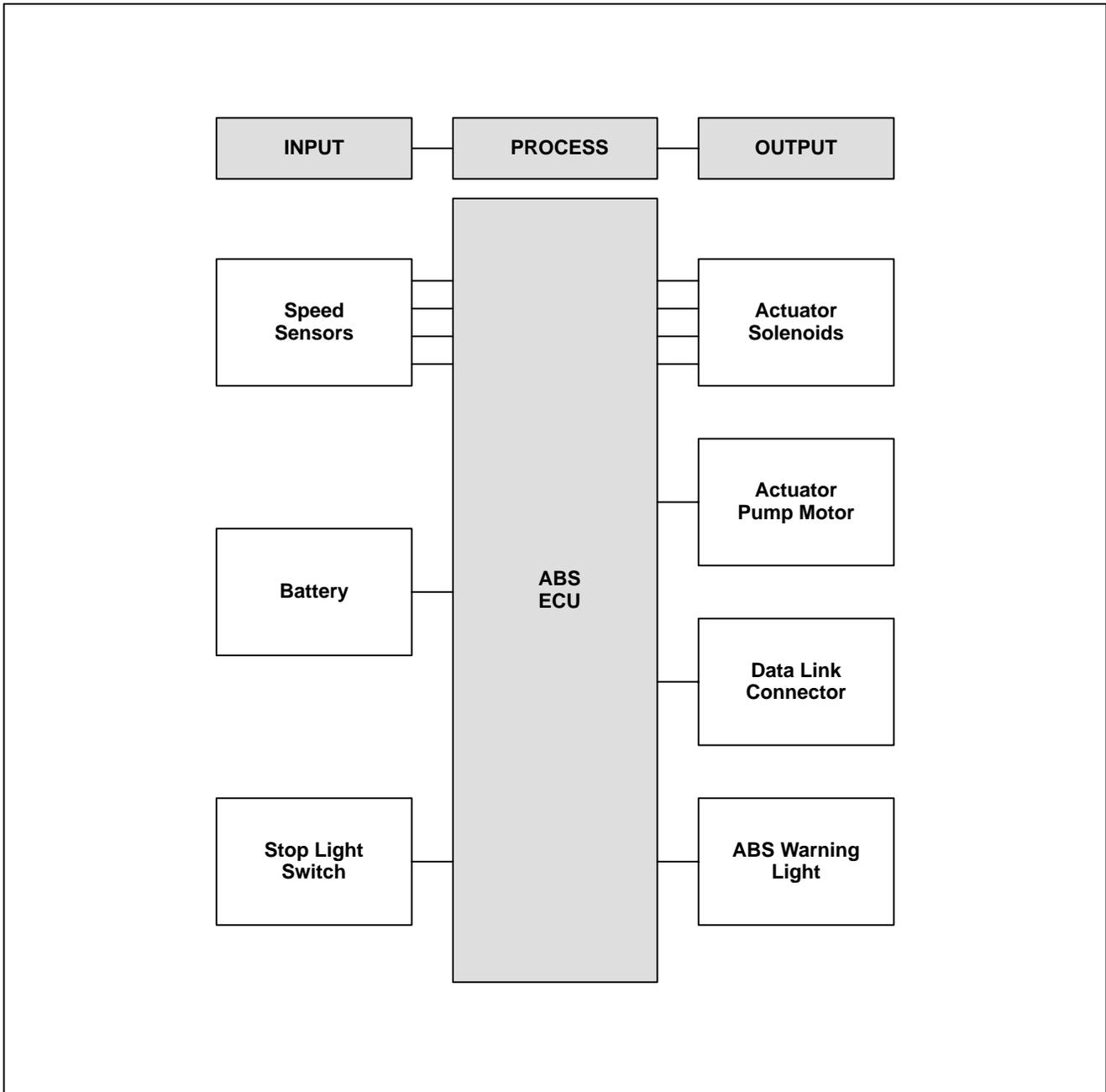


Section 9

ANTI-LOCK BRAKES



- Lesson Objectives**
1. Identify and describe the function of components in the ABS system.
 2. Relate the basic operation strategy of the ABS system.
 3. Explain the control of the solenoid and pump relays.
 4. Describe the signal generation of a speed sensor.
 5. Describe the operation of the two-position solenoid actuator for controlling wheel lock-up.

Fundamental ABS Systems

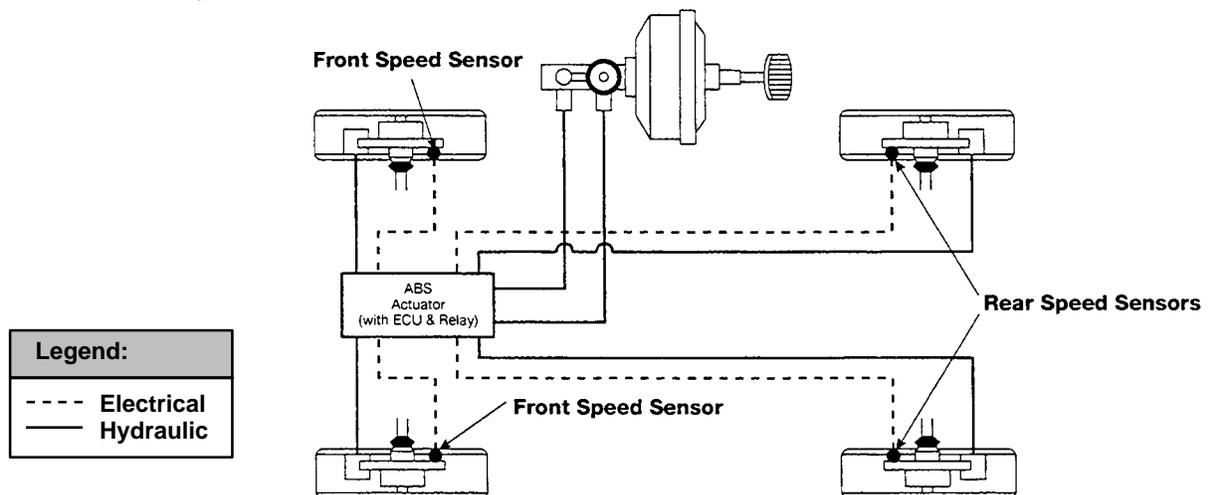
Toyota Antilock Brake Systems (ABS) are integrated with the conventional braking system. They use a computer controlled actuator unit, between the brake master cylinder and the wheel cylinders to control brake system hydraulic pressure.

Antilock Brake Systems address two conditions related to brake application; wheel lockup and vehicle directional control. The brakes slow the rotation of the wheels, but it is actually the friction between the tire and road surface that stops the vehicle. Without ABS when brakes are applied with enough force to lock the wheels, the vehicle slides uncontrollably because there is no traction between the tires and the road surface. While the wheels are skidding, steering control is lost as well.

An antilock brake system provides a high level of safety to the driver by preventing the wheels from locking, which maintains directional stability. A professional driver may be capable of maintaining control during braking by pumping the brake pedal which allows a locked wheel to turn momentarily. Whereas a professional driver may be capable of modulating the brakes approximately once per second, ABS is capable of modulating the brake pressure at a given wheel up to fifteen times per second. An ABS system does something else that no driver can do, it controls each front brake separately and the rear brakes as a pair whenever one of the wheels starts to lock. ABS helps stop a car in the shortest possible distance without wheel lockup while maintaining directional control on most types of road surface or conditions. If a Toyota ABS system malfunctions, normal braking will not be affected.

ABS System Diagram

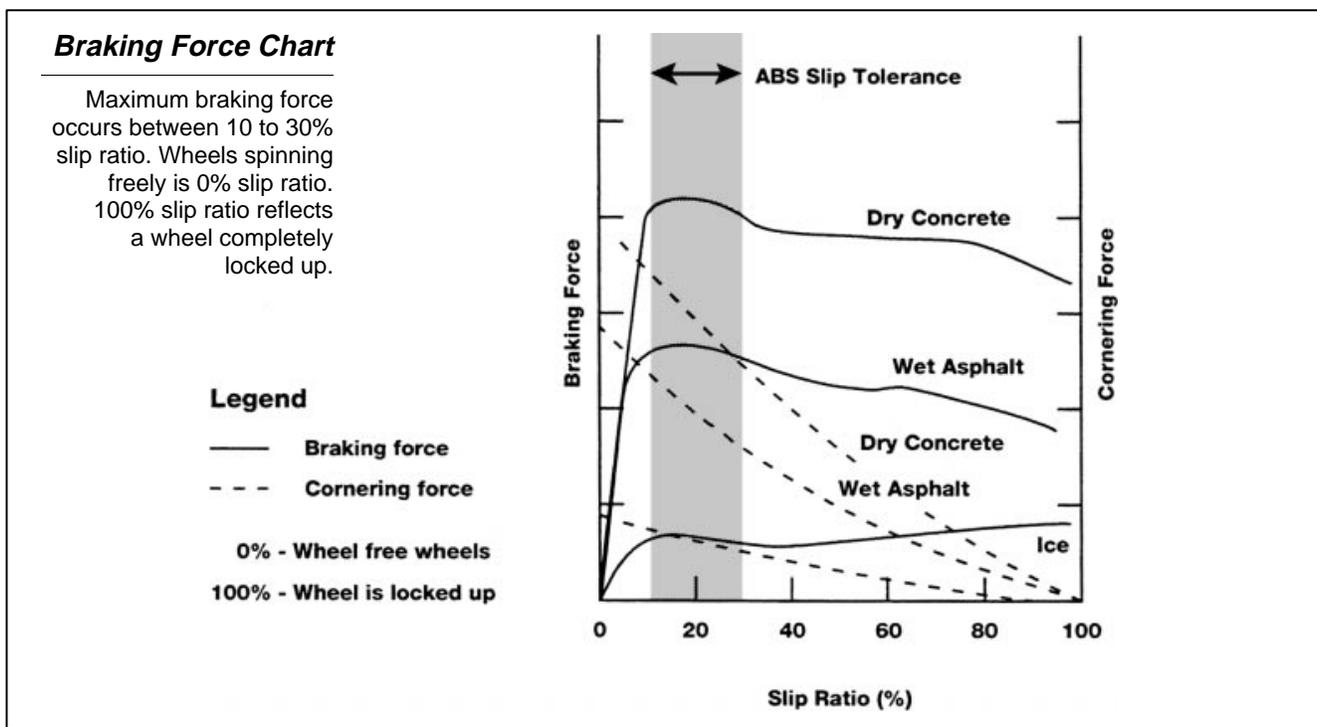
ABS is combined with the conventional braking system and located between the master cylinder and the wheel cylinders.



Tire Traction and ABS

The chart below shows the slip tolerance band (shaded area) in which the most efficient braking occurs. From a slip ratio of zero (0), at which the wheel speed and the vehicle speed are equal, to a slip ratio of 10, braking is mild to moderate and good traction between the tire and the road surface is maintained. Between slip ratios of 10 to 30 the most efficient braking occurs. This is where the tires are at a point where they may begin to lose traction with the road surface. This is also the band in which ABS operation occurs. Beyond a slip ratio of 30%, braking efficiency is reduced, stopping distance is increased and directional control is lost.

The amount of braking force on the left vertical line will vary based on the driver's pressure on the brake pedal and on the road surface; less braking force may be applied on wet asphalt than on dry concrete before lockup occurs, therefore the stopping distance is increased.



Basic Operation

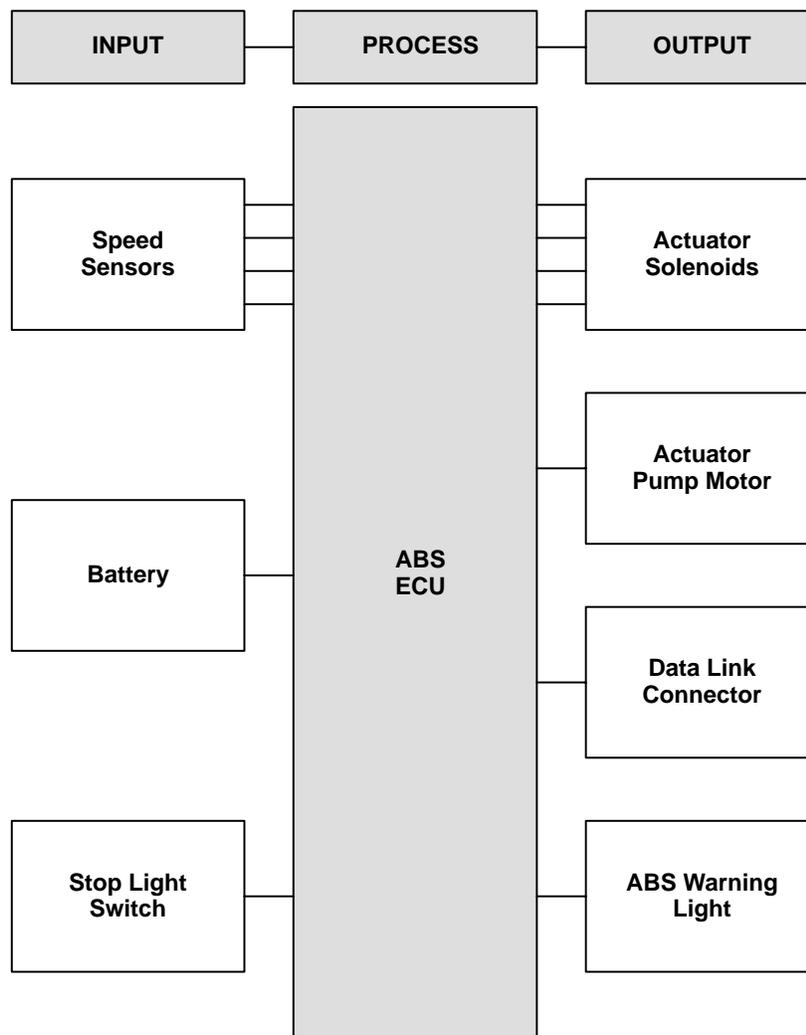
Four Wheel ABS Systems use a speed sensor at each front wheel and either a single speed sensor for both rear wheels or individual speed sensors at each rear wheel. The speed sensors are monitored by a dedicated ECU. The system controls the front brakes individually and rear brakes as a pair.

In a panic braking situation, the wheel speed sensors detect any sudden changes in wheel speed. The ABS ECU calculates the rotational speed of the wheels and the change in their speed, then calculates the vehicle speed. The ECU then judges the slip ratio of each wheel and instructs the actuator to provide the optimum braking pressure to each wheel. For example, the pressure to the brakes will be less on slippery pavement to reduce brake lockup. As a result, braking distance may increase but directional control will be maintained. It is also important to understand that ABS is not active during all stops.

The hydraulic brake actuator operates on signals from the ABS ECU to **hold, reduce or increase** the brake fluid pressure as necessary, to maintain the optimum slip ratio of 10 to 30% and avoid wheel lockup.

Typical ABS Control System

The ECU monitors the four wheel sensors, processes the data and controls the actuator solenoids and pump motor through the ABS Relay.



Types of Toyota ABS

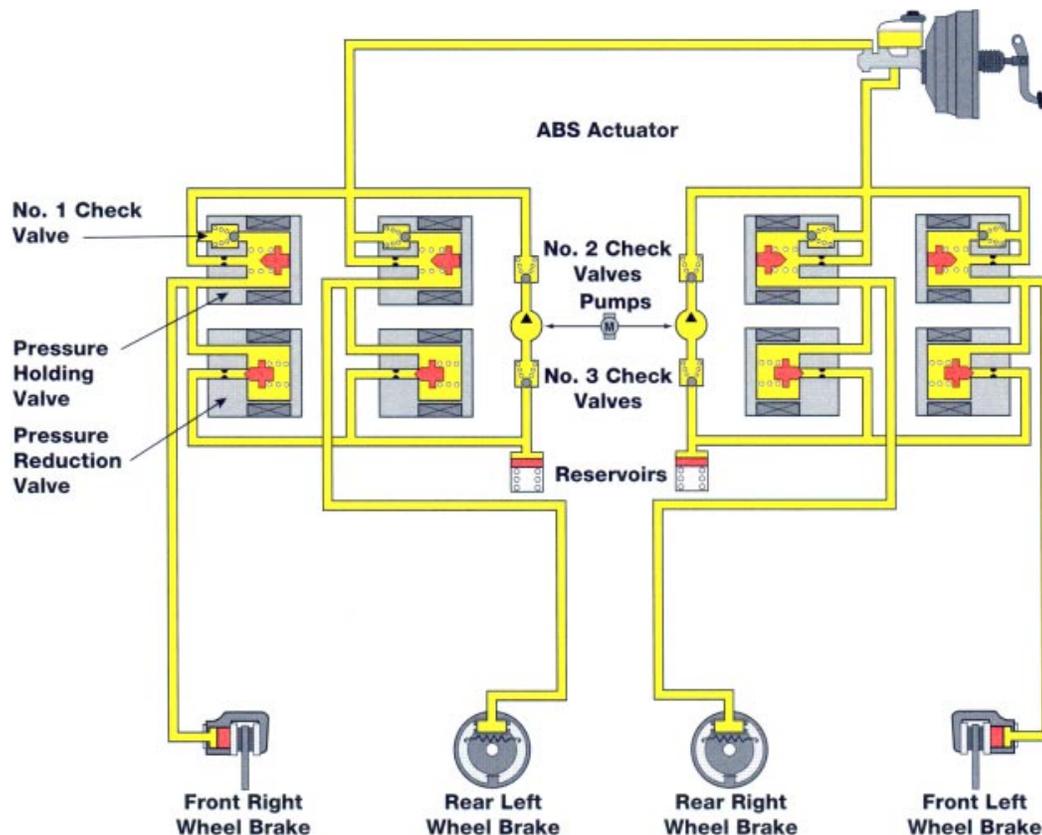
There are four types of ABS systems used in current Toyota models distinguished by the actuator. The four actuator types include:

- 2-position solenoid valves.
- 3-position solenoid valves with mechanical valve (Bosch).
- 3-position solenoid valves (Nippondenso).
- 2-position solenoid controlling power steering hydraulic pressure which controls brake hydraulic pressure.

2-Position Solenoid 2-position solenoid actuators come in configurations of six or eight solenoids. The eight solenoid configuration uses two solenoids per brake assembly. The six solenoid configuration uses two solenoids to control the rear brake assemblies while the front brake assemblies are controlled independently by two solenoids each.

2-Position Solenoid Types

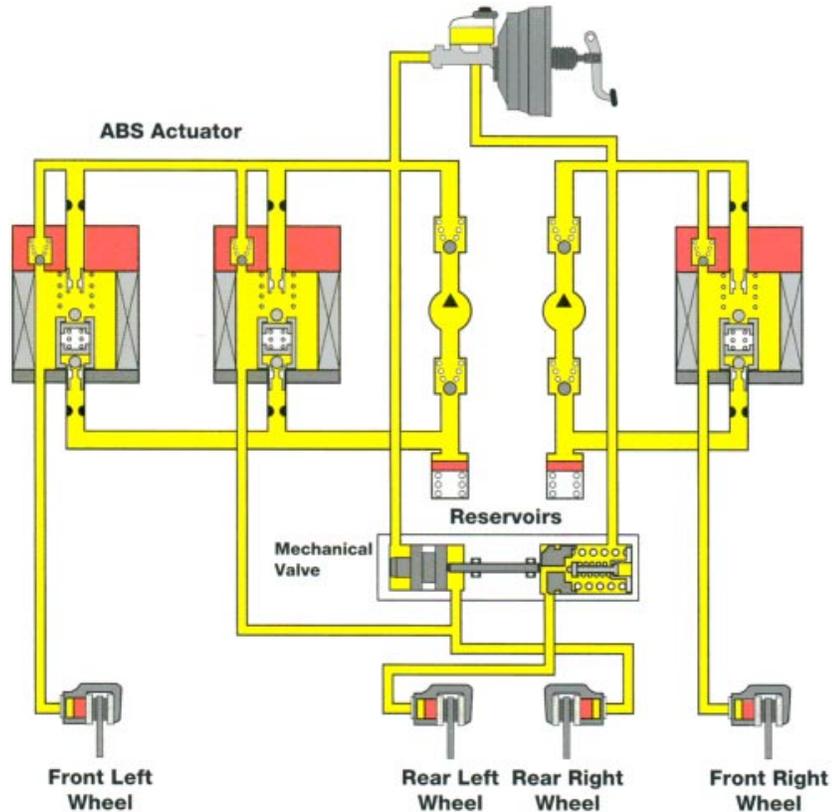
Controls pressure to four brake assemblies in three stages: pressure holding, increase and reduction.



3-Position Solenoid and Mechanical Valve This actuator uses three, 3-position solenoid valves. Two solenoids control the front wheels independently while the third solenoid controls the right rear and the mechanical valve translates controls to the left rear.

3-Position Solenoid With Mechanical Valve

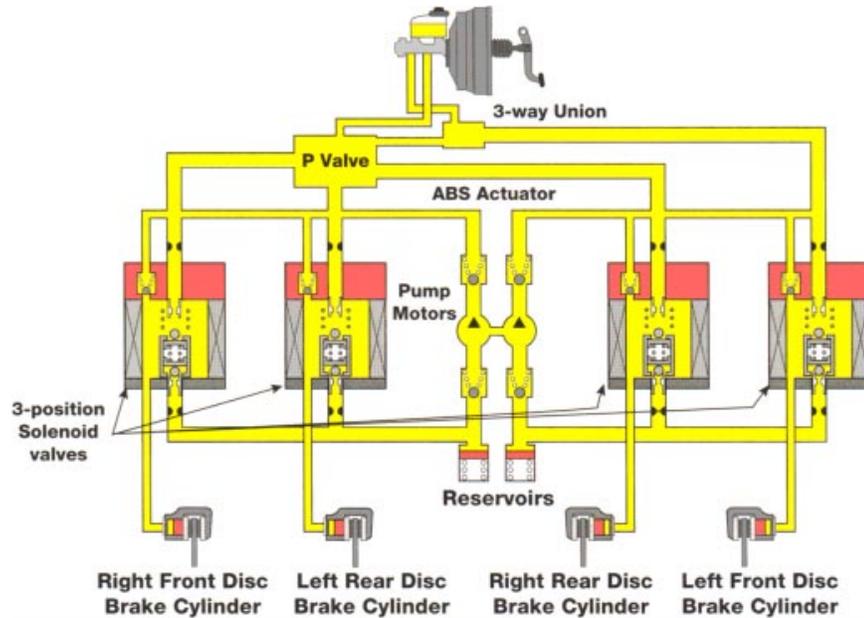
The third solenoid controls the right rear and the mechanical valve translates controls to the left rear.



3-Position Solenoids The 3-position solenoid valve actuator comes in three solenoid or four solenoid configurations. The four-solenoid system controls hydraulic pressure to all four wheels. In the 3-solenoid system, each front wheel is controlled independently while the rear wheels are controlled in tandem.

3-Position Solenoids

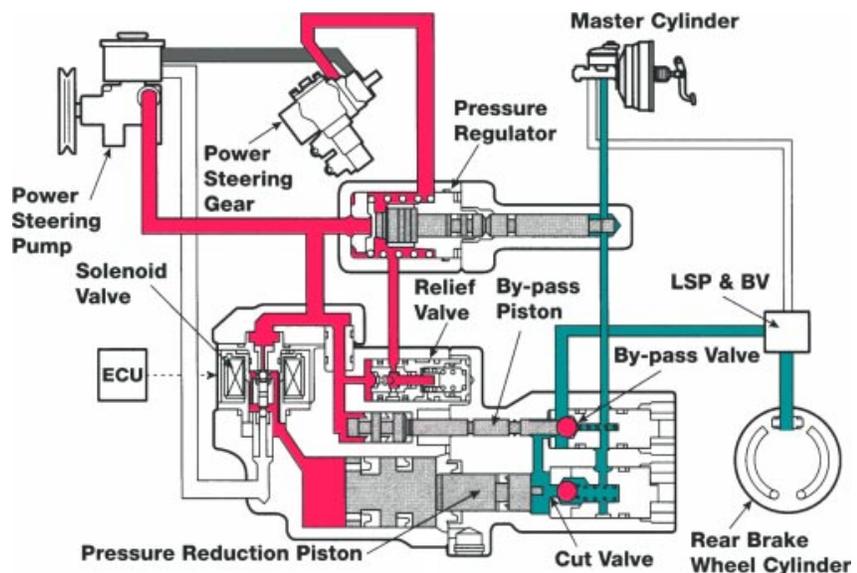
Controls pressure to four brake assemblies in three stages: pressure holding, pressure increase and pressure reduction.



Power Steering Control The last actuator type uses power steering pressure to regulate brake pressure using a single 2-position solenoid, a cut valve and bypass valve. Brake system pressure is controlled for the rear brakes only.

Power Steering Hydraulic Pressure Controls Brake Hydraulic Pressure

A single 2-position solenoid regulates power steering pressure which controls brake hydraulic pressure to the two rear wheels only.



System Components

Each ABS type shares common components which provide information to the ECU. This section will examine each of these components and then describe each of the actuator types and their operation.

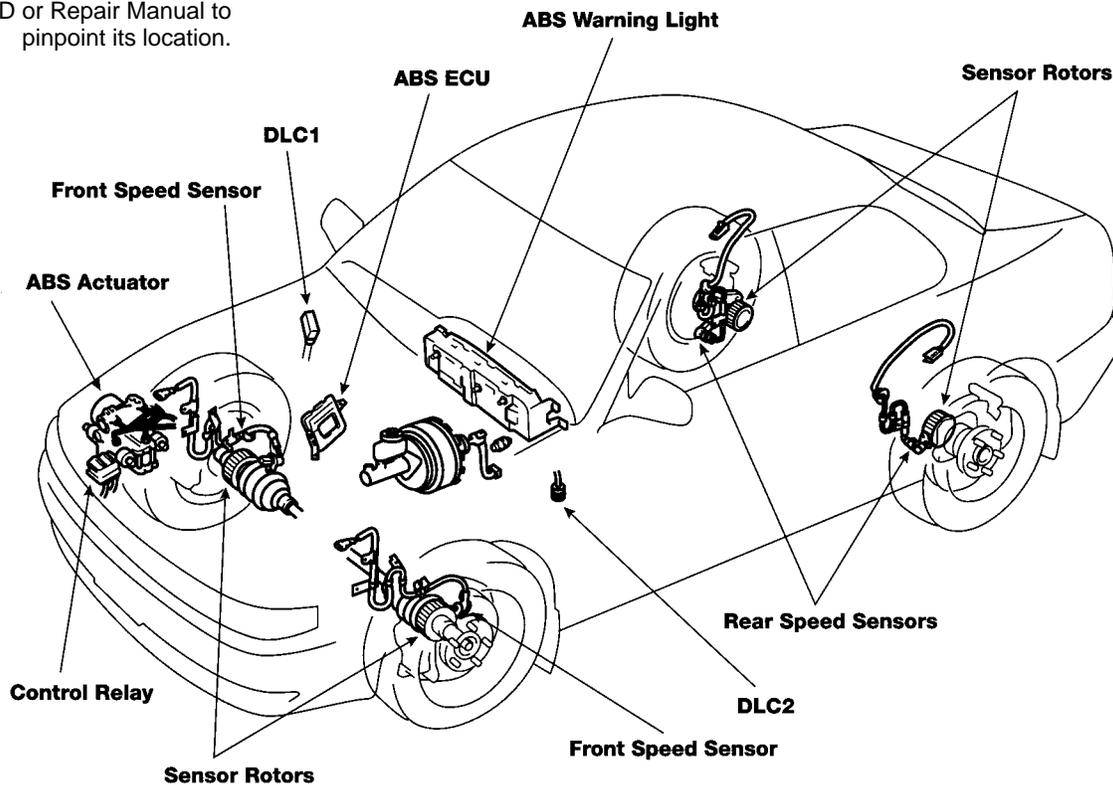
The components identified below are typical of most Toyota ABS systems.

- **Speed Sensors** monitor wheel speed.
- **G-Sensor** monitors rate of deceleration or lateral acceleration.
- **ABS Actuators** control brake system pressure.
- **Control Relay** controls the Actuator Pump Motor and Solenoids.
- **ABS ECU** monitors sensor inputs and controls the Actuator.
- **ABS Warning Lamp** alerts the driver to system conditions.

The location of components may vary by model and year, therefore, for accurate location of components, consult your EWD or Repair Manual.

Typical Component Layout

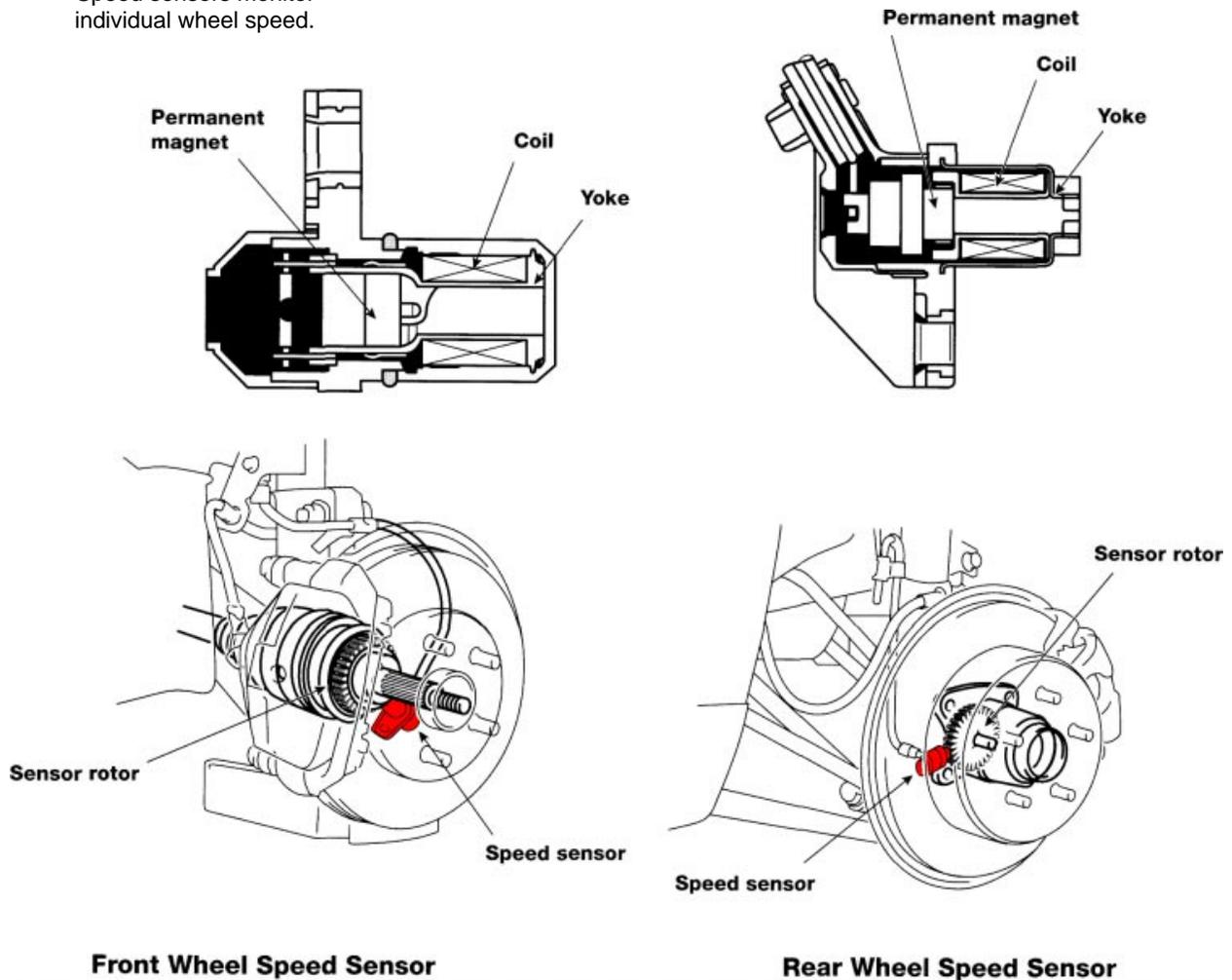
Component location is typical for most models: speed sensors at each wheel, actuator in engine compartment. The ECU however may require an EWD or Repair Manual to pinpoint its location.



Wheel Speed Sensor A wheel speed sensor is mounted at each wheel and sends a wheel rotation signal to the ABS ECU. The front and rear wheel speed sensors consist of a permanent magnet attached to a soft iron core (yoke) and a wire wound coil. The front wheel speed sensors are mounted to the steering knuckle, and the rear speed sensors are mounted to the rear axle carrier. Serrated rotors are mounted to the drive axle shaft or brake rotor, and rotate as a unit.

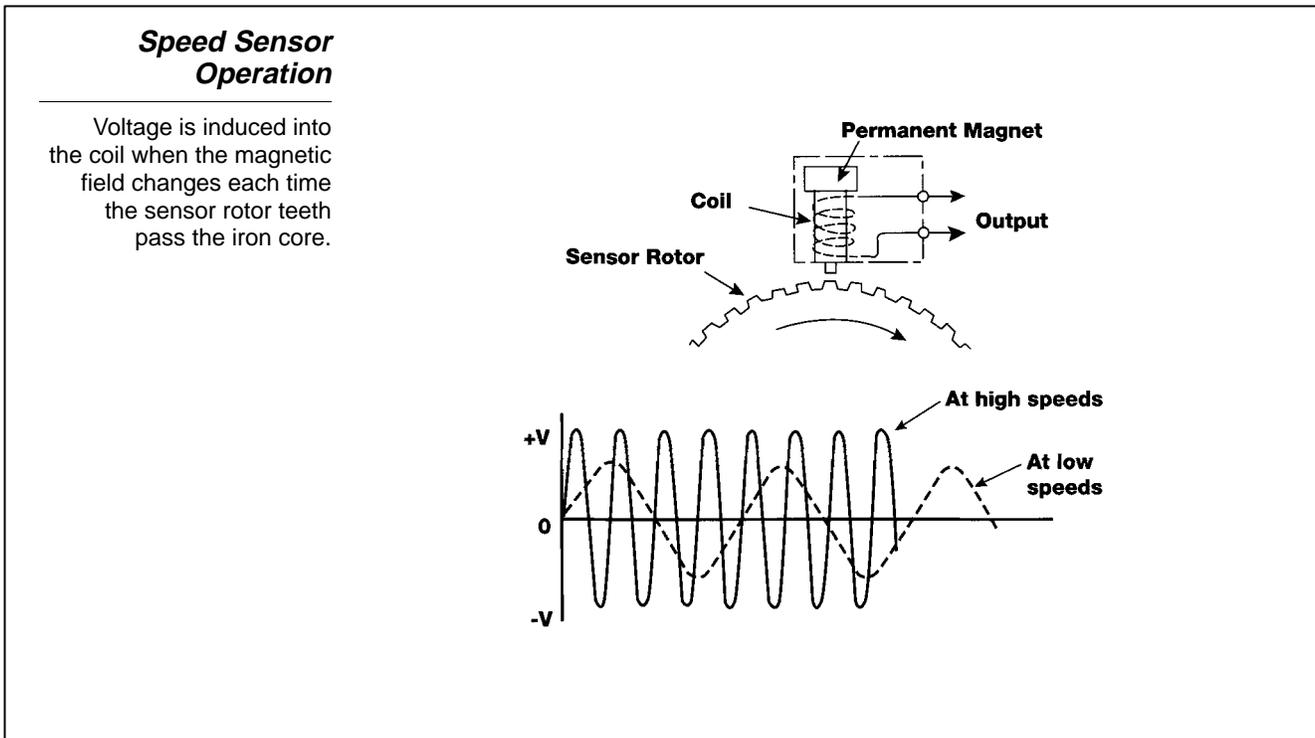
Wheel Speed Sensors

Speed sensors monitor individual wheel speed.



Early Supras including the 1993 model year and Cressidas equipped with ABS, used a single rear speed sensor mounted on the transmission extension housing to monitor rear wheel speed.

Operation Speed sensor operation is similar to the magnetic pick-up in a distributor. When the teeth of the Sensor Rotor pass the iron core, the magnetic lines of force cut through the coil windings causing a voltage to be induced into the coil. As the tooth approaches the iron core, the magnetic field contracts causing a positive voltage to be induced in the coil. When the tooth is centered on the iron core the magnetic field does not move and zero volts are induced in the coil. As the tooth moves away from the iron core the magnetic field expands, resulting in a negative voltage. As the rotation of the sensor rotor increases, the voltage and the frequency of this signal increase, indicating to the ECU a higher wheel speed.

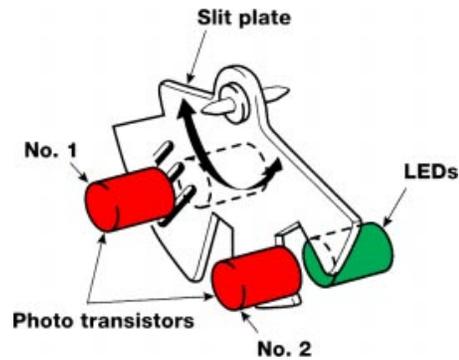


Deceleration Sensor The deceleration sensor is used on some systems to provide input to the ABS ECU about the vehicle's rate of deceleration to improve braking performance. In a typical ABS system, the ECU compares individual speed sensors to determine the speed of the vehicle and rate of wheel deceleration. The deceleration sensor is used on all full-time 4WD vehicles equipped with ABS to determine deceleration, as the front and rear axles are connected through the transfer case and present unique braking characteristics. Models equipped with only rear-wheel ABS have a single speed sensor and no means of determining the actual vehicle speed or rate of deceleration.

The deceleration sensor is composed of two pairs of LEDs (light emitting diodes) and phototransistors, a slit plate, and a signal conversion circuit. The deceleration sensor senses the vehicle's rate of deceleration and sends signals to the ABS ECU. The ECU compares the rate of deceleration and vehicle speed to determine the precise road surface conditions and takes appropriate control measures.

Deceleration Sensor Components

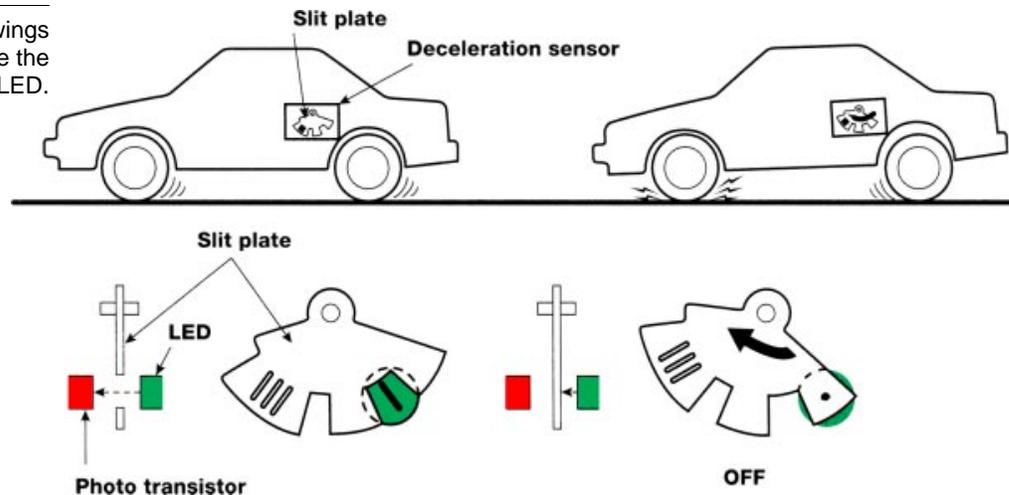
The slit plate swings between the LED's and Phototransistors.



Operation Both LED's are located on one side of the slit plate and both photo transistors are located on the opposite side. The LED's are ON when the ignition switch is in the ON position. When the vehicle's rate of deceleration changes, the slit plate swings in the vehicle's rear-to-front direction. The slits in the slit plate act to expose the light from the LEDs to the phototransistors. This movement of the slit plate switches the phototransistors ON and OFF.

Deceleration Sensor Operation

As the slit plate swings forward the slits expose the phototransistor to the LED.



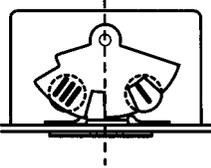
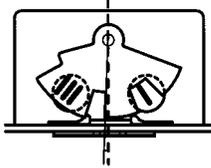
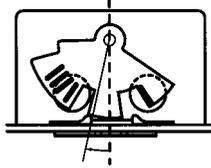
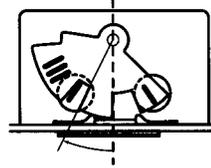
Lateral Acceleration Sensor

The lateral acceleration sensor has similar construction to the deceleration sensor described above. Rather than having the slit plate swing rear-to-front, the sensor is mounted in such a way that the slit plate swings from side to side. This sensor is found only on the 1993 1/2 and later model Supra to detect lateral forces while braking.

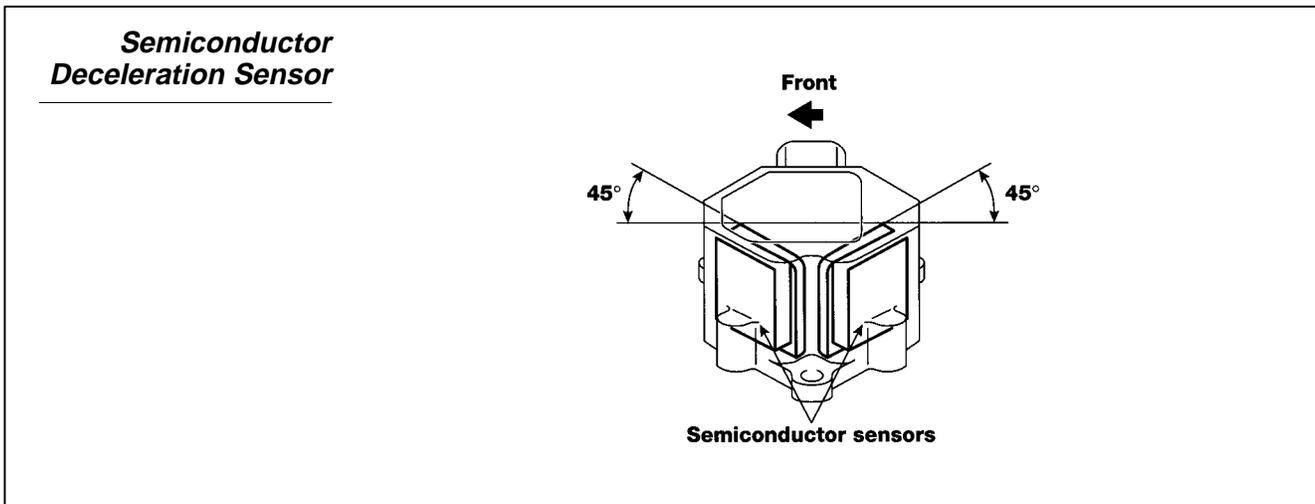
Deceleration Rate The combinations formed by these phototransistors switching ON and OFF distinguish the rate of deceleration into four levels, which are sent as signals to the ABS ECU. The chart below indicates the rate of deceleration based on input from the two phototransistors. For example: when the No. 1 and No. 2 photo transistors are both blocked and turned OFF, the deceleration rate is medium.

Deceleration Rate Level

Deceleration Rate Level

Rate of deceleration	Low-1	Low-2	Medium	High
No. 1 Photo Transistor	ON	OFF	OFF	ON
No. 2 Photo Transistor	ON	ON	OFF	OFF
Position of Slit Plate	 No. 1 Photo Transistor (ON) No. 2 Photo Transistor (ON)	 (OFF) (ON)	 (OFF) (OFF)	 (ON) (OFF)

Semiconductor Deceleration Sensor A new style deceleration sensor was introduced in the 1996 4WD RAV4 only. The sensor consisted of two semiconductor sensors. They are mounted at 90° to one another and installed so that each has an angle of 45° to the centerline of the vehicle. Each semiconductor sensor is provided with a mass which exerts pressure based on the deceleration force applied to the vehicle. The sensor converts the force into electronic signals, and outputs the signals to the ABS ECU.



Actuator The actuator controls hydraulic brake pressure to each disc brake caliper or wheel cylinder based on input from the system sensors, thereby controlling wheel speed. These solenoids provide three operating modes during ABS operation:

- **Pressure Holding.**
- **Pressure Reduction.**
- **Pressure Increase.**

2-Position Solenoid Type The two position solenoid actuator was first used on the 1993 Corolla and subsequently on all Toyota models by 1997 except Land Cruiser. Consult the ABS Comparison Chart on page 225 of this publication for the specific model application.

The actuator consists of six or eight 2-position solenoid valves, a pump and reservoir. Each hydraulic circuit is controlled by a single set of solenoids:

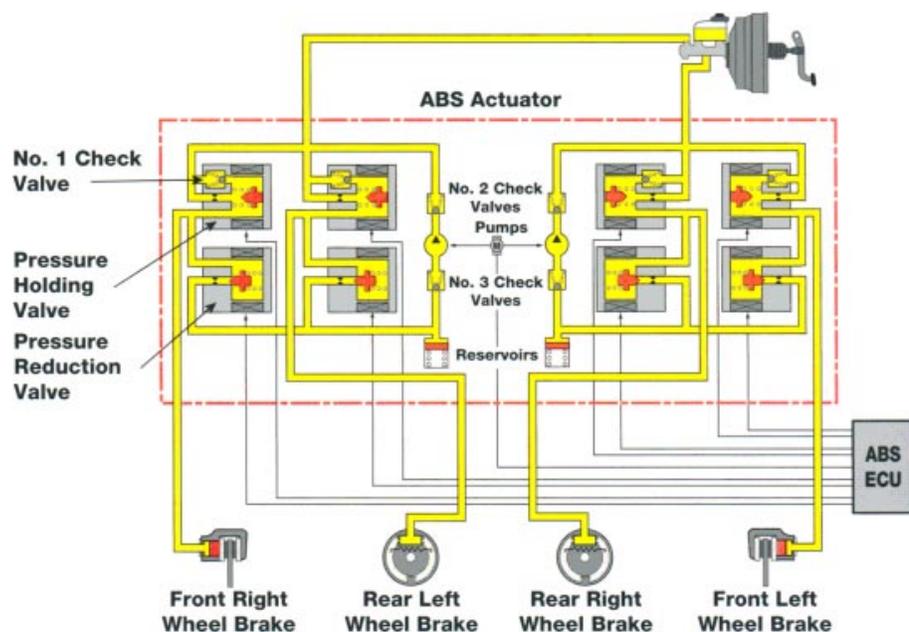
- pressure holding solenoid.
- pressure reduction solenoid.

Aside from the 2-position solenoid valves, the basic construction and operation of this system is the same as the 3-position solenoid system:

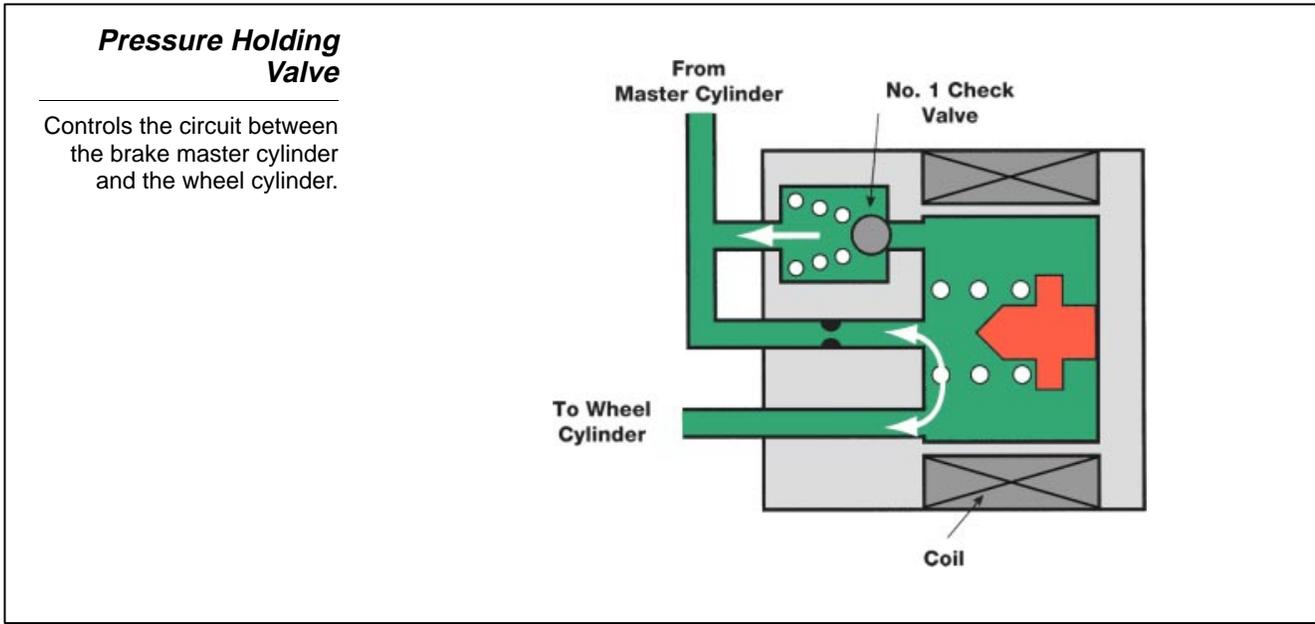
- four speed sensors provide input to the ECU which controls the operation of the solenoids and prevent wheel lock-up.
- the two front wheels are controlled independently and the two rear wheels are controlled simultaneously for three channel control.
- Supra has four channel control where the two rear wheels are controlled independently just like the front wheels.

2-Position Solenoid Hydraulic Circuit

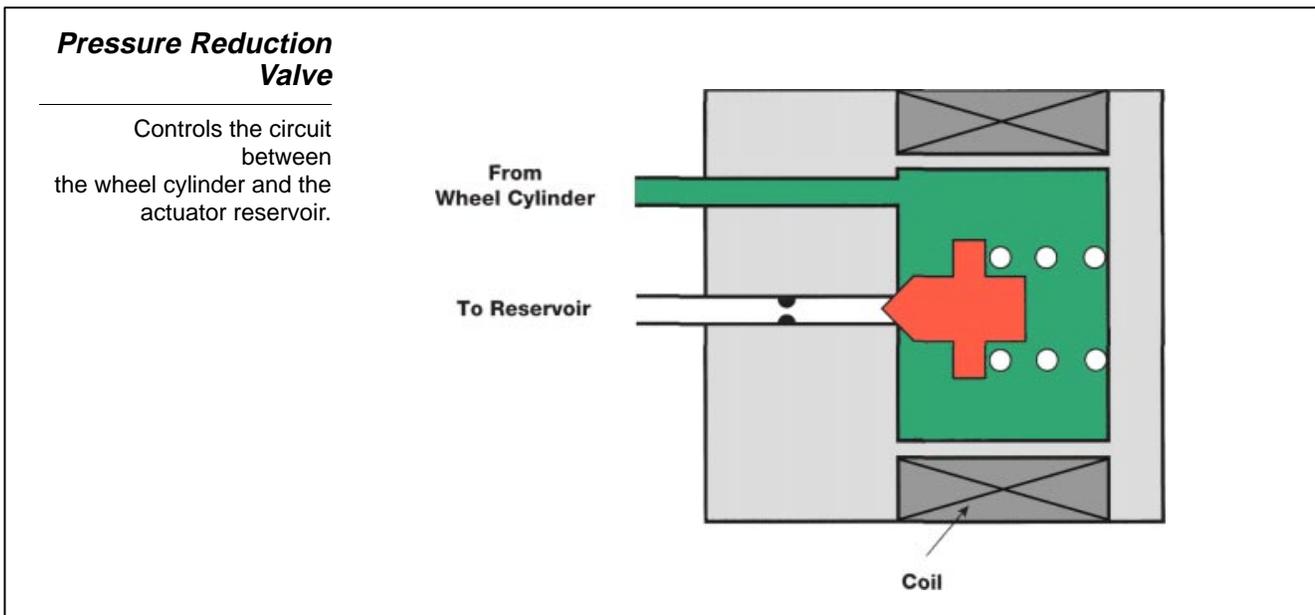
The actuator consists of six or eight 2-position solenoids. Two solenoids are used to control each wheel hydraulic circuit.



Pressure Holding Valve The pressure holding valve controls (opens and closes) the circuit between the brake master cylinder and the wheel cylinder. The valve is spring loaded to the open position (normally open). When current flows in the coil the valve closes. A spring loaded check valve provides an additional release passage when pressure from the master cylinder drops.



Pressure Reduction Valve The pressure reduction valve controls (opens and closes) the circuit between the wheel cylinder and the actuator reservoir. The valve is spring loaded in the closed position (normally closed). When current flows through the coil, the valve compresses the spring and opens the valve.



Operation During Normal Braking (ABS Not Activated)

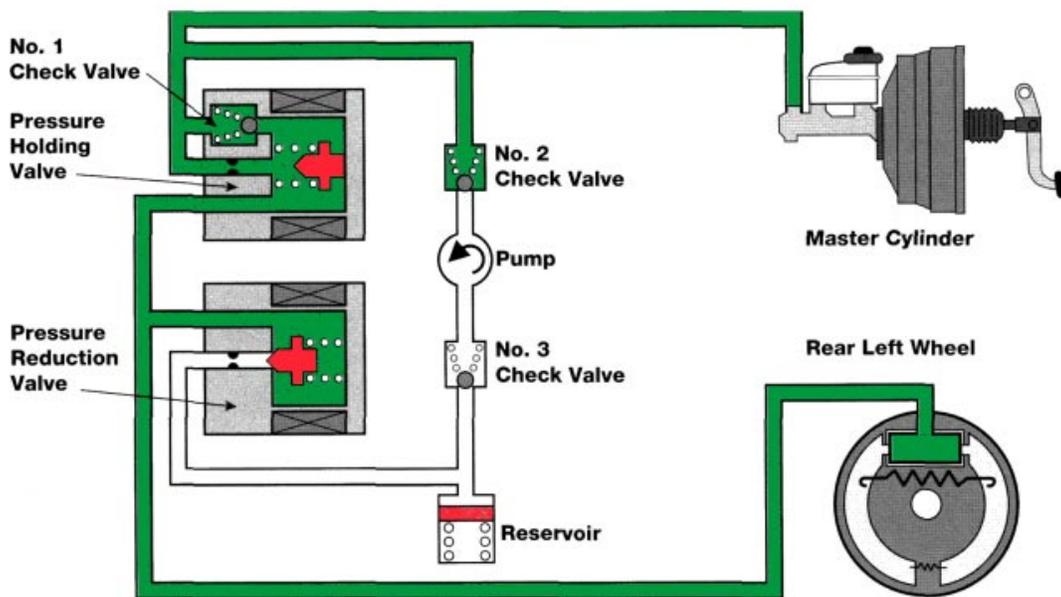
During normal braking the solenoids are not energized so the pressure holding valve remains open and the pressure reduction valve remains closed.

When the brake pedal is depressed, the master cylinder fluid passes through the pressure holding valve to the wheel cylinder. The pressure reduction valve prevents fluid pressure from going to the reservoir. As a result normal braking occurs.

Normal Braking Mode

During normal braking the solenoids are not energized so the pressure holding valve remains open and the pressure reduction valve remains closed.

Part Name		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
ABS Conditions				
Not Activated	During Normal Braking	OFF (Open)	OFF (Closed)	OFF

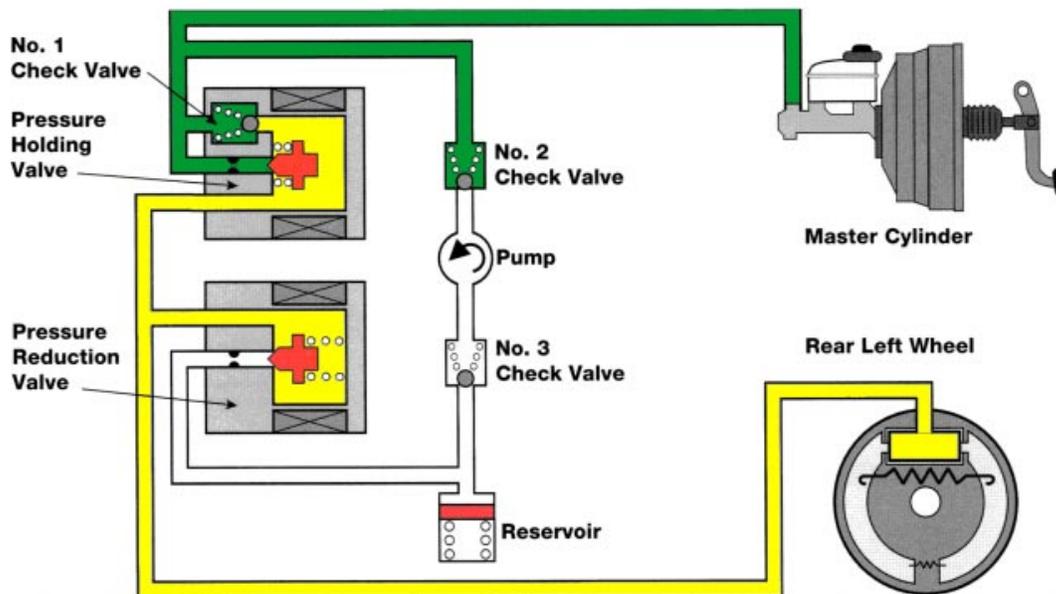


Pressure Holding Mode When any wheel begins to lock, the ABS ECU initially goes to hold mode to prevent any additional increase in pressure. The ECU turns OFF the Pressure Reduction Valve and turns the Pressure Holding Valve ON. The pressure reduction valve closes, preventing hydraulic fluid from going to the reservoir. The pressure holding valve remains closed so no additional fluid pressure can reach the wheel cylinder.

Pressure Holding Mode

The pressure reduction valve closes, preventing hydraulic fluid from going to the reservoir.

Part Name		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
ABS Conditions				
Activated	Holding Mode	ON (Closed)	OFF (Closed)	ON

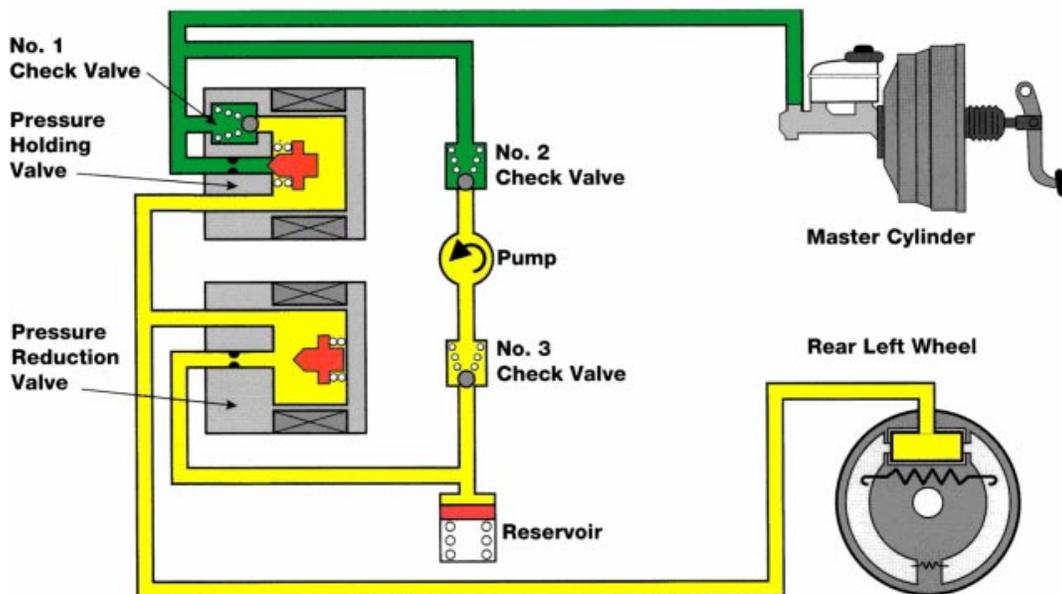


Pressure Reduction Mode After the initial hold mode operation, the ABS ECU energizes both the holding valve and the reduction valve. The pressure holding valve closes and blocks pressure from the master cylinder. The open reduction valve allows hydraulic pressure from the wheel cylinder circuit into the reservoir, reducing brake pressure. The pump is also energized to direct hydraulic fluid back to the master cylinder. This causes brake pedal feedback and alerts the driver to ABS operation.

Pressure Reduction Mode

When the slip ratio of any wheel exceeds 30%, the ABS ECU energizes both the holding valve and the reduction valve.

Part Name		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
ABS Conditions				
Activated	Pressure Reduction Mode	ON (Closed)	ON (Open)	ON

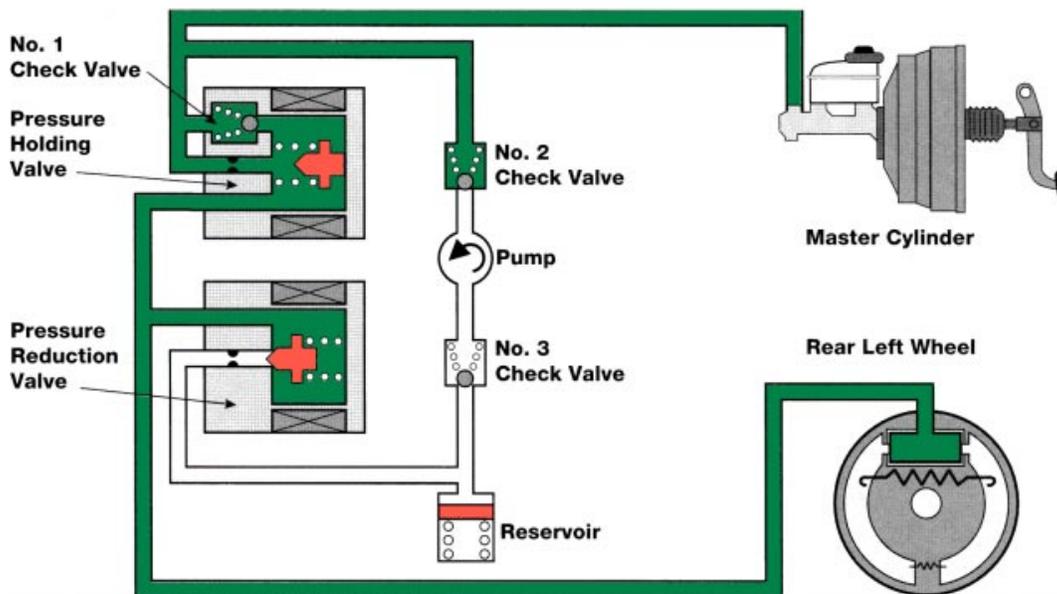


Pressure Increase Mode As pressure inside the wheel cylinder is reduced and the speed sensor sends a signal indicating that the speed is above the target level, the ECU turns OFF both the Pressure Reduction Valve and the Pressure Holding Valve. The pressure reduction valve closes, preventing hydraulic fluid from going to the reservoir. The pressure holding valve opens so additional pressure enters the wheel cylinder if the driver maintains pedal pressure. The operation is the same as Normal Mode except the pump is on.

Pressure Increase Mode

The ECU turns OFF both the Pressure Reduction Valve and the Pressure Holding Valve.

Part Name		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
ABS Conditions				
Activated	Pressure Increase Mode	OFF (Open)	OFF (Closed)	ON

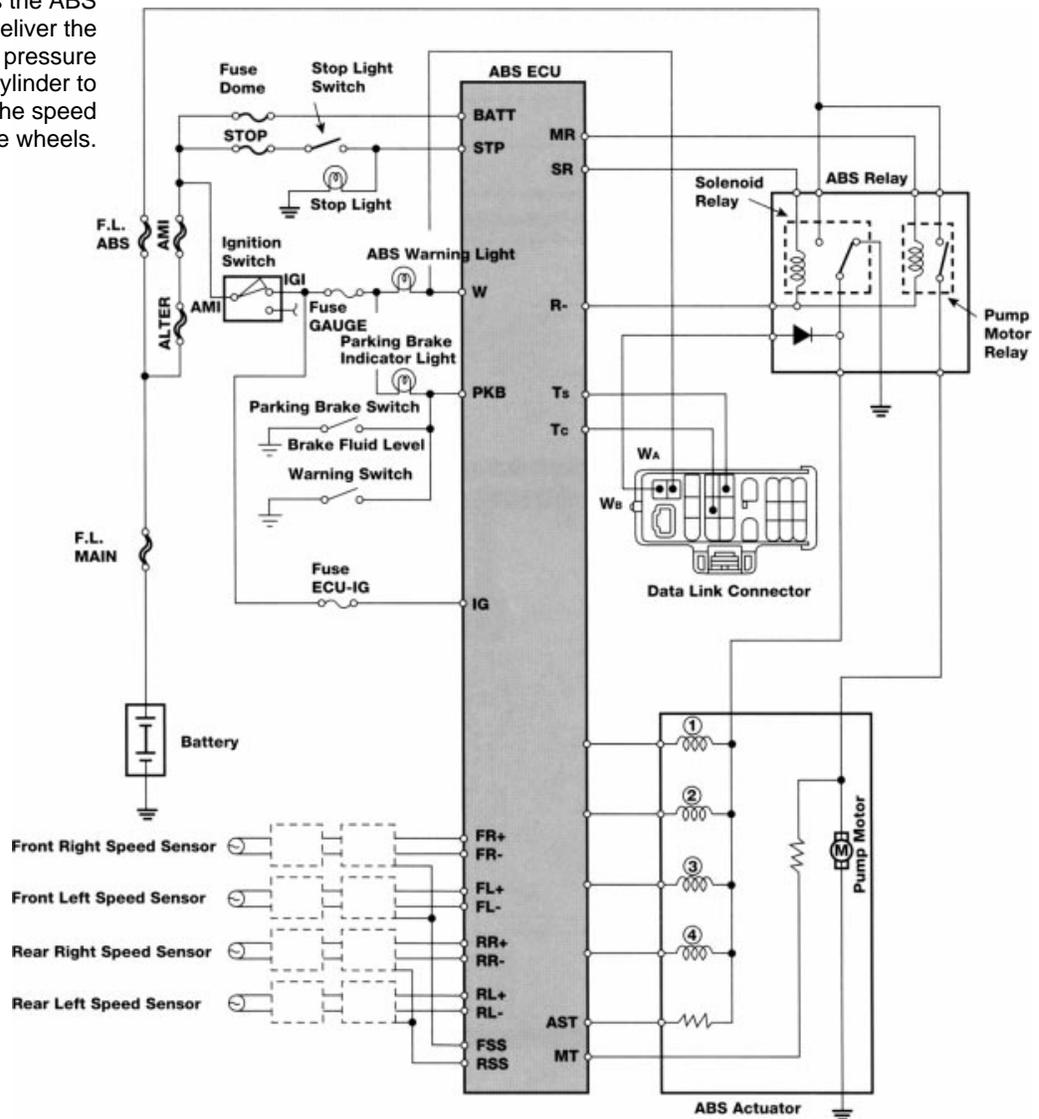


ABS ECU The ABS ECU senses the rotational speed of the wheels as well as the vehicle speed based on signals from the wheel speed sensors. During braking, the deceleration rate will vary depending on pedal pressure, the vehicle speed during braking, and the road surface conditions. For example, the deceleration rate is much greater on dry asphalt, compared to a wet or icy surface.

The ECU judges the slip condition between the wheels and the road surface by monitoring the change in the wheel's rotational speed during braking. The ECU controls the ABS actuator to deliver the optimum hydraulic pressure to the brake cylinder to precisely control the speed of the wheels, maintaining maximum brake force with a 10 to 30% slip ratio.

ABS Wiring Diagram

The ECU controls the ABS actuator to deliver the optimum hydraulic pressure to the disc brake cylinder to precisely control the speed of the wheels.



Solenoid Relay Control

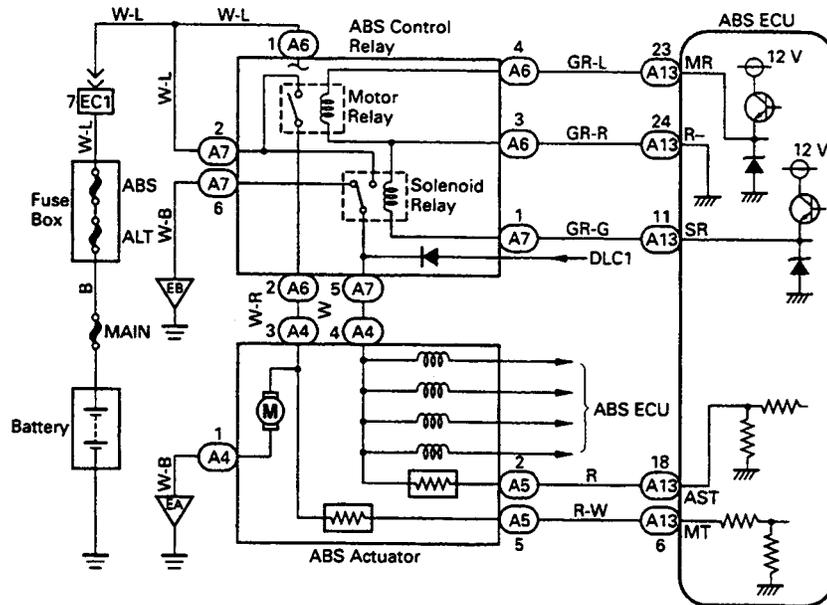
The Solenoid Relay supplies power to the solenoids. The ECU turns the Solenoid Relay ON when the following conditions are met:

- Ignition switch ON.
- The Initial-Check Function is completed properly.

The ECU turns the solenoid relay OFF if any of the above conditions are not met.

ABS Control Relay

The motor relay switches voltage to the pump motor.
The solenoid relay switches voltage to the actuator solenoids.



Pump Motor Relay Control

The Pump Motor Relay supplies power to the ABS pump motor located in the Actuator. The ECU turns the relay ON when the following conditions are met:

- During ABS operation or during the Initial Check.
- When the Solenoid Relay is ON .

The ECU turns the pump motor relay OFF when any of the above conditions are not met.

Wheel Speed Control The ECU continuously receives wheel speed signals from the speed sensors and deceleration sensor. By calculating the speed and deceleration of each wheel, the ECU estimates the vehicle speed. When the brake pedal is depressed, the hydraulic pressure in each disc brake cylinder begins to increase and the wheel speed begins to decrease. If any of the wheels are near a lock-up condition the ECU goes into pressure hold mode to stop the increase of hydraulic pressure in the disc brake cylinder of that wheel.

SECTION A

The ECU sets the solenoid valves to the pressure reduction mode based on wheel speed, thus reducing the hydraulic pressure in the disc brake cylinder.

After the pressure drops, the ECU switches the solenoid valves to the Holding Mode then monitors the change in wheel speed.

If the ECU judges that the hydraulic pressure needs to be reduced further, it will return to reduction mode.

SECTION B

When the hydraulic pressure inside the disc brake cylinder decreases (section A), the hydraulic pressure applied to the wheel falls. This allows the wheel that was locking up to speed up. However, if the hydraulic pressure is held down, the braking force acting on the wheel will become too low. To prevent this, the ECU sets the solenoid valves to the pressure increase mode and holding mode alternately as the wheel which was locking up, recovers speed.

SECTION C

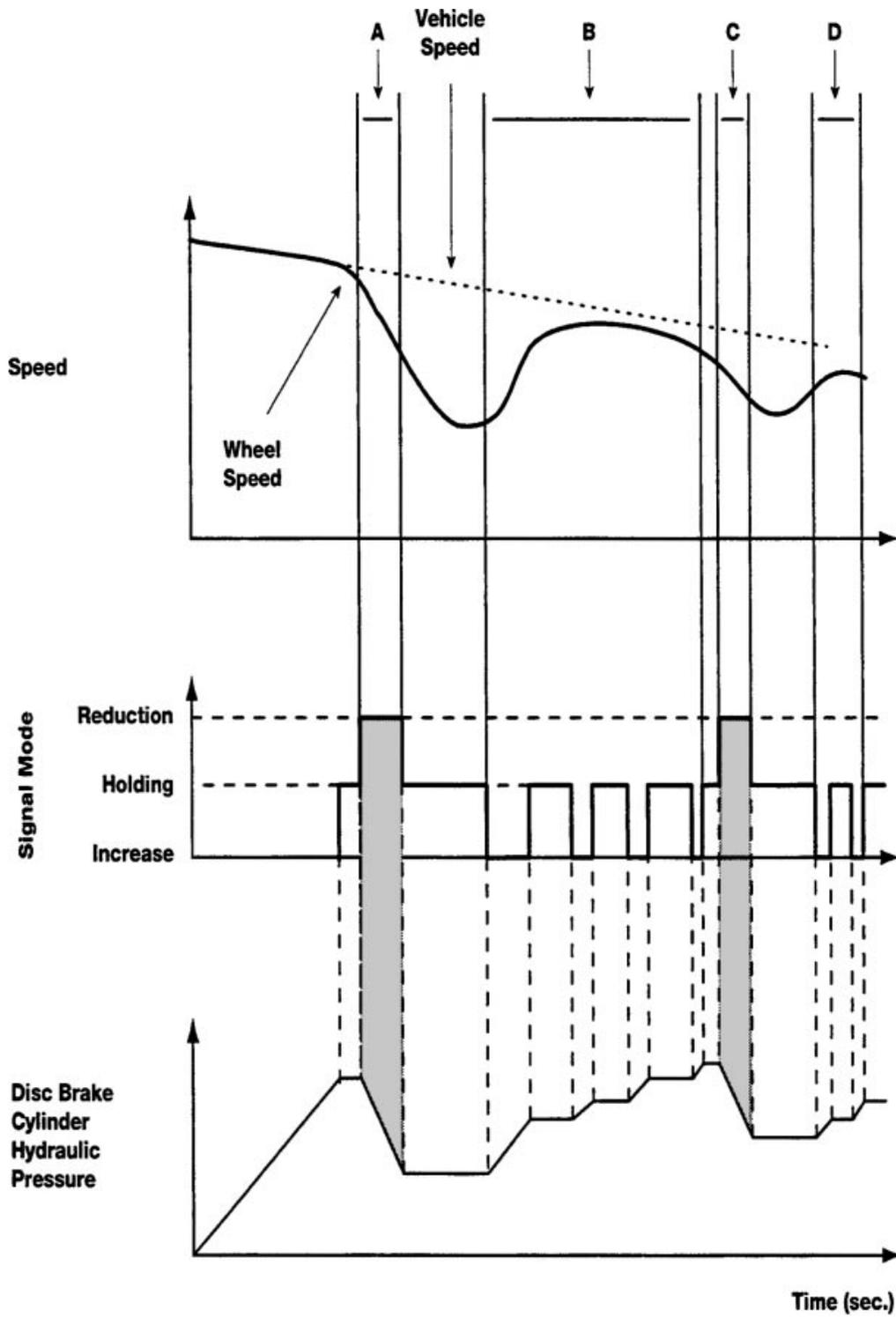
As the hydraulic pressure is gradually increased in the brake cylinder by the ECU actuator (section B), the wheel tends to lock up again. In response, the ECU again switches the solenoid valves to the pressure reduction mode to reduce the hydraulic pressure inside the disc brake cylinder.

SECTION D

Since the hydraulic pressure in the brake cylinder is decreased again (section C), the ECU starts to increase the pressure again as in section B.

The cycle of Hold, Reduce and Increase is repeated many times until the wheels are no longer outside the 30% slip ratio.

Wheel Speed Control Chart





Notes

A large grid area for taking notes, consisting of a fine grid of lines.