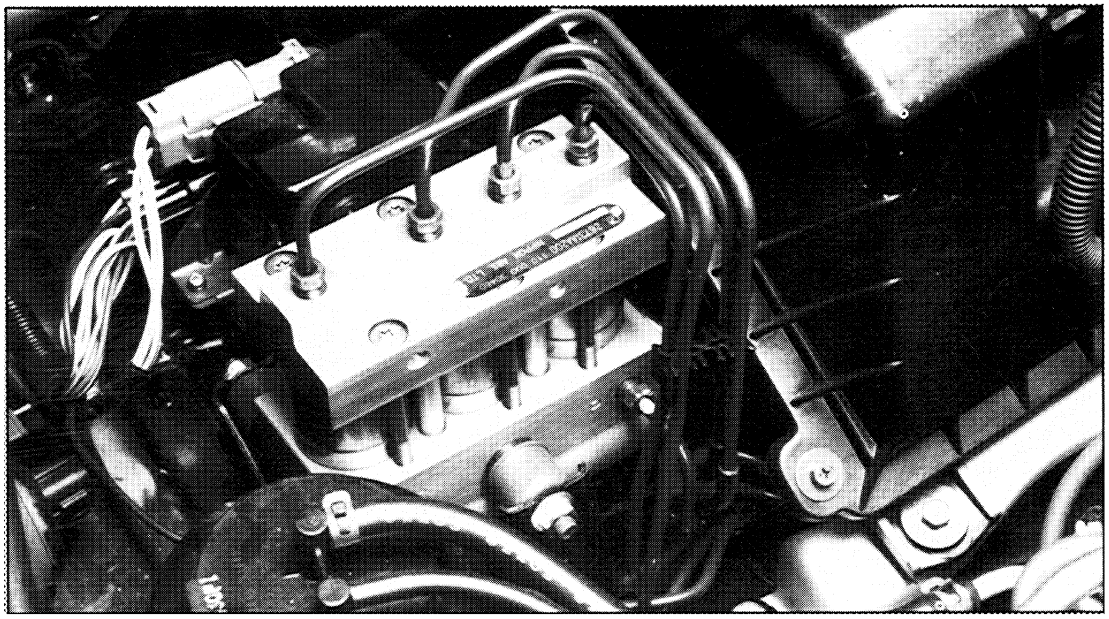
SUBARU®



INTRODUCTION TO ABS-2E SYSTEM DIAGNOSIS

Video Reference Booklet

Subaru of America, Inc. reserves the right at any time to make changes or modifications to systems, procedures, descriptions, and illustrations contained in this book without necessarily updating this document. Information herein is considered current as of December, 1992.

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FOREWORD

This Video Reference Booklet accompanies the "Introduction to ABS-2E System Diagnosis" videotape. The booklet summarizes information in the videotape and provides additional information for a number of subjects, including air bleeding and a pressure test procedure for the hydraulic control unit.

In addition to this booklet and videotape, we recommend that you use the Impreza and Legacy Service Manuals, as well as any other appropriate materials to help you perform effective diagnosis and repair of the ABS-2E system.

Overview

In the past, Subaru vehicles have been fitted with either of two anti-lock braking systems: one is a Robert Bosch unit; the other is the ABS-2SL system from Nippon ABS Limited. Now there is a new anti-lock braking system manufactured for Subaru by Nippon ABS Limited.

The new Nippon system is designated ABS-2E. This system uses ABS components also found in previous anti-lock braking systems. These are as follows:

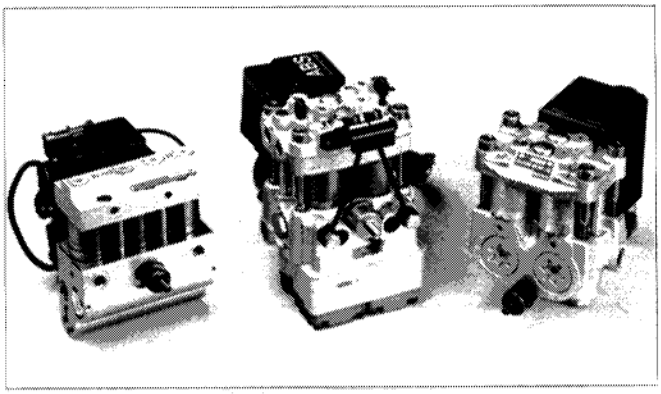
- 4 tone wheels
- 4 wheel speed sensors
- hydraulic control unit (HCU)
- electronic control unit (ECU)
- ABS warning light

The HCU incorporates two relays, three solenoid valves, a mechanical valve, and a fluid pump and motor.

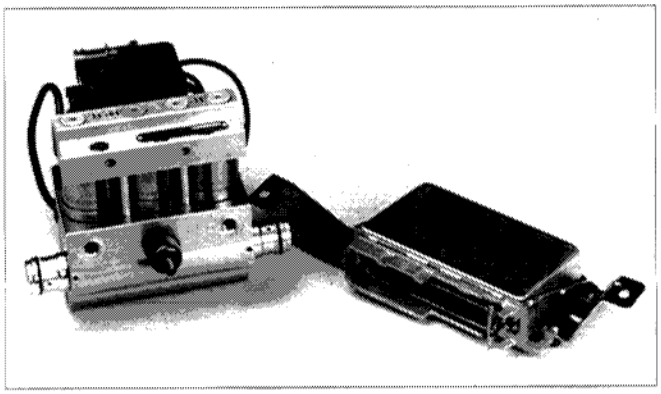
NOTE: The Service Manual refers to the solenoid valves in the HCU as "magnet valves." In the ABS-2E videotape and in this VRB we use "solenoid valve" because it is a name more commonly used in the U.S. market.

Like its predecessors, ABS-2E is a four-sensor, four-channel system. However, it is smaller and lighter than the earlier designs. In addition, the ABS-2E system incorporates improvements in the areas of trouble code memory, self-diagnostics, inspection, and maintenance.

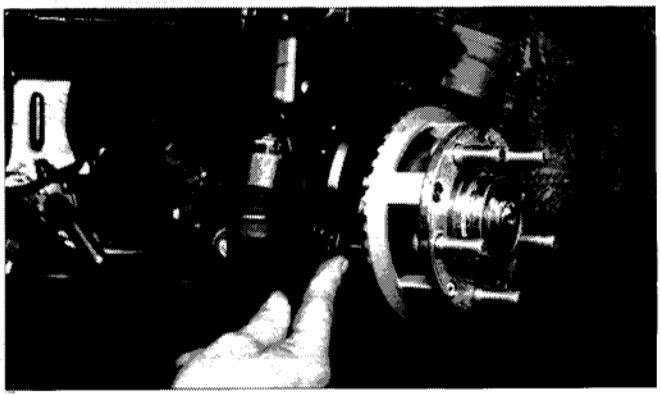
The ABS-2E system will appear in production with the start of the 1993 model year. It will be available on the Legacy model, if equipped with an automatic transmission. Also, every Impreza that has anti-lock braking will be fitted with the ABS-2E system.



Subaru ABS Hydraulic Control Units



ABS-2E HCU and ECU

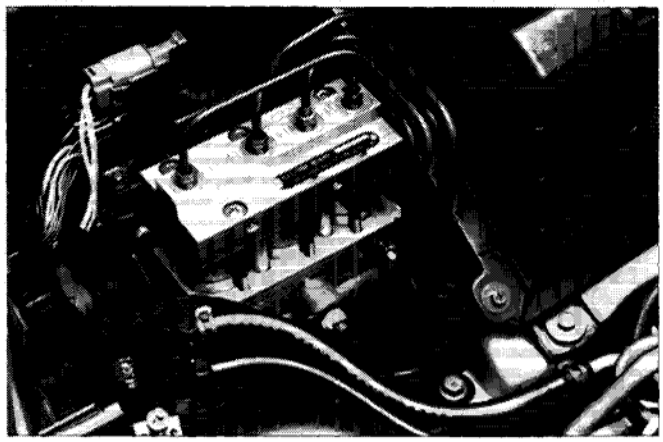


An ABS Wheel Speed Sensor and Tone Wheel

ABS-2E System Differences

The ABS-2E system differs from the earlier ABS designs in four ways:

1. Earlier designs used four solenoid valves. The ABS-2E hydraulic control unit (HCU) uses three solenoid valves and one mechanical valve.
2. Its electronic control unit can store up to three trouble codes, rather than just one.
3. The number of separate error conditions the ECU can recognize has been increased. That means there are more trouble codes available.
4. There is a revised bleeding procedure.



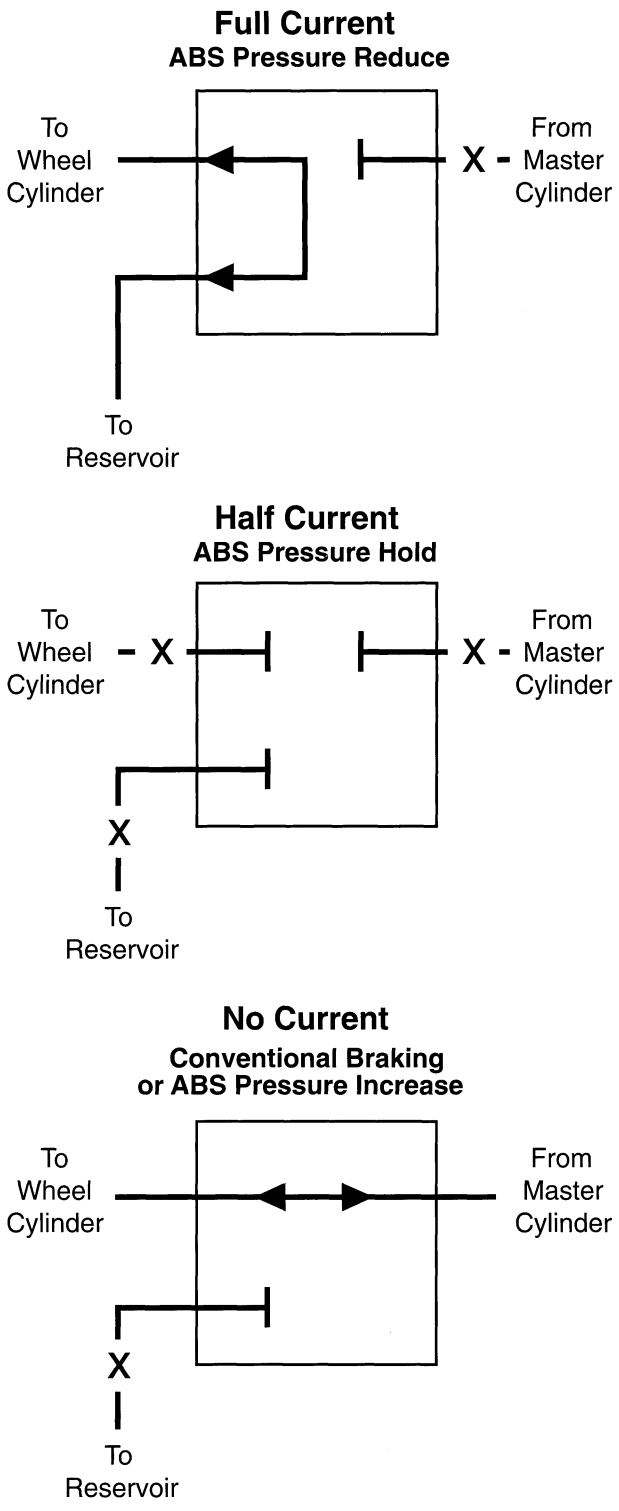
ABS-2E Hydraulic Control Unit

Notes

ABS Operating Modes

During anti-lock braking, the HCU operates one or more of the solenoid valves to control the hydraulic pressure acting on the brakes. Each solenoid valve can operate independently in any of three pressure modes. These are pressure *reduce*, pressure *hold*, and pressure *increase*. These modes are related to the amount of current flowing through the solenoid valve, as determined by the ABS ECU.

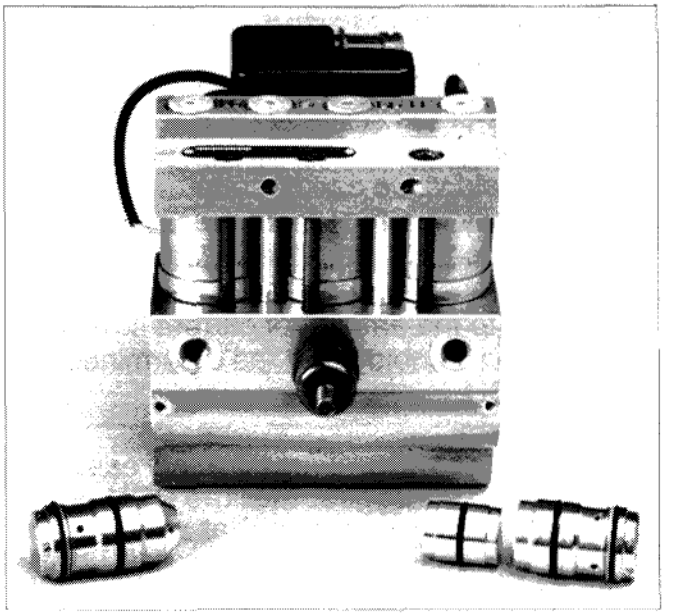
NOTE: The term "pressure increase" may suggest that the HCU raises pressure above that achieved by pressing the brake pedal. This is not the case.



Solenoid Valve Function Diagram

The Mechanical Valve

In the ABS-2E hydraulic control unit, the fourth solenoid valve has been replaced by a mechanical valve containing a plunger piston. This mechanical valve controls the left rear hydraulic brake circuit.



Mechanical Valve Components

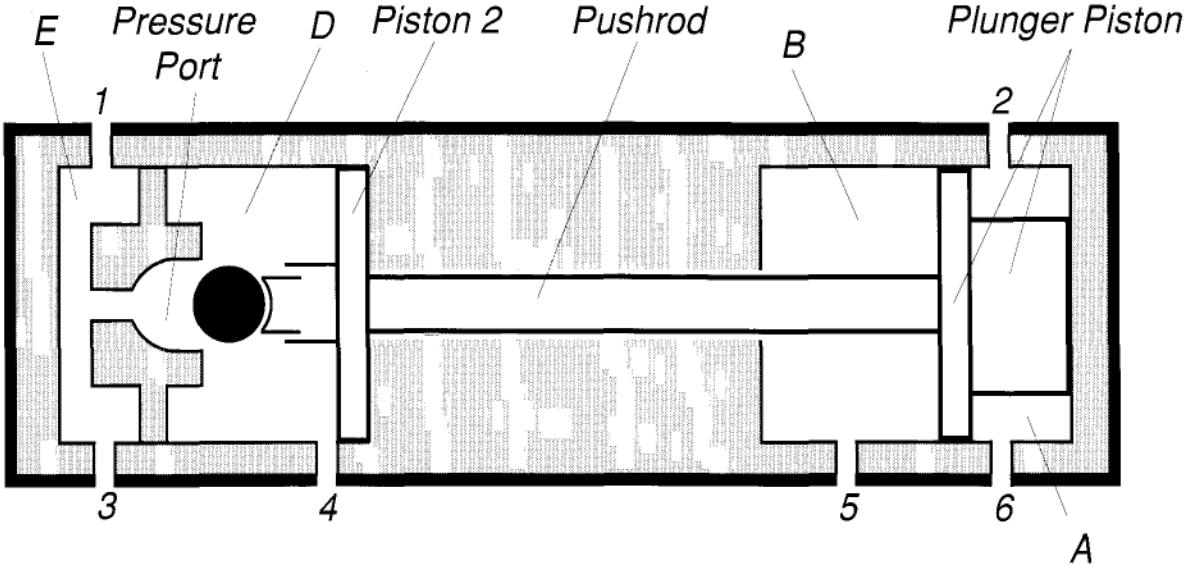
Chambers & Connections

In the right side of the valve, is a pressure equalization chamber. The head of the plunger piston divides this chamber in half (zones A and B in the diagram). If pressure in both halves of the chamber is equal, spring tension keeps the plunger piston in the "home" position, all the way to the right.

The right half of the chamber is connected to the master cylinder (port 2) and to the pump in the HCU (port 6). The left half of the pressure chamber is connected to the right rear hydraulic circuit (port 5).

During conventional braking, the master cylinder pressurizes both sides of this chamber. However, if pressure in the left half of the chamber is lower than pressure in the right half, the plunger piston is allowed to move to the left.

The other side of the mechanical valve contains a passage (zone E). One end of this passage is connected to the master cylinder (port 1); the other side is connected to the pump (port 3). The passage is also connected through a pressure port to a second pressure chamber (zone D). This chamber is connected to the left rear hydraulic brake circuit (port 4). Also in this chamber is a second piston, piston 2. Piston 2 is connected to the plunger piston by means of a pushrod.



Moving the Plunger Piston

When the system puts the right rear hydraulic circuit in *pressure reduce* mode, the solenoid valve in that circuit closes the inlet and opens the outlet. Wheel cylinder pressure is then reduced because brake fluid is allowed to bleed back to the reservoir in the HCU.

Through port 5, there is a hydraulic connection between the wheel cylinder circuit and the left half of the pressure chamber (zone B). With wheel cylinder pressure reduced, pressure acting on the left side of the plunger piston is also reduced. Master cylinder pressure acting on the right side of the plunger piston (zone A) now overcomes spring tension and begins to move the plunger piston to the left. As the plunger piston moves, the push rod causes piston 2 to move along with it.

As piston 2 moves to the left, it first closes the pressure port to isolate the left rear wheel cylinder (port 4) from master cylinder pressure (port 1).

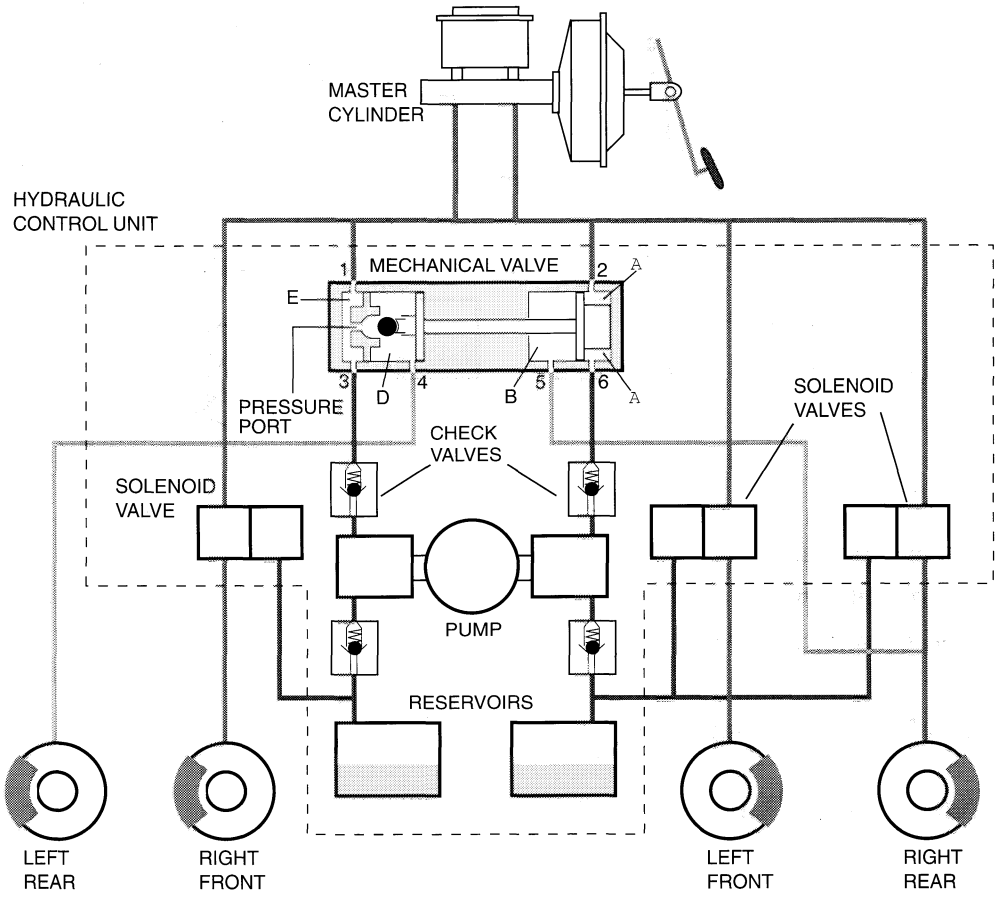
As piston 2 moves farther to the left, it exposes the left rear wheel cylinder (port 4) to the right side of the second chamber (zone D). As piston 2 continues to move to the left, the expanding volume in the second chamber decreases pressure in the left rear hydraulic circuit.

When the system once again allows pressure to increase in the right rear hydraulic circuit, pressure in zone B moves the plunger piston back to the right.

In actual practice, this process of moving the piston happens very quickly and repeats many times per second as the system cycles.

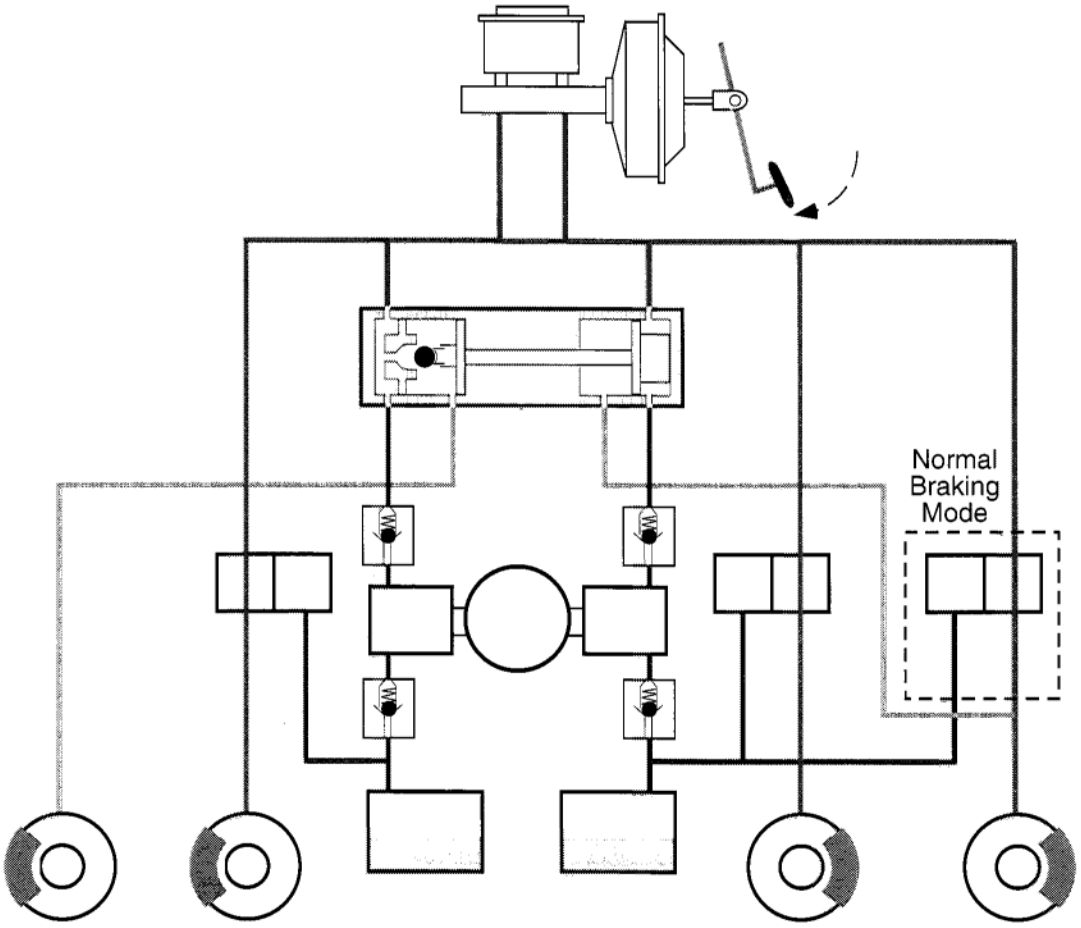
Damping Oscillations

An additional benefit of this arrangement is that the mechanical valve damps out some of the unwanted oscillation in the brake pedal as the ABS pump runs. Because of this, the "F" valve used on the ABS-2SL system is no longer needed and has been eliminated from the circuit.



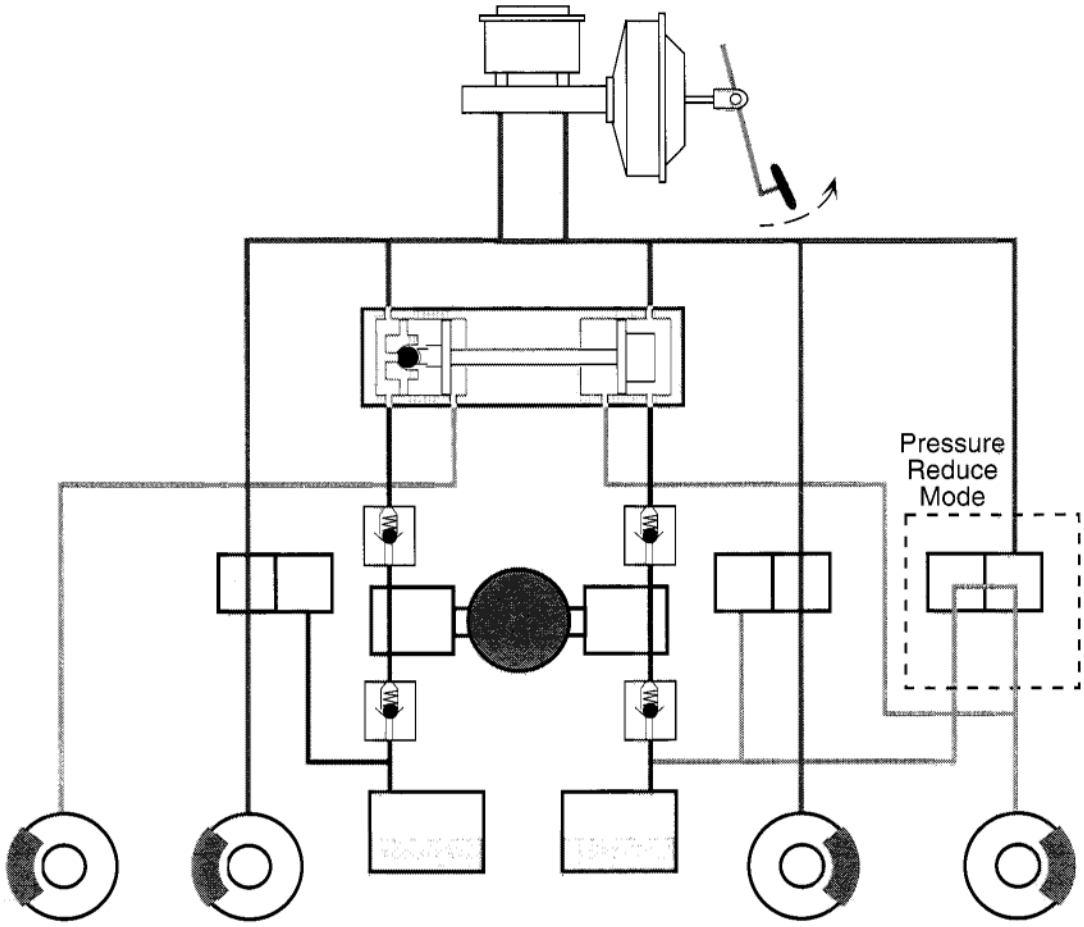
ABS Operating Modes

To illustrate the functioning of the four operating modes of this ABS system, the next four pages show the system diagram with the mechanical valve in the appropriate position for each mode. For clarity, we assume that the ECU is operating only the solenoid for the right rear brake circuit. Recall that this circuit also effects the left rear brake circuit through the mechanical valve.



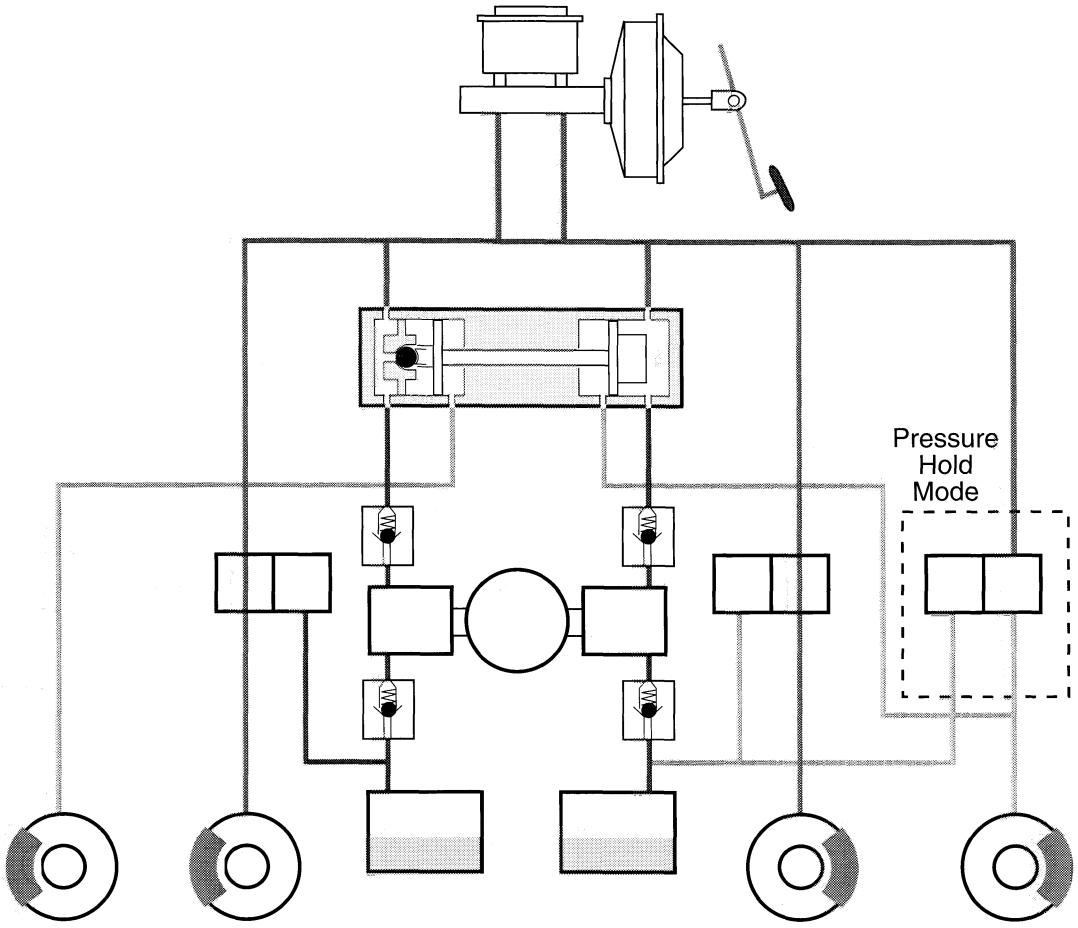
NORMAL BRAKING

- Driver depressing pedal
- ECU passive (monitoring)
- Zero current in solenoid valves
- Pump off
- Plunger piston full right, pressure port open
- Master cylinder pressure supplied to all wheel cylinders



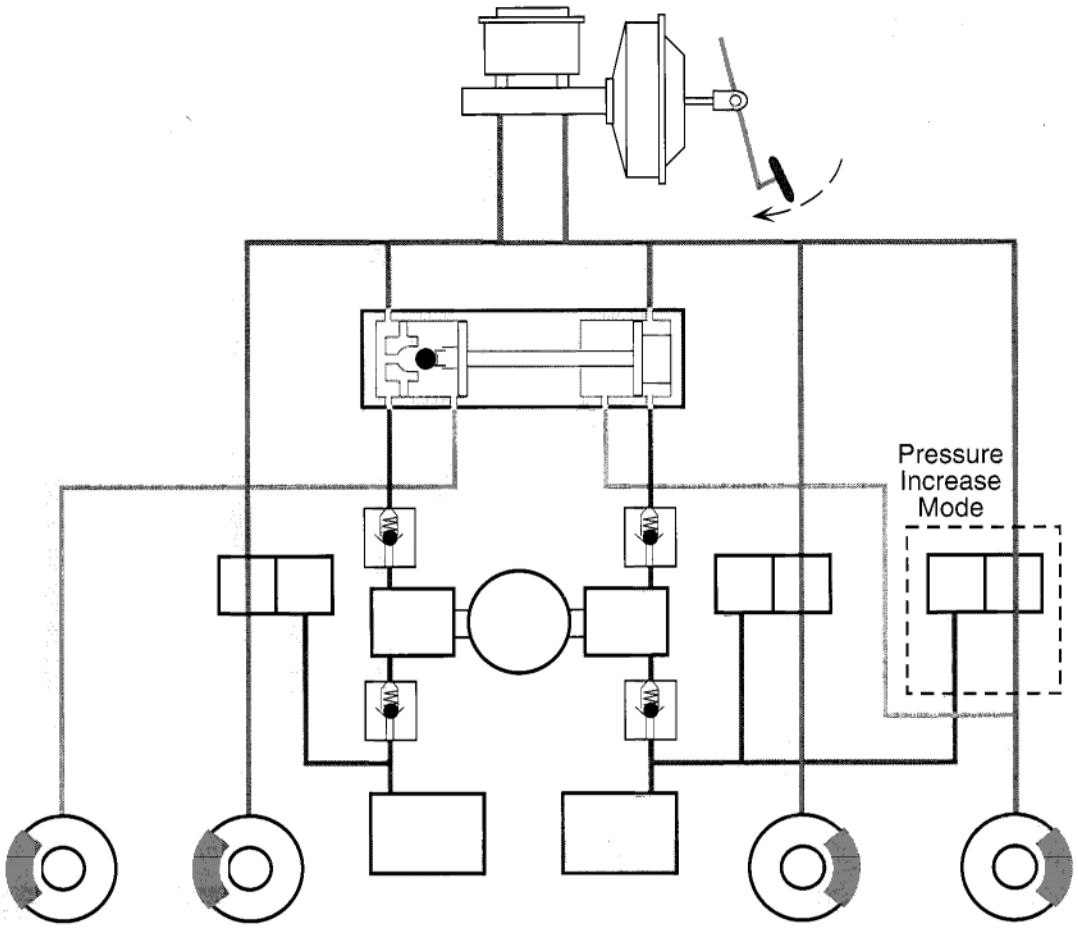
PRESSURE REDUCE

- Pump pressure raising pedal
- ECU controlling solenoid valves and pump
- Full current in the right rear solenoid valve
- Pump running
- Plunger piston moves left, closes pressure port; system balances the two rear wheel cylinders



Pressure Hold

- Pedal firm
- ECU controlling solenoid valves and pump
- Half current in the right rear solenoid valve
- Pump Off
- Pressure port closed
- Plunger piston is stationary, maintains reduced pressure in the right and left rear wheel circuits



PRESSURE INCREASE

- Driver pressing pedal, pedal falling
- Zero current in solenoid valves
- Pump off
- Master cylinder pressure applied to right rear wheel circuit, raises pressure
- Plunger piston begins to move right, opens pressure port, master cylinder pressure drives plunger piston full right
- Full master cylinder pressure applied to the left and right wheel cylinders

NOTE: If necessary, the ECU cycles each brake circuit through the various ABS modes as required to control wheel lock-up.

ABS Self-Diagnostics

The ABS-2E electronic control unit, or ECU, can store up to three trouble codes in its memory. It does this whenever it detects an out of range signal in any of its inputs.

When a fault condition is active, the ECU goes into "fail-safe" mode and turns on the ABS warning lamp. The brake system then functions only in conventional mode.

If the fault condition is caused by an intermittent problem, the ABS warning lamp may go off at the next ignition switch "ON-OFF" cycle, but the code will still be stored in the ECU's memory.

Displaying Codes

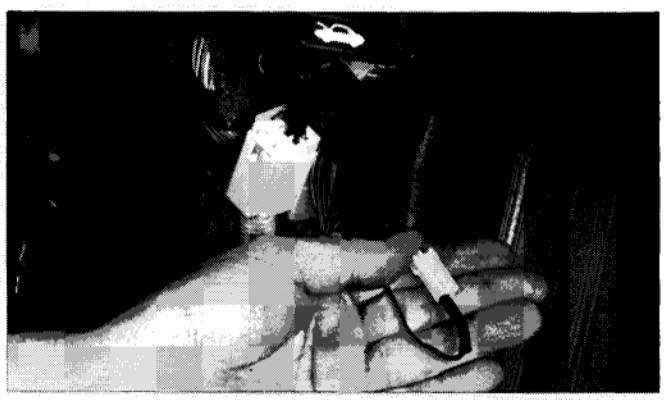
To display any stored codes, use the following procedure:

1. Remove the small kick panel on the lower driver's door "A" pillar.
2. Enter ABS system diagnostic mode by jumpering terminal L in the ABS check connector to body ground. Check the schematic in the service manual to identify terminal L. Note: Some models have a grounding lead attached to the check connector.
3. Turn the ignition switch to "ON."
4. Observe the ABS warning lamp. It will begin to flash out one or more codes.

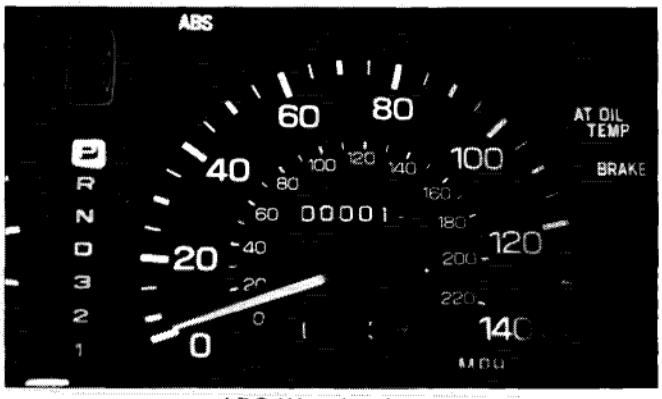
When you enter diagnostic mode, the ECU displays the newest code first, then the second code, and then the oldest.

Removing the Trim Panel

The ABS Check Connector



Grounding Terminal L, ABS Check Connector



ABS Warning Lamp

Each code display cycle begins with the start code "eleven." After code 11, the ECU displays any stored trouble codes. When you see code 11 again, you know the ECU is repeating the cycle.

Interpreting Codes

Each code is made up of long and short flashes, just like those used by the fuel system. Count each long flash as 10, each short flash as one.

For example, if the lamp flashes one long and one short–that represents code 11. If it flashes two long and one short–that is code 21.

Self-Tests

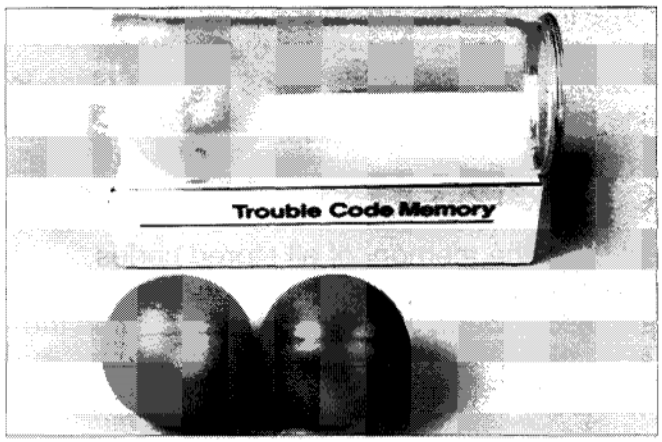
Each time the ignition switch is turned from "OFF" to "ON," the self-diagnostic function begins to look for fault conditions. These self-tests occur in two stages: one at key "ON" and another as soon as the vehicle has been driven at a speed of 6 miles per hour or more for 20 seconds.

Assume that a particular vehicle has no ABS codes stored. If the ECU detects a fault condition, it goes into fail-safe mode and turns on the ABS warning lamp. In fail-safe mode, the ABS system is essentially shut down and completely passive, while the brake system operates conventionally. The system remains in fail-safe mode until the ignition switch is turned to "OFF."

The next time the ignition switch is turned to "ON," the ECU again initializes and looks for fault conditions, first at key "ON," and again after 20 seconds at 6 miles per hour or more. If the fault condition is still there, the ECU simply returns to fail-safe mode.

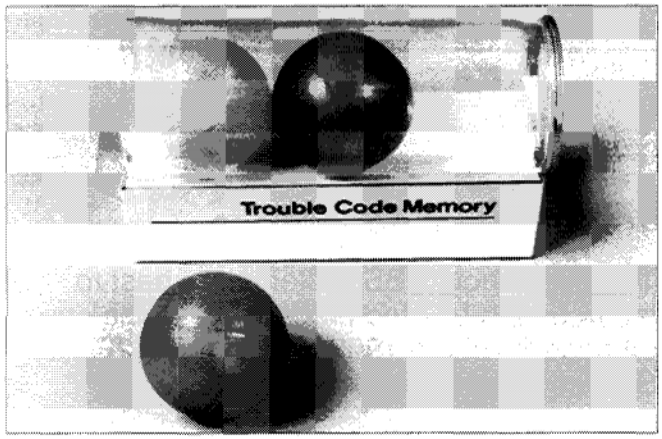
NOTE: Even though the ECU can store up to three codes, this can happen only if at least two of the fault conditions are intermittent.

This means the ECU stays in fail-safe mode as long as the first fault condition remains in effect, and will neither detect nor store in memory any additional fault conditions. If the first fault condition clears, the ECU again exercises active ABS control at the next key "ON."



One Fault Code Stored in Memory

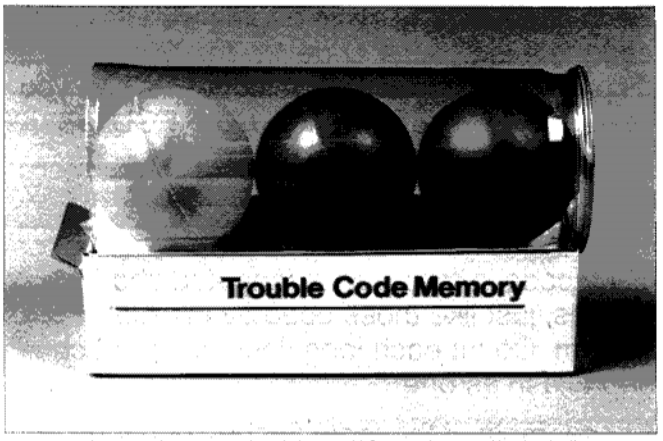
If a second fault condition occurs, the ECU will then store the second code.



Two Fault Codes Stored in Memory

To get a third code into memory, the second fault condition must also be intermittent. When it clears, the ECU can come out of fail-safe mode at the next ignition "ON-OFF"cycle. At that point, the ECU can detect, then store the third code.

If the ECU detects another fault condition once three codes are in memory, the newly arriving code displaces the oldest stored code. The newest code takes the first place in line for display.



Three Fault Codes Stored in Memory

Clearing Codes

To clear the memory of all stored codes, alternately disconnect and reconnect the jumper between ground and terminal L in the ABS check connector. Do this three times in the span of about 12 seconds.

TIP: At the moment the ECU clears its memory, you can hear the relays in the HCU cycle once.

Troubleshooting Process

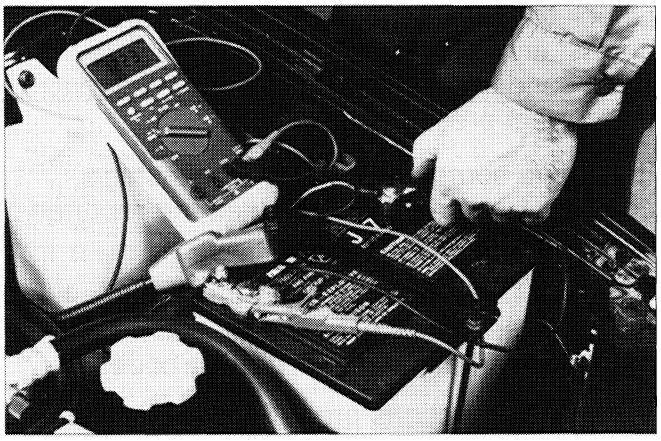
To troubleshoot ABS systems, it's best to follow a step-by-step procedure like the one on page 31 of the 1992 Legacy ABS-2E Service Manual Supplement.

Refer to the Service Manual for Diagnostic Information

Enter the flow diagram with the symptom reported on the repair order. The diagram calls that "Trouble Occurs."

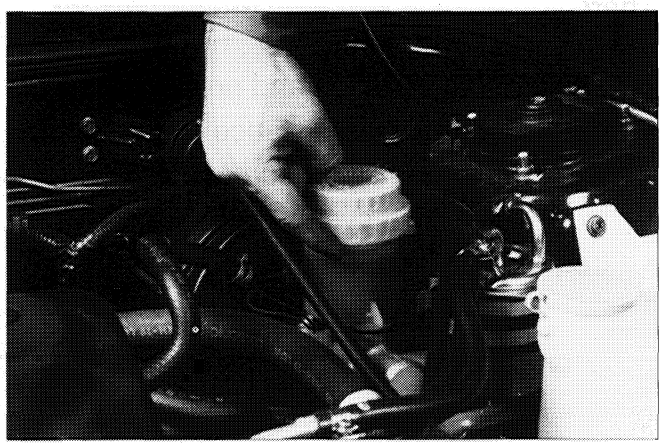
The first step in the procedure is "Basic Checks." This calls for a visual inspection to look for obvious problems and includes the following items:

- improper battery voltage
- low brake fluid level
- brake fluid leaks
- brake drag
- condition of the brake pads and rotors
- size, type, and condition of the tires



Measuring Battery Voltage

Checking for Brake Drag



Checking Brake Fluid Level

Notes

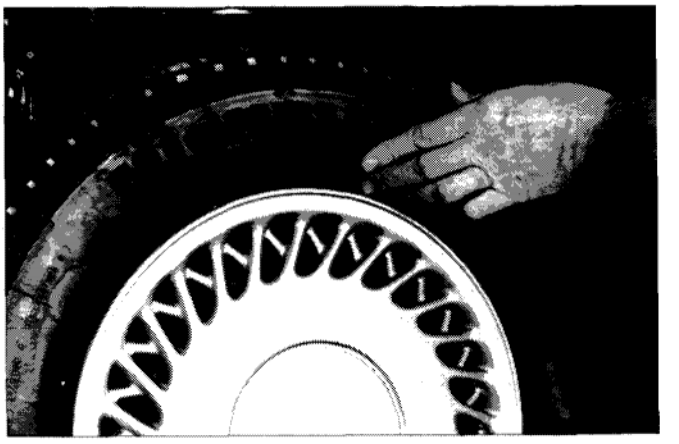
Check the tires to confirm that they are the correct tires for the vehicle, that they are in good condition, and that they are inflated to the correct pressure.

If you find something wrong at this stage, correct it and see if it eliminates the reported symptom. If not, continue to Step 3.

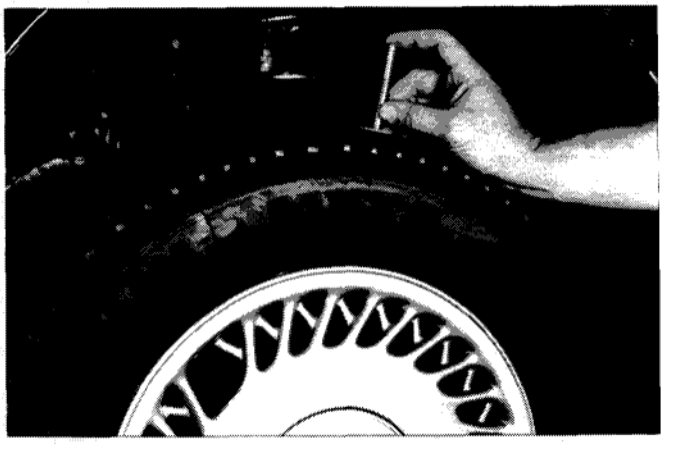
Step 3 is "Self-diagnosis." At this time, put the ECU into self-diagnostic mode, and monitor the ABS warning lamp for trouble codes.

If the lamp functions properly and there are no trouble codes stored, you will see a continuously flashing Code 11. In that case, go to the General Troubleshooting Chart. There you will find separate procedures for the following symptoms:

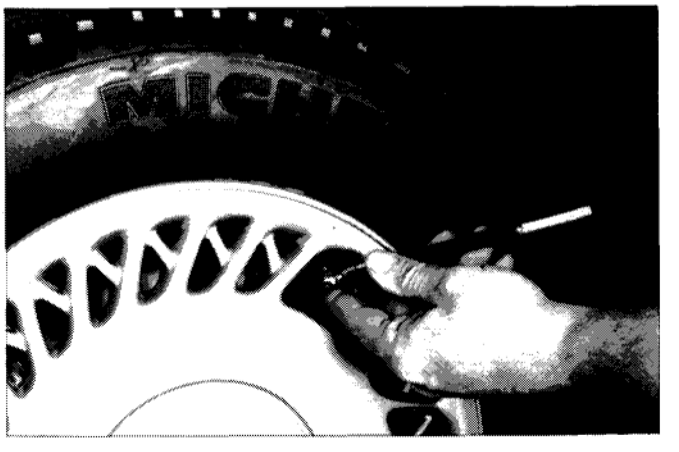
- brake pedal vibration and noise
- excessive stopping distance
- too much or too little pedal travel
- inoperative ABS system
- frequent ABS operation



Checking Tire Size and Type



Checking Tread Depth



Checking Inflation Pressure

Proceed to Step 4 in the diagram if the ECU has stored one or more codes, or if the ABS warning lamp is malfunctioning. Step 4 directs you to "troubleshoot in accordance with trouble code." That means, turn to Section T6 and look for the specific chart that matches the trouble code you recorded. There is a chart in Section T6 to cover every possible ABS trouble code.

A table lists all of the codes, tells you where to look for diagnostic information, and summarizes the reason for the trouble code. Notice that in some cases you have to look all the way over to the right column to find out to which component a specific trouble code refers.

Once you've identified a specific trouble code, the Basic Troubleshooting Procedure tells you what to do next:

1. Follow the troubleshooting steps in the chart.
2. Make the necessary repair.
3. Clear the memory.
4. Repeat the self-diagnostic check.

Checking a Wheel Speed Sensor Circuit

In all cases, road test the vehicle when the preceding steps are done. This is necessary because some codes will not set until vehicle speed has been driven at six miles per hour or more for at least 20 seconds.

NOTE: Do NOT substitute spinning the wheels on the service lift for a road test. On FWD vehicles, this can cause the ECU to incorrectly set a fault code.

Trouble Code	Refer to:	Contents of diagnosis	
0 [Warning light OFF]	[T6A0]	Trouble in the warning light drive circuit (Warning light is not on for 1.5 seconds after ignition switch is on.)	
0 [Warning light ON] or [Trouble code output]	[T6B0]	Trouble in the warning light drive circuit.	
11	—	**Start code:** **a. Trouble code is shown after start code.** **b. Only start code is shown in normal condition.**	
21	[T6C0]	Faulty ABS sensor (Open circuit or input voltage excessive)	Front right wheel sensor
23			Front left wheel sensor
25			Rear right wheel sensor
27			Rear left wheel sensor
22	[T6D0]	Faulty ABS sensor (When there is no open circuit or speed signal input.)	Front right wheel sensor
24			Front left wheel sensor
26			Rear right wheel sensor
28			Rear left wheel sensor
29	[T6E0]	Faulty tone wheel etc.	
31	[T6F0]	Faulty solenoid valve circuit(s) in hydraulic unit.	Front right wheel control
33			Front left wheel control

Partial list of Trouble Codes From 1992 Legacy Service Manual

Air Bleeding

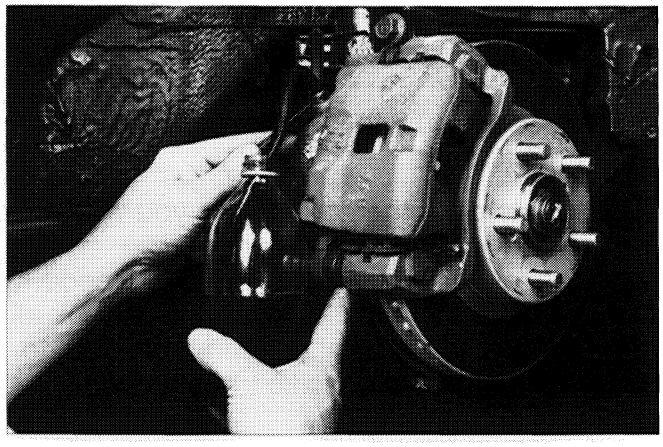
Overview

The air bleeding procedure for the ABS-2E system is similar to that used for other systems, with a few added steps. Refer to the Service Manual for general rules and step-by-step instructions.

As always, pay attention to the basics. Before you begin, make certain there are no leaks in the system.

Then bleed the secondary chamber of the master cylinder first and the primary chamber second. To accomplish this, work in the following order:

1. Right front brake
2. Left rear brake
3. Left front brake
4. Right rear brake



Bleed the Secondary Chamber First

Pedal Travel Measurement

To properly perform the following procedure, you will need a pedal effort gauge (SOA 636500). With all four brake circuits bled, check pedal travel as follows:

1. Put the wheel in a convenient position.
2. With the engine idling, use the pedal effort gauge to apply 110 pounds of load to the brake pedal.
3. Measure the distance between the brake pedal and the rim of the steering wheel.
4. Release the brake pedal and take the same measurement.

Pedal Effort Gauge Measures Force

TIP: **Tie one end of a length of string to the brake pedal. Press the brake pedal, and at the opposite end of the string, place a paper clip to mark the first distance. Then release the brake pedal and place a second paper clip to mark the second distance. Measure between the two paper clips with a ruler or tape measure.**

Measuring Brake Pedal Travel

The difference between the two distances (pedal depressed, pedal released) must be less than 3.75 inches (95 mm). If it is greater than that, there is air trapped in the HCU. Expel this air using Sequence Control (explained in the next section of this VRB).

Pedal Effort Gauge (SOA 636500)

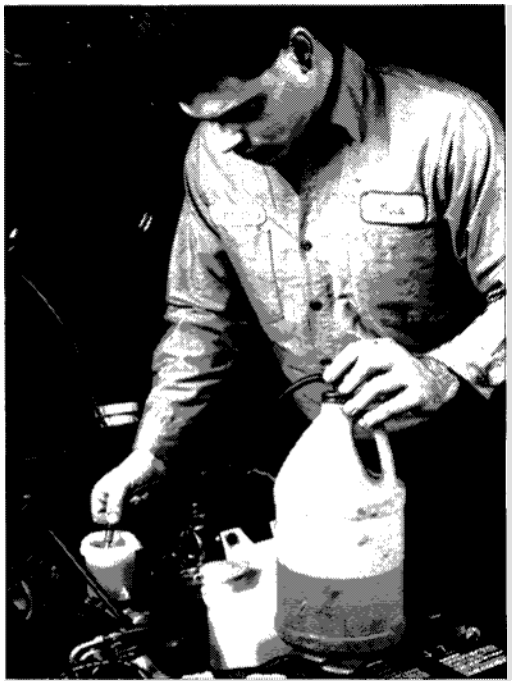
Sequence Control

Sequence Control is the name of a mode in which the system automatically runs the HCU pump motor and cycles the solenoid valves. The Sequence Control actions help to purge air out of the hydraulic control unit.

To activate Sequence Control, proceed as follows:

1. With the ignition off, jumper both the "L" and "K" terminals in the ABS check connector to ground.
2. Turn the ignition switch to ON and watch the ABS warning lamp.
3. When the lamp goes off, immediately press and hold the brake pedal.
4. The ECU now runs the pump and cycles all of the solenoid valves. You will hear and feel this happening.
5. When you hear the pump stop, you know Sequence Control is done. Release the brake pedal and turn the ignition to OFF.

When you have completed Sequence Control, bleed all four brake circuits again. Top off the master cylinder reservoir after bleeding each circuit. Then road test the vehicle at low speed. Apply the brakes hard two or three times to make sure that the brakes are working properly.



Adding Brake Fluid to the Reservoir

HCU Pressure Check

Overview

It is possible to check the operation of the hydraulic control unit using a hydraulic pressure gauge. To do this, you connect the gauge to one of the pressure output ports of the HCU, then start Sequence Control. As you start Sequence Control, press the pedal so that a specified initial pressure shows on the pressure gauge. This initial pressure is shown in the table on page 20. Once Sequence Control starts, the ECU cycles the solenoid valves so that each brake circuit decompresses (pressure reduce mode) and re-compresses (pressure increase mode). As this happens, the reading on the pressure gauge should decrease to 71 psi or less, then come back to 498 psi or more.

Setting Up a Pressure Gauge

To build a set-up for checking HCU pressures, you will need the following parts:

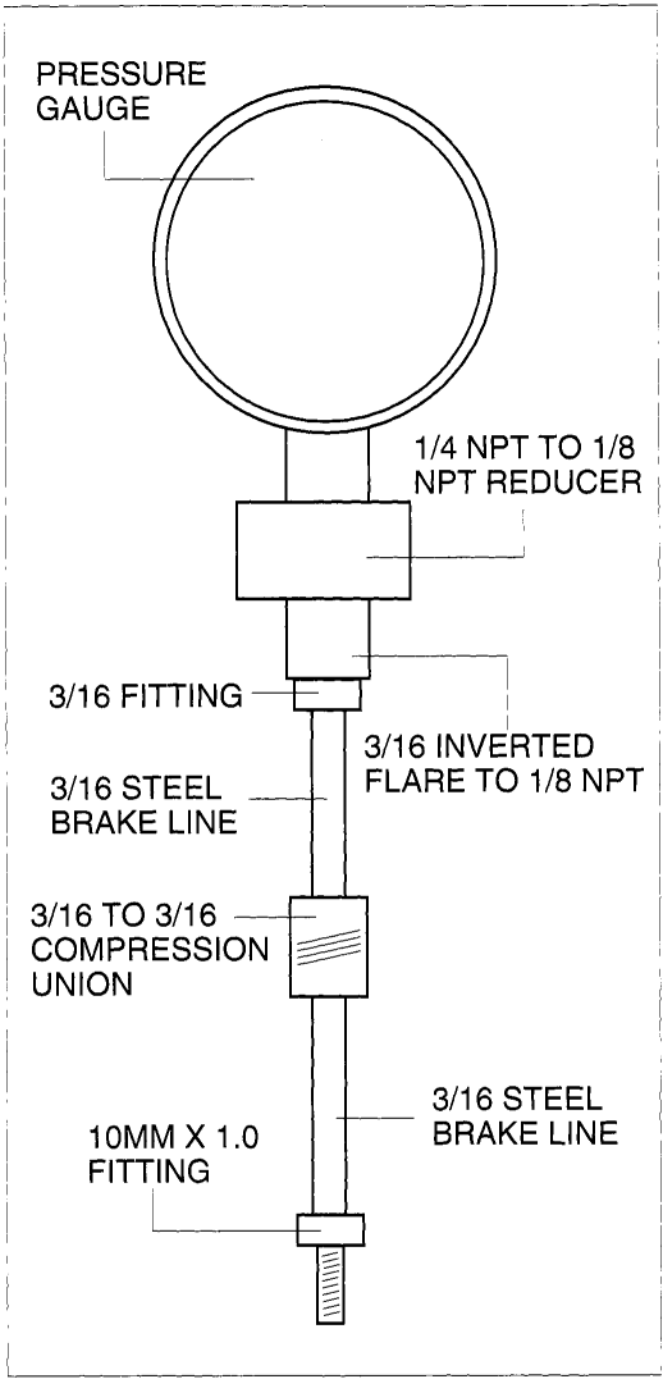
- pressure gauge (1,500 or 2,000 psi)
- 3/16 steel brake line, 8" long, with 5/16 flare fittings (Gibson PN 308CK)
- 3/16 steel brake line, 8" long, with 10 x 1.0 mm flare fittings (Gibson PN 308MJ)
- 1/4 NPT to 1/8 NPT reducer (Edelman PN 219420)
- 3/16 inverted flare to 1/8 NPT (Edelman PN 124320)
- 3/16 to 3/16 compression union

You should be able to find the brake tubing and the connecting parts at most auto parts stores. For the pressure gauge itself, check industrial supply houses.

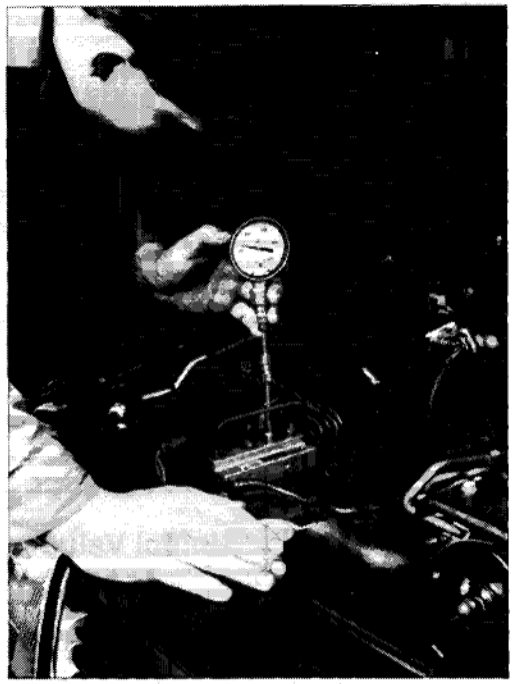
Follow these steps to assemble the parts:

1. Cut each of the two 8" steel brake lines in half (to remove one of the fittings on each line).
2. Join the two cut ends with the 3/16 compression union.
3. Connect the pressure gauge to the 1/4 NPT to 1/8 NPT reducer (use Teflon® tape).
4. Connect the 3/16 inverted flare to 1/8 NPT to the reducer (use Teflon® tape
5. Connect the 5/16 flare fitting to the gauge assembly; the 10 x 1.0 mm fitting will connect to the HCU.

TIP: **When the tester is not in use, put a rubber cap from a bleeder screw over the open fitting to keep dirt out.**



HCU Pressure Check Set-up



Doing an HCU Pressure Check

DESCRIPTION

When Sequence Control starts, the left front solenoid cycles first, then the right front solenoid, and finally the right rear. As the right rear solenoid works, pressure in the left rear brake circuit is simultaneously regulated by the mechanical valve.

It is not necessary to exactly match the values in the pressure table during your tests. The important thing is that you observe the sequence shown in the table below:

1. INTITAL VALUE: the hydraulic circuit pressurizes as you press the brake pedal.
2. WHEN DECOMPRESSED: the circuit automatically loses pressure as the HCU cycles the solenoid valve to pressure reduce mode.
3. WHEN COMPRESSED: the circuit regains pressure (at least equal to the initial reading) as the system returns to pressure increase mode.

CIRCUIT	Initial Value	When Decompressed	When Compressed
Front Brakes	498 psi (3,432 kPa)	71 psi (490 kPa)	498 psi (3,432 kPa)
Rear Brakes	498 psi (3,432 kPa)	71 psi (490 kPa)	498 psi (3,432 kPa)

Normal pressure readings

The pressure check is repeated for each of the four HCU pressure output ports. Recall that three of the brake hydraulic circuits are controlled by solenoid valves (all but the left rear circuit). If a check of any one of these circuits yields incorrect pressure readings, this may indicate a non-functioning solenoid valve.

Typical incorrect readings are shown in the two tables below. In the first example, the pressure does not decrease from the initial value. In the second example, the pressure fails to reach the initial value at the start of Sequence Control.

CIRCUIT	Initial Value	When Decompressed	When Compressed
ANY	498 psi (3,432 kPa)	498 psi (3,432 kPa)	498 psi (3,432 kPa)

Example 1: Pressure does not decrease; may indicate faulty solenoid valve

CIRCUIT	Initial Value	When Decompressed	When Compressed
ANY	Less than 498 psi (3,432 kPa)	71 psi (490 kPa)	Less than 498 psi (3,432 kPa)

Example 2: Pressure does not reach initial value at start of Sequence Control

The third example shows the readings for the right rear circuit are correct, but the readings in the left rear circuit do not change from the initial reading, this may indicate a malfunction in the HCU's mechanical valve.

CIRCUIT	Initial Value	When Decompressed	When Compressed
Right Rear	498 psi (3,432 kPa)	71 psi (490 kPa)	498 psi (3,432 kPa)
Left Rear	498 psi (3,432 kPa	498 psi (3,432 kPa)	498 psi (3,432 kPa)

Example 3: Pressure values for right rear circuit are correct, but left rear pressure does not decrease

CAUTION: For this check, use a pressure gauge that is reserved exclusively for brake fluid. Do NOT use a gauge that has been used for transmission pressure tests; doing so could lead to brake system malfunctions.

NOTE: Before you start the HCU pressure checks, pump the brake pedal several times. That will bleed vacuum from the vacuum booster so that it is at atmospheric pressure.

NOTE: This check requires that you press on the brake pedal so that the pressure gauge displays a pressure equal to or more than the initial value in the table. Be prepared to press on the brake pedal with considerable effort for the duration of the check.

To perform an HCU pressure check, follow these steps:

1. At the HCU, loosen the hydraulic fluid pipe for the left front brake circuit.
2. In its place, attach a suitable pressure gauge.
3. Bleed air from the pressure gauge.
4. Activate the Sequence Control mode.
5. Observe the pressure gauge as the system cycles the left front solenoid valve through pressure reduce, pressure hold, and pressure increase. Compare the readings to the values in the table.
6. Move the pressure gauge to the right front brake circuit connection at the HCU and reconnect the previously disconnected pipe. Then repeat Steps 3 through 5.
7. Repeat these steps for the two remaining HCU ports (left and right rear).

When you have finished these checks, make sure all of the brake fluid pipe connections are secure and free from leaks and that the system is bled properly.

Conclusion

Effective diagnosis of the ABS-2E system depends on a logical, step-by-step approach. When you troubleshoot an ABS-2E system, use the appropriate service manual, follow the procedures, and do not skip any steps. As always, pay attention to the basics. Use the instructions in the service manual and in this VRB to look for fault codes, perform diagnostics, and properly bleed air from the system. When appropriate, use the HCU pressure check to test the functioning of the three solenoid valves and the mechanical valve.

NOTES