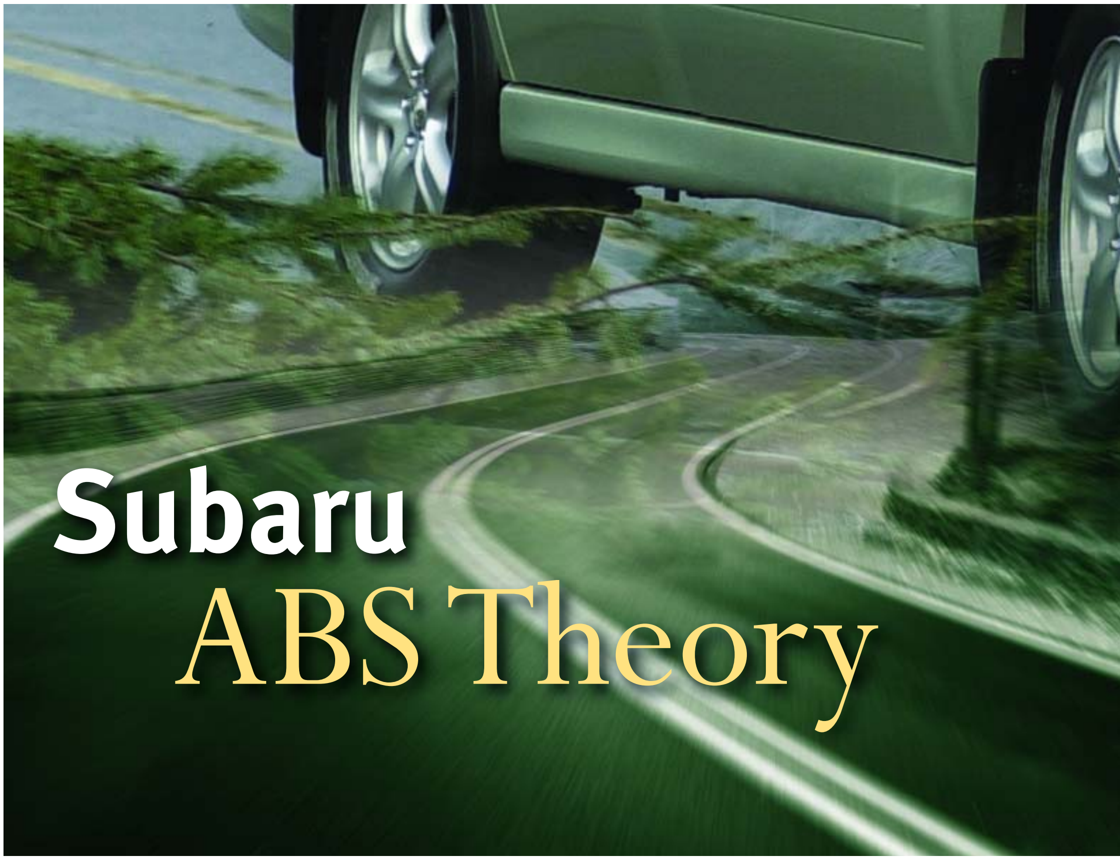


Subaru ABS Theory

Make Sure You Understand ABS Fundamentals Before You Attempt Diagnosis or Repair

If you live in a heavy-traffic area, perhaps you've noticed something interesting: Where you used to frequently hear the wailing squeal of skidding tires during some unfortunate motorist's panic stop, now it's an unusual sound indeed. That demonstrates both the proliferation and performance of ABS.

Speaking of that proliferation, the trend toward anti-lock braking systems is a change in vehicular stopping technology just as profound as the switch from mechanical to hydraulic brakes, or the adoption of discs over drums. And we'll all be safer for it.

Subaru got on this safety bandwagon early on. You could buy a Legacy with ABS back in 1990 — that's 15 years ago.

Demo

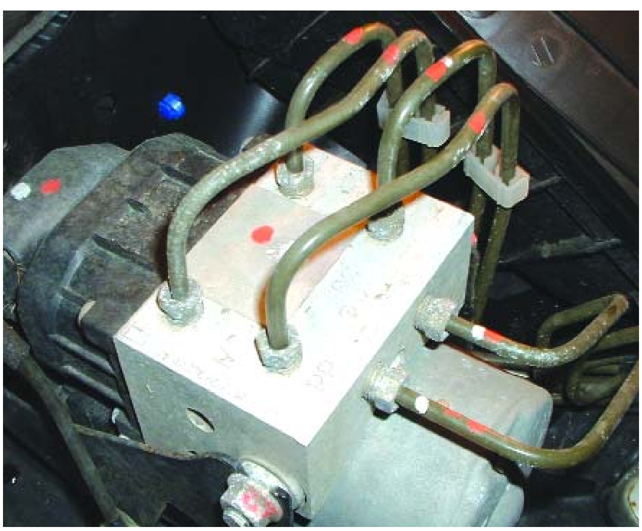
We were once given an impressive demonstration on maybe a half-acre of Mylar film sloshed down with soap and plenty of water from fire hoses. If it hadn't been a perfectly level parking lot, you could barely have walked on this terrifically slippery surface. Two rows of cones were set up, and we were asked to try to stop a car between them. But first a cobbled-up switch on the dash was turned to "off" — it was the juice feed to the ABS controller. Well, whether we pumped furiously or just tried the gentlest decel possible, we got seriously sideways and wiped out cone after cone. Then we tried it with the switch on, and it was almost as if we were driving on dry pavement. We stopped short and straight.

Like most other defensive drivers, we don't have to stand on the brakes very often, and we're wary of limited traction conditions, so it's highly unusual when we get into trouble trying to stop. But, of course, it only takes one bad instance, which recalls a motto often used by Robert Bosch Corp. (a former supplier of ABS components to Fuji Heavy Industries): "If you need it just once, it's paid for itself." And that's what the carmakers are concerned about, that one moment of inattentiveness, or when dangerous conditions stack up all at once.

Basics

The idea, of course, is to prevent lockup during hard deceleration, especially in slippery conditions. This greatly increases control (a locked wheel can't be steered) and reduces stopping distances. It can also save an expensive set of tires from flat-spotting in a panic stop.

The basic operating principles are easy to understand. The electronic control module watches the speed of each wheel by means of gear-like reluctors or exciters mounted on the disc or axle and hermetically-sealed pickup coil sensors that count the teeth as they pass. The computer continually monitors and compares this input, which means it processes thousands of signals per second.



Tucked in unobtrusively under the hood, the hydraulic control unit translates electronic commands into action.

If one wheel slows down more than the others during brake application, or deceleration doesn't match a profile in the microprocessor's memory, the control module responds instantly by sending commands to electro-magnetic fluid valves housed in the main control unit, which freeze or release hydraulic pressure to that wheel or circuit, then reapply it when the tire speeds up again. This cycle is repeated up to 15 times per second — the best driver in the world could never pump the pedal that rapidly, and obviously he can only pulse the system as a whole. With ABS, he can apply the brakes as hard as necessary and give them no further thought while he concentrates on steering.

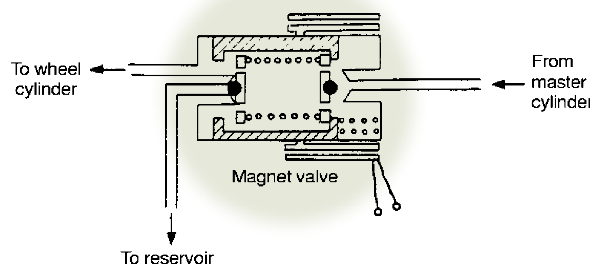
During normal braking, ABS watches and waits. Hydraulic pressure simply passes through the valves as if they weren't there.

Solenoid Valves

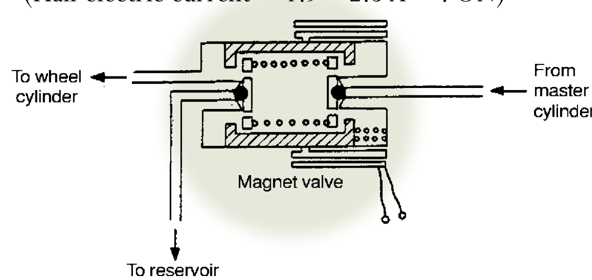
With the dual-diagonal hydraulic system split used on typical FWD and AWD vehicles, there's one inlet and one outlet valve for each front caliper, and another pair for each of the rear brakes, making a total of eight in the valve body.

As we said, the computer activates these solenoids appropriately to tailor fluid pressure to conditions. When a wheel begins to skid, the electrical circuit to the normally-open inlet valve is completed, making it close and blocking the movement of fluid into the caliper. If that corrective action isn't sufficient to stop lockup, the normally-closed outlet valve is opened, which allows pressure to be relieved through a bypass to an accumulator and a return pump so the pads or shoes can retract. No sooner has this been accomplished than the signals are reversed and fluid pressure is again applied to the caliper. This continues on-off at a rate determined by traction.

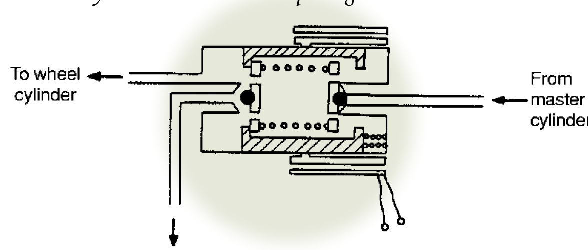
1. **Position** (No electric current: OFF)
   Master cylinder and wheel cylinder passages are connected.



2. **Second position**
   (Half electric current < 1.9 ~ 2.3 A > : ON)

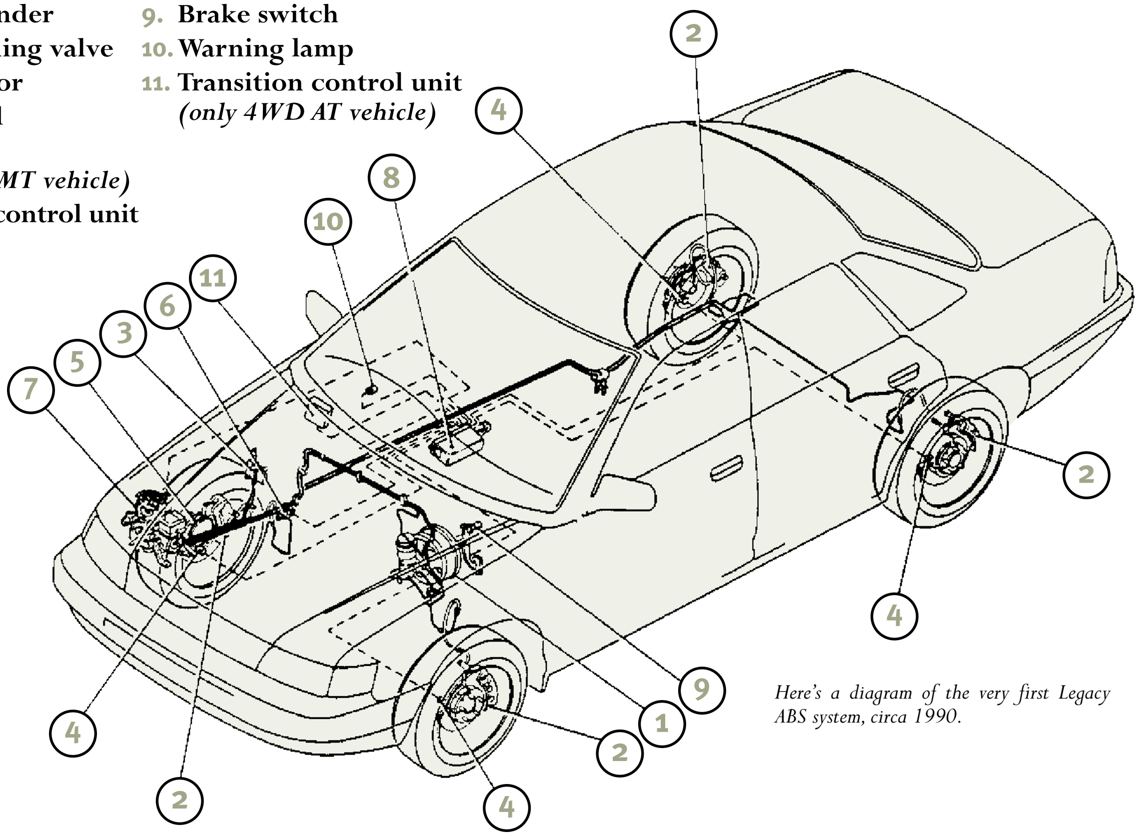


3. **Third position**
   (Full electric current < 4.8 ~ 6.0 A > : ON)
   Wheel cylinder and reservoir passages are connected.



The solenoid valves inside the hydraulic control unit control the pressure to the calipers and wheel cylinders.

1. **Master cylinder**
2. **Wheel cylinder**
3. **Proportioning valve**
4. **Speed sensor**
5. **Tone wheel**
6. **G sensor** *(only 4WD MT vehicle)*
7. **Hydraulic control unit**
8. **Electronic control unit**
9. **Brake switch**
10. **Warning lamp**
11. **Transition control unit** *(only 4WD AT vehicle)*



Here's a diagram of the very first Legacy ABS system, circa 1990.

Semantics

ABS terminology can be confusing. First, there are channels. This refers to the number of fluid passages from the actuator. Early systems have three channels, one for each front wheel and a third for both rears. It is, however, still called a four-wheel system because all four are modulated, even though the rears get one signal and are thus treated alike. So, with the basic FWD dual-diagonal hydraulic arrangement, there are four solenoid sets, but since the rears receive identical control, it still falls into the three-channel category. Later models have four-channel ABS, wherein each rear wheel gets individual control.

As far as componentry is concerned, there are two types of systems, add-on or non-integral and integrated. As the name implies, the add-on variety is used in conjunction with a regular master cylinder and vacuum booster, and this has been the type Subaru has used all along. The integrated approach uses a single unit that combines the master, a hydraulic booster, and the ABS modulator. It's compact, but generally more expensive to manufacture and more complicated to service.

The microprocessors involved typically provide a nearly fail-safe redundancy. If the logic doesn't agree on something, the system reverts to non-ABS hydraulics, and a dash light comes on to warn the driver that his car no longer has that extra margin of safety.

Fortunately, Subaru anti-lock brake systems have shown themselves to be extremely dependable. As one independent specialist tells us, "In 11 years of working on Subaru vehicles, I've only replaced a few wheel speed sensors, which had rust problems, and one control head, which was leaking through an O-ring." As time marches on, and given the public's cavalier attitude toward maintenance, however, we're bound to start getting hydraulic problems — water, corrosion, and dirt in the lines and valve body. See our sidebar on regular fluid changes.

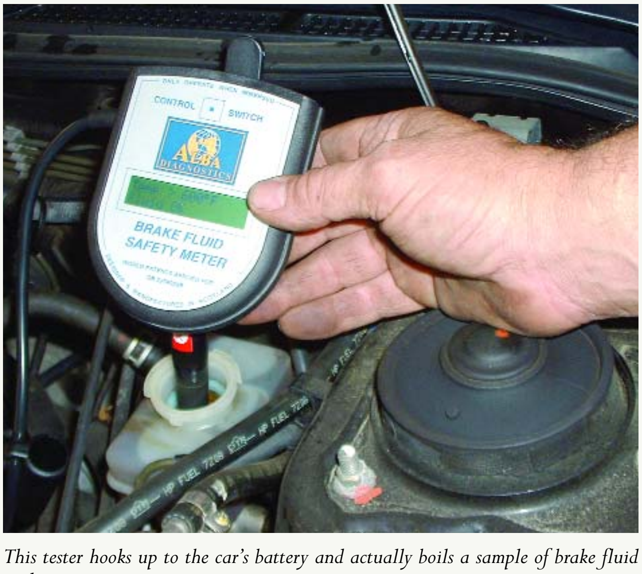
Finally, the latest Subaru models are equipped with EBD (Electronic Brake-force Distribution), the sophistication of which goes beyond that of previous ABS. But that's a topic for a future issue of ***The End Wrench***.

As one ABS system supplier puts it, "If you need it only once, it's paid for itself."

New Juice

To the professional auto service technician, any mention of ABS should bring the subject of brake fluid change recommendations to mind. Attitudes throughout the industry are changing. For example, where once the domestic makers made nary a mention of the need to dump the old stuff periodically, or even during a brake job, now they're giving intervals, something import car manufacturers have been doing for years.

Also, in the past, some brake authorities said that flushing and refilling the system wasn't worth the effort because you can't get all the old fluid out unless you disassemble the calipers and cylinders. True, you won't be able to eliminate every drop of the contaminated liquid, but you can get most of it, and that will effectively reduce the amount of moisture in the circuits. Besides water, there's that nasty sediment, which is a combination of rust and the ashy residue of burned glycol.



This tester hooks up to the car's battery and actually boils a sample of brake fluid to determine its moisture content.

A flushing machine, such as this 12V unit, and a good set of master cylinder adapters make the job thorough, fast and profitable.

This has always been sensible maintenance, but now the presence of expensive and intricate ABS hardware is further justification for the practice. Fluid changes are cheap insurance against big-bucks repairs. Just price a replacement control unit and you'll get our point.

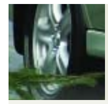
Beyond unnecessary expense, there's the question of ABS performance. "Think about it," says a brake tech trainer. "Sluggish pistons can't respond 15 times a second!" How true.

Depending on whom you talk to, recommended intervals range from one to three years. Personally, we do it every two.

As one former Technician of the Year and successful shop owner puts it, "We've been pushing brake fluid changes since the early days of Subaru hydraulic system problems, way before ABS got popular. If the fluid starts turning brownish, or at 30,000, 60,000, or 90,000 miles, or whenever other brake service is done, we suggest a fluid change."

But how do you get your patrons to act on this stitch-in-time suggestion? Another former Tech of the Year knows how. "For years, we've been trying to tell customers about the importance of changing brake fluid on the basis of time, but it went in one ear and out the other," he says. "Now, we have one of those electronic brake fluid testers, and we test fluid on every car. On DOT 3, a boiling point below 338 deg. F. means the fluid should be dumped. Probably 90% of the customers we show this to have us do the service." Those convenient test strips you dip in the fluid and watch for color change are another alternative, and they cost less than a dollar a shot.

Certainly, it's possible to do this job the old fashioned way — opening bleeders, attaching a drain hose and catch bottle, then pumping the pedal — but a brake fluid flushing machine makes things vastly more efficient, and will pay for itself in a very short time. Look for one with a large assortment of master cylinder adapters.



ABS Fundamentals

What Have You Got?

In the 15 years since Subaru began offering ABS, several different systems from various suppliers have been used. Besides the need to know what you've got in front of you to be sure you order the right part, they all require different diagnostic and service procedures. So, here we're going to tell you how to identify what's what. Since these systems don't seem to develop problems for years and years, and since you're in the aftermarket, we'll just go up to '97 to keep things simple.

From '90 through '94, the Legacy used three distinct systems, Nippon, Bosch (called ABS-2s) and ABS-2E. The Nippon's lines come out of the top of the control head, and also brake bleeders on top. The Bosch unit looks similar, but the outlets are arranged in a square pattern, and there are no bleeders. Neither of these has long-term memory (in other words, when you turn the key off any codes are lost), and they both can display only one code at a time on the LED, which you'll find on the computer under the passenger's seat.

The common ABS-2S has its outlets in line on top.

ABS-2E, on the other hand, has its four lines all in a row, and can display three codes at a time by means of the dash light. It does have long-term memory, and, again, the computer is under the passenger's seat.

None of these early systems communicate with the Select Monitor.

From '95 through '97, four systems were used in Legacy and Impreza. First, ABS-2E, which has the same characteristics as already mentioned. Then there are the ABS/TCS, ABS 5.3 and ABS 5.3i.

You'll find the ABS/TCS system on 1995 FWD Legacy automatics with traction control. The control head has two lines coming out of the top and two out of the side. It has long-term memory and can talk to the Select Monitor, but the electronic control module is still under the passenger's seat.

With ABS 5.3, the motor for the hydraulic unit sticks straight up, and you'll see two lines at the top and four on the side. This also communicates with the Select Monitor, but the computer is to the right of the glove compartment in Legacy, and to the left of the steering column in Impreza.

The control unit motor on ABS 5.3i is horizontal, and has four lines coming out of the top in a square pattern. This system also communicates with the Select Monitor, but the computer is incorporated into the control unit.

Use this chart for quick reference:

1992 through 1994 Legacy ABS (continued on next page)

	Hydraulic Unit	Computer Location	Long Term Memory?	Select Monitor?
Nippon	Brake lines come into top of unit. Has brake bleeders on top of unit.	Under passenger's seat.	No	No
Bosch	Brake lines come in top of unit in shape of a square.	Under passenger's seat.	No	No
ABS-2E	Brake lines come in top of unit lined up in straight line.	Under passenger's seat.	Yes	No

1995 through 1997 Legacy ABS (continued)

	Hydraulic Unit	Computer Location	Long Term Memory?	Select Monitor?
ABS-2E	Brake lines come in top of unit lined up in straight line.	Under passenger's seat.	Yes	No
ABS/TCS 95 front wheel drive Legacy Auto only	Two brake lines come in top and two in side of unit.	Under passenger's seat.	Yes	Yes
ABS 5.3	Motor stands upright, brake lines come in the side of unit.	To the right of the glove box in Legacy. Legacy. To the left of steering column in Impreza.	Yes	Yes
ABS 5.3i	Motor lies down, brake lines come in the top in the shape of a square.	Computer part of the hydraulic unit.	Yes	Yes

ABS Fundamentals

ABS Quick Facts

Bosch Nippon ABS2SL

- No long-term memory
- Electrical faults indicated by ABS warning lamp
- Does not communicate with Select Monitor
- Only stores one trouble code at a time
- Special bleeding procedure
- Select Low Control
- Codes retrieved through cutout in carpet underneath passenger seat.

Teves Mark IV

- Combines ABS and TCS
- Long-term memory
- Electrical faults indicated by ABS or TCS warning lamp
- Communicates with SMI or SMII
- Special bleeding procedure
- Select Low Control
- Codes retrieved by grounding diagnostic terminal and observing TCS warning lamp, or by using SMI or SMII.
- Separate ABS and TCS sequence control procedures

ABS 5.3i

- Electrical faults indicated by ABS warning lamp
- Long-term memory
- Stores up to three trouble codes
- Special bleeding procedure
- Communicates with SMII
- Select Low Control
- Codes retrieved by grounding diagnostic terminal and Observing ABS warning lamp, or by using SMII
- Sequence control

Nippon ABS2E

- Long-term memory
- Electrical faults indicated by ABS warning lamp
- Does not communicate with Select Monitor
- Stores up to three trouble codes
- Special bleeding procedure
- Select Low Control
- Codes retrieved by grounding diagnostic terminal and observing ABS warning lamp
- Sequence control

ABS 5.3

- Electrical faults indicated by ABS warning lamp.
- Long term memory
- Stores up to three trouble codes
- Special bleeding procedure
- Communicates with SMI or SMII
- Select Low Control
- Codes retrieved by grounding diagnostic terminal and observing ABS warning lamp, or by using SMI or SMII
- Sequence control

VDC

- Electrical faults indicated by ABS or VDC warning lamp
- Long term memory
- Stores up to three trouble codes
- Special bleeding procedure
- Communicates with SMII
- Select Low Control
- Separate ABS and VDS sequence control procedures
- Special procedure to calibrate steering sensor

ABS Fundamentals

TCS & VDC:

On ABS's Coattails

If you've ever done much work on big RWD domestic vehicles, you probably know about limited slip differentials, which throw the torque to the wheel with the most traction by means of a complex arrangement of clutches and springs. Well, for several model years before it went to AWD across the board, Subaru offered an even better traction-control feature on its FWD cars without any additional internal transaxle hardware.

How was this achieved? Aha, there's a trick to it, and the trick is only possible because the Teves Mark IV ABS provides the basis. The general idea is to use a computer and a network of sensors to keep you rolling when you try to accelerate on a slippery road. Paradoxically, by applying the brakes and limiting engine output, it'll also cut your 0-60 time. After all, you're not going anywhere at all while you're smoking those tires.

If you're familiar with farm tractors, you know they typically have separate rear wheel brakes. If one of those big lug tires starts spinning, you just apply the pedal for that side and torque flows to the other, which will usually keep you rolling. Same thing here, only we're talking no intervention from the driver, who's probably a mechanically-oblivious soccer mom or an intellectually-preoccupied exec, is required.

Here's the action: Whenever a wheel speed sensor tells the control unit that a tire is spinning, it orders the ABS hydraulic unit to use its servo pump and accumulators to brake that wheel until the differential starts sending power to the opposite side.

The flip side of the traction-control coin is engine output modulation. When the PCM recognizes a spinning wheel, it cuts the electrical signal to the fuel injectors, instantly reducing power. This interruption in pulse width is tailored to the speed of the spinning wheel.

The components that are involved with TCS include the wheel speed sensors and VSS (Vehicle Speed Sensor), the HCU (Hydraulic Control Unit) and, of course, an electronic control module, which interfaces with the PCM for fuel cut. The sensors give the module the input it needs as a basis for its instantaneous decisions. The system is capable of simultaneous or separate usage of rear brake intervention and engine control. The module can direct the ABS hydraulic unit to hold, relieve, or increase brake pressure to either front wheel. Fuel cuts are fast-acting, whereas brake intervention is relatively slow. It is, however, very effective at slow speeds for preventing wheel spin — it gets the most out of the traction available.

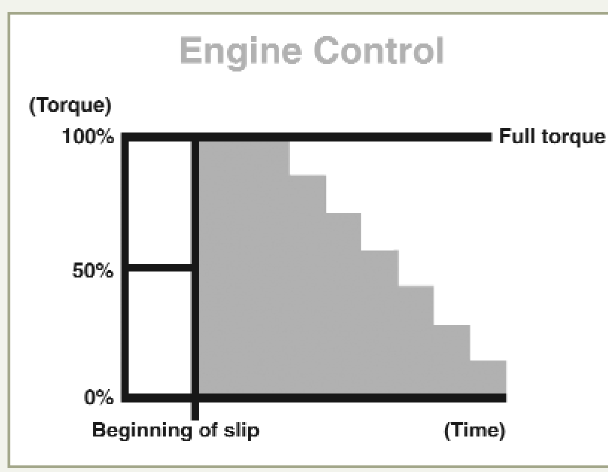
When a TCS event occurs, by the way, the system disables cruise control and the torque converter clutch.

Then there's another, even more dynamic, ABS-related feature: VDC (Vehicle Dynamics Control). It adds stability and heps prevent skids by applying whatever single wheel brake, front or rear, the computer program deems appropriate (something even the most highly-skilled rally driver in the world can't do), and modulating engine power, if necessary.

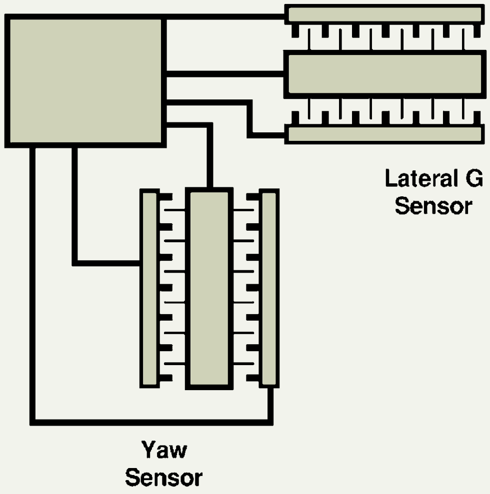
Using input on the steering wheel angle, the relative speed of each tire, lateral G forces, and chassis yaw (that is, rotation on its vertical axis – think of a spin-out), the computer determines whether or not the car is going exactly where it's being steered. Both over- and under-steer can be corrected. For instance, whenever it senses understeer it increases hydraulic pressure to the inside rear wheel. For oversteer, the outside front brake is applied.

For a while, it looked like VDC was going to be exclusive to the European luxury segment, but Subaru has managed to bring it to more modestly-priced cars.

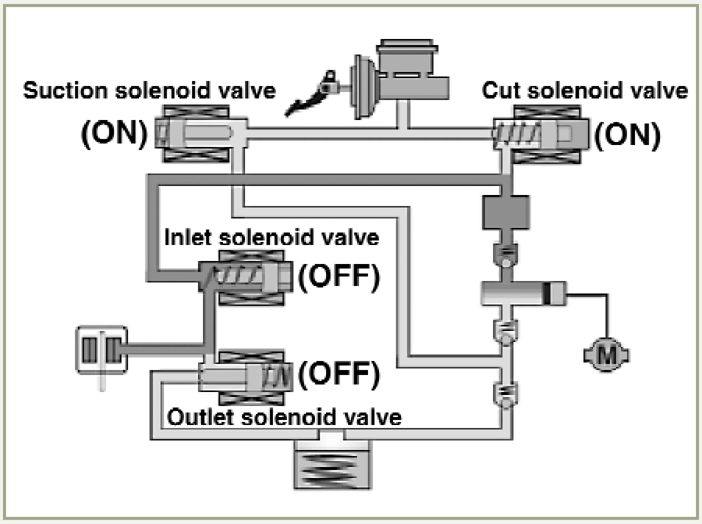
Finally, we should take this opportunity to remind you that while having identical tires of the specified diameter at all four corners is important with any ABS-equipped vehicle, it's even more so with TCS and VDC. So, whenever you get a warning light or a complaint about strange performance characteristics, check the tires before you embark on electronic or hydraulic troubleshooting.



Here are the steps by which TCS reduces engine output.



The yaw rate and lateral G sensors are enclosed in the same unit, which you'll find in the center console.



The VDC system in pressure-increasing mode.

The **Most Common** ABS Problems

No matter how old the system, always open the bleeder before forcing the piston back.

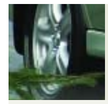
Anti-lock braking systems represent the biggest revolution in vehicular deceleration since the adoption of disc brakes. The systems out there have been remarkably trouble-free, but that doesn't mean no ABS problems will ever come rolling up to your door. As one successful shop owner puts it, "You've got to realize that ABS cars aren't new anymore."

What kinds of problems are the most common so far? "On ABS, speed sensors are at the top of the list of failures," a brake training specialist tells us. Another tech trainer agrees, saying, "As far as the ABS problems we're seeing are concerned, the first is speed sensors with metallic particles sticking to the sensor nose. This may cause system default, or make it constantly go into anti-lock mode. We call that 'false modulation.'"

An award-winning shop owner expands on that, saying, "On wheel speed sensors, it's usually an internal break in a wire. Be careful doing any wheel work because those sensors are delicate."]Yet another authority tells us, "The number-one problem we're seeing is a broken wheel speed sensor wire. The second thing is rust where the sensor mounts. This also causes difficulty when other work is done. As time goes on, we're going to see more and more corrosion in the electrical parts."

A brake troubleshooting expert says, "Make sure the air gaps are correct, and the sensors and tone wheels are clean with no iron filings or debris in the vanes, which can give an erratic speed signal, set a code, and put the system in default."

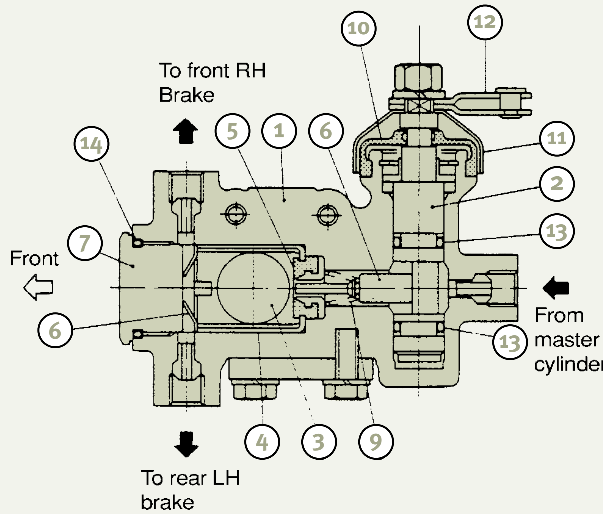
A senior trainer mentions a related point that can really ruin your day: "We're getting calls frequently after a technician has done a basic brake job," he says. "Now, the brake warning light is on. The trouble is they're not opening the bleeder when they push the piston back, so all the sediment in the caliper is getting forced up into the ABS unit." The troubleshooter corroborates the importance of this, saying, "Never, ever push in a caliper piston without opening the bleeder."



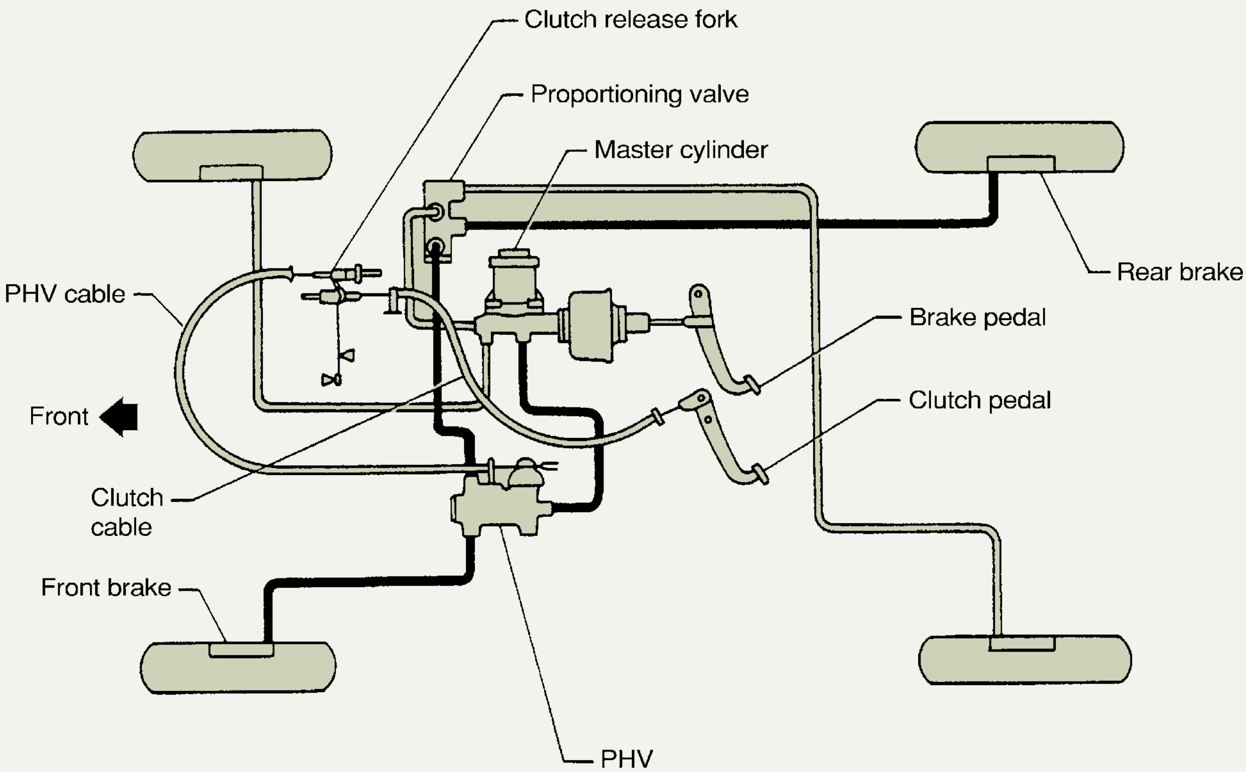
ABS Fundamentals

The **Good Old** Hill-Holder

Maybe you remember teaching some youthful driver to operate a car with a manual transmission. Things might have been going swimmingly with patient explanations from you on how to coordinate the clutch and the throttle. Then, perhaps, your student had to stop on a hill. While applying the parking brake, then releasing it as you engage the clutch might seem perfectly natural to you, it can be an intimidating, confusing situation for a beginner. Come to think about it, it's pretty inconvenient for even the most experienced driver.



1. **Body**
2. **Camshaft**
3. **Ball**
4. **Ball guide**
5. **Seal**
6. **Plate spring**
7. **Cap**
8. **Push rod**
9. **Spring**
10. **Boot**
11. **Collar**
12. **Lever**
13. **O-ring**
14. **O-ring**



Subaru thought so, too. To avoid this awkward scenario, the company introduced its unique Hill-Holder system, which can be found on early manual-transaxle Legacy models through 1994. Given the generally long life of Subaru vehicles, many of these are still out there on the road, yet most technicians don't understand how they work.

Whenever the brake is applied and the clutch pedal is depressed with the car on a grade of three degrees or more, Hill-Holder traps hydraulic pressure in one circuit, thus preventing roll-back. You can then remove your foot from the brake pedal and use it to operate the accelerator. As you let the clutch pedal up, this pressure is released for smooth launch.

The main component is the PHV (Pressure Hold Valve), which is spliced into a hydraulic line from the master cylinder, and is operated by a cable attached to the clutch release fork. Inside is a heavy steel ball that acts as a check valve when gravity causes it to roll toward the rear against a rubber seal. That is, only when the clutch pedal is depressed. With the clutch in the released position, the cable rotates the PHV's camshaft, which moves a pushrod forward that forces the ball off its seat.

Whether you're doing brake work or other service on a Subaru with this feature, it makes sense to check its operation with a test drive. If regular brake fluid changes haven't been part of the customer's maintenance program, there's a possibility that gunk and corrosion may keep the ball from rolling freely, or otherwise compromise operation.

Note: *The PHV is not serviceable; it must be replaced as a unit.*

Before you jump to any unfortunate conclusions and replace a perfectly good PHV, however, make sure clutch pedal free-play is properly adjusted. If the car won't hold on a hill of three degrees or greater, tighten the PHV control cable nut until it does. In cases where brake release is late, loosen the nut.

If your patron wants the system to operate on even smaller inclines, a dealer supplied shim can be installed under the front of the PHV to raise is slightly. Only one shim is allowed.