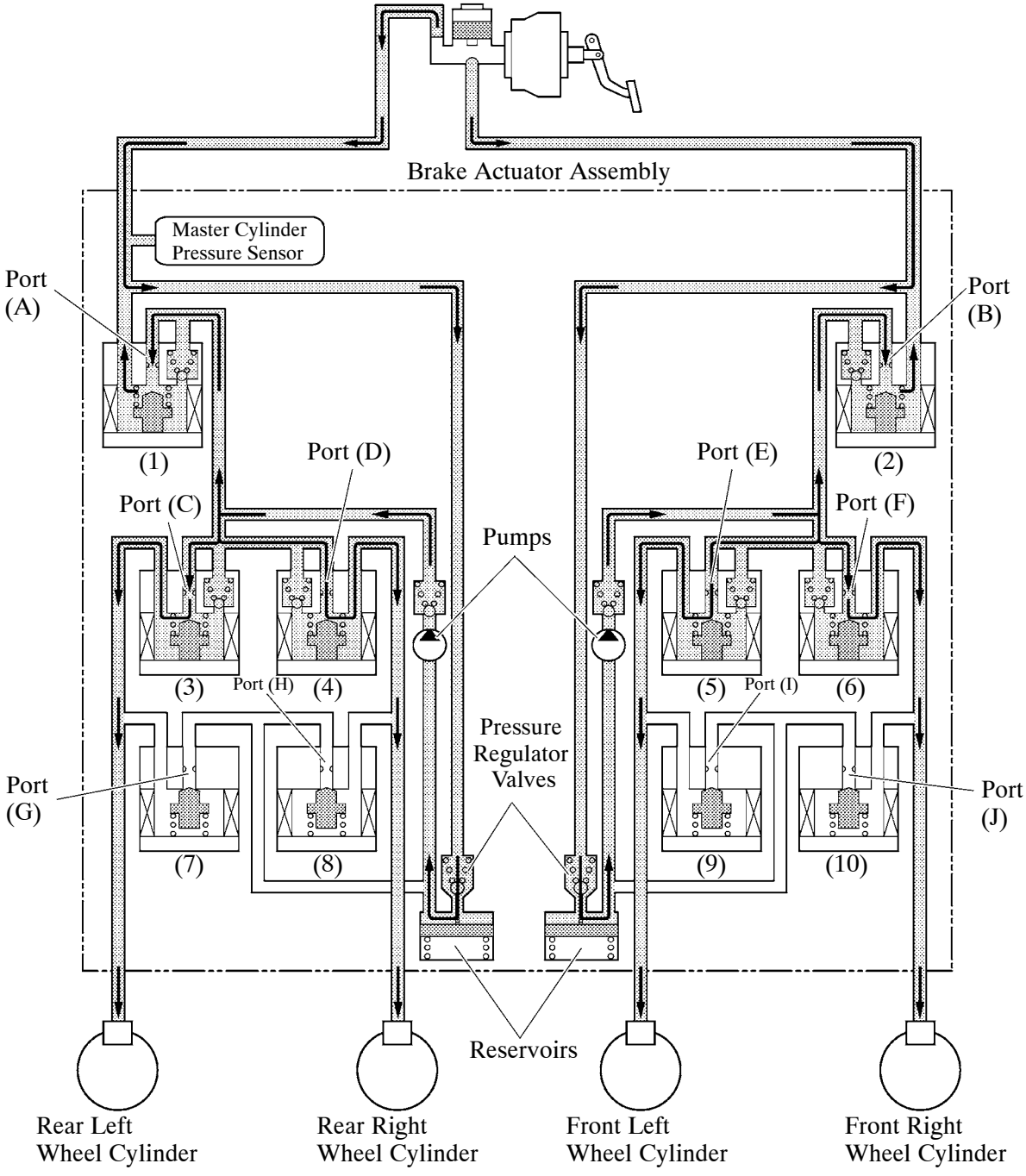
Based on the signals received from the 4 wheel speed sensors and yaw rate & deceleration sensor, the skid control ECU calculates the wheel rotation speed and deceleration for each wheel, in order to check for a wheel slippage condition. According to the slippage condition, the ECU controls the pressure holding solenoid valves and pressure reduction solenoid valves in order to adjust the fluid pressure of the brakes for each of the wheels in the following 3 modes: pressure reduction, pressure holding, and pressure increase modes.

Not Activated	Normal Braking	—	—
Activated	Pressure Increase Mode	Pressure Holding Mode	Pressure Reduction Mode
Hydraulic Circuit			
Pressure Holding Valve (Port A)	OFF/Open	ON/Closed	ON/Closed
Pressure Reduction Valve (Port B)	OFF/Closed	OFF/Closed	ON/Open
Pressure	Increase	Hold	Reduce

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, which is based on the master cylinder pressure sensor signals. If the skid control ECU judges the need for additional brake assist, pressure is generated by the pump in the brake actuator and directed to the brakes to apply a greater fluid pressure than is present in the master cylinder.

▶ Brake Assist Activated ◀



26T1CH14

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	←
	Port: (C), (D), (E), (F)		
(7), (8), (9), (10)	Pressure Reduction Solenoid Valve	OFF/Closed	←
	Port: (G), (H), (I), (J)		

*: The solenoid valves control the hydraulic pressure by adjusting continually between "open" and "closed" according to the operating conditions.

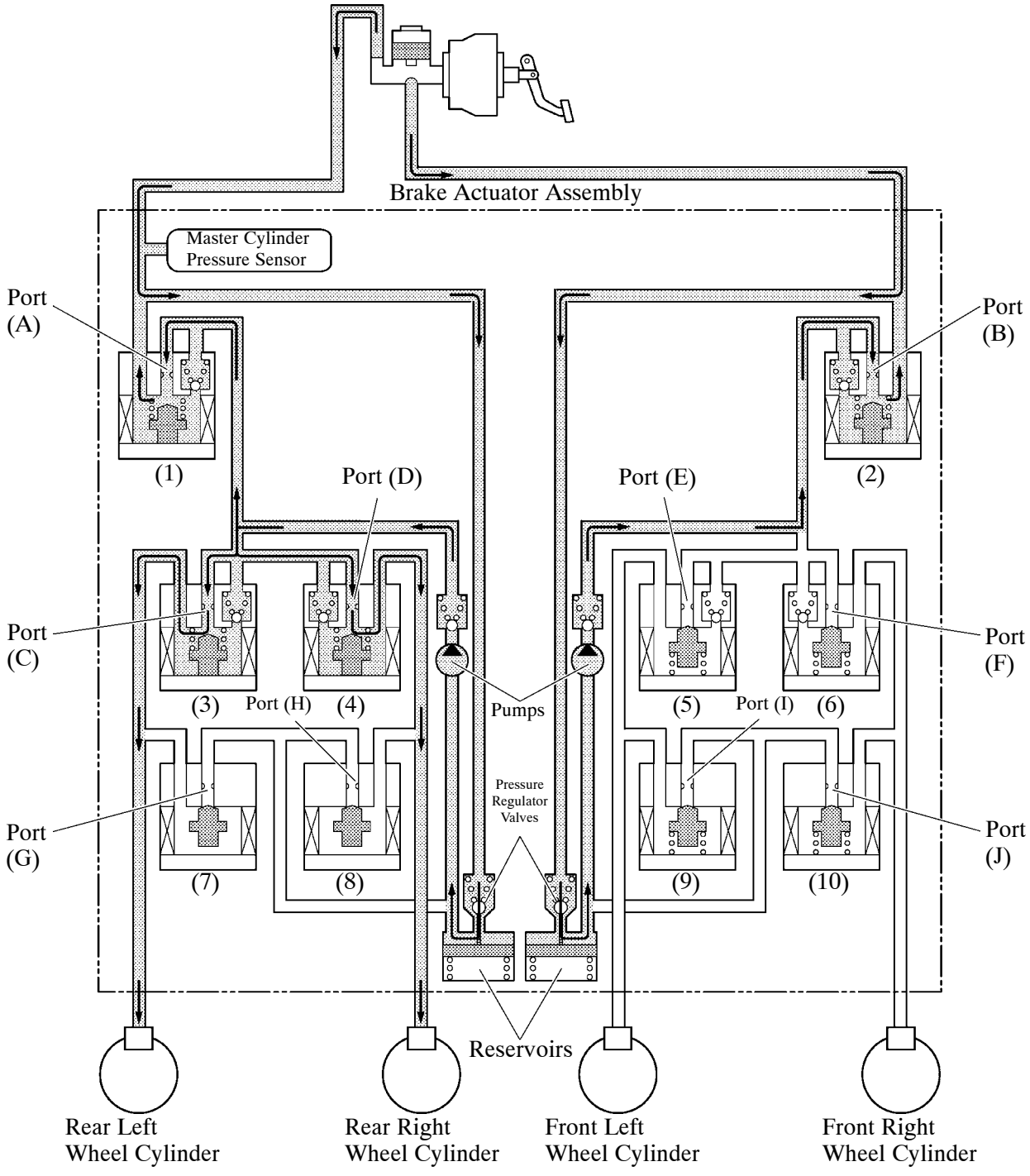
TRC Operation

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

▶ Pressure Increase Mode ◀



26T1CH15

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

*: The solenoid valves control the hydraulic pressure by adjusting continually between "open" and "closed" according to the operating conditions.

VSC Operation

1) General

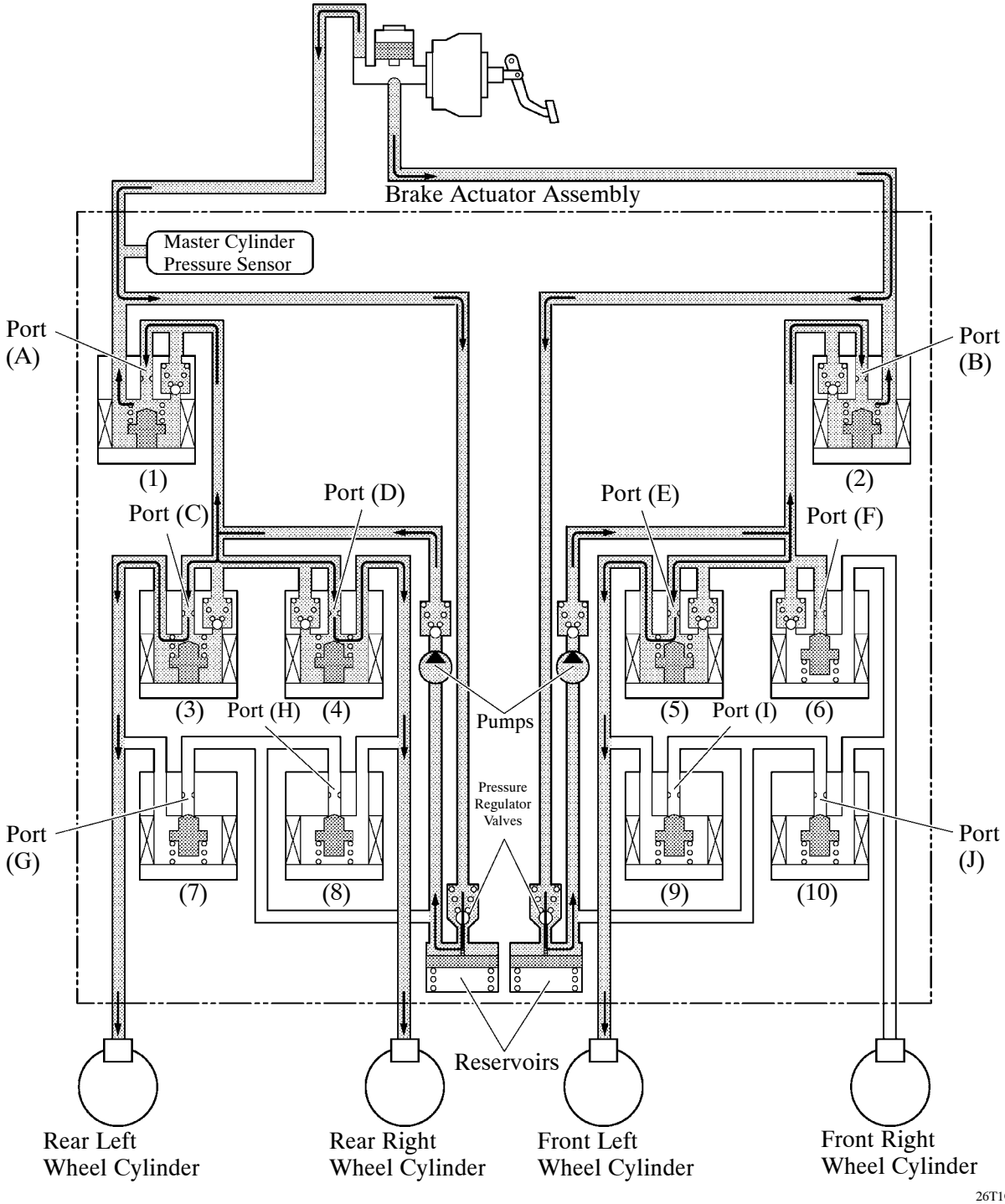
The VSC system, by way of solenoid valves, controls the fluid pressure that is generated by the pump and applies it to the brake wheel cylinder of each wheel in the following 3 modes: pressure reduction, pressure holding, and pressure increase modes. As a result, the tendency of the vehicle to experience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

2) Front Wheel Skid Restraining Control (Right Turn)

For front wheel skid restraining control, the brakes of the front wheel of the outer side of the turn and the rear wheels 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.
- In other operating modes, the pressure holding valve and the pressure reduction valve are turned ON/OFF according to the ABS with EBD operation pattern.

▶ Pressure Increase Mode ◀



26T1CH16

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

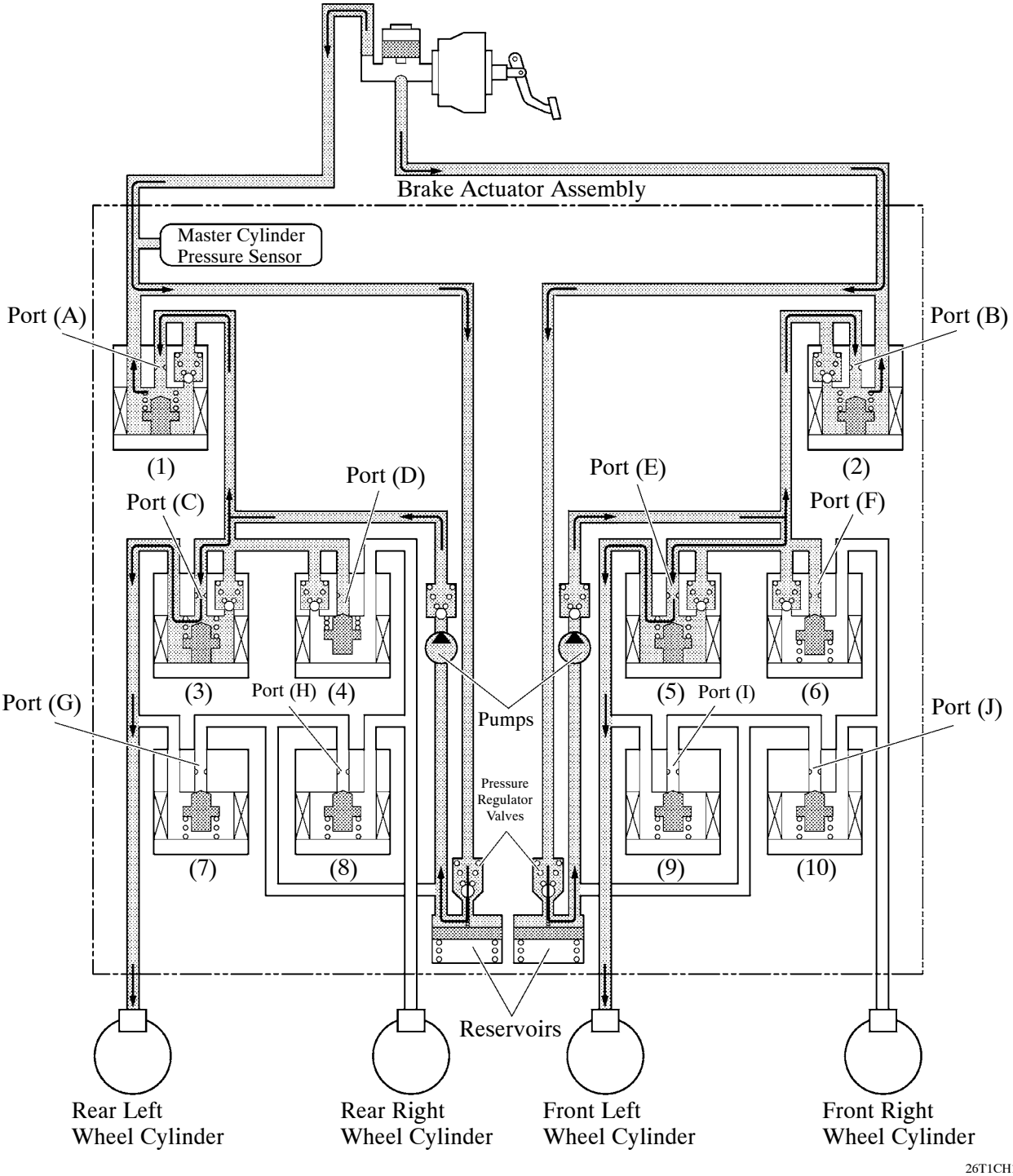
*: The solenoid valves control the hydraulic pressure by adjusting continually between “open” and “closed” according to the operating conditions.

3) Rear Wheel Skid Restraining Control (Right Turn)

For rear wheel skid restraining control, the brake of the front and rear wheels of the outer side 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 rear wheel skid condition while the vehicle makes a right turn.
- In other operating modes, the pressure holding valve and the pressure reduction valve are turned ON/OFF according to the ABS with EBD operation pattern.

▶ Pressure Increase Mode ◀



26T1CH17

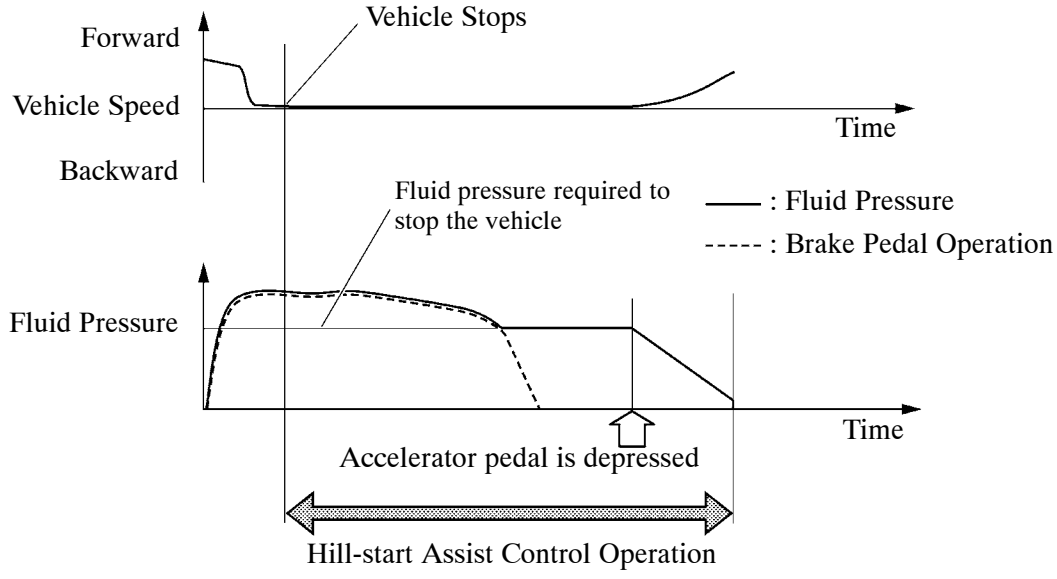
Item			VSC Not Activated	VSC Activated		
				Pressure Increase Mode	Pressure Holding Mode	Pressure Reduction Mode
(1), (2)	Master Cylinder Cut Solenoid Valve		OFF/Open	ON*	←	←
	Port: (A), (B)					
Front Brake	(5)	Pressure Holding Valve	OFF/Open	←	ON/Closed	←
		Port: (E)				
	(6)	Pressure Holding Valve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

*: The solenoid valves control the hydraulic pressure by adjusting continually between “open” and “closed” according to the operating conditions.

Hill-start Assist Operation

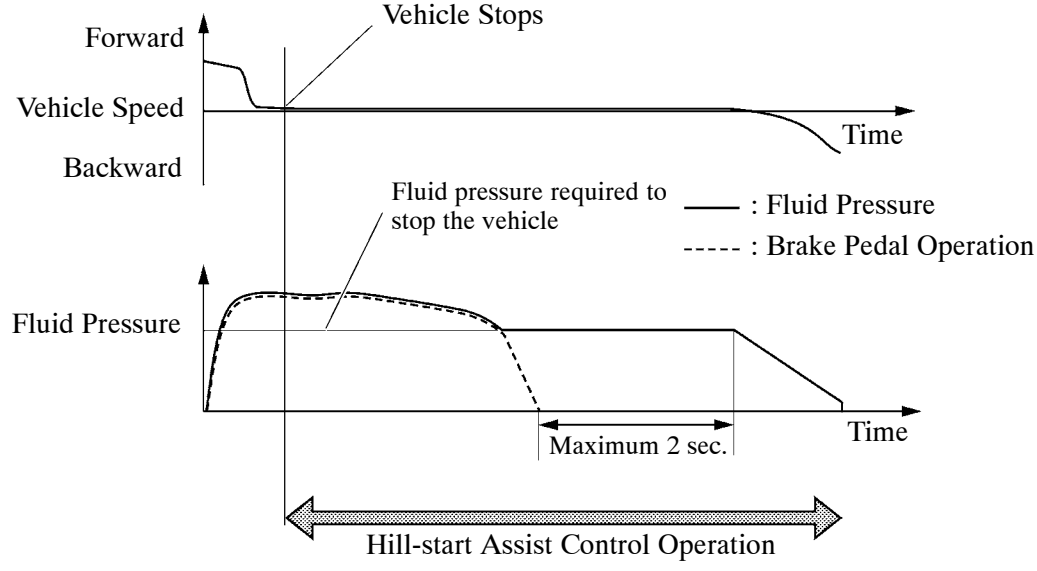
Hill-start assist control operation are performed by closing the master cylinder cut solenoid valves after the driver operates the brake pedal and leaving a certain amount of hydraulic pressure in the wheel cylinder. The diagram below shows the hydraulic circuit in the pressure holding mode.

▶ Example of Hill-start Assist Control when Climbing Uphill with Shift Lever in D (Driver Depresses Accelerator Pedal to Start Off after Hill-start Assist Control Operation) ◀



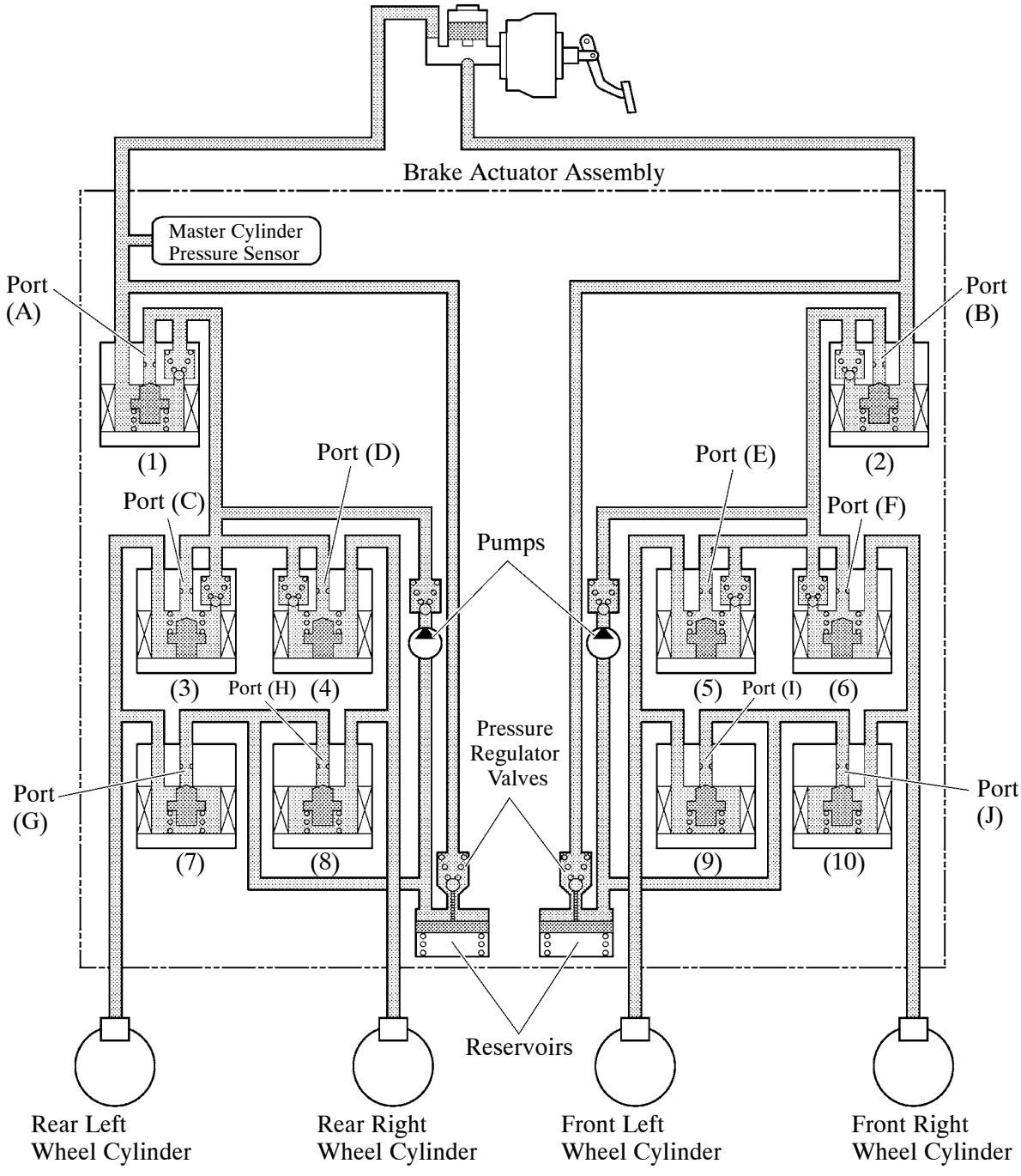
26T1CH22

▶ Example of Hill-start Assist Control when Climbing Uphill with Shift Lever in D (Driver Takes No Action after Hill-start Assist Control Operation) ◀



26T1CH23

▶ Pressure Holding Mode ◀



26T1CH18

Item			Hill-start Assist Control Operation		
			Not Activated	Pressure Holding Mode	Pressure Reduction Mode
(1), (2)	Master Cylinder Cut Solenoid Valve		OFF/Open	ON/Closed	OFF/Open
	Port: (A), (B)				
Front Brake	(5)	Pressure Holding Valve	OFF/Open	←	←
		Port: (E)			
	(6)	Pressure Holding Valve	OFF/Open	←	←
		Port: (F)			
	(9)	Pressure Reduction Valve	OFF/Closed	←	←
		Port: (I)			
	(10)	Pressure Reduction Valve	OFF/Closed	←	←
		Port: (J)			
	Wheel Cylinder Pressure	Right	—	Holding	Reduce
		Left	—	Holding	Reduce
Rear Brake	(3)	Pressure Holding Valve	OFF/Open	←	←
		Port: (C)			
	(4)	Pressure Holding Valve	OFF/Open	←	←
		Port: (D)			
	(7)	Pressure Reduction Valve	OFF/Closed	←	←
		Port: (G)			
	(8)	Pressure Reduction Valve	OFF/Closed	←	←
		Port: (H)			
	Wheel Cylinder Pressure	Right	—	Holding	Reduce
		Left	—	Holding	Reduce

Initial Check

After the ignition switch is turned ON (IG), and the vehicle attains an approximate speed of 6 km/h (4 mph) or more, the skid control ECU performs the initial check.
The functions of each solenoid valve and pump motor in the brake actuator assembly are checked in order.