Advanced Steering and Suspension Systems Damage Analysis

Textbook

I-CAR®

Version: 16.1

DAM15-STMAN1-E

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Contents

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Introduction

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Obligations To The Customer And Liability

The collision repair industry has an obligation to correctly repair the customer's vehicle. Collision repairs must be performed using:

- recommended or tested procedures from vehicle makers, I-CAR, and other research and testing organizations.
- quality replacement parts and materials.
- repair processes and parts as written and agreed upon in the repair order. If items on the repair agreement are not consistent with the repair order, it can be considered fraud.

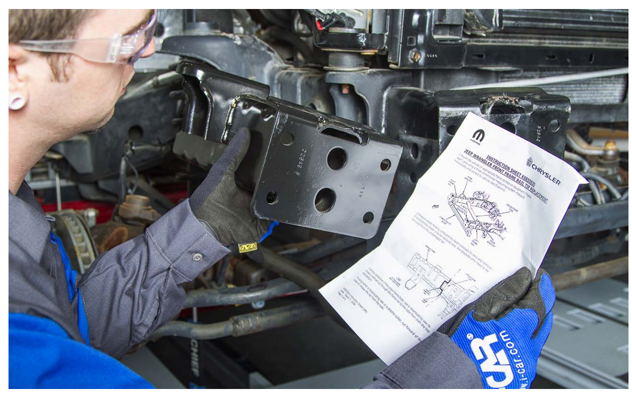
Performing proper collision repairs requires using parts and procedures that keep remaining warranties intact.

Collision repairs must restore:

- safety.
- structural integrity.
- durability.
- performance.
- fit.
- finish.

Throughout the damage analysis and repair process the repairer and insurer must:

- communicate with each other.
- maintain constant communication with the customer.
- be in agreement with each other and the customer on how repairs will be performed.
- inform the customer of any changes in the repair plan from the original repair agreement, and explain the changes and why they have to be made.



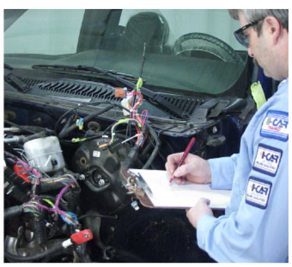
To reduce liability:

- make sure that all repairs are performed thoroughly, correctly and as listed in the damage report.
- follow proper procedures.
- have documentation of required repairs with detailed record keeping available for customers.

Technicians are considered the experts and are expected to be knowledgeable on how to perform a quality repair.

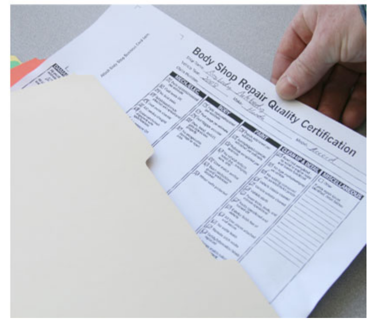
Liability insurance that covers the repair facility may not always cover all damages. For example:

- the policy may not cover faulty repairs, leaving liability responsibility completely on the facility.
- a shop owner may find that repair facility liability coverage may not cover the full amount awarded in a lawsuit. The shop owner would have to pay the difference.



It is difficult to reduce the risk of liability exposure. The part that the repairer can control is the chance of being found at fault. Chances can be minimized by:

- using recommended or tested procedures from the vehicle makers, I CAR, or other research and testing organizations.
- using quality replacement parts and materials that restore fit, finish, durability, and perform at least as well as the original.
- keeping thorough records.



Keeping thorough records includes more than recording the date, mileage, and pre-existing damage. Record keeping also includes:

- making sure all notes are legible.
- verifying the repairs that were made or not made.
- having the customer sign a waiver for repairs that they do not want performed. Repairers must determine their liability on not repairing safety systems such as restraint and anti-lock brake systems.
- keeping computer printouts or worksheets on file showing wheel alignment readings or vehicle dimensions before and after repairs.
- keeping scan tool printouts and records of computer codes for airbag, anti-lock brake, emission, and powertrain control module (PCM) systems.

- attaching the OEM or other tested procedure printout to the vehicle repair order.
- keeping receipts for all sublet work performed.

Refer to "Video: Topics Off Limits" in the presentation. This video identifies topics that should not be brought up in class.

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Module 1 - Electronically Controlled Systems

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Electronically Controlled Systems

Refer to "Video: Learning Objectives" in the presentation.

The learning objectives for this module include:

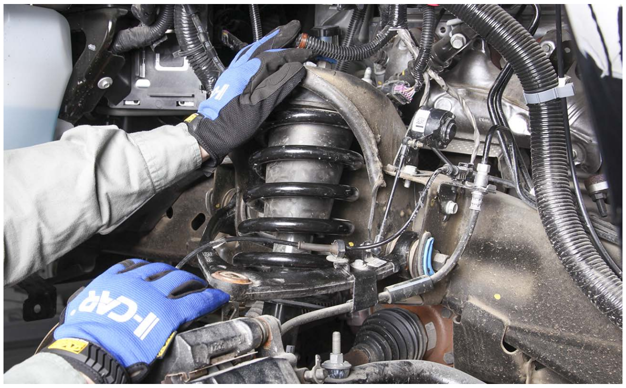
- explaining electronic circuit operation.
- identifying electronic system parts.
- diagnosing problems with electronic circuits.
- explaining basic problem solving steps for electronically controlled systems.

Mercedes-Benz E-Class

This Mercedes-Benz E-Class Coupe is equipped with both electronically controlled steering and suspension.

Electronically controlled steering and suspension systems are:

- computer controlled mechanical systems. They are adjustable systems that have the adjustments controlled on a continual basis by the electronic control module (ECM) of the system. The mechanical parts of the system are similar to those found in conventional steering and suspension systems in regards to their attachment, with the exception of electrical, air, and fluid line connections.
- designed to allow different characteristics for steering and suspension feel with varying driving conditions such as vehicle speed and road surface characteristics.



Physical damage can affect many parts of advanced steering and suspension systems.

Electronic or computer controlled steering and suspension systems on vehicles that have been in a collision are subject to:

- the same types of mechanical damage as conventional steering and suspension systems. Mechanical parts, such as shock absorbers, struts, steering racks, and other steering and suspension parts, can be bent or damaged. When analyzing damage on collision damaged vehicles, use the advantage of knowing where the damage to the vehicle is located. A complete damage inspection may require some disassembly to help locate any hidden damage to electronically controlled steering and suspension parts.
- physical damage to electrical and electronic parts of the system. Many electronic problems on collision damaged vehicles can be traced to physically damaged parts of the electrical circuit.

More information on the types of mechanical damage that may occur to parts of electronically controlled steering and suspension systems can be found in Suspension Systems (STE02) and Rack and Pinion and Parallelogram Steering Systems (STE03).

Inspecting for collision damage includes checking connectors for cracks or breakage.

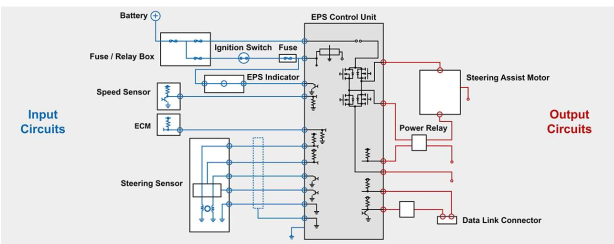
Electrical and electronic problems associated with collision damage include damaged:

- wiring and connectors. This includes cut wires and damaged wiring insulation, which may cause electrical shorts. Connectors may be cracked or smashed, creating high resistance or opens. Wires that have been stretched or pinched between other parts may have wire strands broken inside the insulation with no apparent break in the outer insulation.
- or burned fuses. Burned fuses may be a symptom of another problem, such as damaged wiring or shorted electrical parts.
- relays and solenoids.
- input sensors and loads.
- or shorted control modules.

Electronic parts can be nonfunctional with no signs of physical damage.

KPI Improvement Tip
Careful inspection includes ensuring the water tight seal is intact and remains with connectors that are going back in service. This helps prevent future system failure from water infiltration.

Computer Controlled System Basics



This wiring diagram shows the two circuits, input and output, that make up a typical electronically controlled system.

Computer controlled systems:

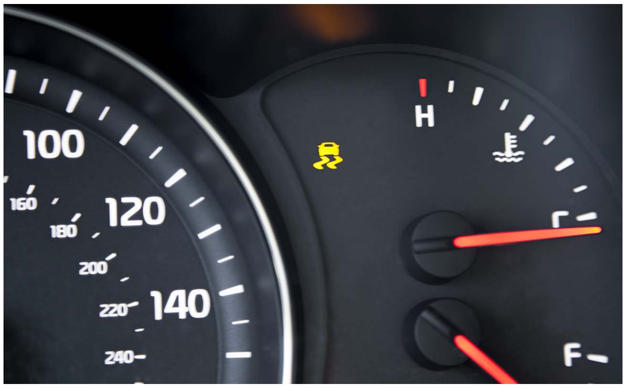
- are made up of two or more interconnected circuits.
- contain an input circuit that has the wiring and input sensors that send signals to the control module. The input signals are typically voltage, resistance, or amperage values. Input signals may also be frequency values, such as a toothed tone ring used for wheel speed sensors in an ABS system. Input signals may also come from control modules for other vehicle systems.
- have an output circuit containing the control module, wiring, and load that is controlled by the control module. Solenoid valves inside shock absorbers or steering control valves are examples of loads in electronic steering and suspension systems.

The input and output circuits of the systems typically contain and share the control module.

The control module for an electronically controlled steering system on a Honda Civic is located below the instrument panel on the driver side.

Typical parts of an electronic circuit include the power source, load, switch, fuse, and wiring, as well as the:

- control modules. Control modules receive inputs from various sources that are processed and used to calculate the required outputs that are supplied to the load. A control module may serve as the switch for the circuit containing the load.
- input sensors. Input sensors supply signals to the control module that are used to calculate the required output. Other control modules may supply input signals into the circuit.



This is a MIL on a vehicle with an electronically controlled steering system problem.

Malfunction indicator lamps (MILs) are:

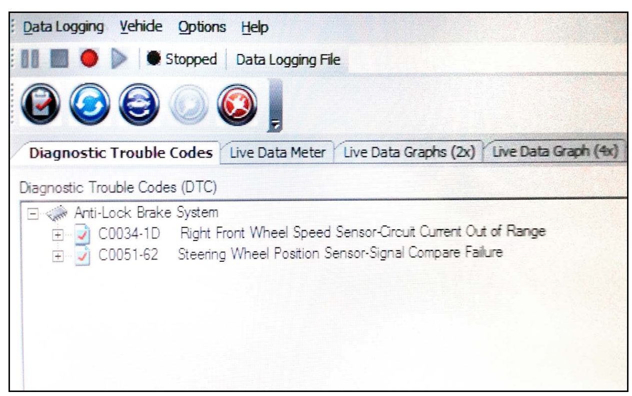
- used to warn of problems and stored diagnostic trouble codes (DTCs) in a circuit.
- designed to be on when the circuit is energized and are turned off by the control module after self-diagnostic checks of the circuit are completed and no problem is detected. This is done to allow the lamp to be on when the key is first turned ON, ensuring that the lamp is functional.
- used to indicate system problems. A MIL that remains lit typically indicates a problem within the electronic or electrical parts of the system.

A MIL that remains lit does not always indicate that parts have to be replaced, just that a problem exists within the system.

Some vehicles use an information message center instead of a MIL to warn of system problems.

The information message center:

- warns of vehicle system problems.
- displays a text message on the instrument cluster. These messages are used to warn of system problems instead of having separate MILs for each system.
- is typically used in vehicles with multiple advanced auxiliary systems, such as the tire pressure monitoring system (TPMS).



Scan tool software is being used to diagnose a problem in an electronic circuit.

Computer controlled circuits are typically capable of self-diagnosis. They can also retain DTCs that are used to locate problems in the circuit. When diagnosing problems with computer controlled circuits:

- DTCs may be read by a scan tool or by using a laptop with the appropriate application. Some systems require a vehicle-specific scan tool be used to retrieve stored DTCs for computer controlled steering and suspension systems.
- verify that the system is mechanically correct, with no physical parts damage, before diagnosing electrical problems. The mechanical side of the system must function correctly for the electronic control system to work properly, to allow for complete and accurate damage analysis.
- look for a MIL or a trouble message on the information message center on the instrument cluster. A MIL or trouble message on the information message center indicates a stored DTC that may be retrieved to help locate the problem. For example, problems may turn on indicator lamps such as ABS, traction control, stability control, and low tire pressure.
- use the diagnostic flowcharts that correspond with the DTC. The flowcharts will call for specific electrical and / or mechanical test procedures to help locate the faulty part or wiring. Testing parts of the system will typically involve measuring for either voltage, resistance, or amperage, or checking fluid pressure, and comparing the values to listed specifications. Electrical testing will typically require a DVOM. When using diagnostic flowcharts read the entire flowchart before beginning diagnosis. This will help to understand what the causes of the problem may be. Using this information together with a knowledge of where the vehicle is physically damaged may shorten diagnostic time.

Some systems on older model vehicles may show DTCs by flashing a code with the MIL. The flash code may be automatically displayed if a DTC is stored or it may require a specific procedure, such as shorting between pins on a diagnostic connector, to activate it. Follow the vehicle maker's procedure for the activation of flash code diagnostics. Vehicle makers have gone away from this type of diagnostics.

Take appropriate precautions when disconnecting control module connectors.

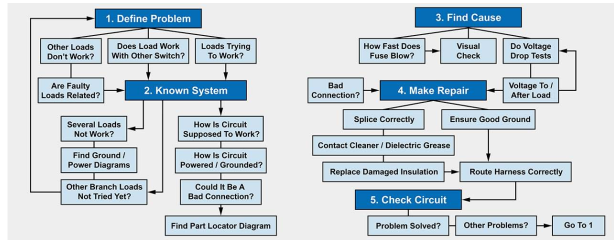
During damage analysis and repairs, precautions need to be taken to protect control modules from:

- excessive current and voltage. Have the ignition switch in the LOCK position and the key out unless otherwise specified for a specific procedure. Keep the vehicle battery connected for proper diagnosis unless otherwise specified for a procedure, personal safety, or vehicle protection.
- excessive heat. Ensure that control modules will be protected if repairs require heat to be applied or welding to be done in close proximity. Normal spraybooth curing temperatures are not high enough to damage control modules.
- vibration and shock. To protect control modules from damage due to vibration and shock, they should be removed from areas where air chisels or hammers will be used in close proximity.
- moisture.

When disconnecting control modules and electrical connectors:

- control static electricity discharge by wearing an electrostatic discharge strap while disconnecting and handling the modules.
- protect the connectors from contamination by covering the ends with tape or plastic bags.
- ensure that the connector pins are not bent or damaged.

Problem Solving System Failures

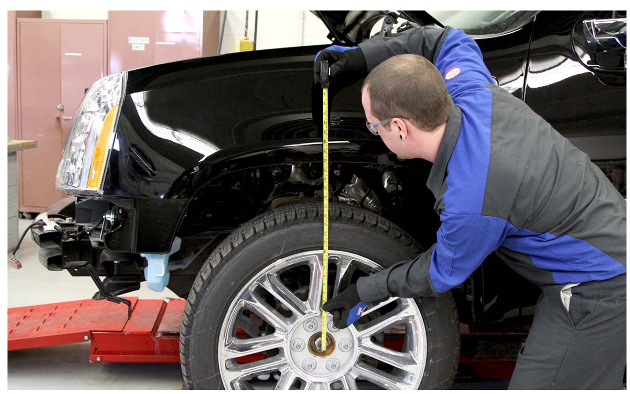


This chart shows the recommended steps for solving a problem in an electronically controlled system.

Recommended steps in solving problems in computer controlled systems:

1. Define the problem.
2. Understand how the system works.
3. Find the cause of the problem.
4. Make the repair to the system.
5. Test the system to verify the problem has been repaired.

Cadillac Escalade

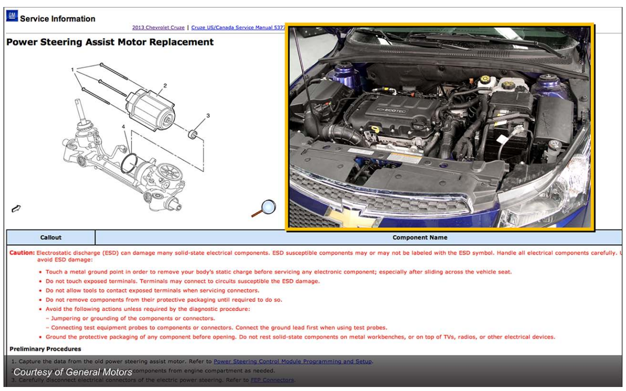


The technician is measuring the vehicle ride height to help define a problem with the electronically controlled suspension system.

Defining the problem with a computer controlled vehicle system includes:

- determining what does not work.

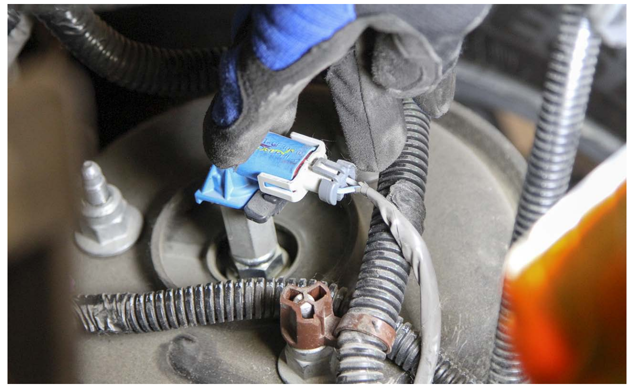
- isolating the problem. Determine if anything else is malfunctioning. Other malfunctioning parts or systems may be related.
- determining if the system is trying to work but cannot because of some mechanical problem. An example of this would be an air spring that the system is trying to inflate but cannot because of a leak in an air line.



The vehicle service information should be referenced to help with understanding how a system operates.

Understanding how the system works is critical when checking if it is functioning properly and includes:

- using the vehicle service information. Service information sources may contain system description and operation sections. They also typically contain system wiring diagrams, part location charts, and symptom and DTC flowcharts.
- checking for any technical service bulletins (TSBs) that may pertain to the system or the specific problem being diagnosed.



When diagnosing electrical and electronic problems on collision damaged vehicles, look in the area of damage first.

When looking for the cause of a problem in a computer controlled system:

- the problem is often collision related. Physical damage to parts of the system or electrical circuits may be the cause of collision-related malfunctions.
- flowcharts, although helpful, do not consider that the vehicle may have been in a collision and may be damaged.
- determine if the system was functional before the collision.
- look in the area of the collision damage and repairs for physical damage to system wiring or parts. Check for poor electrical connections and grounds. Ensure that all electrical connectors have been properly reconnected.

KPI Improvement Tip

Part locator diagrams by system and / or area of the vehicle can be helpful during damage analysis.

The technician is locating a fuse for a circuit that is inoperable.

Additional procedures that can be performed to find the cause of problems include:

- checking the fuse for the circuit involved.
- checking for available voltage at various points in the circuit.
- checking the operation of the load. This may involve testing electric motors or solenoids. Testing parts of the system will typically involve measuring for either voltage, resistance, or amperage, or checking fluid pressure, and comparing the values to listed specifications.
- using symptom-based flowcharts. Many systems may have symptom-based flowcharts to help isolate the cause of mechanical problems that do not set DTCs.
- using a scan tool to retrieve DTCs. The DTC will typically lead to a diagnostic flowchart that can be followed to isolate the cause of the problem.

This estimator is looking up a repair procedure in the vehicle service information.

To make repairs to the system:

- follow vehicle maker recommendations for the procedure being performed.
- replace damaged or defective parts.
- repair or replace damaged wiring and connectors.
- clear any stored DTCs after repairs are complete.

KPI Improvement Tip

It is a good practice to first record the codes before clearing in case follow-up on a code is necessary later. If possible, test drive after clearing codes, then check if any codes remain active. Some codes may be in the control module from a previous problem.

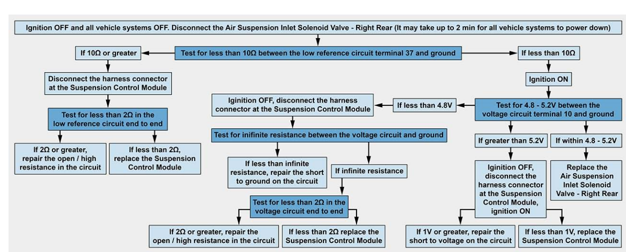
This vehicle is being taken for a test drive to help verify proper system function.

After repairs have been completed, test the system to verify that the system is functioning properly. When testing the system for proper operation:

- look for a MIL that remains lit.
- check for a stored DTC. It may require the vehicle to be driven for a DTC to be set or a MIL to light. Some systems may set a DTC without lighting a MIL. A scan tool can be used to check for the presence of a DTC in these systems. Mechanical problems within the system may not always set a DTC.
- a test drive may be required to ensure that the system is fully functional and operating properly. Test the vehicle under all conditions applicable to the system being checked. For example, if testing a speed-related variable effort power steering system, the vehicle should be driven and steered at a variety of speeds to ensure that the system is functioning properly. Use information from the service manual to determine what conditions need to be met to ensure that the system is functioning as intended.
- document what was done to test the system.

For systems that do not supply obvious indicators of proper functioning and do not have MILs, one possible way of determining that they are working is to disable the system and then drive the vehicle to see if there is a noticeable difference. An example of this again is a speed-related variable effort power steering system. It may be difficult to notice the difference in steering effort at different speeds.

To verify that the system is functioning, the vehicle can be driven, the variable power steering system disabled, and the vehicle driven again. If the system is functional, there should be a noticeable difference in the way the vehicle drives with the system disabled. Use a service manual to determine the best way to disable the system. This may be done by unplugging electrical connectors or removing fuses. Before using this method, check that driving the vehicle with the system disabled will not set a DTC that will require clearing with a scan tool.



Refer to Module 1, "Activity: Using a DTC Flowchart" in the presentation. This activity will show how a DTC flowchart is used to pinpoint a faulty part or wiring on an electronically controlled steering or suspension system.

Module Wrap-Up

Topics discussed in this module included:

- electronic circuit operation.
- electronic system parts.
- diagnosing problems with electronic circuits.
- basic problem solving steps for electronically controlled systems.

Module 2 - Electronically Controlled Steering

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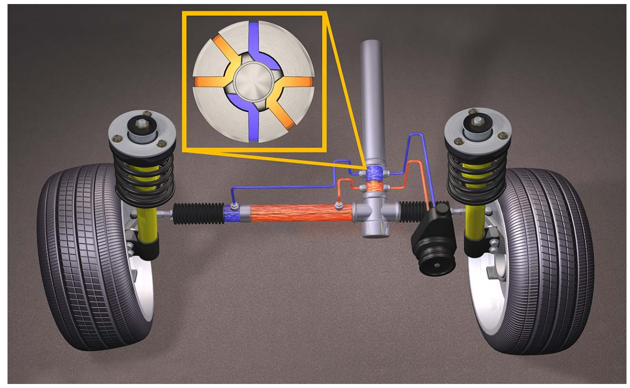
Electronically Controlled Steering

Refer to "Video: Learning Objectives" in the presentation.

The learning objectives for this module include:

- identifying types of electronic steering systems.
- explaining the operation of computer controlled variable assist power steering systems.
- identifying electronic steering system parts.
- diagnosing problems with electronically controlled steering systems.
- identifying cautions when analyzing damage on vehicles with electronically controlled steering systems.
- explaining electric rear steering systems.



This illustration shows the main parts of a conventional power steering system with a cutaway inset of a conceptual spool valve.

Conventional power steering systems have a:

- fluid pump. The fluid pump is belt-driven off the engine.
- rotary or spool valve. The fluid pump supplies pressurized hydraulic fluid to a spool valve that is located in the steering gear. The spool valve has inner and outer parts with fluid ports that direct the fluid to each side of the steering gear. At rest, the spool valve directs equal amounts of fluid to each side of the steering gear. When the steering wheel is turned, fluid pressure is directed to one side of the gear only. Fluid pressure on only one side helps turn the steering gear and reduces the effort needed to turn the steering wheel.
- torsion bar. The spool valve is connected to a torsion bar that is located between the lower steering shaft and the steering gear. The outer part of the spool valve is connected to the bottom of the torsion bar and the inner

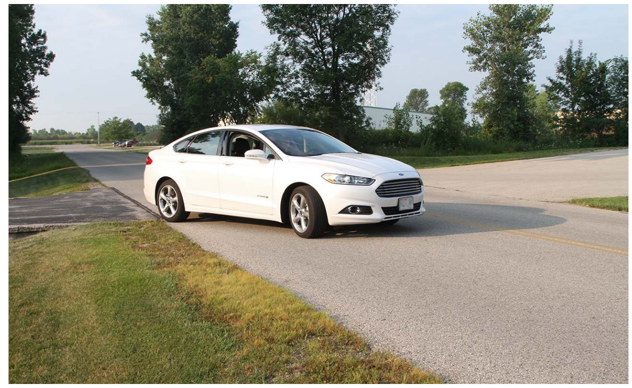
part is connected to the top of the torsion bar.

As the steering shaft is turned, the torsion bar twists and turns the two parts of the spool valve different amounts. As the parts of the spool valve turn, fluid ports in each part are aligned with each other allowing power steering fluid to flow through the valve. The stiffness of the torsion shaft controls how much it will twist and how well the fluid ports will align. The better the ports align, the higher the steering assist level.

The stiffness of the torsion shaft and speed at which the power steering pump is being driven are what determines how much assist a power steering system will deliver.

Refer to Module 2, "Video: Animation Of Power Steeering System" This animation shows the operation of a conventional power steering system.

Ford Fusion

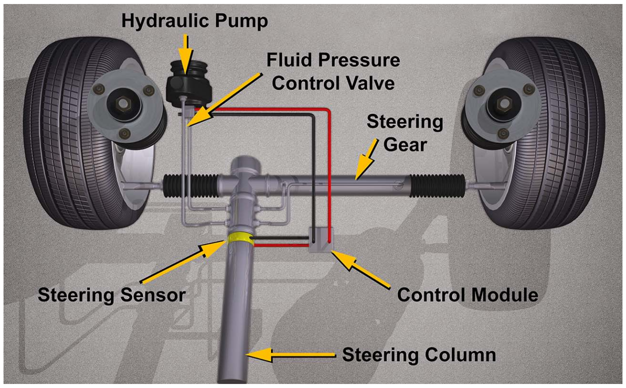


An electronically controlled power assist steering system makes the steering effort easier when turning the vehicle.

Electronically controlled power steering systems provide:

- varied levels of power steering assist as vehicle speed changes. Steering assist is typically reduced as vehicle speed increases. This is done to provide more road feel, to reduce oversteering at high speeds, and for increased directional stability.
- full assist at low speeds for increased steering ease during parking and cornering.
- full assist with quick steering inputs, such as evasive maneuvers on some systems, while other systems will provide reduced assist levels under the same scenario.

Most vehicle makers offer electronically controlled variable assist power steering as an option on at least some vehicles.



This is one example of an electronically controlled hydraulic variable assist power steering system.

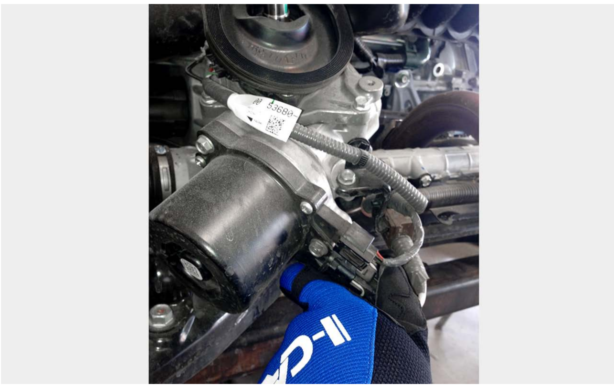
Electromagnetic fields control and vary the hydraulic fluid flow in this type of electronically controlled power steering system.

The level of steering assist in an electronically controlled steering system may be varied in a number of different ways depending on the type of system used. Types of electronically controlled steering include:

- variable assist hydraulic power steering. These systems operate by varying the flow and pressure of hydraulic fluid to the spool valve.
- electro-hydraulic power steering. These systems use an electric motor to drive the hydraulic fluid pump.
- electric assist power steering. These systems use an electric motor, instead of hydraulics, to provide steering assist.
- electric steer or steer-by-wire. These systems use an electric motor, instead of a mechanical shaft, to turn the wheels. Electric steer is typically used for the rear steering of 4-wheel steering systems.

Vehicle makers use varying terminology for electronically controlled power steering systems. Some examples include:

- Variable Effort Steering (VES), commonly used to describe the electronic power steering system on General Motors vehicles.
- Magnasteer, a trademarked name of Delphi Automotive Systems, that General Motors uses to describe the magnetically controlled variable assist power steering system used on some vehicles.
- Electric Power Assist Steering (EPAS) on Ford vehicles.
- Speed Sensitive Steering. Toyota, Lexus, Mercedes-Benz, Volvo, and Nissan are among the vehicle makers that use this terminology.
- Electro-Hydraulic Power Steering, which is a term used by a variety of vehicle makers including BMW, General Motors, and Toyota.
- Servotronic Steering. Audi, Jaguar, and BMW are among the vehicle makers that use this terminology.



This technician is pointing to the electric assist power steering motor on a Honda Civic.

The presence of electronically controlled steering systems is typically not noted by emblems or other highly visible labeling on the vehicle. To identify that a vehicle is equipped with an electronically controlled steering system:

- perform a thorough visual inspection of the steering system, looking for wiring connected to steering parts that control the power steering assist level. Check for the presence of electric motors on the steering rack or column. Look for actuators or solenoids on the fluid pump outlet or the steering gear at the fluid line inlet. Check for the presence of a MIL for electronic steering systems when the key is first turned ON.
- use the information located on the option label or tag. A dealership parts department can provide information on the decoding of the option tag to determine if an electronically controlled steering system is on the vehicle.
- use a VIN-driven parts ordering system. These systems use a VIN to identify some of the specific parts and systems on a particular vehicle.

This is a stand-alone control module for an electronically controlled power steering system.

All electronically controlled steering systems have a computer or electronic control module to determine the proper assist level for the driving conditions. The control module determines the assist level using data from various inputs. Electronic parts for computer controlled power steering systems include the:

- ECM for the power steering assist. This may be a stand-alone unit or part of the ABS / traction control module. Some systems may use the body control or electronic suspension control module to control the steering assist.
- input sensors for the circuit.

Vehicle speed and steering are two common inputs for electronically controlled steering systems.

Various inputs may be used for computer controlled power steering systems. These may include:

- vehicle speed. Vehicle speed is used on all electronically controlled power steering systems. Some systems use vehicle speed as the only input for steering assist.
- steering input, including steering wheel position and speed.
- foot and parking brake switches.
- the transmission gear selector.
- yaw rate or lateral acceleration sensors. Yaw rate is the rotational rate of the vehicle around its center of mass.

Solenoid valves and electric assist motors are two common outputs for the control module in electronically controlled steering systems.

The output from the control module in electronically controlled power steering systems is the electrical signal to the load that controls the power steering assist. Typical loads include:

- a solenoid valve for power steering fluid flow control.
- a stepper motor that opens and closes a variable orifice to control hydraulic fluid flow.
- an electric motor that provides steering assist.
- an electromagnet that controls the alignment of the fluid ports in the steering gear pinion valve.

The electric assist motor and control module should be inspected for collision damage.

Electronically controlled steering system parts that should be inspected for collision damage include the:

- control module. Physical damage to control modules is typically limited due to the location of the module in the vehicle. Damage to wiring and connectors may lead to

short circuits that may electrically damage the control module.
- input sensors.
- wiring and connectors. Physical damage to wiring and connectors is the most common type of collision-related damage to these systems.
- power steering assist motor.

This is an example of a steering wheel position sensor from an electronically controlled steering system.

Common considerations when analyzing damage on electronically controlled steering systems include:

- understanding that electronic problems will typically disable the variable function of the system. Depending on system design, if variable function is disabled, the steering will either have maximum assist or minimum assist at all times.
- a possible steering wheel position sensor, which typically requires centering before installation. Steering wheel position sensors may be similar in design to a clock spring and may be damaged by excessive turning of the steering column when disconnected from the steering gear. Always follow the vehicle maker's recommendations and procedures for the replacement and centering of steering wheel position sensors.
- using the correct power steering fluid. Vehicle makers may require a specific fluid be used in the power steering system. Types of power steering fluid may vary in viscosity. Using a fluid with a different viscosity than the system was designed for may cause improper function.

KPI Improvement Tip

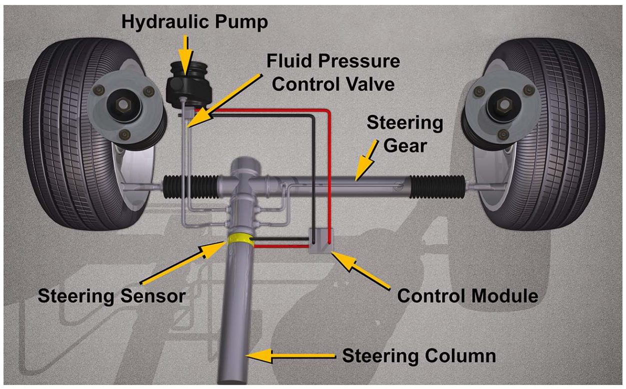
Be aware that initialization or programming procedures may be required on some systems to enable electronic assist.

Hydraulic Variable Assist Steering

This illustration shows the high pressure hydraulic fluid assisting in pushing the rack in the direction of the turn while hydraulic fluid from the opposite side is returned to the fluid reservoir.

Electronically controlled hydraulic variable assist power steering systems work by varying the pressure or flow of the power steering fluid. For hydraulic variable assist operation:

- more fluid flow or pressure provides more steering assist.
- less fluid flow or pressure provides less assist.



This illustration shows the typical parts of a hydraulic variable assist power steering system.

Typical parts of an electronically controlled hydraulic variable assist power steering system include the:

- steering column.
- steering gear, which will either be a reciprocating ball gear or a rack and pinion design.
- hydraulic fluid pump. The hydraulic fluid or power steering pump may be belt-driven off the engine or driven by an electric motor.
- fluid pressure control valve. Systems with engine-driven power steering pumps vary the fluid flow with a control valve that may be on the power steering pump outlet or steering gear inlet.
- control module.
- steering sensor.

This solenoid valve is used to control fluid pressure at the fluid outlet of the power steering pump in an electronically controlled power steering system.

Hydraulic fluid flow and pressure may be controlled by a solenoid valve or a stepper motor that:

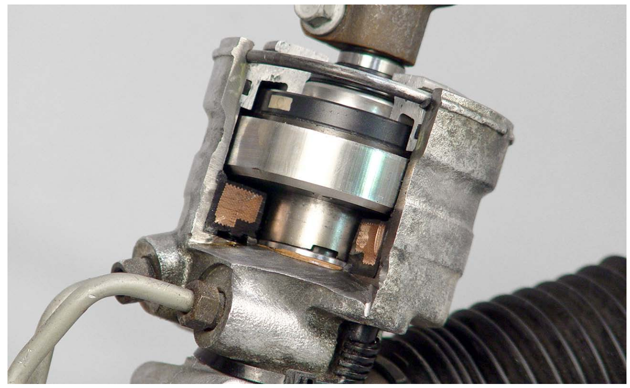
- has two positions, open or closed. This allows for two different levels of assist.
- has a number of settings available. A solenoid valve may move a pintle in and out for continuously variable levels of steering assist. A pintle valve has a conical-shaped end that fits into a seat when closed. The further the conical end is pulled from the seat, the greater the flow through the valve. The solenoid will typically move the pintle in steps or increments. Systems that use a stepper motor may have a variety of fluid openings sizes that are controlled by the stepper motor.

- is located on the steering gear at the fluid inlet valve.
- is located on the power steering pump at the pressure line outlet.

This is a rack and pinion steering gear from a vehicle with the Magnasteer electronically controlled power steering system.

The Magnasteer power steering system used on some General Motors vehicles uses electromagnetic fields to control and vary the hydraulic fluid flow inside the steering rack. The 2014 Buick LaCrosse and Cadillac XTS are two examples of vehicles with the Magnasteer power steering system. Magnasteer systems work by:

- the electromagnets in the control valve either aiding or resisting the twisting of the torsion shaft in the hydraulic spool valve. This is located in the pinion assembly of the steering gear.
- altering the amount of shaft twist, which affects the alignment of the spool valve halves. The amount of shaft twist controls the alignment of the two halves of the spool valve that are located at opposite ends of the torsion shaft. The better the orifices in the spool valve halves align with each other, the greater the fluid flow is and the higher the steering assist will be.



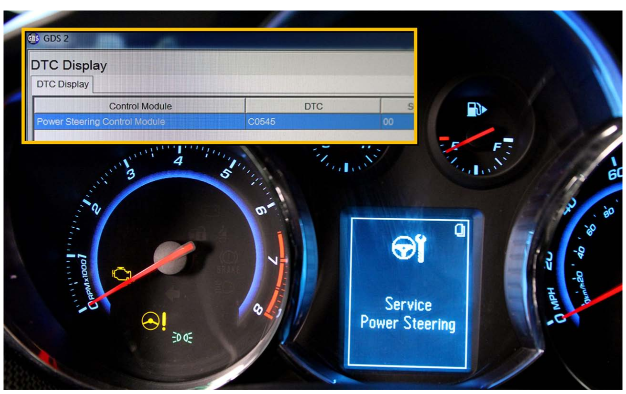
This cutaway of the pinion assembly shows the magnets used to vary the steering assist in a first generation Magnasteer power steering gear.

Magnasteer power steering systems:

- provide infinitely adjustable rates of steering assist by varying the polarity and amperage of the current input to the electromagnetic rotary actuator. The amount and direction of current flow controls the amount of assistance or resistance to torsion shaft twist. Current flow varies from negative two amps to positive three amps. At low speeds, negative current is supplied to the actuator and torsion shaft twist is aided, providing increased steering assist. At medium speeds, no current is supplied and steering assist is dependent on hydraulics only. At higher speeds, positive current is

supplied and torsion shaft twist is resisted resulting in reduced steering assist.
- have a first and second generation design. Second generation designs only resist torsion shaft twist as speed increases and provides no input to steering assist at low speeds. Maximum steering assist is supplied at low speeds and as speed increases, the magnetic actuator resists torsion shaft twist to decrease the amount of fluid flow and steering assist. Current flow for second generation designs is from zero to three amps.

Some Magnasteer systems provide increased steering effort if excessive lateral forces are detected. This is to combat oversteering during evasive maneuvers. Other systems may provide no change with steering speed or lateral force increase.



It may be necessary to use a scan tool or scan tool application to check for DTCs.

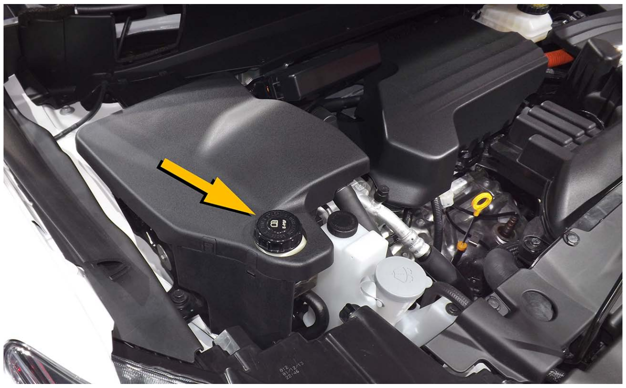
When analyzing damage on malfunctioning electronically controlled hydraulic power steering systems:

- check for a MIL that remains on. This may indicate stored DTCs that can be retrieved to help locate the problem. Some systems may not display a MIL if a system malfunction occurs. This is why a test drive to verify proper operation of the system is important. After repairs have been made, clear all stored DTCs and recheck to verify that no new DTCs exist.
- follow all general cautions.
- service information is required to diagnose electronic circuit problems.
- mechanical problems may not set a DTC or light a MIL.
- a test drive may be required to verify that the system is functioning properly. Understand how the system is supposed to work and test it under all possible operating conditions.

Refer to "Activity: Fill In The Blanks" in the presentation.

Electro-Hydraulic Power Steering

Nissan Pathfinder

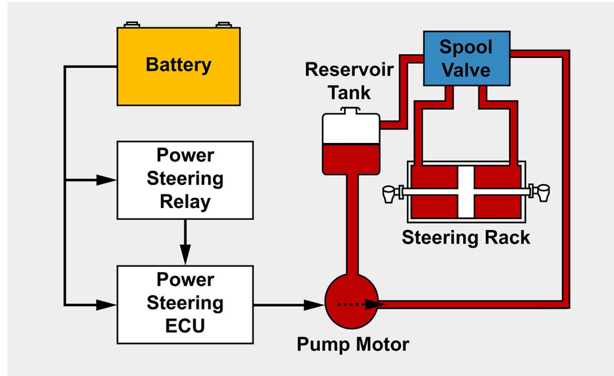


The reservoir tank is part of the electro-hydraulic power steering system on this vehicle.

Electro-hydraulic power steering systems:

- have electrically driven power steering pumps.
- operate independently of the engine. Because they are not driven by a belt off the engine, these systems can help increase the fuel mileage of a vehicle.
- are high amperage systems. At full steering assist, systems can draw more than 75 amps of current. Because of the high current draw, electro-hydraulic systems work well on hybrid electric vehicles that are equipped with high voltage batteries.

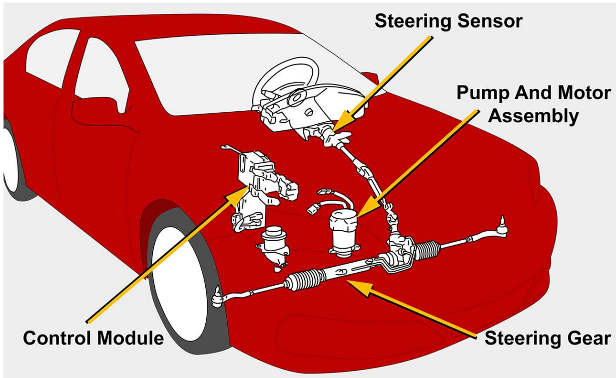
An advantage of electro-hydraulic systems over electric assist systems is that the hydraulics provide greater steering assist with less energy input than can be achieved with an electric assist steering system. This is important for heavy vehicles and vehicles with large tires.



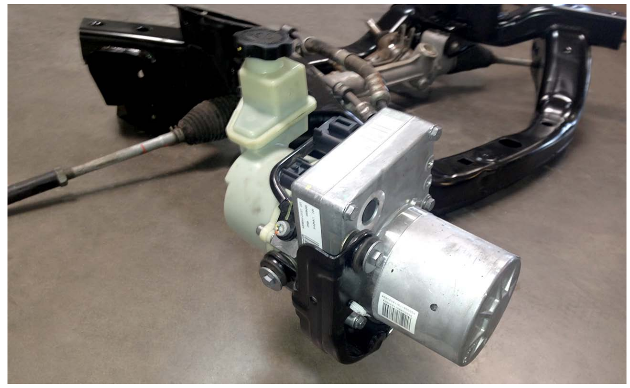
This illustration shows the basic operation of an electro-hydraulic power steering system.

Electro-hydraulic power steering systems operate by:

- varying the torque output of the electric motor that drives the hydraulic fluid pump. The control module varies the amperage to the electric motor. The more amperage sent to the motor, the higher the motor torque and the higher the fluid pressure from the pump. The higher the fluid pressure supplied to the steering gear, the greater the steering assist provided.
- running the electric drive motor for the hydraulic fluid pump as needed to produce the required steering assist. When no steering assist is required, the electric motor will not run.



This illustration shows the parts of a typical electro-hydraulic power steering system.



This is a power steering pump and motor assembly from a Chrysler 300.

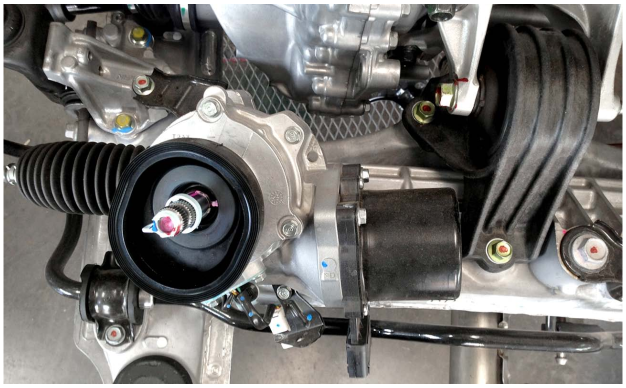
The main parts of an electro-hydraulic power steering system include:

- the electric motor and hydraulic pump assembly. These are typically one-piece integral units. Depending on the vehicle, these may be located in front of the vehicle, vulnerable to collision damage.
- the electronic control module and input sensors. The control module may be integrated into the pump and motor assembly. Typical input sensors include vehicle speed and electric motor temperature.
- a conventional power steering gear assembly.

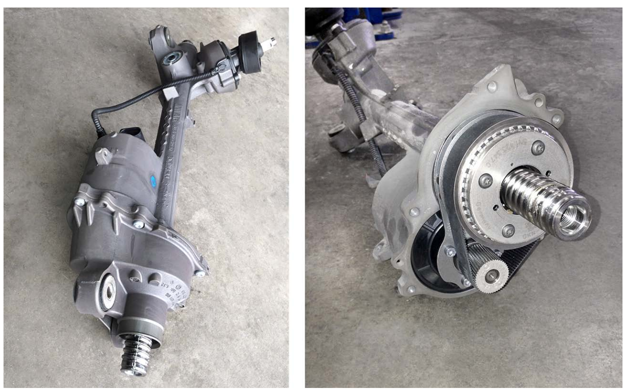
Damage analysis considerations with electro-hydraulic power steering systems include:

- the pump and motor assembly are typically serviced as a one-piece unit. On some vehicles, damage to the plastic reservoir or return line may require complete assembly replacement. These assemblies are in a vulnerable location with front collisions.
- that replacement may require part programming. Some vehicles, such as the 2013 Mazda3, may require programming the part with a scan tool when replacing the pump and motor assembly.
- excessive turning of the steering wheel with the vehicle not moving may overheat the motor and temporarily disable the system until it cools down.

Electric Assist Power Steering



Electric assist power steering systems do not use a hydraulic fluid pump for steering assist.

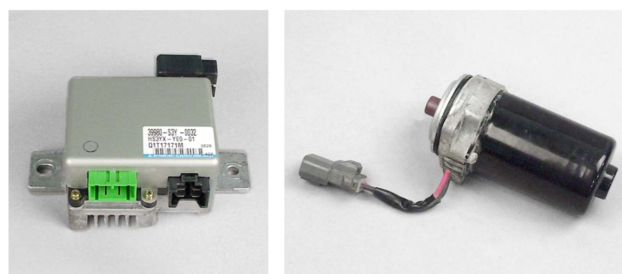


Shown here is the electric power steering rack from a 2012 Volkswagen Passat.

Electric assist power steering systems:

- use no hydraulics to provide steering assist.
- provide steering assist with an electric motor. The torque input from the electric motor is used to help turn the steering shaft or steering gear.
- operate independently of the vehicle engine.
- have a broad range of tuning possibilities available. Because steering assist is provided by an electric motor, the amount of assist can be infinitely adjustable by changing the current input to the motor.
- offer improved fuel mileage over vehicles with conventional power steering systems. Since there is no belt-driven hydraulic fluid pump, engine power is not used to assist steering effort. Removing this power drain from the engine will typically improve vehicle fuel mileage.

Systems are typically found on small lightweight vehicles with small tires that require less steering force to turn. With 42 volt technology, electric assist power steering systems can be used on any vehicle due to increased motor torque available from higher voltage motors.



This is the control module (left) and steering assist motor (right) from a vehicle with electric assist power steering.

Electric assist power steering systems operate by:

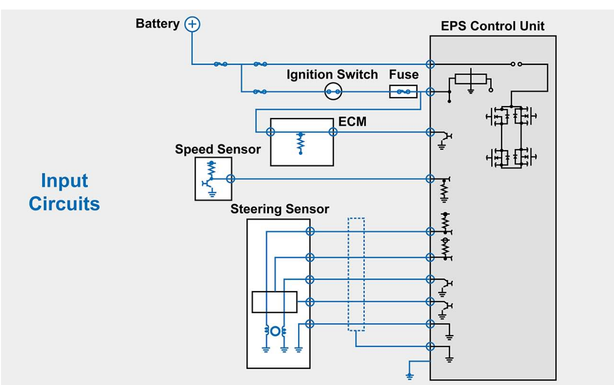
- providing steering assist with a high amp bidirectional motor that is mounted on the steering column or steering gear.
- using the control module to vary the current to the electric motor. The amount and polarity of the current sent to the motor varies the

direction and amount of steering assist provided.

This is a complete electric assist power steering system with the exception of the system wiring harness.

The main parts of an electric assist power steering system include the:

- steering column.
- steering gear.
- electric assist motor.
- control module.
- input sensors.



This wiring diagram shows the input side of a typical electric assist power steering system.

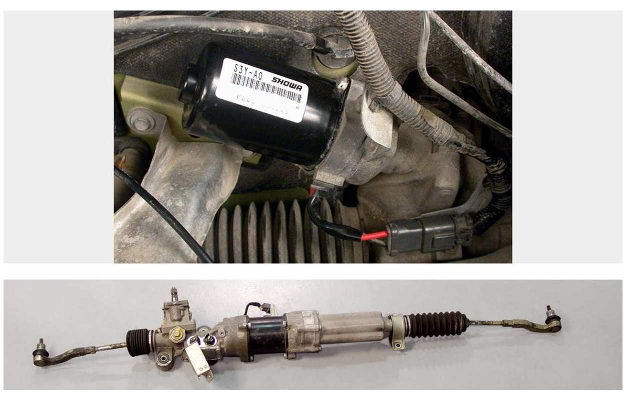
Typical inputs for electric assist power steering systems include:

- vehicle speed.
- steering input. Steering inputs include steering column torque and rotation. The torque sensor determines how quickly the steering wheel is turned and the rotation sensor determines how far it is turned.
- the assist motor temperature.
- system calibration figures that set the level of maximum steering assist and the system tuning profile. System calibration may vary according to the vehicle configuration; front-wheel drive, all-wheel drive, 4 cylinder, 6 cylinder, etc. System calibration inputs are either programmed into the EPS control module or provided by another vehicle control module, such as the body control module.

This steering column with an integrated assist motor and control module is from a vehicle with an electric assist power steering system.

Electric assist power steering systems with steering column mounted motors:

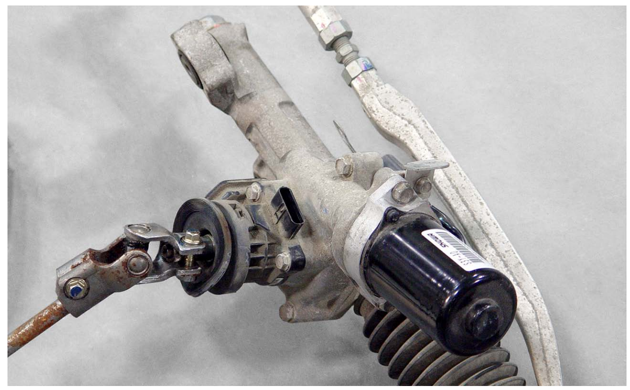
- have a worm shaft and reduction gear in the column that the assist motor connects to.
- typically have the motor, torque sensor, and control module integrated into the steering column.
- are typically serviced as integral one-piece units. The steering column and assist motor may only be supplied together.
- use a conventional non-power steering gear assembly. The steering assist is supplied by the electric motor that is connected to the steering shaft in the column. Since the steering gear plays no part in the power assist of the system, a conventional non-power steering gear is used.



These examples of rack and pinion mounted electric assist motors show an external motor mounted to the pinion (top) and an internal motor mounted around the rack (bottom).

Electric assist power steering systems with rack and pinion mounted motors may have the motor mounted:

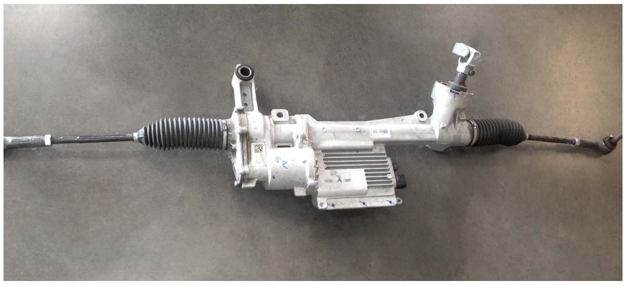
- externally at the pinion shaft. These motors may be serviced separately.
- internally around the rack. These motors are serviced as part of the rack and pinion assembly.



The electric steering assist motor is mounted externally at the pinion on this steering gear.

Systems with external pinion mounted motors:

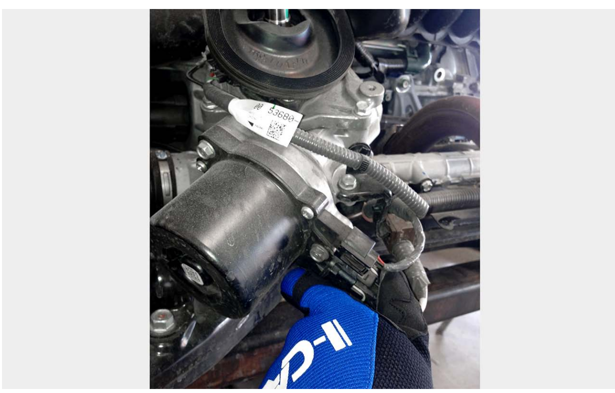
- have a worm shaft and reduction gear between the motor and pinion.
- may have the steering torque sensor located on the pinion assembly in the steering gear.
- typically have external control modules for the steering system.



The Ford Mustang electric steering assist motor is mounted internally on the steering rack.

Systems with the assist motor mounted internally in the steering rack have:

- the motor installed around the rack inside the steering gear.
- a gear on the motor that drives a recirculating ball mechanism attached to the rack.



Follow all electrical cautions when inspecting an electronically controlled steering system.

Damage analysis considerations with electric assist power steering systems include:

- the high amperage draw of these systems. Electric power steering assist motors can draw 75 or more amps to provide the necessary torque for adequate steering assist.
- following all general electronic cautions when diagnosing the steering system. The service manual is required for diagnosis of the electronic system. Electronic problems will typically set a DTC and light a MIL.
- control module replacement may require programming the replacement control module with a specialized vehicle-specific scan tool or computer.

Refer to Module 2, "Video: Diagnosing An Electric Power Steering Problem " This video shows one example of diagnosing an electric power steering problem.

Electric Steering

Acura RLX

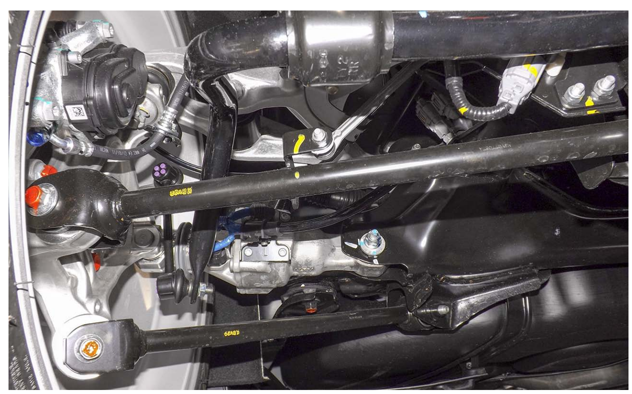
This vehicle is equipped with electric rear steering.

Electric steering systems are totally electronic or steer-by-wire. There is no mechanical connection between the steering column and steering gear. Electric steering systems are used for the rear steering in 4-wheel steer applications. Some examples of vehicles with rear wheel steering systems include:

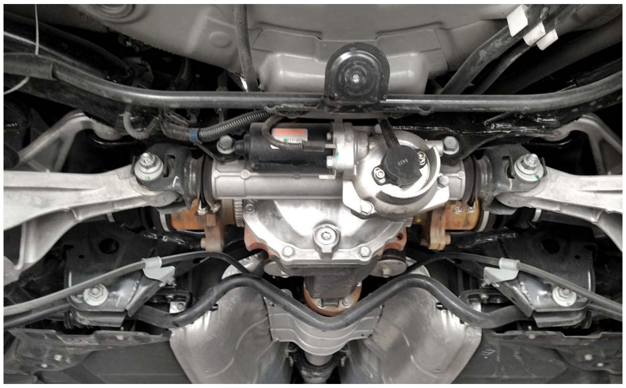
- Acura RLX. Some 2014 Acura RLX models are equipped with the precision all-wheel steering (P-AWS) system.
- BMW 535i. The 2013 BMW 535i is available with integral active steering system.
- Infiniti M. The 2013 Infiniti M is available with the 4-wheel active steering system.

Some 2002 - 2005 Chevrolet Silverado and GMC Sierra models were available with the Quadrasteer rear wheel steering system. Earlier versions of rear or 4-wheel steering systems that were used on sports and performance vehicles in the late 1980s and early 1990s were various designs. Some systems were totally mechanical with a steering shaft controlling a rear steering gear, while others used hydraulics to turn the rear wheels with or without electronic control.

Refer to Module 2, "Video: Acura P-AWS Electronic Rear Wheel Steering " This video shows the operation of the Acura P-AWS electronic rear wheel steering system.



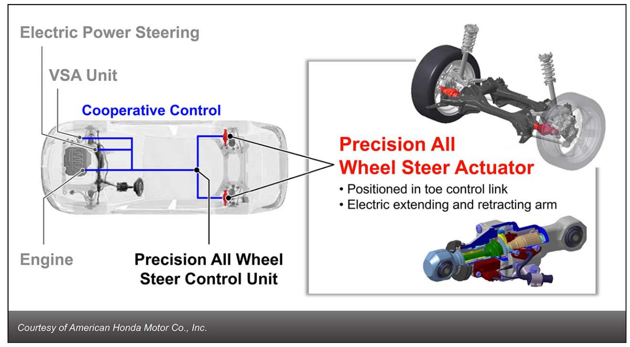
This is the rear steering on an Acura RLX with P-AWS system.



This is the rear steering system on a 2010 Infiniti M35.

The main parts of an electric rear steering system may include:

- the wheel position sensors. Wheel position sensors provide the primary input to the rear steering control module. For example, on the 2014 Acura RLX P-AWS system, an electric actuator with a toe position sensor is installed at each rear wheel between the steering knuckle and subframe.
- a steerable rear axle assembly. The rear axle assembly is similar in design to the steerable solid front axle used on some 4-wheel drive vehicles.
- a rear steering gear assembly or actuator.
- the control module for the rear steering system.
- various secondary input sensors.

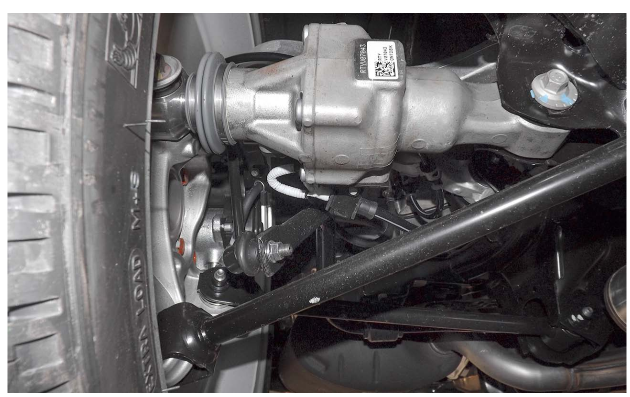


This illustration shows the parts of an Acura P-AWS rear steering system.

The main and secondary inputs to the control module of electric rear steer systems in a typical 4-wheel steer application includes:

- vehicle speed.
- steering wheel position.
- yaw rate and lateral acceleration of the vehicle body. Yaw rate and lateral acceleration inputs can come from the same sensor.
- rear wheel position. A rear wheel position sensor on the rear steering gear is used to determine the amount in degrees and direction that the rear wheels are turned.

Acura RLX



This is the actuator on a Acura RLX with P-AWS.

When analyzing damage on vehicles that have electric rear steering systems:

- do not allow the jack or lifting arms to contact the rear steering gear or other parts of the system when lifting the vehicle.
- a scan tool is required to access diagnostic trouble codes and to perform specific repair procedures. For example, on the 2014 Acura RLX P-AWS system, the neutral position of the toe sensors must be relearned using a Honda specific scan tool if the control unit or an actuator is replaced.
- note that some parts may be vulnerable to collision damage from a wheel hit.

KPI Improvement Tip
Identify required tools and equipment to run diagnostics and repairs or the need to sublet repairs.

Module Wrap-Up

Topics discussed in this module included:

- different electronic steering systems.
- the operation of computer controlled variable assist power steering systems.
- electronic steering system parts.
- diagnosing problems with electronically controlled steering systems.
- cautions when analyzing damage on vehicles with electronically controlled steering systems.
- electric rear steering systems.

Module 3 - Electronically Controlled Suspension

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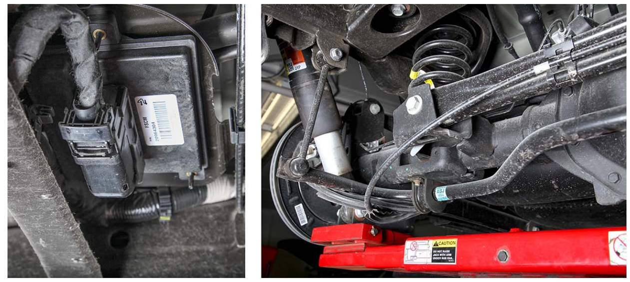
Types Of Electronic Suspensions

Refer to "Video: Learning Objectives" in the presentation.

The learning objectives for this module include:

- identifying the different types of electronic suspension systems.
- explaining the operation of electronic suspension systems.
- identifying electronically controlled system parts.
- identifying damage analysis cautions with electronically controlled suspension systems.
- identifying the different types of tire pressure monitoring systems.
- identifying tire pressure monitoring system parts.
- identifying damage analysis cautions with tire pressure monitoring systems.

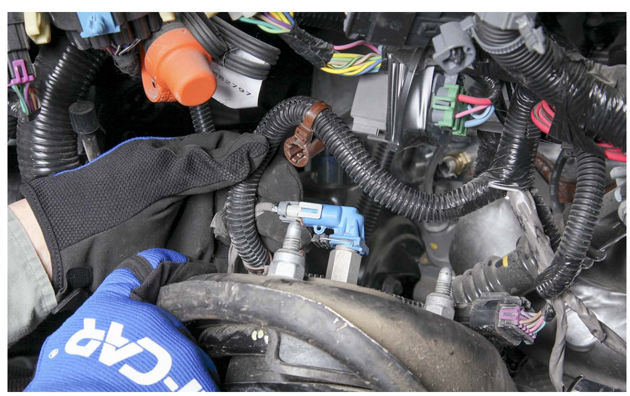
Cadillac Escalade



Shown is the control module (left) and electronically controlled ride height system (right).

One type of electronically controlled suspension system is computer controlled ride height systems. These systems are sometimes called level-ride or automatic load leveling systems. Computer controlled ride height systems may:

- be on the rear of the vehicle only.
- be on all four corners of the vehicle.
- be air systems. The ride height may be adjusted using air shock absorbers or the vehicle may be equipped with air springs.
- use a hydraulic system to control the ride height adjustment.



This estimator is inspecting the electrical connector for the electronically controlled shock absorber, which is located at the top of the strut assembly.

Another type of electronically controlled suspension is computer controlled variable shock absorber damping. Variable shock absorber damping may be controlled:

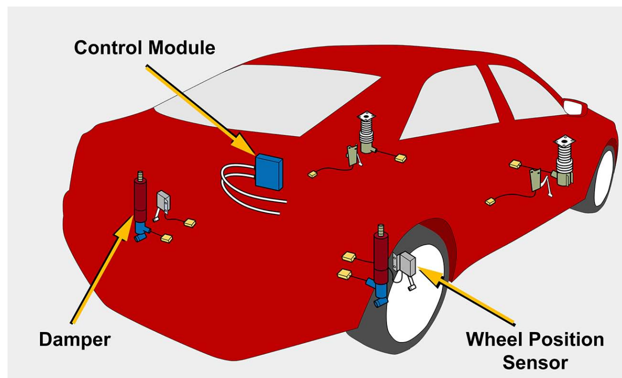
- mechanically by varying the orifice size for the shock absorber fluid.
- magnetically by varying the viscosity of the shock absorber fluid. The fluid orifice size remains constant in these systems.

Cadillac Escalade

This strut has both an electrical connector for shock absorber damping and an air line for ride height control.

Vehicles with electronically controlled suspensions may have combination systems. Combination systems:

- have computer control of both ride height and shock absorber damping.
- may have air springs and separate computer controlled variable dampers.
- may use computer controlled dampers to adjust both the ride height and handling characteristics of the vehicle. Dampers in these systems may be hydraulic struts with air bladders built in for springs or be totally hydraulic for both suspension damping and ride height.

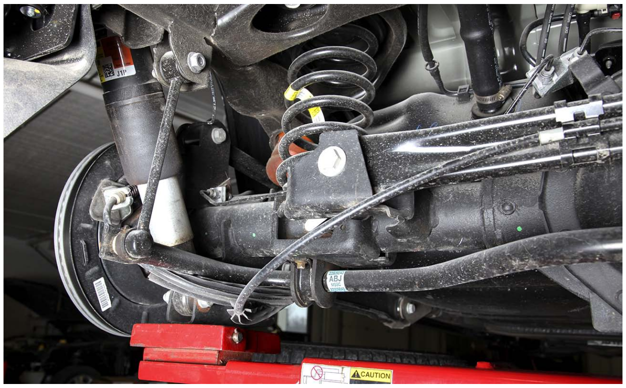


This illustration shows the main parts of a semi-active suspension system.

Semi-active suspension systems:

- typically consist of computer controlled variable dampers that respond to up-and-down body motion inputs to read the road surface.
- react to the first bounce or suspension deflection to control the second bounce or deflection. They are not active but rather reactive. Semi-active systems do not directly control suspension deflection, they indirectly control it by altering the firmness of the shock absorber damping.

Cadillac Escalade



The suspension system on this vehicle has a variety of complex parts used to control suspension deflection.

Full-active suspension systems are:

- more complex than semi-active systems.
- combination systems that control both ride height and shock absorber damping.
- active rather than reactive. They control the first bounce or deflection by pushing the wheel into the dip to keep the vehicle level. Full-active systems directly control the deflection of the suspension and hold the body level by varying both damper and spring rates.

The electrical connector at the top of the strut indicates the presence of an electronically controlled suspension system.

The presence of electronically controlled suspension systems is typically not noted by emblems or other highly visible labeling on the vehicle. To determine if a vehicle is equipped with an electronically controlled suspension system:

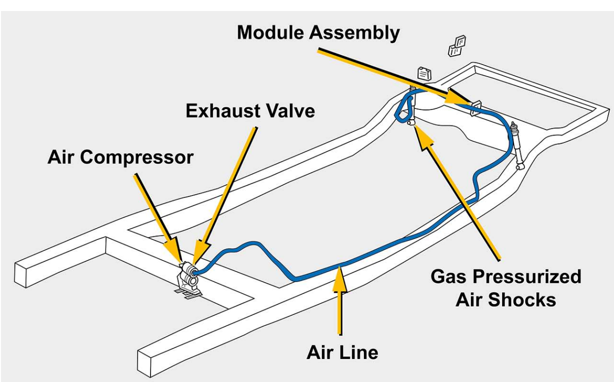
- perform a thorough visual inspection of the suspension system. Look for wiring connected to suspension parts, such as shock absorbers or struts. Look for the presence of air or hydraulic fluid lines to the shock absorbers, struts, or springs. Check for the presence of a MIL for an electronic suspension system when the ignition is first turned ON. Look for switches on the dash or console for manual control of electronic suspension systems. Systems may have an ON / OFF switch, a switch for sport or comfort damper settings, or a switch for control of vehicle height. Visually identify parts that would indicate the presence of specific electronic or electronic / hydraulic systems.

- use the information located on the option label or tag that is located on many vehicles. The dealership parts department can provide information on the decoding of the option tag to determine if an electronically controlled suspension system is on the vehicle.
- use a VIN-driven parts ordering system.

KPI Improvement Tip
Identify the need to disable the suspension system before lifting the vehicle.

Be aware that initialization / programming procedures may be required on some systems to enable electronic assist / operation.

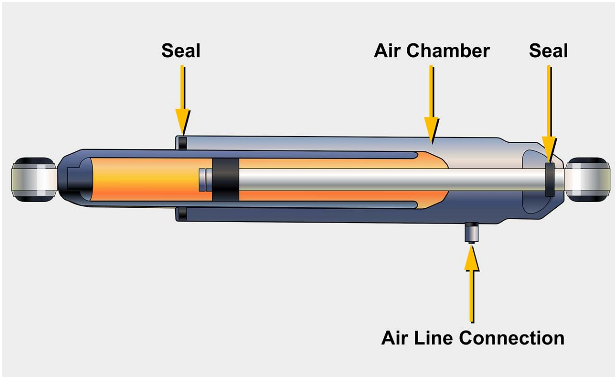
Air Shock Absorber Height Control Systems



This illustration shows the main parts of an air shock absorber rear height control system.

The simplest type of height control system is the air shock absorber system. Air shock absorber systems only control the height at the rear of the vehicle. Typical parts of an air shock absorber height control system include:

- the rear air shock absorbers. Typical air shock absorbers used in rear height control systems have an internal air chamber that air pressure is added to or removed from to control the vehicle height. The damping function of the shock absorber works like a conventional shock absorber. The air shock absorbers do not act as springs for the vehicle, but rather are used to assist the springs in holding the vehicle level with heavy loads.
- an air compressor with a drier to remove moisture from the air. Depending on the vehicle, air compressors may be located in the front or rear of the vehicle.
- the air lines from the compressor to the shock absorbers.
- an exhaust valve to allow air to be removed from the shock absorbers. The exhaust valve is typically built into the air compressor.
- height sensors that monitor the ride height of the vehicle.
- a control module. Some rear-only air shock absorber systems have a combination height sensor and control module assembly.



This illustration shows a cutaway view of a typical air shock absorber from a rear-only height control system.

This auto physical damage appraiser is inspecting the rear air shock absorber for damage.

Rear air shock absorber based height control systems:

- control the ride height by either adding or removing air from the shock absorber air chamber.
- are controlled by the rear height sensor and control module. The height sensor determines rear ride height and either instructs the air compressor to run or the exhaust valve to open.
- typically have delayed activation to avoid having the compressor run in response to temporary changes in ride height.

Common types of collision damage to rear air shock absorber height control systems include:

- bent shock absorbers.
- cut or kinked plastic air lines.
- damaged sensors or control modules. Sensors may be physically damaged or misaligned, causing improper operation of the system.
- cut wiring or smashed connectors.
- a damaged air compressor. Air compressors may be physically damaged or be inoperative due to electrical damage.

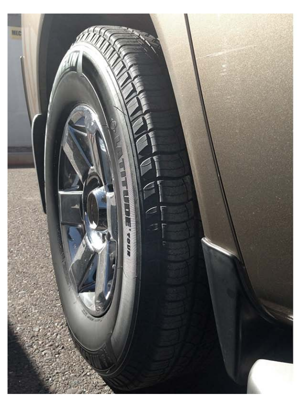
Shown here is the air line and connector on rear air shock absorber.

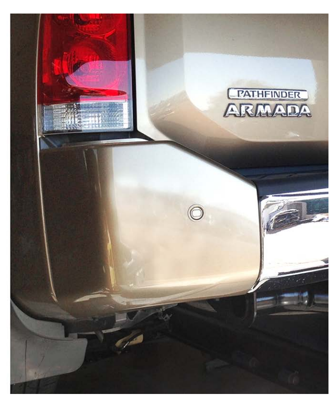
Considerations when inspecting vehicles with air shock absorber rear height control systems include:

- replacing a damaged shock absorber with the correct part. Always ensure that the damping rate and load capacity of the replacement shock absorber matches that of the one removed.
- disabling the height control system before lifting the vehicle. Follow vehicle maker procedures for disabling the height control system. On some systems, simply having the ignition in the OFF position or the battery disconnected will disable the height control system. Other systems may have an ON / OFF switch for disabling the height control system. Procedures for disabling are typically located in the vehicle owners manual and service manual.
- ensuring that the air shock absorber system is disabled and depressurized before loosening or removing any part of the system. Follow the vehicle makers procedure for disabling and depressurizing the system.
- pressurizing the air shock absorbers before driving the vehicle. Driving a vehicle with rear air shock absorbers that have no air pressure may damage the air shock absorbers.
- protecting the plastic air lines from damage. Damaged air lines may be repaired if the vehicle maker has a procedure or parts available for the repair.
- confirming that height sensor placement and adjustment is correct. Damage to the brackets or mounting points of the height sensor may result in false or incorrect readings from the sensor.
- that a door ajar may disable the system. A door that is not fully closed or that does not turn off the door ajar warning when fully closed will typically cause the rear height control system to become inoperable.

Refer to Module 3, "Activity: Fill In The Blank" in the presentation.

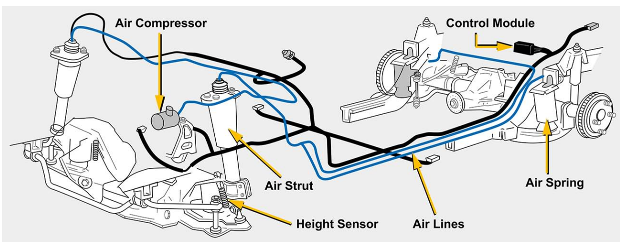
Activity: Suspension Problem





Refer to Module 3, "Activity: Suspension Problem" in the presentation. This activity presents one example of why a thorough inspection is important when analyzing damage on a vehicle with an advanced suspension system.

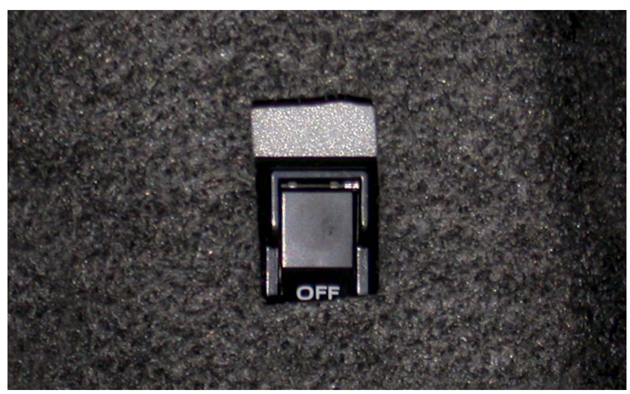
Load Leveling / Self-Leveling Suspension Systems



This illustration shows the main parts of a typical four corner electronic air spring height control system.

Another form of vehicle height control system uses air springs with conventional shock absorbers. These systems may be on the rear only or both the front and rear of the vehicle. Typical parts of an air spring height control system include:

- air springs or air struts. Systems may have separate air springs and shock absorbers or be equipped with air struts, which are similar to conventional struts except the spring is replaced by an air bladder. Unlike air shock absorbers that assist the springs in supporting the vehicle, air springs or struts completely replace the conventional springs.
- an air compressor with a drier to remove moisture from the compressed air and air lines from the compressor to the springs. The air lines are typically made of plastic.
- control valves. Systems with air springs at all four wheels have control valves to control the distribution of compressed air to the proper spring or springs.
- a control module.
- sensors to input signals to the control module. Typical inputs are for ride height, vehicle speed, steering angle, and vehicle acceleration. Ride height may be measured for front and rear or independently at each wheel. Acceleration data may be provided both front and back and laterally.

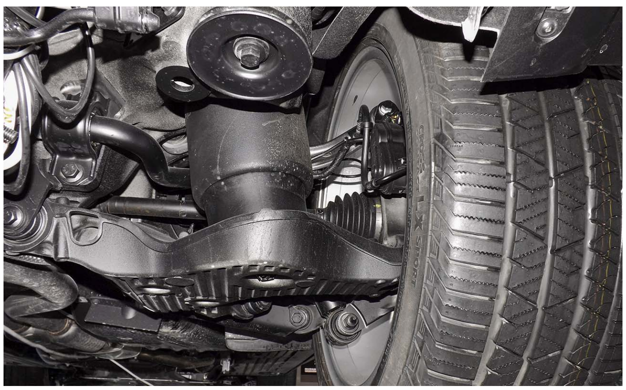


This is the ON / OFF switch for an electronic air spring height control system.

Air spring based height control systems:

- may have a manual ON / OFF switch. The systems typically must be disabled or turned off when towing or lifting the vehicle.
- have a control module that receives inputs from various sensors and calculates the

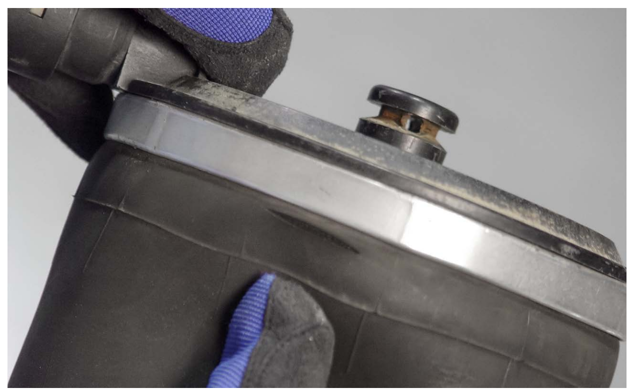
required output to the air compressor and control valves. This keeps the ride height at the desired level.
- have control valves that route the air from the compressor to the appropriate air spring.
- control the vehicle height by adding or removing air pressure from the air springs.



Air spring height control systems may control both front and rear ride height.

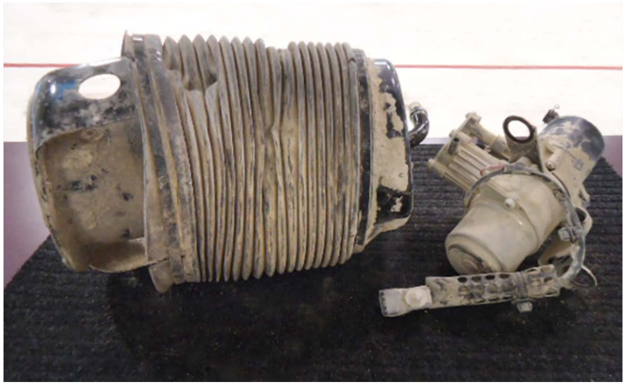
Air spring height control systems may:

- control both front and rear ride height. Both springs on either end may be controlled together in tandem, allowing for adjustment of the front and rear ride height.
- allow each corner to be adjusted independently.
- have a manual selector switch for height adjustment. Some systems have a switch that allows the ride height to be changed to suit the driving conditions. The vehicle can be raised for additional ground clearance when driving off road, or lowered when driving on the highway or when parking to aide in vehicle entry and exit.
- be speed related. Some systems are designed to lower the vehicle at speeds above a certain amount to allow for greater high speed stability. Four-wheel drive vehicles that are raised for off-road driving will typically lower automatically above a certain speed to reduce the risk of rollover.
- only operate with the ignition in the ON position. Having the ignition OFF will typically disable the height control system.



This technician is pointing out a small tear in the air bladder of a rear air spring.

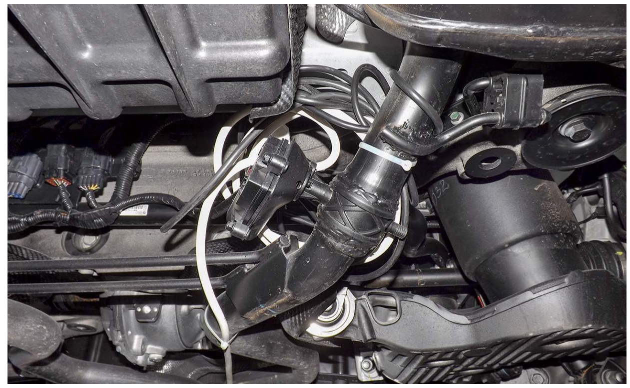
This 2012 Toyota Sequoia has a damaged air spring and air spring compressor. Click to the next slide to see these off the vehicle.



The damaged air spring and air compressor from the previous slide are shown here off the vehicle.

Common types of collision damage to air spring height control systems include:

- bent shock absorbers. Bent shock absorber rods may cause the shock absorber to bind and not allow the suspension to deflect.
- cut or damaged air springs. Air springs are typically made of rubber and can be cut or punctured by sharp metal during a collision. Collision forces can also compress and blow out air springs resulting in a loss of spring force.
- air line damage. Air lines are typically made of plastic and are susceptible to damage from sharp metal or kinks, restricting the air flow.
- electrical part damage.
- damage to height sensors. Height sensors may sustain physical damage. Mounting locations or brackets may be bent or out of position causing improper sensor readings. Height sensors may be adjustable and could be knocked out of adjustment during a collision. Height sensors must be positioned properly in order to function as intended.



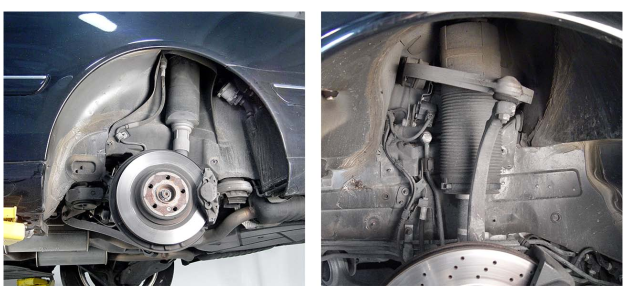
The height control system should be depressurized before lifting the vehicle.

Considerations for damage analysis of air spring height control systems include:

- disabling the system before lifting the vehicle. Follow the vehicle makers procedure for disabling the height control system before towing or lifting the vehicle. Some vehicles have ON / OFF switches, others simply require the ignition be left in the OFF position.
- depressurizing the system before loosening or replacing parts. Follow vehicle maker recommendations for the depressurization of air height control systems.
- the repair of damaged air lines. Repair only where allowed by the vehicle maker with repair parts designed for the application. Ensure the proper routing of air lines during replacement. Protect air lines from damage during

repairs by shielding them from heat or sharp objects.
- understanding that having a door ajar will typically disable automatic height control systems. When working with air spring height control systems, ensure that all vehicle doors are fully closed.
- following vehicle maker recommendations. When changing air springs in computer controlled height control systems, always follow the vehicle makers recommendations and procedures for repair. Air spring replacement may require specific procedures be followed to avoid damaging the spring or causing personal injury. Procedures typically require the suspension to be loaded before inflating the spring and the spring to be inflated before driving or moving the vehicle.

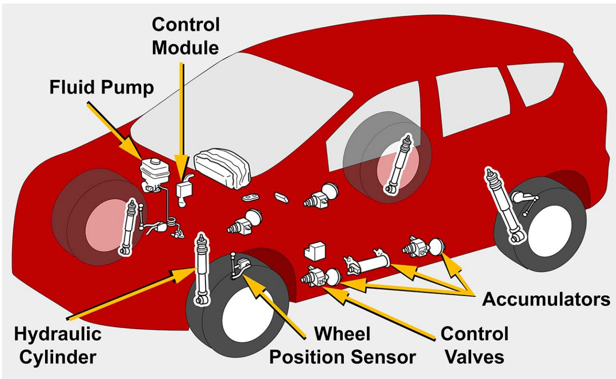
Hydraulic Height Control Systems



This vehicle has both rear (left) and front (right) hydraulic cylinders for height control.

Hydraulic height control systems:

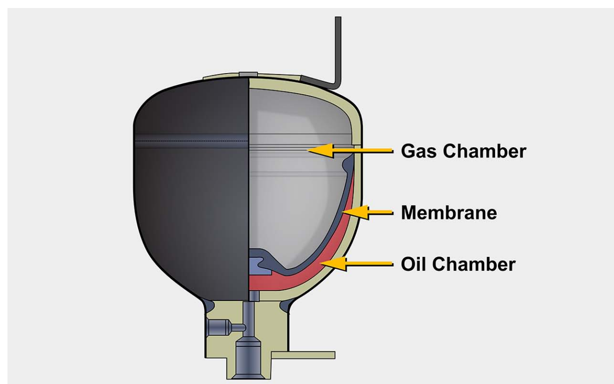
- have hydro-pneumatic cylinders in place of the conventional shock absorbers or struts. The cylinders are filled with pressurized hydraulic fluid. There may be a gas-filled damper built in or separate external pressurized gas reservoirs for damping control.
- use the hydro-pneumatic cylinders to control both the ride height and suspension damping force. Both functions may be performed by the hydraulic cylinder but be controlled independently, or there may be a conventional nonadjustable damper built into the hydraulic cylinder for suspension damping.
- use hydro-pneumatic cylinders that work in series with the vehicle springs. The hydraulic cylinders are used to work with the conventional springs and provide additional and adjustable spring rate and ride height to the vehicle. This allows the conventional springs to be softer, allowing for improved highway riding comfort without sacrificing high speed handling characteristics. Neither the conventional springs nor the hydraulic cylinders are intended to support the vehicle weight or control suspension deflection alone, they are designed to work together.



This illustration shows the main parts of a typical hydraulic height control system.

The basic parts of a hydraulic height control system typically include:

- a hydraulic fluid pump. The power steering pump is typically used as the fluid pump for hydraulic suspension systems. The pump is a tandem pump that has a vane pump used for power steering and a radial pump used for the suspension system. The two pumps are in the same case and driven by a common shaft. Both sides of the pump typically have separate oil feeds. Fluid pressure may be as high as 13,100 kPa (1,900 psi).
- the fluid pressure accumulator that stores hydraulic fluid under pressure. The accumulator is a vessel with two areas separated by a bladder. One side contains hydraulic fluid and the other a high pressure gas to maintain the pressure on the hydraulic fluid. There may be more than one accumulator in some systems.
- control valves or actuators. The control valves or actuators control the flow of hydraulic fluid between the pump, accumulator, and cylinders.
- the hydraulic cylinders that replace the conventional shock absorbers or struts in the system. There are also lines to carry hydraulic fluid between the different parts of the system.
- input sensors for vehicle ride height, speed, and acceleration; horizontally, vertically, and laterally.
- a control module.
- switches and other basic electrical circuit parts.

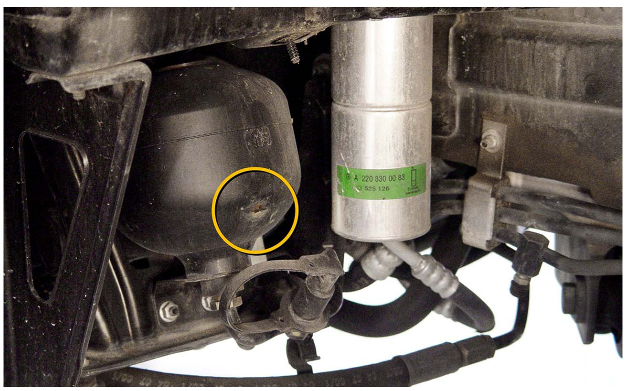


This cutaway illustration shows the inside of a typical hydraulic fluid pressure accumulator.

Hydraulic height control systems:

- have accumulators that store hydraulic fluid in one chamber, separated from high pressure gas in another chamber by a rubber bladder. The system may have a front and rear accumulator or separate accumulators for each corner of the suspension.
- use control valves to control the flow of hydraulic fluid between

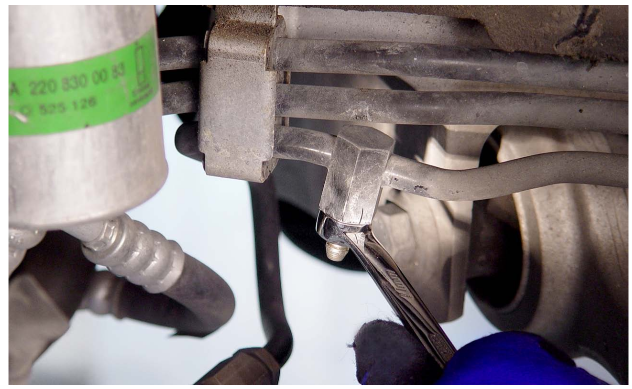
the accumulator and hydraulic cylinder. When the control module calls for increased ride height at a corner, the control valve opens a valve that allows fluid to flow into the hydraulic cylinder and lift the vehicle.
- add or remove hydraulic fluid from the hydraulic cylinders at each corner of the vehicle to either raise or lower ride height.



The accumulator on this vehicle is damaged and will require replacement.

Common collision damage to hydraulic height control systems include damage to:

- fluid pumps, such as bent pulleys or shafts. Fluid leaks may result from damage to shaft seals or pump housings.
- accumulators.
- hydraulic cylinder rods. Hydraulic actuators and cylinders can also have damaged seals resulting in fluid leaks and the inability to maintain ride height.
- height sensors. Height sensors are typically located on or near suspension system parts where they can be easily damaged.
- electrical parts including cut wiring or smashed connectors.



This technician is loosening a bleeder valve on a fluid line from a hydraulic height control system.

Considerations with damage analysis of hydraulic height control systems include:

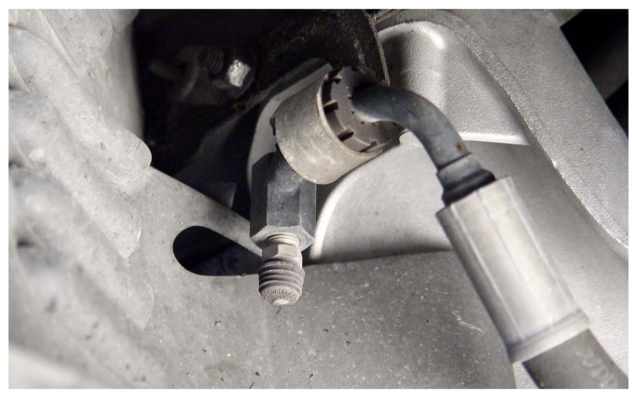
- high pressure. Hydraulic pressure can exceed 13,100 kPa (1,900 psi). The systems must be depressurized before servicing any hydraulic system parts. Accumulators must also be handled with care and should not be repaired if damaged. Never hammer or weld on accumulators and replace them if there are any signs of physical damage.
- proper alignment and adjustment of the height sensors. The height sensors supply the main input to the control module. A misaligned or out-of-adjustment height sensor will supply the control module with inaccurate information and cause the height of the corner to

be incorrect. Follow vehicle maker recommendations for measuring and adjusting ride height.
- following the general cautions and procedures for electronic systems.

These fluid lines and distribution blocks for the hydraulic height control system are located where they are susceptible to damage in a collision.

Additional considerations when analyzing damage on hydraulic suspension systems include:

- using the correct hydraulic fluid. The systems typically share the fluid pump with the power steering system, but may require a specific fluid for proper operation. Always use the specified fluid when adding fluid to the system.
- fluid lines are not repairable and must be replaced if damaged. Due to the high pressures, fluid lines should not be repaired. Ensure that the fluid lines are properly routed if any are replaced. Fluid lines should also be checked for kinks and leaks wherever repairs have been made or in the area of collision damage.
- using a scan tool. When working on hydraulic suspension systems, scan tools may be required for diagnosis of electronic problems and for service procedures, such as bleeding air from the hydraulic system after parts are replaced or measuring and setting ride height. Leak-checking of most systems involves using a vehicle-specific scan tool to open and close valves, pressurizing various parts of the system, and looking for fluid leakage in parts and connections.



The bleeder valve for this hydraulic fluid line has a protective rubber cap.

When diagnosing damage on hydraulic suspension systems, be aware that some systems may require bleeding. Bleeding the hydraulics on hydraulic suspension systems:

- should be done following vehicle maker recommendations.
- is typically required after parts replacement or disconnection of any hydraulic fluid line.

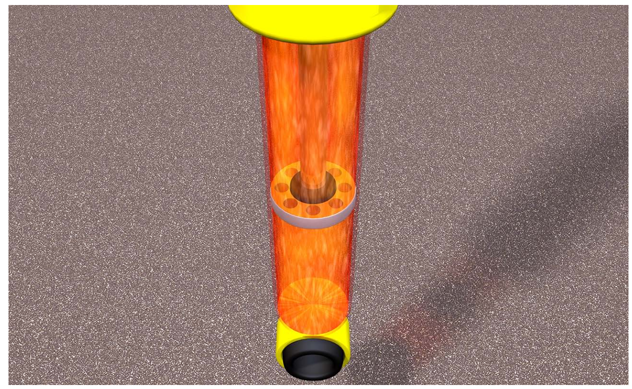
- may require different procedures for different parts of the system. Some parts may be bled by opening a bleeder valve similar to those used on brake calipers.
- may require vacuum bleeding on some parts of the system.
- may require a scan tool. Some parts of the system require certain valves to be controlled by a vehicle-specific scan tool in order to bleed the air.

Computer Controlled Dampers

The computer controlled damper on this strut assembly has the fluid control valve located externally at the bottom of the strut.

Electronically controlled suspension dampers (shock absorbers):

- are the main parts of road sensing suspension systems.
- vary the ride and handling characteristics of the vehicle. This is done by altering the firmness of the shock absorber damping in response to various sensor inputs.
- are considered semi-active suspension systems when used by themselves with no other electronic suspension control.
- may be part of a fully active suspension when used in combination with other electronically controlled suspension systems.

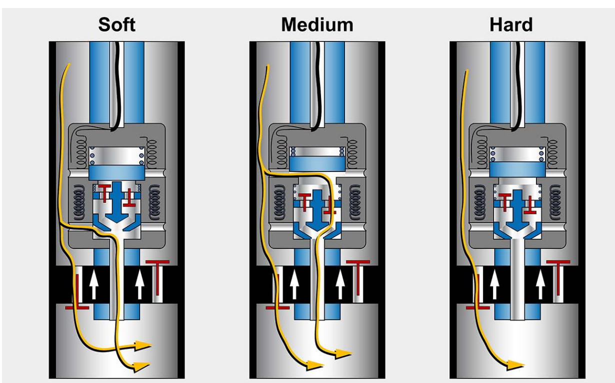


This illustration shows the openings in the shock absorber piston that control fluid flow and shock absorber damping stiffness.

An explanation of conventional damper operation is that:

- a piston on the end of the damper rod travels in a cylinder filled with hydraulic fluid. The cylinder is the damper body.
- orifices or openings in the piston allow the hydraulic fluid to flow between the two chambers of the cylinder. The size of the openings in the piston control the amount and speed of fluid flow between chambers in the damper body, and consequently the speed at which the piston can travel. The opening size is what determines the firmness of the damper.

Refer to Module 2, "Video: Conventional Damper Operation" This animation shows the operation of a conventional suspension damper or shock absorber.



These illustrations show how a typical variable damper varies the resistance to movement by opening and closing internal valves.

The firmness or resistance to movement that a damper in electronically controlled suspension systems has is controlled by a control module that:

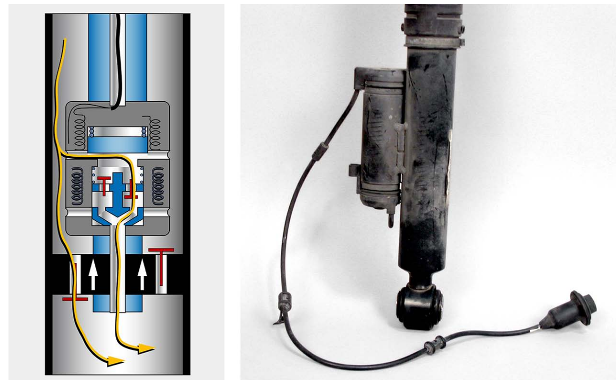
- uses a variety of input signals to determine the appropriate damper stiffness for current road and driving conditions. These input signals may be supplied by individual sensors and by control modules for other vehicle systems.
- can be controlled by varying the opening size that the hydraulic fluid flows through or by varying the viscosity of the fluid.

The parts that supply inputs to the control module for an electronically controlled suspension damping system include (left to right) a steering wheel position sensor, vehicle height sensor, and lateral acceleration sensor.

Typical inputs to control modules for computer controlled suspension dampers include:

- vehicle height. Vehicle height sensors measure the wheel-to-body position and input signals on up and down movement of the vehicle body. Height sensors are typically located at each corner of the vehicle with an arm connected to a movable suspension part.
- vehicle acceleration. Vehicle acceleration is monitored in three planes, longitudinally, laterally, and vertically. Longitudinal acceleration is the front and rear acceleration of the vehicle caused by throttle and braking forces. Lateral acceleration is the sideways acceleration of the

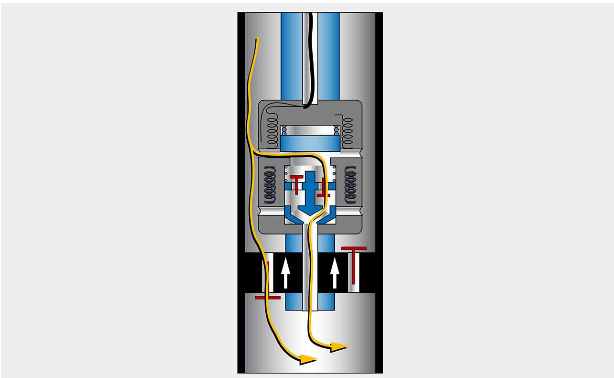
vehicle, or the rate of change of the side-to-side movement of the body. Vertical acceleration is the rate of change in the up-and-down movement of the vehicle body caused by irregularities in the road surface and suspension deflection from lateral and longitudinal acceleration forces. Acceleration sensors are typically mounted in various locations on the vehicle structure.
- steering input from the driver. Steering input may be monitored for both the angle and speed of the input. Steering angle input is the direction and amount the steering wheel is turned and the speed input is how fast it is turned. Steering wheel position sensors are typically mounted to the steering column shaft and are similar in appearance to a clock spring.
- vehicle speed. The damping force is typically controlled to be firmer at higher vehicle speeds for increased vehicle stability. The faster the vehicle is traveling, the more resistance the suspension damper will provide.



A control module sends an output signal to a stepper motor in the shock absorber actuator for damping control.

Control of variable rate dampers is handled by a control module, which sends an output signal to:

- a solenoid valve located inside the shock absorber body or in a damping control unit located outside the shock absorber body.
- a stepper motor in the shock absorber actuator located in or on the shock absorber body. The stepper motor controls a multiple-position rotary valve on or in the shock absorber body.
- an electromagnetic coil located in the piston of the damper. The electromagnetic coil is used to produce a magnetic field that changes the viscosity of the hydraulic fluid.



This illustration shows how an internal valved variable damper operates.

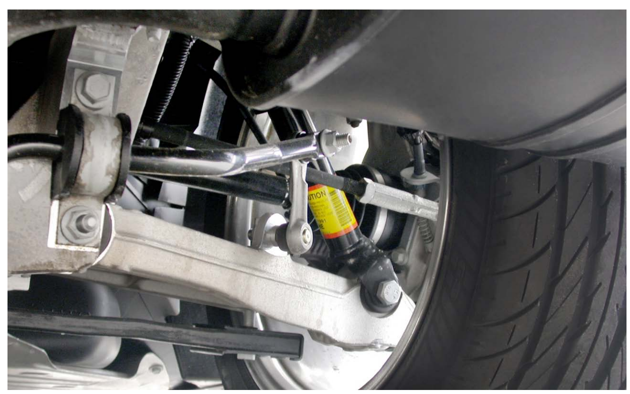
The operation of computer controlled suspension dampers may be electrically controlled by a solenoid or stepper motor. These use internal actuators or valves located in the damper body or piston to control the flow of the fluid in the shock absorber.

Valves are opened or closed to vary the opening size and resistance to fluid flow inside the shock absorber. More resistance to flow produces a firmer suspension damping force and less resistance produces a softer damping force.

This shock absorber has an external damping valve to control the firmness of its damping force.

The operation of computer controlled suspension dampers may be electrically controlled by a solenoid or stepper motor located in external damping valves on some systems. The shock absorber may have an external damping unit connected to it that, through a series of valves, controls the firmness of the damping force of the shock absorber. The hydraulic fluid in the shock absorber travels through the damping control unit as it is forced from the upper shock absorber chamber into the lower chamber.

External damping units are used to allow for more valves than would fit internally in the shock absorber body. The additional valves allow a greater degree of tuning flexibility due to the increase in the number of damping force settings.



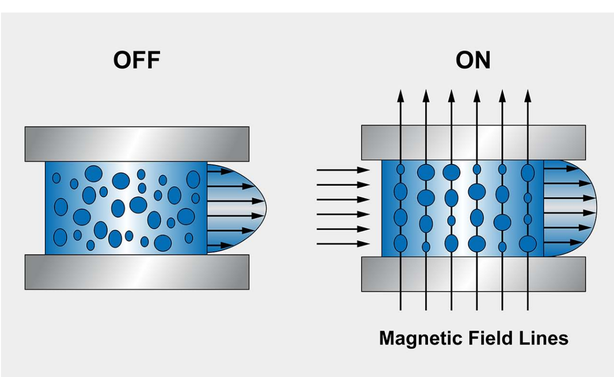
This magnetically controlled shock absorber looks like a typical conventional shock absorber from this angle.

Magnetically controlled variable damper systems:

- include MagneRide. Other names for the system include Magneto-Rheological Real Time Damping (MRRTD) or

Magnetic Ride Control. The 2013 Chevrolet Corvette is one example of a vehicle with the MRRTD electronic suspension system.

- have constant shock absorber valving with a variable viscosity fluid. These systems control firmness by varying the viscosity of the fluid inside the shock absorber instead of varying the opening size that the fluid is forced through. The thicker the fluid, the harder it will be to force through the openings in the piston and the slower the piston will travel.
- are less complicated and have fewer parts than valve-based variable dampers.
- have a faster response rate than typical valve-based variable dampers.
- have dampers that are similar in construction to a conventional suspension system. The shock absorbers are a single tube, gas-filled unit with fixed nonvariable valves for fluid control.



This illustration shows how the presence of a magnetic field aligns the magnetic particles in the magneto-rheological fluid and increases the fluid viscosity.

MagneRide suspension systems use a special fluid to control the damping force firmness. The fluid has special randomly suspended magnetic particles.

In the presence of a magnetic field, the particles align themselves with the magnetic field lines and each other. This raises the viscosity of the fluid. The fluid has an unlimited range of viscosity depending on the strength of the magnetic field in which it is placed. It can go from a fluid-like state when no magnetic field is present, to an almost plastic-like state in the presence of a strong magnetic field. The magnetic field is produced by an electromagnet located on the piston of the damper.

This variable damper air strut has been bent in a collision and requires replacement.

Considerations for damage analysis on computer controlled suspension damping systems include:

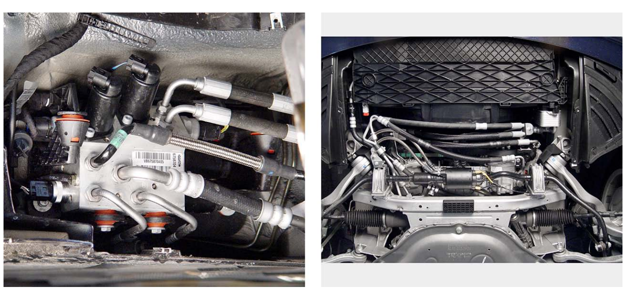
- they are subject to the same types of mechanical damage as conventional suspension dampers.
- removal and replacement procedures, which are the same as conventional suspension dampers

with the exception of having an electrical connector to disconnect.
- hydraulic pressure may be present in lines from the shock absorber to external valve units. Follow vehicle maker procedures for depressurizing the lines before loosening or disconnecting.

Electrical problems will typically light a MIL or trigger a trouble message on the driver information center. The MIL or trouble message indicates a stored DTC that will typically require a scan tool to retrieve.

Mechanical problems with the systems typically will not light a MIL or trigger a trouble message. Verification of proper system operation requires a test drive under a variety of road and driving conditions.

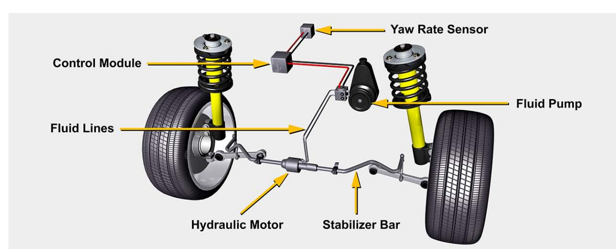
Computer Controlled Stabilizer Bars



This active stabilizer bar system has a hydraulic fluid control valve (left) to allow for precise body roll control and improved straight line driving comfort, and a split stabilizer bar with an oscillating motor (right).

Active or computer controlled stabilizer bars:

- act on each wheel independently. Unlike conventional stabilizer bars that transmit forces from the wheel being deflected to the wheel on the opposite side of the vehicle. The left and right sides of active stabilizer bars may be decoupled from each other and introduce fewer forces into the vehicle body. The bars are typically made in two or more parts that are connected together in a way that allows each side of the bar to move independently.
- allow for high levels of body roll control and suspension handling while using softer springs and dampers for increased ride comfort.
- have improved straight line suspension comfort over conventional stabilizer bars because they do not stiffen the basic suspension during a one-sided suspension compression.

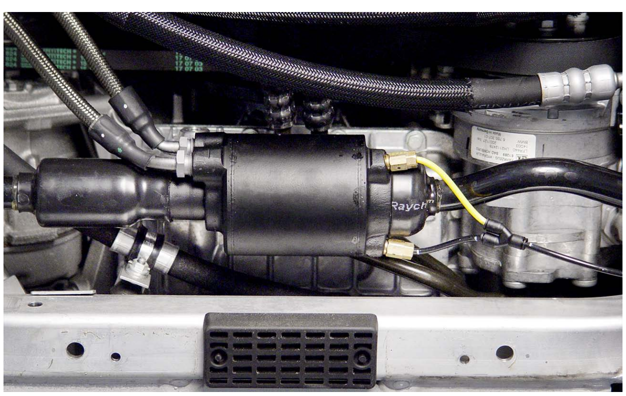


This illustration shows the main parts of an active stabilizer system.

The basic parts of an active stabilizer bar system include:

- a hydraulic fluid pump and reservoir. The pump may be a separate radial design pump for the stabilizer bar or the system may share the fluid pump with the power steering system. This tandem pump has a vane pump for power steering and a radial pump for the suspension system that are driven off the same shaft.

- a control module.
- control valves for control of the hydraulic fluid flow.
- high pressure hydraulic fluid lines.
- lateral acceleration sensors to measure the yaw rate, pitch, and roll of the vehicle body.
- hydraulic motors or actuators that are used to lock stabilizer bar halves together or connect the bar to the vehicle suspension.
- stabilizer bars. Each axle may have a stabilizer bar that is made of two parts or it may have a solid bar that is connected to the suspension on one side with a variable hydraulic linear actuator.



This is the oscillating motor that connects the two halves of the active stabilizer bar on a BMW 745i equipped with the optional dynamic drive system.

When a vehicle that is equipped with active stabilizer bars goes around a corner or curve:

- the lateral acceleration or yaw rate sensors detect the body roll and send a signal to the control module.
- the control module acts on the valve blocks to supply pressurized hydraulic fluid to the correct side of the oscillating motor or hydraulic actuator. The oscillating motor, or actuator, then twists the stabilizer bar halves in opposite directions to counteract the roll of the vehicle body over the suspension. This action keeps the body level and balances out the forces between the tires and the road, improving vehicle handling. The hydraulic oscillating motors are split chamber hydraulically controlled rotary actuators. One half of the stabilizer bar is attached to the oscillating motor shaft and the other half to the motor housing. As the shaft twists one way, the housing twists the other. Systems using a linear actuator apply pressure to one end of the stabilizer bar while twisting the other bar half in the direction that applies pressure in the opposite direction to the wheel on the opposite side.
- the reaction of the oscillating motors or actuators on the stabilizer bar halves is speed sensitive. At low speeds, the system is designed to provide neutral handling and lower turning

effort. At high speeds, the system is designed to have a larger stabilizing force on the front axle compared to the rear axle. This is done to give a slight amount of understeer to the vehicle handling. This creates a higher turning effort to reduce oversteer at higher speeds and gives the vehicle a more stable feel.

- if only one wheel is deflected by a bump, there is no opposition to suspension deflection caused by the stabilizer bar bump. When one wheel is deflected on a vehicle with a conventional stabilizer bar, the spring rate of the stabilizer bar will oppose the movement of the wheel and transmit forces to the wheel on the opposite side. With an active stabilizer bar, the two sides of the bar are allowed to twist independently of each other unless the hydraulic oscillating motor is activated. Unless the oscillating motor is activated by inputs that sense body roll, the stabilizer bar has no effect on the vehicle suspension.

Refer to Module 2, "Video: Active Stabilizer Operation" This animation shows the operation of an active stabilizer bar system.

These are the special hydraulic fluids required for the active stabilizer bar system used on some BMW vehicles.

Considerations when analyzing damage on active stabilizer bar systems include:

- electrical failures will typically give a trouble message on the information message center or light a MIL.
- vehicle-specific computer testers may be required for bleeding air from system parts if they have been replaced, or if hydraulic lines are opened. The system may also require a specific recalibration procedure using the vehicle-specific scan tool if parts are replaced or hydraulic lines are opened. Follow the vehicle maker's recommendations when performing system bleeding or recalibration. Stay clear of moving suspension parts as system parts may move on their own during the procedures.

- the use of specific hydraulic fluids are required for proper system operation. Use the fluid specified by the vehicle maker when adding fluid. Any disconnected hydraulic lines should be covered to seal them from contamination.
- correct positioning of the lateral acceleration sensors is critical to proper system operation. Damaged brackets or mounting points for the sensors may render the system inoperable. The sensors are also sensitive to shock loads and may require replacement if dropped or shocked in any way. To avoid damage, remove the sensors from areas where air chisels will be used or stress-relieving will be done.

KPI Improvement Tip
There may be special material / equipment requirements for some systems. For example, some systems require specialized high-pressure service equipment.

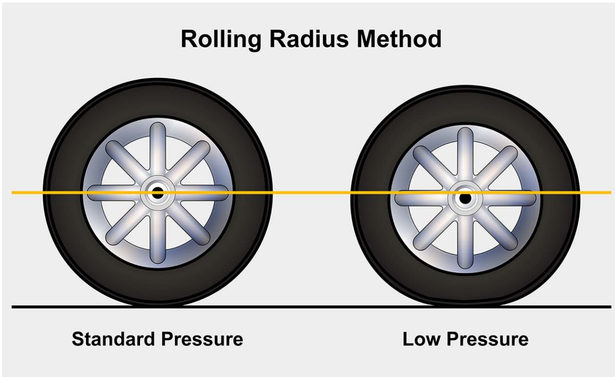
Tire Pressure Monitors

Ford Explorer

A tire pressure monitoring system would detect this low tire and warn the driver that a tire needs checking.

Tire pressure monitoring systems (TPMS):

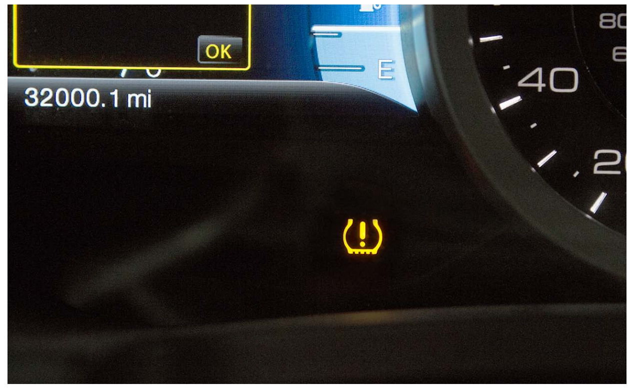
- warn the vehicle driver of a low tire. A warning lamp on the dash or message on the information message center is used to alert the driver of a low tire.
- are typically one of two different basic designs. Systems may be an indirect system, which calculates a pressure difference for a low tire using the ABS system, or a direct system which measures the actual pressure of each tire.



The rolling radius method used by indirect tire pressure monitoring systems detects a low tire by sensing the rotational speed difference between the low tire and the other tires.

Indirect tire pressure monitoring systems:

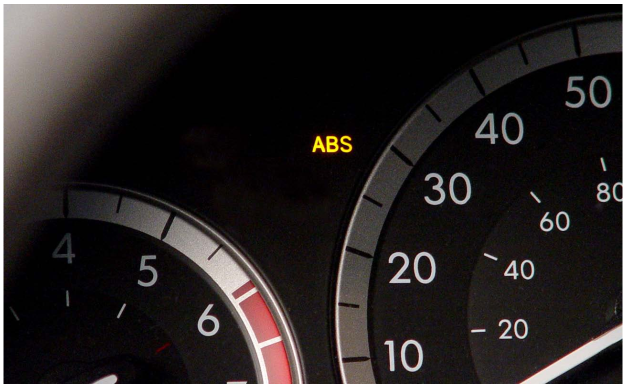
- use the anti-lock brake system (ABS) control module and sensors to operate. No new or added sensors or electronics are used in the system.
- detect differences in tire pressure. These systems do not calculate the actual pressure in the tire, but rather warn of differences between the pressures of the tires. A low tire will have a smaller effective diameter and will roll at a different speed than a fully inflated tire. By using the wheel speed sensors of the ABS system, the control module can detect that a tire is rolling at a different speed from the other tires. A drawback to this system is that the tire air pressure typically has to vary by about 25 - 30% before a low tire can be detected.
- typically require the vehicle to be driven for a specific driving sequence to calculate any pressure differences.



This is the warning lamp that indicates a low tire on this vehicle.

Indirect tire pressure monitoring systems:

- will not detect if two or more tires are low. Because they only detect pressure differences, they cannot make a determination if more than one tire is low.
- require a recalibration procedure when the diameter of the tires on the vehicle is changed.
- have a warning lamp on the dash that warns of a low tire. The lamp will not indicate which tire is low and will typically require resetting after the pressure difference or low tire is repaired.



A vehicle with an indirect tire pressure monitoring system will light the ABS MIL when a system problem is detected.

Indirect tire pressure monitoring collision repair issues include:

- no new or added sensors or electronics are used in the systems.
- the ABS MIL will typically be lit if a system problem is detected.
- scan tools are typically required for system diagnosis and to retrieve DTCs. DTC-based repair flowcharts are typically available in vehicle service manuals for repairing electronic system problems.

This is an example of an instrument panel display for a direct tire pressure monitoring system.

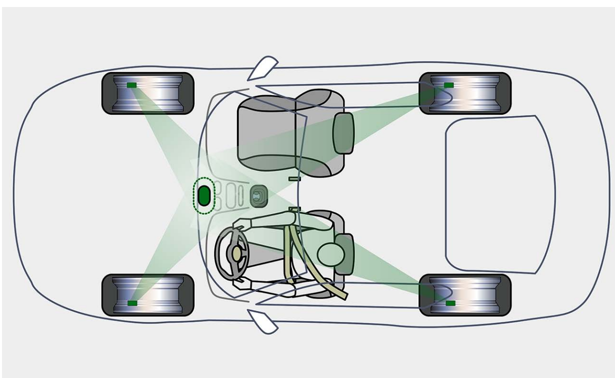
Direct tire pressure monitoring systems:

- measure and display the actual pressure of the tire.
- are not affected by changes in tire diameter.
- have a separate sensor for each tire. The sensors may be integrated into the valve stem or strapped to the inside of the rim. Some systems have the sensor designed into the rim and require rim replacement if a sensor is defective.

This is the direct tire pressure monitoring sensor for a Chevrolet Corvette.

Direct tire pressure monitor sensors:

- are small electronic circuit boards with a silicon-based pressure sensor built in.
- contain a radio frequency (RF) transmitter.
- have a built-in battery.
- contain a small computer processor with a small amount of read-only memory (ROM) and a clock speed of less than 4 MHz.



This illustration shows the radio signals sent from the individual tire pressure monitoring sensors, in each wheel, to the control module.

Direct tire pressure monitors:

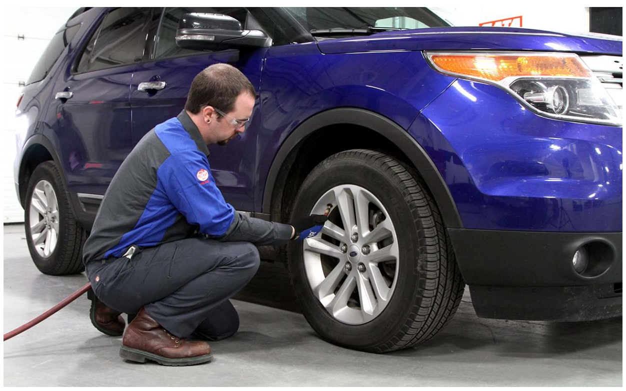
- typically measure both the pressure and temperature of the air in the tire.
- send a radio signal from the sensor in the tire to an antenna or receiver. The antenna may be located in the control module, or there may be separate antennas on the body near each tire that are wired into the control module.
- indicate a low tire with a warning lamp or message on the driver information center. On some systems, high air pressure may also set the low tire indicator.

This is the receiving antenna located in the wheelhouse area of a BMW 745i with a direct tire pressure monitoring system.

Repair considerations with direct tire pressure monitoring systems include:

- checking for damaged antennas or wiring. Receiving antennas may be located in areas susceptible to collision damage. Check antennas and wiring in the area of collision damage. Repair of the antenna wiring harness is typically not recommended.
- electronic malfunctions will typically require a scan tool for diagnosis.
- replacing damaged sensors. Sensors are not repairable. The valve stem core and cap used on direct tire pressure monitor sensors have a special design and function as the sensor antenna. Replacing them with valve stem

cores and caps from conventional valve stems may cause radio signal interference and cause a system malfunction. Replace the sensor if the correct valve stem core or cap is not available.
- not using tire sealers in tires with direct tire pressure monitor sensors. Tire sealers can clog the pressure sensor and cause a system malfunction.



After making an air pressure adjustment to this low tire, the technician will have to perform an initialization procedure on the tire pressure monitoring system.

Other issues with the repair of vehicles with direct tire pressure monitoring systems are that the systems typically require an initialization procedure after:

- tire rotation or replacement.
- tire pressure adjustments.
- pressure sensor replacement.

Follow the vehicle makers procedures for system initialization after repairs. Initialization or reprogramming may require a scan tool and may also require other vehicle specific tools.

Some Nissan models, such as the 2013 Altima and Quest, come with the "Easy-Fill Tire Alert" system. When a low tire is being filled with air, this system will activate a horn chirp when the tire hits the proper inflation level.

Module Wrap-Up

Topics discussed in this module included:

- the different types of electronic suspension systems.
- the operation of electronic suspension systems.
- electronically controlled system parts.
- damage analysis cautions with electronically controlled suspension systems.
- the different types of tire pressure monitoring systems.
- tire pressure monitoring system parts.
- damage analysis cautions with tire pressure monitoring systems.