

# Anti-lock Brake System (ABS)

## Features/Construction/Operation

In a conventional brake system, if the brake pedal is depressed very hard, the wheels can lock before the vehicle comes to a stop. In such a case, the stability of the vehicle is reduced if the rear wheels are locked, and maneuverability of the vehicle is reduced if the front wheels are locked, creating an extremely unstable condition.

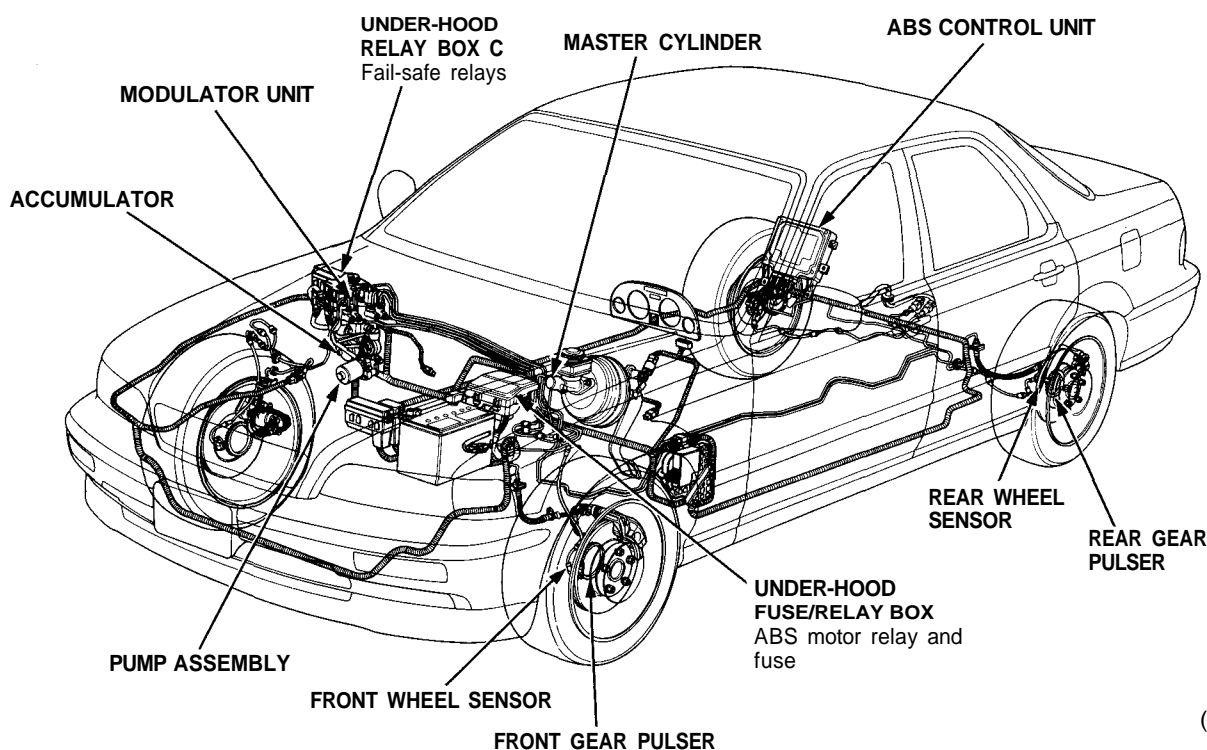
The Anti-lock Brake System (ABS) modulates the pressure of the brake fluid applied to each front caliper or both rear calipers thereby preventing the locking of the wheels, whenever the wheels are likely to be locked due to hard braking. It then restores normal hydraulic pressure when there is no longer any possibility of wheel locking.

### Features

- Increased braking stability can be achieved regardless of changing driving conditions.
- The maneuverability of the vehicle is improved as the system prevents the front wheels from locking.
- When the anti-lock brake system goes into action, a kickback is felt on the brake pedal.
- The system is equipped with a self-diagnosis function. When an abnormality is detected, the ABS indicator light comes on. The location of the system's trouble can be diagnosed from the frequency of the system indicator light blinks.
- This system has individual control of the front wheels and common control ("Select Low") for the rear wheels. "Select Low" means that the rear wheel that would lock first (the one with the lowest resistance to lock-up) determines anti-lock brake system activation for both rear wheels.
- The system has a fail-safe function that allows normal braking if there's a problem with the anti-lock brake system.

### Construction

In addition to the conventional braking system, the anti-lock brake system consists of: gear pulsers attached to the rotating part of individual wheels; wheel sensors, which generate pulse signals corresponding to the revolution of the gear pulsers; ABS control unit, which controls the working of the anti-lock brake system by performing calculations based on the signals from the individual wheel sensors and the individual switches; modulator unit, which adjusts the hydraulic pressure applied to each caliper on the basis of the signals received from the ABS control unit; an accumulator, in which high-pressure brake fluid is stored, a pressure switch, which detects the pressure in the accumulator and transmits signals to the ABS control unit; a pump assembly, which supplies the high-pressure working fluid to the accumulator by means of a pump; a motor relay for driving the pump; fail-safe relays, which cut off the solenoid valve ground circuit when the fail-safe device is at work; and, an ABS indicator light.



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# Anti-lock Brake System (ABS)

## Features/Construction/Operation (cont'd)

### Master Cylinder

#### 1. Construction

A tandem master cylinder is used to improve the safety of the braking system. In addition, center valves are used to match the anti-lock brake system operation.

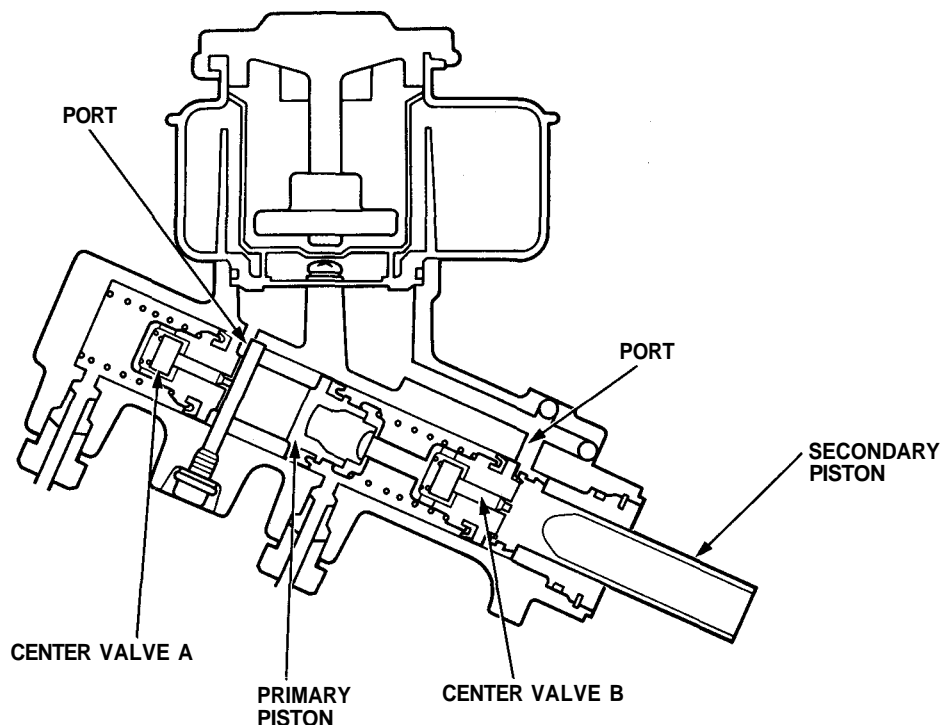
The master cylinder has one reservoir tank which is connected to the cylinder sections by two small holes. It has two pistons—primary and secondary, which are crisscross connected with the calipers so that the fluid pressure works separately on each system (front right wheel & rear left wheel, and front left wheel & rear right wheel).

A stop bolt for controlling movement of the primary piston is provided at the side of the master cylinder body. A reed switch for detecting the brake fluid volume is also provided in the cap of the reservoir tank.

#### 2. Operation

When the brake pedal is depressed, the secondary piston is pushed through the brake booster and the center valve B is closed so that fluid pressure is generated on the secondary side. At the same time, the primary piston is pushed by the secondary fluid pressure and the center valve A is closed so that braking fluid pressure is generated both on the primary and secondary sides.

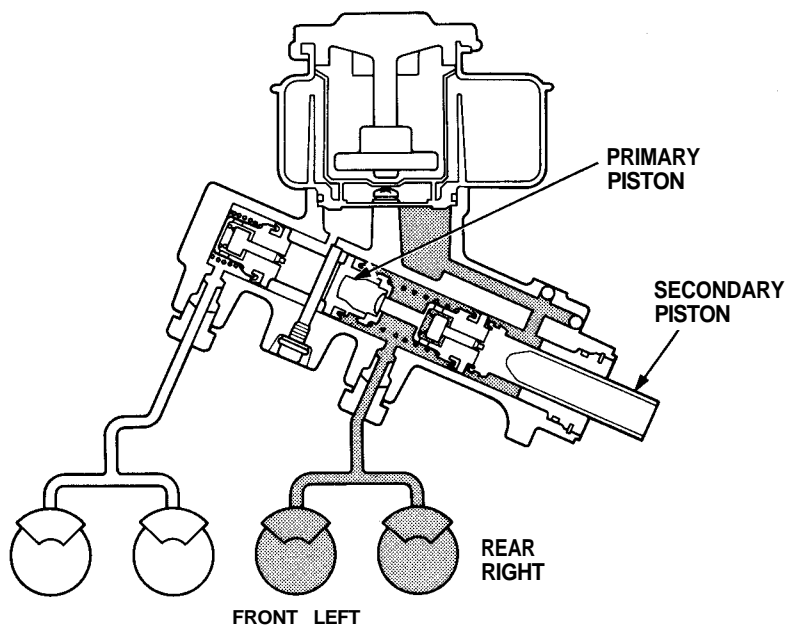
When the brake pedal is released, the primary and secondary pistons are returned to the original position by the brake fluid pressure and piston spring.



### 3. Responses when fluid is leaking

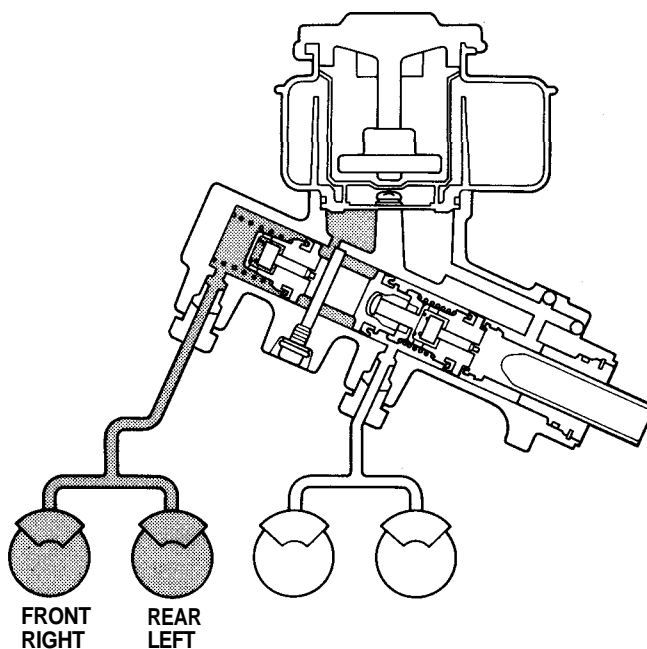
#### (1) In case of leaking from the primary system:

Since the fluid pressure on the primary side does not rise, the primary piston is pushed by the fluid pressure of the secondary piston and the tension of the piston spring until the end hits on the cylinder, the braking is performed by the fluid pressure on the secondary side.



#### (2) In case of leaking from the secondary system:

The secondary piston does not produce fluid pressure, keeps moving ahead, hits on the end surface of the primary piston so that the primary piston is pushed under the same condition as an ordinary rod. Therefore, the braking is conducted by the fluid pressure on the primary side.



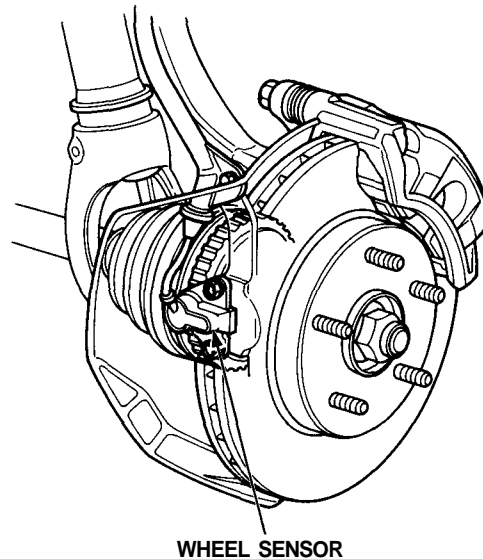
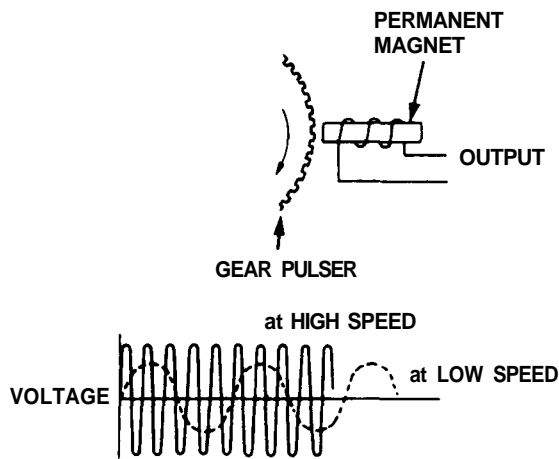
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# Anti-lock Brake System (ABS)

## Features/Construction/Operation (cont'd)

### Wheel Sensor

The wheel sensor is a contactless type that detects the rotating speed of a wheel. It is comprised of a permanent magnet and coil. When the gear pulsers attached to the rotating parts of each wheel (front wheel: outboard joint of the driveshaft, rear: hub bearing unit) turn, the magnetic flux around the coil in the wheel sensor alternates, generating voltages with frequency in proportion to wheel rotating speed. These pulses are sent to the ABS control unit and the ABS control unit identifies the wheel speeds.



### ABS Control Unit

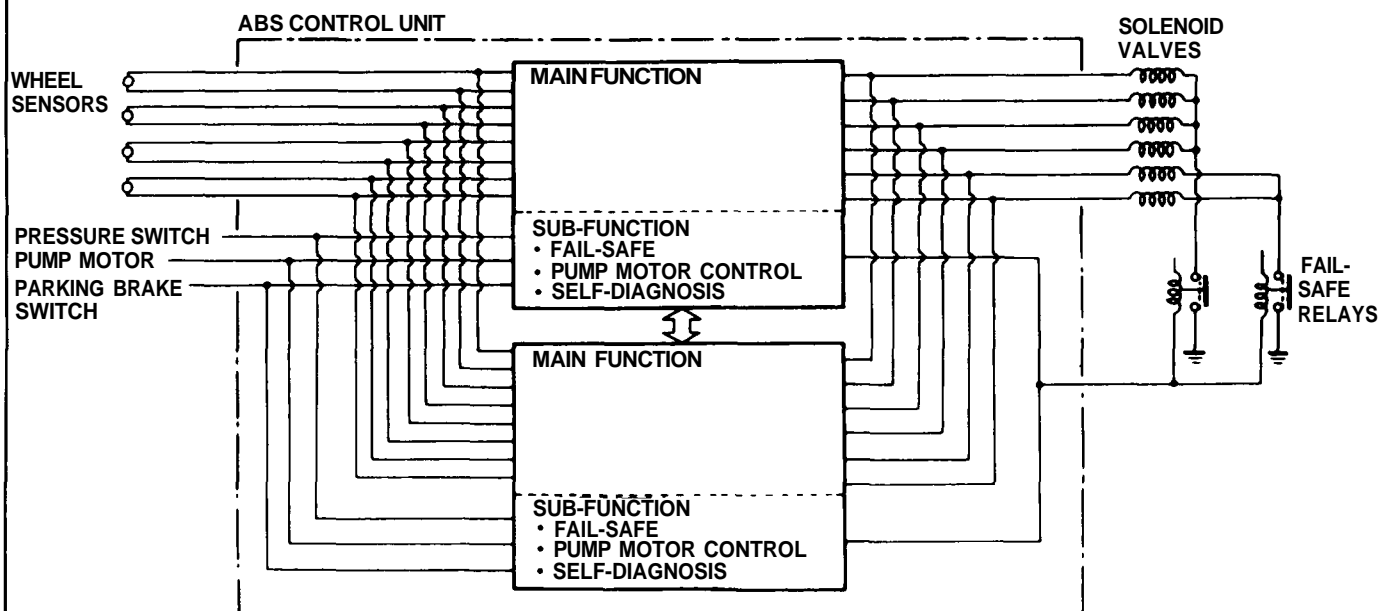
The ABS control unit consists of a main function section, which controls the operation of the anti-lock brake system, and sub-function, which controls the pump motor and "self-diagnosis".

#### 1. Main Function

The main function section of the ABS control unit performs calculations on the basis of the signals from each wheel sensor and controls the operation of the anti-lock brake system by putting into action the solenoid valves in the modulator unit for each front brake and for the two rear brakes.

#### 2. Sub-function

The sub-function section gives driving signals to the pump motor and also gives "self-diagnosis" signals, necessary for backing up the anti-lock brake system.



### 1. Self-diagnostic Function

Since the anti-lock brake system modulates the braking pressure when a wheel is about to lock, regardless of the driver's intention, the system operation and the braking power will be impaired if there is a malfunction in the system. To prevent this possibility, at speeds above 6 mph (10 km/h), the self-diagnosis function, provided in the sub-function of the ABS control unit, monitors the main system functions. When an abnormality is detected, the ABS indicator light goes on. There is also a check mode of the self-diagnosis system itself; when the ignition switch is first turned on, the ABS indicator light comes on and stays on for a few seconds after the engine starts, to signify that the self-diagnosis system is functional.

### 2. Fail-safe Function

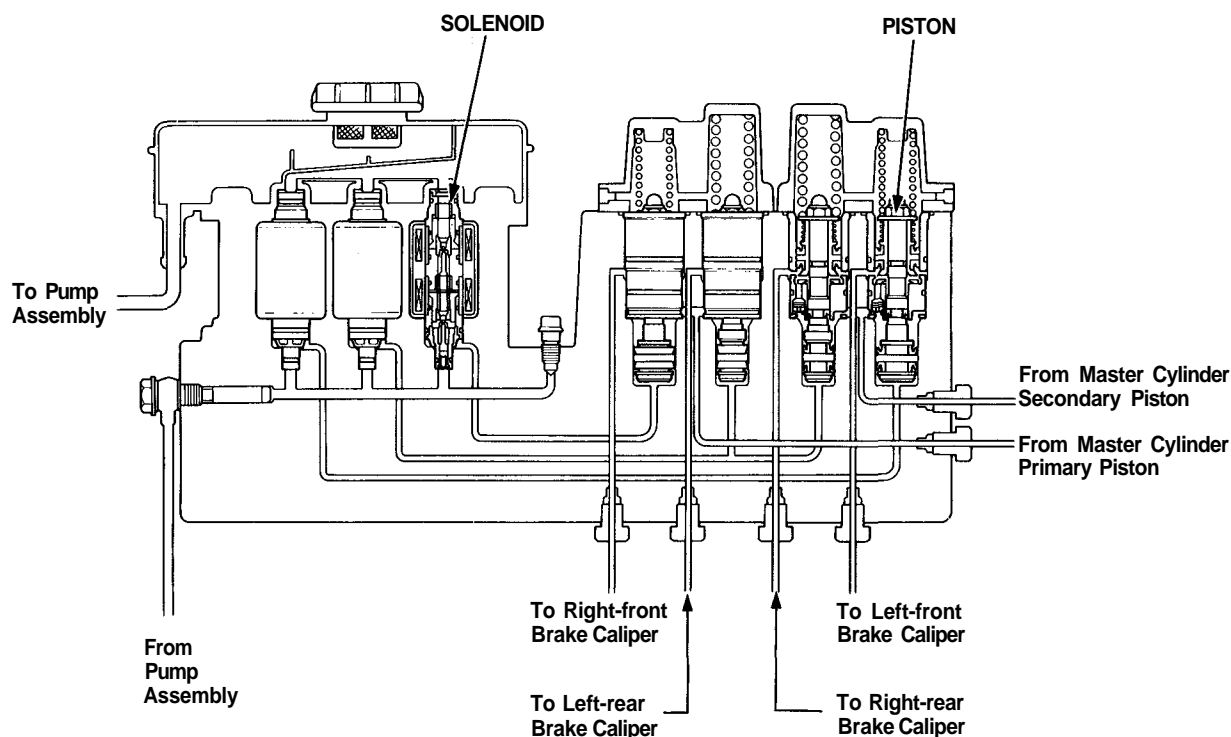
When abnormality is detected in the control system by the self-diagnosis, the solenoid operations are suspended by turning off the relays (fail-safe relays) which disconnect the ground lines of all the solenoid valves to inhibit anti-lock brake system operations. Under these conditions, the braking system functions just as an ordinary one, maintaining the necessary braking function. When the ABS indicator light is turned on, it means the fail-safe is functioning.

## Modulator Unit

Modulators for each wheel and solenoid valves are integrated in the modulator unit.

The modulators for front and rear brakes are of independent construction and are positioned vertically for improved maintainability. The modulators for rear brakes are provided with a Proportioning Control Valve function in order to prevent the rear wheel from locking when the anti-lock brake system is malfunctioning or the anti-lock brake system is not activated. The solenoid valve features quick response (5 ms or less).

The inlet and outlet valves are integrated in the solenoid valve unit. There are three solenoid valves, one for each front wheel, and one for both rear wheels.



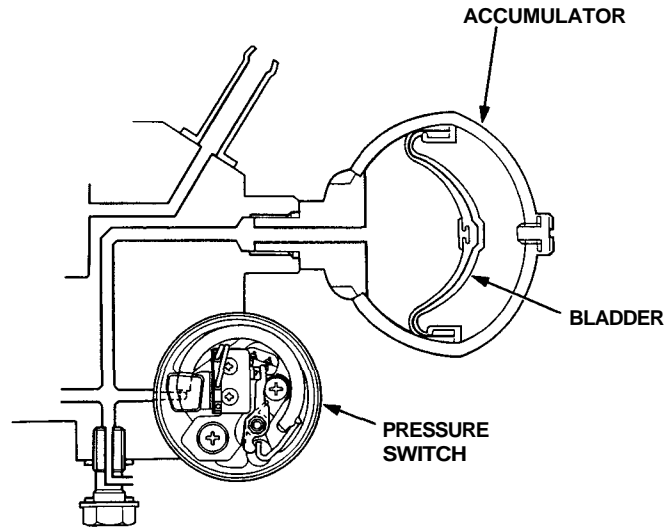
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# Anti-lock Brake System (ABS)

## Features/Construction/Operation (cont'd)

### Accumulator

The accumulator is a pneumatic type which accumulates high-pressure brake fluid fed from the pump incorporated in the pump assembly. When the anti-lock brake system operates, the accumulator and the pump assembly supply high-pressure brake fluid to the modulator valve via the inlet side of the solenoid valve.

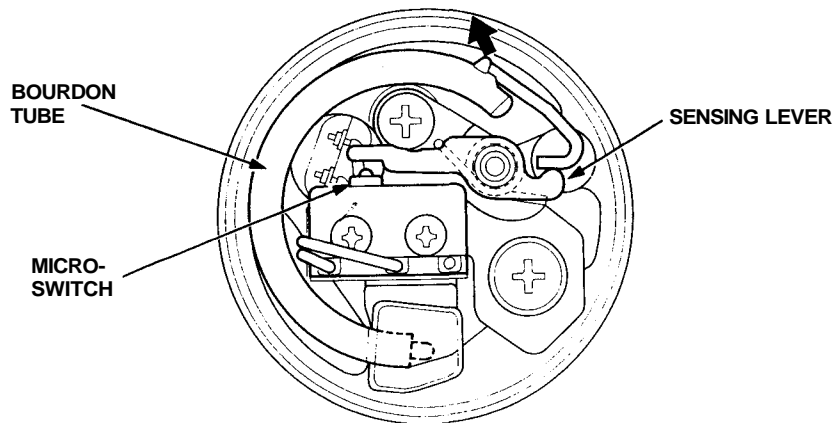


### Pressure Switch

The pressure switch monitors the pressure accumulation (pressure from the pump) in the accumulator and is turned off when the pressure becomes lower than a prescribed level. When the pressure switch is turned off, the switching signal is sent to the ABS control unit. Upon receiving the signal, the ABS control unit activates the pump motor relay to operate the motor. If the pressure doesn't reach the prescribed value, the ABS indicator light comes on.

### Operation

When the pressure in the accumulator rises, the Bourdon tube in the pressure switch deforms outwards. When the free end of the Bourdon tube moves more than the prescribed amount, the micro-switch is activated by the force of the spring attached to the sensing lever. When the pressure in the accumulator decreases due to anti-lock brake system operations, the Bourdon tube moves in the direction opposite to the one described above, and the micro-switch is eventually turned off. Upon receiving this signal, the ABS control unit activates the motor relay to operate the motor.



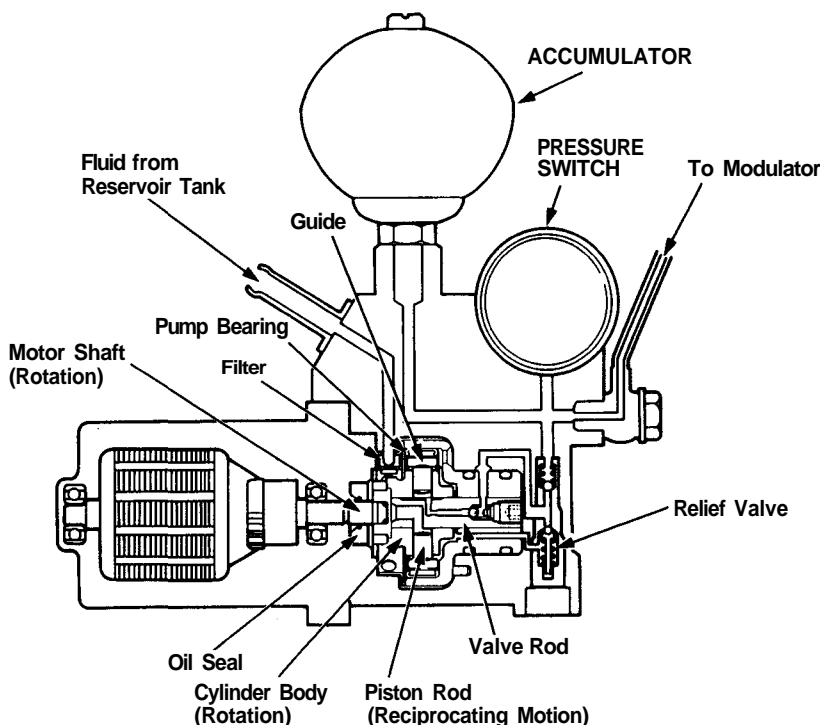
## Pump Assembly

The pump assembly consists of a motor, filter, guide, piston rod and cylinder body. Since a guide is positioned offset to the center of the motor shaft, the rotation of the motor and cylinder body provides the reciprocating motion to the piston rod.

The brake fluid is thus pressurized and fed to the relief valve, accumulator and modulator unit.

As the pressure in the accumulator exceeds the prescribed level, the pressure switch is turned on. Approx. 0.5 seconds after receiving the ON-signal, the ABS control unit stops the motor relay operation. In this state, the pressure in the accumulator reaches 23,000 kPa (230 kg/cm<sup>2</sup>, 3,270 psi).

If the pressure doesn't reach the prescribed value after the motor has operated continuously for a specified period, the ABS control unit stops the motor and activates the ABS indicator light.



## Anti-lock Brake System (ABS) Indicator Light

This ABS control unit turns on the ABS indicator light when one or more of the below described abnormalities is detected. This is only a partial list.

- When the operating time of the motor in the power unit exceeds the specified period.
- When vehicle running time exceeds 30 seconds without releasing the parking brake lever.
- When one of the rear wheels is locked during running.
- When absence of speed signals from any of the four wheel sensors is detected.
- When the activation time of all solenoids exceeds a given time or an open or short circuit is detected in the solenoid system.
- When solenoid output is not detected in the simulated anti-lock brake system operation carried out during running at speeds of 6 mph (10 km/h) or more.

To check the ABS indicator light bulb, the light is activated when the ignition switch is turned on. It is turned off after the engine is started if there is no abnormality in the system.

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# Anti-lock Brake System (ABS)

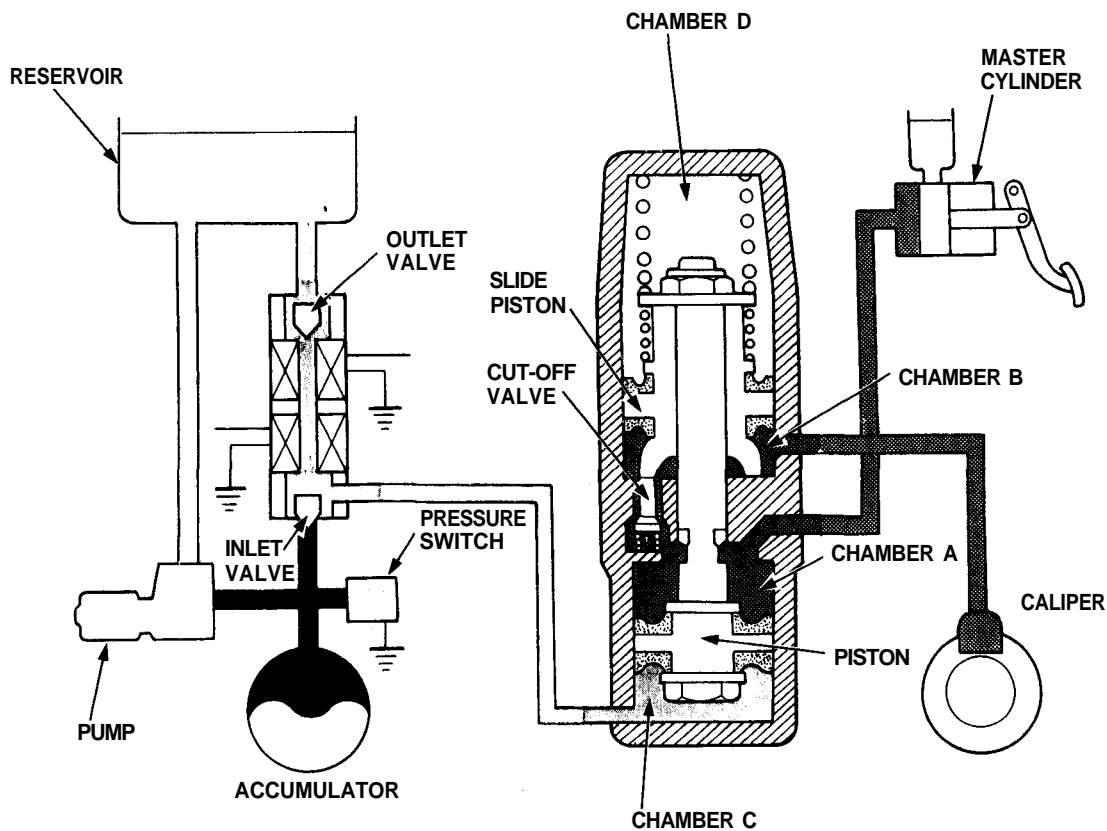
## Features/Construction/Operation (cont'd)

### Operation

#### 1. Ordinary Braking Function

In ordinary brake operations, the cut-off valve in the modulator is open, transmitting the hydraulic pressure from the master cylinder to the brake calipers via chamber A and chamber B.

Chamber C is connected to the reservoir through the outlet valve, which is normally open. It is also connected to the hydraulic pressure source (pump, accumulator, pressure switch, etc.) via the inlet valve, which is normally closed. Chamber D serves as an air chamber. Under these conditions, the pressures of chambers C and D are maintained at about atmospheric pressure, permitting regular braking operations.



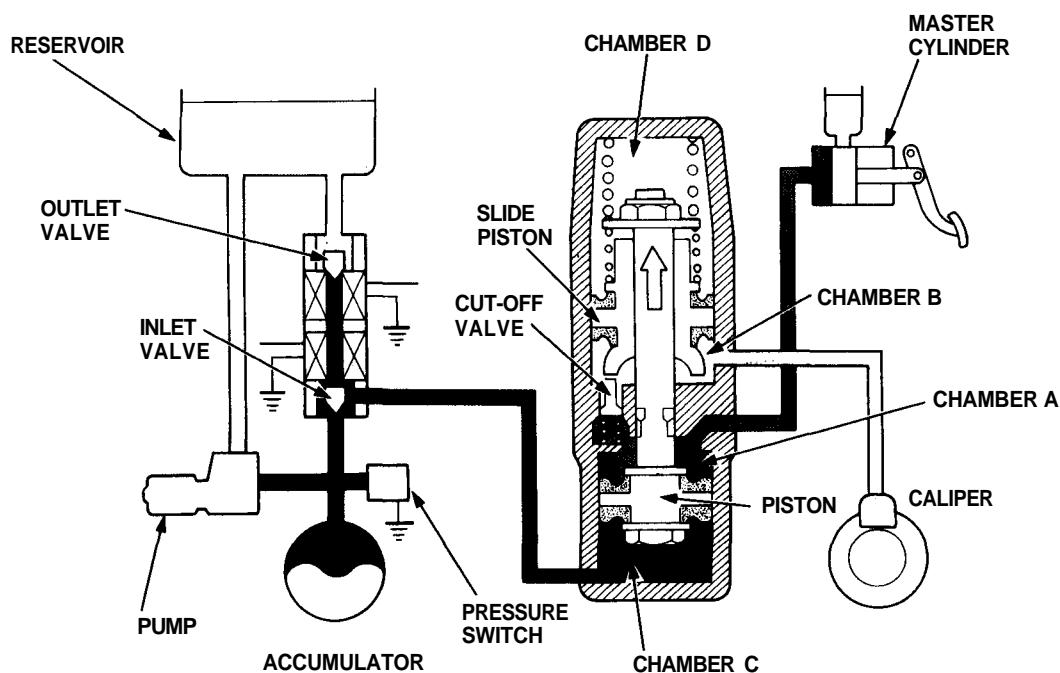


If brake inputs (force exerted on brake pedal) are excessively large and a possibility of wheel locking occurs, the ABS control unit operates the solenoid valve, closing the outlet valve and opening the inlet valve. As a result, the high pressure is directed into chamber C, the piston is pushed upward, causing the slide piston to move upward and the cut-off valve to close. As the cut-off valve closes, the flow from the master cylinder to the caliper is interrupted, the volume of chamber B, which is connected to the caliper, increases, and the fluid pressure in the caliper declines.

When both of the valves, inlet and outlet, are closed (when only the outlet valve is activated) the pressure in the caliper is maintained constant.

When the possibility of wheel locking ceases, it is necessary to restore the pressure in the caliper. The solenoid valve is therefore turned off (outlet valve: open, inlet valve: closed).

Process	Caliper Pressure	Outlet Valve		Inlet Valve	
		Electric Power	Hydraulic Circuit	Electric Power	Hydraulic Circuit
Caliper pressure declining	→	ON	Close	ON	Open
Caliper pressure constant	→	ON	Close	OFF	Close
Caliper pressure increasing	→	OFF	Open	OFF	Close



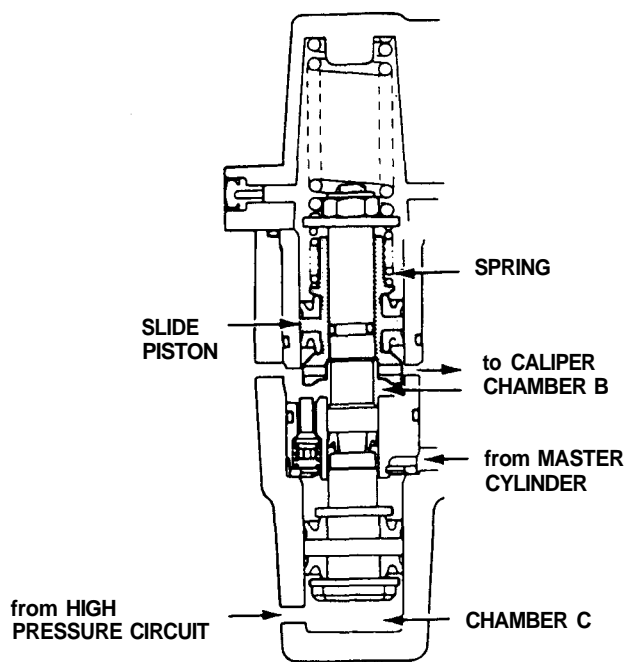
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# Anti-lock Brake System (ABS)

## Features/Construction/Operation (cont'd)

### 2. Slide Piston Function

When the car is used on rough roads where the tires sometimes lose adhesion, the anti-lock brake system may function excessively, causing a very large volume of brake fluid to flow into chamber C. When this occurs, the piston is moved excessively, resulting in an abnormal loss of pressure in chamber B. In order to overcome this problem, the slide piston is kept in proper position by spring force to prevent the pressure in chamber B from becoming negative.



### 3. Kickback

When the anti-lock brake system is functioning, the piston moves upward, the volume of chamber B increases, and the fluid pressure on the caliper side is reduced. At the same time, the volume of chamber A is reduced and the brake fluid is returned to the master cylinder. When the brake fluid is pushed back to the master cylinder, the driver can feel the functioning of the anti-lock brake system because the brake pedal is kicked back.

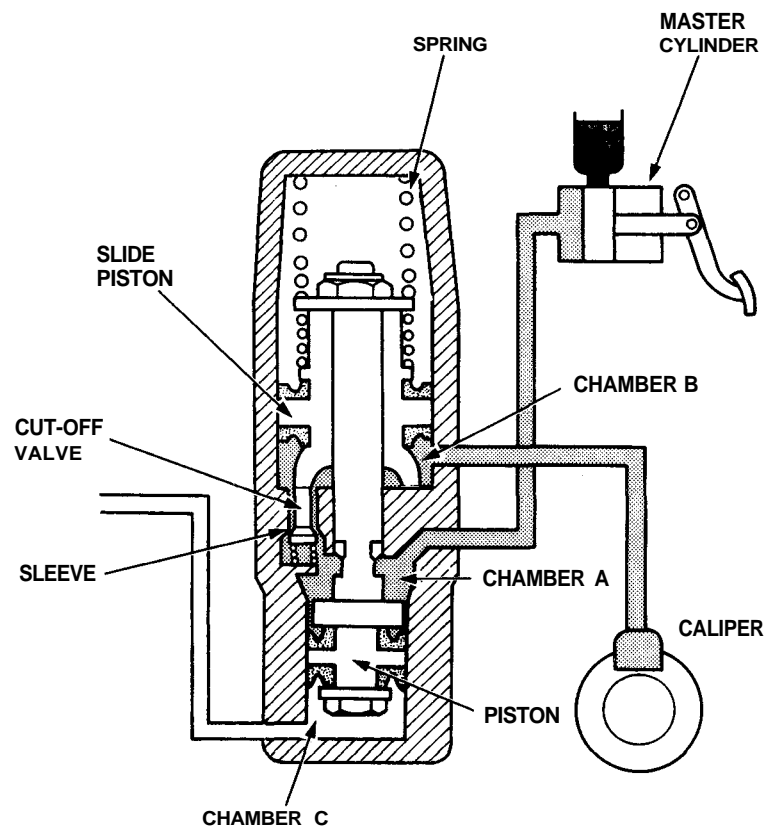
### 4. Proportioning Control Valve Function

In the modulator for the rear wheels, the diameters of the piston and the slide piston are distinctly different. This provides a Proportioning Control Valve function to prevent the rear wheels from locking during an emergency stop.

#### (1) Before the Turning Point:

- 1) When the fluid pressure from the master cylinder is below the turning point, the cut-off valve is always pushed downward by the force of the slide piston and its spring.

Under these conditions, there is a gap between the cut-off valve shoulder and the sleeve. Chamber A and chamber B are therefore connected through the gap. The pressure from the master cylinder flows into the rear calipers through chamber A and chamber B.

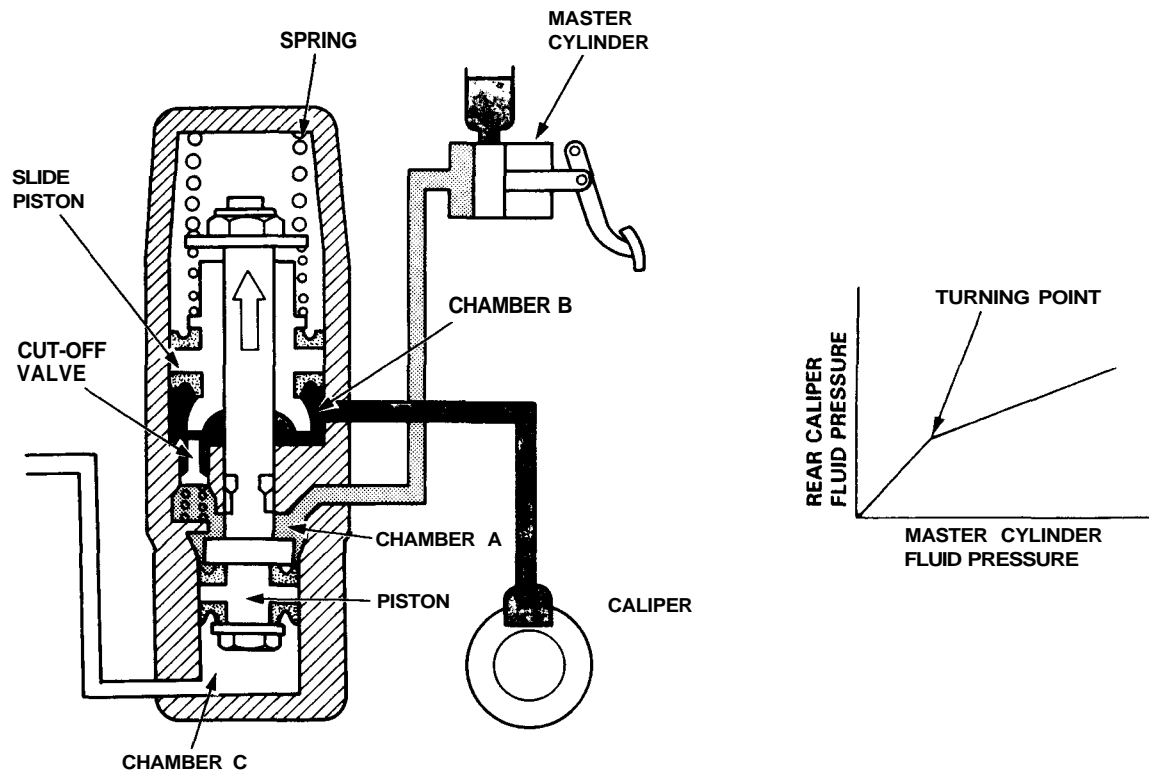


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# Anti-lock Brake System (ABS)

## Features/Construction/Operation (cont'd)

- 2) When the fluid pressure from the master cylinder reaches the turning point, the force on the slide piston overcomes the force of the spring, causing the slide piston to travel upward. The cut-off valve, previously being in contact with the bottom of the slide piston, then moves upward and the cut-off valve shoulder hits the sleeve, blocking the fluid passages (the fluid pressure at this point is called the turning point).



- (2) After the turning point:

As the fluid pressure from the master cylinder increases, the pressure in chamber A becomes higher, causing a force to push down the large diameter portion of the piston. Consequently, the slide piston comes down, the cut-off valve is pushed downward by the bottom of the slide piston, allowing chambers A and B to connect momentarily. As this occurs, pressure in chamber B increases, the slide piston is pushed upward, the cut-off valve goes up, and the connection between chamber A and chamber B is blocked again. As described above, when the pressure in the master cylinder is above the turning point, the slide piston reduces the pressure in the rear caliper to the prescribed amount by repeating this process.