TO INDEX

E3 BRAKE CONTROL

ABS

1 OUTLINE

1-1 DESCRIPTION

1.The ABS with EBD control has been adopted.

(1) The ABS is a brake system designed to prevent the wheels from slipping, which is caused by wheel lock-up during hard braking or driving on a slippery road covered with snow, etc. It is also used to achieve maximum braking performance in every driving situation in order to maintain stable vehicle posture and steering control.

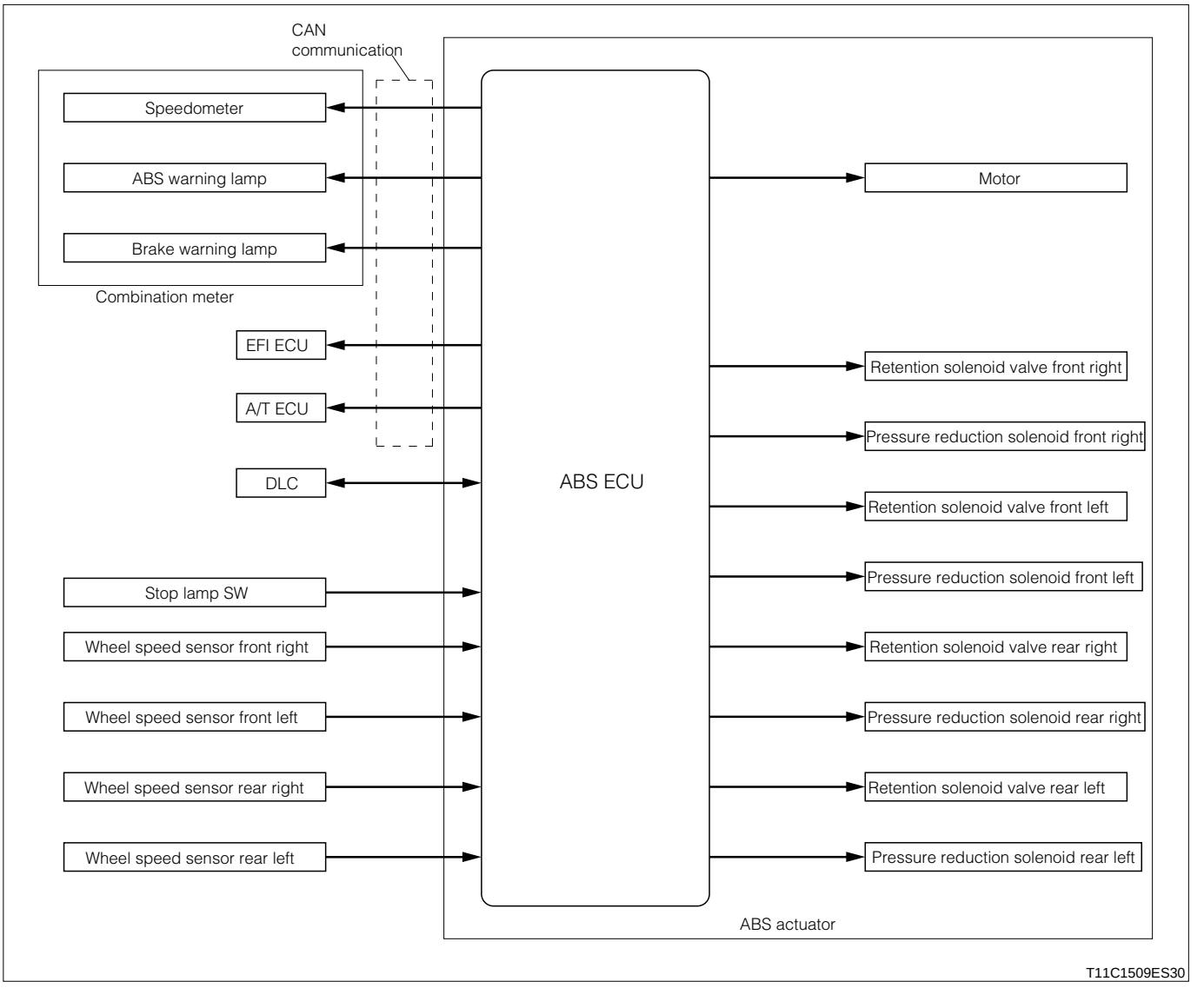
(2) The ABS with EBD control is the system that controls the distribution of brake forces between the front and rear wheels in addition to ABS. The brake forces between the front and rear wheels are properly adjusted in accordance with the load movements due to changes in load conditions, deceleration, etc. Also the ABS with EBD controls the distribution of braking forces between the left and right wheels, helping to maintain the vehicle stability during braking while the vehicle is turning.

2.When a fault occurs, the warning lamp lights up by the fail safe function, letting the driver know that there is a malfunction, while. Also, the diagnosis (self-diagnosis) function lets the operator know where that malfunction is occurring.

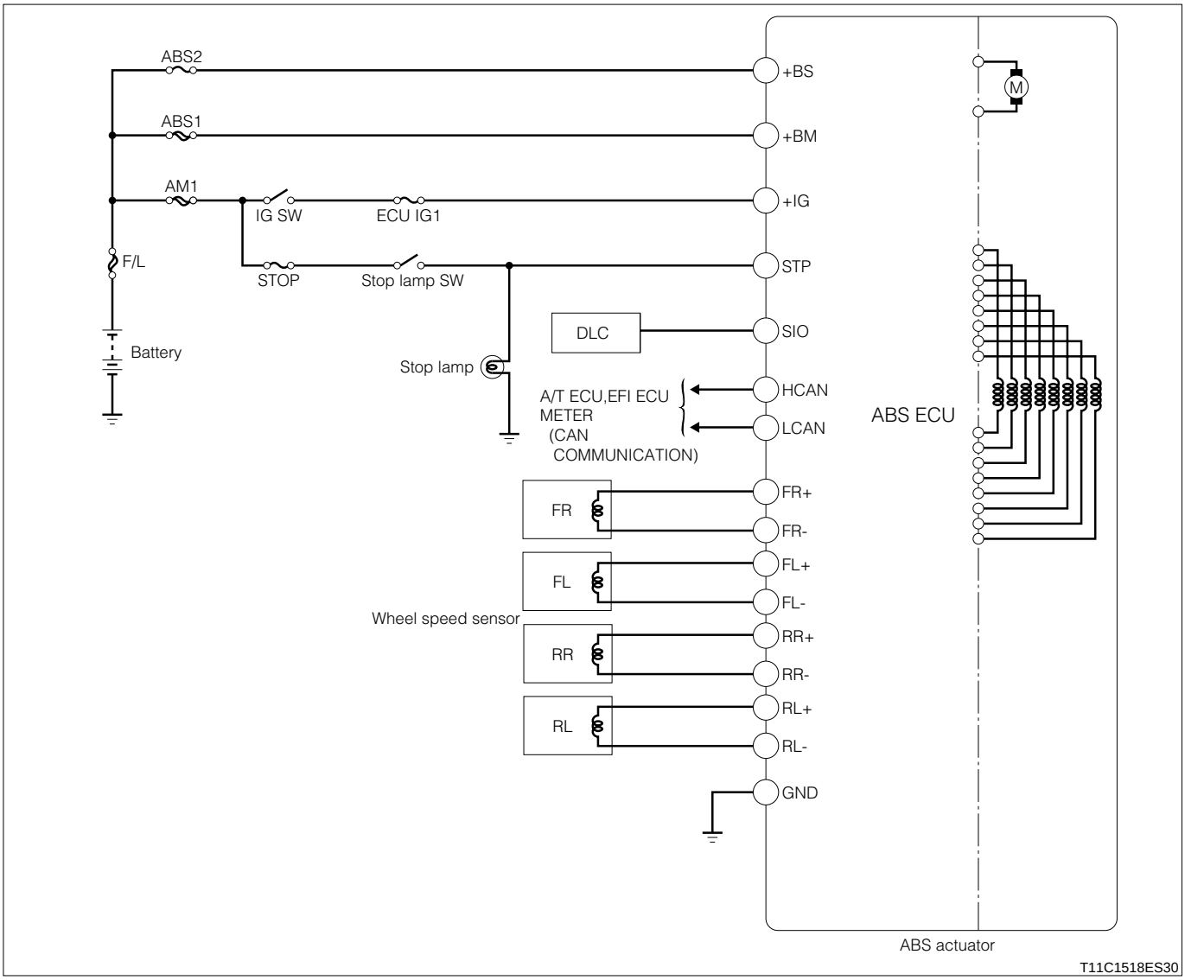
3.The ABS ECU uses CAN communication to communicate with the meter ECU, A/T ECU, and EFI ECU. Refer to the section "CAN communication system" for details.

Refer to Page L2-1.

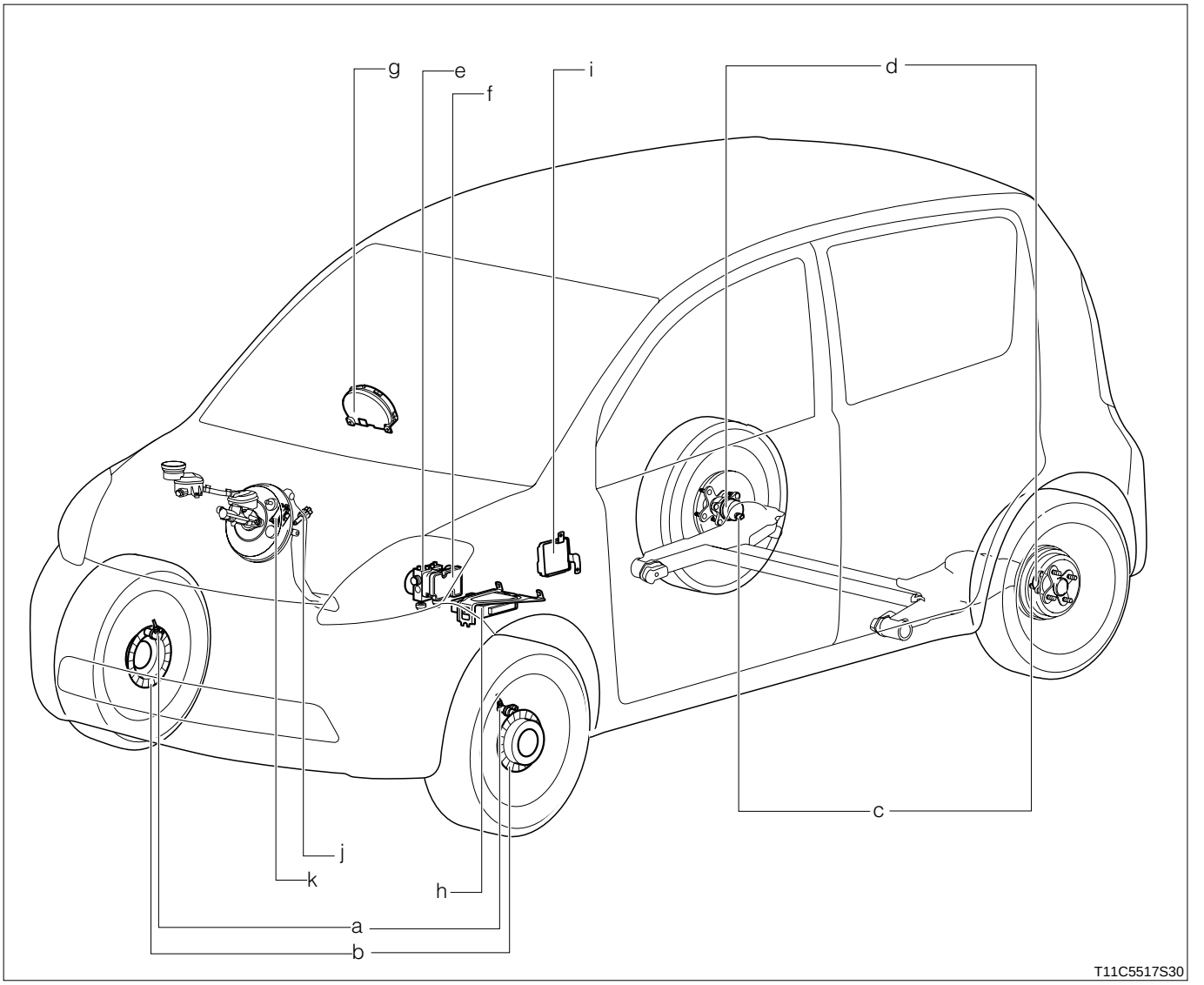
1-2 SYSTEM DRAWING



1-3 SYSTEM WIRING DIAGRAM



1-4 LOCATION OF COMPONENTS



a	Front wheel speed sensor
b	Front wheel speed sensor rotor
c	Rear wheel speed sensor
d	Rear wheel speed sensor rotor
e	ABS actuator
f	ABS ECU
g	Combination meter (ABS warning lamp, brake warning lamp, LCD)
h	EFI ECU
i	A/T ECU
j	Stop lamp switch
k	DLC

2 CONTROL

2-1 BASIC PRINCIPLE

When the brake is depressed, the wheel speed will drop below the vehicle speed, causing slippage between wheels and the road surface. The magnitude of this slippage is called slip rate, which is calculated using the formula below.

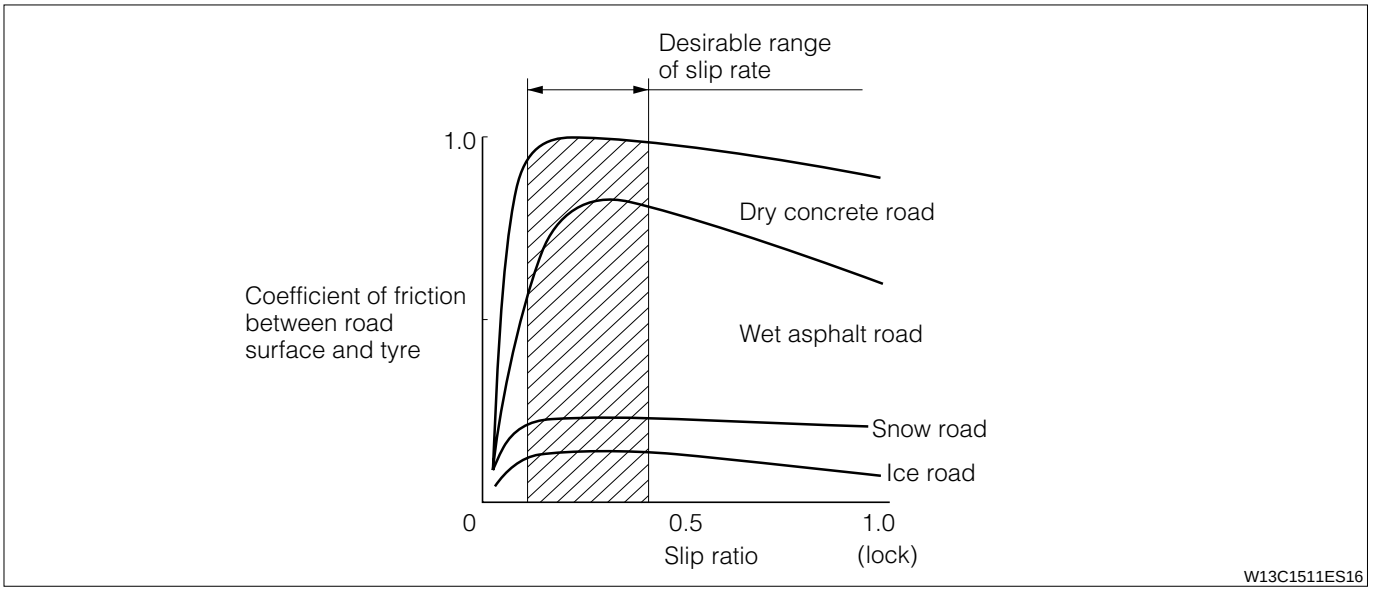
Slip ratio = (vehicle speed − wheel speed) / vehicle speed

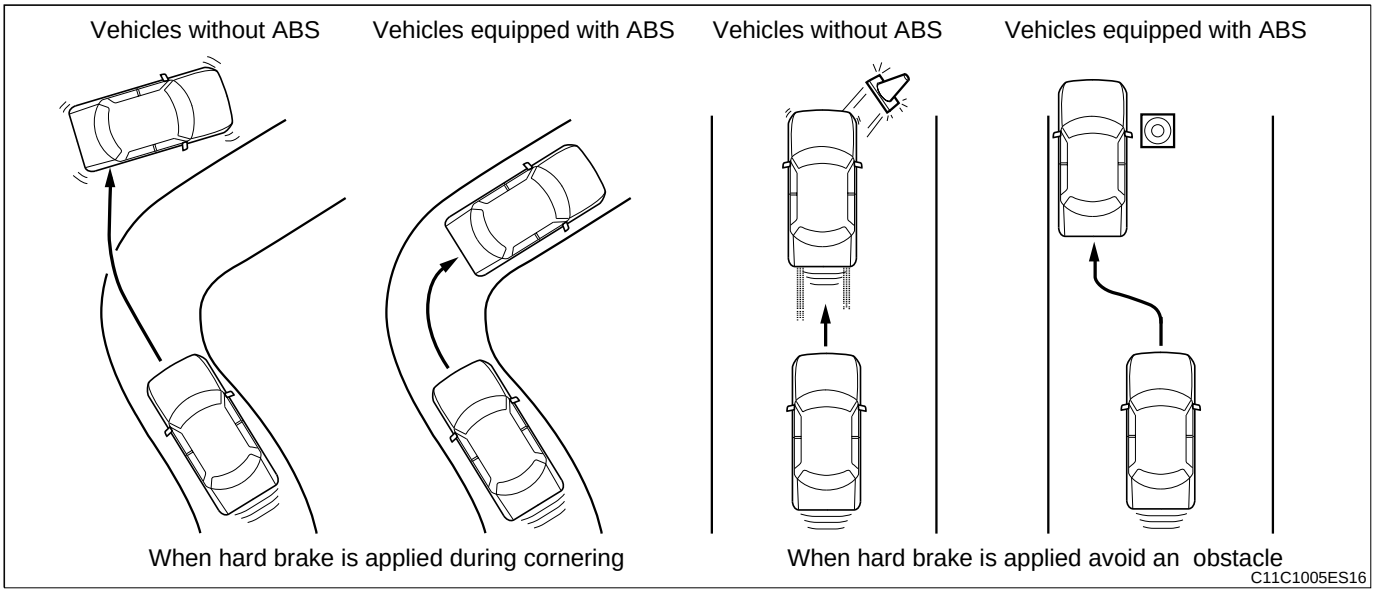
Normally, the friction coefficient between a tire and a road surface reaches the peak at the slip ratio of 0.1−0.3, with the braking effort also reaching the maximum. The value falls below the maximum when the wheels are locked.

The cornering force generated by tires when the vehicle is turning reaches the peak when the slip ratio is "0". The cornering force decreases as the slip ratio increases, reaching the minimum force during locking (slip ratio 1.0).

When steering with the front wheels being locked, the direction of the front wheels change, but they only slip on the road surface without causing any change in vehicle's direction. When the rear wheels are locked, if an external force, such as a change in the coefficient of friction of the road surface, is applied, the rear wheels start to skid, causing the vehicle slip laterally.

The ABS controls the ABS actuator based on the signal from each wheel speed sensor so that the wheel slip ratio can be constantly maintained in the high slip region of the friction coefficient by increasing, holding, or reducing the brake fluid pressure applied to each wheel, in order to maintain stable vehicle posture and directional control during deceleration.

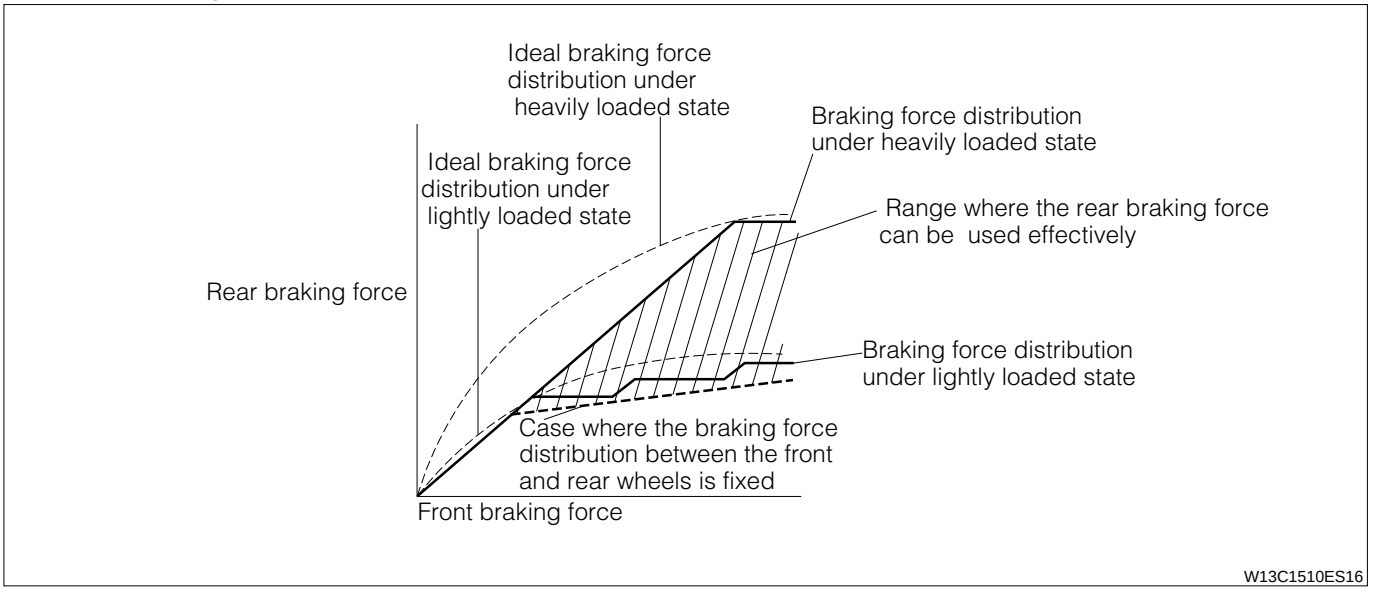




2-1-1 CONTROL OF BRAKING FORCE DISTRIBUTION BETWEEN FRONT AND REAR

The brake force distribution control between the front and rear wheels has achieved optimum distribution of braking force between the front and rear wheels in response to the driving conditions with a view to obtaining the excellent braking performance.

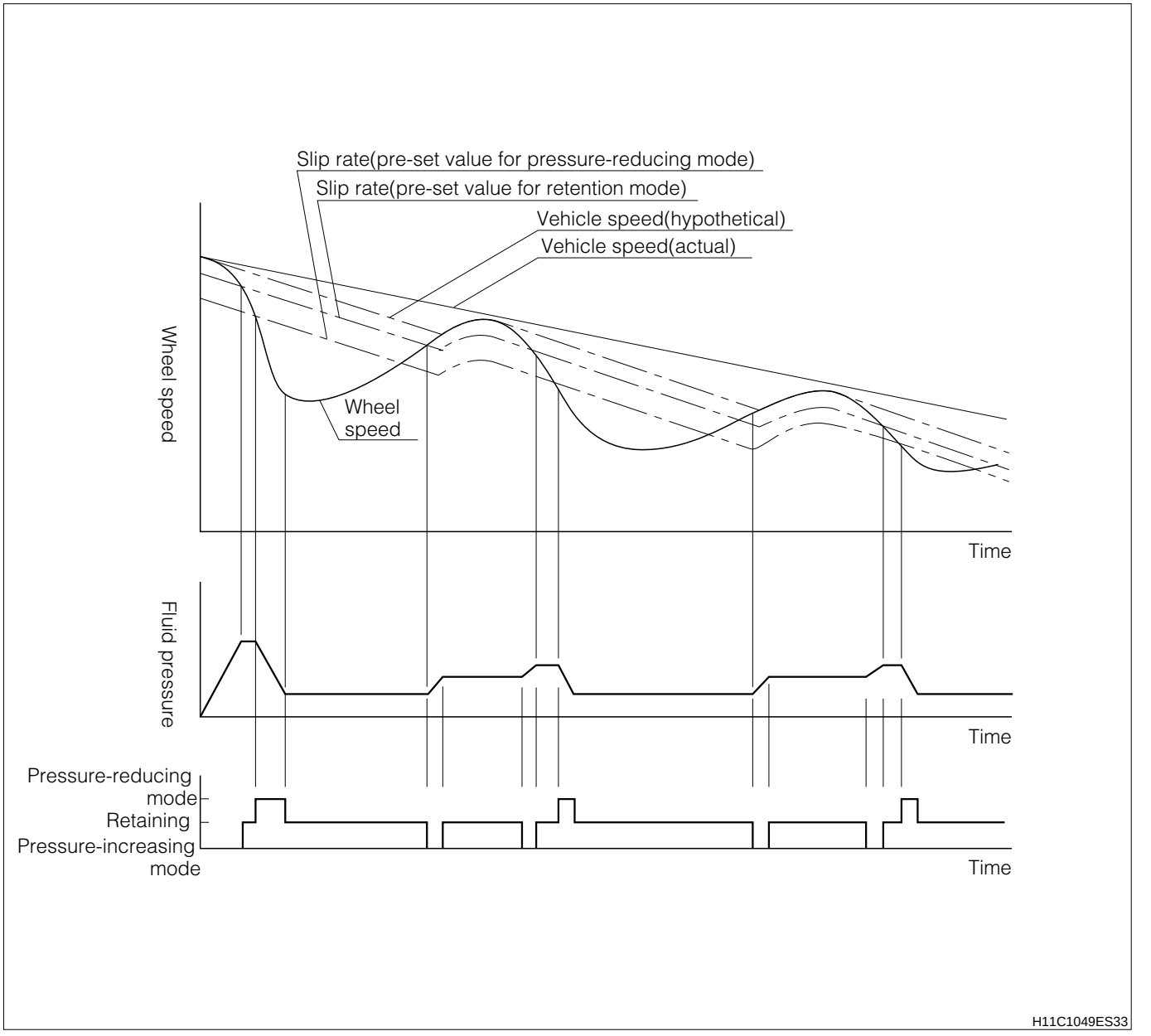
This allows the braking force of the rear wheels to function effectively responsive to changes in load condition or deceleration, thereby reducing braking effort especially during loading conditions to ensure excellent braking performance.



2-2 FLUID PRESSURE CONTROL

2-2-1 BASIC CONTROL

The ABS ECU calculates the speed and deceleration rate (magnitude of the drop in wheel speed) for each wheel based on the signal from the wheel speed sensor, and estimates the vehicle speed and the wheel slip rate. Based on the calculations, the ABS ECU controls the solenoid valve inside the ABS actuator by increasing/holding/reducing the brake fluid hydraulic pressure for each wheel, thus controlling the brake fluid pressure applied to the wheel cylinder so that the optimal vehicle speed and wheel slip rate can be maintained.



2-2-2 ABS OPERATION

The ABS hydraulic system consists of four systems; right front wheel, left front wheel, right rear wheel, left rear wheel.

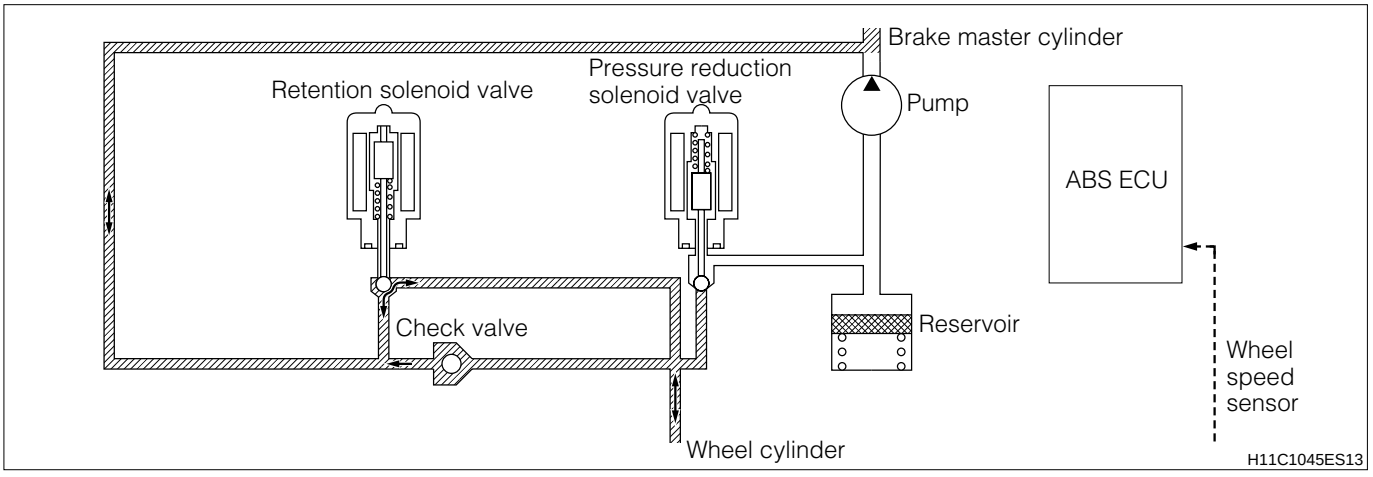
The following explanation is about the operation of only one system of the front wheel. The other systems work in the same way.

(1) During normal braking(During ABS non-operation)

1.Because the signal from the ABS ECU is not inputted, the solenoid valve will not be energized, causing the retention solenoid valve to open, while the pressure-reducing solenoid valve to close.

2.When the brake pedal is depressed in this state, the brake fluid pressure from the master cylinder will increase, pumping the brake fluid through the retention solenoid valve into the wheel cylinder.

3.At this time, the pump is not activated. When the brake pedal is released, the brake fluid in the wheel cylinder flows through the retention solenoid valve and check valve, and returns to the master cylinder.



(2) During hard braking(during ABS operation)

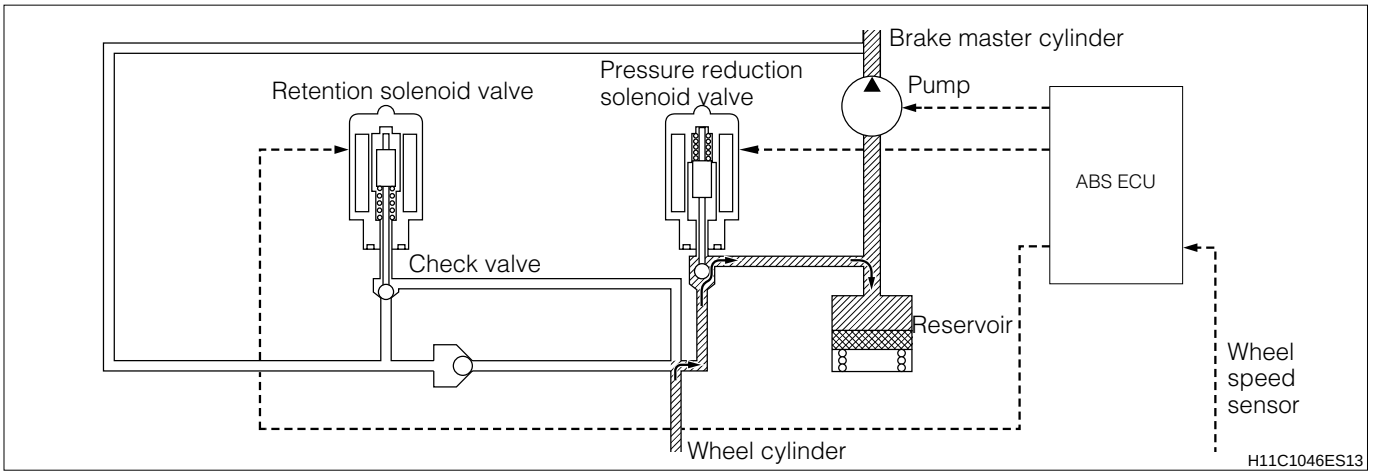
ABS control operation

During ABS operation	Pressure - reduction	Retention	Pressure - increasing
Retention solenoid valve	ON (Closed)	ON (Closed)	OFF (Open)
Pressure reduction solenoid valve	ON (Open)	OFF (Closed)	OFF (Closed)
Hydraulic pressure of the wheel cylinder	Releases hydraulic pressure.	Retains hydraulic pressure.	Applies hydraulic pressure.

The words in parentheses indicate open/close status of the solenoid valve.

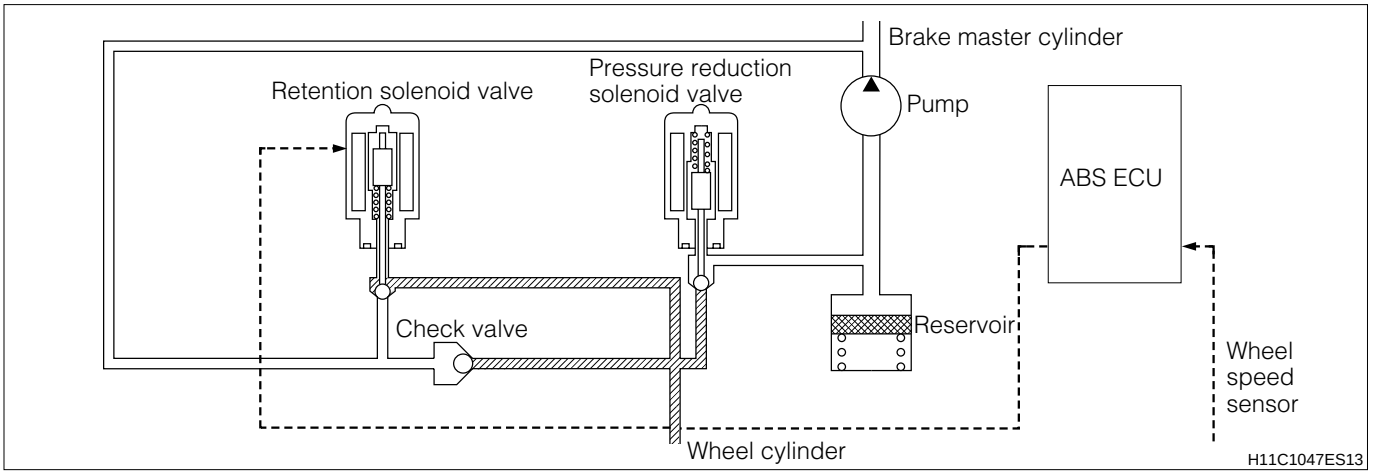
① **Pressure - reduction**

1.The ABS ECU sends a signal to the solenoid valve to activate each solenoid valve.
2.The brake fluid passes through the pressure reduction solenoid valve and flows into the reservoir, thereby reducing the hydraulic pressure.
3.During the ABS operation, the pump is activated to flush the brake fluid that collects in the reservoir back to the master cylinder.
4.The rate of fluid pressure reduction is controlled by repetition of the pressure reduction mode and the retention mode, which is described below.



② **Retention**

1.The ABS ECU sends a signal only to the retention solenoid valve, which shuts off the brake fluid passage.
2.The brake fluid pressure of the wheel cylinder is maintained.

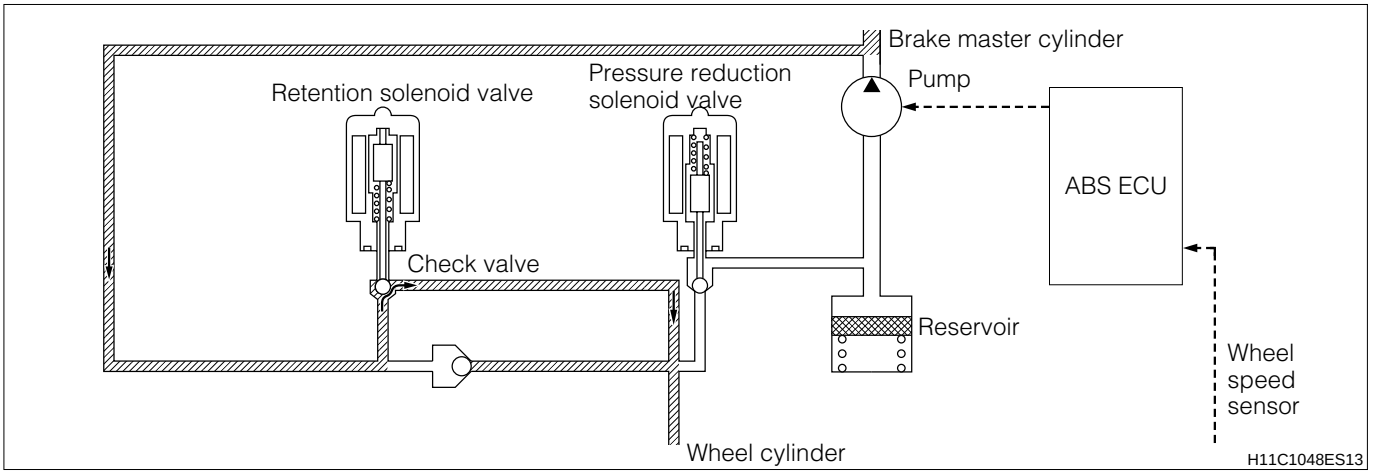


③ **Pressure - increasing**

1.The ABS ECU does not send a signal to the solenoid valve. The brake fluid is sent to the wheel cylinder, causing the fluid pressure to increase.

2.When the reservoir has some remaining brake fluid, the pump is activated to send the brake fluid in the reservoir back to the master cylinder.

3.The rate of fluid pressure increase is controlled by repetition of the pressure increase mode and the retention mode, which is described above.



2-3 CAN COMMUNICATION

1.The ABS ECU performs CAN communication with the meter ECU, A/T ECU, and EFI ECU, transmitting and receiving multiple pieces of information via a pair of communication wires (twisted pair wire). Refer to the section "CAN communication system" for details.

Refer to Page L2-1.

2-4 INITIAL CHECK FUNCTION

2-4-1 LAMP CIRCUIT

When the IG SW is turned ON, the ABS ECU will light up the ABS warning lamp and brake warning lamp for approx. 3 seconds, and check the lamp circuit.

2-4-2 DRIVING OF ACTUATOR

When the vehicle is started with the IG SW turned ON and the stop lamp switch turned OFF, the ABS ECU will check the motor operation inside the ABS actuator.

NOTE

- Although the operating sound of the motor and other components is generated from the engine compartment during the initial check of the actuator, that is not a sign of malfunction.

2-5 DIAGNOSIS

2-5-1 DESCRIPTION

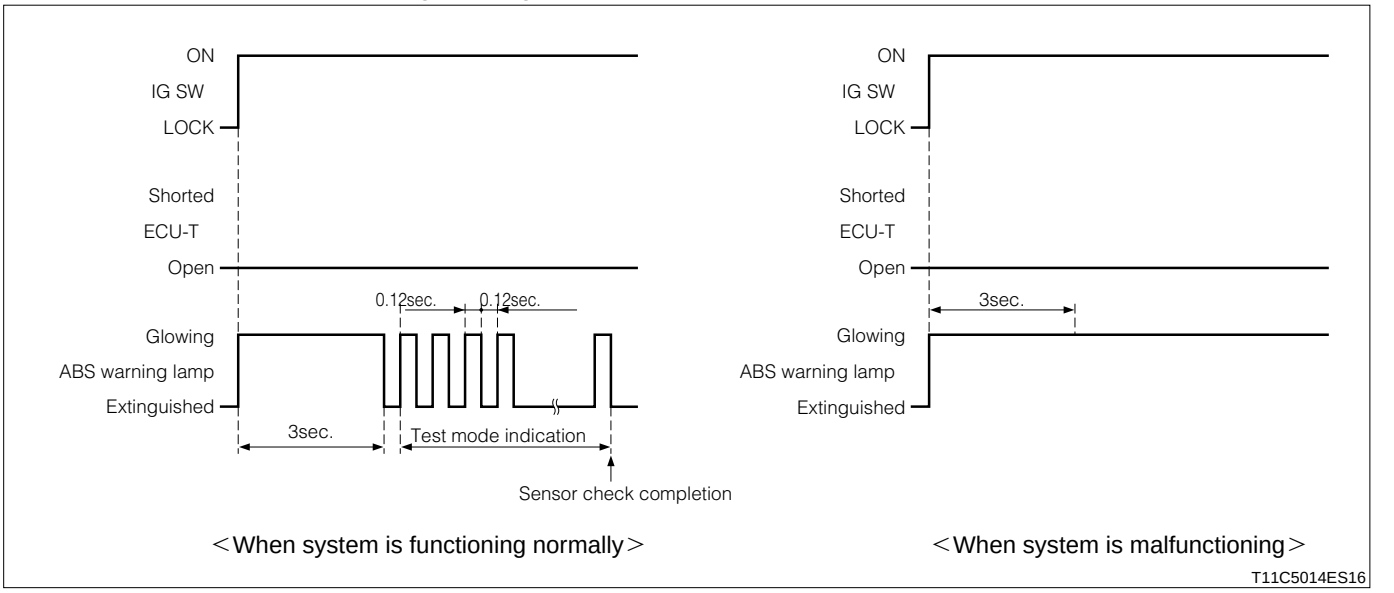
Diagnosis literally means {{}} failure diagnosis ″, which provides the function that allows the ECU to notify an operator of the fault that has occurred in the input and output system. The ECU stores faulty conditions when a fault occurs. The information is stored in the nonvolatile (EEPROM), therefore the diagnosis result will be stored even when the power supply is shut down.

Refer to the service manual for the details of diagnosis.

2-6 TEST MODE FUNCTION

2-6-1 DESCRIPTION

1. The ABS has a test mode function that checks the output value from each sensor to determine if the sensor is functioning properly, in addition to the diagnosis function that checks failure, open circuit, short-circuit, etc. of the system components.
2. The test mode is executed in any of the following cases.
   (1) Immediately after the abnormality code is erased by brake pedal operation.
   (2) When the IG SW is turned ON for the first time after the new ABS actuator is installed.
3. The test mode checks the following items. It also detects any faulty output value of each sensor, and deformation, missing teeth, etc. of the wheel speed sensor rotor.
   (1) Output voltage of wheel speed sensor
   (2) Output interval of wheel speed sensor
4. During the test mode, the ABS warning lamp flashes. When the checks of each sensor are completed properly, the ABS warning lamp goes out.



2-6-2 CHECK ITEMS

1.When the mode is switched to the test mode, first the ABS ECU memorizes all test mode codes automatically.

2.When the vehicle is driven straight at speeds of 4 km/h−7 km/h, the ABS ECU will check the wheel speed sensor and erase the test mode code previously stored when the ABS ECU has verified that no fault is present.

3.When the vehicle is driven straight at speeds of 10km/h−40km/h for 5 seconds, or driven straight until the vehicle speed becomes above 40 km/h, the ABS ECU will check the signal cycle of each wheel speed sensor, and erase the test mode code previously stored when the ABS ECU has verified that no fault is present.

Check system	Code No.		Check items	Checking condition
	2-digit	4-digit		
Wheel speed sensor Output voltage	81	C1271	RH front wheel speed sensor output voltage fault	Runs straight ahead at a vehicle speed of 4km/h−7km/h.
	82	C1272	LH front wheel speed sensor output voltage fault	
	83	C1273	RH rear wheel speed sensor output voltage fault	
	84	C1274	LH rear wheel speed sensor output voltage fault	
Wheel speed sensor Output interval	85	C1275	RH front wheel speed sensor output cycle fault	Runs straight ahead for five seconds or more at a vehicle speed of 10km/h−40km/h. Or driving the vehicle straight through at the speeds above 40 km/h.
	86	C1276	LH front wheel speed sensor output cycle fault	
	87	C1277	RH rear wheel speed sensor output cycle fault	
	88	C1278	LH rear wheel speed sensor output cycle fault	

2-7 FALE-SAFE FUNCTION

1.This is a function by which control takes place so that the system may not malfunction even if any abnormality is found in the input/output signal system.

2.When the fail-safe operates, the ABS warning lamp and brake warning lamp inside the combination meter go on as follows, thus telling the driver of the abnormality. Also, the system control will be prohibited.

(1) In cases where an abnormality which makes the ABS inoperative takes place, the ABS warning lamp goes on. Thus, the ABS control is prohibited.

(2) In addition, in cases where an abnormality which makes the EBD inoperative takes place, the ABS warning lamp and brake warning lamp go on at the same time. Thus, the EBD control is prohibited.

LIST OF FAIL-SAFE CONTROL FUNCTIONS

System diagnosed	Diagnosis items	Warning indication (Provided: ○, Not-provided:×)		Fail safe	
		ABS	Brake	Contents of control	Conditions of control release
Solenoid relay	Open wire / Short circuit	○	○	·Prohibition of EBD control ·Prohibition of ABS control	Control will be deactivated, when the IG SW is turned from LOCK to ON after returning to the normal state.
Power supply system	Voltage increase/ drop	○	×/○*1	·Prohibition of EBD control ·Prohibition of ABS control	Releasing after the normal condition has been restored
Wheel speed sensor front right	Open wire / Short circuit	○	×*2	·2 wheels or more EBD control is prohibited. ·Prohibition of ABS control	Control will be deactivated, when the IG SW is turned from LOCK to ON after returning to the normal state.
Wheel speed sensor front left	Open wire / Short circuit	○	×*2		
Wheel speed sensor rear right	Open wire / Short circuit	○	×*2		
Wheel speed sensor rear left	Open wire / Short circuit	○	×*2		
Wheel speed sensor front right	Cycle fault	○	×*2	·2 wheels or more EBD control is prohibited. ·Prohibition of ABS control	After returning to the normal state, turn the IG SW from LOCK to ON. If the outputs of the wheel sensors at all four wheels are found normal during the driving, the control will be deactivated.
Wheel speed sensor front left	Cycle fault	○	×*2		
Wheel speed sensor rear right	Cycle fault	○	×*2		
Wheel speed sensor rear left	Cycle fault	○	×*2		
Wheel speed sensor rotor	Teeth missing	○	×*2		
Pump	No-rotation fault	○	×	·Prohibition of ABS control	Released if the initial check confirms the normal operation when the IG SW is set from LOCK to ON.
Retention or pressure-reduction solenoid front RH	Abnormal	○	○	·Prohibition of EBD control ·Prohibition of ABS control	Control will be deactivated, when the IG SW is turned from LOCK to ON after returning to the normal state.
Retention or pressure-reduction solenoid front LH	Abnormal	○	○		
Retention or pressure-reduction solenoid rear RH	Abnormal	○	○		
Retention or pressure-reduction solenoid rear LH	Abnormal	○	○		
ABS ECU	ECU internal error	○	○	· Prohibition of EBD control · Prohibition of ABS control	Control will be deactivated, when the IG SW is turned from LOCK to ON after returning to the normal state.

*1:When the voltage rises: "○", When the voltage drops:"×"
*2:When failure occurred on two or more wheels: "○"

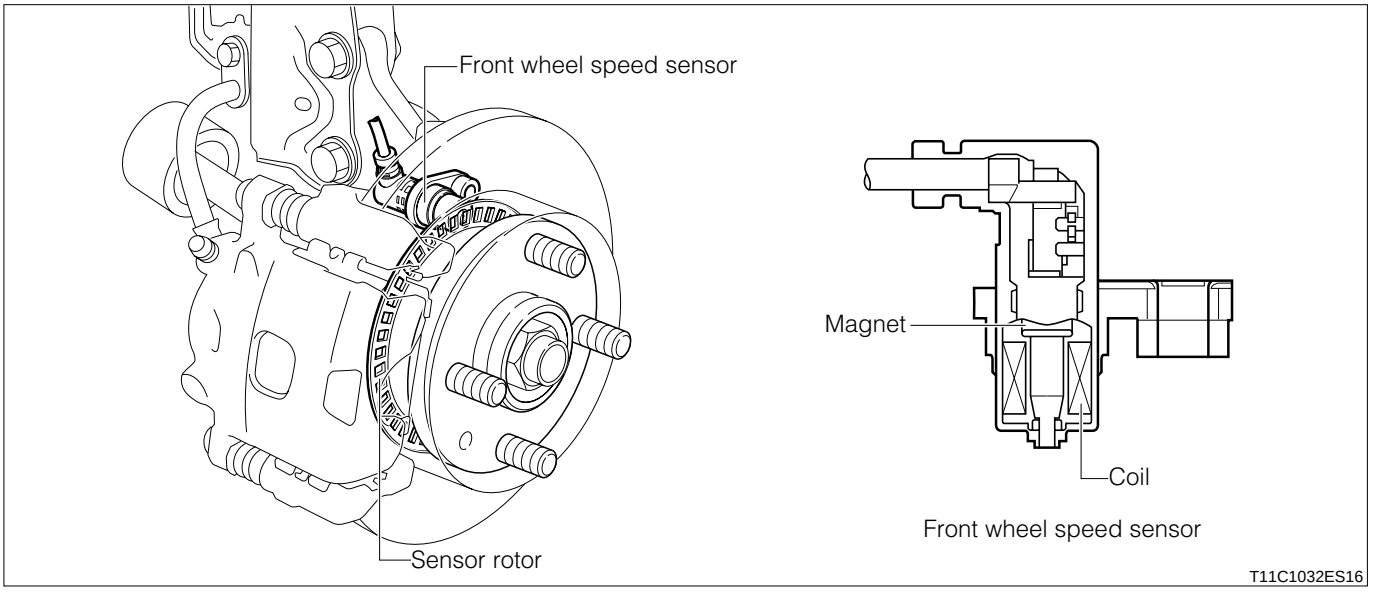
3 COMPONENTS

3-1 WHEEL SPEED SENSOR & SENSOR ROTOR

The wheel speed sensor consists of a magnet and a coil. When the sensor rotor rotates, magnetic flux that flows through the coil of the wheel speed sensor will change, generating alternating voltage in the coil. The frequency of this alternating voltage changes in proportion to the wheel rotation speed. By detecting this frequency, the vehicle speed is determined.

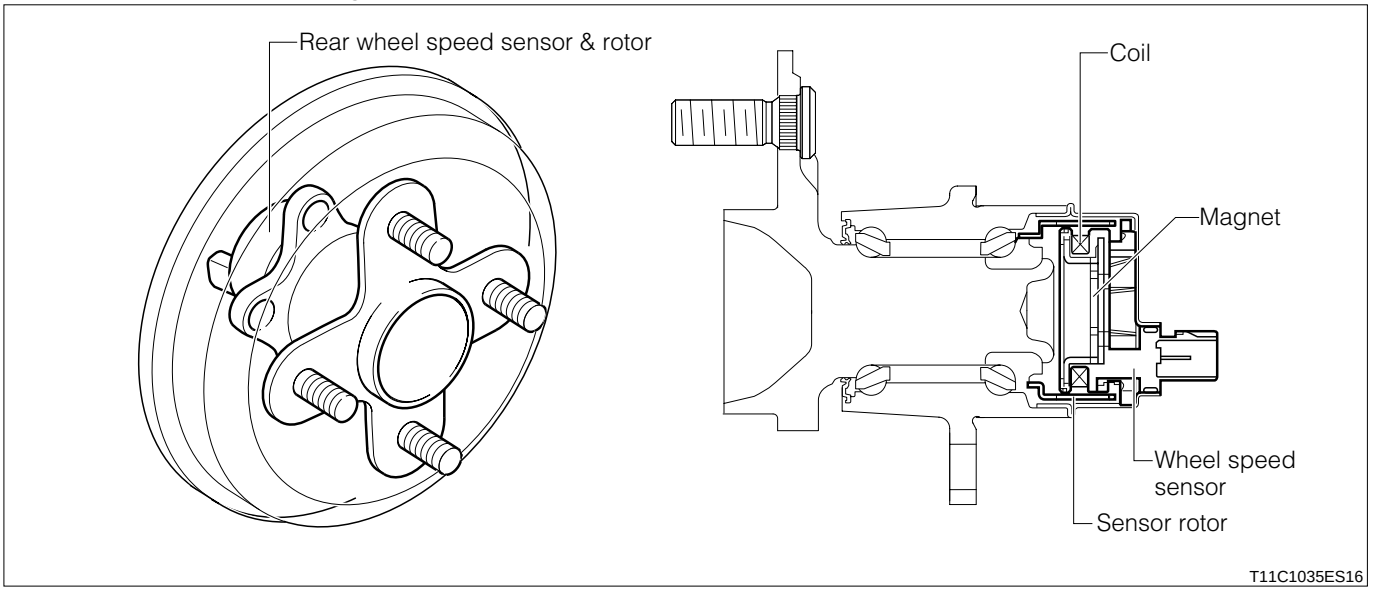
3-1-1 FRONT

These are installed to the right and left steering knuckles, and the sensor rotor is mounted on the front axle hub.



3-1-2 REAR

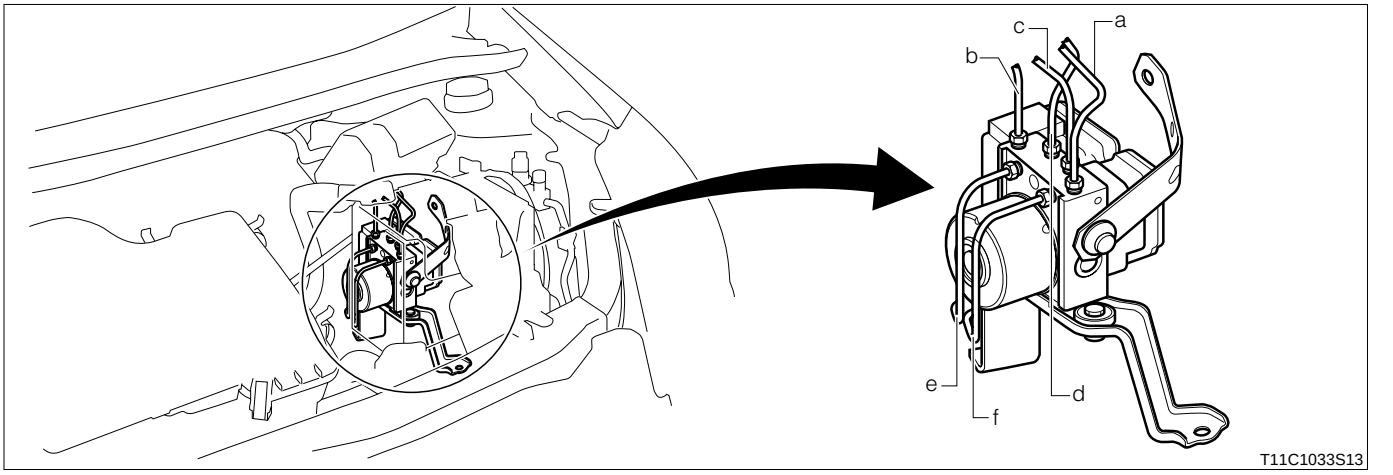
The rear axle and hub integrated type has been employed.



3-2 ABS ACTUATOR

ABS actuator, which consists of the ABS ECU, solenoid valve, pump, a motor, etc., controls fluid pressure that is applied to the wheel brakes during ABS control.

It is installed at the back of the battery in the engine compartment.

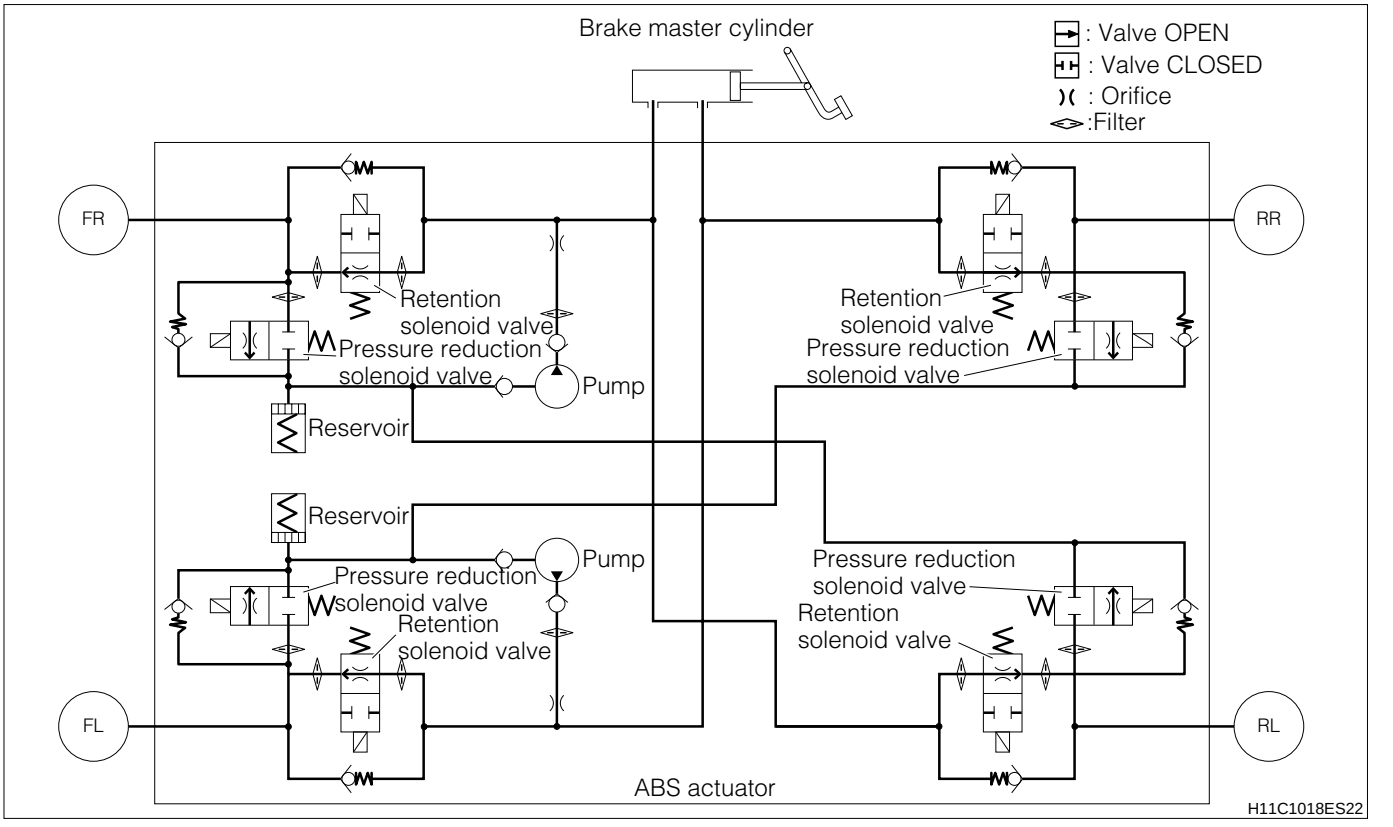


The illustration shows the RHD vehicle.

Brake pipe is connected to:

a	Master cylinder (primary side)
b	Master cylinder (secondary side)
c	Front brake RH
d	Front brake LH
e	Rear brake RH
f	Rear brake LH

3-2-1 ABS ACTUATOR FLUID PRESSURE CIRCUIT



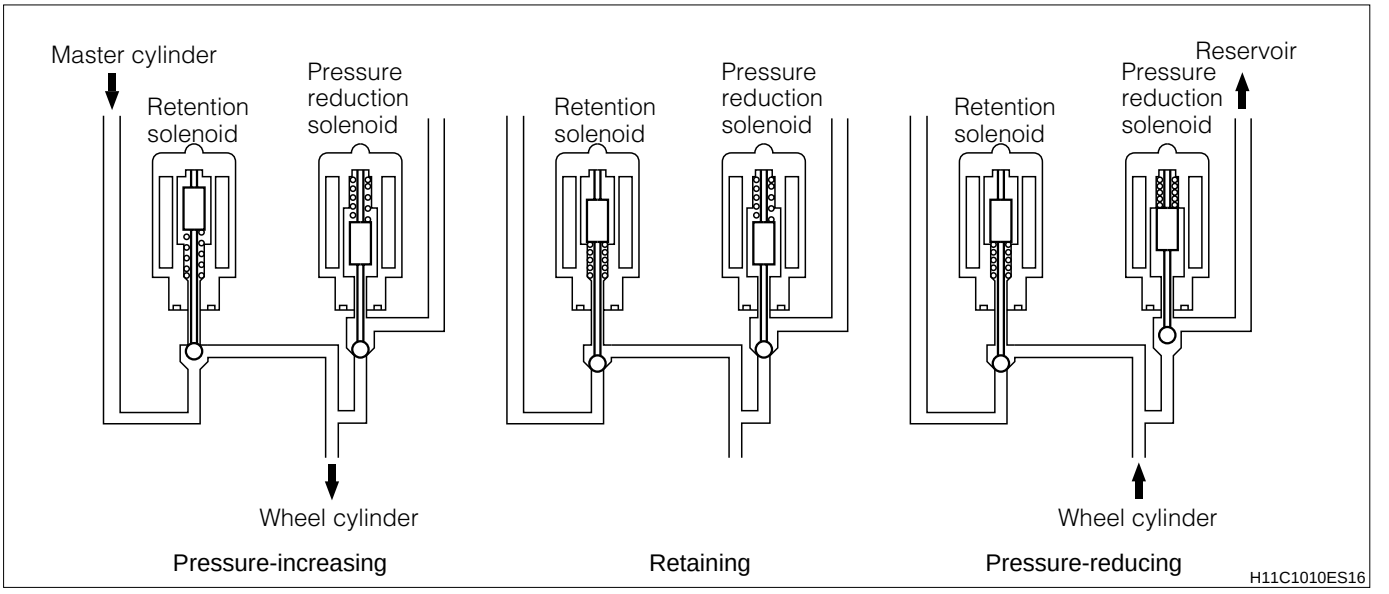
3-2-2 SOLENOID VALVE

Based on the signals from the ABS ECU, the electric current flowing into the coil is changed and the plunger is moved up and down so as to open/close the valve.

(1) The retention solenoid valve is normally open. However, it is closed upon receiving a signal from the ECU.

(2) Conversely, the pressure-reducing solenoid valve is normally closed. However, it opens upon receiving a signal from the ECU.

(3) Through the combination of this movement, the brake fluid pressure circuit can be switched into three modes of the pressure-increasing mode, retention mode, and pressure-reducing mode.



Solenoid valve operation

	Pressure - increasing	Retention	Pressure - reduction
Retention solenoid valve	OFF (Open)	ON (Closed)	ON (Closed)
Pressure reduction solenoid valve	OFF (Closed)	OFF (Closed)	ON (Open)

The words in parenthesis indicate open/close status of the solenoid.

3-2-3 RESERVOIR

1. This temporarily stores the brake fluid from the wheel cylinder, when each solenoid valve is under the pressure reduction mode.
2. When the passage between the wheel cylinder and the reservoir opens in the pressure reduction mode, the brake fluid from the wheel cylinder flows into the reservoir, by overcoming the spring force of the reservoir and pushing down the piston.

3-2-4 PUMP

It is driven by the motor, and it sends the brake fluid, which is stored in the reservoir in the pressure reduction mode, back to the master cylinder.

3-2-5 ABS ECU

This estimates the control status of the wheel by the signal from each wheel sensor, and controls the solenoid valve and the pump motor to prevent the wheel from getting locked. Also, it constantly monitors the system. When a fault is detected, it lights up the warning lamp and executes the fail safe function.

3-3 WARNING LAMP

1.An ABS warning lamp and brake warning lamp are mounted inside the combination meter. When the system is normal, the lamp lights up for about 3 seconds after the IG SW is turned on to check the lamp, and then turned off.

2.When a malfunctions occurs in the system, the ABS warning lamp and the brake warning lamp will remain illuminated.

3-3-1 BRAKE WARNING LAMP

1.When an error condition occurs and the EBD is inoperative, this lamp as well as the ABS warning lamp light up.

2.The lamp lights up when the parking brake SW or the brake fluid level SW is ON.
Refer to Page J3-12.

3-3-2 ABS WARNING LAMP

When malfunction occurs in the ABS, the lamp will remain illuminated. Also a diagnosis code is output.
Refer to Page J3-12.

3-4 STOP LAMP SWITCH

1.This is mounted at the base of the brake pedal.

2.This detects the brake pedal status. It turns ON when the brake pedal is depressed, and turns OFF when the brake pedal is released.