

HPBooks

BRAKE SYSTEMS

OEM & RACING BRAKE TECHNOLOGY

MIKE MAVRIGIAN & LARRY CARLEY

B R A K E S Y S T E M S

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ANTILOCK BRAKE SYSTEMS

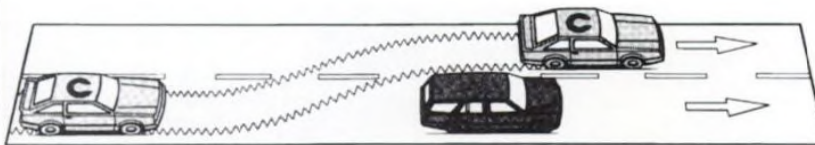
BRAKING IN EMERGENCY OR SLIPPERY CONDITIONS



Car without anti-lock braking system (all wheels lock, skidding, unsteerable)

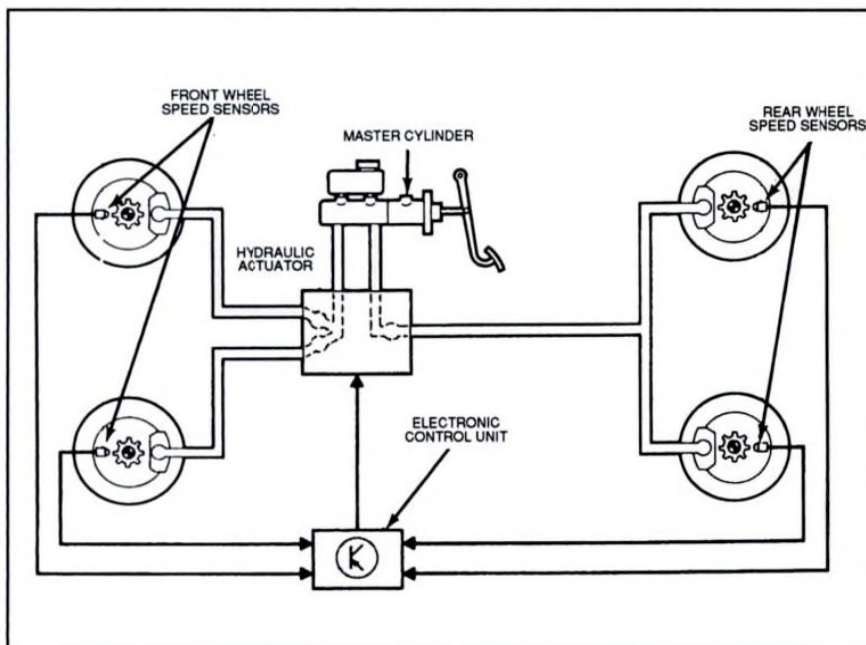


Light truck with rear wheel anti-lock braking system (some stability, front wheels lock, still unsteerable)



Car with 4-wheel anti-lock braking system (wheels don't lock, vehicle stable and steerable)

Antilock brakes do not decrease a vehicle's stopping distance, but they do prevent loss of control and allow you steer your way around obstacles. Four-wheel ABS is better in this respect than rear-wheel only ABS. Courtesy Bosch.



Schematic of a typical ABS system. Wheel speed is monitored by wheel speed sensors. If ABS braking is needed, the hydraulic actuator (also called a modulator) intervenes by isolating the brake circuit(s) to the wheel(s) that are starting to lock up, then rapidly cycling the brake pressure off and on so the wheel(s) can regain traction. Courtesy Brake Parts, Inc.

electronics, the system deactivates itself and the vehicle reverts to normal braking.

HOW ABS WORKS

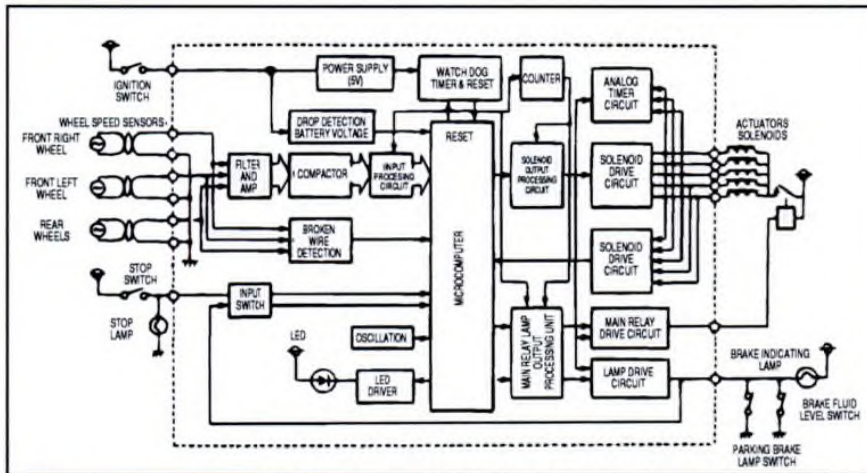
All antilock brake systems control tire slip by monitoring the relative deceleration rates of the wheels during braking. If one wheel starts to slow at a faster rate than the others, or at a faster rate than that which is programmed into the antilock control module, it's an indication that the wheel is starting to slip and is in danger of breaking traction and locking up. The antilock system responds by momentarily reducing hydraulic pressure to the brake on the affected wheel or wheels.

Electrically operated solenoid valves are used to hold, release and reapply hydraulic pressure to the brakes. This produces a pulsating effect, which can be felt in the brake pedal during hard braking. The rapid modulation of brake pressure in a given brake circuit reduces the braking load on the affected wheel and allows it to regain traction, thus preventing lockup. It's the same as pumping the brakes, except that the ABS system does it automatically for each brake circuit, and at speeds that would be humanly impossible—up to dozens of times per second depending on the system (some are faster than others).

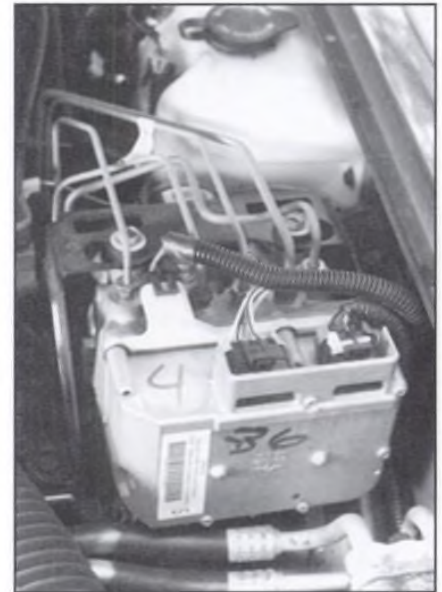
Once the rate of deceleration for the affected wheel comes back in line with the others, normal braking function and pressure resume, and antilock reverts to a passive mode.

SYSTEM CONFIGURATIONS

All ABS systems keep track of



Electrical schematic for a typical ABS system. Inputs from the wheel speed sensors are monitored by the microprocessor, which decides if ABS is needed during a stop. If the microprocessor determines that one or more wheels are starting to lose their grip, it energizes and cycles the appropriate solenoids in the ABS hydraulic modulator unit to prevent lockup. The microprocessor also monitors the health of the various components in the ABS system (including itself) and illuminates the ABS warning light if a fault is detected. Courtesy Brake Parts, Inc.



On nonintegral ABS systems, the hydraulic modulator is separate from the master cylinder. This one happens to be a Kelsey-Hayes 4WAL unit on a Chevy Blazer.

wheel deceleration rates with wheel speed sensors. On some applications, each wheel is equipped with its own speed sensor. This type of arrangement would be called a “four wheel, four channel” system since each wheel speed sensor would give its input into a separate control circuit or “channel.”

On other applications, fewer sensors are used. Many four-wheel ABS systems have a separate wheel speed sensor for each front wheel but use a common speed sensor for both rear wheels. These are called “three channel” systems. The rear wheel speed sensor is mounted in either the differential or the transmission. The sensor reads the combined or average speed of both rear wheels. This type of setup saves the cost of an additional sensor and reduces the complexity of the system by allowing both rear wheels to be controlled simultaneously.

Another variation is the “single channel” rear-wheel only ABS system that is used on many rear-wheel drive

pickups and vans. Ford’s version is called “Rear Antilock Brakes” (RABS) while GM and Chrysler call theirs “Rear Wheel Anti-Lock” (RWAL). The front wheels have no speed sensors and only a single speed sensor mounted in the differential or transmission is used for both rear wheels. Rear-wheel antilock systems are typically used on applications where vehicle loading can affect rear wheel traction, which is why it’s used on pickup trucks and vans. Because the rear-wheel antilock systems have only a single channel, they’re much less complex and costly than their three- and four-channel, four-wheel counterparts.

Integral & NonIntegral

Another difference in ABS systems is that some are “integral” and others are “nonintegral.”

Integral systems combine the master brake cylinder and ABS hydraulic modulator, pump and accumulator into one assembly. Integral systems do not have a vacuum booster for power

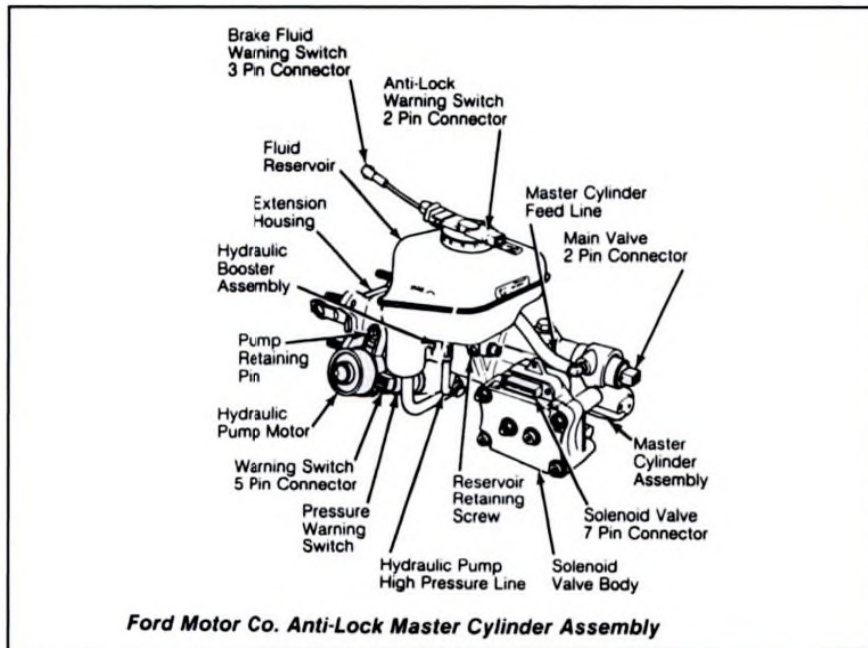
assist and rely instead on pressure generated by the electric pump for this purpose. The accumulators in these systems can contain over 2700 psi. The accumulator must be depressurized prior to doing any type of brake repair work by pumping the brake pedal 40 times while the key is off.

Integral ABS systems include the Bendix 10 & Bendix Jeep ABS systems, Bosch 3, Delco Moraine Powermaster III and Teves Mark 2.

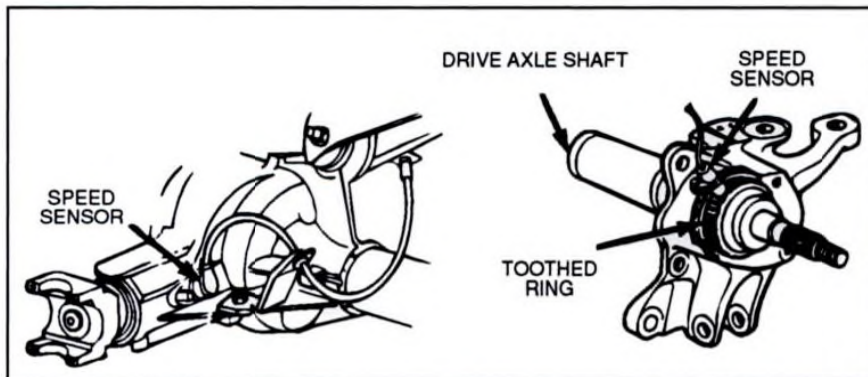
Nonintegral ABS systems, which are sometimes referred to as “add-on” systems, use a conventional master brake cylinder and vacuum power booster with a separate hydraulic modulator unit. Some also have an electric pump for ABS braking (to reapply pressure during the ABS hold-release-reapply cycle), but do not use the pumps for normal power assist. Nonintegral systems do not have to be depressurized or deactivated prior to doing brake work.

Nonintegral (add-on) systems

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Integral ABS systems such as this Teves Mark 2 unit, combines the ABS modulator, pump, accumulator and master cylinder into one assembly. Courtesy Ford.



The rear wheel speed sensor on three-channel ABS systems is often mounted in the differential (left), while front sensors may be mounted in the front wheel bearing hub assembly (right). Courtesy Bosch.

include Bendix 6, Bosch 2, Delco Moraine VI, Kelsey-Hayes RABS/RWAL & 4WAL, and Teves Mark 4 ABS.

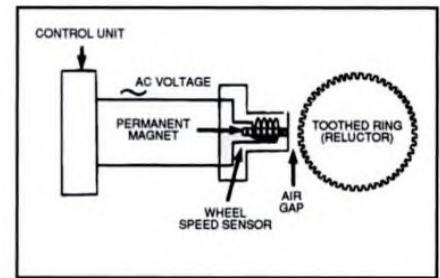
BASIC ABS COMPONENTS

Basic components that are common to all antilock brake systems include: (1) wheel speed sensors, (2) an electronic control module, and (3) a hydraulic "modulator" assembly with

electrically operated solenoid valves. Some systems also use an electric pump to generate hydraulic pressure for power assist as well as ABS braking.

Wheel Speed Sensors

The wheel speed sensors consist of a magnetic pickup and a toothed sensor ring (sometimes called a "tone" ring). The sensor(s) may be mounted in the steering knuckles,



ABS wheel speed sensors use a permanent magnet to generate an alternating current (AC) signal. The sensor's output increases in frequency and amplitude as the speed of the wheel increases. A close air gap is critical for a strong signal. Some sensors have an adjustable air gap but most do not. Courtesy Brake Parts, Inc.

wheel hubs, brake backing plates, transmission tailshaft or differential housing. On some applications, the sensor is an integral part of the wheel bearing and hub assembly. The sensor ring(s) may be mounted on the axle hub behind the brake rotor, on the brake rotor itself, inside the brake drum, on the transmission tailshaft or inside the differential on the pinion shaft.

The sensor pickup has a magnetic core surrounded by coil windings. As the wheel turns, teeth on the sensor ring move through the pickup's magnetic field. This reverses the polarity of the magnetic field and induces an alternating current (AC) voltage in the pickup's windings. The number of voltage pulses per second that are induced in the pickup changes in direct proportion to wheel speed. So as speed increases, the frequency and amplitude of the wheel speed sensor goes up. The signal is sent to the ABS control module, where the AC signal is converted into a digital signal and then processed. The control module then counts pulses to monitor changes in wheel speed. On some applications (namely GM trucks with RWAL), the wheel speed sensor signal is first sent to a separate

ABS DO'S AND DON'TS

Antilock brake systems (ABS) are used on millions of vehicles, but many drivers still don't know the "right way" to use ABS in an emergency. So here are the "do's and don'ts" of ABS braking:

DO'S

DO keep your foot on the brake. Maintain firm and continuous pressure on the brake pedal to let four-wheel ABS work properly. Avoid pumping the brake, even if the brake pedal is pulsating. If you own a light truck with rear-wheel antilock (RWAL) brakes, apply the brake pedal with just enough force to stop your truck without locking the front wheels. This way you can maintain steering control while the rear-wheel antilock system prevents the vehicle from skidding sideways.

DO allow enough distance to stop. Follow three seconds or more behind vehicles when driving in good conditions. Allow more time if conditions are hazardous.

DO practice driving with ABS. Become accustomed to pulsations that occur in the brake pedal when ABS is activated. Empty parking lots or other open areas are excellent places to practice emergency stops.

DO consult your vehicle owner's manual for additional driving instructions regarding your ABS system.

DON'TS

DON'T drive an ABS-equipped vehicle more aggressively than a vehicle without ABS. Driving around curves faster, changing lanes abruptly or performing other aggressive steering maneuvers is risky in any vehicle.

DON'T pump the brakes. With four-wheel ABS systems, pumping the brakes turns the ABS system on and off, which decreases braking efficiency and increases your stopping distance. ABS pumps the brakes for you automatically at a much faster rate than you could do it manually, and allows better steering control. What's more, it also pumps the brakes on individual wheels as needed — which is something you can't do.

DON'T forget to steer. Four-wheel ABS can help you steer around hazardous situations, but your vehicle won't steer itself.

DON'T be alarmed by clicking noises and/or pedal pulsations when braking hard. These conditions are normal when ABS is active and lets you know the ABS system is working. There should be no ABS feedback, though, when braking normally on dry pavement. ABS should only come into play during panic stop situations or when the road is wet, icy, slick or covered with loose gravel.

ABS control module come from two sources: the wheel speed sensors and a brake pedal switch. The switch signals the control module when the brakes are being applied, which causes it to go from a "standby" mode to an active mode. At the same time, the wheel speed sensors keep it informed about what's happening while the brakes are being applied.

If the control module detects a difference in the deceleration rate between one or more wheels while braking, or if the overall rate of deceleration is too fast and exceeds the limits programmed into the control module, it triggers the ABS control module to momentarily take over. The control module cycles the solenoid valves in the modulator assembly to pulsate hydraulic pressure in the affected brake circuit (or circuits) until its sensor(s) tell it deceleration rates have returned to normal and everything's under control. At that point, normal braking action resumes under the watchful eye of the ABS system. When the brake pedal is released or when the vehicle comes to a stop, the control module returns to a standby mode until it is again needed.

Like any other electronic control module, the ABS module is vulnerable to damage caused by electrical overloads, impacts and extreme temperatures.

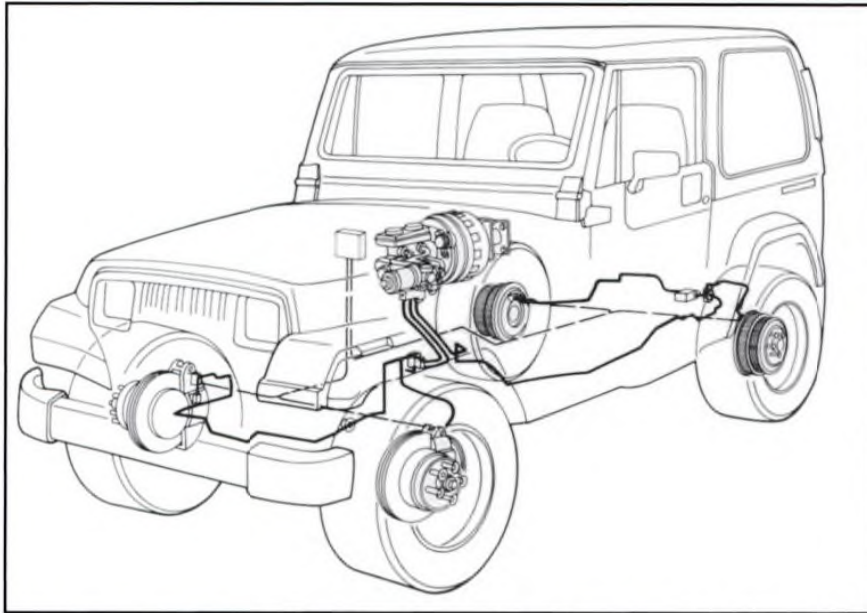
ABS electrical connectors should never be connected or disconnected while the key is on. Doing so can create momentary high voltage spikes in the electrical system that can damage electronic components such as the ABS control module. The ABS control module should be unplugged before any type of arc, MIG or TIG welding is done on your vehicle.

lockup. The ABS module may be located in the trunk, passenger compartment or under the hood. It may be a separate module or

integrated with other electronics such as the body control or suspension computer.

Inputs—The key inputs for the

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ABS is a real plus on off-road vehicles with four-wheel drive, such as this Jeep Wrangler, because it allows the driver to maintain steering control while braking on slick or muddy surfaces.

1. The first step is to hold or isolate the pressure in a given brake circuit by closing an "isolation" solenoid in the modulator assembly. This blocks off the line and prevents any further pressure from the master cylinder from reaching the brake.

2. If the wheel speed sensor continues to indicate the wheel is slowing too quickly and is starting to lock up, the same solenoid or a second "release" solenoid is energized to open a vent port that releases pressure from the brake circuit. The fluid is usually routed into a spring loaded or pressurized storage reservoir (called an "accumulator") so it can be reused as needed. Releasing pressure in the brake circuit allows the brake to loosen its grip so the wheel can speed up and regain traction.

3. The release and/or isolation solenoid(s) are then closed and/or an additional solenoid energized so pressure can be reapplied to the brake from the master cylinder or accumulator to reapply the brake. The

hold-release-reapply cycle repeats as many times as needed until the vehicle either comes to a halt or the driver takes his foot off the brake pedal. The speed at which this occurs depends on the particular ABS system that's on the vehicle, but can range from a few times per second up to 10 times per second.

The hydraulic modulator is not a serviceable component, so you can't take it apart and replace internal components if it's defective. Replacement as an assembly is the only repair option.

Pump Motor & Accumulator

A high pressure electric pump is used in some ABS systems to generate power assist for normal braking as well as the reapplication of brake pressure during ABS braking. In some systems, it is used only for the reapplication of pressure during ABS braking.

The pump motor is energized via a relay that's switched on and off by the

ABS control module. The fluid pressure that's generated by the pump is stored in the "accumulator." The accumulator on ABS systems where the hydraulic modulator is part of the master cylinder assembly consists of a pressure storage chamber filled with nitrogen gas. A thick rubber diaphragm forms a barrier between the nitrogen gas and brake fluid. As fluid is pumped into the accumulator, it compresses the gas and stores pressure. When the brake pedal is depressed, pressure from the accumulator flows to the master cylinder to provide power assist. A pair of pressure switches mounted in the accumulator circuit signals the ABS control module to energize the pump when pressure falls below a preset minimum, then to shut the pump off once pressure is built back up.

Should the pump fail (a warning light comes on when reserve pressure drops too low), there is usually enough reserve pressure in the accumulator for 10 to 20 power-assisted stops. After that, there is no power assist. The brakes still work, but with increased effort.

On ABS systems that have a conventional master cylinder and vacuum booster for power assist, a small accumulator or pair of accumulators may be used as temporary holding reservoirs for brake fluid during the hold-release-reapply cycle. This type of accumulator typically uses a spring loaded diaphragm rather than a nitrogen charged chamber to store pressure.

TRACTION CONTROL

The same basic setup that allows an

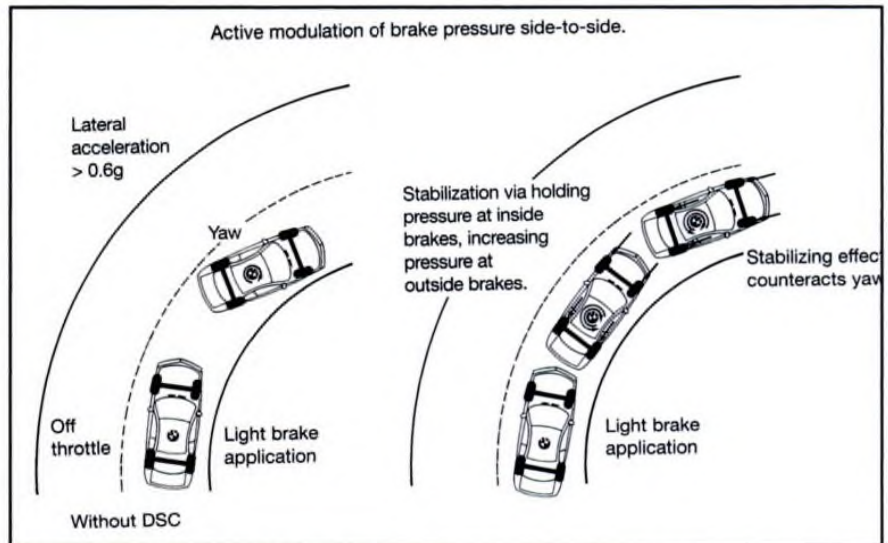
ABS system to control wheel lockup during deceleration can be adapted to control wheel spin during acceleration. This is called "Traction Control," "Traction Assist" or "Acceleration Slip Reduction" (ASR).

When traction control is combined with ABS, it greatly enhances all-weather traction capabilities. Performance cars and those with low profile performance tires (which provide great dry traction but generally do poorly on wet or slick surfaces) are the ones that often benefit most from the addition of traction control.

But traction control isn't an electronic substitute for a limited slip differential or all-wheel drive. It is designed primarily to improve traction and vehicle stability on wet or slick surfaces, not for traction in deep snow or mud, or for racing.

Traction control uses the same wheel speed sensors as ABS, but requires reprogramming the ABS control module and adding additional solenoids to the hydraulic modulator. An ABS system with traction control also must have a pump and accumulator to generate and store pressure.

The traction control/ABS system monitors wheel speed during acceleration as well as deceleration (braking). If a wheel speed sensor detects wheel spin in one of the drive wheels during acceleration, the control module energizes a solenoid that allows stored fluid pressure from the accumulator to apply the brakes on the wheel that's spinning. This slows the wheel that's spinning and redirects engine torque through the differential to the opposite drive wheel to restore traction. It works just as well on front-wheel drive as it does



Stability control is putting ABS to work in a new way, taking it from the passive braking only mode to a full-time active mode. Stability control applies individual wheel braking as needed to maintain steering control when cornering or making sudden maneuvers.

on rear-wheel drive.

On some vehicle applications, additional control strategies may also be used to limit wheel spin. Some traction control systems add a "throttle relaxer" that pushes back against the gas pedal if the driver's foot is a little too heavy. By reducing the throttle opening, engine power is reduced to regain traction. Some applications also link the ABS/traction control computer to the engine computer electronically to retard ignition timing and/or deactivate fuel injectors to reduce power. Another strategy is to upshift the automatic transmission to a higher gear to reduce engine torque.

Many vehicles with traction control have a dash mounted switch that allows the driver to deactivate the system when desired (as when driving in deep snow). An indicator light shows you when the system is on or off, and may also tell you when the traction control system is actively engaged during acceleration. A separate warning light may be used to alert you if anything goes wrong with

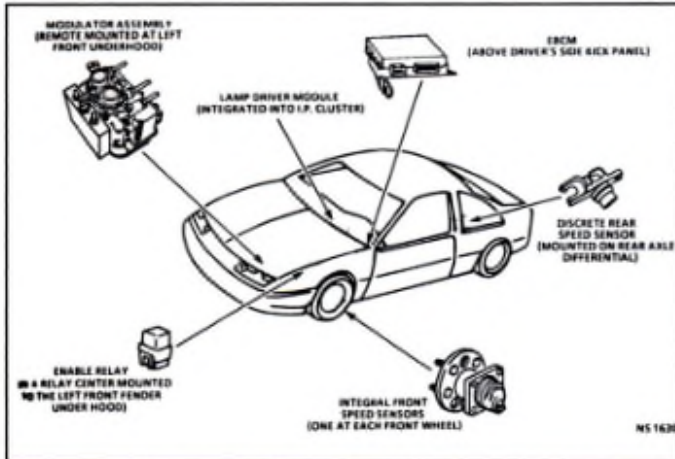
the system.

Most traction control systems are only functional at speeds up to about 30 mph. At higher speeds, they are deactivated because of the adverse effects braking could have on handling and steering stability. Some traction control systems are also programmed to turn themselves off after a predetermined period of constant use to prevent excessive heat buildup in the brakes. Such might be the case if both drive wheels were buried in mud or snow and you kept on gunning the engine in a vain attempt to get free.

STABILITY CONTROL

The latest advancement in ABS technology takes antiskid and traction control to a new level. Called "stability control," it allows the ABS system to automatically brake individual wheels as needed under all driving conditions to improve or restore handling and steering control.

Stability control essentially makes ABS a full-time "expert" back seat



ABS-IV component locations on the F-body. On cars with rear drum brakes, a single rear wheel speed sensor mounted on the differential as shown is used. But on cars with four-wheel disc brakes, each rear wheel has its own speed sensor. Courtesy Delphi Chassis Systems.

Traction Control & ASR

When traction control became available as an option mid-year in 1994 on the Z-28 and Trans Am with

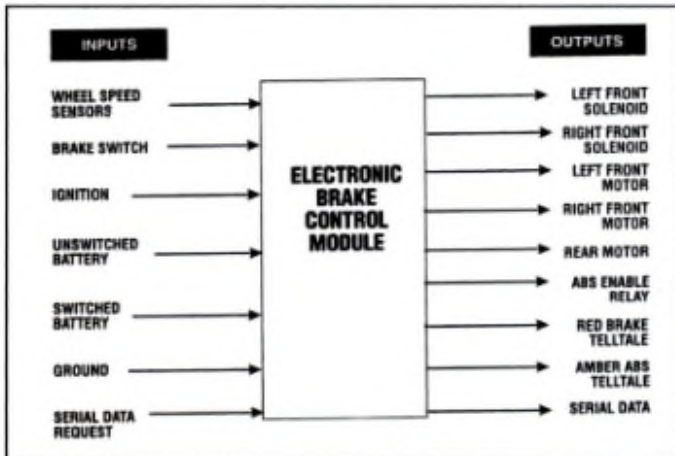
four wheel disc brakes, Chevrolet called their version "ASR" (Acceleration Slip Reduction) while Pontiac went with "TCS" (Traction Control System). Both ABS-VI

systems use the same hardware, which includes a throttle relaxer similar to the one used on Corvettes with Bosch ABS/ASR.

Wheel spin is controlled three ways: by the throttle relaxer which pushes back against the driver's foot, by braking both drive wheels, and by reducing engine torque (spark retard). A light on the instrument panel signals when the ASR or TCS system is doing its job.

The traction control applications also have four rather than three wheel speed sensors. Each rear wheel has its own separate speed sensor instead of a common sensor in the differential. The EBCM needs to monitor the speed of each rear wheel separately in order to provide traction control, but the ABS-VI system still functions in the same three-channel mode when called upon for ABS braking.

SERVICE & BLEEDING THE BRAKES



The Electronic Brake Control Module (EBCM) is the brains of the system, receiving inputs from the wheel speed sensors and other items shown. When ABS (or ASR/traction assist if available) is needed, the EBCM generates the appropriate outputs. Courtesy Delphi Chassis Systems.

The ABS-VI system is designed for easy service. The motor pack as well as the solenoids on the hydraulic modulator assembly are all replaceable.

The ABS-VI system can be manual or pressure bled. Use DOT 3 brake fluid only. But prior to bleeding, the rear displacement cylinder piston in the ABS modulator must be returned to its home position using a Tech 1 or similar scan tool. This is done by entering the manual control mode. Make sure the enable relay is on, then apply the rear motor to run the piston to the upper home position. The recommended bleeding sequence is right rear, left rear, right front, left front.

If you don't have a scan tool, use