■BRAKE CONTROL SYSTEM (ABS with EBD, Brake Assist, TRC, A-TRC, and VSC)

1. General

The brake control system has the following functions:

×: Standard OP: Option

Function	Outline	Equipment
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 the ABS, realizing the proper brake force distribution between front and rear wheels in accordance with the driving conditions. In addition, during braking while cornering, it also controls the brake forces of right and left wheels, helping to maintain the vehicle behavior.	×
Brake Assist	The primary purpose of Brake Assist is to provide an auxiliary brake force to assist a driver who cannot generate a large brake force during emergency braking, thus helping improve the vehicle's brake performance.	×
TRC (Traction Control)	TRC helps prevent the drive wheels from slipping if the driver presses the accelerator pedal excessively when starting off or accelerating on a slippery surface.	×
A-TRC (Active Traction Control)	When the A-TRC switch is turned on with the transfer shift lever in the L4 or LL position, the A-TRC operates. A-TRC controls the engine output and the brake hydraulic pressure that is applied to the slipping wheel, and distributes the drive force that would have been lost through the slippage to the remaining wheels in order to achieve an LSD effect.	OP*
VSC (Vehicle Stability Control)	The VSC helps prevent the vehicle from slipping sideways as a result of strong front wheel skid or strong rear wheel skid during cornering.	×

*: Models with rear differential lock are also equipped with A-TRC.

2. Drive Modes

Drive Modes and Each Function

The functions of the various drive modes are shown in the following table:

▶ Full-time 4WD Models (M/T) ◀

○: Operate

Drive Mode			Brake Control					
			ABS	EBD	Brake Assist	TRC	A-TRC	VSC
4WD	H		○	○	○	○	-	○
	HL		○	○	○	○*2	-	-
	LL	Rear Diff. Free	○	○	○	-	○*3	-
		Rear Diff. Lock*1	-	○	-	-	○*4	-

*1: Models with Rear Diff. Lock *2: Engine output is not regulated.
*3: When the A-TRC switch is turned on.
*4: When the A-TRC switch is turned on and vehicle speed is 6 mph (10 km/h) or less.

▶ Part-time 4WD Models (A/T) ◀

○: Operate

Drive Mode			Brake Control					
			ABS	EBD	Brake Assist	TRC	A-TRC	VSC
2WD	H2		○	○	○	○	-	○
4WD	H4		○	○	○	○*2	-	-
	L4	Rear Diff. Free	○	○	○	-	○*3	-
		Rear Diff. Lock*1	-	○	-	-	○*4	-

*1: Models with Rear Diff. Lock *2: Engine output is not regulated.
*3: When the A-TRC switch is turned on.
*4: When the A-TRC switch is turned on and vehicle speed is 6 mph (10 km/h) or less.

Rear Diff. Lock Mode (Models with Rear Diff. Lock)

When the rear differential is locked, the operation of ABS, Brake Assist, TRC/A-TRC, and VSC will be halted and the ABS warning light, the VSC OFF indicator light and the slip indicator light turn ON.

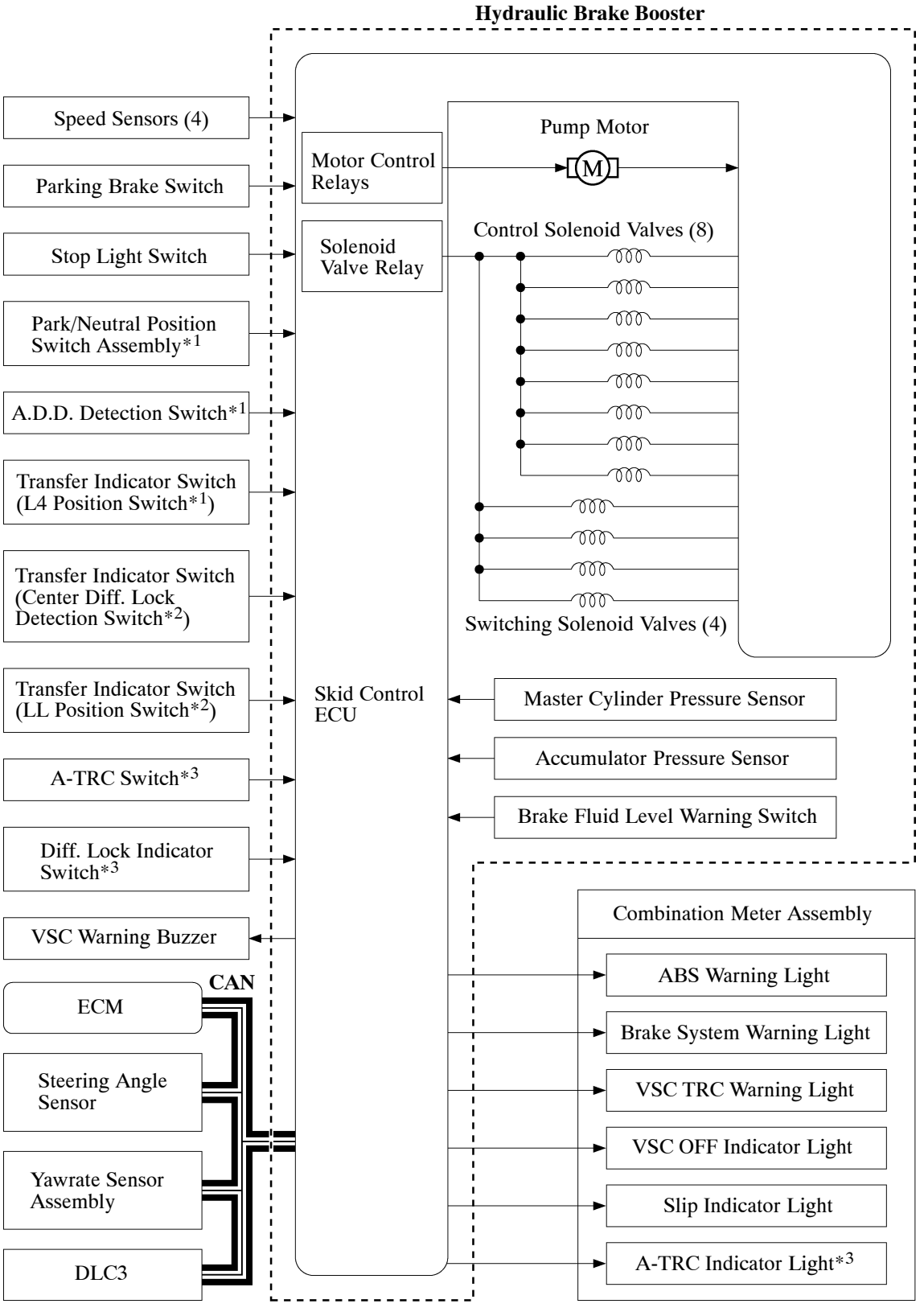
Center Diff. Lock Mode (Full-time 4WD Models with Manual Transmission)

When the transfer shift lever is in the HL position, VSC operation will be halted and the VSC OFF indicator light will turn ON.

H4 Mode (Part-time 4WD Models with Automatic Transmission)

When the transfer shift lever is in the H4 position, VSC are halted and the VSC OFF indicator light turns ON.

3. System Diagram



*1: Models with Automatic Transmission *2: Models with Manual Transmission
*3: Models with Rear Diff. Lock

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4. Outline of EBD Control

General

The EBD control distributes the braking force in accordance with the vehicle's driving conditions. The Skid Control ECU electrically controls the control solenoid valves to distribute the braking force.

- Braking force distribution is divided into two main categories: one is to the front and rear wheels, and the other is to the right to left sides (braking while cornering).

Front/Rear Wheel Brake Force Distribution

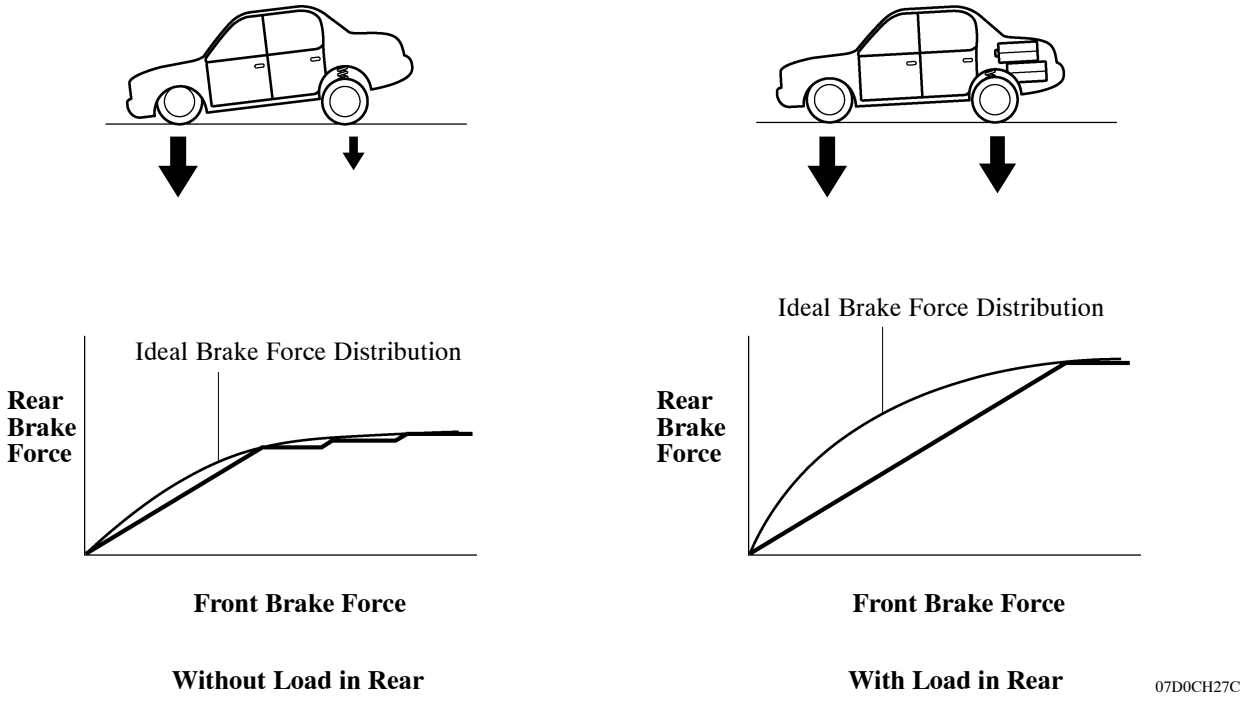
If the brakes are applied while the vehicle is moving straight forward, the transfer of the load reduces the weight that is applied to the rear wheels. The Skid Control ECU determines this condition by way of the signals from the speed sensors, and the brake actuator regulates the distribution of the brake force of the rear wheels to optimally control braking operation.

For example, the amount of the brake force that is applied to the rear wheels during braking varies whether or not 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 the brake force to the rear is optimally controlled in order to effectively utilize the braking force of the rear wheels under these conditions.

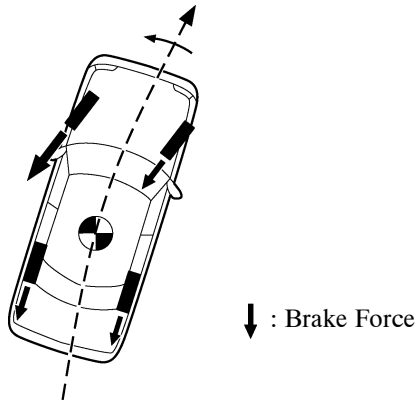
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▶ EBD Control Concept ◀



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

When the brakes are applied while the vehicle is cornering, the load that is applied to the inner wheel decreases as the load applied to the outer wheel increases.
The Skid Control ECU determines this condition by way of the signals from the speed sensors, and the brake actuator regulates the brake force in order to optimally control the distribution of the brake force to the inner and outer wheels.

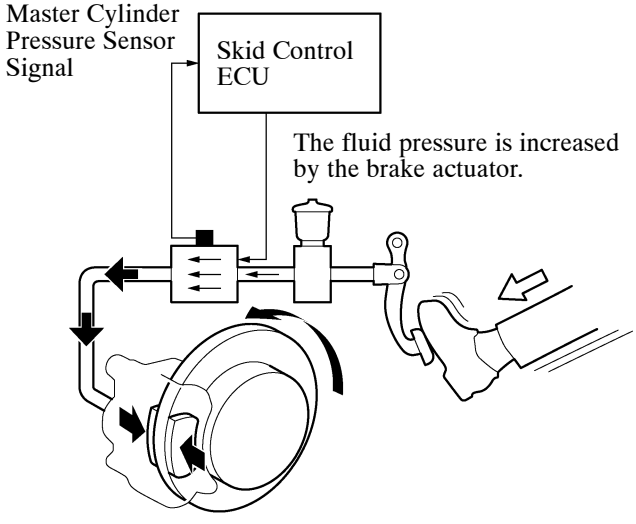


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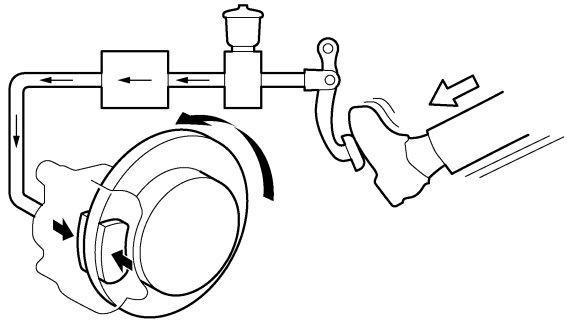
5. Outline of Brake Assist

- The Brake Assist, in combination with ABS, helping improve the vehicle's brake performance.
- The Brake Assist interprets a quick push of the brake pedal as emergency braking. It 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.
- When the vehicle is fully loaded, stronger brake force may be required, even if the brakes are not applied quickly. In such a case where stronger brake force is required, the Brake Assist also increases brake force.

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

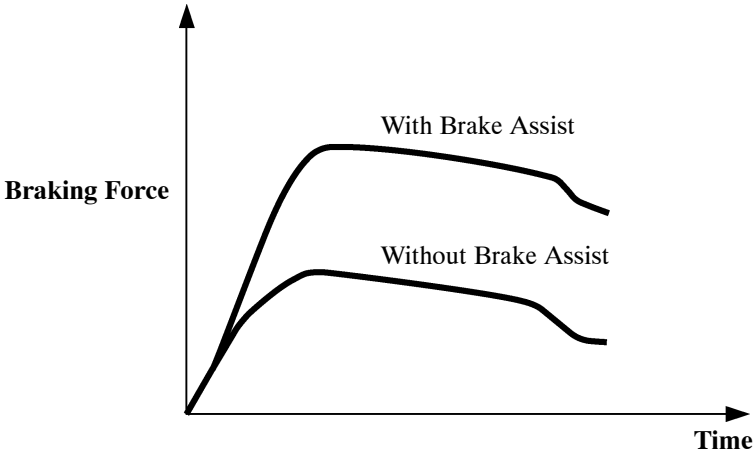


With Brake Assist D13N67



Without Brake Assist* D13N68

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

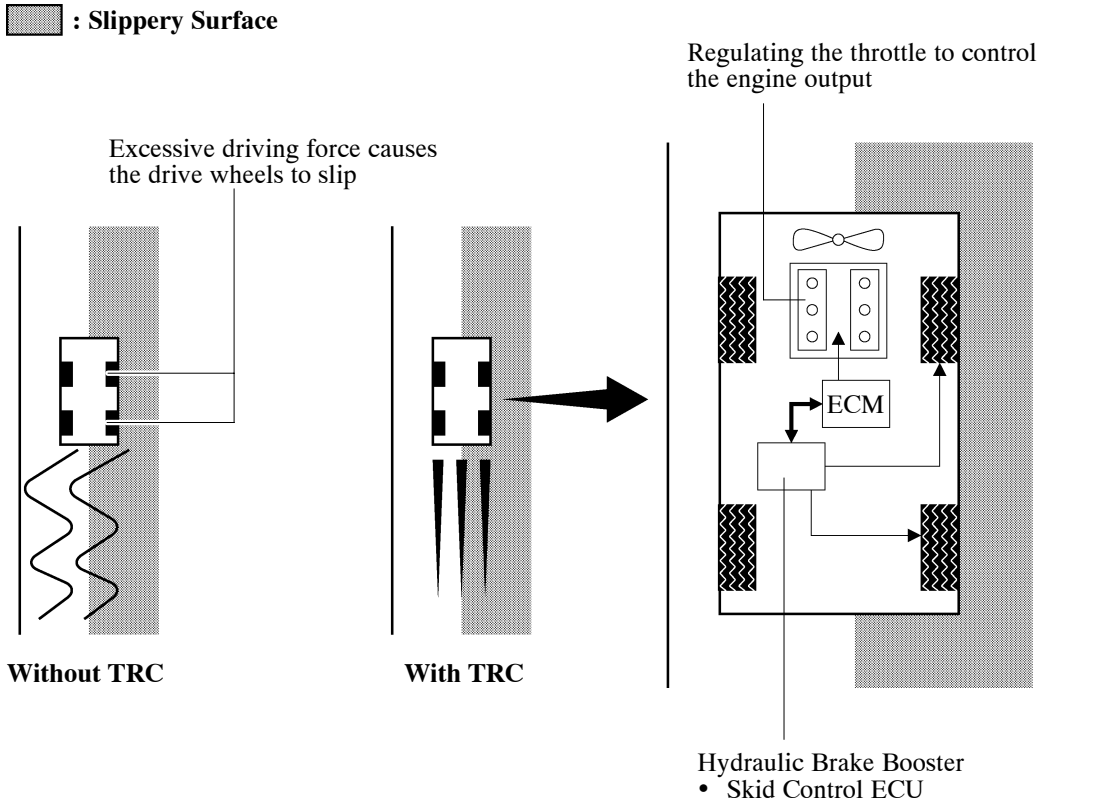


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6. Outline of TRC

- If the driver presses the accelerator pedal aggressively when initially accelerating 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, TRC helps minimize the slippage of the drive wheels, thus helping to apply the drive force that is appropriate for the road surface conditions.
- For example, a comparison may be made between two vehicles, one with 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 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, TRC can constantly help the driver to maintain stability while accelerating.

▶ Driving condition on road with different surface friction characteristics ◀



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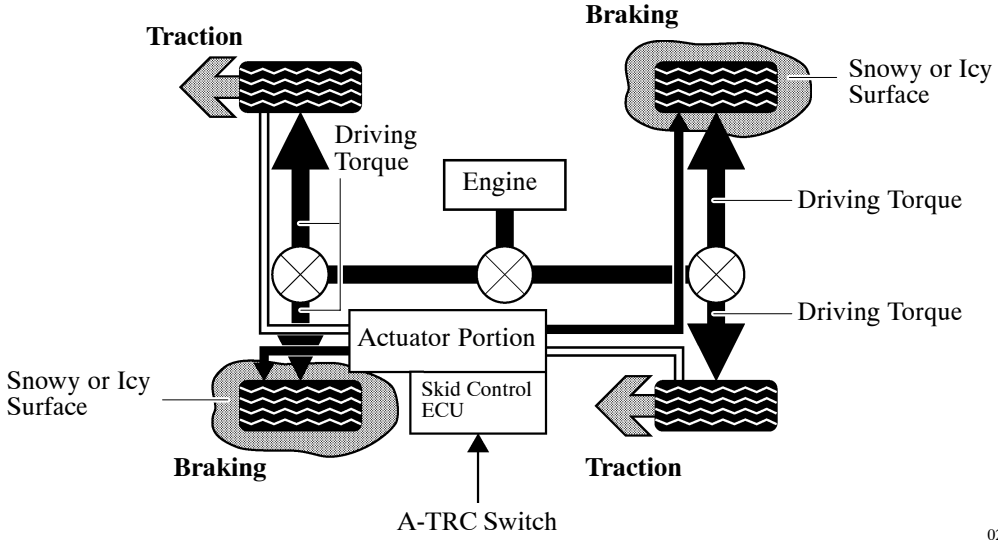
7. Outline of A-TRC (For Models with Rear Diff. Lock)

General

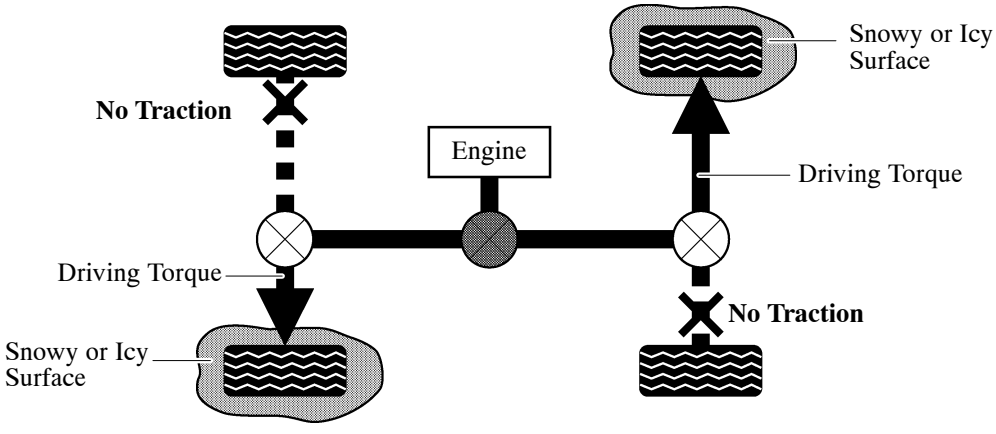
When the transfer shift lever is L4 or LL position and A-TRC switch is turned on, the A-TRC helps restrain wheelspin by controlling the brake fluid pressure that is applied to the spinning wheels, and distributes the drive force that would have been lost through the slippage to the remaining wheels in order to achieve an effect that is similar to LSD.

- It independently controls the brake hydraulic pressure to the four wheels in accordance with the extent of the slippage at the wheels, as detected by the Skid Control ECU.

▶ With A-TRC ◀



▶ Without A-TRC ◀



Effectiveness of A-TRC

The effectiveness of A-TRC is as follows:

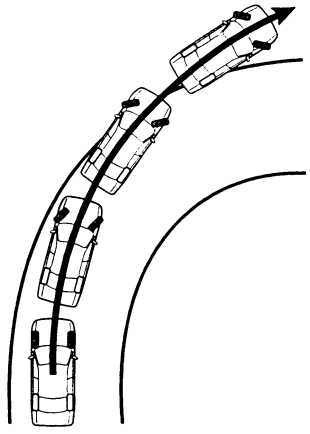
- Off-road drivability that is equivalent to having the center differential locked and limited slip differentials on both front and rear has been realized.
- This function makes the operation of the differential lock switches basically unnecessary to ensure the ease of driving.
- A-TRC allows for drivability benefits similar to those of locked differentials, while still allowing for the vehicle to be steered at low speeds, without the binding that would normally be associated with locked differentials.

8. Outline of VSC

General

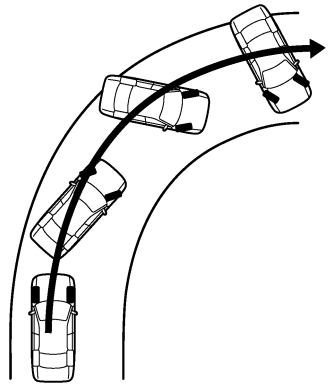
The followings are two examples that can be considered as circumstances in which the tires exceed their lateral grip limit.
The VSC is designed to help control the vehicle behavior by controlling the engine output and the brakes at each wheel when the vehicle experiences one of the conditions indicated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



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Front Wheel Skid Tendency



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Rear Wheel Skid Tendency

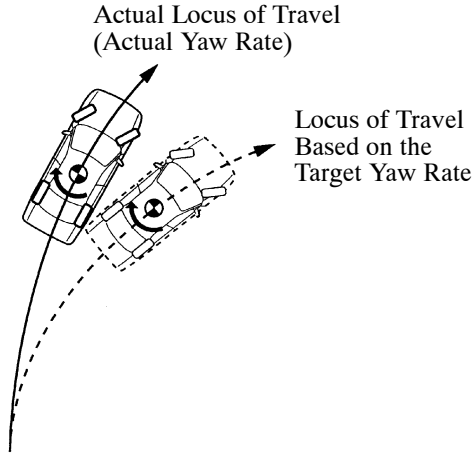
Method for Determining the Vehicle Condition

1) General

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 used by the Skid Control ECU for calculations.

2) Determining a Front Wheel Skid

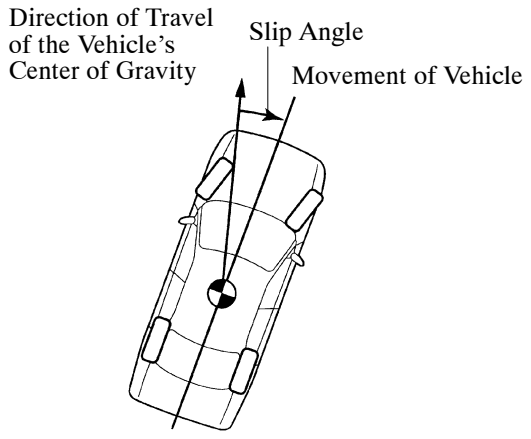
Whether or not the vehicle is experiencing a front wheel skid is determined by the difference between the target yaw rate and the vehicle's actual yaw rate.
When the vehicle's actual yaw rate is smaller than the target yaw rate (a target yaw rate is determined based on the vehicle speed and steering 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.



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3) 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.



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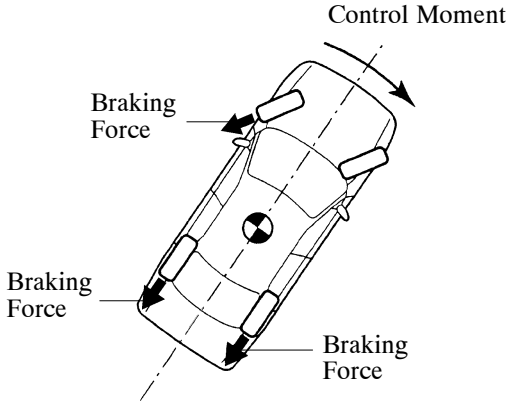
VSC Operation Methods

1) General

When the Skid Control ECU determines that the vehicle exhibits a tendency to front wheel skid or rear wheel skid, it decreases 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.

2) 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 outside wheel (the outside of the turn) and rear wheels in order to restrain the front wheel skid tendency.

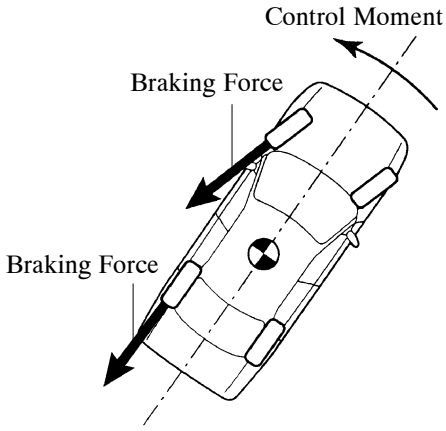


Making a Right Turn

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3) Dampening a Strong Rear Wheel Skid

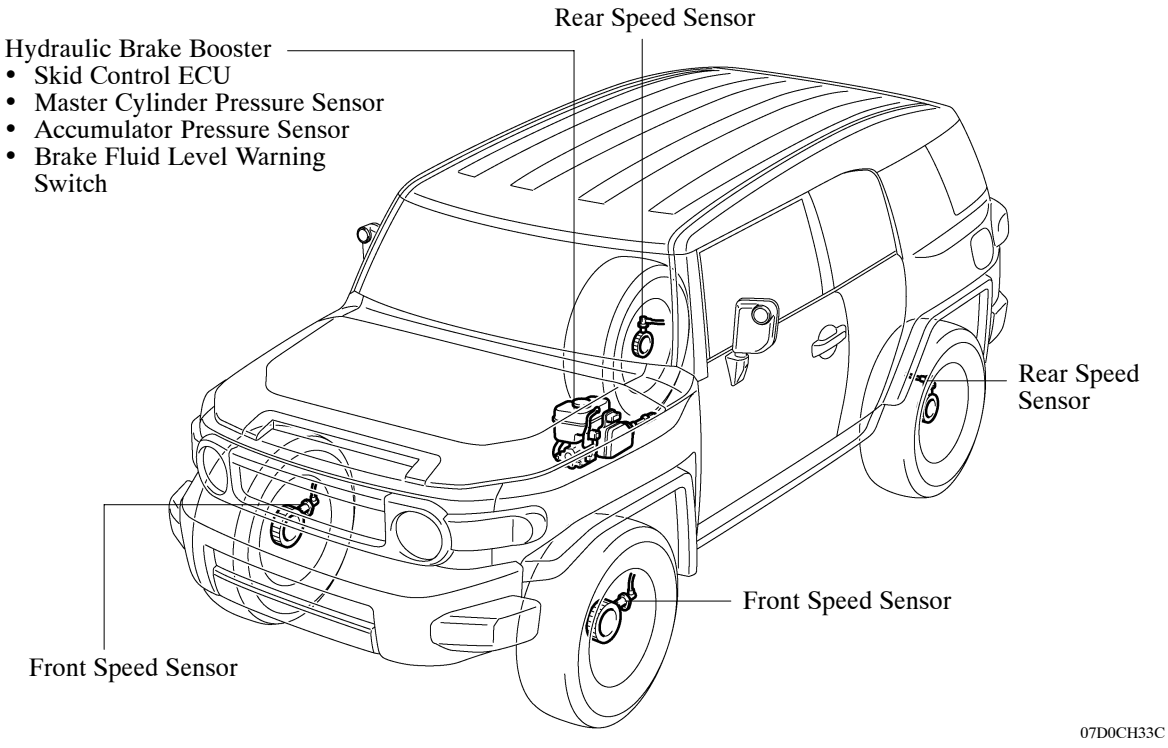
When the Skid Control ECU determines that there is a large rear wheel skid tendency, it attempts to counteract the tendency based on the extent of that tendency. It applies the brakes of the front and rear outer wheels (the outside of the turn), and generates an outward moment of inertia in the vehicle, 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 rear brakes, as necessary.

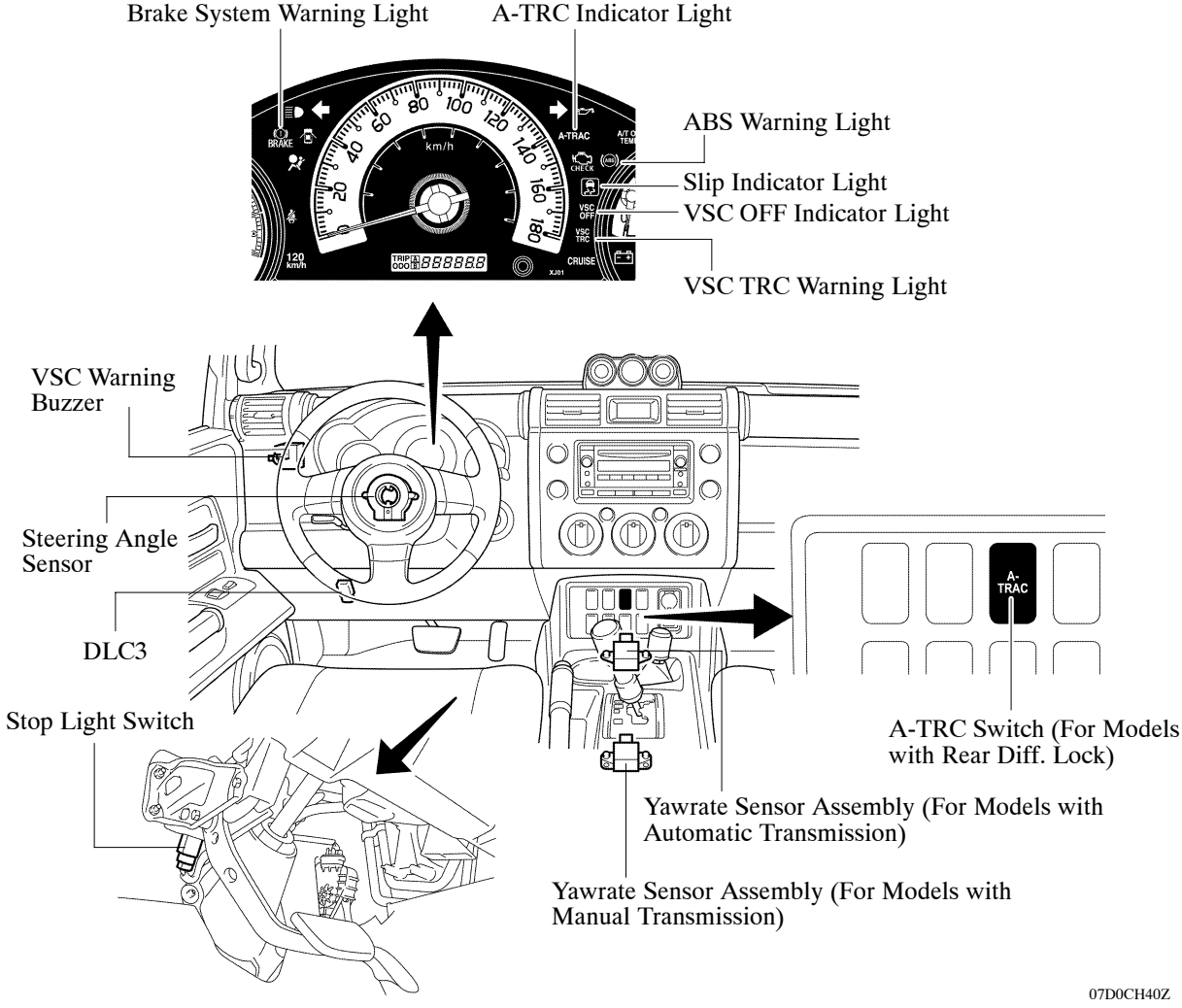


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Making a Right Turn

9. Layout of Main Components





10. Function of Main Components

Component		Function
Hydraulic Brake Booster	Skid Control ECU	Judges the vehicle driving condition based on signals from each sensor, and sends brake control signals to the control solenoid valves and switching solenoid valves.
	Brake Actuator Portion • Control Solenoid Valves (8) • Switching Solenoid Valves (4) • Pump Motor	• Assists with the brake pedal effort applied to the brake pedal. • Changes the brake fluid path based on the signals from the skid control ECU during the operations of the ABS with EBD, Brake Assist, TRC, A-TRC, and VSC, in order to control the fluid pressure that is applied to the wheel cylinders.
	Solenoid Valve Relay	Supplies or cuts off power to control solenoid valves and switching solenoid valves.
	Motor Control Relays (2)	Supplies or cuts off power to pump motor.
	Master Cylinder Pressure Sensor	Detects the master cylinder pressure.
	Accumulator Pressure Sensor	Detects the accumulator pressure.
	Brake Fluid Level Warning Switch	Detects the brake fluid level.
Combination Meter Assembly	ABS Warning Light	• When the Skid Control ECU detects a malfunction and determines that the ABS, EBD, or brake assist is not available, the ABS warning light comes on to alert the driver. • When the rear differential is locked, the ABS warning light comes on to inform the driver that the ABS is not available. (Models with Rear Differential Lock)
	Brake System Warning Light	When the Skid Control ECU detects a malfunction and determines that the EBD is not available, the brake system warning light comes on along with the ABS warning light to alert the driver.
	VSC TRC Warning Light	When the skid control ECU detects a malfunction and determines that the TRC, A-TRC, or VSC is not available, the VSC TRC warning light comes on to alert the driver.
	VSC OFF Indicator Light	• When the skid control ECU detects a malfunction and determines that the VSC is not available, the VSC OFF and slip indicator lights come on to alert the driver. • When the rear differential is locked, the VSC OFF indicator light lights up to alert the driver. (Models with Rear Diff. Lock) • When the center differential is locked, the VSC OFF indicator light lights up to alert the driver. (For Models with M/T) • When the transfer shift lever is H4 position, the VSC OFF indicator light lights up to alert the driver. (For Models with A/T)

(Continued)

Component		Function
Combination Meter Assembly	Slip Indicator Light	• When the skid control ECU detects a malfunction and determines that the VSC is not available, the VSC OFF and slip indicator lights come on to alert the driver. • When the TRC, or A-TRC is operated, slip indicator light blinks to inform the driver. • When the rear differential is locked, the slip indicator light lights up to alert the driver. (Models with Rear Diff. Lock) • When the transfer shift lever is L4 or LL position and A-TRC switch turns off, the slip indicator light lights up to alert the driver. (Models with Rear Diff. Lock)
	A-TRC Indicator Light*1	When the A-TRC switch turns on and the transfer shift lever is L4 or LL position, and the A-TRC indicator light lights up to inform the driver.
Speed Sensors (4)		Detects the wheel speed and rotating direction of each of four wheels.
Steering Angle Sensor		Detects the steering direction and steering angle of the steering wheel.
Yawrate Sensor Assembly		• Detects the vehicle's yaw rate. • Detects the vehicle's acceleration in the forward, rearward, and lateral.
VSC Warning Buzzer		The VSC warning buzzer has three types of sounds. • The buzzer sounds intermittently to inform the driver that the VSC are actives. • The buzzer sounds intermittently to inform the driver if the temperature of the hydraulic brake booster has increased excessively due to the continuous operation of the TRC or A-TRC. • The buzzer sounds continuously to alert the driver that the hydraulic pressure of the accumulator in the hydraulic brake booster has decreased, and that the brake pressure supply system in malfunctioning.
Stop Light Switch		Detects the brake pedal depressing signal.
Parking Brake Switch		Detects the parking brake signal.
A-TRC Switch		The A-TRC switch allows the driver to turn A-TRC on or off.
Transfer Indicator Switch (Rear Diff. Lock Detection Switch)*1		Detects the condition of the rear differential lock.
Transfer Indicator Switch (Center Diff. Lock Detection Switch)*2		Detects the condition of the center differential lock.
Transfer Indicator Switch (LL Position Switch)*2		Detects the LL condition of the transfer.

*1: Models with Rear Diff. Lock. *2: Models with Manual Transmission.

(Continued)

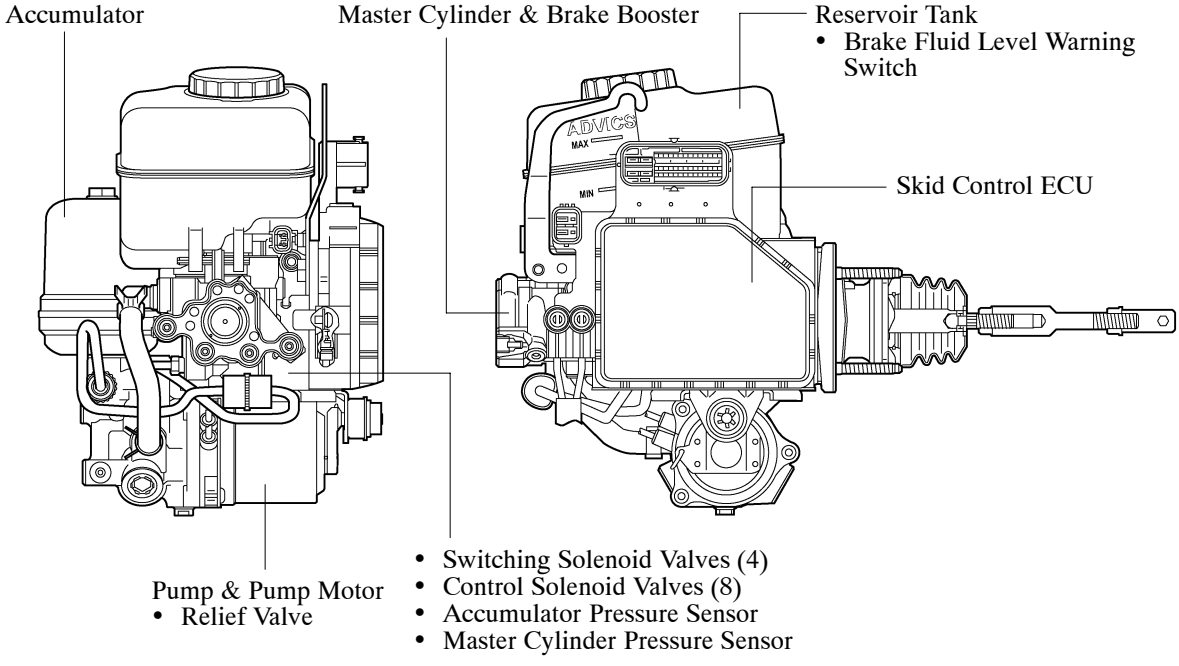
Component	Function
A.D.D. Detection Switch (Models with Automatic Transmission)	Detects the condition of the A.D.D..
L4 Position Switch (Models with Automatic Transmission)	Detects the L4 condition of the transfer.
ECM	• Sends the throttle valve angle signal, accelerator pedal position signal, engine speed signal, and intake air temperature signal to the Skid Control ECU. • Receives an engine output adjustment command signal from the Skid Control ECU. Based on this signal, the ECM operates the throttle valve to control engine output.

11. Hydraulic Brake Booster

General

The hydraulic brake booster consists of a brake pressure supply portion, brake pressure application portion, and brake control portion.

- The brake pressure supply portion is a pump & pump motor, relief valve, reservoir tank, brake fluid level warning switch, accumulator, and accumulator pressure sensor.
- The brake pressure application portion is a master cylinder & brake booster and master cylinder pressure sensor.
- The brake control portion is a Skid Control ECU, 4 switching solenoid valves, and 8 control solenoid valves.



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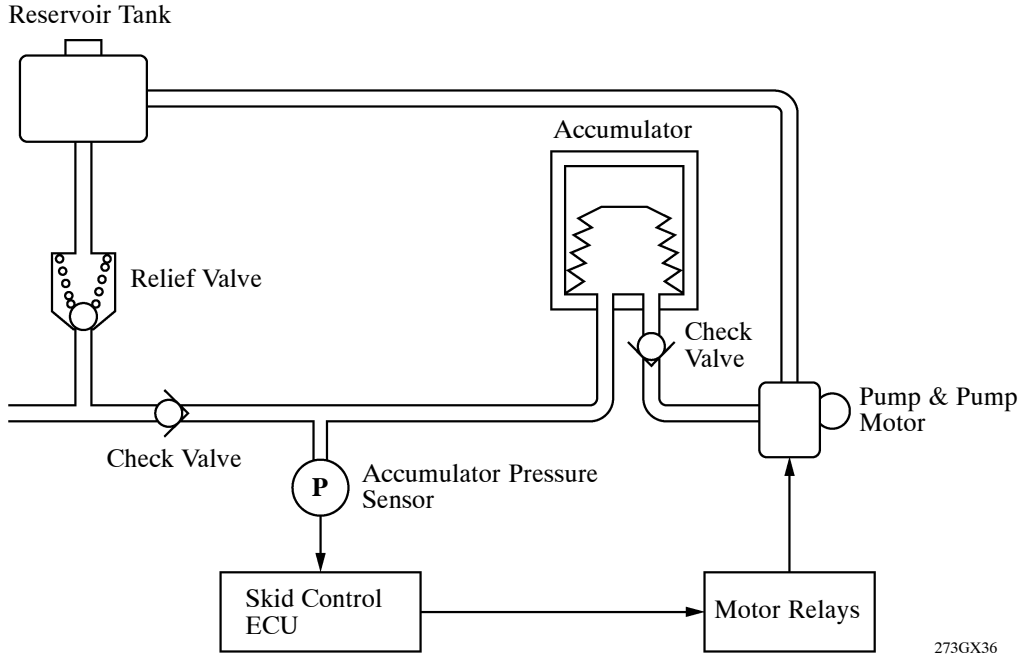
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Component		Function
Brake Pressure Portion	Pump & Pump Motor	Draws up the brake fluid from the reservoir tank and provides high hydraulic pressure to the accumulator.
	Accumulator	Stores the hydraulic pressure that was generated by the pump. The accumulator is filled with high-pressure nitrogen gas.
	Accumulator Pressure Sensor	Monitors the hydraulic pressure of the accumulator and outputs this signals for the pump motor control.
	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 accumulator pressure sensor.
	Reservoir Tank	Stores the brake fluid.
	Brake Fluid Level Warning Switch	Detects the low brake fluid level.
Brake Pressure Application Portion	Master Cylinder & Brake Booster	• Generates the hydraulic pressure that is provided to the wheel cylinders during normal brake. • Regulates the accumulator pressure in accordance with the pedal effort that is applied to the brake pedal and introduces this pressure to the booster chamber in order to provide a power assist to the brakes.
	Master Cylinder Pressure Sensor	Detects the master cylinder pressure and outputs this signal to the Skid Control ECU.
Brake Control Portion	Switching Solenoid Valves (4)	Switches the brake hydraulic path when the brake control system is activated.
	Control Solenoid Valves (8)	Controls the hydraulic pressure that is applied to the wheel cylinders during brake control.
	Skid Control ECU	• Judges the vehicle driving condition based on signals from each sensor, and sends brake control signals to the control solenoid valves and switching solenoid valves. • Operates/stops the pump & pump motor to control accumulator pressure based on accumulator pressure sensor signal.

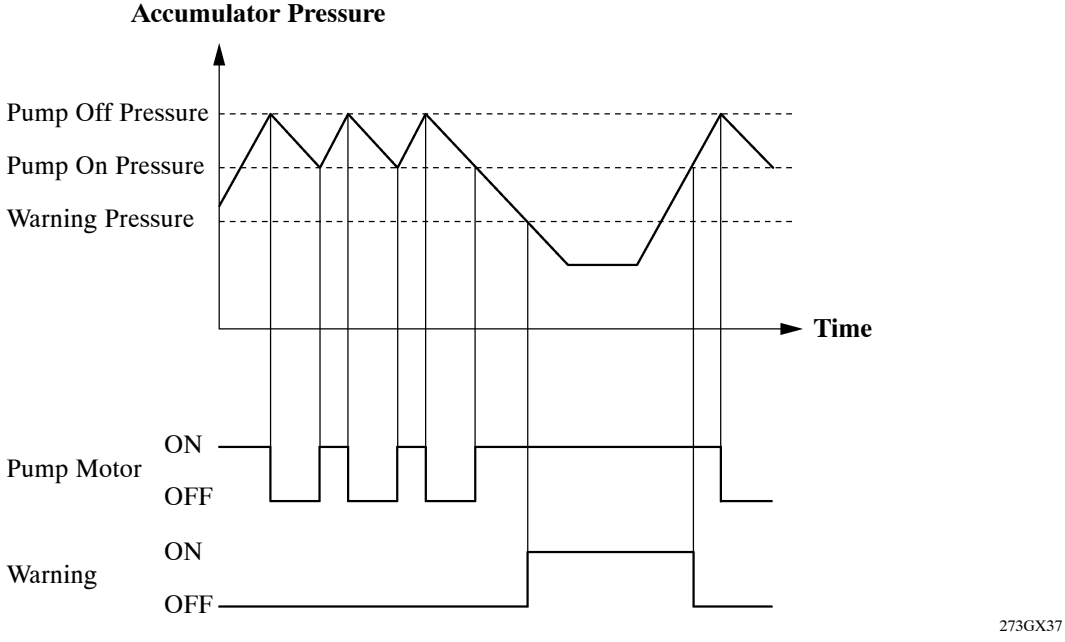
Brake Pressure Supply Portion

The brake pressure supply portion operates based on the accumulator pressure sensor signal as shown in the timing chart below.

- When the accumulator pressure drops to "pump ON pressure", the Skid Control ECU operates the pump & pump motor.
- When the accumulator pressure increases to "pump OFF pressure", the Skid Control ECU stops the pump & pump motor.
- When the accumulator pressure drops to "warning pressure", the Skid Control ECU illuminates all warning and indicator lights other than the A-TRC indicator lights, and sounds the VSC warning buzzer continuously.



▶ Timing Chart ◀



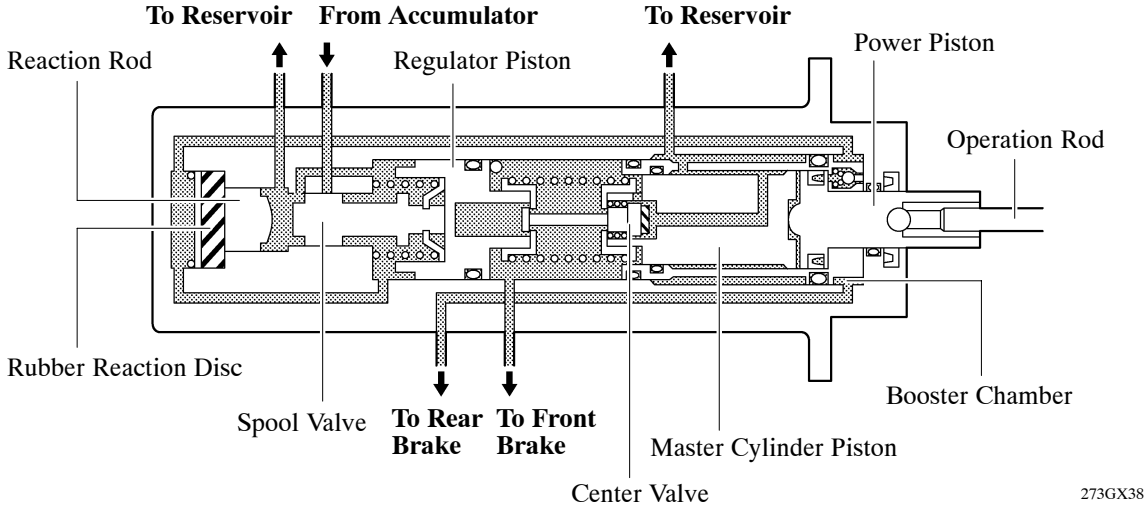
Master Cylinder & Brake Booster

1) Construction

The master cylinder & brake booster consists of a brake booster portion, master cylinder portion, and regulator portion. These are positioned coaxially to achieve a simple and compact construction.

- The brake booster portion consists of an operation rod, power piston and booster chamber.
- The master cylinder portion consists of a master cylinder piston (large diameter piston and small diameter piston), return spring and center valve.
- The regulator portion consists of a regulator piston, return spring, spool valve, reaction rod, and rubber reaction disc.

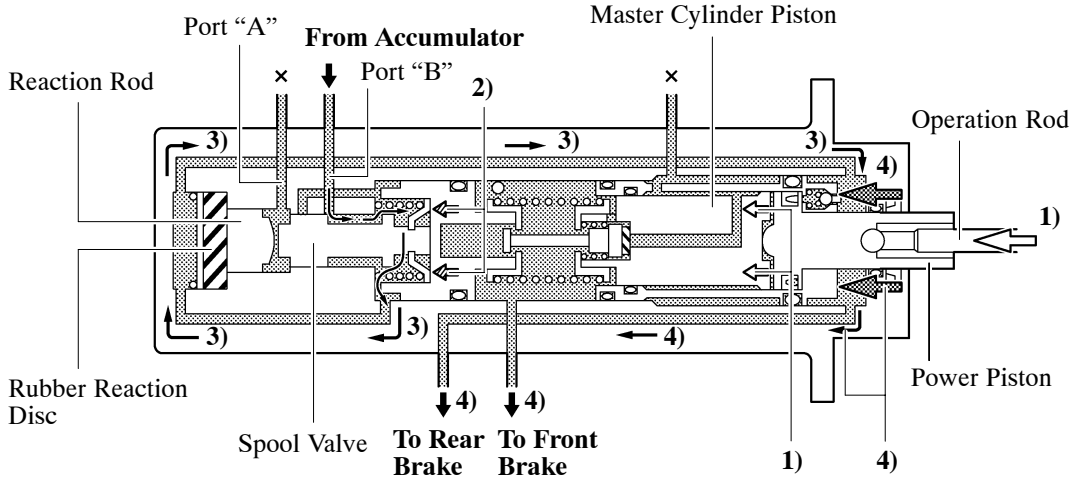
▶ Simplified Diagram ◀



2) Operation

a. Pressure Increase (Low Pressure)

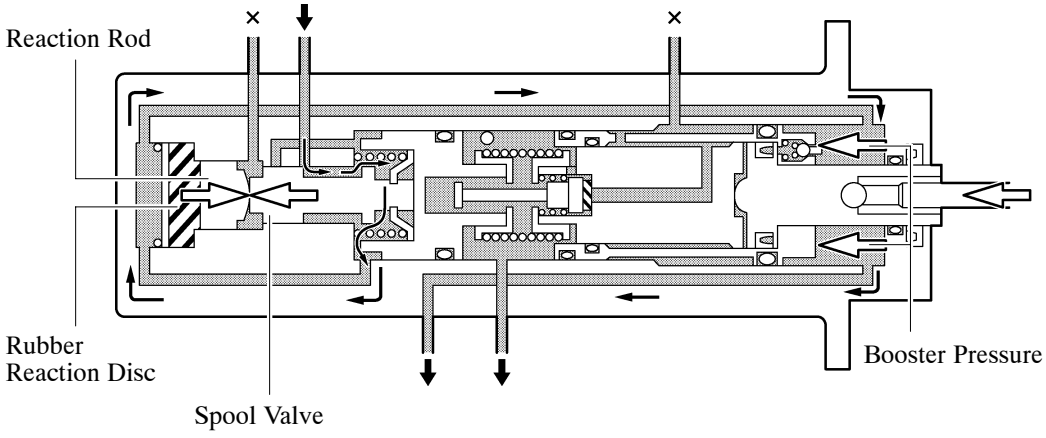
1) The pedal operation force is transmitted as follows: Operation Rod → Power Piston → Master Cylinder Piston (Small Diameter Piston)
2) The load setting of the master cylinder's return spring is higher than that of the regulator piston's return spring, the regulator piston gets pushed before the fluid in the master cylinder becomes compressed.
3) The spool valve closes the port "A" (between the reservoir tank and booster chamber) and opens the port "B" (between the reservoir tank and accumulator). Then, the pressurized brake fluid is introduced into the booster chamber to provide a power assist to the pedal effort. The pressure of the pressurized brake fluid is transmitted to the large diameter master cylinder piston.
4) This time, the power assist overcomes the force of the master cylinder's return spring. This causes the fluid in the master cylinder to become compressed and increases the pressure that is applied to the front brakes. At the same, 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 is not applied to the spool valve via the reaction rod.

b. Pressure Increase (High Pressure)

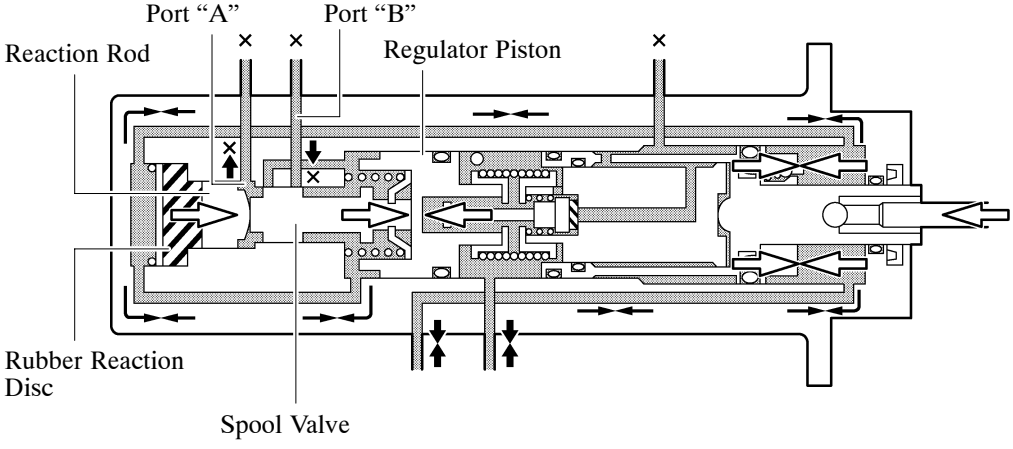
In contrast to the time when the pressure is low, when the pressure is high, the booster pressure that is applied to the rubber reaction disc increases. Accordingly, the rubber reaction disc deforms and causes a return force in the rightward direction to be applied to the spool valve via the reaction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



07D0CH34C

c. 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 port “B” from the booster chamber to the accumulator and port “A” to the reservoir. As a result, the brake is in the holding state.

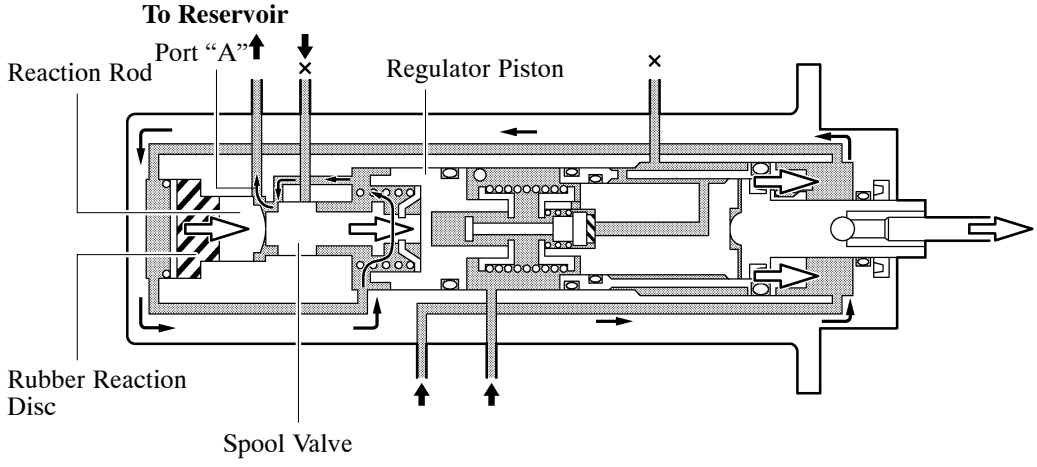


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d. Pressure Reduction

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 port "A" between the reservoir tank and the booster chamber opens.

The booster pressure becomes reduced in this state, creating a balance that corresponds to the change of brake pedal application force. This process occurs constantly to reduce the booster pressure and the master cylinder pressure in accordance with the force that is applied via the brake pedal.

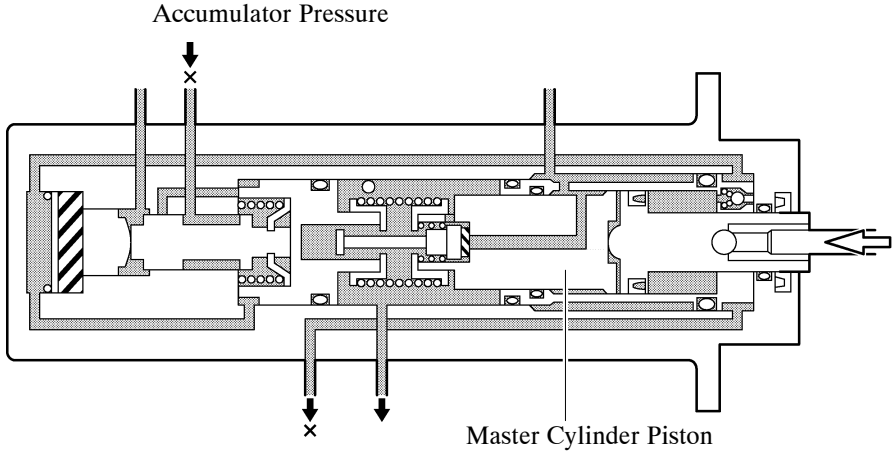


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e. During Brake Pressure Supply Malfunction

If the accumulator pressure is affected by any malfunction, no hydraulic pressure will be supplied to the booster chamber. For this reason, 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. Since there is no pressurized brake fluid in the large diameter master cylinder piston at this time, the piston does not move from the original position.

However, the pressure to the front brakes will be increased by the small diameter master cylinder piston in accordance with the pedal effort applied to the brake pedal.

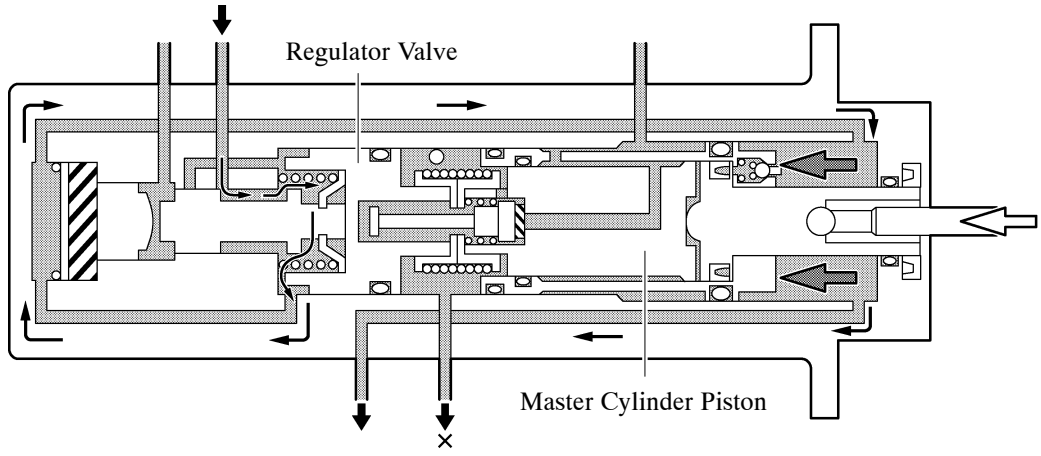


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f. Front Brake System Malfunction

- In the front brake system, the master cylinder piston is moved by the booster chamber pressure but the hydraulic pressure does not increase. The piston moves until it hits the regulator piston while the brake fluid in the master cylinder is drained.
- The rear brake system operates the same as in the normal operation.

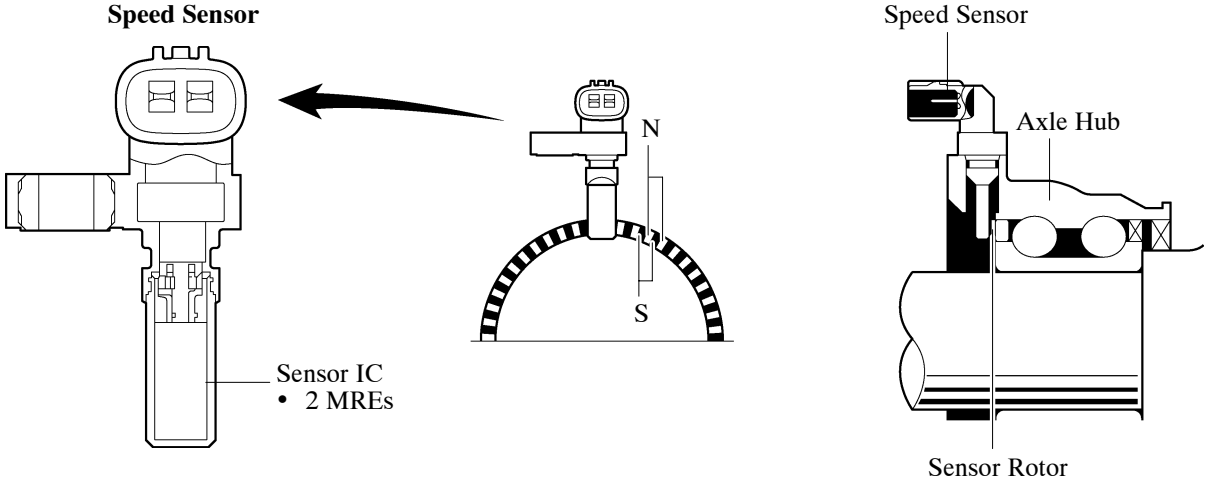


07D0CH38C

12. Speed Sensor

General

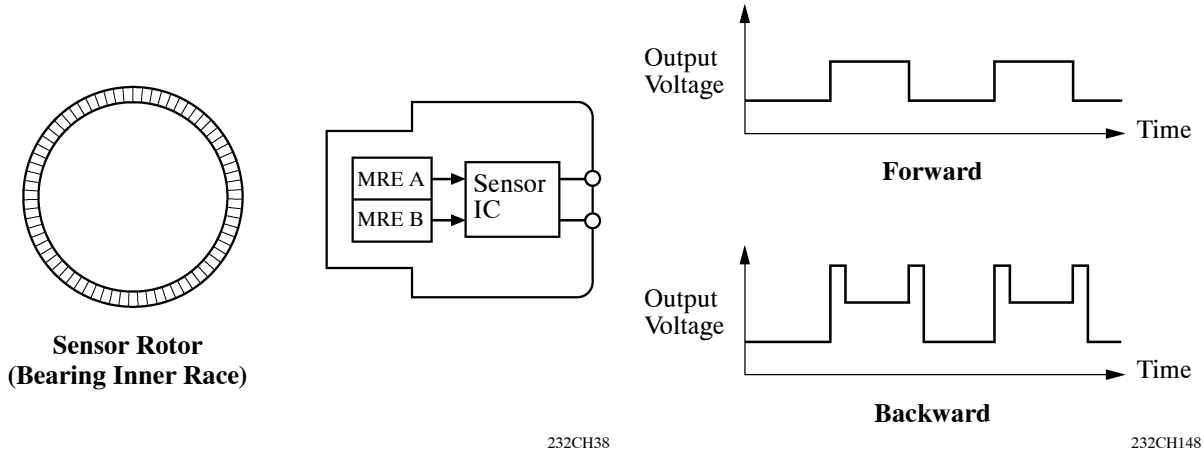
- Active type speed sensors can detect the wheel rotation direction (forward or backward). This sensor contains a sensor IC, which consists of two MREs (Magnetic Resistance Elements).
- The sensor rotor, which consists of N and S poles that are arranged in a circle, is integrated with the inner race of the hub bearing.



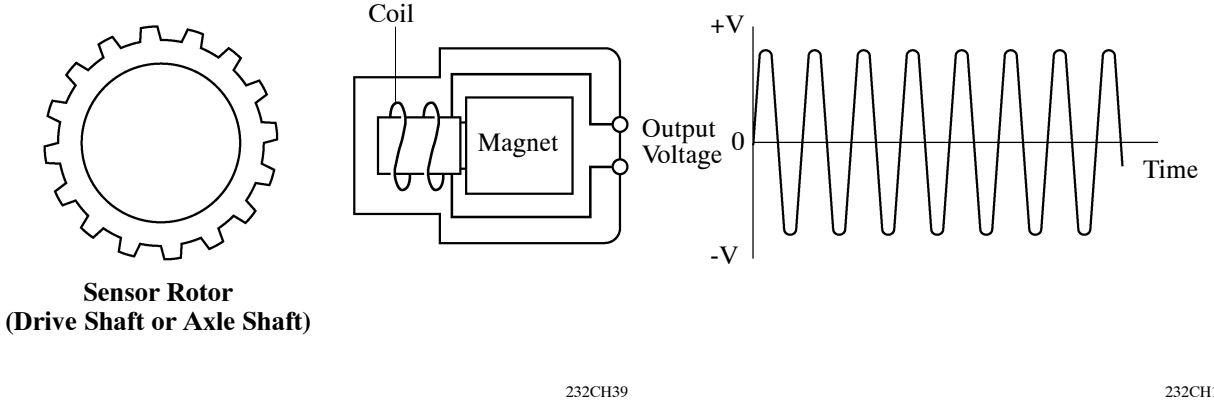
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- The following differences exist between a passive type speed sensor (contains a pick-up coil) and an active type speed sensor:

▶ Active Type Speed Sensor ◀



▶ Passive Type Speed Sensor ◀



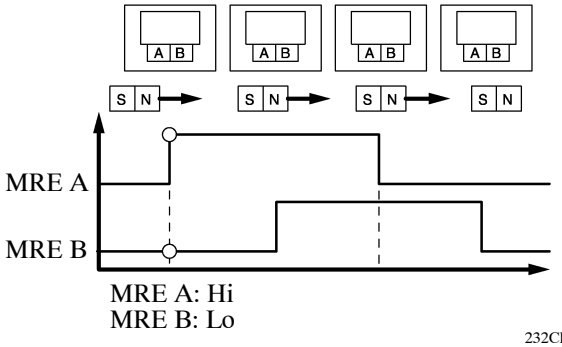
Type	Active	Passive
Direction Detection	Possible to judge both forward and backward rotation	Impossible to judge the wheel rotation direction
Detection Speed	From approx. 0	3 km/h (5 mph) or more

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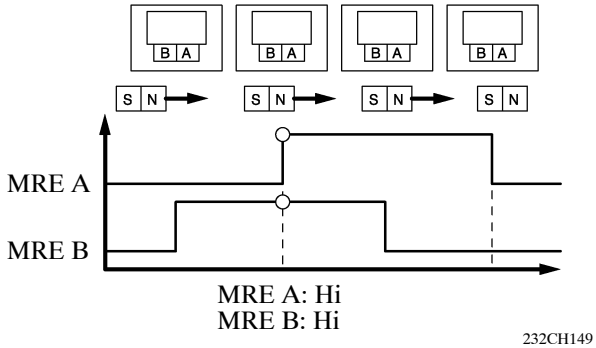
Detection Method

- To detect the rotation direction, the output waves are used to determine the relationship of the pulses that are generated by the 2 MREs.
- Upon receiving this signal, the sensor IC outputs a forward or backward wave.

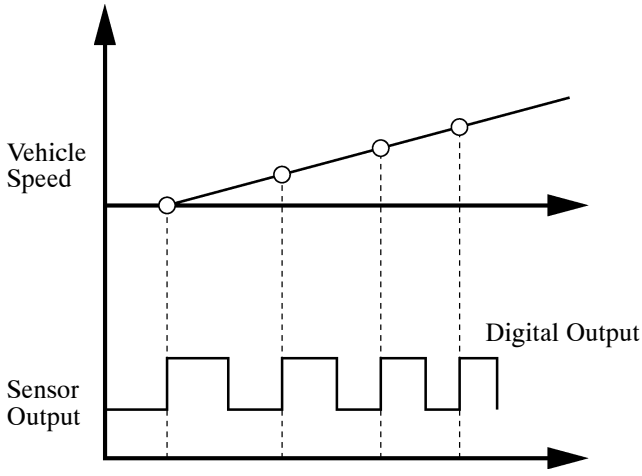
▶ Forward ◀



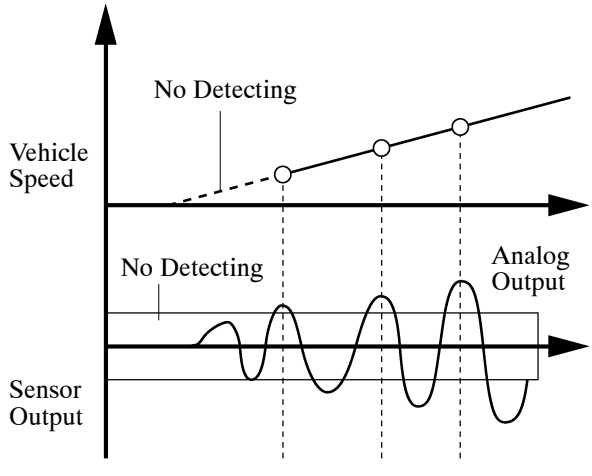
▶ Backward ◀



- To detect the vehicle speed, the duration of the output pulses is used. Because the active type sensor outputs digital pulses, it can detect vehicle speeds even at approximately 0.



Active Type



Passive Type 232CH41

13. Warning and Indicator Lights and VSC Waning Buzzer

The warning and indicator lights and VSC warning buzzer operate as follows:

		Warning Light			Indicator Light			VSC Warning Buzzer
		BRAKE	ABS	VSC TRC	VSC OFF		A-TRAC	
Initial Check		○	○	○	○	○		
During Operation	TRC					Blink		
	AUTO LSD					Blink		
	A-TRC					Blink	○*4	
	VSC					Blink		Intermittent Sound
Drive Mode	HL*1, H4*2				○			
	LL*1, L4*2				○	○*4		
	Rear Diff. Lock*3		○		○	○		
During Hydraulic Brake Booster Protection						○*5		Intermittent Sound*6
Cannot operate due to a malfunction	ABS & Brake Assist		○	○	○	○		
	EBD	○	○	○	○	○		
	TRC			○	○	○		
	A-TRC			○	○	○		
	VSC			○	○	○		
Others	Low Brake Fluid Level	○	○	○	○	○		
	ABS Malfunction		○	○	○	○		
	Zero point calibration of yawrate sensor assembly not done			○	○	○		
	Low Accumulator Pressure	○	○	○	○	○		Continuous Sound
	Skid Control ECU Malfunction	○	○	○	○			

07D0CH41C

*1: Models with M/T *2: Models with A/T *3: Models with Rear Diff. Lock

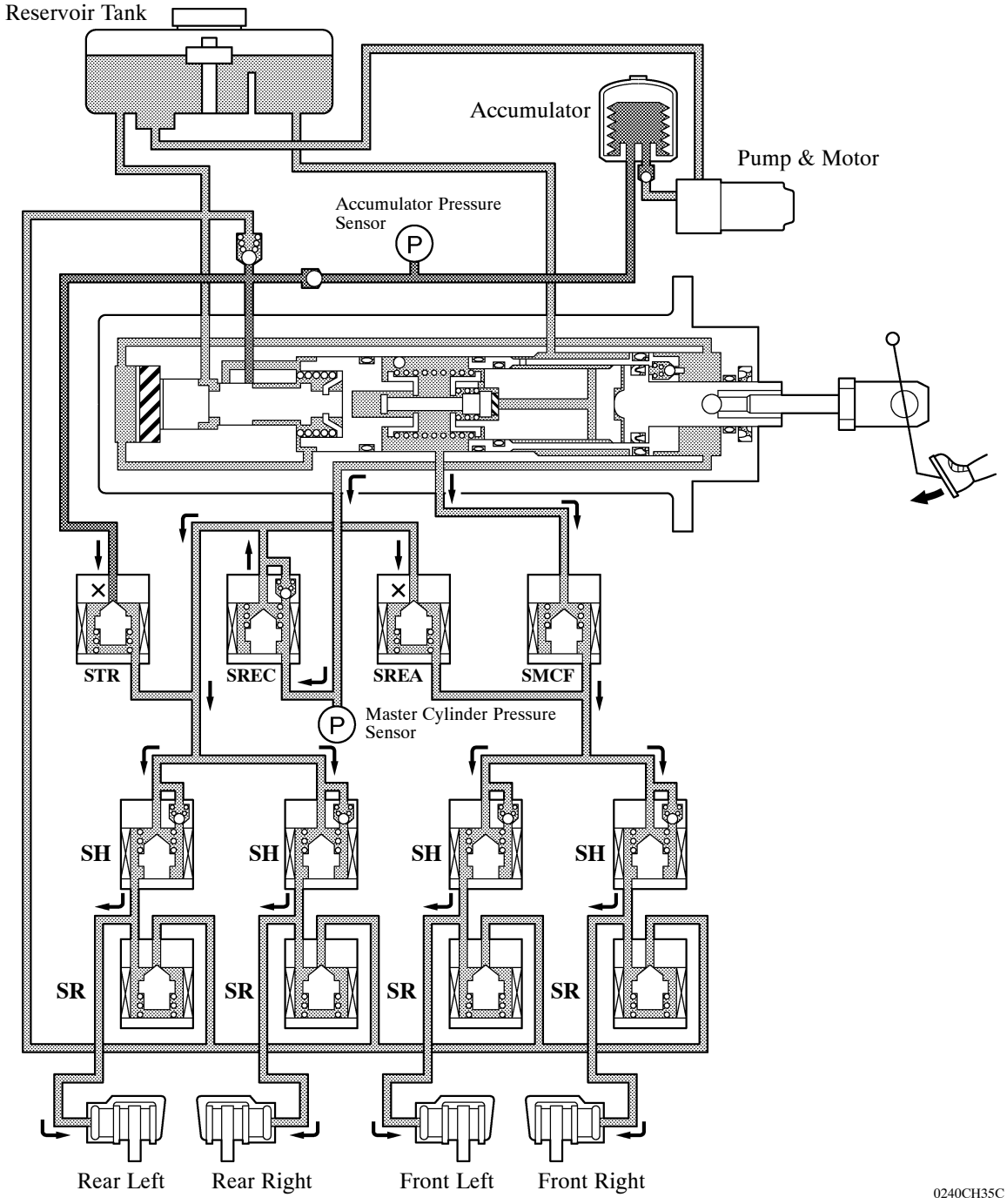
*4: These indicator lights turn on when the A-TRC is operational (standby state) with the A-TRC switch pressed.

*5: An extreme rise in the temperature of the hydraulic brake booster causes the VSC warning buzzer to sound. Further rise in the temperature causes the VSC buzzer to sound (continuously for 3 seconds) and the slip indicator light to come on.

14. System Operation

Normal Braking

During normal braking, all solenoid valves are turned OFF.



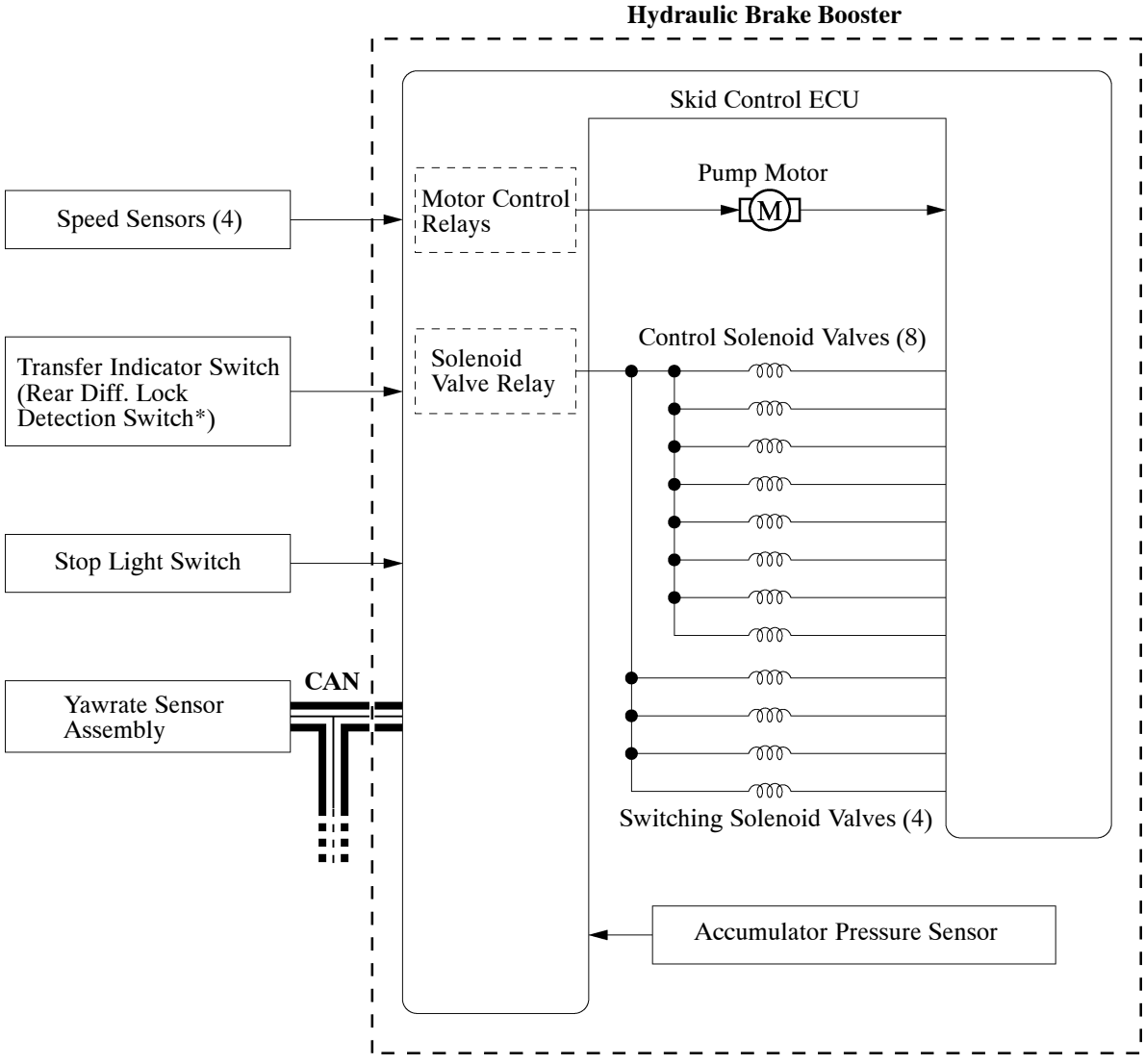
SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

ABS with EBD Operation

The Skid Control ECU calculates speed and deceleration of each wheel, and checks the likeliness of wheel slipping (locking condition) based on signals from the four wheel speed sensors and the yawrate sensor assembly.

- The ECU compares the front and rear wheel speed sensor signals, judges the slipping condition of the rear wheels, and operates the EBD.
- If a wheel is likely to be locked, the ECU controls the pressure holding solenoid valve and pressure reduction solenoid valve in the following three modes: increase, hold, and reduce. This is the same type of pressure control operation as is performed during ABS operation.

▶ System Diagram ◀

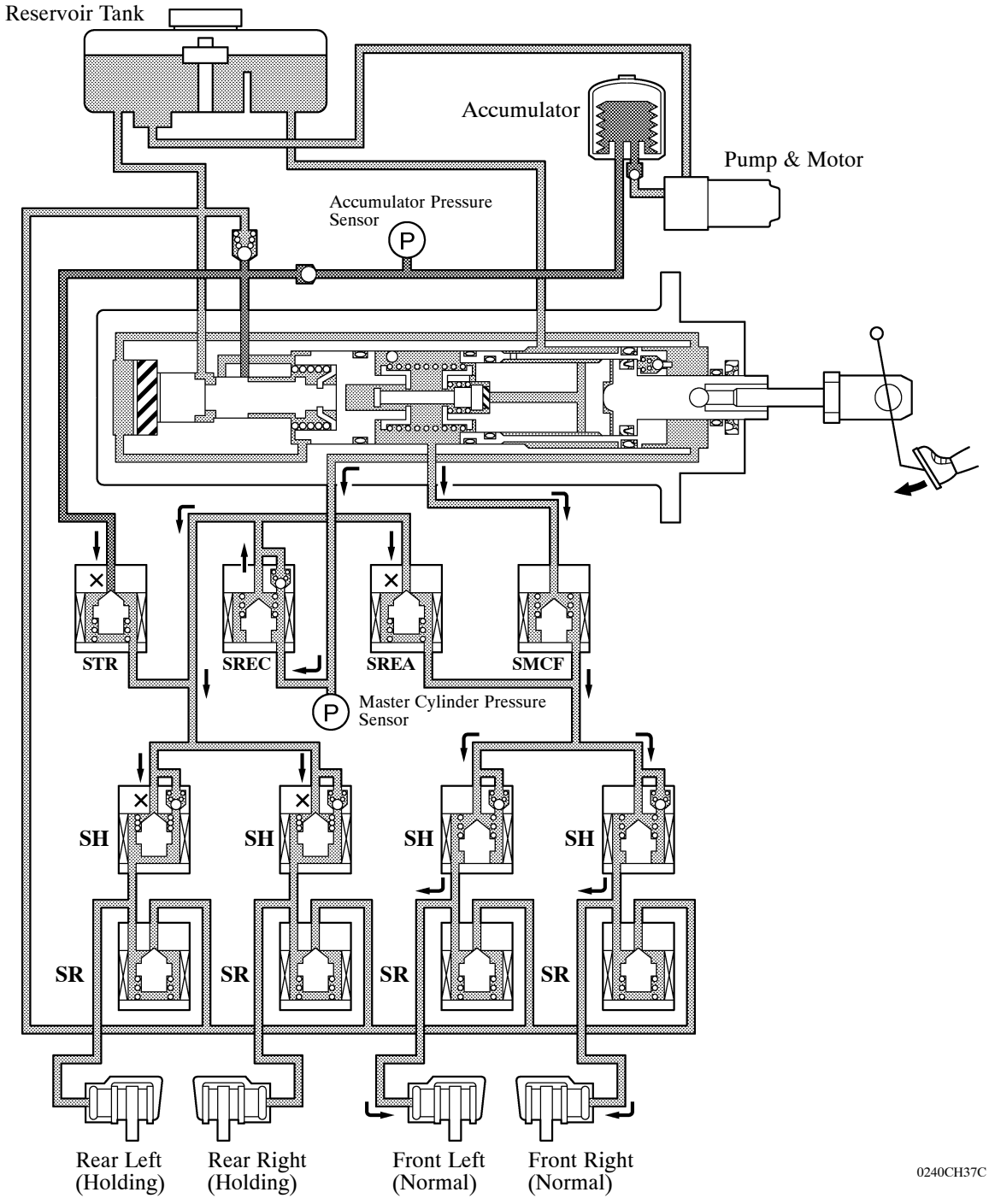


*: Models with Rear Diff. Lock

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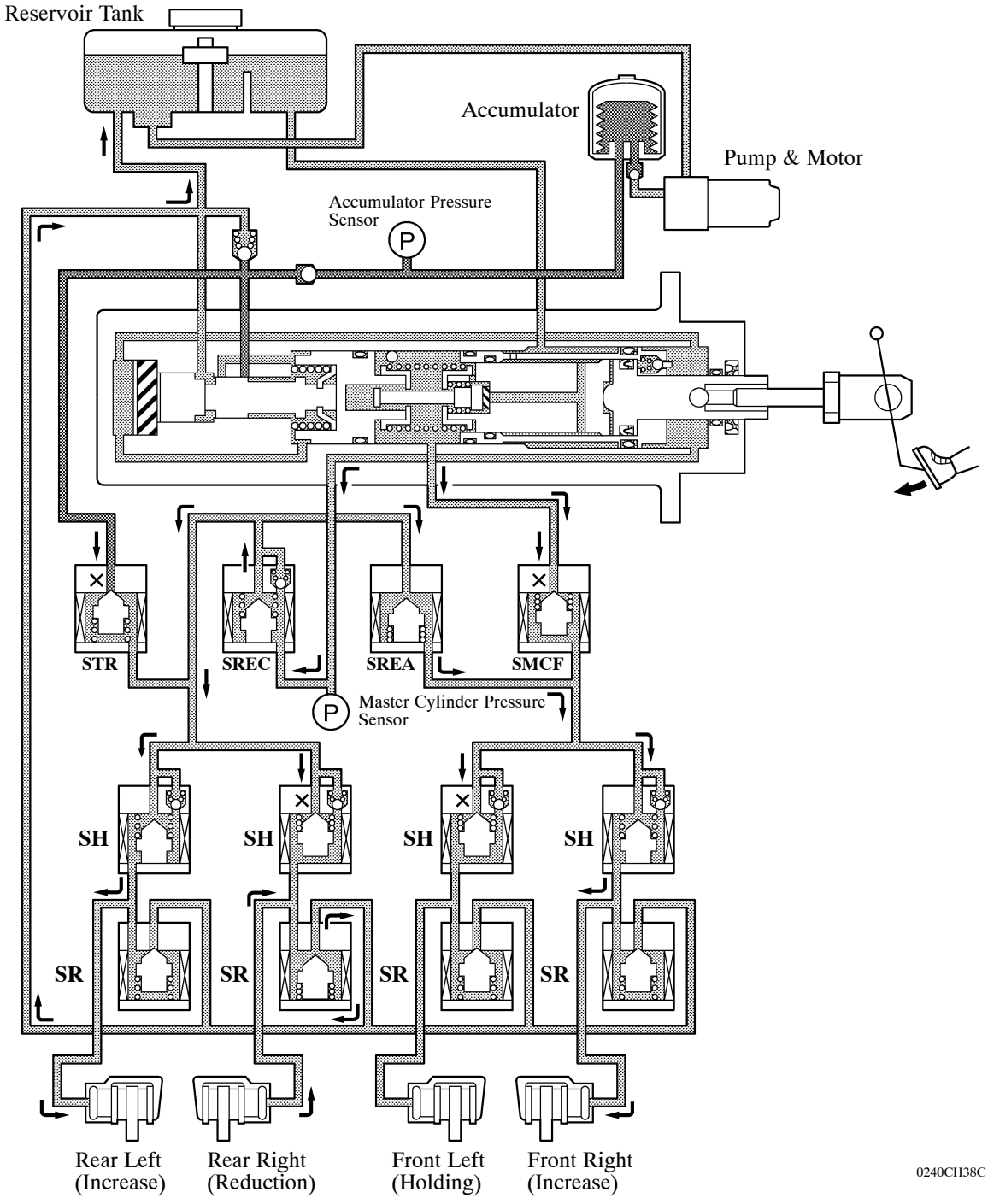
CH

▶ EBD Operation ◀



SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

▶ ABS Operation ◀



SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

CH

Item			ABS with EBD not Activated	ABS with EBD Activated		
				Mode		
				Increase	Holding	Reduction
Switching Solenoid Valve		SREC	OFF (Open)	←	←	←
		STR	OFF (Close)	←	←	←
		SMCF*1	OFF (Open)	ON (Close)	←	←
		SREA*1	OFF (Close)	ON (Open)	←	←
Control Switching Valve	Front Brake	SH	OFF (Open)	←	ON (Close)	←
		SR	OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure	—	Increase	Hold	Reduce
	Rear Brake	SH*2	OFF (Open)	←	ON (Close)	←
		SR	OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure	—	Increase	Hold	Reduce

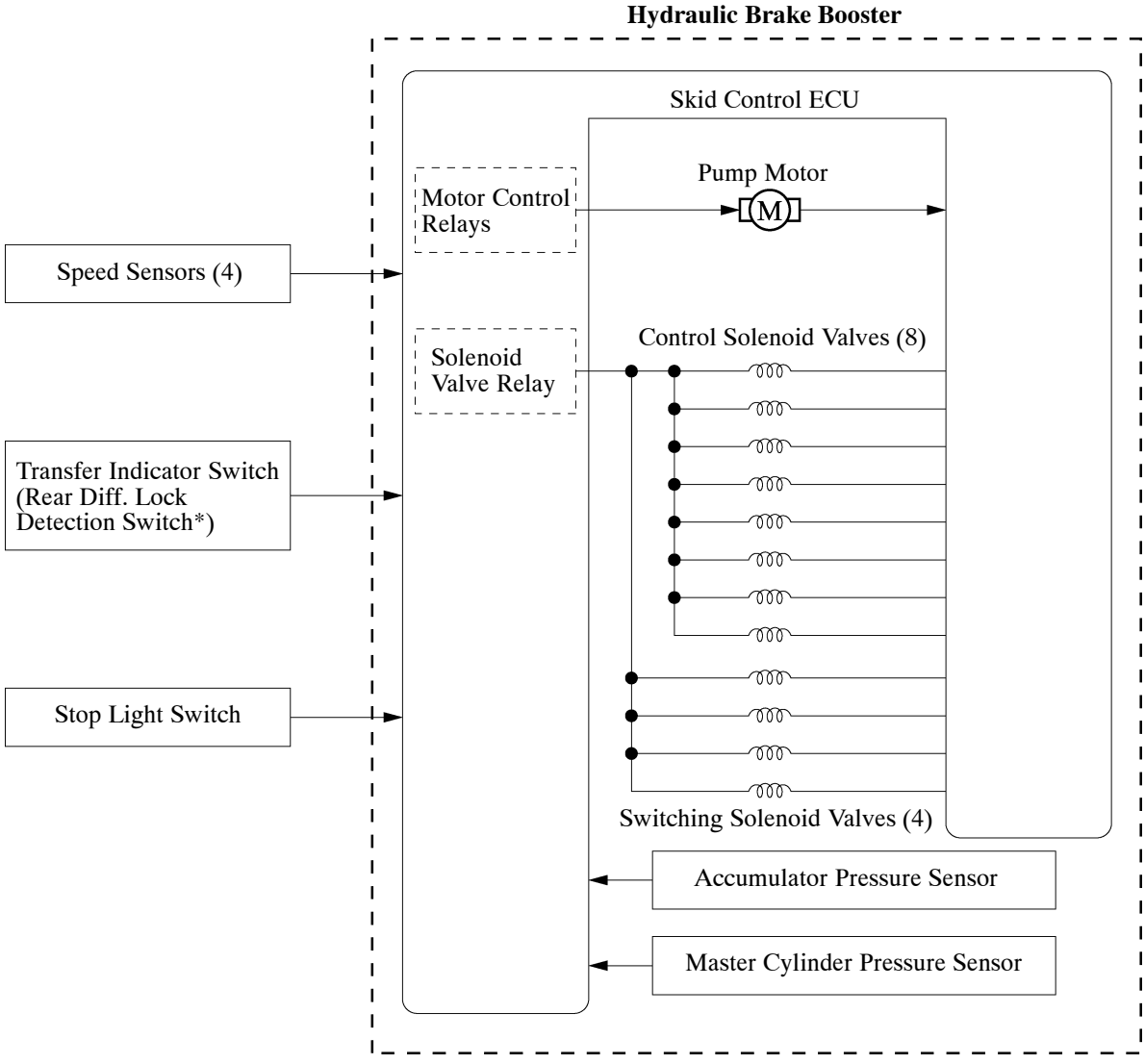
*1: While the front wheels are in ABS operation, SMCF and SREA are ON.
While only rear wheels are in ABS operation, SMCF and SREA are OFF.

*2: During EBD operation, only SH for both rear wheels is ON (close).

Brake Assist Operation

If an emergency braking situation has occurred, it is detected by the Skid Control ECU based on the vehicle speed signal which is based on the wheel speed sensors, the brake pedal application speed from the master cylinder pressure sensor, and a signal representing the amount of pedal effort. Then, the Skid Control ECU actuates each solenoid valve. As a result, the pressure from the accumulator is applied to the wheel cylinders. The accumulator pressure that is applied to the wheel cylinders (brakes) generates a higher pressure than the master cylinder.

▶ System Diagram ◀

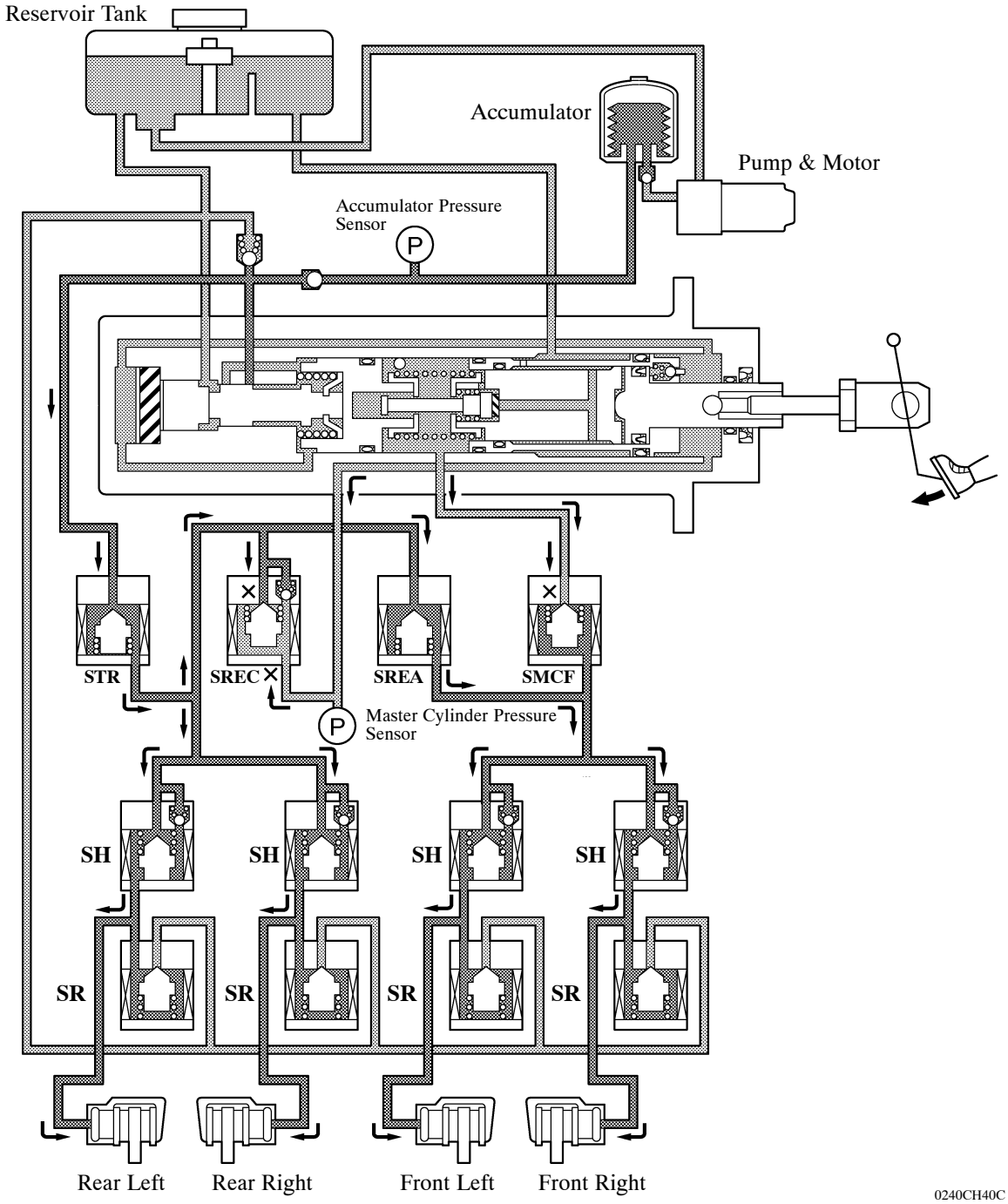


*: Models with Rear Diff. Lock

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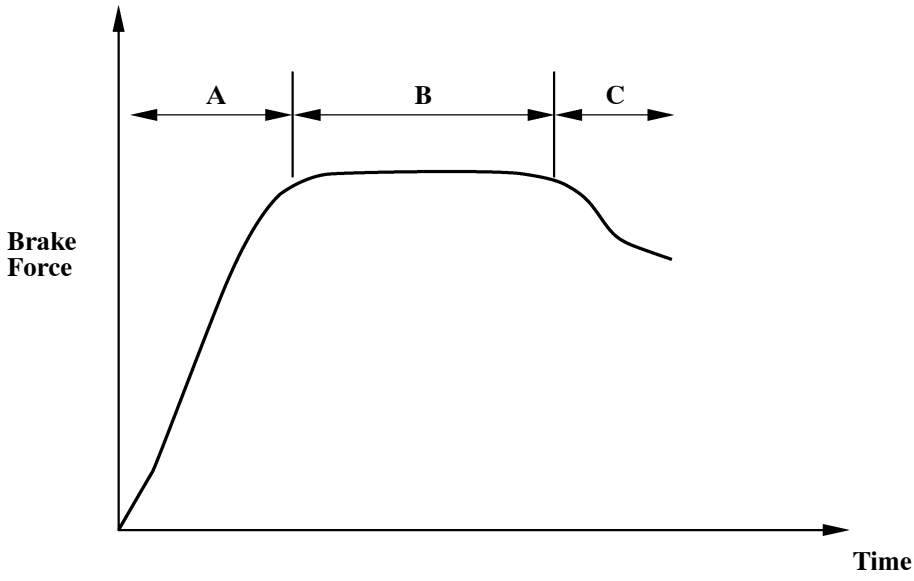
CH

▶ Brake Assist Operation ◀



SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

▶ Brake Assist Timing ◀



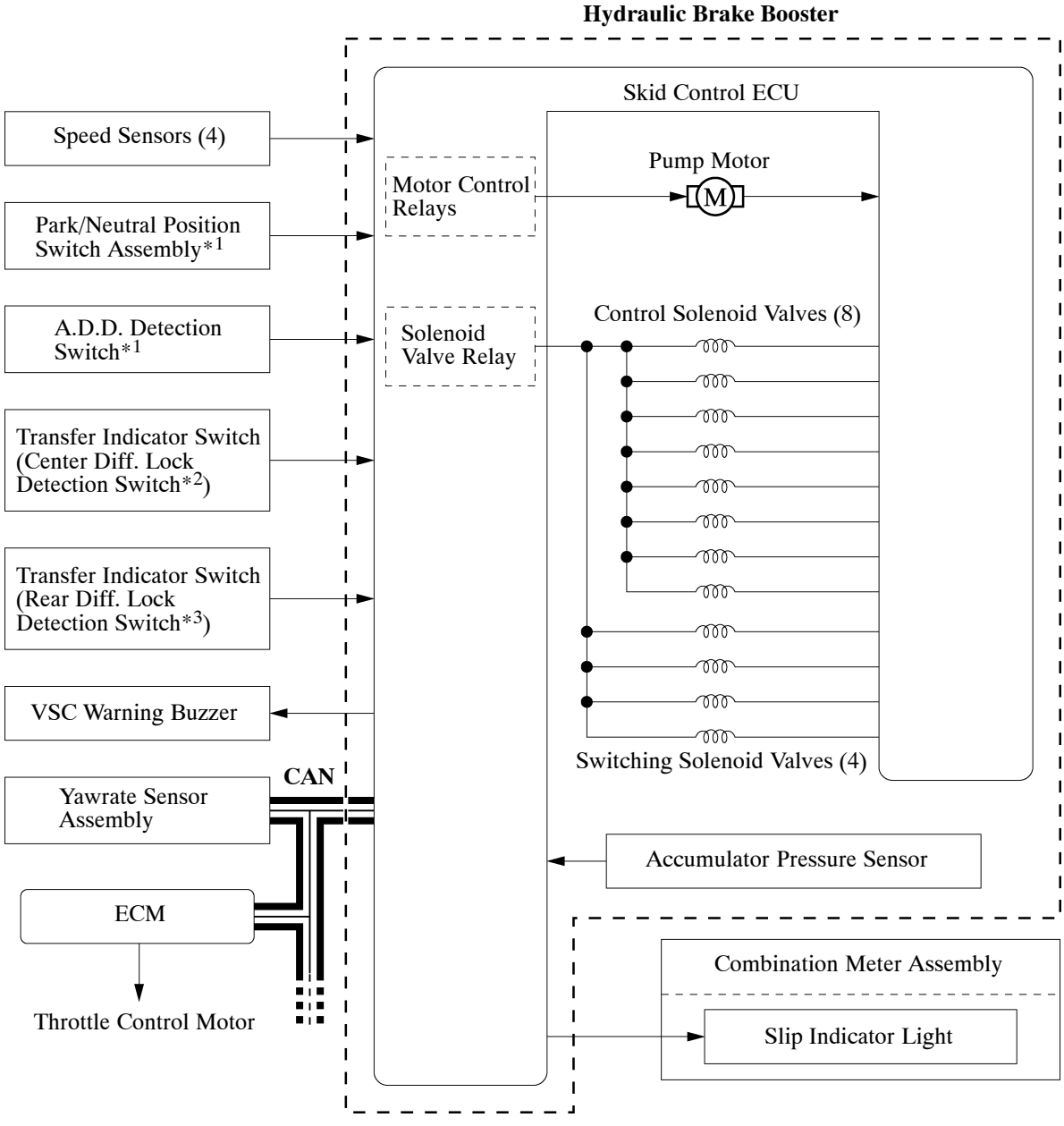
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Item			Brake Assist not Activated	Brake Assist Activated		
				A	B	C
Switching Solenoid Valve		SREC	OFF (Open)	ON (Close)	←	OFF (Open)
		STR	OFF (Close)	ON (Open)	←	OFF (Close)
		SMCF	OFF (Open)	ON (Close)	←	←
		SREA	OFF (Close)	ON (Open)	←	←
Control Switching Valve	Front Brake	SH	OFF (Open)	←	ON (Close)	OFF (Open)
		SR	OFF (Close)	←	←	←
	Rear Brake	SH	OFF (Open)	←	ON (Close)	OFF (Open)
		SR	OFF (Close)	←	←	←
Wheel Cylinder Pressure			—	Increase	Hold	Reduce

TRC Operation

- The fluid pressure that is generated by the pump & pump motor is regulated by the switching solenoid valves and control solenoid valves to the required pressure. Thus, the pressure to the wheel cylinders of the drive wheels are controlled in the following 3 modes: pressure reduction, pressure holding, and pressure increase modes, to restrain the slippage of the drive wheels.
- The Skid Control ECU outputs a TRC operation signal to the ECM and the combination meter. Upon receiving this signal, the ECM effects throttle control to regulate the engine output. The combination meter causes the slip indicator light to blink.
- If the accumulator pressure drops during this operation, the Skid Control ECU receives the signals from the accumulator pressure sensor and actuates the pump & pump motor to ensure the proper accumulator pressure.

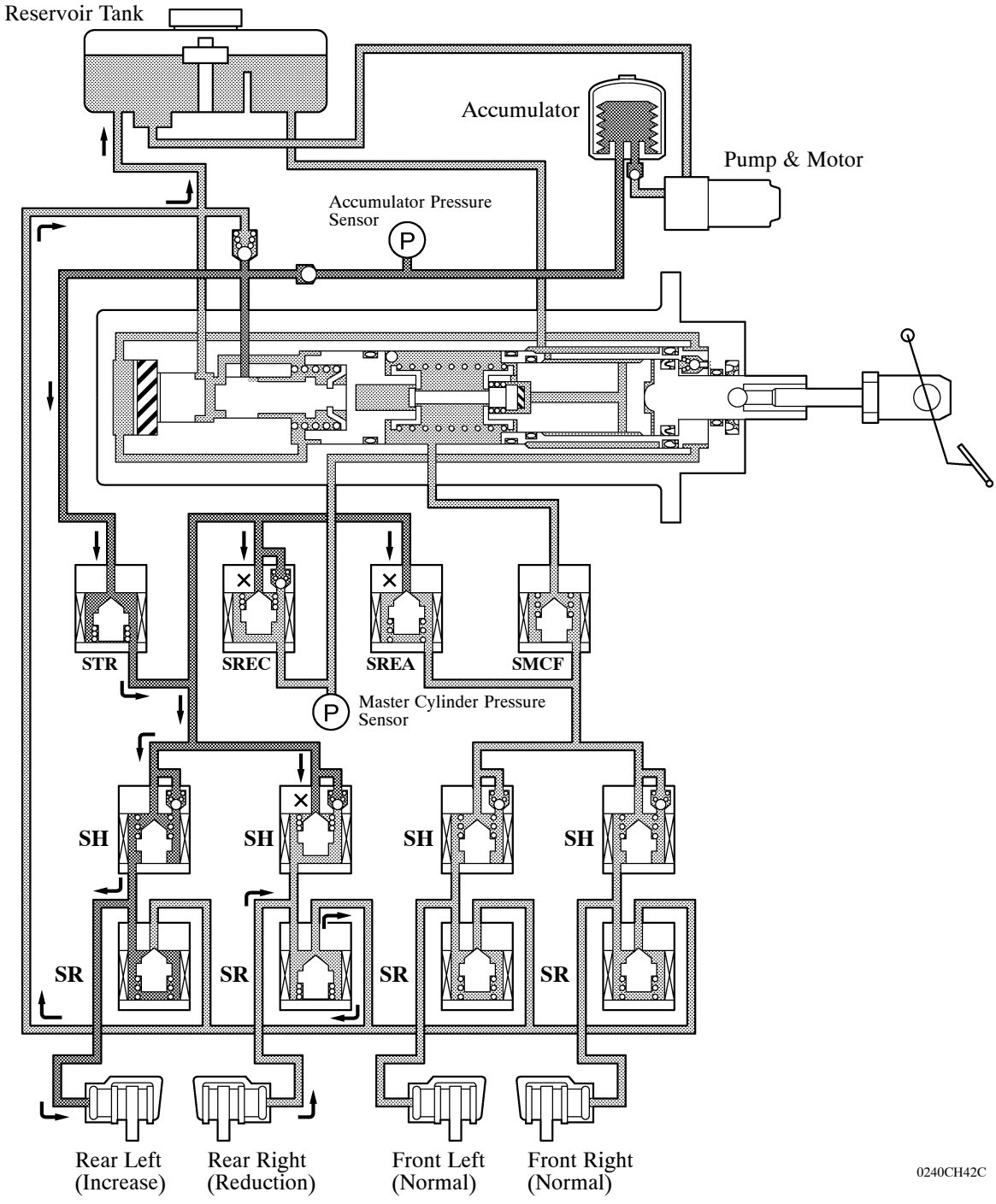
▶ System Diagram ◀



*1: Models with Automatic Transmission
*2: Models with Manual Transmission
*3: Models with Rear Diff. Lock

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▶ TRC Operation ◀



SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

CH

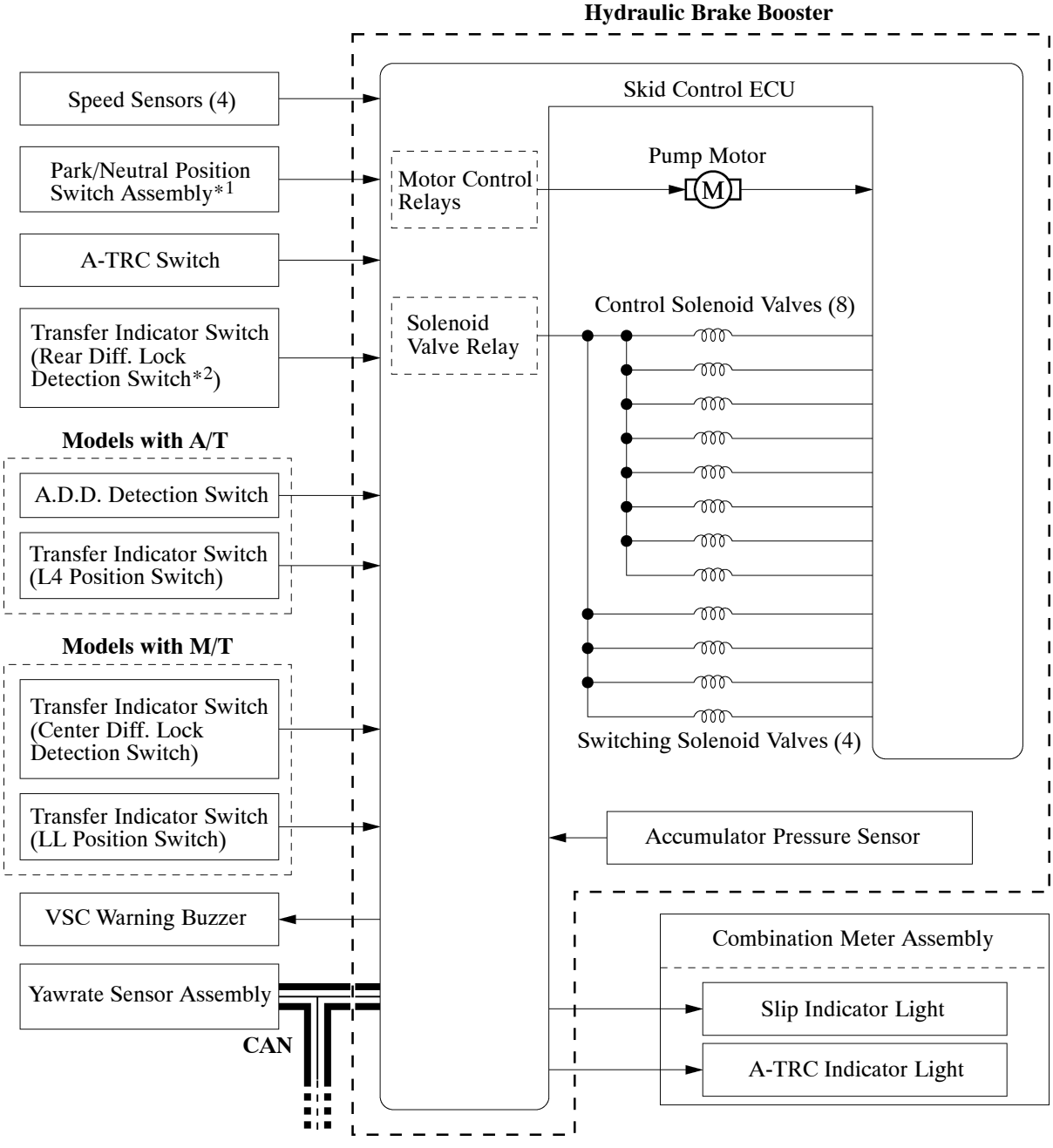
Item			TRC not Activated	TRC Activated		
				Mode		
				Increase	Holding	Reduction
Switching Solenoid Valve		SREC	OFF (Open)	ON (Close)	←	←
		STR	OFF (Close)	ON (Open)	←	←
		SMCF	OFF (Open)	←	←	←
		SREA	OFF (Close)	←	←	←
Control Switching Valve	Front Brake	SH	OFF (Open)	←	←	←
		SR	OFF (Close)	←	←	←
		Wheel Cylinder Pressure	—	—	—	—
	Rear Brake	SH	OFF (Open)	←	ON (Close)	←
		SR	OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure	—	Increase	Hold	Reduce

A-TRC Operation

Based on the vehicle speed that has been calculated from the wheel speed sensors, and the signals of the yaw rate & deceleration sensor, the Skid Control ECU computes the target control speed.

- The Skid Control ECU compares the target control speed and the speeds of the wheels to determine whether or not slippage exists. Upon detecting slippage, the Skid Control ECU controls the solenoid valve of the hydraulic brake booster to control the brake fluid pressure that is applied to the slipping wheel. When the wheel speed becomes lower than the target control speed, the Skid Control ECU stops increasing the brake fluid pressure.

▶ System Diagram ◀



07D0CH48C

*1: Models with A/T *2: Models with Rear Diff. Lock

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- As shown in the table below, the target control speed and the brake fluid pressure control.

Road Condition	Transfer Range	Control		Outline
Rocky or Offroad	L4 or LL	Target Control Speed	Vehicle Speed + Slip Rate (L range set value)	Control designed for rugged offroad driving conditions. • A-TRC can operate when the A-TRC switch is turned on.
		Brake Control	Sudden fluid Pressure Control	
Downhill (Only A/T)	L4 + 1st gear	Target Control Speed	Vehicle speed when deceleration slippage has been determined during downhill driving.	Designed for rugged, offroad downhill driving conditions when the engine braking is occurring. It helps to prevent undesirable acceleration of the vehicle that could occur if engine braking stops.
		Brake Control	Fluid pressure control to each wheel	

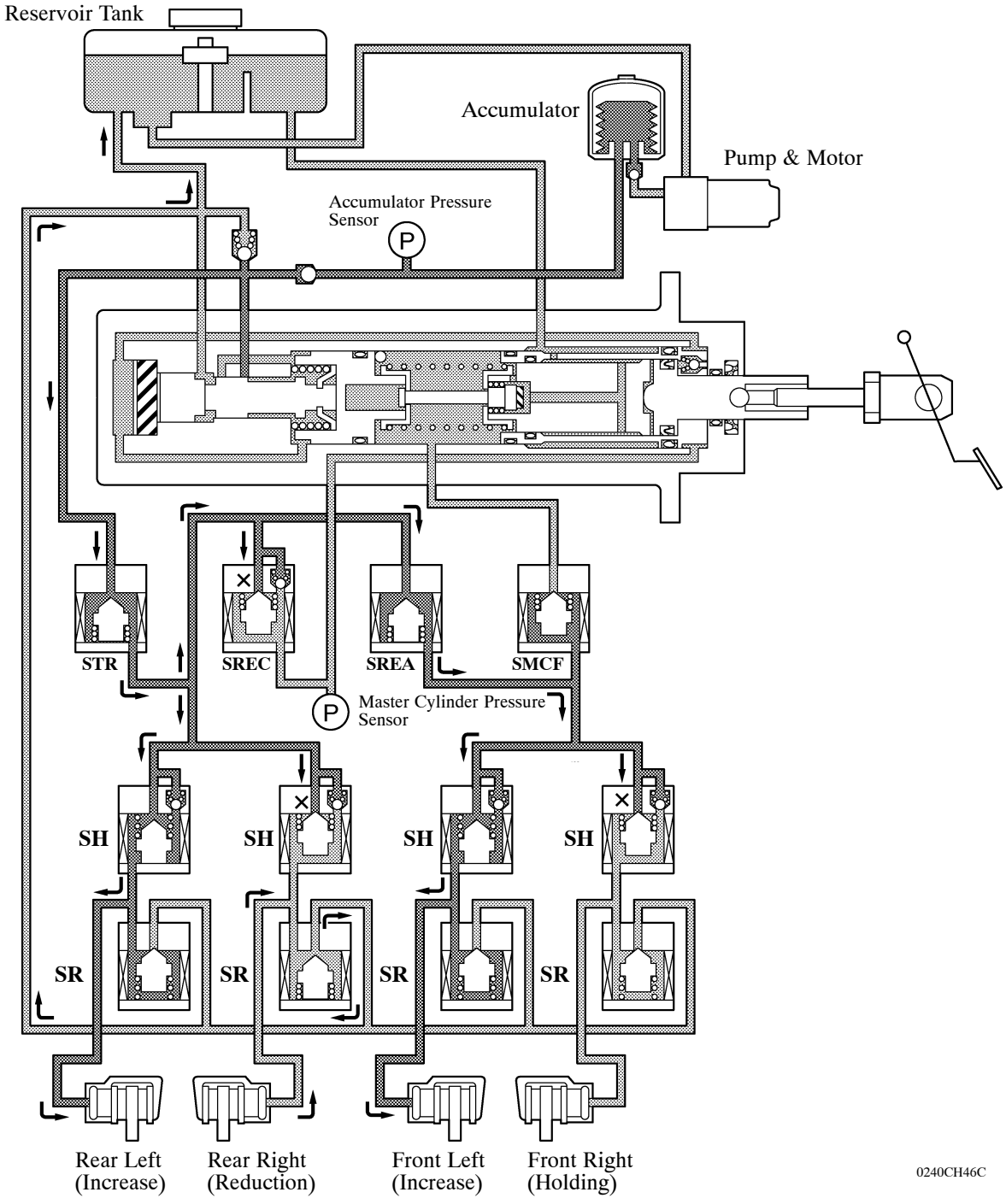
- The A-TRC independently controls fluid pressure to the brake of each wheel by operating the individual solenoid valves in accordance with the signals received from the Skid Control ECU. The brake of each wheel is controlled in the following three modes: pressure reduction, pressure holding, and pressure increase modes

Precaution on A-TRC Operation

When the A-TRC is operating continuously while the vehicle is being driven on a slippery surface, the temperature of the actuator in the hydraulic brake booster increases. After a set length of time elapses, the Skid Control ECU alerts the driver of this condition by causing the VSC warning buzzer to sound, and the slip indicator warning light to illuminate. Also, the A-TRC operation is temporarily interrupted to protect the actuator.

When the temperature of the actuator decreases, the slip indicator light turns OFF, and the A-TRC is automatically restored to an operating state.

▶ A-TRC Operation ◀



SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

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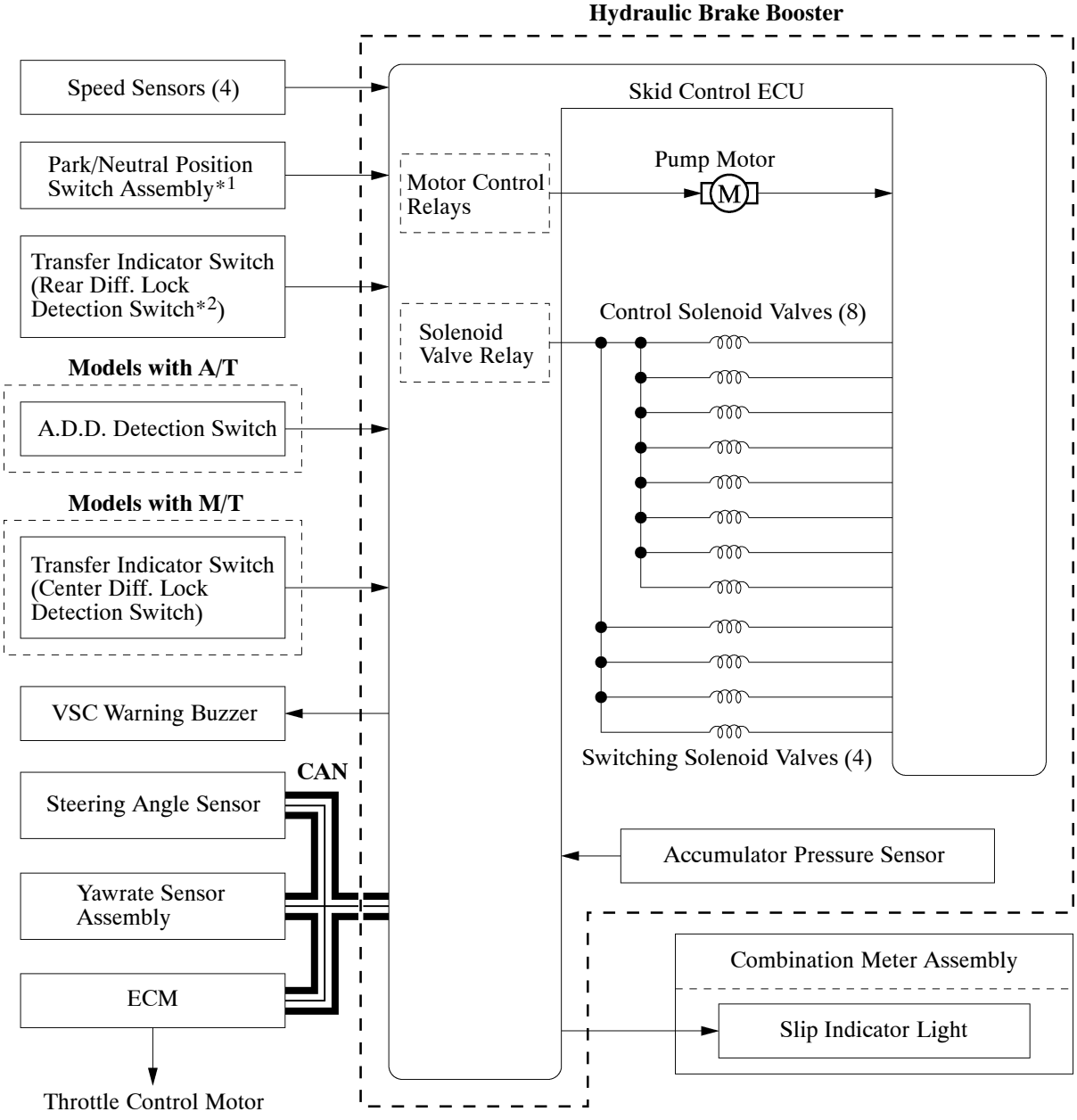
Item			A-TRC not Activated	A-TRC Activated		
				Mode		
				Increase	Holding	Reduction
Switching Solenoid Valve		SREC	OFF (Open)	ON (Close)	←	←
		STR	OFF (Close)	ON (Open)	←	←
		SMCF	OFF (Open)	ON (Close)	←	←
		SREA	OFF (Close)	ON (Open)	←	←
Control Switching Valve	Front Brake	SH	OFF (Open)	←	ON (Close)	←
		SR	OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure	—	Increase	Hold	Reduce
	Rear Brake	SH	OFF (Open)	←	ON (Close)	←
		SR	OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure	—	Increase	Hold	Reduce

VSC Operation

1) General

- Based on the information provided by various sensors, switches, and the ECM, the Skid Control ECU determines the vehicle's yaw moment. Then, the Skid Control ECU controls the fluid pressure that is generated by the pump & pump motor and applies it by way of the solenoid valves to the brake wheel cylinder of each wheel in the following three modes: pressure reduction, pressure hold, and pressure increase modes. As a result, the tendency of the front wheels or the rear wheels to skid sideways is restrained.
- At this time, the Skid Control ECU outputs a VSC operation signal to the ECM, and the combination meter and causes the VSC warning buzzer to sound. Upon receiving this signal, the ECM controls the throttle to regulate the engine output. The slip indicator light will blink in the combination meter.

▶ System Diagram ◀



*1: Models with A/T *2: Models with Rear Diff. Lock

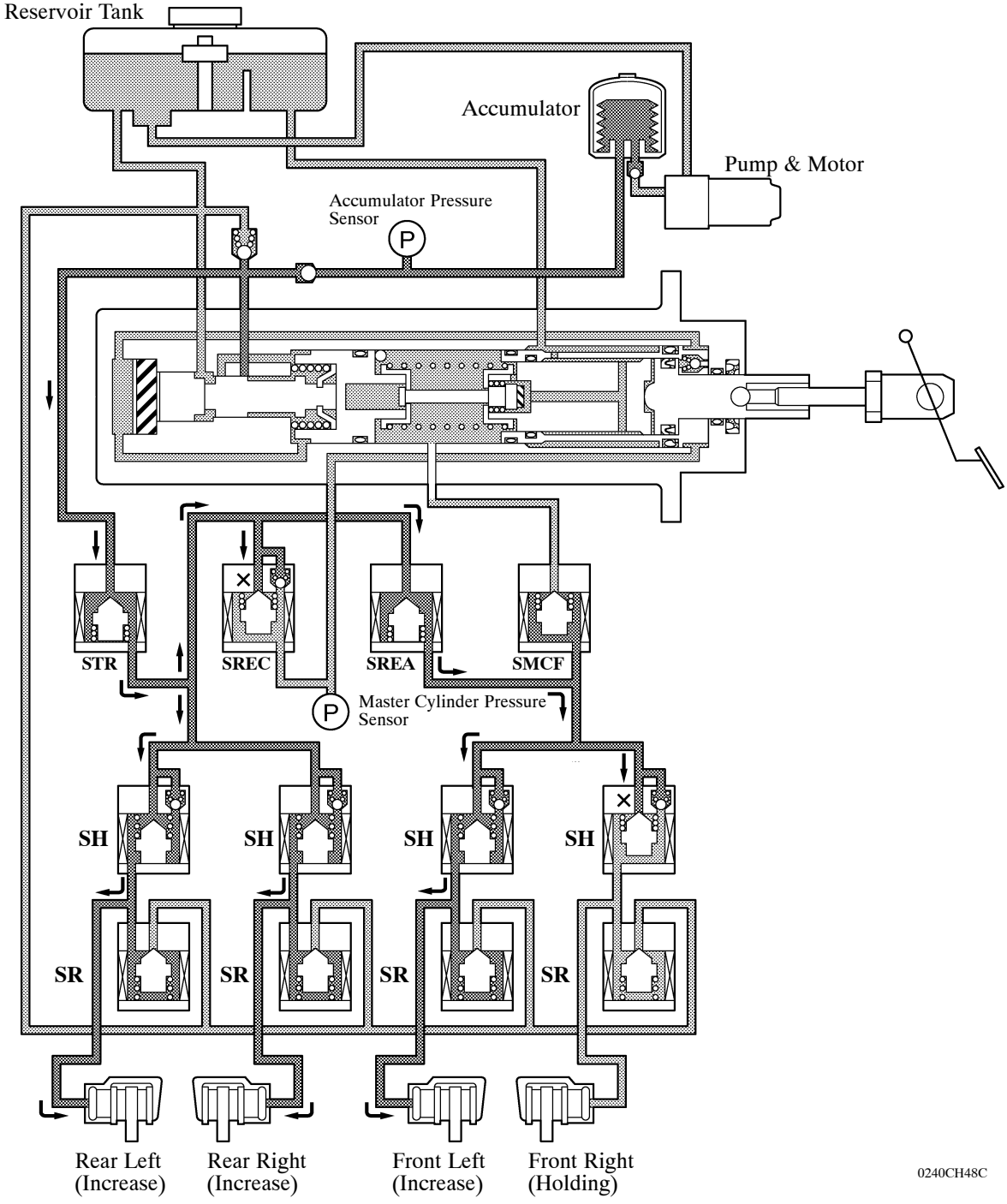
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2) Front Wheel Skid Restraining (Turning to the Right)

For front wheel skid restraining control, the brakes of the rear wheels and front wheel of the outside of the turn is 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 restrains a 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.



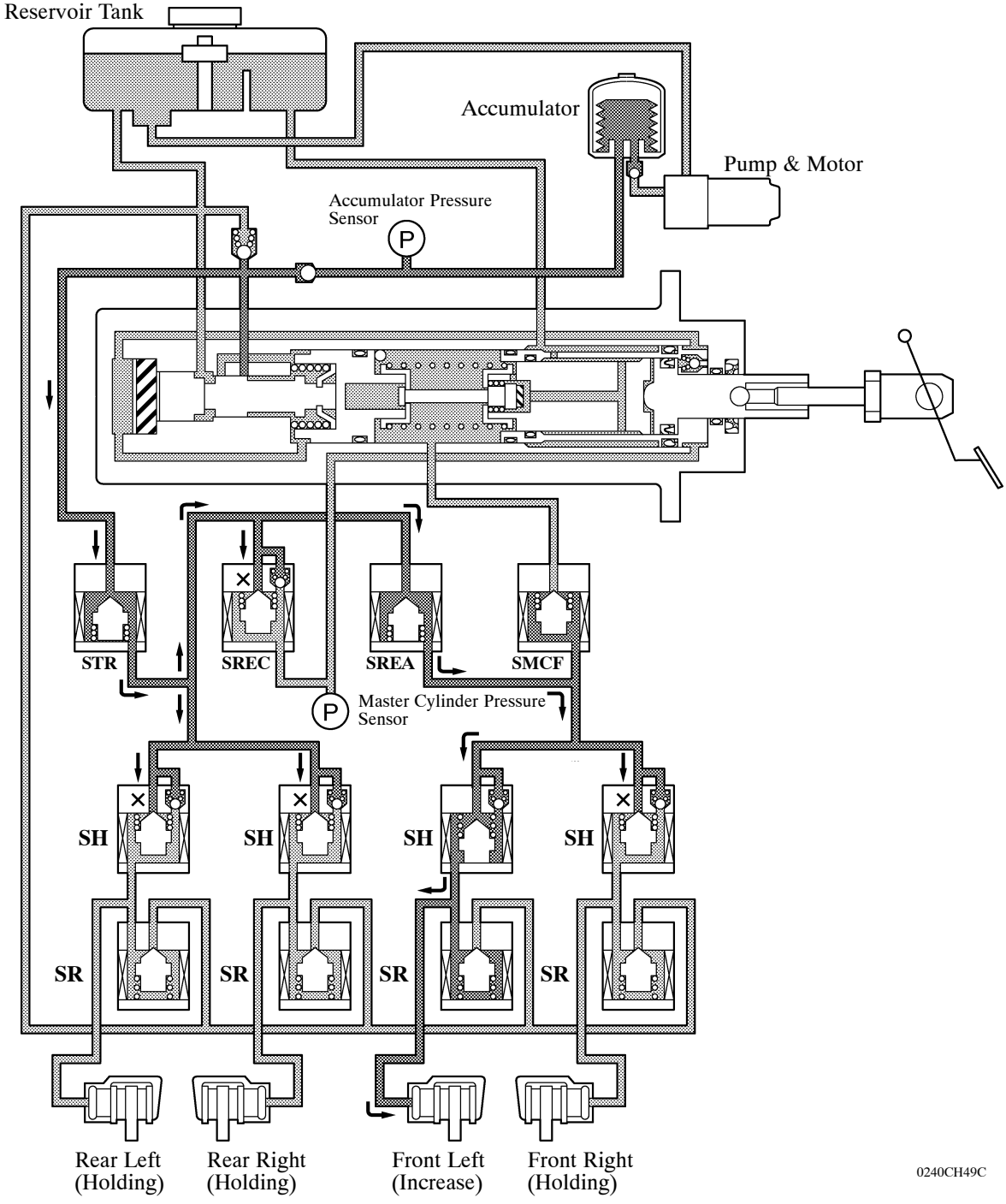
SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

Item				VSC not Activated	VSC Activated		
					Mode		
					Increase	Holding	Reduction
Switching Solenoid Valve		SREC		OFF (Open)	ON (Close)	←	←
		STR		OFF (Close)	ON (Open)	←	←
		SMCF		OFF (Open)	ON (Close)	←	←
		SREA		OFF (Close)	ON (Open)	←	←
Control Switching Valve	Front Brake	SH	RH	OFF (Open)	ON (Close)	←	←
			LH	OFF (Open)	←	ON (Close)	←
		SR	RH	OFF (Close)	←	←	←
			LH	OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure	RH	—	—	—	—
			LH	—	Increase	Hold	Reduce
	Rear Brake	SH		OFF (Open)	←	ON (Close)	←
		SR		OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure		—	Increase	Hold	Reduce

3) Rear Wheel Skid Restraining (Turning to the Right)

In rear wheel skid restraining control, the front brake on the outside of the turn is 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 be applied to the rear brake of the outside of the turn.

- The diagram below shows the hydraulic circuit in the pressure increase mode, as it restrains a 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.



SMCF: Master Cut for Front Solenoid Valve
SREA: Regulator Apply for Front Solenoid Valve
SREC: Regulator Cut Solenoid Valve
STR: Traction Solenoid Valve (Accumulator Cut Solenoid Valve)
SH: Pressure Holding Solenoid Valve
SR: Pressure Reduction Solenoid Valve

Item				VSC not Activated	VSC Activated		
					Mode		
					Increase	Holding	Reduction
Switching Solenoid Valve		SREC		OFF (Open)	ON (Close)	←	←
		STR		OFF (Close)	ON (Open)	←	←
		SMCF		OFF (Open)	ON (Close)	←	←
		SREA		OFF (Close)	ON (Open)	←	←
Control Switching Valve	Front Brake	SH	RH	OFF (Open)	ON (Close)	←	←
			LH	OFF (Open)	←	ON (Close)	←
		SR	RH	OFF (Close)	←	←	←
			LH	OFF (Close)	←	←	ON (Open)
		Wheel Cylinder Pressure	RH	—	—	—	—
			LH	—	Increase	Hold	Reduce
	Rear Brake	SH		OFF (Open)	ON (Close)		
		SR		OFF (Close)	OFF (Close)		
		Wheel Cylinder Pressure		—	Hold		

CH

Initial Check

Each time the ignition switch is turned ON, and the vehicle reaches approximately speed of 6 km/h (4 mph) or more, the Skid Control ECU performs an initial check.
The functions of each solenoid valve and pump & pump motor in the hydraulic brake booster are checked in order.

15. CAN (Controller Area Network)

CAN communication is used between the Skid Control ECU, steering angle sensor, yawrate sensor assembly, ECM and DLC3. For details, see page BE-8.

16. Diagnosis

If the Skid Control ECU detects a malfunction in the brake control system (ABS with EBD, Brake Assist, TRC, A-TRC, or VSC), the warning light or indicator light lights up to alert the driver of the malfunction, as indicated in the table below. At the same time, Skid Control ECU stores the DTC (Diagnostic Trouble Code) in memory.

- There are 2-digit DTCs and 5-digit DTCs.
- 2-digit DTCs can be read by connecting the SST (09843-18040) to Tc and CG terminals of the DLC3, and observing the diagnostic code indicated on the multi-information display in the combination meter.
- 5-digit DTCs can be read by connecting an intelligent tester to the DLC3.

The self-diagnosis has a sensor signal check (test mode) function.

- This function is activated by connecting the SST (09843-18040) between the Ts and CG terminal of the DLC3 or by connecting an intelligent tester.
- If the Skid Control ECU detects a malfunction during a sensor check, it stores the DTCs in its memory.
- These DTCs can be read during a sensor check operation by connecting the SST (09843-18040) to the Tc and CG terminals of the DLC3 and observing the blinking of the ABS warning light or the VSC warning light. These DTCs can also be read by connecting an intelligent tester.

17. Fail-safe

- In the event of a malfunction in the ABS and/or Brake Assist controls, the Skid Control ECU prohibits ABS, Brake Assist, TRC, A-TRC, and VSC operations.
- In the event of a malfunction in the EBD control, the Skid Control ECU prohibits EBD operation. In this case, normal (non electronically assisted) braking performance will be available. Functions of the brake control system (ABS with EBD, Brake Assist, TRC, A-TRC, and VSC) will not be available.
- In the event of a malfunction in the TRC, A-TRC, and/or VSC, the Skid Control ECU prohibits TRC, A-TRC, and VSC operations.
- If a communication malfunction occurs between the Skid Control ECU and the steering angle sensor or the yawrate sensor assembly, the Skid Control ECU stops TRC, A-TRC, and VSC operation.
- When the ECM detects the DTC, it will disable the TRC, A-TRC, and VSC operations.