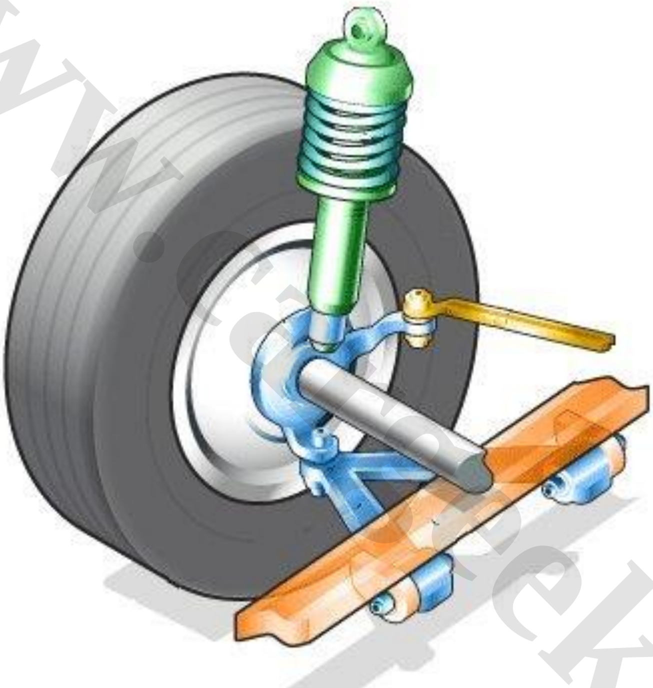
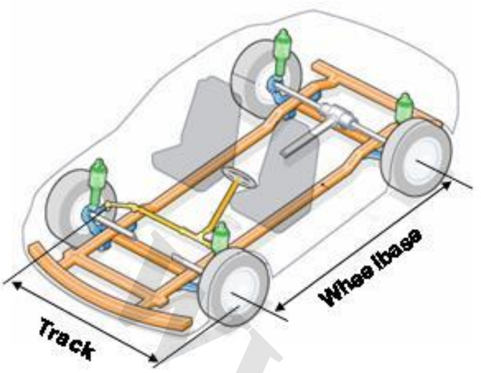
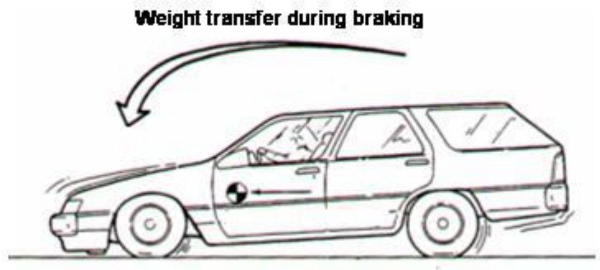
Suspension system 1



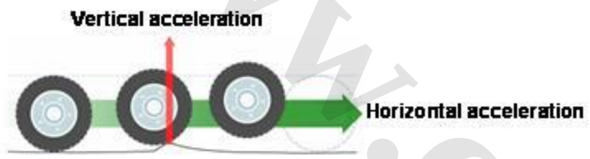
Index

Fundamentals of suspension

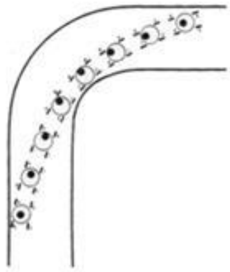




Tire force variation



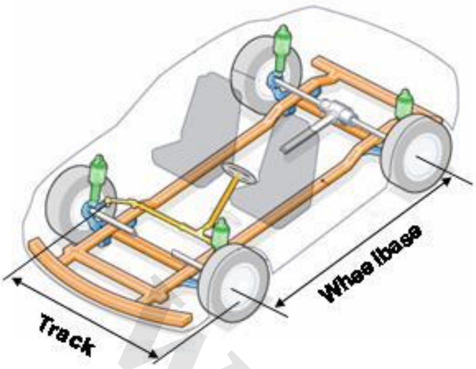
Road Isolation

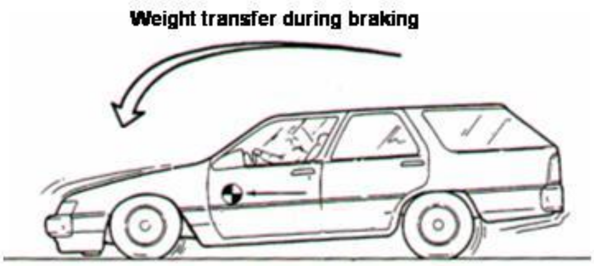


Vehicle turn

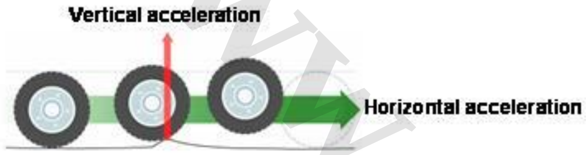
Wheelbase and Track:

The side to side distance between the centerline of the tires on an axle is called track. The distance between the centerline of the front and rear tires is called wheelbase. If the vehicle is in proper alignment, the wheels will roll in a line that is parallel with the vehicle's geometric centerline. The amount of grip or friction between the road and the tires is the major factor that limits how the vehicle accelerates, maneuvers through corners, and stops. The greater the frictions, the faster the car can accelerate, corner and stop. The tire to road contact of a vehicle is affected by several forces. Vehicle dynamics is the study of these forces and their effects on a vehicle in motion. Vehicle geometry, suspension, and steering design all affect the handling of a vehicle. Road isolation is the vehicle's ability to absorb or isolate road shock from the passenger compartment. The degree to which this is accomplished is controlled by the condition of the suspension system and its components. A properly functioning suspension system allows the vehicle body to ride relatively undisturbed while traveling over rough roads. This is accomplished through the combined use of bushings, springs, and hydraulic dampers.

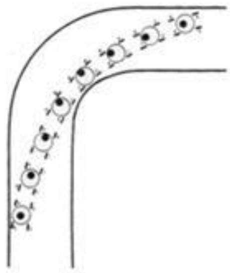




Tire force variation



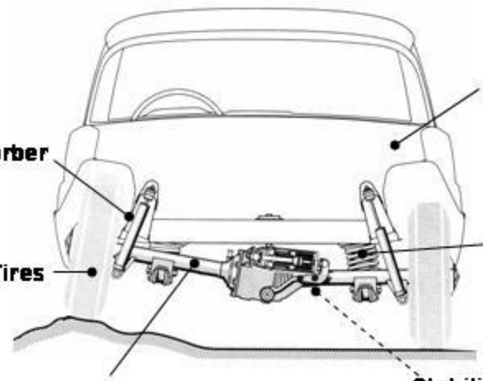
Road Isolation



Vehicle turn

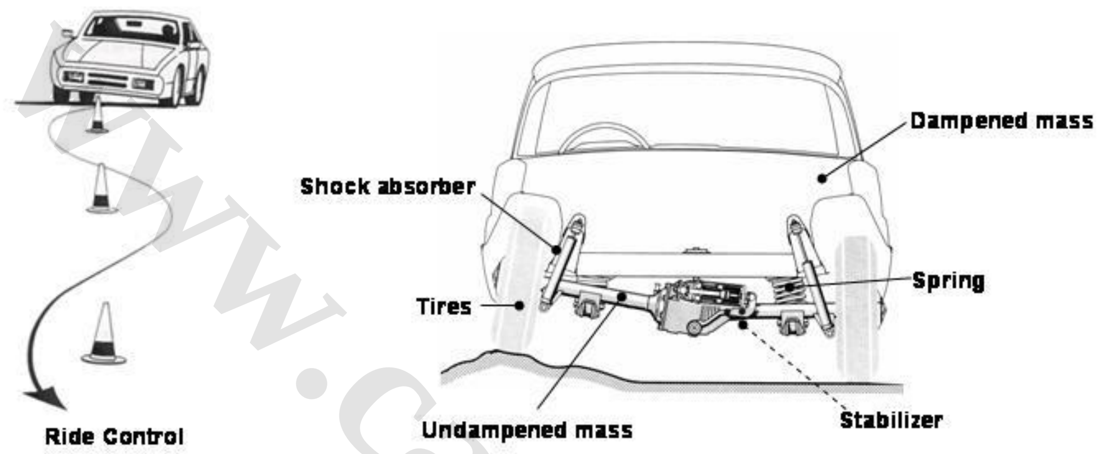
Tire force variation is a measure of the road holding capability of the vehicle and is directly influenced by shock absorber or strut performance. Shock absorbers and struts help maintain vertical loads placed on the tires by providing resistance to vehicle bounce, roll and sway during weight transfer. They also help reduce brake dive along with acceleration squat to achieve a balanced ride. Tire loading changes as a vehicle's center of gravity shifts during acceleration, deceleration, and turning corners.

The center of gravity is a point near the center of the car; it is the balance point of the car. As the vehicle brakes, inertia will cause a shift in the vehicle’s center of gravity and weight will transfer from the rear tires to the front tires. This is known as dive. Similarly, weight will transfer from the front to the back during acceleration. This is known as squat. As a vehicle turns a corner, centrifugal force pushes outward on the car’s center of gravity. Centrifugal force is resisted by the traction of the tires. The interaction of these two forces moves weight from the side of the vehicle on the inside of the turn to the outside of the car, and the car leans. As this occurs, weight leaves the springs on the inside and that side of the vehicle rises. This weight goes to the springs on the outside, and that side of the vehicle lowers. This is what is known as body roll.



Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serve a dual purpose - contributing to the car's handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear car suspensions may be different. Vehicle shock absorbers are actually vibration dampers. However, in automotive chassis application “shock absorbers” has become the most widely used term.

As you have learned before many things affect vehicles in motion. Weight distribution, speed, road conditions and wind are some factors that affect how vehicles travel down the highway. Under all these variables however, the vehicle suspension system including the shocks, struts and springs must be in good condition. Worn suspension components may reduce the stability of the vehicle and reduce driver control. They may also accelerate wear on other suspension components. With no suspension: the vehicle is solid and loses contact with the road as it goes over bumps. With springs but no shock absorbers: The vehicle is able to absorb bumps, but the un dampened suspension means that the vehicle continues to bounce and causes the tires to leave the road. With springs and shock absorbers: the vehicle not only absorbs bumps but also the shock absorbers dampen the springs and prevent the vehicle from bouncing. Together they keep the tires in contact with the road.



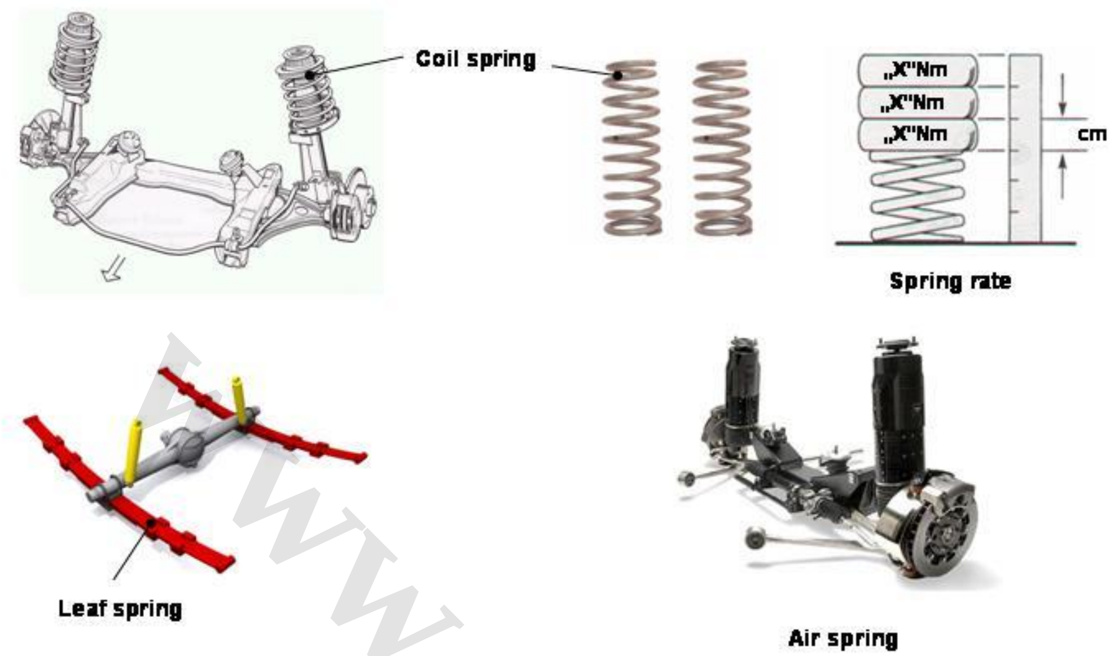
The chassis is what connects the tires and wheels to the vehicle's body. The chassis consists of the frame, suspension system, steering system, tires and wheels. The frame is the structural load-carrying member that supports a car’s engine and body, which are in turn supported by the suspension and wheels. The suspension system is an assembly used to support weight, absorb and dampen road shock, and help maintain tire contact as well as proper wheel to chassis relationship. The steering system is the entire mechanism that allows the driver to guide and direct a vehicle.

Spring

The springs support the weight of the vehicle, maintain ride height, and absorb road shock. Springs are the flexible links that allow the frame and the body to ride relatively undisturbed while the tires and suspension follow the bumps in the road. Springs are the compressible link between the frame and the body. When an additional load is placed on the springs, or the vehicle meets a bump in the road, the springs will absorb the load by compressing. The springs are a very important component of the suspension system that provides ride comfort. During the study of springs, the term bounce refers to the vertical (up and down) movement of the suspension system. The upward suspension travel that compresses the spring and shock absorber is called the jounce, or compression. The downward travel of the tire and wheel that extends the spring and shock absorber is called rebound, or extension.

Coil spring

The most commonly used spring is the coil spring. The coil spring is a length of round spring steel rod that is wound into a coil. The diameter and length of the wire determine the strength of a spring. Increasing the wire diameter will produce a stronger spring, while increasing its length will make it more flexible. Spring rate, sometimes referred to as deflection rate, is used to measure the spring strength. It is the amount of weight that is required to compress the spring 2.5cm. Some coil springs are made with a variable rate. This variable rate is accomplished by either constructing this spring from materials having different thickness or by winding the spring so the coil will progressively compress at a higher rate. Variable rate springs provide a lower spring rate under unloaded conditions offering a smoother ride, and a higher spring rate under loaded conditions, resulting in more support and control.



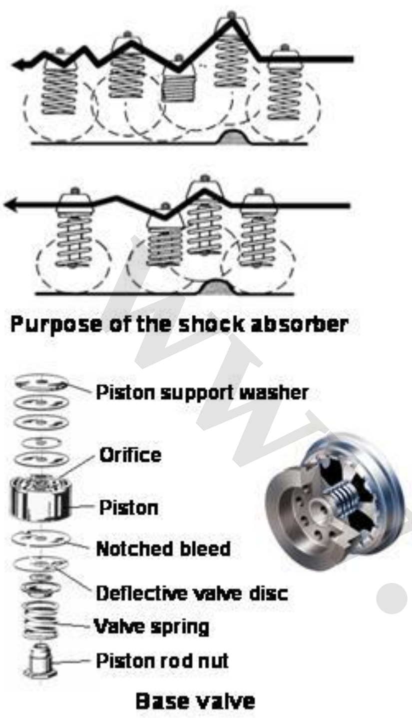
Leaf spring

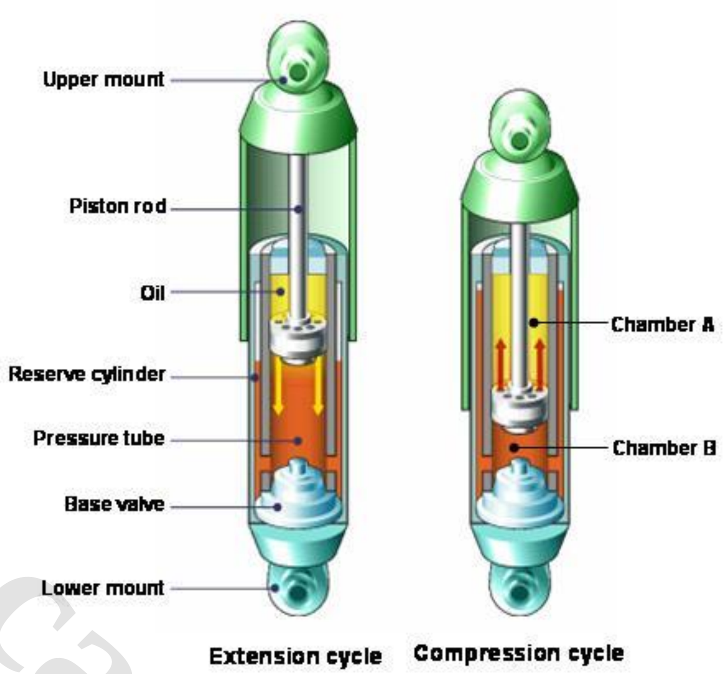
Leaf springs are designed two ways: multi-leaf and mono-leaf. The multi-leaf spring is made of several steel plates of different lengths stacked together. During normal operation, the spring compresses to absorb road shock. The leaf springs bend and slide on each other allowing suspension movement. An example of a mono-leaf spring is the tapered leaf spring. The leaf is thick in the middle and tapers toward the two ends. Many of these leaf springs are made of a composite material, while others are made of steel. In most cases leaf springs are used in pairs mounted longitudinally (front to back). However, there are an increasing number of vehicle manufacturers using a single transverse (side to side) mounted leaf spring.

Air spring

The air spring is another type of spring that is becoming more popular on passenger cars, light trucks, and heavy trucks. The air spring is a rubber cylinder filled with compressed air. A piston attached to the lower control arm moves up and down with the lower control arm. This causes the compressed air to provide spring action. If the vehicle load changes, a valve

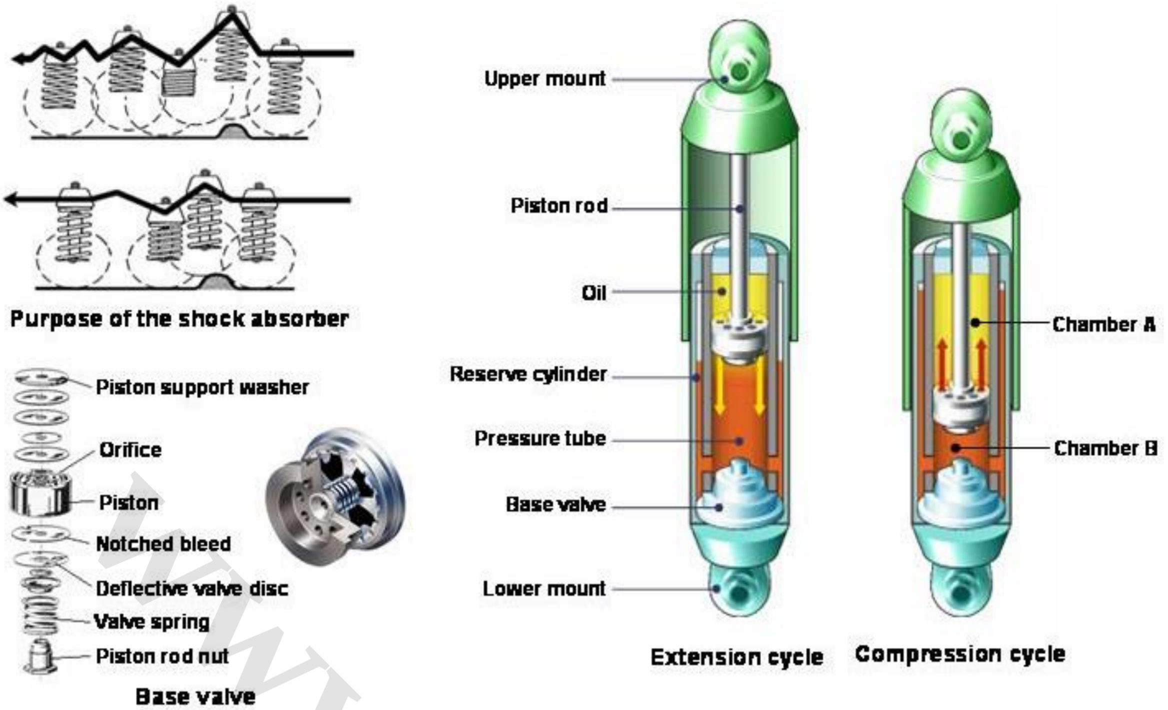
Shock absorber operation principle





Without shock absorbers and struts the spring will extend and release its energy at an uncontrolled rate. By controlling spring and suspension movement, components such as tie rods will operate within their design range and, while the vehicle is in motion, dynamic wheel alignment will be maintained. Conventional shock absorbers do not support vehicle weight. Instead, the primary purpose of the shock absorber is to control spring and suspension movement. This is accomplished by turning the kinetic energy of suspension movement into thermal energy, or heat energy, to be dissipated through the hydraulic fluid. Shock absorbers are basically oil pumps. A piston is attached to the end of the piston rod and works against hydraulic fluid in the pressure tube.

As the suspension travels up and down, the hydraulic fluid is forced through tiny holes, called orifices, inside the piston. However, these orifices let only a small amount of fluid through the piston. This slows down the piston, which in turn slows down spring and suspension movement. The amount of resistance a shock absorber develops depends on the speed of the suspension and the number and size of the orifices in the piston. All modern shock absorbers are velocity sensitive hydraulic damping devices - meaning the faster the suspension moves, the more resistance the shock absorber provides. Because of this feature, shock absorbers adjust to road conditions. As a result, shock absorbers reduce the rate of: bounce, roll or sway, brake dive and acceleration squat.

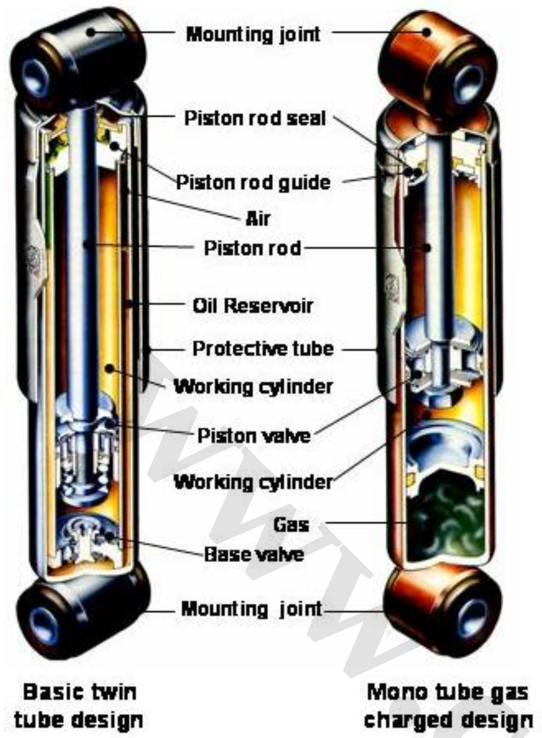


Shock absorbers work on the principle of fluid displacement on both, the compression and extension cycle. A typical car or light truck will have more resistance during its extension cycle then its compression cycle. The compression cycle controls the motion of a vehicle's unsprung weight, while extension controls the heavier sprung weight.

Compression cycle: During the compression stroke or downward movement, some fluid flows through the piston from chamber B to chamber A, and some through the compression valve into the reserve cylinder. To control the flow, there are three valve stages each in the piston and in the base valve. At slow piston speeds, the first stage come into play and restricts the amount of oil flow. This allows a controlled flow of fluid from chamber B to chamber A. At faster piston speeds, the increase in fluid pressure below the piston in chamber B causes the discs to open up away from the valve seat. At high speeds, the limit of the second stage discs phases into the third stage *orifice* restrictions. Compression control, then, is the force that results from a higher pressure present in chamber B, which acts on the bottom of the piston and the piston rod area.

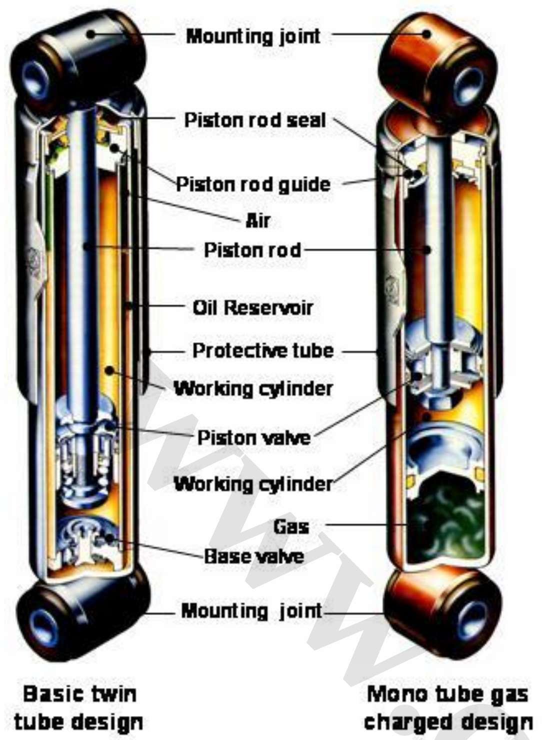
Extension cycle: As the piston and rod move upward toward the top of the pressure tube, the volume of chamber A is reduced and thus is at a higher pressure than chamber B. Because of this higher pressure, fluid flows down through the piston's 3-stage extension valve into chamber B. However, the piston rod volume has been withdrawn from chamber B greatly increasing its volume. Thus the volume of fluid from chamber A is insufficient to fill chamber B. The pressure in the reserve tube is now greater than that in chamber B, forcing the base intake valve to unseat. Fluid then flows from the reserve tube into chamber B, keeping the pressure tube full. Extension control is a force present as a result of the higher pressure in chamber A, acting on the topside of the piston area.

Shock absorber types



There are several shock absorber designs in use today such as single or twin tube, gas and or oil charged designs. The twin tube design has an inner tube known as the working or pressure tube and an outer tube known as the reserve tube. The outer tube is used to store excess hydraulic fluid. Notice that the piston rod passes through a rod guide and a seal at the upper end of the pressure tube. The rod guide keeps the rod in line with the pressure tube and allows the piston to move freely inside. The seal keeps the hydraulic oil inside and contamination out. The base valve located at the bottom of the pressure tube controls fluid movement during the compression cycle. Bore size is the diameter of the piston and the inside of the pressure tube. Generally, the larger the unit, the higher the potential control levels because of the larger piston displacement and pressure areas. The larger the piston area, the lower the internal operating pressure and temperatures. This provides higher damping capabilities. Twin Tube - Gas Charged Design

The development of gas charged shock absorbers was a major advance in ride control technology. This advance solved many ride control problems which occurred due to an increasing number of vehicles using uni-body construction, shorter wheelbases and increased use of higher tire pressures. The pressure of the nitrogen in the reserve tube varies from 6bar to 10 bar, depending on the amount of fluid in the reserve tube. The pressure of the nitrogen gas compresses air bubbles in the hydraulic fluid. This prevents the oil and air from mixing and creating foam. Foam affects performance because it can be compressed - fluid can not. With aeration reduced, the shock is able to react faster and more predictably, allowing for quicker response time and helping keep the tire firmly planted on the road surface.



An additional benefit of gas charging is that it creates a mild boost in spring rate to the vehicle. This does not mean that a gas charged shock would raise the vehicle up to correct ride height if the springs were sagging. It does help reduce body roll, sway, brake dive, and acceleration squat. This mild boost in spring rate is also caused by the difference in the surface area above and below the piston. With greater surface area below the piston than above, more pressurized fluid is in contact with this surface. This is why a gas charged shock absorber will extend on its own.

Mono-tube design

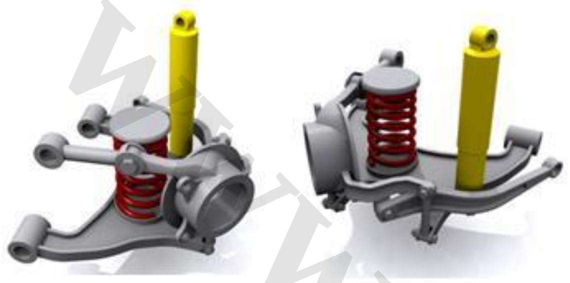
These are high-pressure gas shocks with only one tube, the pressure tube. Inside the pressure tube there are two pistons: a dividing piston and a working piston. The working piston and rod are very similar to the twin tube shock design. The difference in actual application is that a mono-tube shock absorber can be mounted upside down or right side up and will work either way. In addition to its mounting flexibility, mono-tube shocks are a significant component, along with the spring, in supporting vehicle weight. Another difference you may notice is that the mono-tube shock absorber does not have a base valve. Instead, all of the control during compression and extension takes place at the piston. The pressure tube of the mono-tube design is larger than a twin tube design to accommodate for dead length. A free-floating dividing piston travels in the lower end of the pressure tube, separating the gas charge and the oil. The area below the dividing piston is pressurized to about 24bar with nitrogen gas. This high gas pressure helps support some of the vehicle's weight. The oil is located in the area above the dividing piston. During operation, the dividing piston moves up and down as the piston rod moves in and out of the shock absorber, keeping the pressure tube full all times.

Independent front suspension


McPherson


Double wishbone (Coil Spring type 1)


Double wishbone (Coil Spring type 2)


Multi-link


Trailing arm

McPherson struts:

The system basically comprises of a spring and shock absorber which pivots on a ball joint on the single, lower arm. At the top end there is a needle roller bearing on some more sophisticated systems. The strut itself is the load-bearing member in this assembly, with the spring and shock absorber performing their duty as oppose to actually holding the car up. In the picture here, you can't see the shock absorber because it is encased in the black gaiter inside the spring. The steering gear is either connected directly to the lower shock absorber housing, or to an arm from the front or back of the spindle (in this case). When you steer, it physically twists the strut and shock absorber housing (and consequently the spring) to turn the wheel. The spring is seated in a special plate at the top of the assembly which allows this twisting to take place.

Double wishbone (Coil Spring type 1)

This is a type of double-A or double wishbone suspension. The wheel spindles are supported by an upper and lower 'A' shaped arm. In this type, the lower arm carries most of the load. If you look head-on at this type of system, what you'll find is that it's a very parallelogram system that allows the spindles to travel vertically up and down. When they do this, they also have a slight side-to-side motion caused by the arc that the wishbones describe around their pivot points. This side-to-side motion is known as scrub. Unless the links are infinitely long the scrub motion is always present. There are two other types of motion of the wheel relative to the body when the suspension articulates. The first is a toe angle (steer angle). The second is the camber angle. Steer and camber are the ones which wear tires.


McPherson


Double wishbone (Coil Spring type 1)


Double wishbone (Coil Spring type 2)


Multi-link


Trailing arm

Double wishbone (Coil Spring type 2)

This is also a type of double-A arm suspension although the lower arm in these systems can sometimes be replaced with a single solid arm (as shown in the picture). The only real difference between this and the previous system mentioned above is that the spring/shock combo is moved from between the arms to above the upper arm. This transfers the load-bearing capability of the suspension almost entirely to the upper arm and the spring mounts. The lower arm in this instance becomes a control arm.

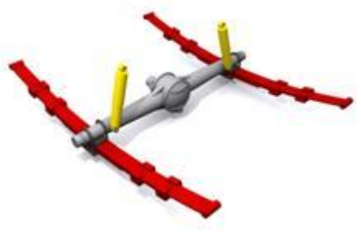
Multi-link suspension

The basic principle of the multi link suspension is the same as described under double wishbone, but instead of solid upper and lower wishbones, each 'arm' of the wishbone is a separate item. These are joined at the top and bottom of the spindle thus forming the wishbone shape. As the spindle turns for steering, it alters the geometry of the suspension by torque all four suspension arms. They have complex pivot systems designed to allow this to happen. There are a lot of variations possible with huge differences in the numbers and complexities of joints, numbers of arms, positioning of the parts etc. but they are all fundamentally the same. Note that in this system the spring (red) is separate from the shock absorber (yellow).

Trailing-arm suspension

The trailing arm system has a suspension arm which is joined at the front to the chassis, allowing the rear to swing up and down. Pairs of these become twin-trailing-arm systems and work on exactly the same principle as the double wishbones in the systems described before. The difference is that instead of the arms sticking out from the side of the chassis, they travel back parallel to it.

Dependent rear suspension types


Solid axle, leaf spring


Solid axle, coil spring


Beam Axle


4-Bar system

Solid axle, leaf spring

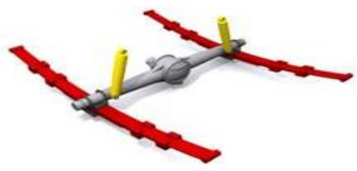
On this system the drive axle is clamped to the leaf springs and the shock absorbers normally bolt directly to the axle. The ends of the leaf springs are attached directly to the chassis, as are the tops of the shock absorbers. The main drawback with this arrangement is the lack of lateral location for the axle, meaning it has a lot of side-to-side slop in it.

Solid-axle, coil-spring

The basic idea is the same, but the leaf springs have been removed in favor of both ‘coil-over-oil’ spring and shock combos, or as shown here, separate coil springs and shock absorbers. Because the leaf springs have been removed, the axle now needs to have lateral support from a pair control arms. The front ends of these are attached to the chassis, the rear ends to the axle. The variation shown here is more compact than the coil-over-oil type, and it means you can have smaller or shorter springs. This in turn allows the system to fit in a smaller area under the car.

Beam Axle

This system is used in front wheel drive cars, where the rear axle isn't driven. The beam runs across under the car with the wheels attached to either end of it. Spring / shock units or struts are bolted to both end and seat up into suspension wells in the car body or chassis. The beam has two integral trailing arms built in instead of the separate control arms required by the solid-axle coil-spring system. Variations on this system can have either separate springs and shocks, or the combined 'coil-over-oil' variety as shown here.


Solid axle, leaf spring


Solid axle, coil spring


Beam Axle


4-Bar system

One noticeable feature of this system is the track bar (or Panhard rod). This is a diagonal bar which runs from one end the beam to a point either just in front of the opposite control arm (as here) or sometimes diagonally up to the top of the opposite spring mount . This is to prevent side-to-side movement in the beam which would cause handling problems. A variation on this them is the twist axle which is identical with the exception of the Panhard rod. In a twist axle, the axle is designed to twist slightly. This gives, in effect, a semi-independent system whereby a bump on one wheel is partially soaked up by the twisting action of the beam. Another variation on this system does away with the springs and replaces them with torsion bars running across the chassis, and attached to the leading edge of the control arms.

4-Bar system

4-bar suspension can be used on the front and rear of vehicles and come in two varieties. Triangulated, shown on the right here, and parallel, shown on the left.

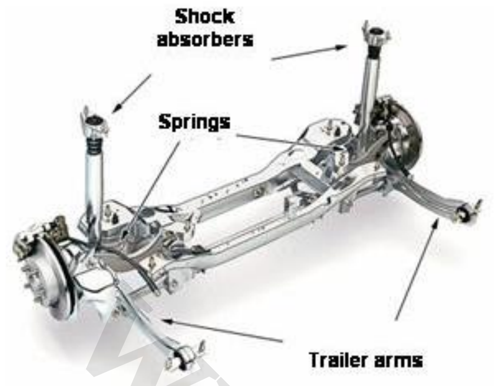
The parallel design operates on the principal of a "constant motion parallelogram". The design of the 4-bar is such that the rear end housing is always perpendicular to the ground, and the pinion angle never changes. This, combined with the lateral stability of the Panhard Bar, does an excellent job of locating the rear end and keeping it in proper alignment.

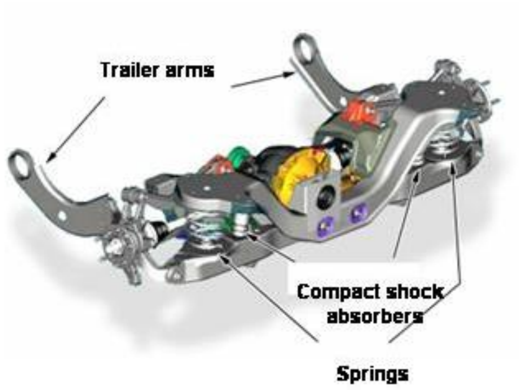
The triangulated design operates on the same principle, but the top two bars are skewed inwards and joined to the rear end housing much closer to the centre. This eliminates the need for the separate Panhard bar, which in turn means the whole setup is even more compact.

There are many variations on the 4-bar systems for example.

If the four angled bars go from the axle outboard to the chassis near the centreline, this is called a "Satchell link".It has certain advantages over the above examples. Both of these angled linkages can be reversed to have the angled links below the axle and the parallel links above. The roll centre will be lowered with the angled bars under the axle, a function which is difficult to accomplish without this design.

Independent rear suspension

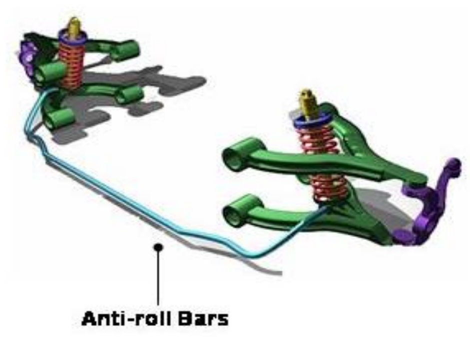




It follows, that what can be fitted to the front of a car, can be fitted to the rear to without the complexities of the steering gear. Simplified versions of all the independent systems can be found on the rear axles of cars. This means all the wheels are independently mounted and sprung. The primary purpose of this type of suspension is to increase the interior space available in the vehicle. Most suspension systems used have strut towers front and rear. In the front it's not really a problem, but in the rear it impedes on boot (or trunk) space.

The independent rear suspension type separates the shock absorber from the springs. To do this, a trailing-arm type suspension is required so that there are no swing arms up under the wheel arches. The springs are shortened and moved inboard and underneath. In one variation, the shock absorbers still sit vertically but the space they take up now is hugely reduced because they no longer have the coil springs around the outside. In the second variation the shock absorber is a subminiature unit mounted inboard of the springs underneath the vehicle.

Anti roll bars, strut brace, suspension bushes



Suspension bushes: there are many types of shock absorber mounts used today. Most of these use rubber bushings between the shock absorber and the frame or suspension to reduce transmitted road noise and suspension vibration. The rubber bushings are flexible to allow movement during suspension travel. The upper mount of the shock absorber connects to the vehicle frame.

Anti-roll bar: (also stabilizer bar, anti-sway bar, sway bar, or anti-roll bar, ARB) is an automobile suspension device. It connects opposite (left/right) wheels together through short lever arms linked by a torsion spring. A sway bar increases the suspension's roll stiffness -- its resistance to roll in turns, independent of its spring rate in the vertical direction. Increasing the roll stiffness of the suspension increases the rate of weight transfer to the wheels on the outside of the turn. As more weight is applied to the outer wheels, the adhesion of the tires is increased until their limits are reached, increasing their slip angles. If the front and rear weight transfer is unequal, the slip angles of the end with the greater weight transfer will be larger, resulting in under steer or over steer. The use of anti-roll bars allows the weight transfer of the front and rear wheels to be adjusted separately, compensating for unequal front/rear weight balance and "tuning" the vehicle's handling characteristics.

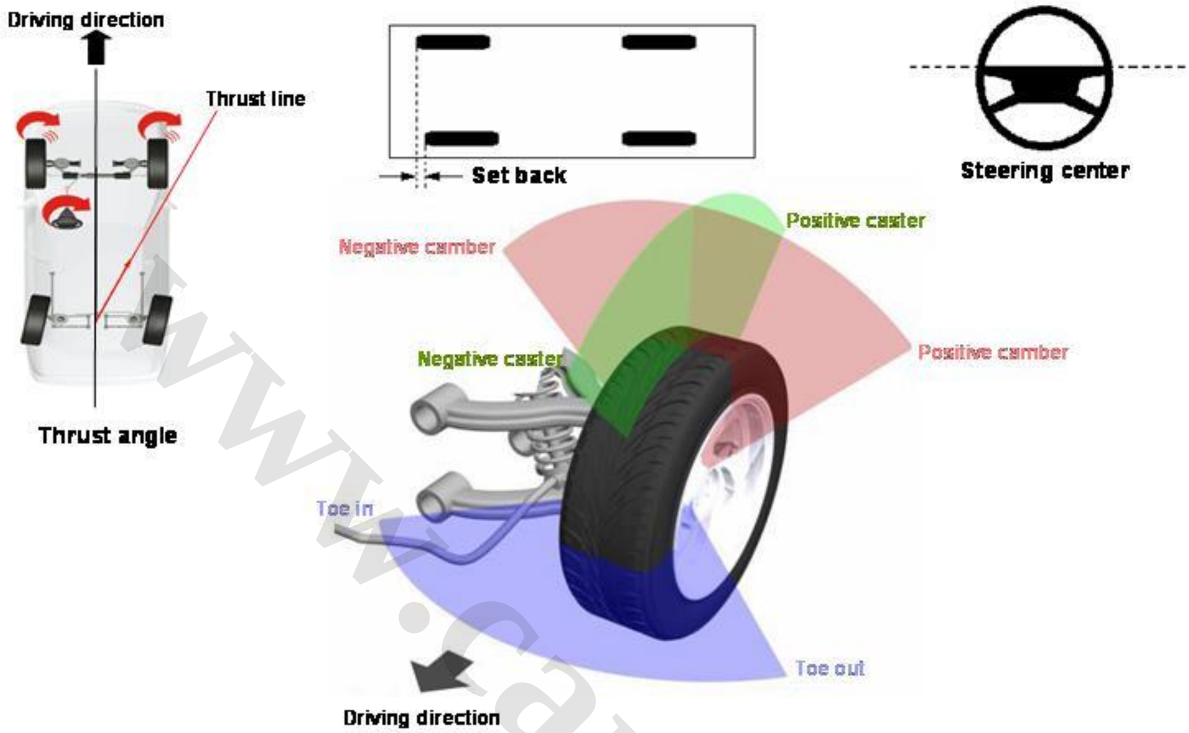
Strut braces: a strut bar or strut brace can be used in conjunction with McPherson struts on monocoque or unibody chassis to provide extra strength between the strut towers. A strut bar is designed to reduce this strut tower flex by tying two parallel strut towers together. This transmits the load of each strut tower during cornering via tension and compression of the strut bar which shares the load between both towers. A direct result of this is improved chassis rigidity, the under-steer is reduced, tire wear improved and metal fatigue is greatly reduced in the strut tower.

Service and diagnosis

Coil springs require no adjustment and for the most part are trouble-free. The most common failure is spring sag. Springs that have sagged below vehicle design height will change the alignment geometry. This can create tire wear, handling problems, and wear other suspension components. During suspension service it is very important that vehicle ride height be measured. Ride height measurements not within manufacturer's specifications require replacement of springs.

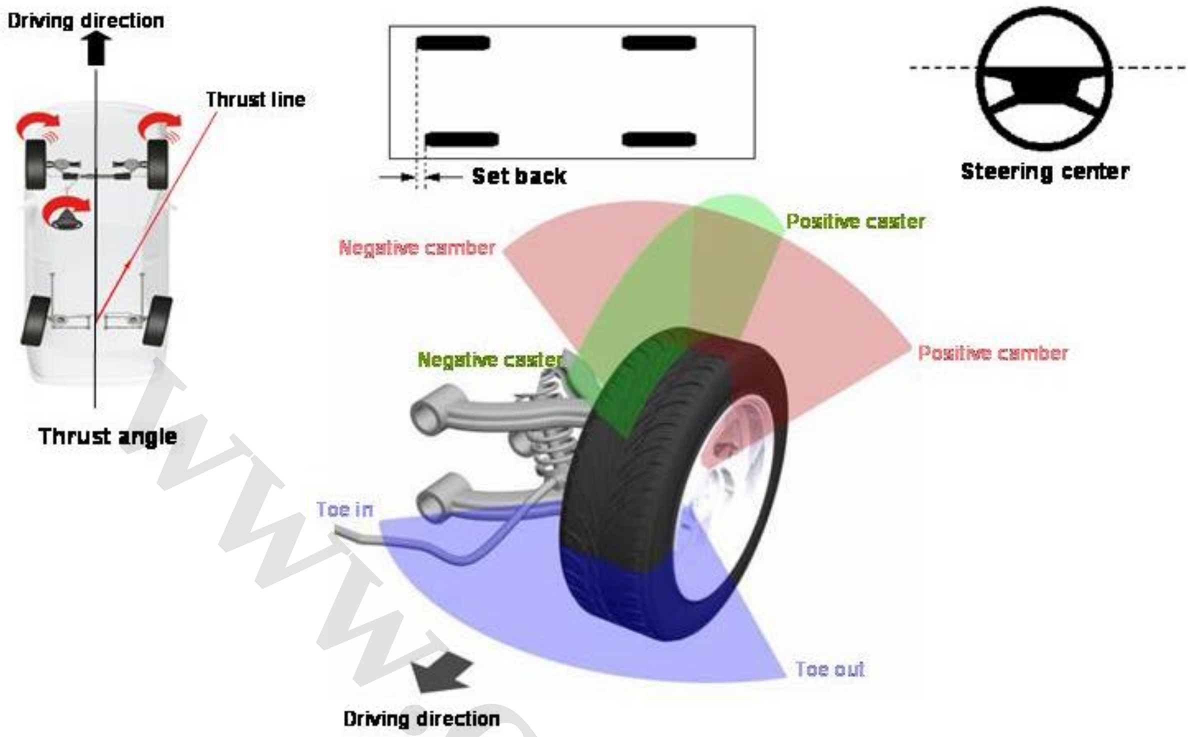
Shock absorbers can be checked by using a shock absorber test bench, by teeter the car or by removing the shock absorber from the car. Visual checks should be performed to identify damaged oil seals (which can result in a sticking shock absorber) , sliding marks or cracked mounting joints. Please tighten the bolts to the specified tightening torque given in the workshop manual.

Wheel alignment



Every driver expects their vehicle to have a straight steering wheel and travel in a straight line, without deviation, unless they're turning. In a turn, the vehicle should travel only where it's steered and return to center when you complete the turn. Incorrect wheel alignment can create several problems such as : the steering wheel is not straight when driving on a level road, unusual noises in the suspension system, the vehicle wanders from one side of a lane to the other, the vehicle pulls or drifts to one side when traveling in a straight line or when braking , you feel vibration in the steering wheel or through your vehicle's seat, the vehicle's steering feels loose, the tires are wearing unevenly, the Tires are squealing on turns or the steering wheel does not return easily after a turn.

Correct alignment is critical to safely controlling your vehicle, braking stability, extending tire life, and ensuring a comfortable ride. The complexity of modern suspension systems requires careful measurements at all four wheels and precise adjustments.



Thrust angle

On this vehicle, the front wheels are not aligned to the rear thrust line. This can happen from normal wear and stress, whether your vehicle has adjustable or non-adjustable rear suspension. To steer straight ahead, you would have to steer the front wheels slightly to the right. A common result would be that the vehicle would "dog track" and possibly "pull" to the side. Of course, the angles are exaggerated so you can more easily see the condition. But it takes only a small misalignment to create problems.

It is extremely important that your vehicle's front wheels are aligned to the rear wheels.

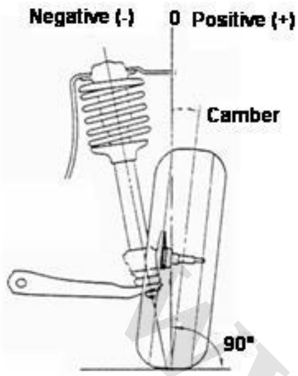
Set back

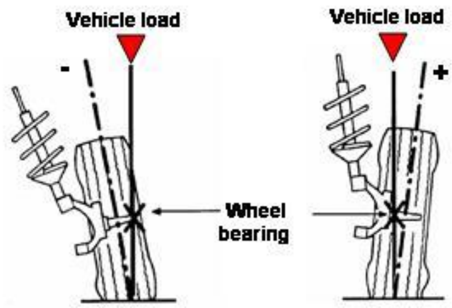
Set back is when one front wheel is set further back than the other wheel. With alignment equipment that measures toe by using only the front instruments, any setback will cause a un-centered steering wheel. Any good 4-wheel aligner will reference the rear wheels when setting toe in order to eliminate this problem. Some good alignment equipment will measure set back and give you a reading in inches or millimeters. If the value is out of specification there is a good chance that something is bent.

Steering center

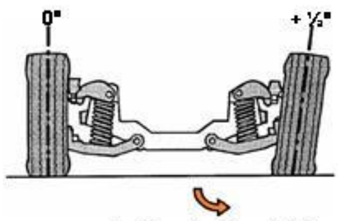
Steering center is simply the fact that the steering wheel is centered when the vehicle is traveling down a straight and level road. A crooked steering wheel is usually the most common complaint that a customer has after a wheel alignment is performed. Assuming that the steering wheel stays in the same position when you let go of the wheel (in other words, the car is not pulling), then steering center is controlled by the front and rear toe settings.

Camber and caster

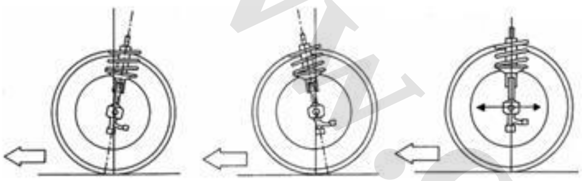




Vehicle load and wheel bearing

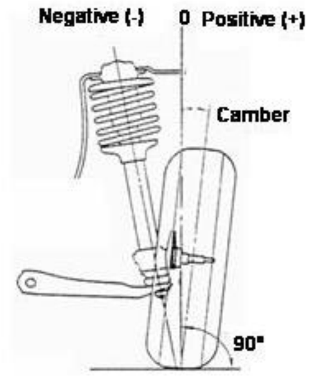


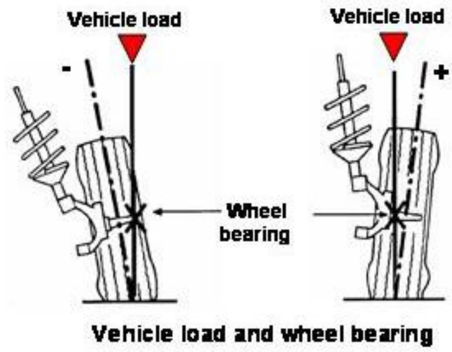
Pulling to the right

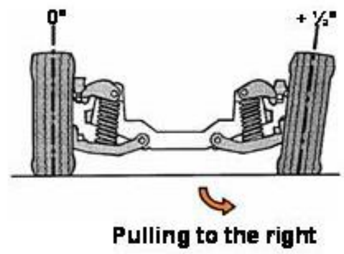

Positive Caster Negative Caster 0 Caster

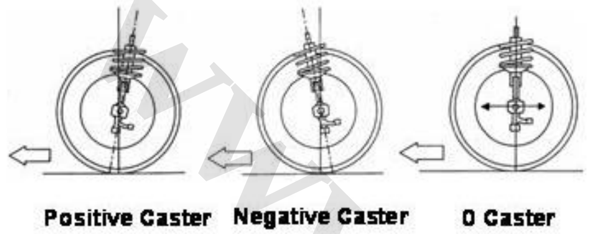
Camber

Camber is the angle of the wheel, measured in degrees, when viewed from the front of the vehicle. When the top of a wheel is tilted outward, it is called positive camber. Conversely, inward inclination is called negative camber. On many vehicles, camber changes with different road speeds. This is because aerodynamic forces cause a change in riding height from the height of a vehicle at rest. Because of this, riding height should be checked and problems corrected before setting camber. On many front-wheel-drive vehicles, camber is not adjustable. If the camber is out on these cars, it indicates that something is worn or bent, possibly from an accident and must be repaired or replaced. Rear camber is not adjustable on most rear wheel drive vehicles. These vehicles are built with zero camber setting. Slight positive camber results in a dynamic loading that allows the tire to run relatively flat against the road surface. Positive camber also directs the weight and shock load of the vehicle on the larger inner wheel bearing and inboard portion of the spindle. Positive camber in moderation results in longer bearing life, less likely sudden load failure, and as a side benefit, easier steering. Excessive positive camber wears the outside of the tire and can cause wear to suspension parts such as wheel bearings and spindles. Variations in negative camber can be used to improve the handling of a vehicle. Negative setting compensates for the slight positive camber change of the outside tire due to vehicle roll, thereby allowing a flatter tire contact patch during cornering.







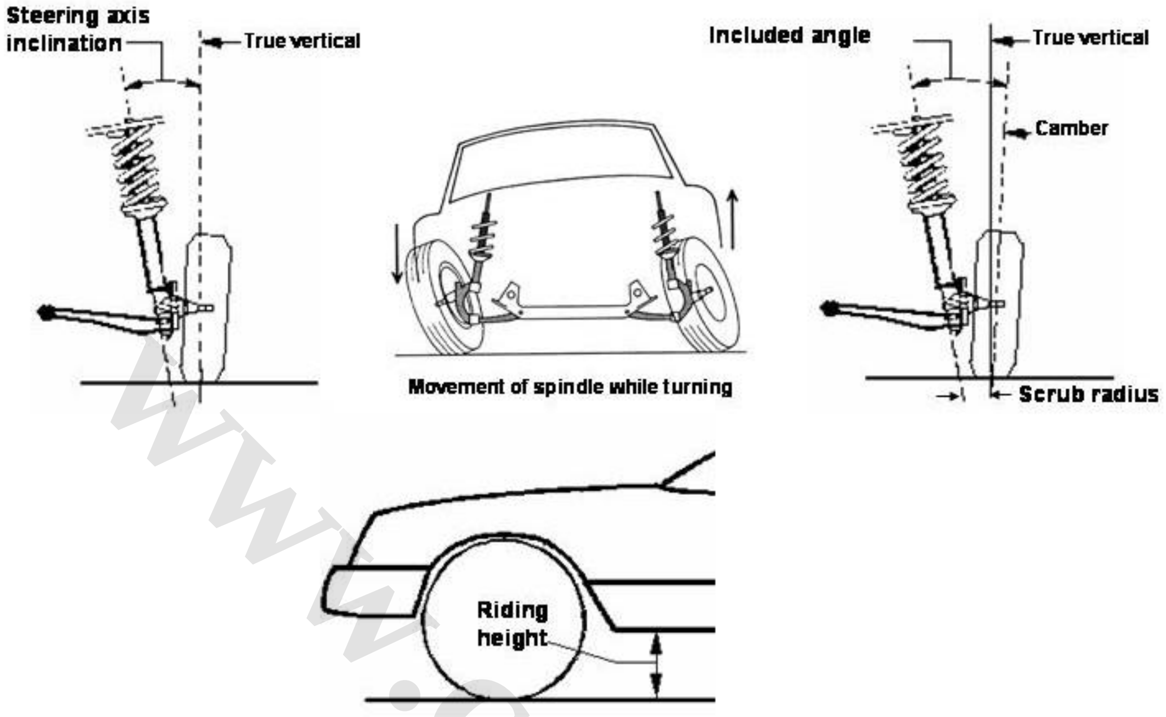


Caster

When you turn the steering wheel, the front wheels respond by turning on a pivot attached to the suspension system. Caster is the angle of this steering pivot, measured in degrees, when viewed from the side of the vehicle. If the top of the pivot is leaning toward the rear of the car, then the caster is positive, if it is leaning toward the front, it is negative. If the caster is out of adjustment, it can cause problems in straight line tracking. If the caster is different from side to side, the vehicle will pull to the side with the less positive caster.

If the caster is equal but too negative, the steering will be light and the vehicle will wander and be difficult to keep in a straight line. If the caster is equal but too positive, the steering will be heavy and the steering wheel may kick when you hit a bump. Caster has little affection on tire wear. Like camber, on many front-wheel-drive vehicles, caster is not adjustable. If the caster is out on these cars, it indicates that something is worn or bent, possibly from an accident, and must be repaired or replaced.

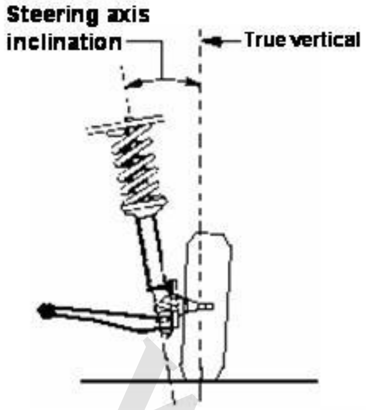
Steering angle inclination

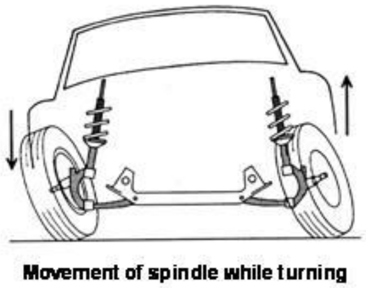


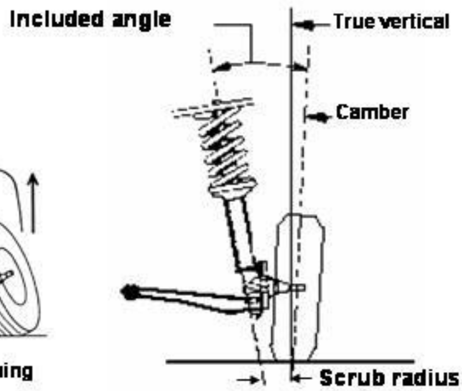
Steering Axis Inclination (SAI)

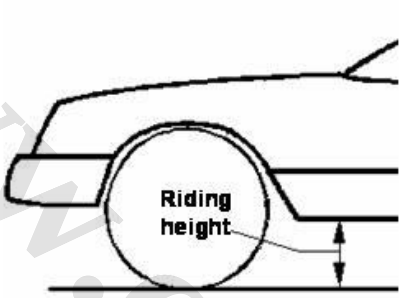
SAI is the measurement in degrees of the steering pivot line when viewed from the front of the vehicle. This angle, when added to the camber to form the included angle causes the vehicle to lift slightly when you turn the wheel away from a straight ahead position. This action uses the weight of the vehicle to cause the steering wheel to return to the center when you let go of it after making a turn. Because of this, if the SAI is different from side to side, it will cause a pull at very slow speeds. Most alignment machines have a way to measure SAI; however it is not separately adjustable. The most likely cause for SAI being out is bent parts which must be replaced to correct the condition. SAI is also referred to as KPI (King Pin Inclination) on trucks and old cars with king pins instead of ball joints.

Included angle: is the angle formed between the SAI and the camber. Included angle is not directly measurable. To determine the included angle, you add the SAI to the camber. If the camber is negative, then the included angle will be less than the SAI, if the camber is positive, it will be greater. The included angle must be the same from side to side even if the camber is different. If it is not the same, then something is bent, most likely the steering knuckles.







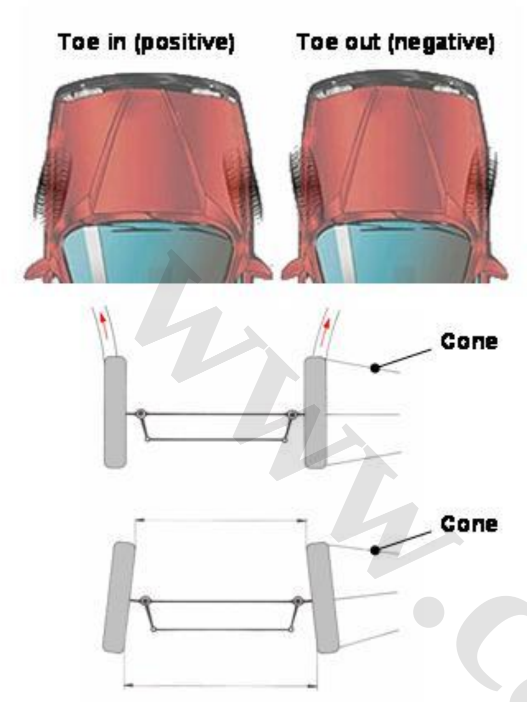


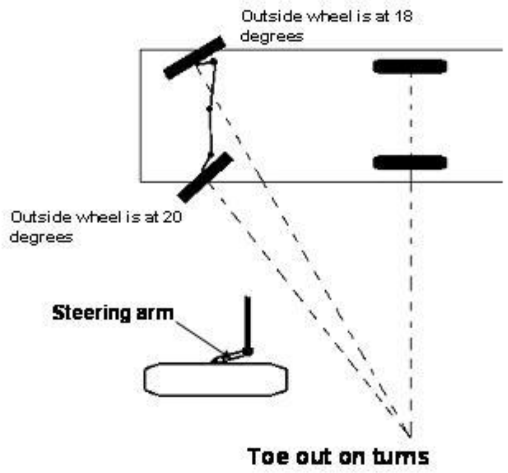
Scrub radius is the distance between where the SAI intersects the ground and the center of the tire. This distance must be exactly the same from side to side or the vehicle will pull strongly at all speeds. While included angle problems will affect the scrub radius, it is not the only thing that will affect it. Different wheels or tires from side to side will cause differences in scrub radius as well as a tire that is low on air. Positive scrub radius is when the tire contact patch is outside of the SAI pivot, while negative scrub radius is when the contact patch is inboard of the SAI pivot (front wheel drive vehicles usually have negative scrub radius). If the brake on one front wheel is not working, with positive scrub radius, stepping on the brake will cause the steering wheel to try to rip out of your hand. Negative scrub radius will minimize that effect. Scrub radius is designed at the factory and is not adjustable. If you have a vehicle that is pulling even though the alignment is correct, look for something that will affect scrub radius.

Riding height

Riding height is measured from the rocker panel to the ground. Riding height is not adjustable except on vehicles with torsion bar type springs. Changes in riding height will affect camber and toe so if springs are replaced or torsion bars are adjusted, then the wheel alignment must be checked to avoid the possibility of tire wear. It is important to note that the only symptom of weak coil springs is a sag in the riding height. If the riding height is good, then the springs are good. Note: Springs should only be replaced in matched pairs.

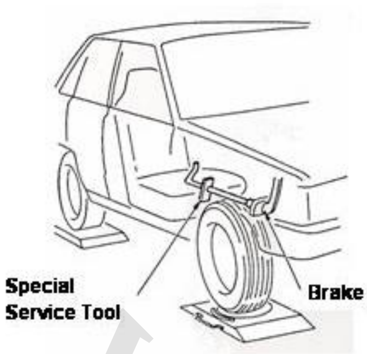
Toe in

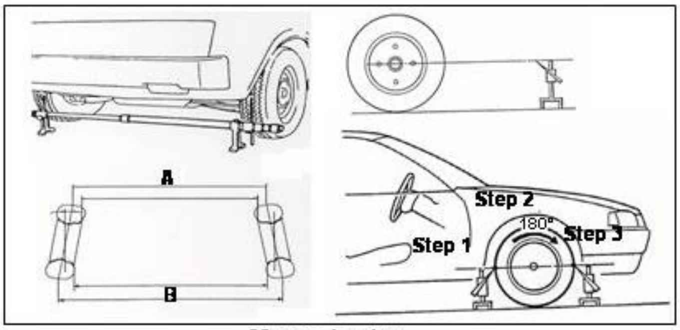




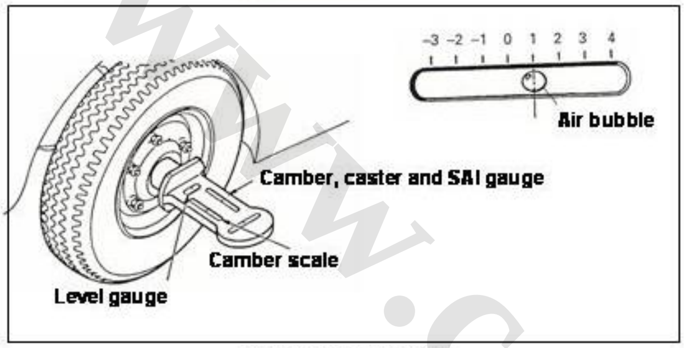
The main function of toe angle is to cancel out the camber thrust generated when camber is applied. When the front wheels are given positive camber, they tilt outward at the top. This causes them to attempt to roll outward as the car moves forward and therefore to side-slip. This subjects the tires to wear. Therefore, toe-in is provided for the front wheels to prevent this by canceling outward rolling due to camber. Since camber approaches zero in most recent vehicles, the toe angle value is also becoming smaller. Like camber, toe will change depending on vehicle speed. As aerodynamic forces change the riding height, the toe setting may change due to the geometry of the steering linkage in relation to the geometry of the suspension. Because of this, specifications are determined for a vehicle that is not moving based on the toe being at zero when the vehicle is at highway speed. When you are going to measure the toe, the measurement is the difference in the distance between the front of the tires and the back of the tires. Toe-in, or positive toe, is defined as the front of the tires being closer together than the rear of the tires. Toe-out, or negative toe, is when the rear of the tires is closer together than the front of the tires. Zero toe is when the tires are parallel to each other. It is important to note that although toe has historically been measured as a distance in milliliters or decimal inches (B-A), it is becoming more common to express toe in degrees (α,β).

Measuring toe and camber

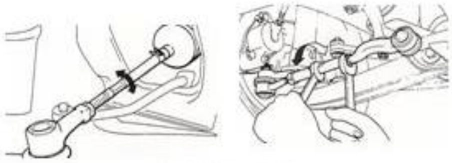




Measuring toe



Measuring camber


Adjusting toe

The following items should be checked before measuring:

Tire air pressure, Suspension components and mountings, Flat / leveled surface, Vehicle height level, Apply service brakes except when toe in is to be measured, Move suspension up and down several times to settle it down.

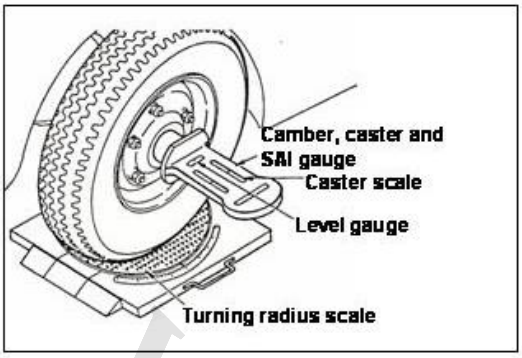
For measurement of toe-in, use a toe in gauge. Place the front wheels in the straight ahead position. Adjust the height of the measuring portions of the toe-in gauge to the wheel center height. Make measurement marks on the rear treads of the right and left wheel at the positions equal to the heights of the measuring positions of the toe in gauge, and measure the distance between the marks (Step1). Slowly move the vehicle forward to rotate the right and left wheels 180° until the marks made on the rear treads of the tires come forward (Step2). On the front side of the tires, measure the distance between the marks (Step3). The rear side reading-the front side reading gives toe in. Toe in= B- A

Adjusting toe: to adjust toe in, increase or reduce the tie rod length. Rack and pinion type: Tie rods have to be rotated the same amount. Gear box type: Make sure that the difference in length between the left and the right tie rods does not exceed 5mm.

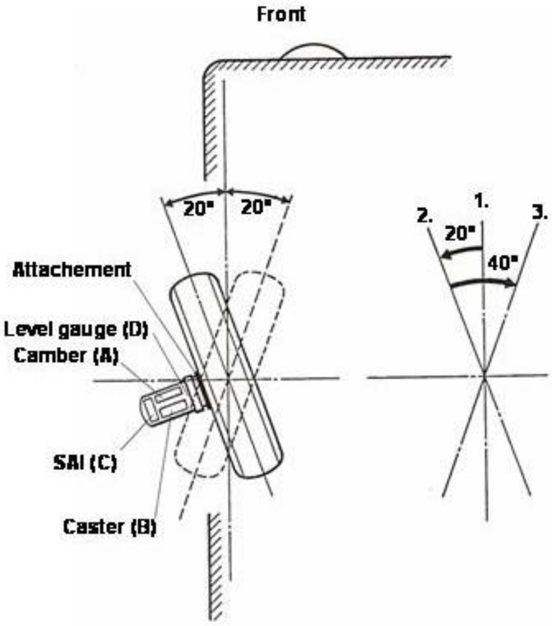
Measuring camber

For measuring camber the vehicle has to be place in the straight ahead direction. Place the level gauge air bubble at the center and read the camber scale of the gauge. Both right and left wheels should be checked.

Measuring caster and SAI



Measuring caster



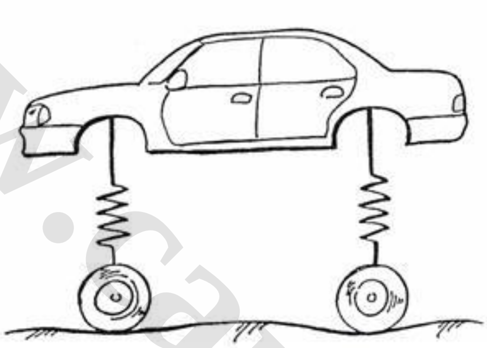
Measuring caster: for measuring caster set the wheel on a turning radius gauge. Mount a tester and level it by using the level gauge. Turn the front wheel 20° inward (in the inward rotating direction with respect to the measuring person) and level the tester suing the level gauge. Set the caster gauge air bubble at 0°. Turn the front wheel 20° outward from the straight ahead position and level the tester using the level gauge. Read the caster scale.
Measure the Steering Axis Inclination (SAI) using the same procedure as for measuring caster. In this case however read the SAI scale of the gauge.

Tires

Support the weight of the vehicle

Run by kicking the ground

Generate traction and braking force

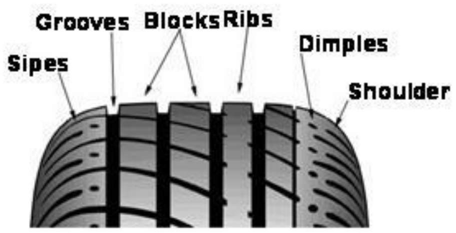


Absorb some of the impact force

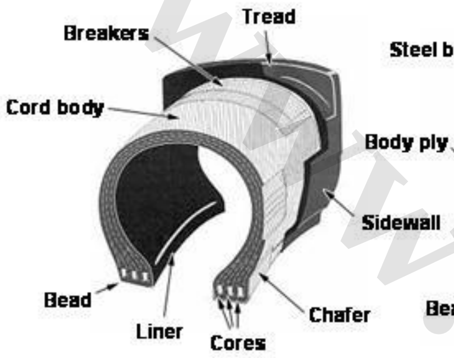
You may have wondered how a car tire with around 2.0bar of pressure can support a car. There is a flat spot on the bottom where the tire meets the road. This flat spot is called the contact patch. When the tire is spinning, the contact patch must move around the tire to stay in contact with the road. At the spot where the tire meets the road, the rubber is bent out. It takes force to bend that tire, and the more it has to bend, the more force it takes. The tire is not perfectly elastic, so when it returns to its original shape, it does not return all of the force that it took to bend it. Some of that force is converted to heat in the tire by the friction and work of bending all of the rubber and steel in the tire. Tire manufacturers sometimes publish a coefficient of rolling friction (CRF) for their tires. You can use this number to calculate how much force it takes to push a tire down the road. The CRF has nothing to do with how much traction the tire has; it is used to calculate the amount of drag or rolling resistance caused by the tires. The CRF is just like any other coefficient of friction: The force required to overcome the friction is equal to the CRF multiplied by the weight on the tire.

Tires types and construction

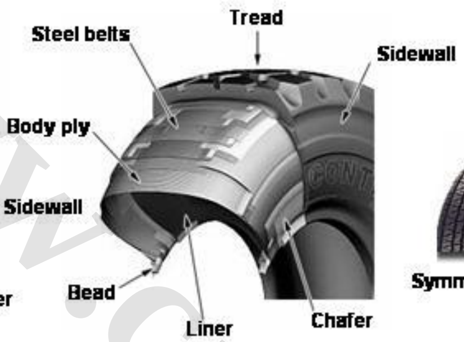
Tire Types



Tire tread



Cross-Ply Construction



Radial Construction

There are several different types of tires for a car. The type of tire used depends on many factors such as how the car is used or the time of season (summer/winter).

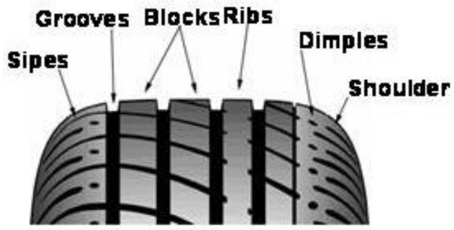
Performance tires or summer tires

Performance tires are designed for faster cars or for people who prefer to drive harder than the average consumer. They typically put performance and grip ahead of longevity by using a softer rubber compound. Tread block design is normally biased towards outright grip rather than the ability to pump water out of the way on a wet road. The extreme example of performance tires are "slicks" used in motor racing, so-called because they have no tread at all.

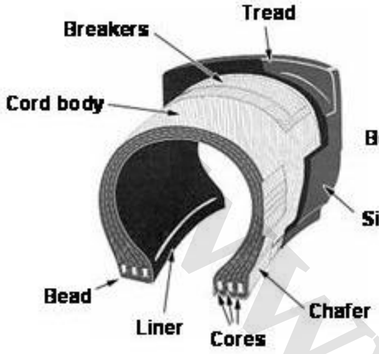
All-round or all-season tires

These tires are designed to be a compromise between grip, performance, longevity, and noise and wet-weather safety. For increased tire life, they are made with a harder rubber compound, which sacrifices outright grip and cornering performance. The tread block design is normally a compromise between quiet running and water dispersion. All-season tires are neither excellent dry-weather, nor excellent wet-weather tires.

Tire Types



Tire tread



Cross-Ply Construction

Radial Construction

Wet-weather, snow & mud or winter tires

Winter tires come at the other end of the spectrum to performance tires, obviously. They're designed to work well in winter conditions with snow and ice on the roads. Winter tires actually use a softer compound than performance tires. The rubber needs to heat up quicker in cold conditions and needs to have as much mechanical grip as possible. Winter tires typically have larger and thus nosier tread block patterns. They'll normally also has a lot more sipping to try to disperse water and snow. In extreme climates, true snow tires have tiny metal studs fabricated into the tread for biting into the snow and ice. The downside of this is that they are incredibly noisy on dry roads and wear out both the tire and the road surface extremely quickly if driven in the dry.

All-terrain tires:

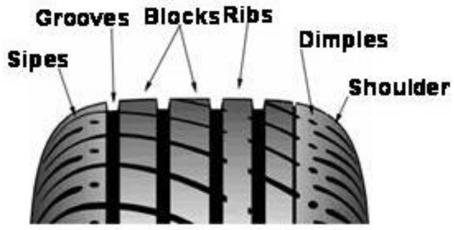
These are typically used on SUVs and light trucks. They are larger tires with stiffer sidewalls and bigger tread block patterns. The larger tread block means the tires grip loose sand and dirt very well when you take the car or truck off-road. The rubber compound used in these tires is normally middle-of-the-road - neither soft nor hard.

Mud tires:

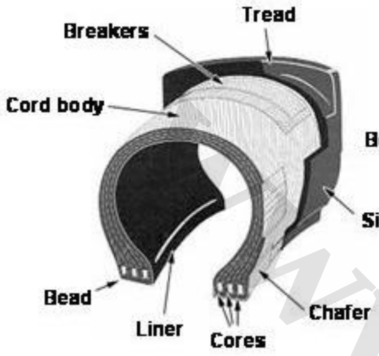
At the extreme end of the all-terrain tire classification are mud tires. These have massive, super-chunky tread blocks and really shouldn't ever be driven anywhere other than loose mud and dirt. The tread sometimes doesn't even come in blocks any more but looks more like paddles built in to the tire carcass.

High pressure spare tire (Temporary tire / space saver) has a smaller cross sectional area (bias construction) than that of a standard tire, and is used with an inflation air pressure about twice of a standard tire. The tire volume is as small as about a standard tire, allowing effective use of the trunk space.

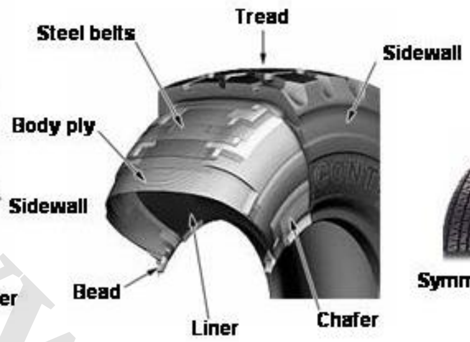
Tire Types



Tire tread



Cross-Ply Construction



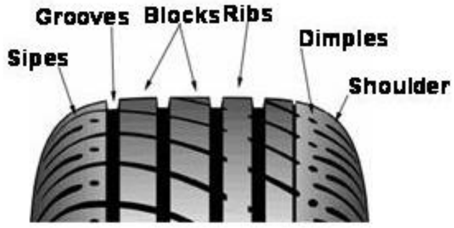
Radial Construction

Types constructions

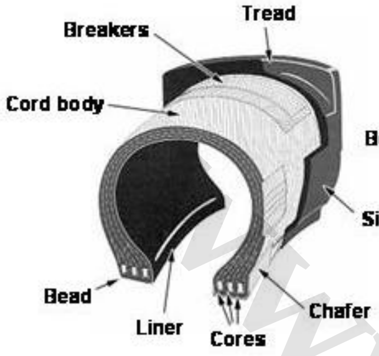
A proper tread design improves traction, improves handling and increases Durability. It also has a direct effect on ride comfort, noise level and fuel efficiency. Each part of the tread of your tire has a different name, and a different function and effect on the overall tire. Sipes are the small, slit-like grooves in the tread blocks that allow the blocks to flex. This added flexibility increases traction by creating an additional biting edge. Sipes are especially helpful on ice, light snow and loose dirt. Grooves create voids for better water channeling on wet road surfaces. Grooves are the most efficient way of channeling water from in front of the tires to behind it. By designing grooves circumferentially, water has less distance to be channeled. Blocks are the segments that make up the majority of a tire's tread. Their primary function is to provide traction. Ribs are the straight-lined row of blocks that create a circumferential contact "band“.

Dimples are the indentations in the tread, normally towards the outer edge of the tire. They improve cooling. Shoulders provide continuous contact with the road while maneuvering. The shoulders wrap slightly over the inner and outer sidewall of a tire. The Void Ratio is the amount of open space in the tread. A low void ratio means a tire has more rubber is in contact with the road. A high void ratio increases the ability to drain water.

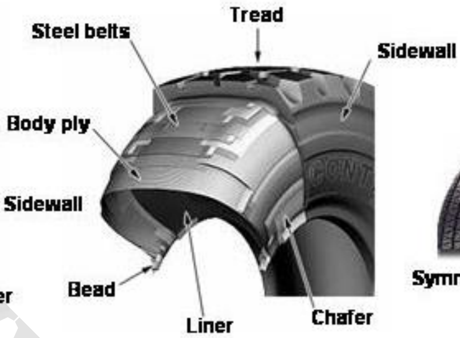
Tire Types



Tire tread



Cross-Ply Construction



Radial Construction

Sports, dry-weather and high performance tires have a low void ratio for grip and traction. Wet-weather and snow tires have high void ratios. Radial tires are almost used on all the worlds' passenger cars today since they offer better overall performance and fuel economy. There are three basic types of tread pattern that the manufacturers can choose to go with:

Symmetrical

It has consistent across the tire's face. Both halves of the tread face are the same design.

Asymmetrical

The tread pattern changes across the face of the tire. These designs normally incorporate larger tread blocks on the outer portion for increased stability during cornering. The smaller inner blocks and greater use of grooves help to disperse water and heat. Asymmetrical tires tend to also be unidirectional tires.

Unidirectional

Designed to rotate in only one direction, these tires enhance straight-line acceleration by reducing rolling resistance. They also provide shorter stopping distance. Unidirectional tires must be dedicated to a specific side of the vehicle, so the information on the sidewall will always include a rotational direction arrow. Make sure the tires rotate in this direction.

Tire information on the side wall

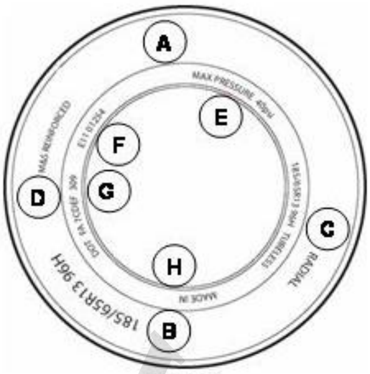
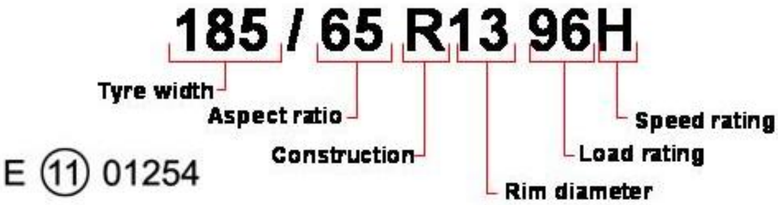
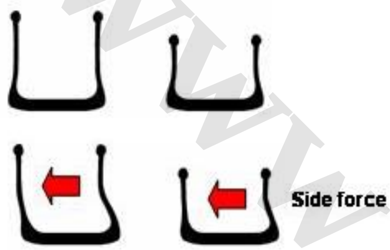


Figure 1



Speed symbol	Max. Car speed capability	
	Km/h	Mph
L	120	75
M	130	81
N	140	87
P	150	95
Q	160	100
R	170	105
S	180	113
T	190	118
U	200	125
H	210	130
V	240	150
W	270	168
Z	2	

Load index	Weight (kg)
50	190
52	200
54	212
70	335
72	355
74	375
90	600
91	615
92	630
93	650
94	670
95	690



Aspect ratio

Various information's can be found on the sidewall of a tire (refer to figure 1).

A: Manufacturer or brand name, and commercial name or identity

B: Tire size, construction and speed rating designations. Tubeless designates a tire which requires no inner tube. DIN-type marking also has the load index encoded in it. These go from a load index of 50 (190kg) up to an index of 169 (5800kg).

C: Denotes type of tire construction.

D: M&S denotes a tire designed for mud and snow. Reinforced marking only where applicable

E: Pressure marking requirement

F: ECE type approval mark

G: North American Dept of Transport compliance symbols and identification numbers.

H: Country of manufacture

Also on the sidewall, you might find the following info embossed in the rubber.

The temperature rating: an indicator of how well the tire withstands heat buildup. "A" is the highest rating; "C" is the lowest.

The traction rating: an indicator of how well the tire is capable of stopping on wet pavement. "A" is the highest rating; "C" is the lowest.

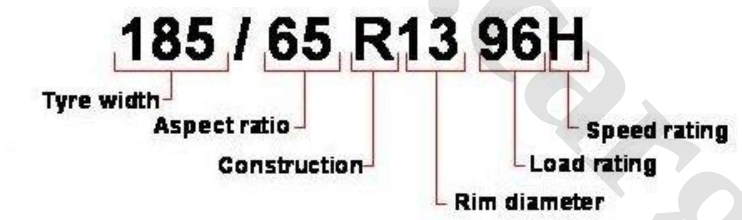
The tread-wear rating: a comparative rating for the useful life of the tire's tread.

A tire with a tread: wear rating of 200, for example, could be expected to last twice as long as one with a rating of 100. Tread-wear grades typically range between 60 and 600 in 20-point increments.

Encoded in the US DOT information (G in figure 1) is a two-letter code that identifies where the tire was manufactured in detail. In other words, which factory and in some cases, which city it was manufactured in. As part of the DOT code (G in figure1), there is a tire manufacture date stamped on the sidewall. A three or four digit code denotes when the tire was manufactured, and as a rule-of-thumb, you should never use tires more than 6 years old.

The rubber in tires degrades over time, irrespective of whether the tire is being used or not. The three digit code was for tires manufactured before 2000. So for example 1 7 8 means it was manufactured in the 17th week of 8th year of the decade. After 2000, the code was switched to a 4-digit code. Same rules apply, so for example 3 0 0 3 means the tire was manufactured in the 30th week of 2003. All tires sold in Europe after July 1997 must carry an E-mark (F in figure). The mark itself is either an upper or lower case "E" followed by a number in a circle or rectangle, followed by a further number.An "E" (upper case) indicates that the tire is certified to comply with the dimensional, performance and marking requirements of ECE regulation 30. An "e" (lower case) indicates that the tire is certified to comply with the dimensional, performance and marking requirements of Directive 92/33/EEC.

The number in the circle or rectangle denotes the country code of the government that granted the type approval. 11 is the UK. The last number outside the circle or rectangle is the number of the type approval certificate issued for that particular tire size and type.



Tire sizes and what they mean, example 185/65HR13

185: This is the width in mm of the tire from sidewall to sidewall when it's unstressed and you're looking at it head on (or top-down),

65: This is the ratio of the height of the tire sidewall, (section height), expressed as a percentage of the width. It is known as the aspect ratio. In this case, 65% of 185mm is 120.25mm - the section height. High performance tires usually have a lower aspect ratio than other tires. This is because tires with a lower aspect ratio provide better lateral stability. Tires with a lower profile have shorter, stiffer sidewalls so they resist cornering forces better.

H: This is the speed rating of the tire,

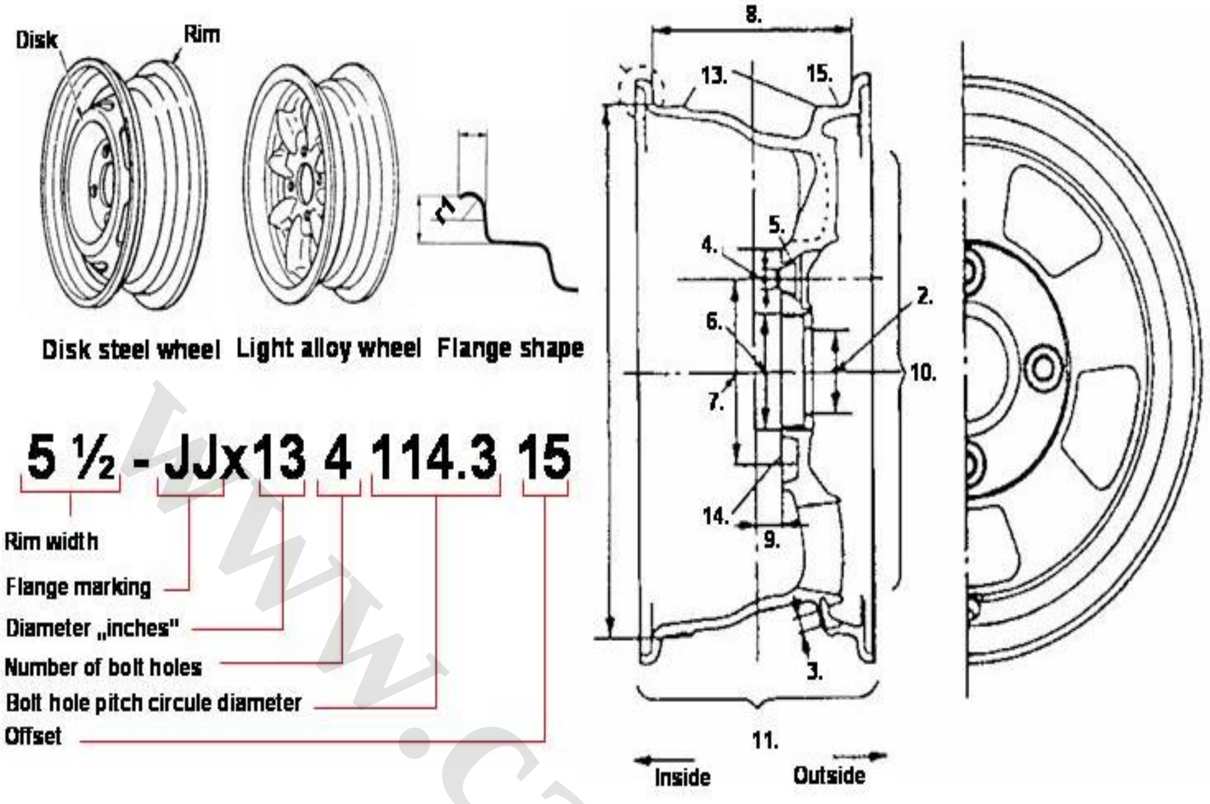
R: This tells you that the tire is a radial construction.

13: This is the diameter in inches of the rim of the wheel that the tire has been designed to fit on.

Recently, there has been a move (especially in Europe) to adjust tire designations to conform to DIN (Deutsche Industrie Normal). This means a slight change in the way the information is presented to the following:

18565R1391V = Section width, Aspect ratio, Radial, Rim diameter, load rating, speed rating.

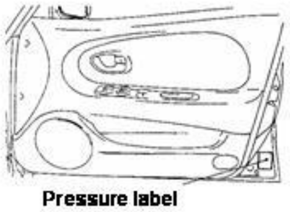
Wheels and its markings



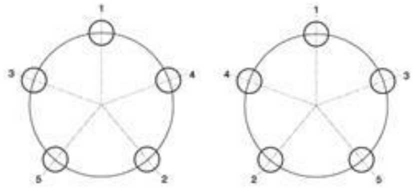
Names and markings of wheel

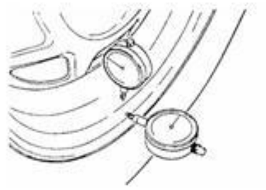
The wheels take various types of stress generated during operation. Since they are rotary bodies, they are required to reduce their dimensional errors and amount of unbalance to a minimum. Also they are required to hold the tires in position, while satisfying the requirements for sufficient strength, weight reduction and economy. The two types mainly used by Hyundai are disk steel or light alloy wheels. The light alloy wheels offer less weight and better ride comfort.

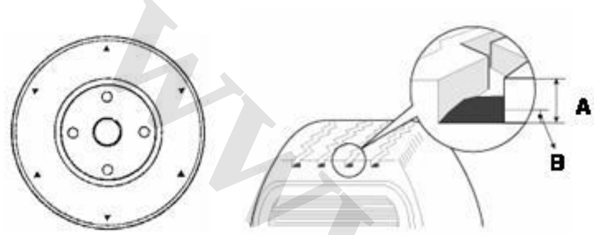
Wheel inspection



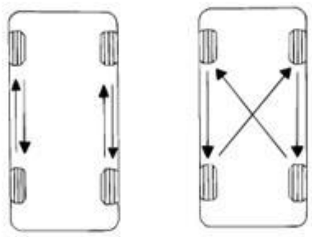
Inflation pressure check


Tightening procedure


Wheel runout check



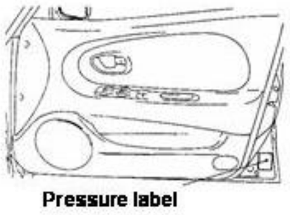
Wear Indicator


Tire rotation

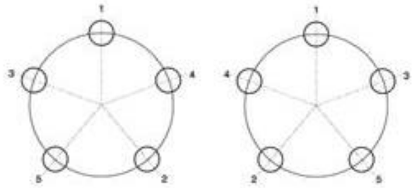
Under inflation can cause tires to wear more and it also causes reduced fuel efficiency and increased heat buildup in the tires. Over inflation causes tires to wear more in the center of the tread. The tire pressure should never exceed the maximum that is listed on the side of the tire.

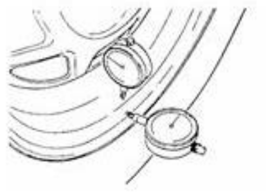
Tightening procedure:
Hyundai offers wheels with four of five bolt holes. Always follow the tightening procedure and torque given in the workshop manual.

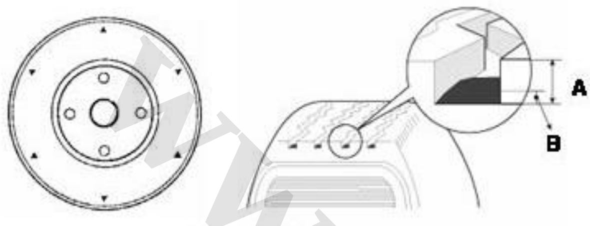
Wheel run out check: raise the vehicle on a jack until the tires are completely of the ground. Slowly rotate the tire and measure the wheel run out by using a dial indicator. If the wheel run out is in excess of the limit value, replace the wheel.



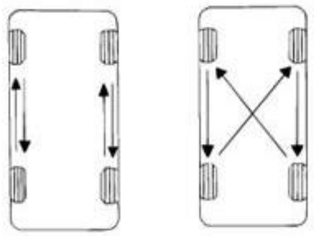
Inflation pressure check


Tightening procedure


Wheel runout check



Wear Indicator


Tire rotation

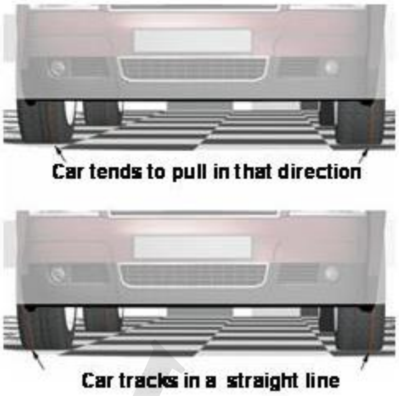
Tread depth and tread wear indicators: for the most part, motoring law in most countries determines that your tires need a minimum tread depth to be legal. This varies from country to country but is normally around 1.6mm.

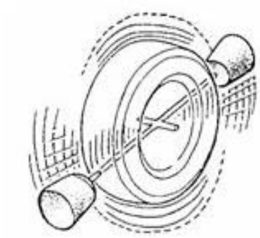
To assist you in figuring out when you're getting close to that value, most tires have tread wear indicators built into them. If you look around the tread carefully, at some point you'll see a bar of rubber which goes across the tread and isn't part of the regular pattern (see the picture for an example). This is the wear indicator. It's really basic, but it's also pretty foolproof. The tread wear indicator is molded into the rubber at a depth of about 2mm normally. As the rubber in your tires wears away due to everyday use, the tread wears down.

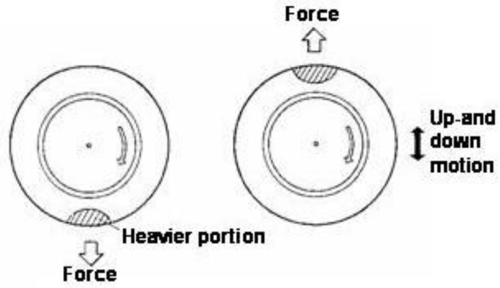
At some point, the tire tread will become flush with the wear indicator (which is normally recessed into the tread). At this point you have about 2mm of tread left - in other words it is time to change tires.

Tire rotation: if tires are used at he same locations for a long period, they receive the different amounts of wear that depend on their locations. The rotation of tires at regular intervals equalizes the wear and helps extend the tire life. In case the vehicle pulls or wanders, the tires should also be rotated. Please refer to the Shop Manual for more detailed information.

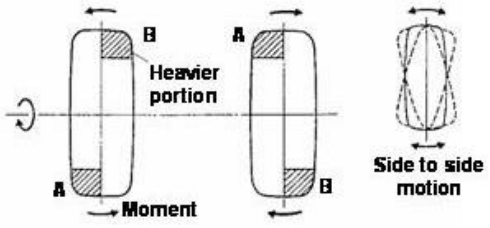
Tire installation and balancing







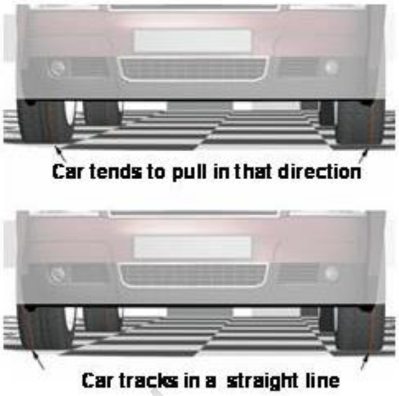
Static unbalance

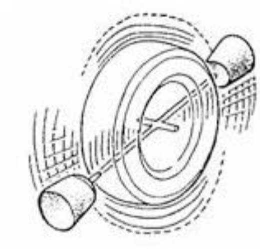


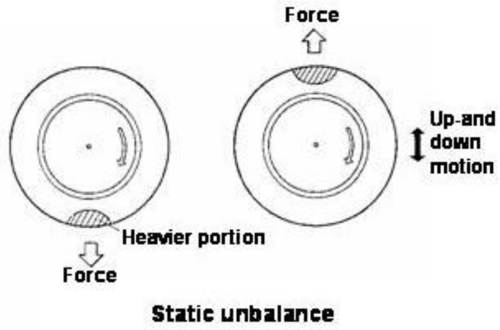
Dynamic unbalance

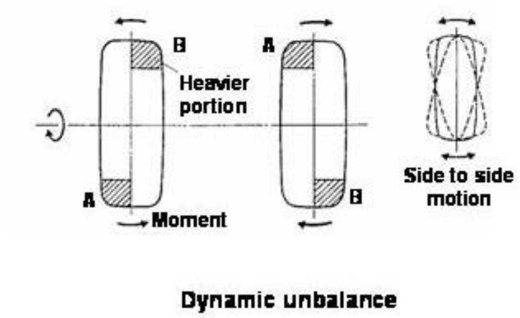
On new tires, you'll often see some colored dots on the tire sidewall, and bands of color in the tread. The dots on the sidewall typically denote uniformity and weight. It's impossible to manufacture a tire which is perfectly balanced and perfectly manufactured in the belts. As a result, all tires have a point on the tread which is lighter than the rest of the tire.
Typically this is a yellow dot (although some manufacturers use different colors) and is known as the weight mark. Typically the yellow dot should end up aligned to the valve stem on your wheel and tire. This can help minimize the amount of weight needed to balance the tire. As well as not being able to manufacture perfectly weighted tires, it's also nearly impossible to make a tire which is perfectly circular. Every tire has a high and a low spot, the difference of which is called radial run out. Manufacturers typically mark this point with a red dot on the tire sidewall, although again, some tires have no marks, and others use different colors. This is called the uniformity mark.

Correspondingly, most wheel rims are also not 100% circular, and will have a notch or a dimple stamped into the wheel rim somewhere indicating their low point. It makes sense then, that the high point of the tire should be matched with the low point of the wheel rim to balance out the radial run out.









Often when you buy tires, there will be a colored band or stripe running around the tire inside the tread. These can be any color and can be placed laterally almost anywhere across the tread. Some are on the tread blocks whilst others are on the tire carcass. As well as the color, the actual position of the lines is something to take note of too. Depending on how the belts are laid on the tire during manufacturing, they can cause the tire to "run out" - to not track perfectly straight, but pull to the left or right. The closer to the centre of the tire that these lines are, the less run out the tire has and the straighter it will track when mounted on your car. So for example, if you were looking at your car from the front and you saw the colored striped running around the right side of both your front tires, the car would likely have a tendency to pull to that side. The best thing is to have the colored stripes on opposite sides of the tires for opposite sides of the car, so that the run out on each side will counteract the other and help maintain a good straight running. The obvious solution to having the stripes both on one side is to flip one of the tires around, but that will only work if they're not unidirectional tires.

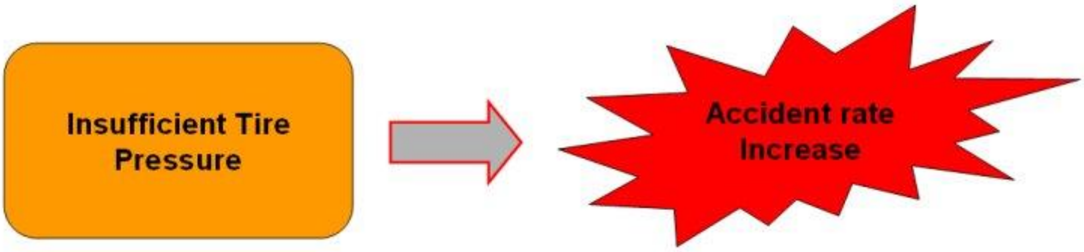
Static unbalance:

The heavier portion of the tire creates centrifugal forces which lead to an up, down movement.

Dynamic unbalance:

In this picture, weight A is located at the far left. This plane is called "Left plane of Rotation”. Weight B is located at the far right side, this plane is called ‘Right plane of rotation’ Centrifugal forces generated by both weights are acting in different planes of rotation. Because of this, each weight will try to pull the drum in the direction of its centrifugal force. The result is a side to side motion of the tire.

TPMS Introduction



TPMS has been applied on the vehicle as an advanced safety device since NHTSA FMVSS 138 has made the related regulation. According to the frequent accident due to the insufficient tire pressure, it has been necessary to develop more reliable system to monitor the actual pressure and give a proper telltale to the driver while driving.

As an added safety feature, it has been equipped with a tire pressure monitoring system (TPMS) that illuminates a low tire pressure telltale when one or more of your tires is significantly under-inflated. Accordingly, when the low tire pressure telltale illuminates, you should stop and check your tires as soon as possible, and inflate them to the proper pressure. Driving on a significantly under-inflated tire causes the tire to overheat and can lead to tire failure. Under-inflation also reduces fuel efficiency and tire tread life, and may affect the vehicle's handling and stopping ability.

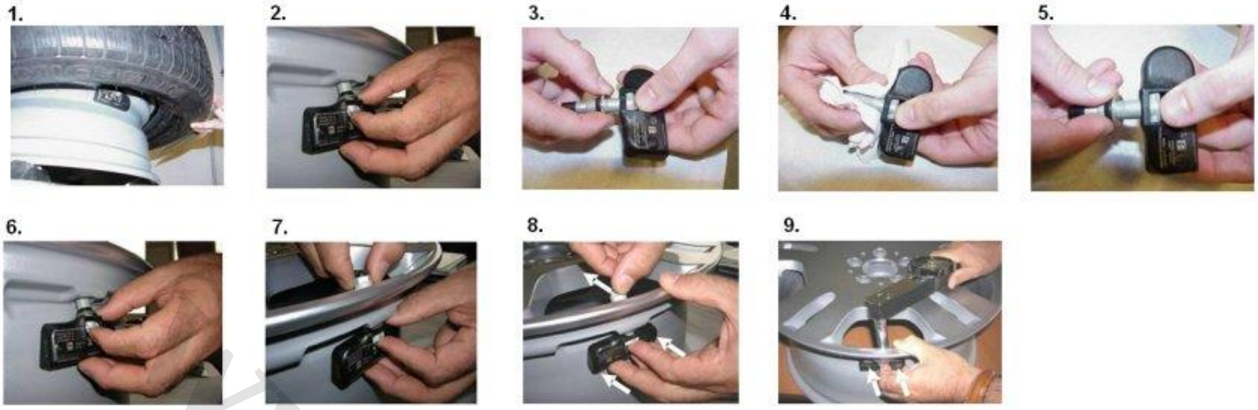
Please note that the TPMS is not a substitute for proper tire maintenance, and it is the driver's responsibility to maintain correct tire pressure, even if under-inflation has not reached the level to trigger illumination of the TPMS low tire pressure telltale.

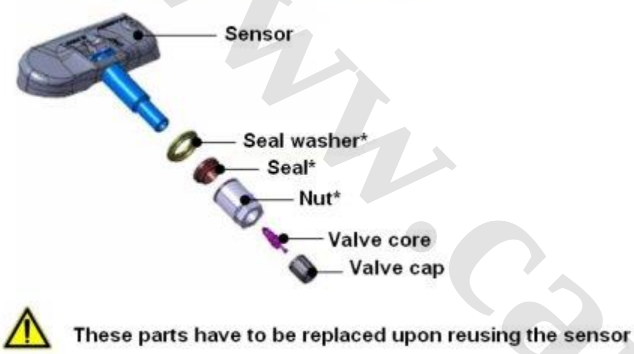
Your vehicle has also been equipped with a TPMS malfunction indicator to indicate when the system is not operating properly. The TPMS malfunction indicator is provided by a separate telltale, which displays the symbol "TPMS" when illuminated. When the malfunction indicator is illuminated, the system may not be able to detect or signal low tire pressure as intended. TPMS malfunctions may occur for a variety of reasons, including the installation of replacement or alternate tires or

wheels on the vehicle that prevent the TPMS from functioning properly.
Always check the TPMS malfunction indicator after replacing one or more tires or wheels on your vehicle to ensure that the replacement or alternate tires and wheels allow the TPMS to continue to function properly.

The TPMS malfunction indicator may be illuminated if the vehicle is moving around electric power supply cable or radio transmitter such as police stations, government and public offices, broadcasting stations, military installations, airports, or transmitting tower, etc. this can interfere with normal operation of the Tire Pressure Monitoring System (TPMS).
The TPMS malfunction indicator may be illuminated if some electronic devices, such as notebook computers, are used in the vehicle. This can interfere with normal operation of the Tire Pressure Monitoring System (TPMS). In winter or cold weather, the low tire pressure telltale may be illuminated if the tire pressure was adjusted to the recommended tire inflation pressure in warm weather. It does not mean TPMS is malfunctioning because the decreased temperature leads to a proportional lowering of tire pressure. When you drive your vehicle from a warm area to a cold area or from a cold area to a warm area, or the outside temperature significantly increases or decreases, you should check the tire inflation pressure and adjust the tires to the recommended tire inflation pressure.

Replacement and inspection of tire pressure sensor





1. When removing or mounting the tire, pay attention not to damage the sensor.
2. While supporting the sensor unit, unscrew the nut
3. Remove the sensor
4. Hold the sensor and the seal washer, then extract it, this also extract the seal. Take care not to damage the valve thread.

Note:
For each change of tire and disassembling of the tire it is necessary to change the wearing parts such as the seal, seal washer, nut and valve core. These parts are available as a service kit which includes also the cap.

4. Clean the sensor and the valve stem by using a dry cloth as shown in the picture. Take care to support the rear of the valve with the thumb so that there is no movement of the stem.
5. When removing the sensor, a new washer seal must be used. Insert these up to the base of the sensor, making sure to secure the valve bas with the thumb as shown in the picture. Wipe the seal and threading using a dry cloth.
6. Insert the valve in the valve hole without modifying the angle of the stem (retain position of delivery). The laser r marking should be visible to the operator.
7. When the valve is completely inserted, maintain the sensor in contact with the rim (as shown

in the picture). Tighten the nut by hand until it is in contact with the rim.

8. While maintaining the sensor contact with the rim by applying pressure to the back of the sensor housing, slightly press the valve cap towards the center of the rim in order to adapt the angle of the valve/sensor to the profile of the rim. It is mandatory to guarantee the contact of the housing unit on the rim drop center.
9. While maintaining the sensor unit and valve position, screw the nut with a torque wrench. Apply a torque of 8Nm+/- 0.5Nm. Take care that the wrench socket is correctly inserted to the nut. It is normal that the seal washer becomes bent during tightening. After tightening the nut, the visible part of the antenna and the plastic bridge should be checked for cracks.

Note:

Upon replacing the sensor with a new one, the frequency range should be checked. The frequency range is stamped on to the sensor housing. 433MHz are used for the European market, 315MHz are being used for the US and middle east market.

Replacement of tires

Removing the tire from the rim

Note:

During all the operations on the tire, the sensor must be correctly maintained and thus it is forbidden to unscrew the nut and to force the sensor into the wheel since this could damage the sensor.

1. Take of the first side of the tire. The tool should not be used near the valve (no less than 30cm)
2. Take the second side of the tire. The tool should not be used near the valve (no less than 30cm)
3. Dismount the first side of the tire. Place the shoe of the tool between 5 and 15cm away from the sensor and use the tire lever as shown in the picture.
4. By using the tire lever, extract the external side wall of the tire and engage it on to the shoe of the machine. The lever and tire must not come into contact with the sensor! Then remove the lever.
5. The wheel rotation allows the complete extraction of the first side of tire.
6. Raise the tire to prepare the introduction of the tire lever to aid extraction of the second side wall. The same recommendations as for the first side will apply.
7. By using the tire lever, extract the external side wall of the tire and engage the shoe of the machine. The lever and tire must not come into contact with the sensor. Then remove the lever.

8. Extract entirely the second side wall of the tire.

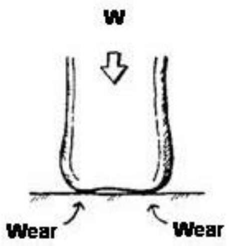
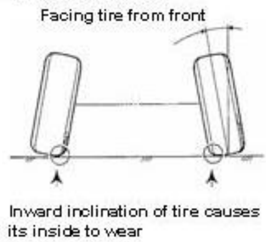
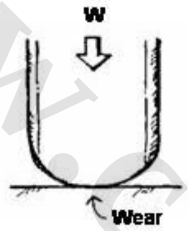
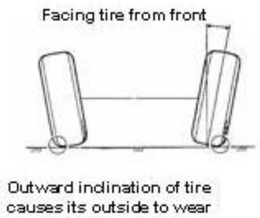
Mounting the tire

Note:

Before any tire mounting operation, make sure that the sensor has been correctly mounted and tightened to the rim. No lubricant product or any other material may partially or completely should cover the air pressure inlet of the sensor. The assembly tools should never get in contact with the sensor.

1. Prepare the tire and fix the rim as usual.
2. Put the tire on to the rim, so that the cross point of the belt with the rim is between 15 and 20cm away from the valve (see picture).
3. Engage the shoe and make sure that the 20cm are maintained between the cross point and the valve. The arrow shows the direction of rotation of the wheel.
4. Turn the wheel in order to engage all the first side of the tire. The standard shoes can pass over the sensor without damaging it.
5. Put the second side of the tire into position, so that the cross point of the belt with the rims is approximately 20cm away from the valve (see picture). The curved arrows shows the direction of rotation of the wheel.
6. Turn the wheel in order to engage all of the second side tire.

Wear of tires and probable causes

Wear pattern	Probable cause	Wear pattern	Probable cause
Both shoulders worn 	▪ Insufficient air pressure 	Inside worn 	▪ Negative camber 
Worn at center 	▪ Excessive air pressure 	Outside worn 	▪ Excessive camber 

Effects of incorrect camber

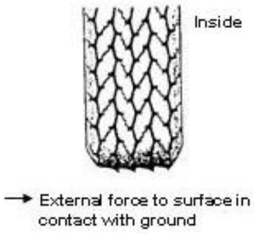
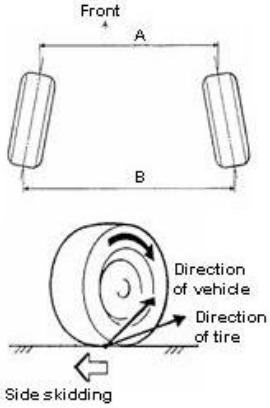
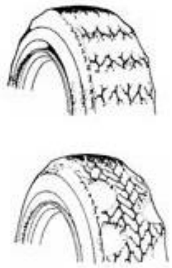
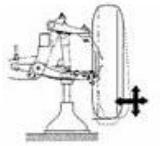
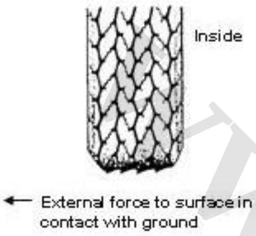
Excessive negative camber wears the inside of the tire and similar to positive camber, it can cause wear and stress on suspension parts.

Problems caused by incorrect camber

Vehicle pulls to one side, Rapid wear on inside or outside of tire tread, increased wear on the wheel bearings, increased wear on ball joints (incorrect camber creates increased leverage on spindle and spindle support resulting in increased loads on ball joints).

Causes of camber changes

Incorrect ride height (changes in ride height affect camber), sagging of spring, sagging of cross-member or sub-frame

Wear pattern	Probable cause	Wear pattern	Probable cause
Toe in wear 	▪ Excessive toe in (B-A>Specified toe value)  Since the traveling directions of the vehicle and tire are different, the tire presses the ground surface from inside to outside. That is, the tire skids on the ground surface sideways.	Wavy or bald spots 	▪ Wheel out of balance ▪ Wheel out of alignment ▪ Loose bearing ▪ Loose suspension 
Toe out wear 			

Effects of incorrect toe

Excessive toe increases tire scuffing and results in tire wear and drag on the vehicle.

Problems caused by incorrect toe

Early indication of toe tire wear can appear as a feather edge or scuff on the edge of the tire tread surface. Toe tire wear can also be found on rear tires as a cupping, feather edge or smooth edge on the tire tread surface. Too much toe in will cause the feather edge to point in while toe out will cause the feather edge to point out.

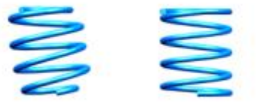
Causes of toe changes

Variation from factory specs is usually caused by worn or bent suspension parts or changes in caster, camber settings. Toe angle can also be affected by body structure or frame damage.

Suspension system 2

Index

Amplitude selective damper and side load coil



Amplitude selective damper

Front suspension:

The front McPherson type wheel suspension comprises a spring, damper and upper suspension strut pivot integrated in one unit. Newly adopted is the side load coil spring which reduces the side forces acting on the damper piston, thereby providing a smoother operation. The anti roll bar connects the McPherson struts on the right and left sides. Toe in adjustment is made possible through track rod ends connected to the track rod via threaded joints. Camber and caster is fixed and can not be adjusted.

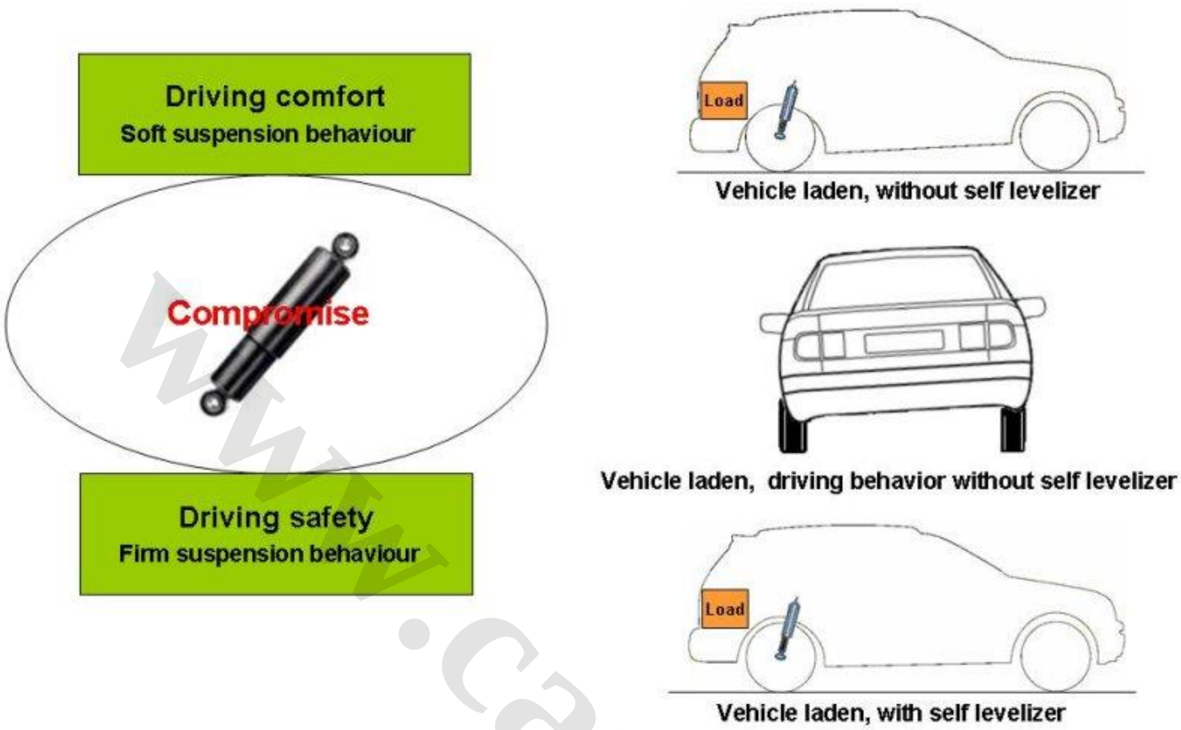
Rear suspension:

The rear suspension is multilink type. This means that the rear wheels are individually suspended and can move up and down independently. During oscillation, wheel geometry is altered in a controlled manner. Wheel geometry, or arm movement in relation to each other causes slight over steering during cornering since the outer rear wheel toe in approaches 0°. If the front wheels are turned towards the left, the right rear wheel turns toward the right and vice versa. Toe in can be adjusted by turning the rear assist arm cam bolt, camber can be adjusted by turning the rear lower arm cam bolt. An anti roll bar is mounted between the sub frame and trailing arms.

Dampers and springs:

Amplitude selective dampers are available as an option for the general market only. The difference to conventional dampers is that two pistons are incorporated, a fixed one and a sliding one. In case of smooth road condition, the piston set moves only a little bit, so that only the fixed piston is creating the required dampening force, thereby providing a comfortable ride. In this operation mode, the sliding piston moves freely within the spring operation limits. If the road gets more bumpy, stroke and speed of the damping unit increase, so that finally the springs of the sliding piston are fully compressed so that the additional valves in the sliding piston create a higher dampening force. This increases driving stability.

Self levelizer



The suspension systems developed for vehicles are always a compromise between driving safety and driving comfort. When load is put into the trunk or when occupants take seat the height and driving behavior of the vehicle changes. To cope with this behavior a self levelizer system can be applied to the vehicle (for example CM-Santa Fe). Purpose of the self levelizer is to regulate the vehicle height, according to the vehicle load, therefore improving driving safety and comfort. The self levelizer is used on the rear axle instead of conventional gas pressure shock absorbers. The compact unit incorporates all required system components such as mounting elements and pump. The self levelizer also fulfills suspension and dampening functions. One characteristic of the self levelizer system is, that the energy caused by the relative movement of the axle and vehicle body while driving is used to adjust the optimal body height. This means that no external power supply is required.

Construction

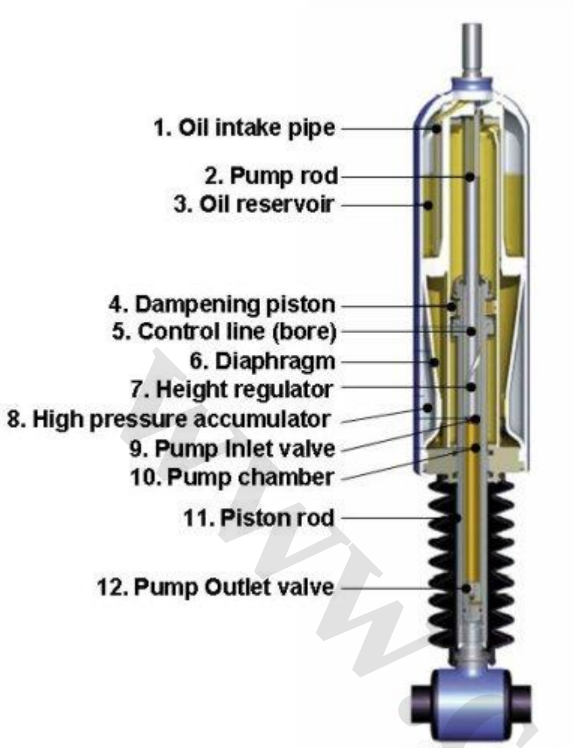


Figure A

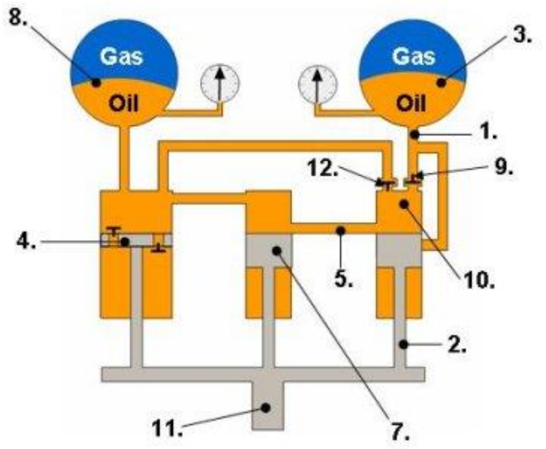
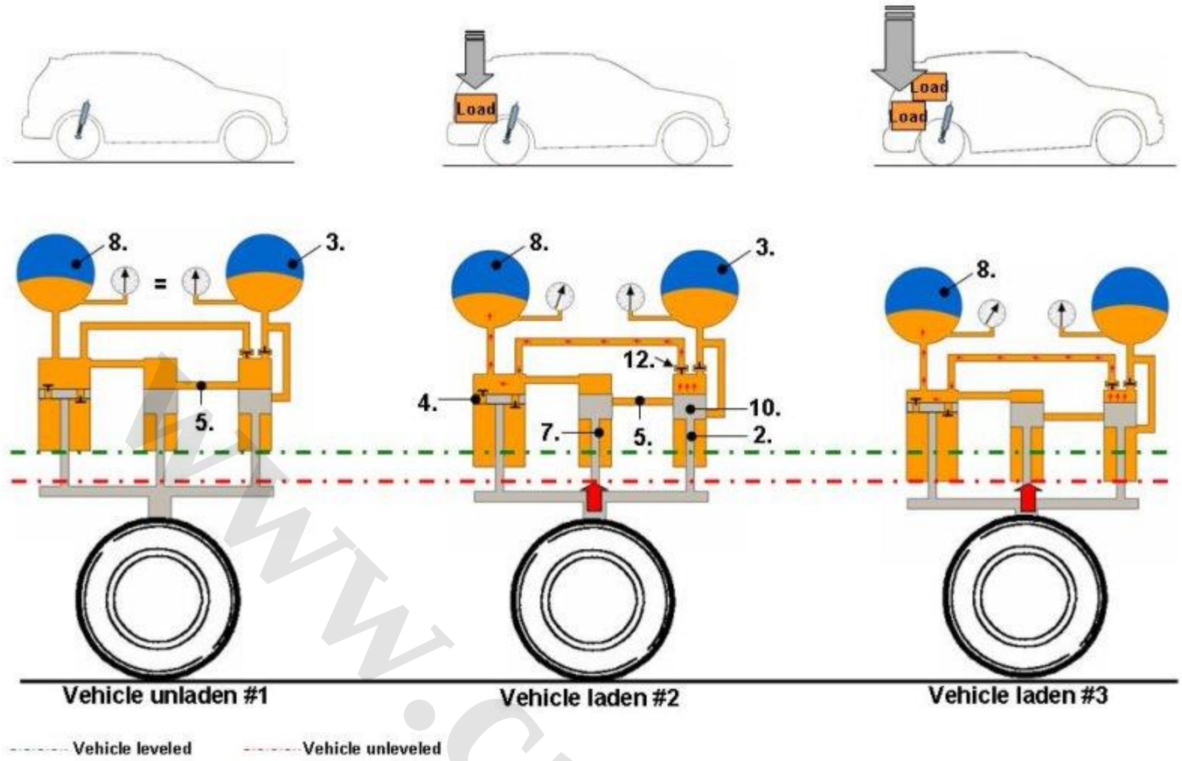


Figure B

Figure A shows the main components of the self levelizer shock absorber. The high pressure accumulator (8) is located in radial direction to the cylinder and is filled with gas and oil. Due to that layout the length of the shock absorber can be reduced. The diaphragm (6) separates the oil from the gas. From now on the schematic and simplified drawing (Figure B) will be used to understand the construction and operating principle of the self levelizer shock absorber. Figure B shows the main components inside the self levelizer shock absorber. The oil reservoir (3) filled with gas and oil is connected to the pump rod (2) via a oil intake pipe (1). The dampening piston (4), the height regulator (7) and the pump rod (2) are one unit and move together with the piston rod (11). Pump inlet (9) and pump outlet (12) valves control the oil flow to and away from the pump chamber (10). A control line (5) is opened depending on the position of the height regulator (7).

Operating principle

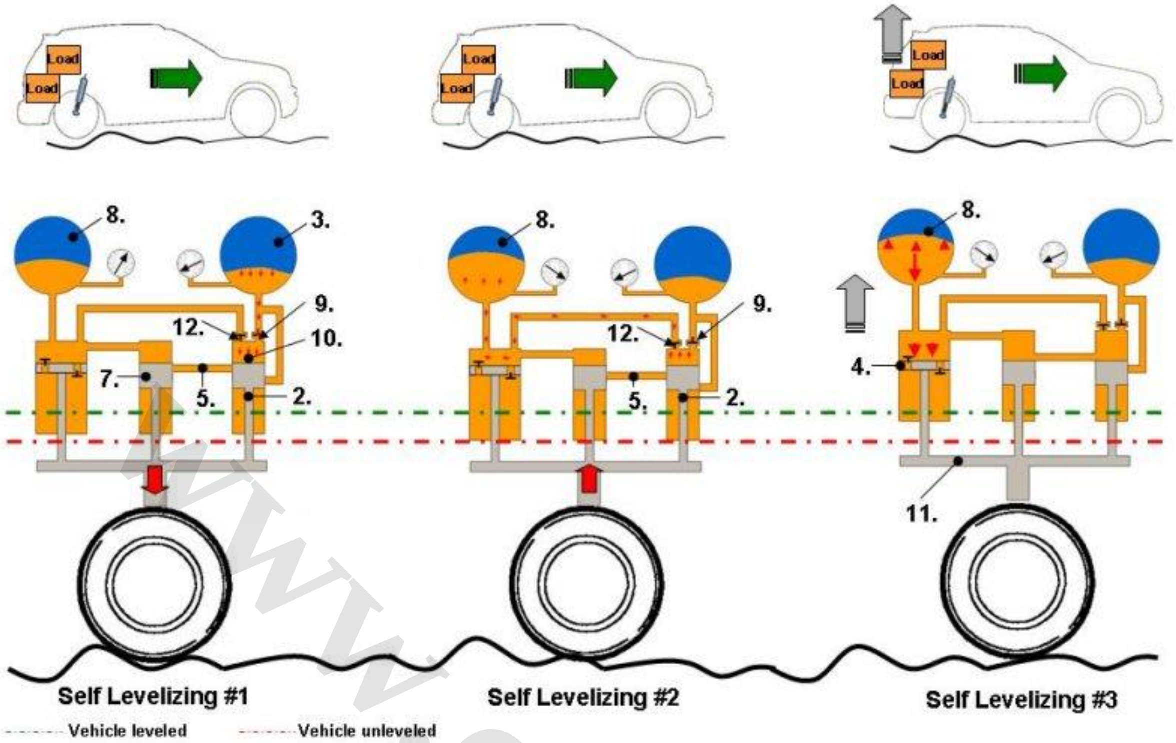


Vehicle un-laden #1:

With the vehicle un-laden the control line (5) is open and the pressure inside the Oil reservoir (3) and high pressure accumulator (8) are equal.

Vehicle laden #2 / #3:

When the vehicle is laden, the movement of the vehicle body pushes the piston rod (11) connected to the pump rod (2), height regulator (7) and dampening piston (4) towards the oil reservoir (3) and high pressure accumulator (8). Since the height regulator moves up (7) the control line (5) is closed and oil from the pump chamber (10) is pushed towards the high pressure accumulator (8) via the pump outlet valve (12). This causes a pressure increase inside the high pressure accumulator (8). Further vehicle load as shown in Vehicle laden #3, causes a further pressure increase inside the high pressure accumulator (8).



The relative movement of the vehicle body and axle while driving is used to level the vehicle.

Note:

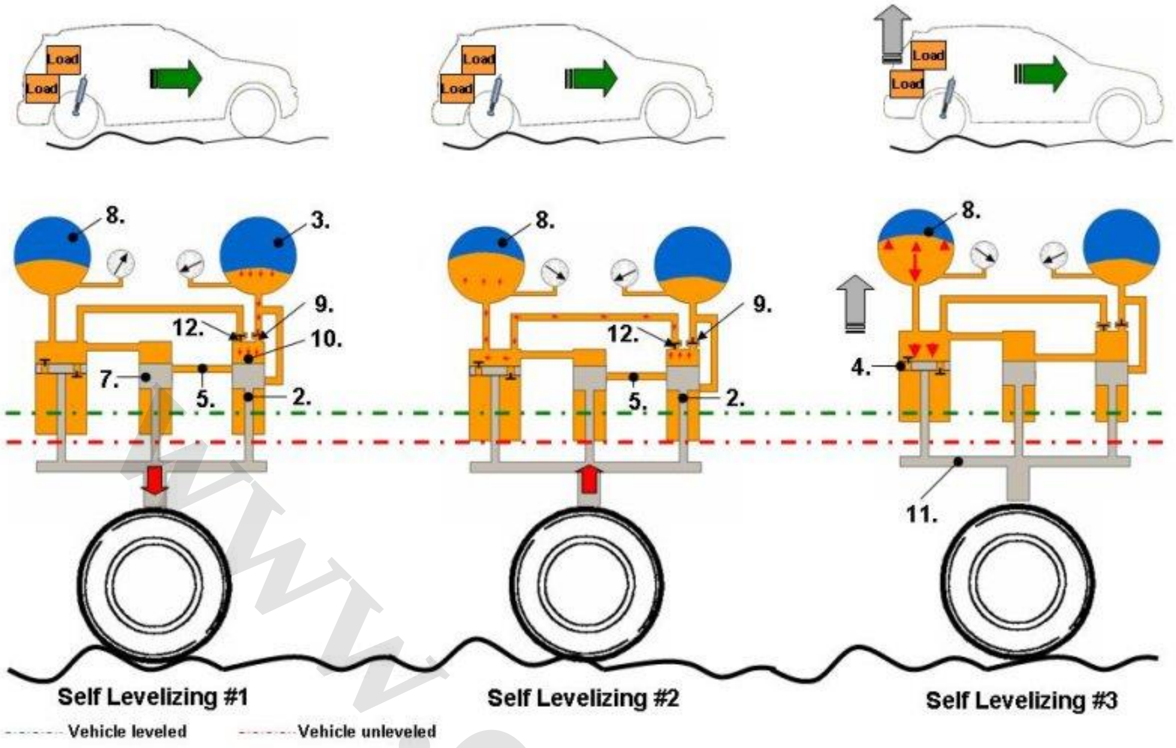
Due to the internal construction of the shock absorber the vehicle remains in the leveled position for a defined period of time even it is stopped.

Self levelizing #1:

Since the vehicle is laden, the height regulator (7) will not open the control line (5), thus separating the oil reservoir (3) from the high pressure accumulator (8). The pump rod (2) moves downward during rebound. Oil is drawn into the pump chamber (10) via the pump inlet valve (9). This causes a pressure drop inside the oil reservoir (3). Pump outlet valve (12) and control line (5) are closed under this condition.

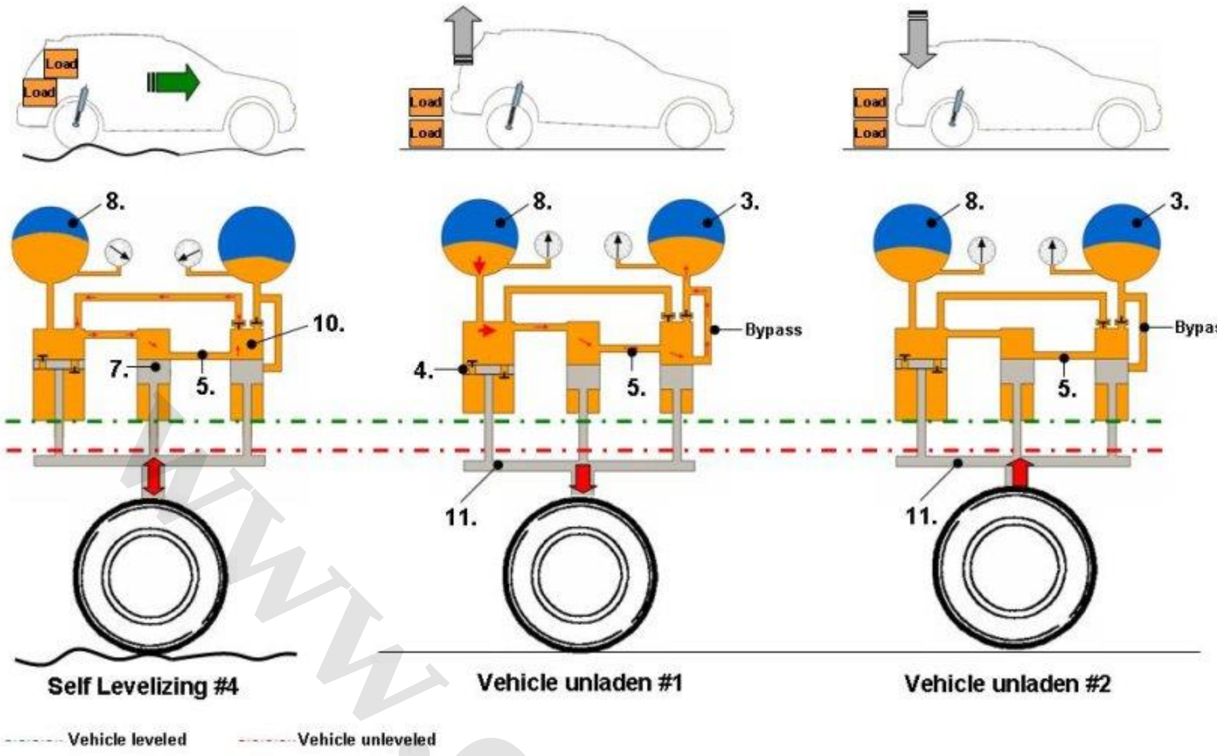
Self levelizing #2:

The pump rod (2) moves upward during compression. Oil is pushed towards the high pressure accumulator (8) via the opened pump outlet valve (12) which causes a pressure increase inside the high pressure accumulator (8). Pump inlet valve (9) and control line (5) are closed under this condition.



Self levelizing #3:

The increased pressure inside the high pressure accumulator (8) now acts against the surface of the dampening piston (4) which is connected to the piston rod (11). The pressure acts against the dampening piston (4), trying to push it downward. As this is not possible the vehicle body is raised instead.



Self levelizing #4:

Once the vehicle is leveled, the height regulator (7) opens the control line (5). Oil now „circulates“ between the pump chamber (10) and high pressure accumulator (8).

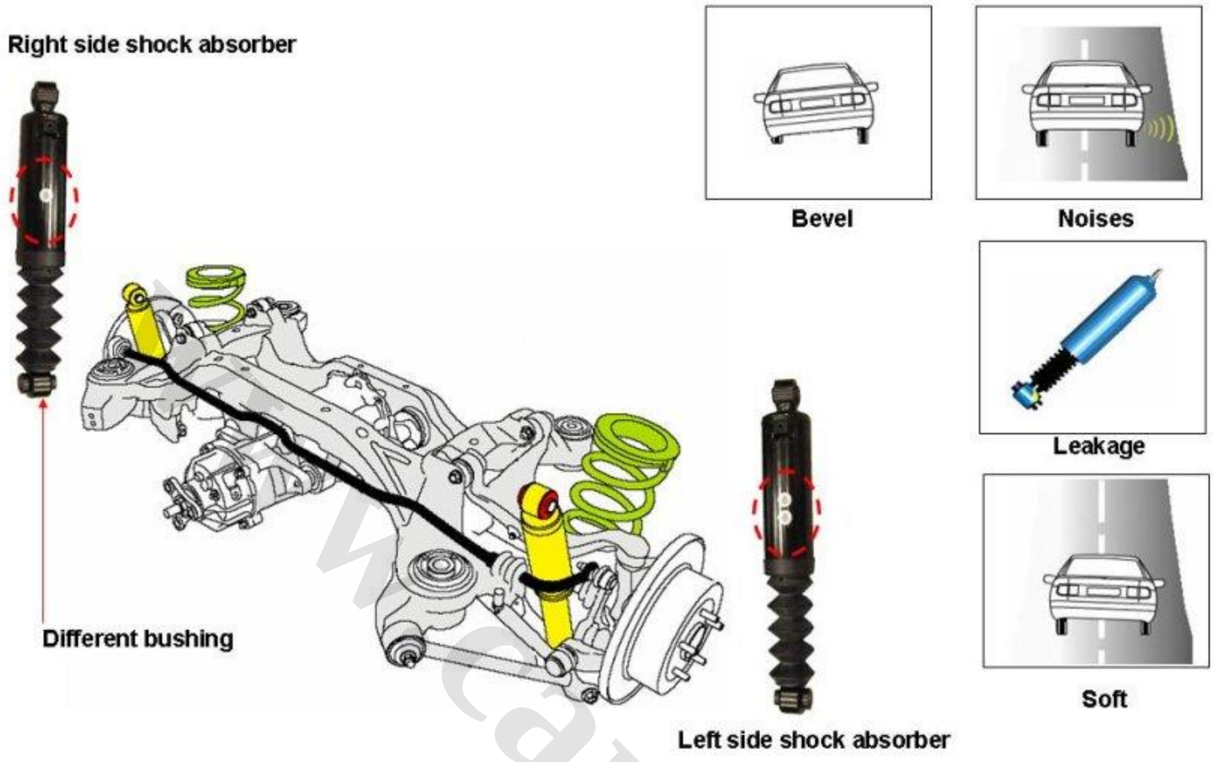
Vehicle un-laden #1:

As the counterforce (load) is removed, the high pressure inside the high pressure accumulator (8) rises the vehicle further. Under this condition the control line (5) as well as a bypass inside the pump chamber are opened allowing the oil to flow from the high pressure accumulator (8) to the oil reservoir (3). This continuous until the pressure in the oil reservoir (3) and high pressure accumulator (8) are equal.

Vehicle un-laden #2:

Once the pressure is equal, the vehicle body moves downward until Control valve (5) as well as the bypass are closed. By this the standard vehicle height is achieved.

Service and diagnosis



Leakage:

Pull the gaiter from the lower fixation and turn inside out. Check if there are oil drops inside the gaiter. If yes, replace the shock absorber.

Noises:

Test drive the vehicle. Check the following possible sound sources before replacing the shock absorber:

Exhaust chatter, Worn arm bushes, Heat protection shield chatter, Worn stabilization bushes, Coil spring noises, Hand brake cable rattle, Untighten tool set, Wheel house chatter, Untighten good in trunk or somewhere else

Soft:

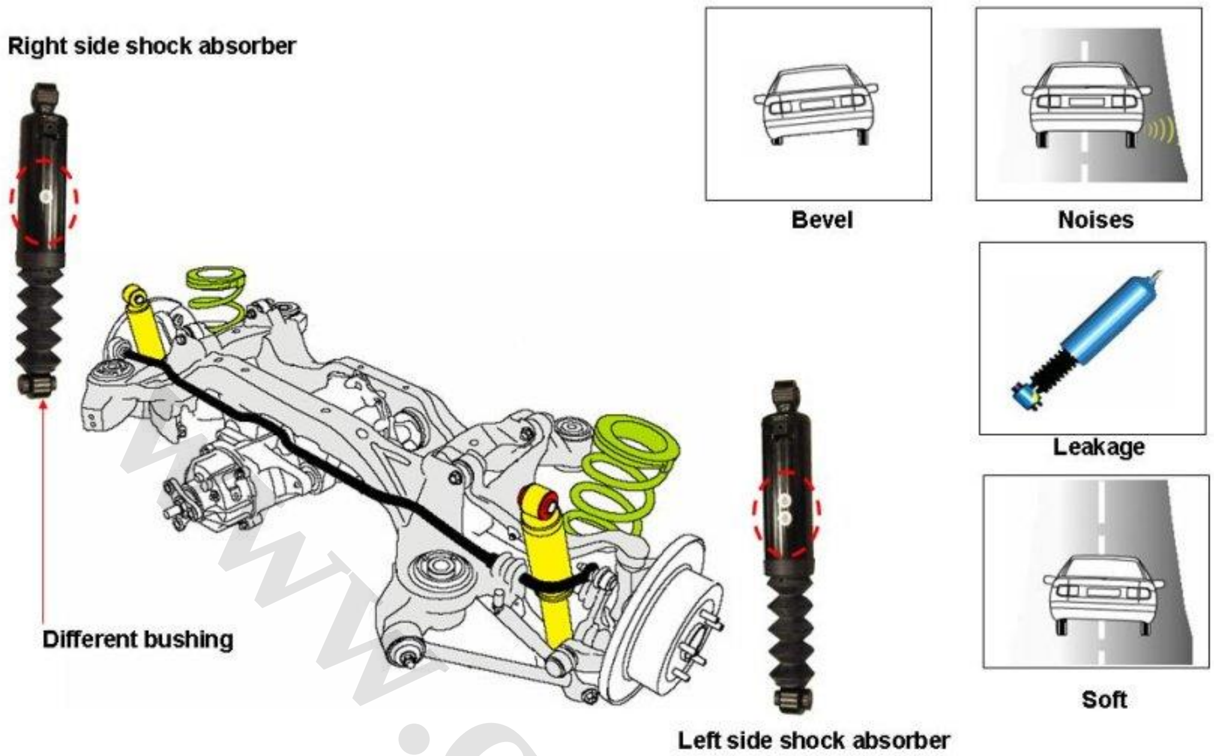
Perform a visual inspection of the shock absorber. Test drive the vehicle. Check the following before replacing the shock absorber:

-Has the car been driven overloaded?

-Does the car has the right tire pressure on all wheels?

-Are the front and rear stabilizer bars and the rubber bushes ok?

-Are the rear arm bushes worn?



Bevel:

Perform a visual check of the shock absorbers. Before replacing the shock absorber perform the following checks:

One side laden?

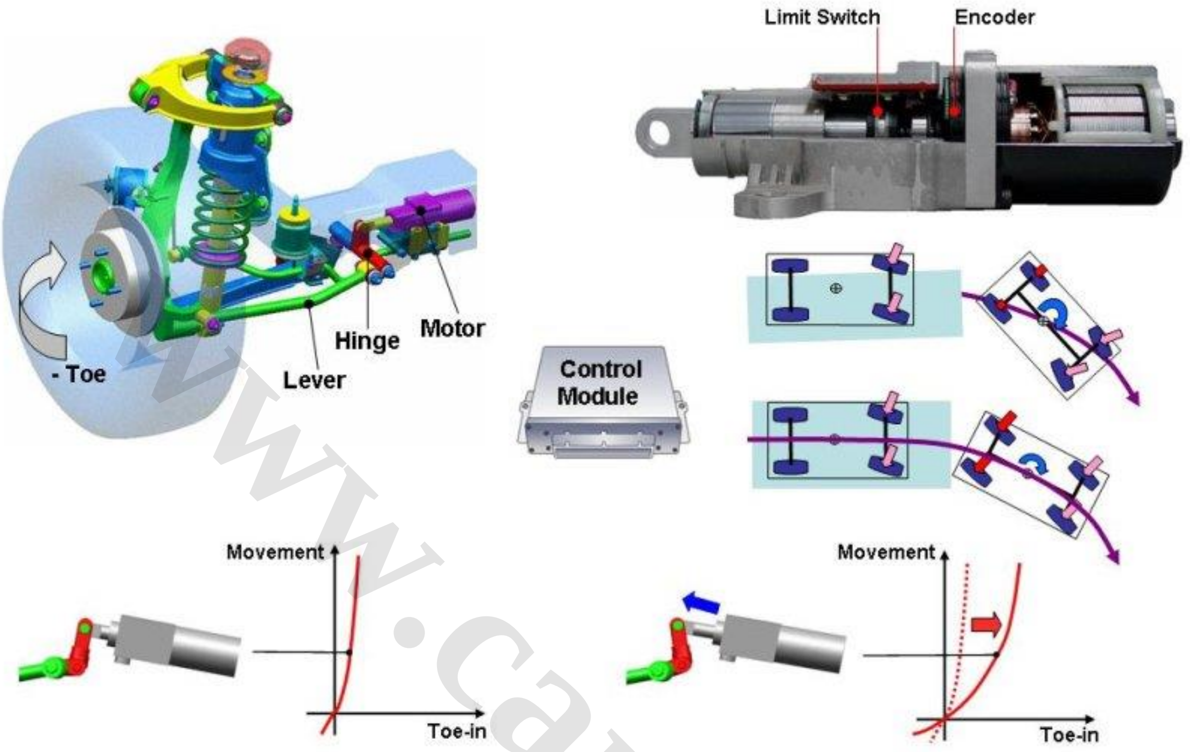
Does the car has the right tire pressure on all wheels?

Broken coil spring (check rear and front)

Important Note:

The lower bushings of the rear shock absorbers are different. The left side shock absorber is marked with two white dots, the right side shock absorber is marked with one dot. The shock absorbers are installed in a certain angle. Wrong installation (for example installing the left side shock absorber to the right side, or the right side shock absorber to the left side) will cause incorrect self levelizer operation since the height regulator bore will be out of position under this condition.

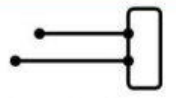
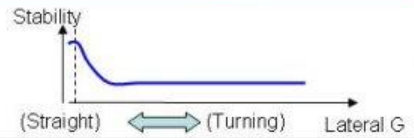
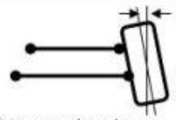
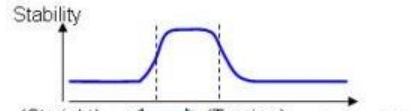
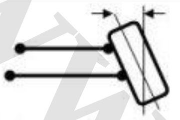
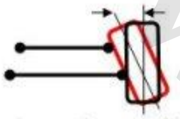
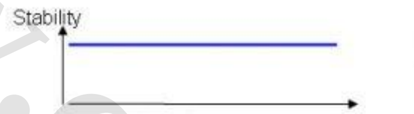
Active geometry controlled suspension



Active Geometry Controlled Suspension (AGCS) serves to increases the turning limit of a vehicle. This allows the driver to corner at a higher speed. When a critical driving condition is detected, the AGCS takes over by adjusting the toe on the wheel of the rear axle. If the critical driving condition remains, ESP (Electronic Stability Program) becomes active to stabilize the vehicle.

The components of the Active Geometry Controlled Suspension (AGCS) are the Control Module, two electro motors (each equipped with a limit switch and a position sensor (Encoder). A hinge connected to the motor serves to operate a lever which changes the toe in position of the wheel in accordance to the motor position.

Influence of toe on driving stability

Rear Geometry		Stability	Effectiveness
Without AGCS	 Rear toe angle = 0	 Stability (Straight) ⟺ (Turning) Lateral G	Straight : High Turning : Low
	 Rear toe angle = low	 Stability (Straight) ⟺ (Turning) Lateral G	Straight : Low Turning at low/mid : High Turning at high speed : Low
	 Rear toe angle = high	 Stability (Straight) ⟺ (Turning) Lateral G	Straight : Low Turning at low/mid : Low Turning at high speed : High
With AGCS	 Rear toe angle = variable	 Stability (Straight) ⟺ (Turning) Lateral G	Straight : High Turning at low/mid : High Turning at high speed : High

The rear toe has a big influence on the stability of a front wheel driven vehicle.

Rear toe angle=0:

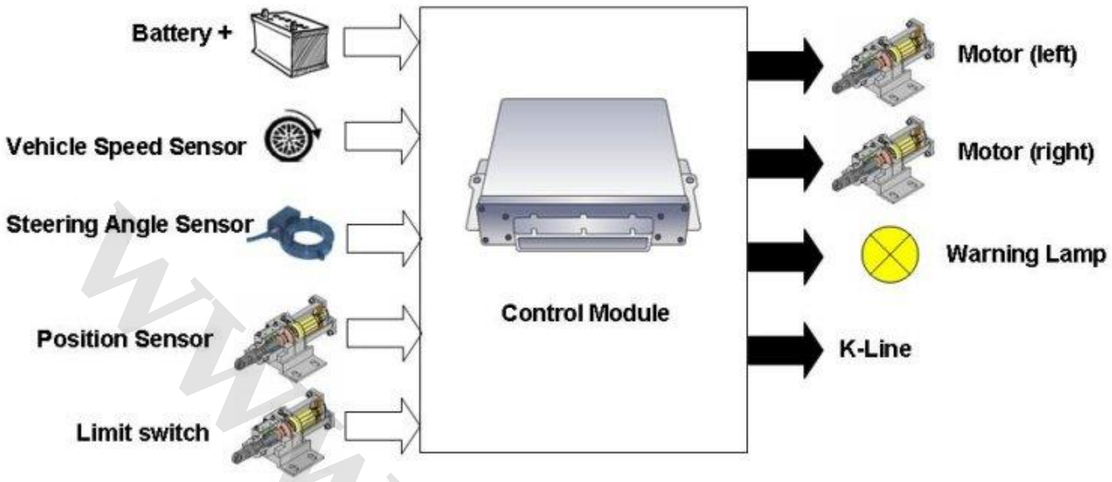
The image shows the rear axle with the parallel to each other and to the direction of travel of the car. This is a neutral toe angle position and is the base line measurement from which the other toe angle position is measured from. With a toe angle of 0° the vehicle shows a high stability while driving forward but the stability decreases when the vehicle is turning.

Rear toe angle= Low/High:

The rear wheels on the car are angled inwards towards themselves and are in what is termed as Toed-in position. This means that the front parts of the wheels are nearer together than the rear parts. With the toe angle set to a low negative toe-in, the vehicle shows a high stability while turning at low or mid speeds. On the other side this setting has an negative influence on the vehicle stability when driving straight or turning at high speed. With the toe angle set to a high negative toe in, the vehicle shows a high stability while turning at high speeds, while the stability is negatively influenced while driving straight or turning at low or middle speed.

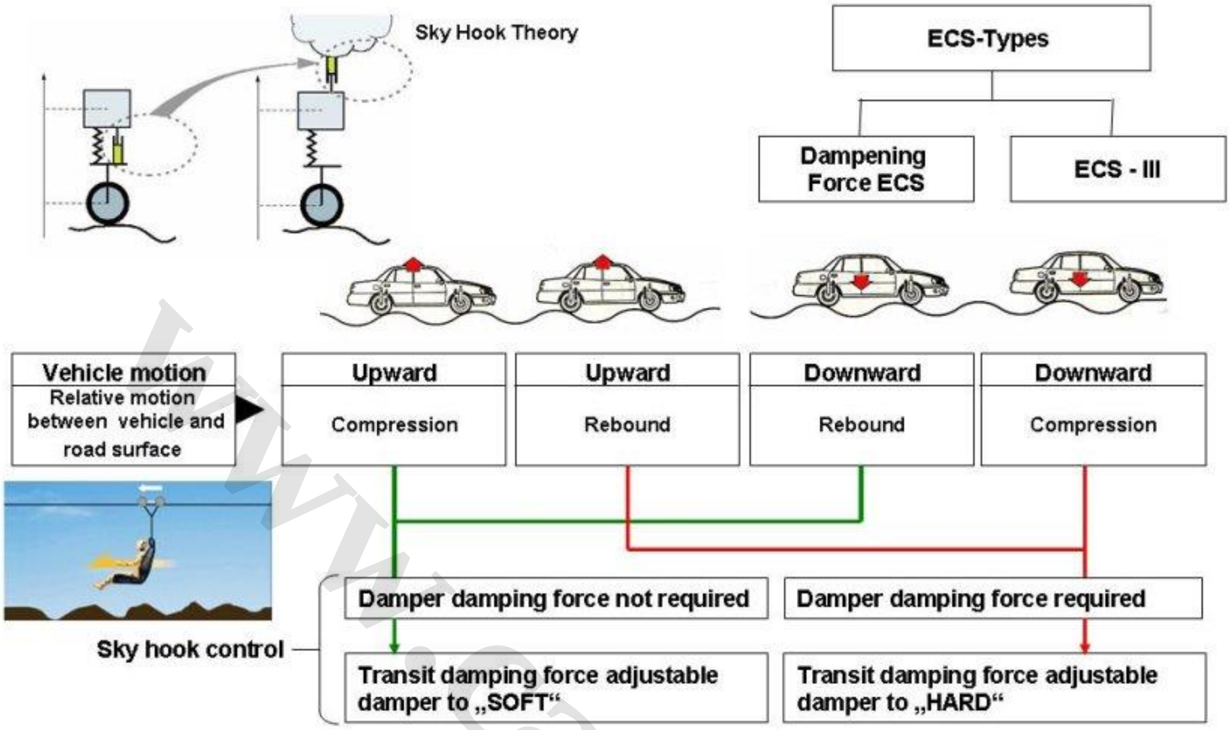
With AGCS the toe angle can be controlled resulting in a high stability under all driving conditions.

Inputs and outputs I/O



The Control Module receives several input signals from sensors. The Vehicle Speed Sensor (VSS) and Steering Angle Sensor (SAS) signals are used by the Control Module to calculate the motor operation (Toe in/out). The input signal of the position sensor enable the Control Module to detect the current position of the motor. The Limit switch becomes active when the end position of the motor is reached in order to stop the voltage supply. A Warning Lamp in the instrument cluster indicates system readiness and failures to the driver. Communication to the Scan Tool is established via K-Line.

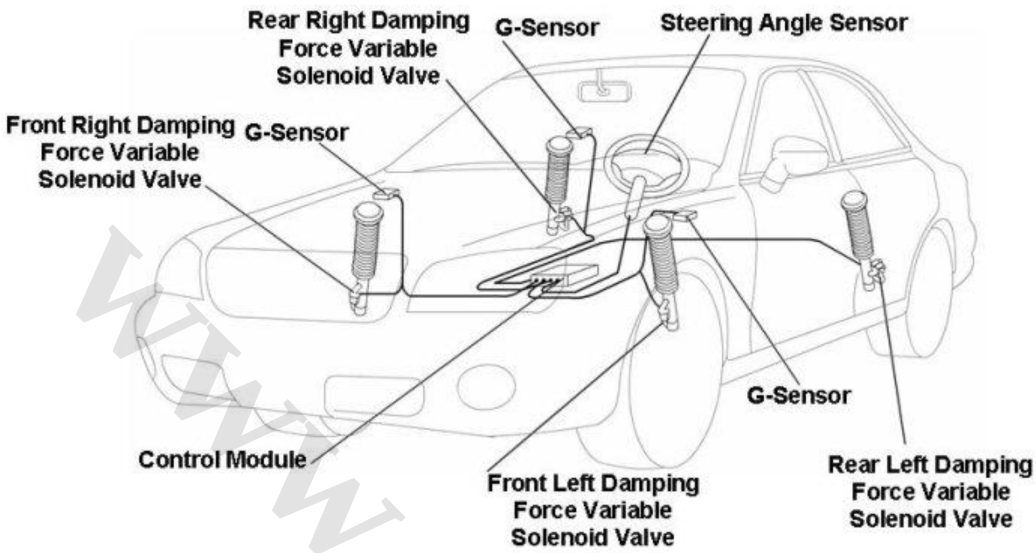
Electronic controlled suspension, general



Electronic Controlled Suspension (ECS) in general is based on the Sky-Hook theory. This theory has been established by Dr. Karnopp in 1974. He considered that if the damper is hooked to the absolute axis, vibration of the mass will be most effectively absorbed. Also he found out that the same effect can be achieved by using a variable damper. ECS selects an optimum damping force of the shock absorber depending on operating and road surface condition. As a result, the system can provide more precise control for better riding comfort and directional stability.

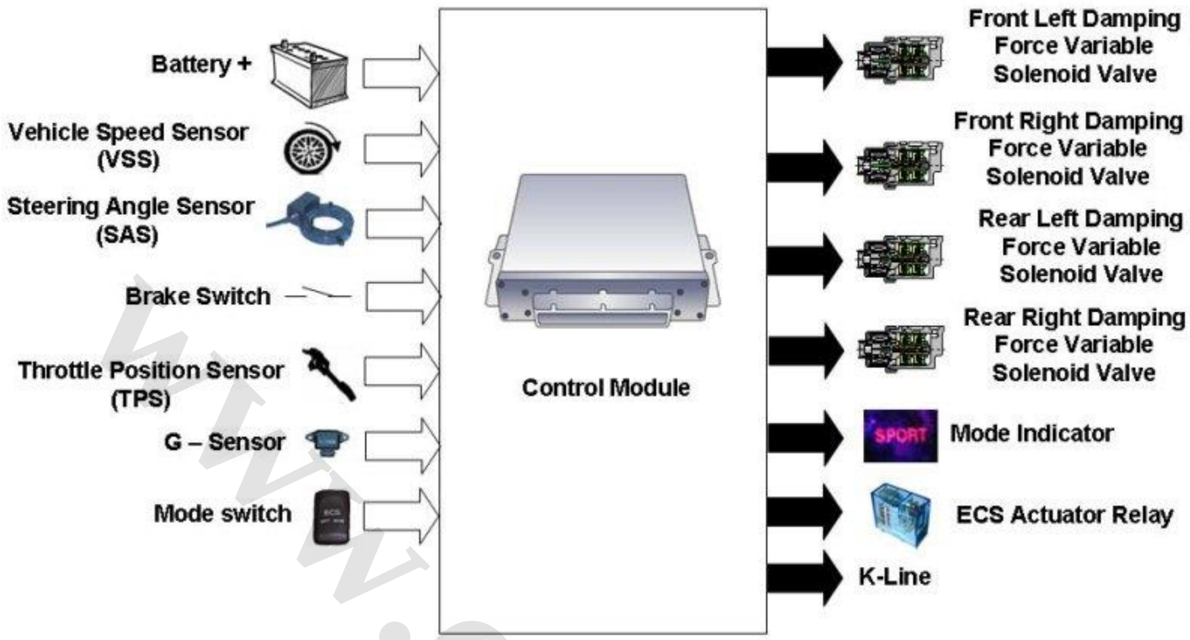
Currently two types of Electronic Controlled Suspension (ECS) systems are used on Hyundai vehicles. These systems are referred to as Dampening Force ECS and ECS-III.

Dampening force ECS

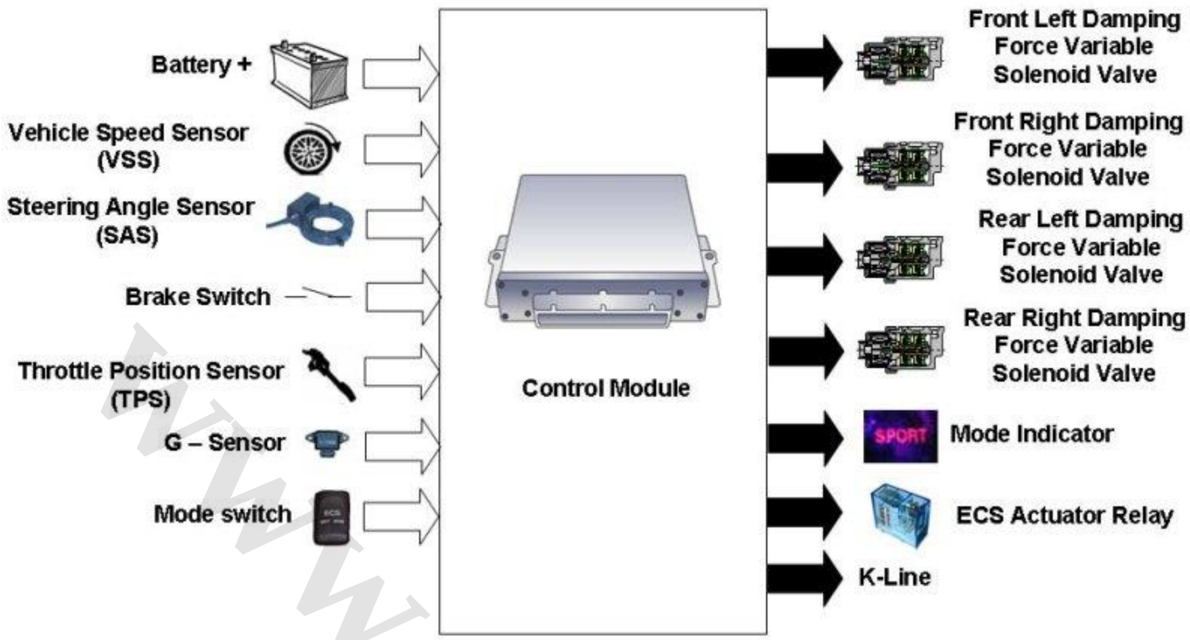


The main components of the Damping Force Electronic Controlled Suspension (ECS) are the shock absorbers with Damping Force Variable Solenoid Valve, G-Sensors, Steering Angle Sensor (SAS) and the Control Module. The G-Sensors detect the body up-down movement and are mounted on the sprung weight. In addition, information from Throttle Position Sensor (TPS), brake switch, Vehicle Speed Sensor (VSS) are inputted to the Control Module. According to the information from the sensors the ECS Control Module decides the dampening force of each shock absorber by controlling the current to the Damping Force Variable Solenoid Valves. The damping force ECS system has an select switch, so the drivers can select between normal mode or sport mode.

Inputs and outputs



The block diagram shows the input / output interaction of the Damping Force ECS system. The steering angle sensor and G-Sensors are for detecting the steering wheel operating speed and body lateral acceleration (G), respectively. The steering angle sensor is a contact less optical sensor. The G sensor is a small – size, highly responsive sensor using a semiconductor. At least three points are required In order to detect a plane. On the Damping Force ECS there are three G-Sensors. The ECS Control Module sends appropriate shock absorber damping force switch over signals for individual modes to make the shock absorber actuators operate accordingly. The Control Module monitors the charging current. If the generator output voltage is below specification, ECS will stop to operate. The Vehicle Speed Sensor signal is used for controlling anti-dive, anti-roll and high speed driving stability. The brake switch signal is required for anti-dive control as well as the signal from the Throttle Position Sensor (TPS). The ECS mode switch is used to select sport or normal mode depending on the running condition. The selected mode as well as system failures are displayed by means of a mode indicator located in the dashboard.



Damping Force Variable Solenoid Valve:

The Damping Force Variable Solenoid Valve current is controlled by the Control Module. Depending on the supply current, the dampening force is changed.

ECS Actuator Relay:

The ECS Actuator Relay operation is controlled by the Control Module. Upon actuator relay operation, power is supplied to the Damping Force Variable Solenoid Valves. The Control Module will quit relay operation upon detecting low system voltage.

Control features

Depending on the road surface and operating conditions, the damping force characteristics are controlled.

Shock Absorber Damping Force:
The damping force ECS has the possibility to adjust the suspension stiffness to „Hard“ and „Soft“.

Anti- Rolling Control:
Anti rolling control switches the damping force modes according to the steering wheel handling information and referring to the steering wheel angular velocity to vehicle speed map.

Pitching/Bouncing Control:
When the system determines (based on the values of the G-Sensors) that the vehicle is in an excessively soft suspension mode, it switches the damping force mode of the shock absorber into a one which ensures a flat ride least affected by the vibrations of the vehicle body.

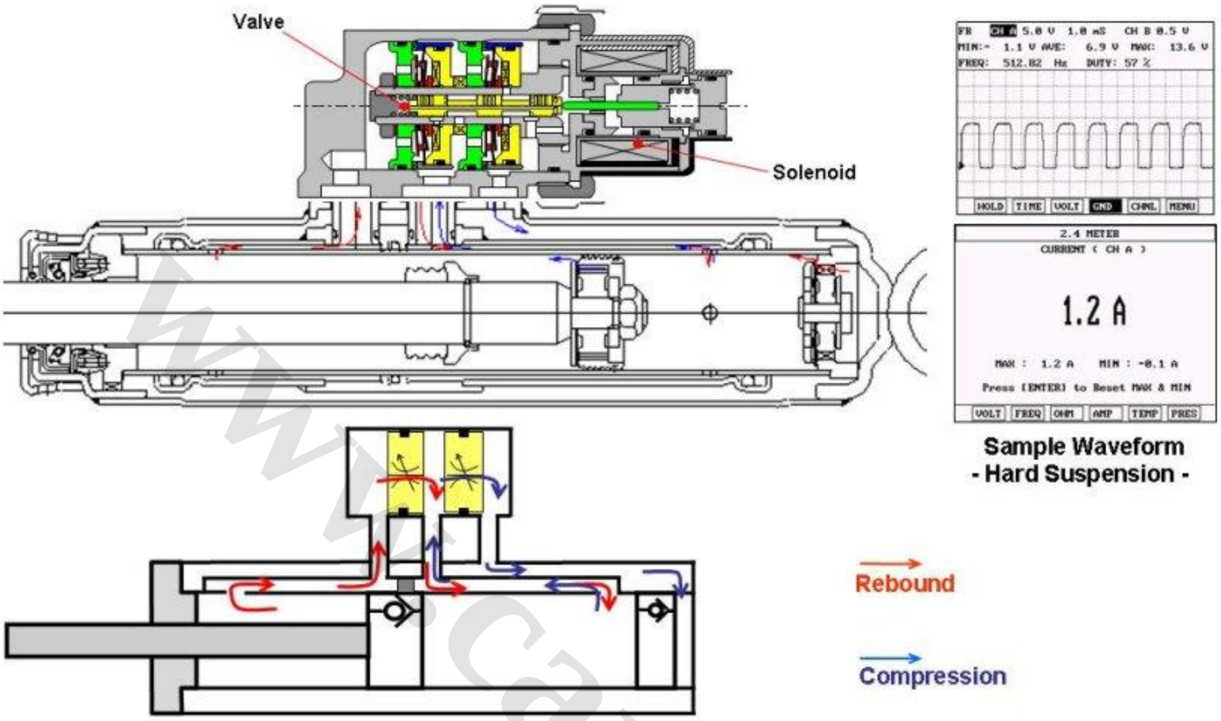
Anti Diving Control:

When the brake pedal is depressed and the stop lamp switch contact is closed, the ECS Control Module calculates the damping force on the basis of the changing vehicle speed. If the deceleration calculated within the predetermined time after the stop lamp switch contact closure is found to be in excess of the predetermined G value, the system will switch the shock absorber damping force to „Hard“.

High Speed Control:

When the vehicle speed exceeds a predetermined value, the control switches the damping force mode from „Soft“ to „Hard“ to ensure greater high speed operation stability.

Shock absorber and damping force valve

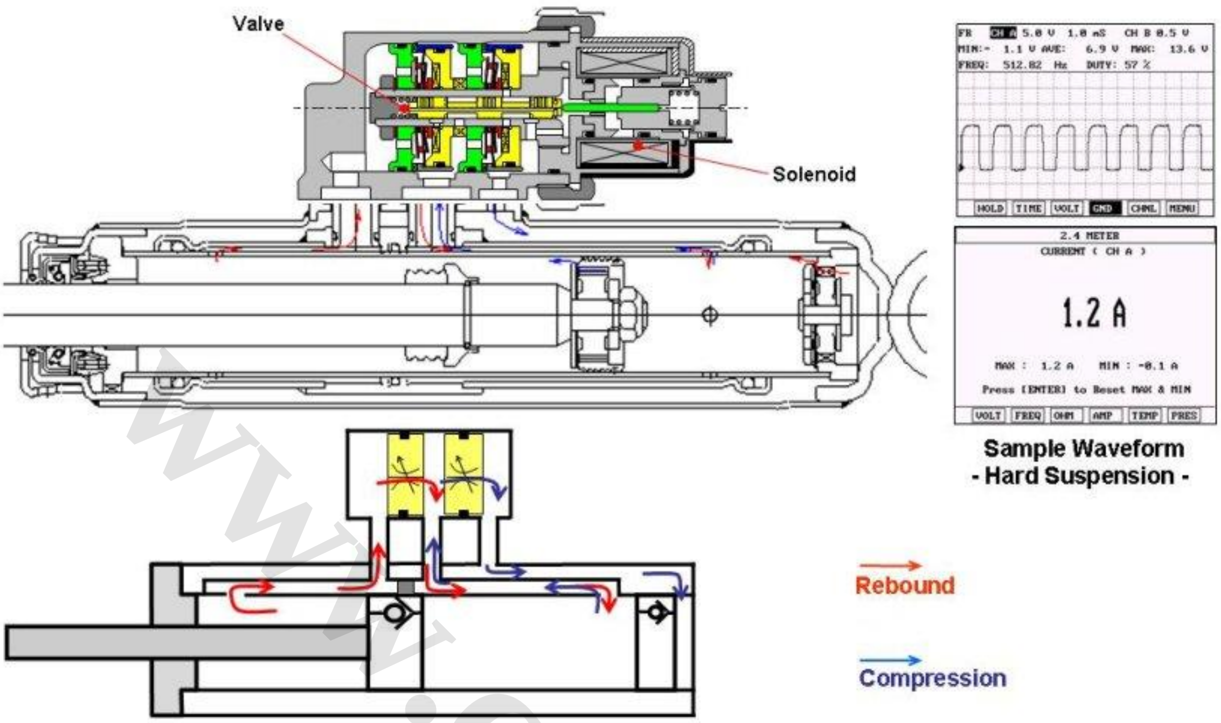


The damping force control valve is located on the side of the shock absorber. It connects the lower room of the piston to the upper room of the piston via orifices. Depending on the current applied, the spool valve in the actuator moves to change the size of the orifices, thus leading to the damping force variation. The applied current to the Damping Force Variable Solenoid Valve is controlled by the ECSCM.

Damping force „Hard":
Current supply to the solenoid actuator is increased. The pilot spool moves to the right side

When bounding; Since all the orifices are blocked, the fluid flows up into the upper chamber, forcing the valve at the top of the piston to open. A higher damping force is obtained because the resistance the fluid encounters when the it flows through the valve is greater than when it would flow through the orifice in the „Soft" mode.

When rebounding;Al the orifices are blocked, and the fluid flows down while forcing the valve at the bottom of the piston. Since the valve gives the fluid greater resistance than the orifice would do in the „Soft"   mode, the resulting damping force is also greater than in the „Soft" mode.



Damping force “soft”:

Current supply to the solenoid actuator is reduced. The pilot spool moves to left side.

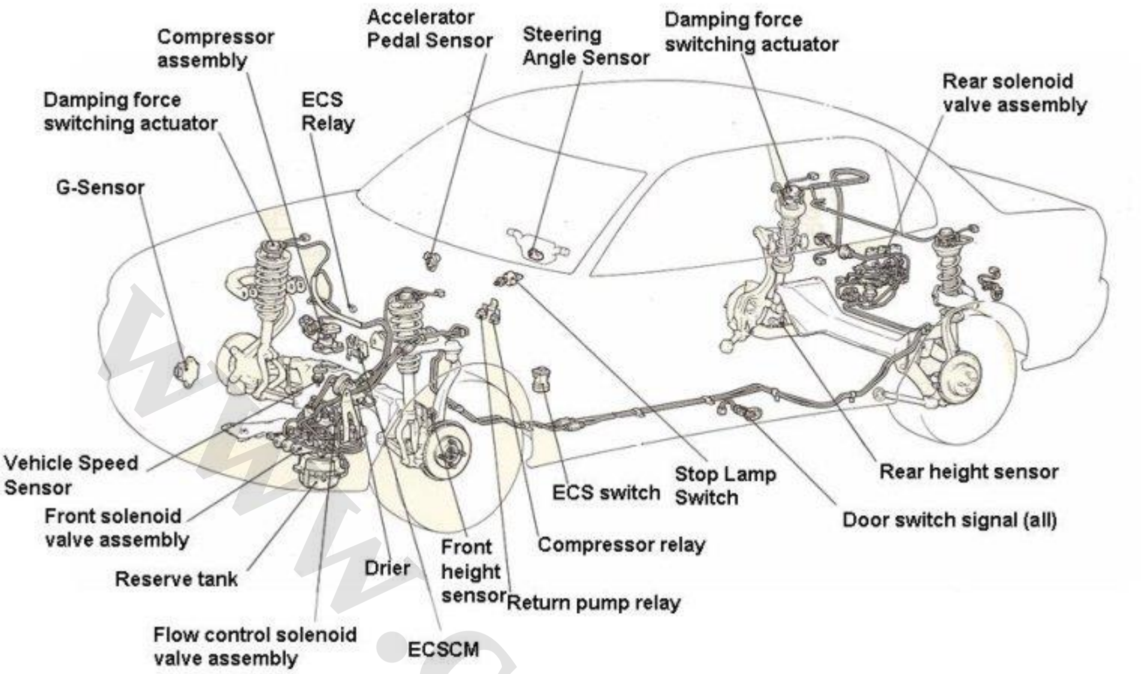
When bounding;

A compression side damping force is generated through the base valve in the bottom of the shock absorber. The fluid flows up through the check valve inside the piston nut into the chamber above the piston without any resistance. Therefore the, the damping force obtained in this state is small.

When rebounding;

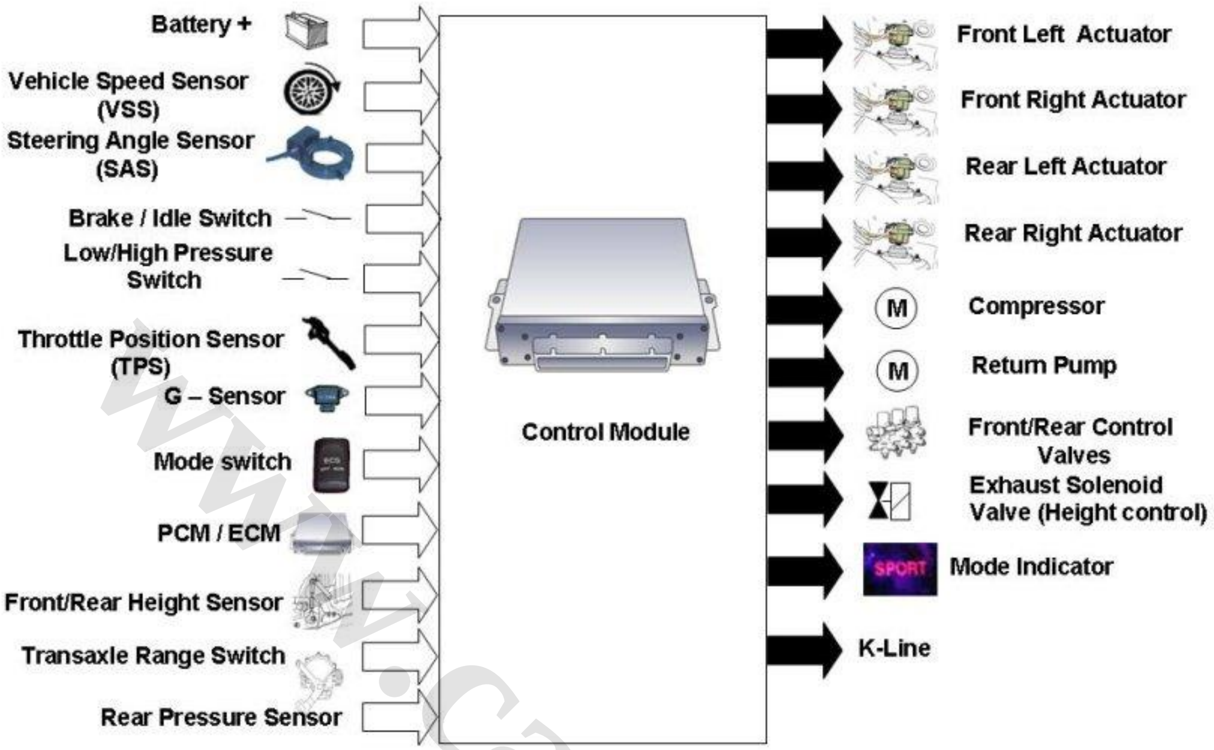
The fluid that flows through the orifices passes by way of the valve inside the piston nut into the chamber below the piston.

ECS-III

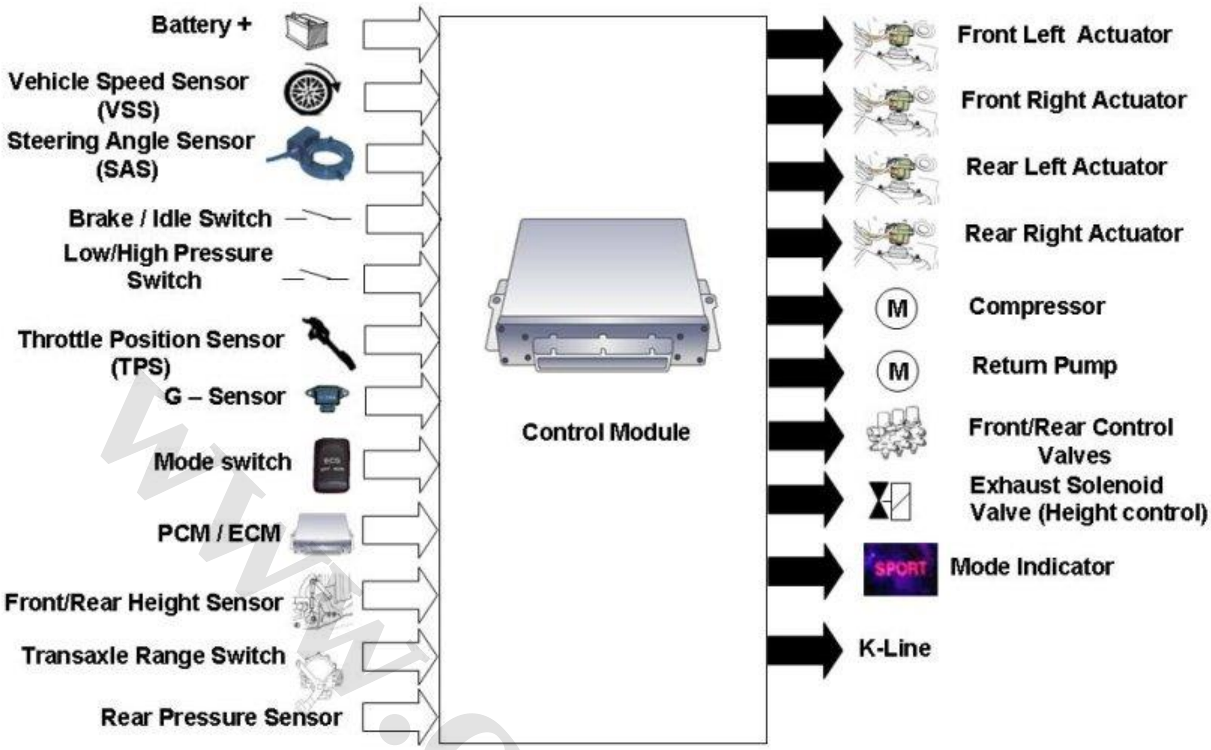


The ECS-III system incorporates fuzzy control functions in addition to the functions of the previously described dampening force ECS. By analyzing the stroke of the suspension in terms of frequency, the system determines the degree of excessive softness or stiffness of the suspension and uses the result for fuzzy control of the damping force so that the driver and passenger can enjoy more comfortable ride. This system provides the anti-rolling control for the front and rear wheels at different timing to obtain proper steering characteristics suitable for the operating conditions which have been estimated from the road slope and steering wheel handling frequency information. The new addition to this control is the timing difference (time lag) adjustment which is accomplished on the fuzzy control basis. In this system, each of the front and the rear shock absorbers has a coaxially arranged air spring. The damping force of the shock absorber is changeable in four steps, and to achieve this, an air system that supplies compressed air to the air springs and a control system that control the air system are provided. Through combination of these systems, the active body attitude control, damping force switching control and vehicle height control are accomplished. For the active body attitude control purpose, the operating and road surface conditions are detected by using several kinds of sensors such as Throttle Position Sensor (TPS), Steering Angle Sensor (SAS), Vehicle Speed Sensor (VSS), G-Sensor and vehicle height sensors. Using the information from these sensors, the ECS Control Module energize or de-energize solenoid valves to control the internal pressure of the air springs so that the vehicle attitude will be always maintained parallel (flat) to the road surface.

Inputs and outputs



The block diagram shows the input / output interaction of the ECS-III system. The height sensors, steering angle sensor and G-Sensor are for detecting the vehicle height, steering wheel operating speed and body lateral acceleration (G), respectively. The height sensor uses a potentiometer with high resolution capabilities. The steering angle sensor is a contactless optical sensor. The G sensor is a small – size, highly responsive sensor using a semiconductor. The sensors used in the air pressure system include the high and low pressure switches which control the compressor and return pump operation by detecting the pressure in the reserve tank(s), and the rear pressure sensor which detects the internal pressure of the air springs. The rear pressure sensor is a potentiometer type sensor. It converts a change in pressure in the displacement of a diaphragm and transmits the voltage changes in proportion to the diaphragm displacement to the control Module. The Control Module consists of an 8-bit one chip microprocessor, an input interface circuit, an output drive circuit, a fail safe circuit and a regulated power supply circuit. The self diagnosis function included in the Control Module causes the Warning lamp to be illuminated when a failure occurs in the system . The Control Module also provides the service data display function which allows the information in the Control Module memory to be displayed and the actuator testing function which provides the means for simulation test of each actuator. These two functions, available when HI-SCAN Pro is used, are useful for precise and quick diagnosing operation.



Height Sensor:

Two height sensors, one for the front and the other one for the rear, are provided for obtaining the vehicle height change information by detecting the change in relative position of the body and the axle. Each of them consist of a sensor proper and linked rod and lever combination. The sensor proper is a rotary type potentiometer balance resistor which detects a change in body height in terms of the amount of rotation of the lever.

Control features

Depending on the road surface and operating conditions, the damping force characteristics are controlled in four stages, and the internal pressure of air springs is controlled to keep the body position flat with respect to the road surface for better ride and directional stability. Addition of fuzzy control functions has further improved ride and stability when the vehicle goes over bumps on a road, travels on a wavy surface, or goes up or down a slope.

Fuzzy control:
Road surface condition dependent control; By analyzing the stroke of the suspension in terms of frequency, the system determines the degree of excessive softness or stiffness of the suspension and uses the results to control the damping force on the fuzzy control basis so that more comfortable ride can be obtained. This control ensures an excellent ride even under the operating conditions which would involve excessive softness and stiffness of suspension simultaneously.

Upward/Downward slope control; This control changes the anti rolling control activating timing for the front wheels and that for the rear wheel according to the road slope information from the Transmission Control Module (TCM) and the steering wheel handling frequency which reflect the driver's vehicle control behavior (degree of sportyness). When the vehicle is on an upward slope and the degree of sportyness is great.

Anti-rolling control timing of the front wheels is delayed to bring the vehicle in an „over-steer“ state. The amount (time lag) of the delay is determined according to the slope, degree of sportyness and vehicle speed on the fuzzy control basis. When the vehicle is on an downward slope and the degree of sportyness is small, anti-rolling control timing of the rear wheels is delayed to bring the vehicle in an „under-steer“ state. The amount (time lag) of the delay is determined according to the slope, degree of sportyness and vehicle speed on the fuzzy control basis.

Anti- rolling control:

Depending on the steering speed and the magnitude of the lateral G induced in the body, the exhaust time of the air springs for the inner wheels and the supply time of the ones for the outer wheels are controlled. At the same time, the damping force of the air springs are switched for a stiffer support. These controls help suppress the rolling of the vehicle body during cornering.

Anti-diving control:

Depending on the magnitude of the G induced in the front and rear suspensions during a brake application, the supply time of the front wheel air springs and the exhaust time of the rear wheel are controlled. At the same time, the damping force of the air springs are switched for a stiffer support. These controls effectively suppress the vehicle's nose dive tendency during braking.

Anti-squatting control:

When the vehicle is started in motion or accelerated, the exhaust time of the front wheel air springs and the supply time of the rear wheel air springs are controlled depending on how much the accelerator pedal is depressed. At the same time, the damping force of the air springs is switched for a stiffer support. These control help suppress squatting that would occur when the vehicle is started or accelerated. On A/T models, squatting during gear shifting is prevented by controlling the damping force for a stiffer characteristic when the vehicle is stationary with the accelerator pedal not depressed.

Pitching / bouncing control:

The air supply/exhaust control is made depending on the extension or retraction of the shock absorber so that the air will be supplied to the expansion side springs and exhausted from the compression side springs. This controls to reduce up and down swings of the body when the vehicle runs on a wavy road.

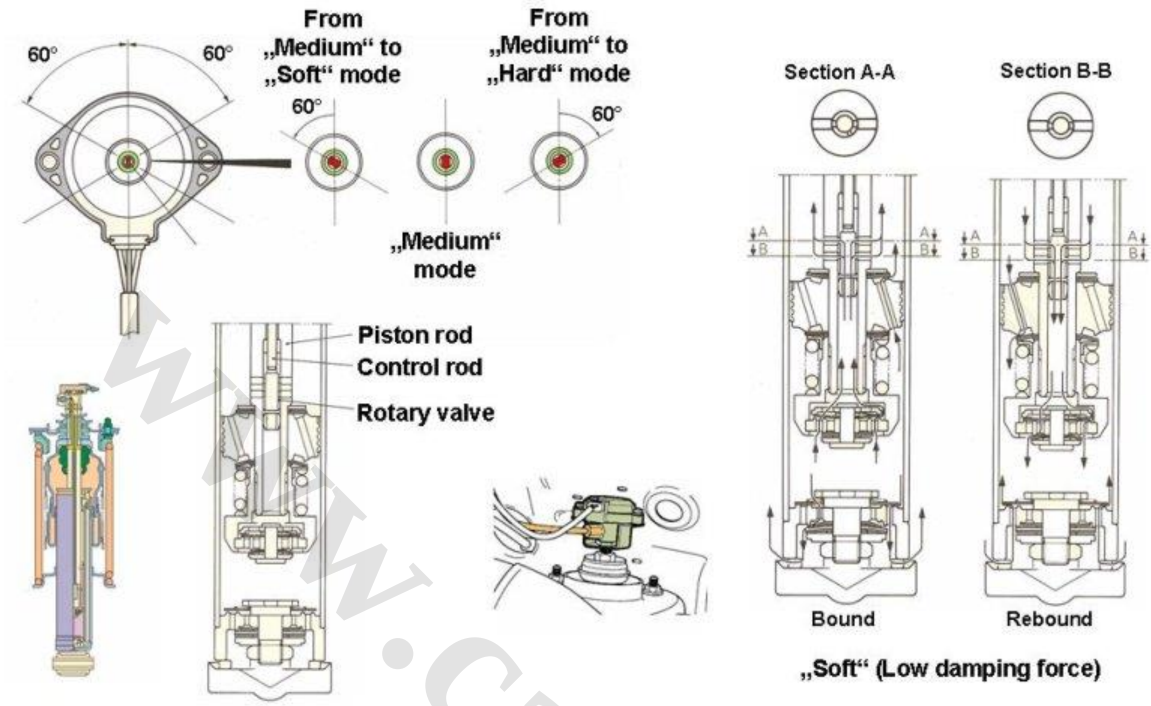
Vehicle height control function:

This function automatically controls the pressure in the air springs in order to maintain the target vehicle height according to the change in the number of passengers or the amount of luggage. The front and rear height sensors detect the vehicle height while the Control Module automatically determines the start and stop point for vehicle height adjustment.

High speed control:

When the vehicle speed exceeds a predetermined value, the control switches the damping force mode from „soft“ to „hard“ to ensure greater high

Actuator and shock absorber

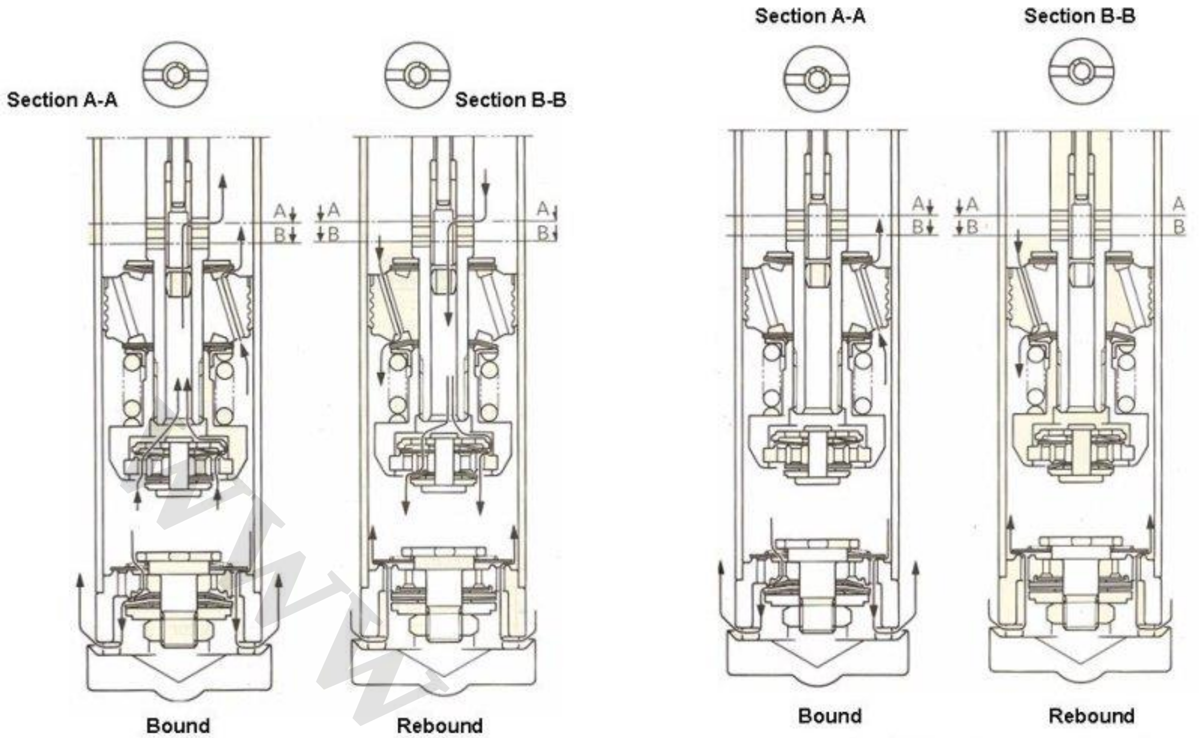


The damping force switching control is achieved by driving a four step adjustable actuator mounted on top of each air spring unit. The shock absorber actuator rotates the control rod of each shock absorber to select the opening of the rotary in response to signals from the ECS control module. A 60° clockwise or counterclockwise turn of the actuator shaft selects, respectively, the „hard“ or the „soft“ mode with the „medium“ mode at its center. Both the rotary valve which is driven by the shock absorber actuator via the control rod, and the piston rod which incorporates the rotary valve have two orifices each. The three damping force modes are selected by placing the two orifice pairs in the clear or blocked state through rotation of the rotary valve to increase or reduce the fluid passage area in the shock absorber.

„Soft“ (low damping force):

When bounding; A compression side damping force is generated through the base valve in the bottom of the shock absorber. The fluid flows up through the check valve inside the piston nut into the chamber above the piston without any resistance. Therefore the, the damping force obtained in this state is small.

When rebounding; The fluid that flows through the orifices in the A-A and B-B sections passes by way of the valve inside the piston nut into the chamber below the piston.



„Medium“ (Medium damping force)   „Hard“ (Hard damping force)

„Medium“ (Medium damping force):

When bounding; As in the „soft“ mode, the fluid passes through the check valve inside the nut and flows up into the chamber above the piston. However, since the orifice is narrower than in the „soft“ mode as shown in the section A-A, the fluid flow resistance increases that much , that the damping force in this state is grater than in the „soft“ mode.

When rebounding; The fluid that flows through the orifice in the A-A section passes through the valve inside the nut and flows into the chamber below the piston as in the „soft“ mode. Since the orifice area in the A-A section is narrower than in he „soft“ mode, the fluid flow resistance increases that much, that the damping force obtained in this state is greater than in the „soft“ mode.

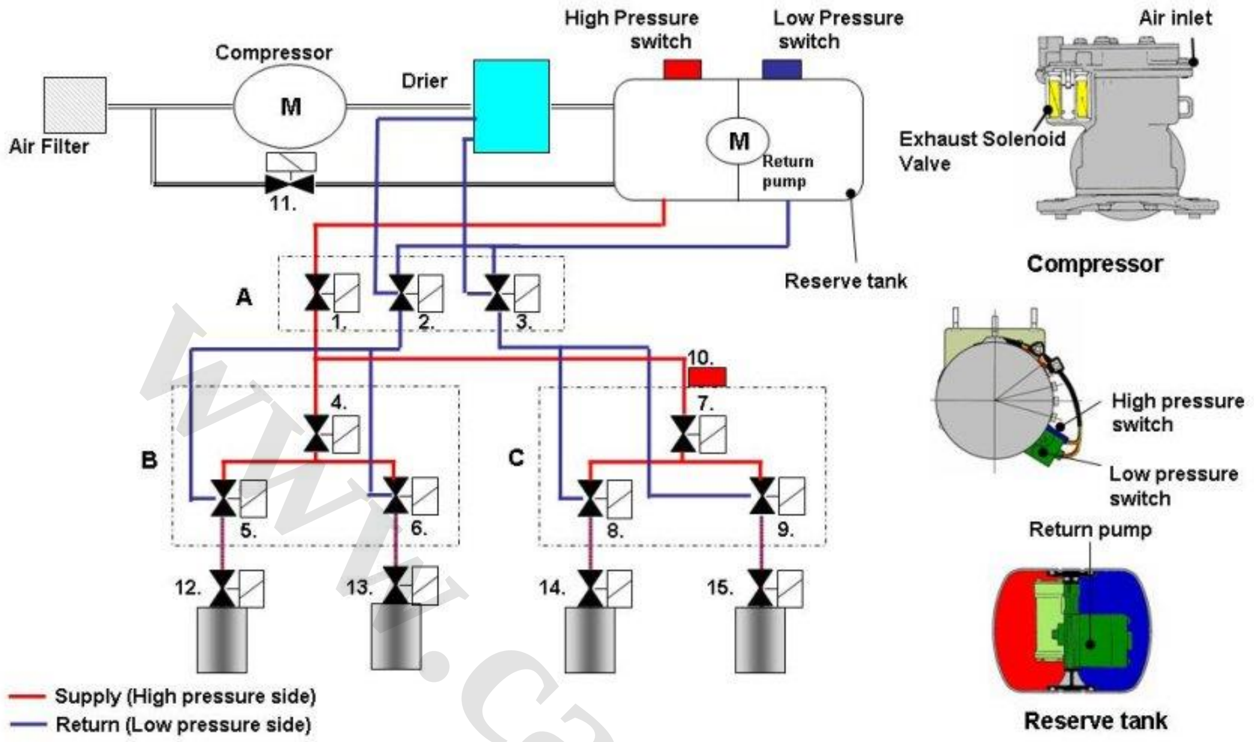
„Hard“ (high damping force):

When bounding; Since all the orifices in both the A-A and B-B sections are blocked, the fluid flows up into the upper chamber, forcing the valve at the top of the piston to open. A higher damping force is obtained because the resistance the fluid encounters when the it flows through the valve is greater than when it would flow through the orifice in the „medium“ mode.

When rebounding;

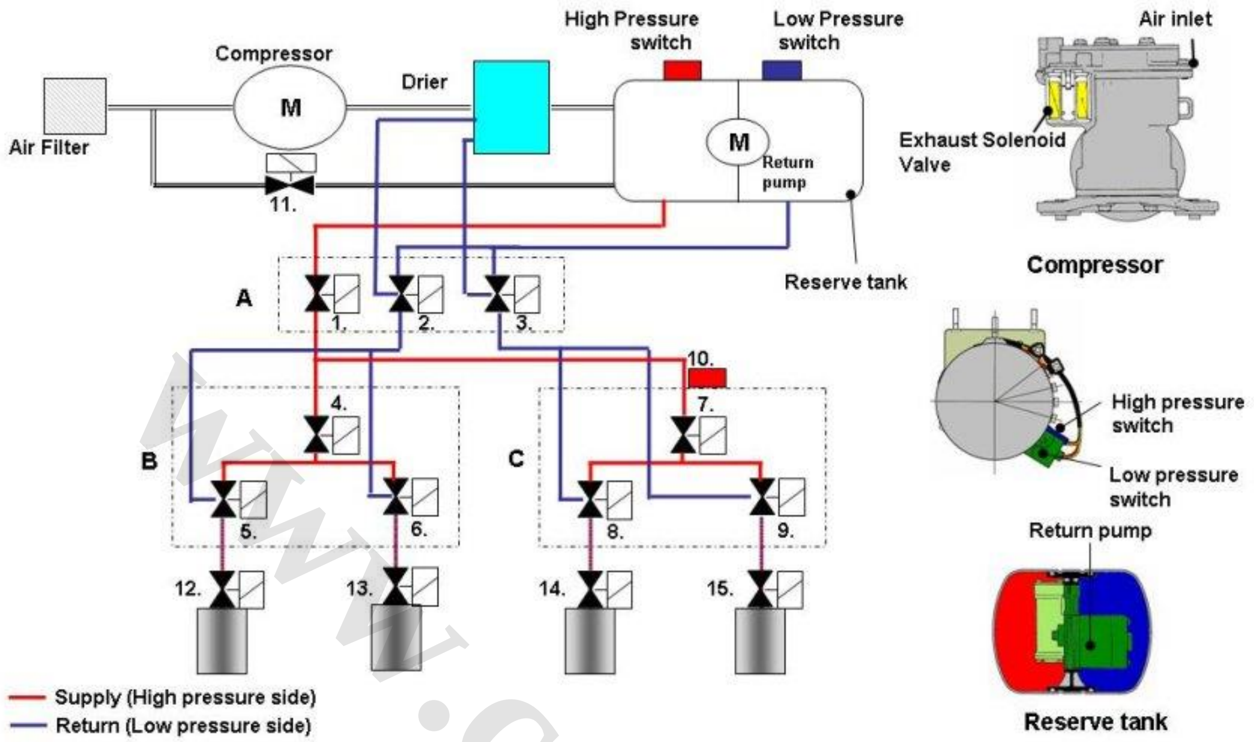
Al the orifices in both the A-A and B-B sections are blocked, and the fluid flows down while forcing the valve at the bottom of the piston. Since the valve gives the fluid greater resistance than the orifice would do in the „medium“ mode, the resulting damping force is also greater than in the „medium“ mode.

Air pressure system



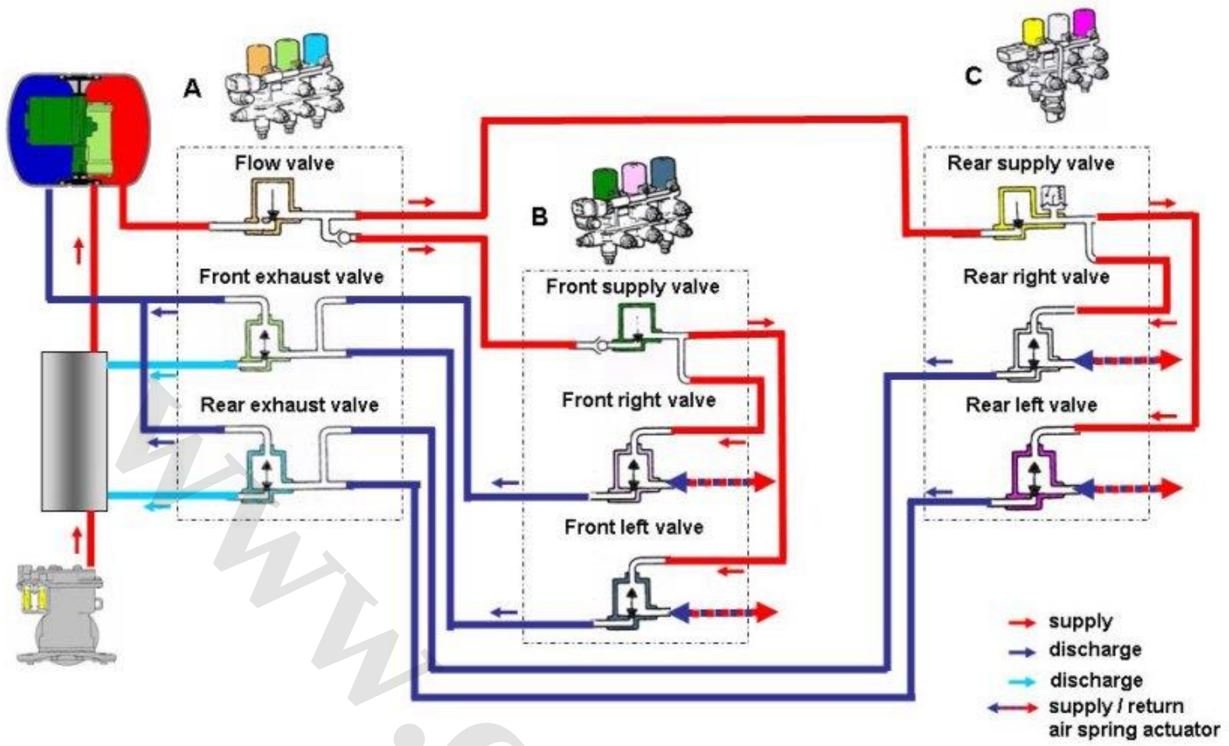
The diagram shows the whole air lines of the ECS-III system. For utilization of the air pressure energy, the pneumatic system is designed in such a way that a closed loop circuit is established any time the air spring internal pressure is controlled during driving except for the vehicle height control. The reserve tank consist of a high pressure tank which supplies the air to the air springs, a low pressure tank into which the air spring air is temporarily exhausted and a return pump inside the tank. When the pressure in the high pressure tank fall below the predetermined level, the high pressure switch is caused to be ON , the compressor relay is energized and the compressor is operated. When the pressure exceeds the predetermined value („high") pressure, the switch is forced to be „OFF" to stop the compressor.

The air accumulated in the high pressure chamber of the reserve tank is therefore always maintained at a given pressure. When the pressure in the low pressure chamber of the reserve tank exceeds the predetermined pressure, the low pressure switch is caused to be „OFF. The return pump relay under this condition is energized to operate the return pump. When the pressure falls below the set value („low" pressure"), , the switch returns to the „ON" position to stop the pump. The compressor has a built in exhaust valve for the vehicle height control. The exhaust valve is opened to release the air in the air springs to the atmosphere only when the vehicle height is to be lowered.



The drier, positioned between the compressor and the reserve tank, contains silica gel to absorb the moisture in compressed air to prevent rust formation in the system components. Since the silica gel is regenerated by the dry air during exhausting, the drier is maintenance free.

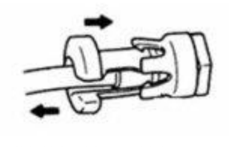
No.	Item	No	Item	No.	Item
1.	Flow Valve	2.	Front Exhaust Valve	3.	Rear Exhaust Valve
4.	Front supply valve	5.	Front left valve	6.	Front right valve
7.	Rear supply valve	8.	Rear left valve	9.	Rear right valve
10.	Rear Pressure Sensor	11.	Exhaust Solenoid Valve (Height Control)	12.	Front left actuator
13.	Front right actuator	14.	Rear left actuator	15.	Rear right actuator

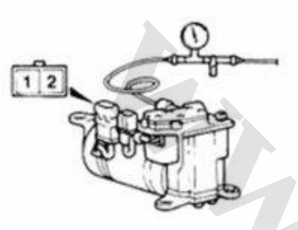


The system estimates a change in vehicle attitude by making reference to a program map and provides controls by energizing/de-energizing (opening/closing) the flow control solenoid valves.

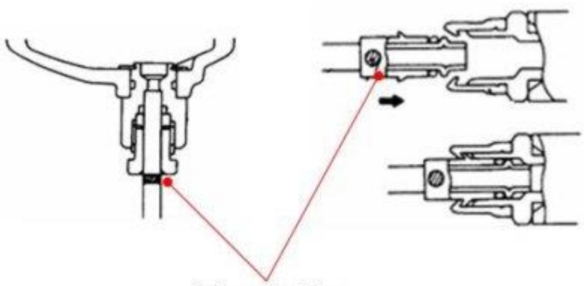
Flow control solenoid valve A contains the flow valve, front exhaust- and rear exhaust valve.
Flow control solenoid valve B contains the front supply valve, front right- and front left valve
Flow control solenoid valve C contains the rear supply valve, rear right- and rear left valve.

Service and diagnosis


Special Service Tool



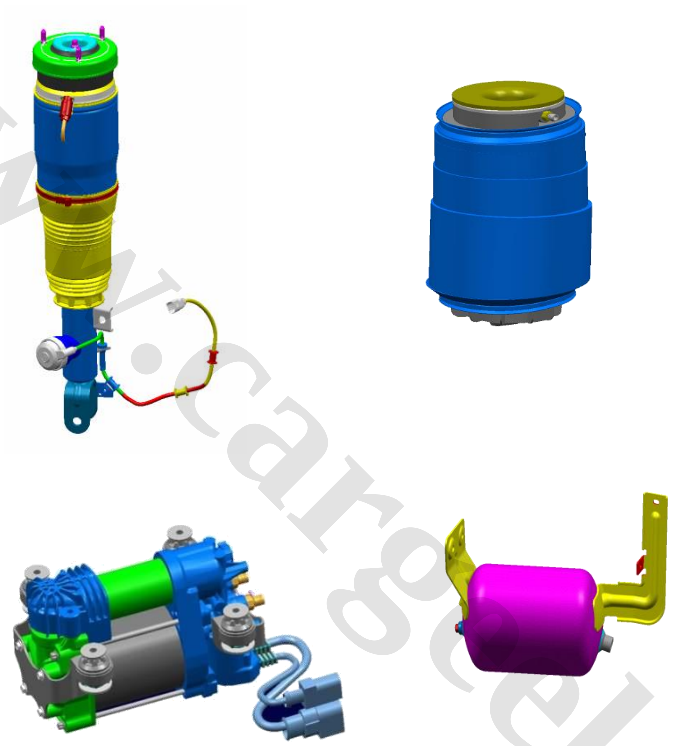
Pressure check


Color marking

Always refer to the shop manual before servicing or diagnosing the ECS-III system. Special attention should be paid when installing or removing air pipes. For removing the air pipes a special service tool is required. When reinstalling the hair pipe, oil should be applied on to the seal (O-ring). Marks on the air pipe help to identify if the air pipe was installed correctly.

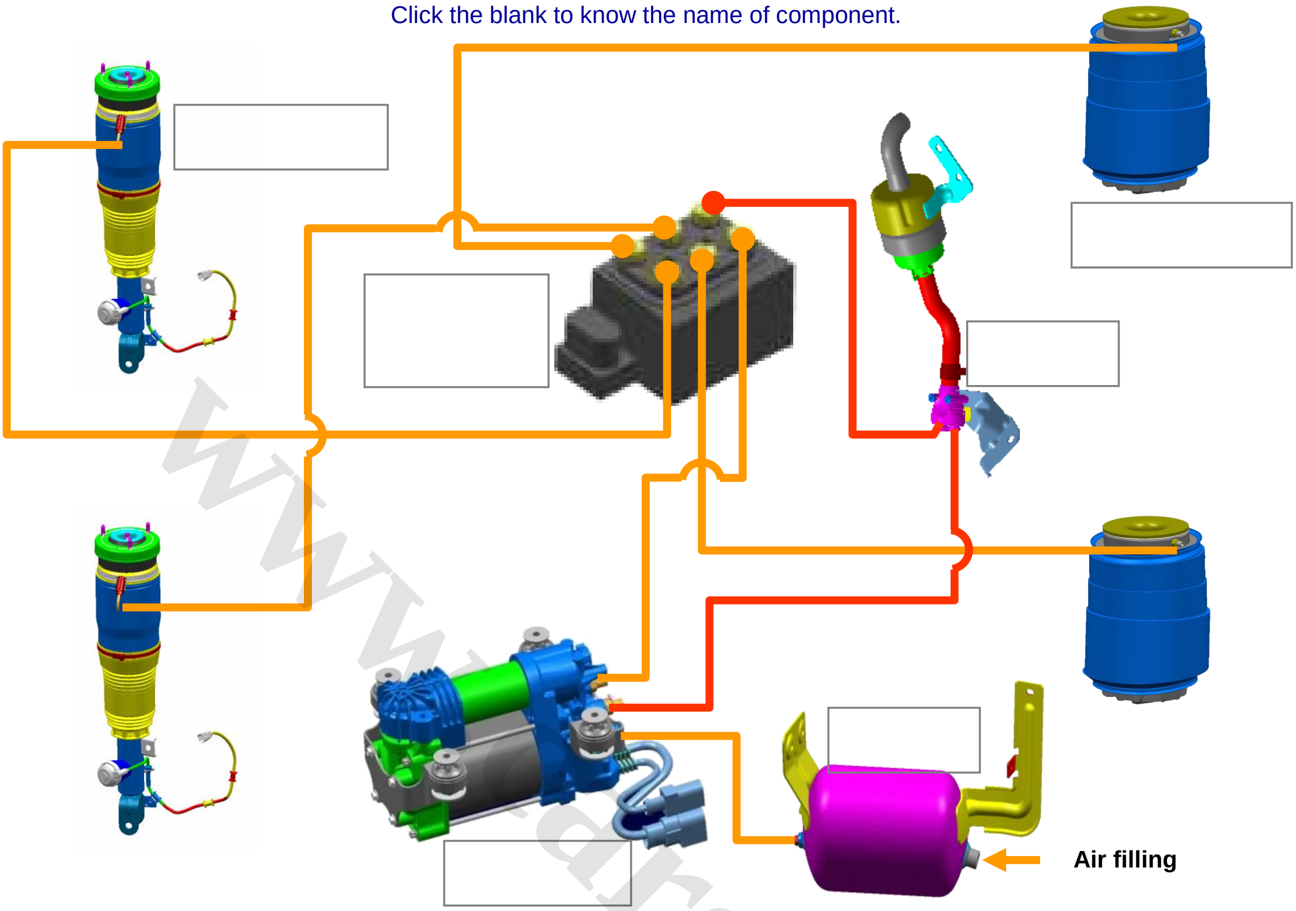
The ECS system can be checked by using HI-SCAN. Air pressure checks can be performed by using a pressure gauge and the appropriate adapter. Please refer to the shop manual for more detailed information.

Electronically Controlled Suspension



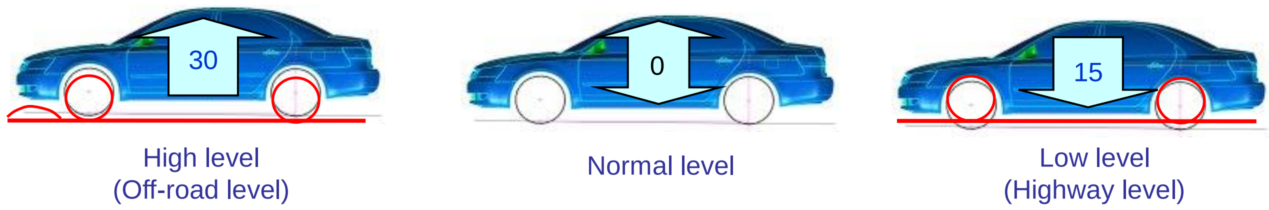
Index

Air tube connection

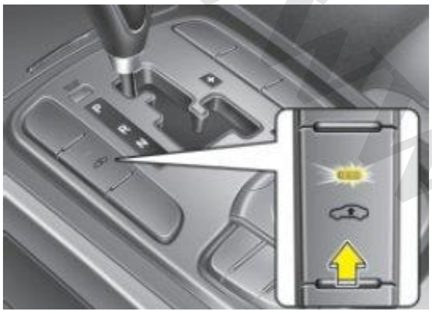


This picture has been prepared to help understanding how the pneumatic components are connected in closed type ECS system.

Leveling control



Level	Front	Rear
High level (Off-road level)	+ 30mm	+ 30mm
Normal level	0mm (D.H:394)	0mm (D.H:387)
Low level (Highway level)	-15mm	-15mm



※ D.H: Design Height (the height from the wheel center to the top edge of wheel housing)

High level:
In order to minimize the interference between the vehicle body and the road surface, the vehicle level is controlled by following two features.

Manual – As long as the vehicle speed is lower than 70kph, possible to lift from normal to high level. Opposite manual operation (from high to normal) has no restriction for the vehicle speed.

Automatic – If the vehicle speed exceeds 70kph with high level, it will be alternated into normal level automatically after 10sec for the safety.

Normal level:
This is the basic level for normal driving condition. As same as high level, there are two features.
Manual – Refer to the above 'High level'.

Automatic – If the vehicle speed exceeds 120kph with normal level, it will be alternated into low level after 10sec for the safety and better fuel consumption.
Low level:

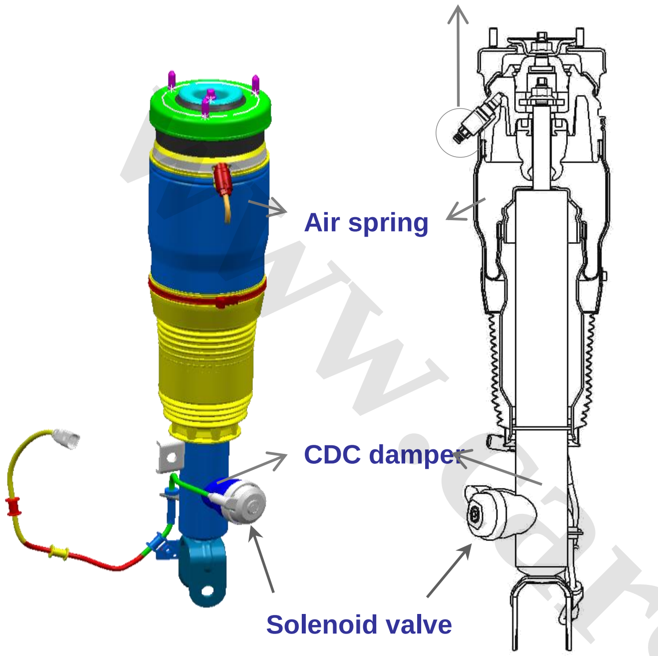
No manual operation is supported.

Automatic – If the vehicle speed is lower than 80kph for more than 5sec, it will be alternated into normal mode automatically, however if it is lower than 40kph, it will be normal level immediately regardless of the time.

Whenever the level is changed, there is a time delay between front and rear wheel for the safety. For lift, rear side will be advanced and front side will be lifted later on. For lowering, it is opposite. (because of this operating sequence, there may be a noise if the brake (AVH, EPB) is being engaged while level control)

Component

Front Air strut



- Consists of
  Air spring, CDC damper

- Function
  - Air spring
    Controls the vehicle height in real time
  - CDC damper
    Controls damping force depending on the road condition

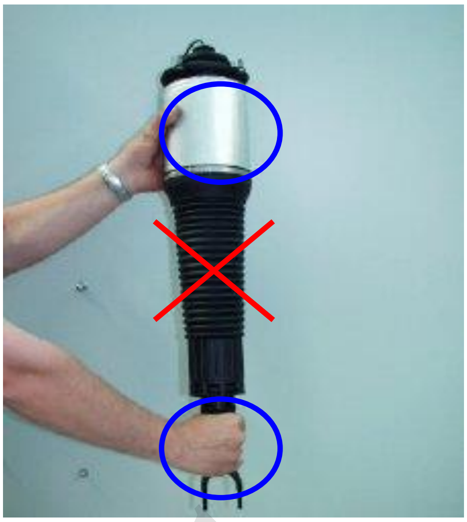
Front Air Strut

The air spring & damper is one unit so that it is not possible to make separation.

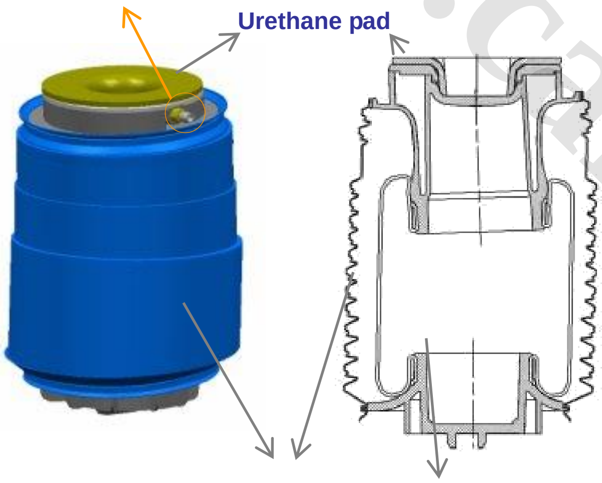
The average pressure of front air spring is around 7.5 bar.

When the front air spring is delivered as service spare part, the air is filled with the pressure of 3 bar. (Therefore, the filling air pressure should be higher than 3 bar to open the inlet valve on the front air spring)

When handle the front air strut, hold the top and lowest portion of the part as shown in the picture below, do not hold the rubber portion then it may damage on the internal components.



Rear Air spring



❑ Consists of

Air spring, Urethane pad to absorb the shock and Protector to isolate the foreign materials.

❑ Function

Controls the vehicle height in real time (Air spring)

❑ Principle – Air spring

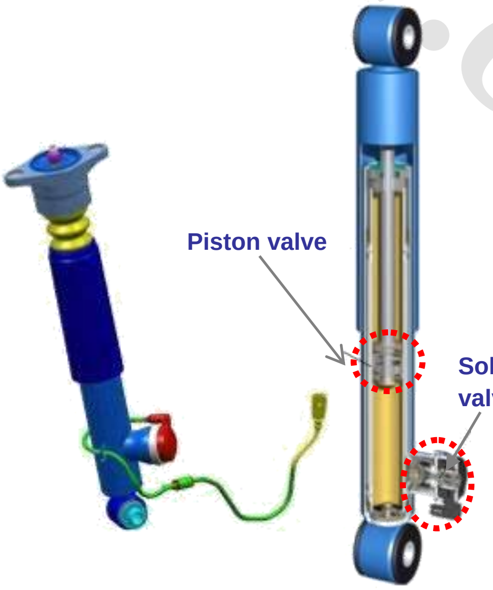
Controls the vehicle height filling or discharging the air via tube.

Rear Air Strut

Because of the design layout, the air spring and the shock absorber (damper) is separated. The average (target) pressure of rear air spring for normal operation is around 8.5 bar.
When the rear air spring is delivered as service spare part, no air is filled so that the intensive care is required to handle. It will be explained more detail in the section of 'Caution of handling'.
Due to the stopper inside of spring, the upper end and lower end do not contact (gap exists around 10mm) each other even if the air is totally discharged.

Take care to handle the rear air spring. Don't pull the air spring intentionally, it may very difficult to restore to the original shape. If it was extended untended, a small amount of air pressure inside spring will help you pushing the spring to the original position.

CDC damper



❑ Function

Controls the damping force depending on the road condition (CDC damper)

❑ Principle

A slider inside solenoid valve moves depending on the input current.

Controlling the oil flows the solenoid valve, adjusts the damping force.

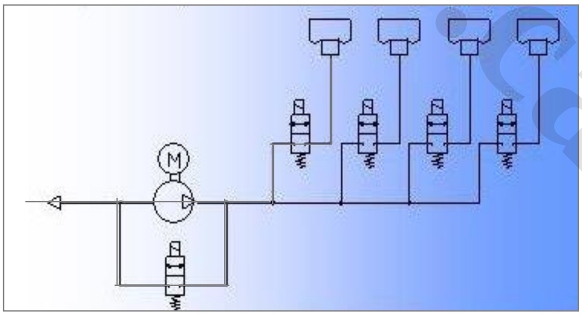
CDC Damper

While CDC damping control, 4 corner will be controlled by same damping force (hard, soft). The system controls all required factors which is necessary for all driving conditions such as pitch, roll, ride and sky hook. The solenoid only cannot be replaced, that is the air damper assembly should be replaced if the solenoid valve is failed. The damping force will be the maximum (hard damper), if the current of solenoid valve is not supplied.

Caution:

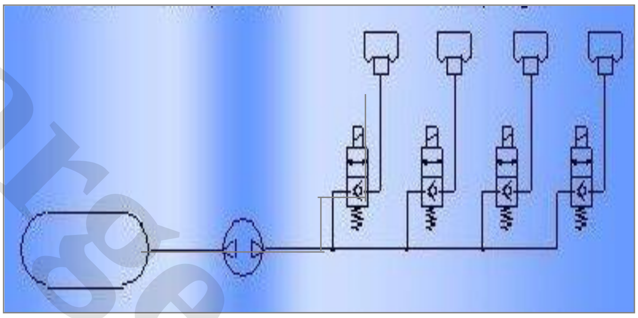
Be sure that the air spring does not function for the damping control, but only for vehicle level control.

Comparison of pneumatic circuit



[Open Loop system]

- Intake & Exhaust the air in every cycle
- Use low / high air pressure
- Low leveling control speed
- Low energy efficiency



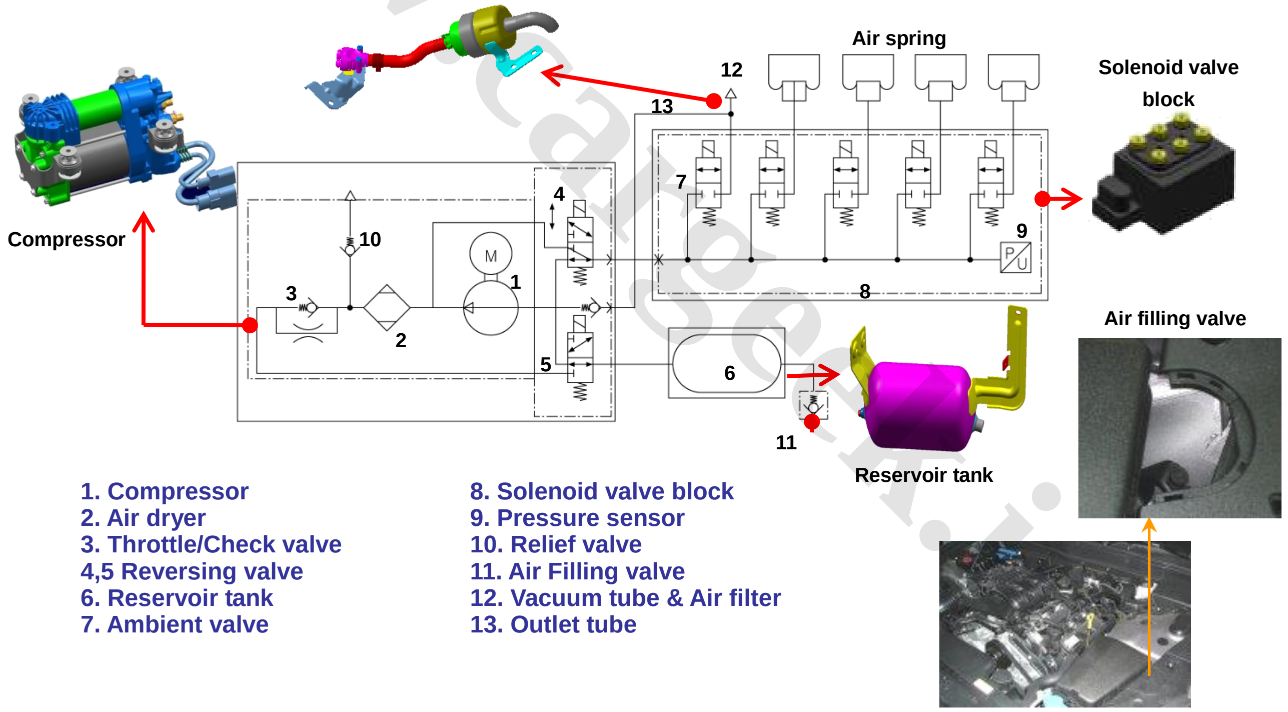
[Closed Loop system]

- Intake & Exhaust the air supplementary (Leakage, etc..)
- Use high pressure
- High leveling control speed
- High energy efficiency
  (Higher than open loop type by 20 ~ 30%)
- Reduced compressor operating time and volume

As it is explained in the section of system layout, the close loop has some merit comparing the existing open loop type applied in Centennial.
In case of open loop type, system intakes the air from atmosphere and compresses it whenever necessary, therefore the system response time (leveling control time) is long. Even Lexus takes several minutes for controlling the vehicle level.
However in case of close loop type, the high pressure is stored in the reservoir tank in ordinary time and used whenever necessary, therefore the response time reduces dramatically. Of course

even close loop system also does intake and exhaust for the supplementary filling of air, dryer regeneration accordingly but the actual air amount is very low.

Pneumatic components



Pneumatic components

Air filter:

Air filter is a maintenance free (permanent use)

Reservoir (Air tank):

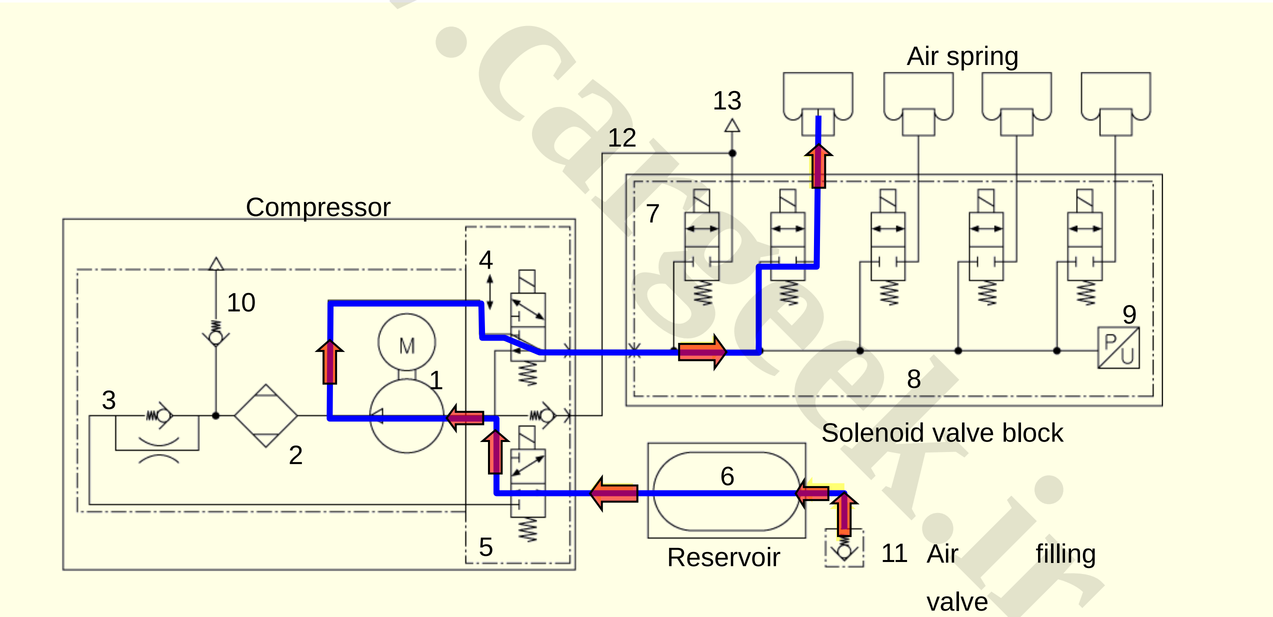
The volume is 5.2 liter and the maximum operation pressure is 16bar. (bursting pressure: 40bar)

The pressure of reservoir tank is monitored every 30 min while driving.

Compressor:

The air dryer and electrical motor are built in the compressor. In addition two solenoid valves (reverse valve) are embedded. Both are normal off with 3-way solenoid valve and the vehicle is lifted or lowered depending on the on, off combination. For example, while lifting, one is off and the other one is off so that both left and right air springs are expanded at the same time.

Pneumatic circuit – System air filling



11. Air filling valve ➔ 6. Reservoir ➔ 5. Reversing valve ➔ 1. Compressor ➔ 4. Reversing valve ➔ 8. Solenoid valve block ➔ Air spring

Pneumatic circuit – System air filling

This job should be done whenever the system components were replaced with new one (except the electrical sensor or control module). Using air filling machine, supply the air to the air filling valve offered in the LH side of engine room. Air will flow to reservoir tank, compressor and will arrive in the air springs.

- Due to the length of air tube and location, at first the front air spring is fulfilled and the rear air spring will be completed later on.
- The vehicle has to be lifted up. (the air spring (rubber) may be bent if the air spring was empty when starts the system filling)
- IG ON and the particular mode in the scanner are required but engine starting is not necessary.

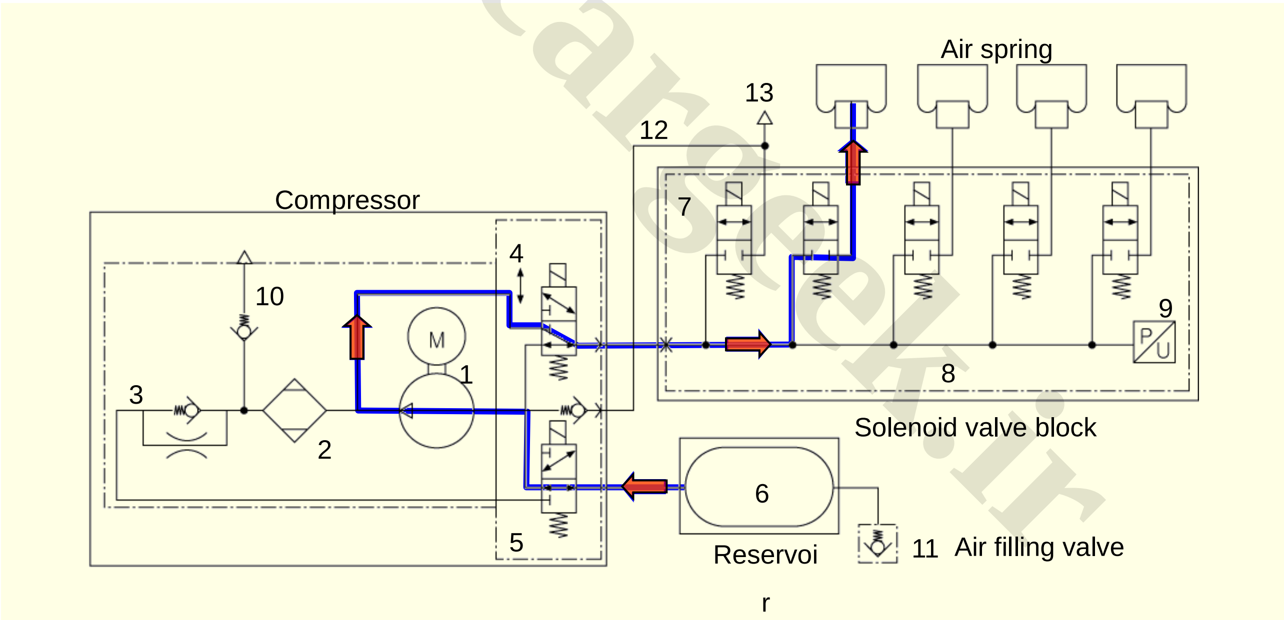
  (Refer to the section of 'System air filling procedure' for more detail information)

- While the system air filling, the compressor (built in vehicle) does not operate.
- There are two kinds of air filling;
  System air filling: the external air pressure is supplied at the factory or workshop (1 time)
  The vehicle compressor does not operate. It is not possible to do this filling by vehicle compressor. Because the overload of compressor must be avoided and furthermore the vehicle compressor will not operate if the air pressure (volume) is too low. (less than 80 ~ 120 bar-liter)
  Garage air filling (Supplementary filling): whenever the supplemental air is required in the system, the air is filled by the vehicle compressor.

Depending on the capacity and the pressure of the air filling machine, the whole time to complete differs but mostly it takes around 50 sec.
The target air pressure level at each component is;
- Front air spring: around 7.5bar, Rear air spring: around 8.5bar, Reservoir: around 9~10bar.

However, it may change with a little amount in the case of air spring depending on the weight of vehicle (passenger & baggage)

Pneumatic circuit – Lifting level

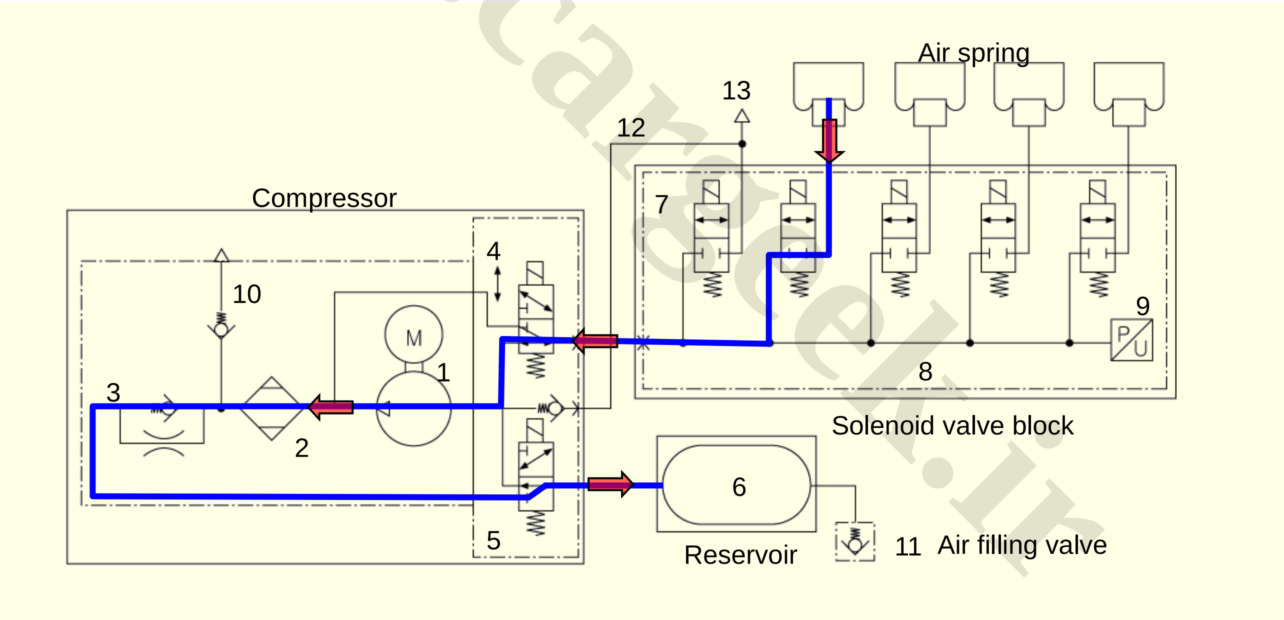


6. Reservoir ➔ 5.Reversing valve ➔ 1. Compressor ➔ 4. Reversing valve ➔ 8. Solenoid valve block ➔ Air spring

Pneumatic circuit

Operating the compressor, the compressed air inside reservoir tank moves to the air spring via solenoid valve block in order to lift up the vehicle height. During lifting mode, the air does not pass the dryer as shown in the picture. The front rear springs are lifted at first and then front springs are followed when lift the vehicle. The reason is to reduce the air resistance while driving and avoid to give an excessive headlamp beam to the driver in opposite direction lane on the road for the safety.

Pneumatic circuit – Lowering level



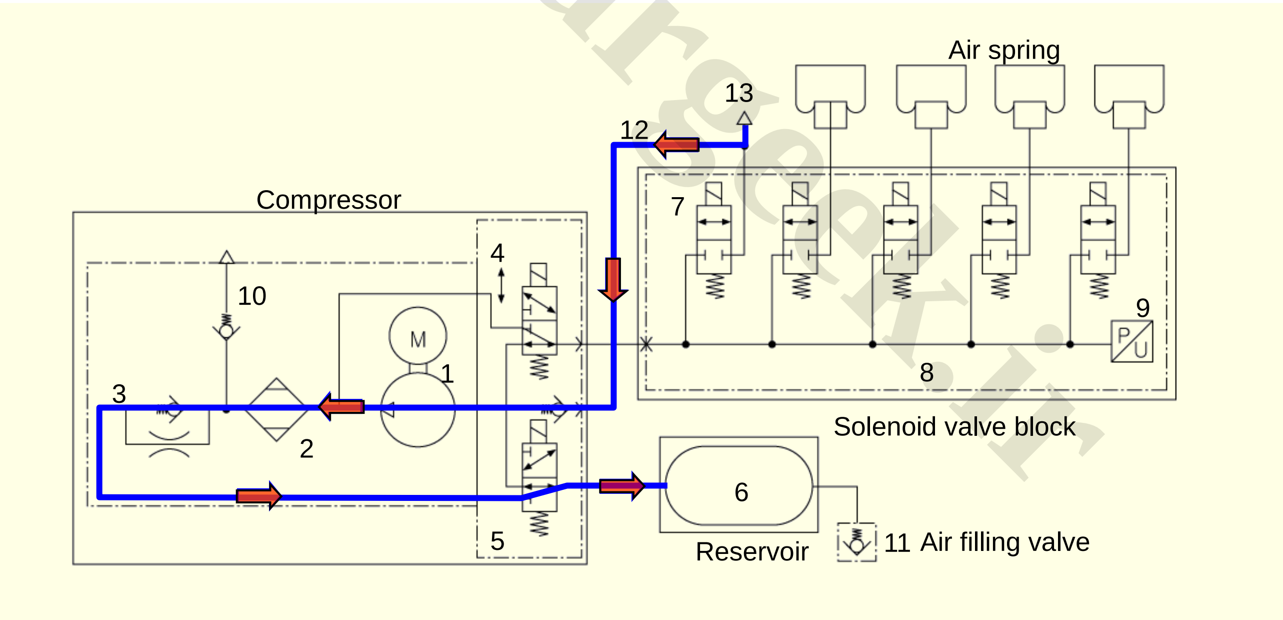
Air spring ➔ 4. Reversing valve ➔ 1. Compressor ➔ 2. Air dryer ➔ 3. Check valve ➔ 5. Reversing valve ➔ 6. Reservoir

Pneumatic circuit – Lowering

Whenever lowering the vehicle, the dryness is accomplished flowing the air through dryer as shown in the slide. The reverse valve and air spring valves are open so that the compressed air comes out from the air spring. At the same time, the compressor is operated so that the air passes through the dryer in order to store dried air into the reservoir tank. Be sure that even during the process of lowering, the compressor will operate in normal condition (as long as the compressor and compressor relay is normal).

Of course, if the compressor or compressor relay is failed, the lowering (down-leveling) is available by operating the ambient valve (No. 7 in the picture) only like a process of 'air discharge' but this is done only in case of emergency condition.
For example, the vehicle is running with high level and the compressor (or relay) failure is detected, if the vehicle speed is higher than 70kph for 10sec or more, the vehicle height should be lowered to normal level by ambient valve for the safety and lower fuel consumption.

Pneumatic circuit – Air filling (Supplementary)

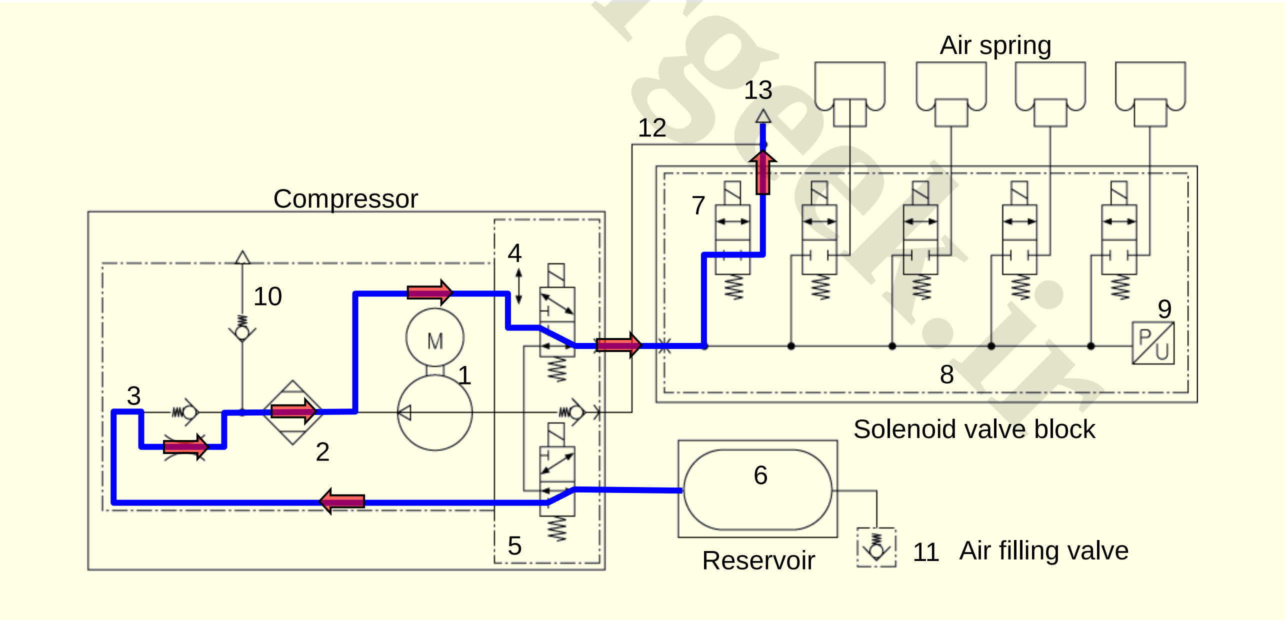


13. Air filter ➔ 1. Compressor ➔ 2. Air Dryer
➔ 3. Check valve ➔ 5. Reversing valve ➔ 6. Reservoir

Pneumatic circuit

If the air mass inside the system is less than 93 bar-liter (refer to the concept of 'bar-liter' in the last slide in this syllabus), the air is added by the compressor in the vehicle. At this time the air passes through the dryer as shown in the picture so that the dry air can be supplied into the system. Mostly this may happen in case of long time parking.

Pneumatic circuit – Air discharge (dryness)



6. Reservoir ➔ 5. Reversing valve ➔ 3. Throttle ➔ 2. Air dryer ➔ 4. Reversing valve ➔ 7. Ambient valve ➔ 13. Air filter

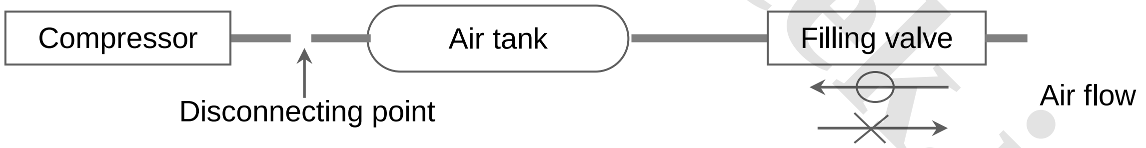
Pneumatic circuit – Air discharge (dryness)

The purpose of doing air discharge is only to regenerate the air dryer built in the compressor. The discharged air amount is very small.
The independent logic to perform air discharge is implemented to decide the regeneration period based on the following factors. (not performed every ignition cycle)

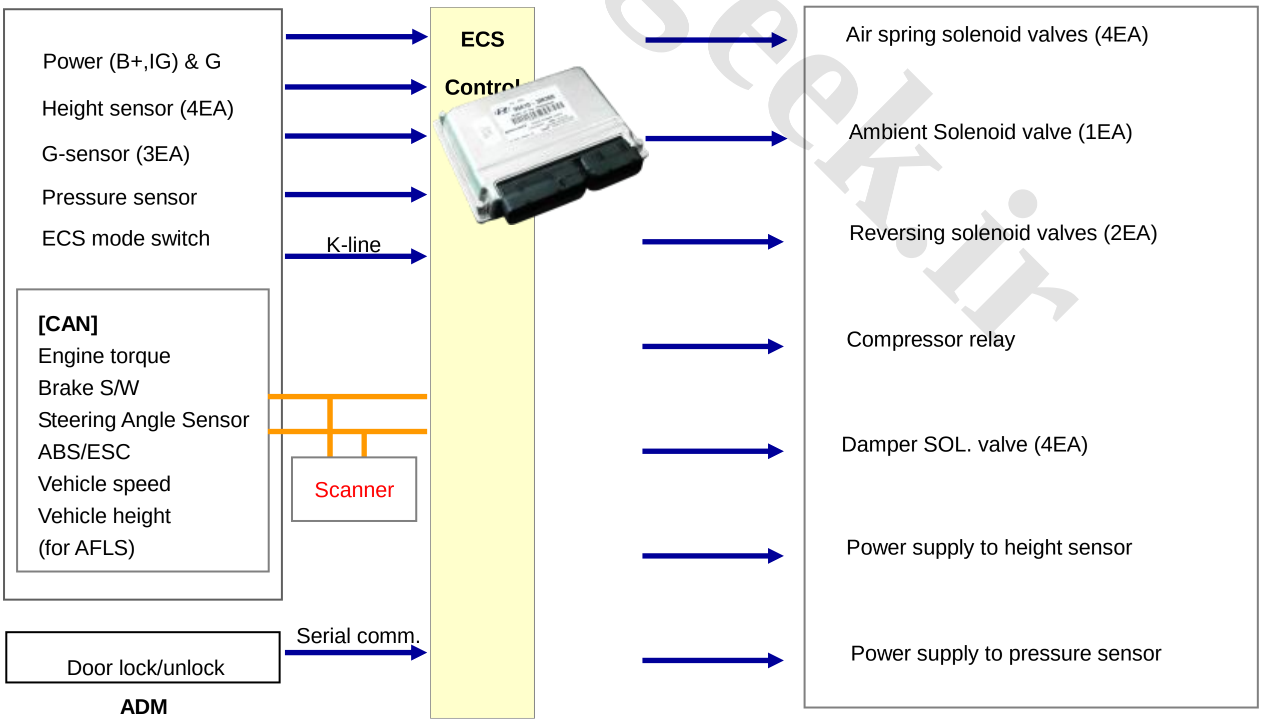
- Air pressure sensor (built in the compressor) signal
- Height sensor signal
- Engine room temperature

Not only for dryer regeneration but also for other reason, sometimes it is necessary to discharge the air from the system. Scanner offers the 'Air discharge mode' to cope with this time, and just enter to the above mode and perform the air discharge. Sometimes, air discharging is required to inspect the noise from the rear chassis frame or front suspension. Scanner will control the reverse valve and five solenoid valves in the solenoid block in order to discharge the air electrically.
Be sure that this menu in the scanner does not offer the discharge of air in the reservoir tank as follows.

1) From air filter to solenoid valve block (mostly air in the air springs):
   the air in this area can be discharged by the scanner (electrically)
2) Air in the reservoir cannot be discharged by electrical driving of solenoid valve in the scanner.
   Instead, you can disconnect the air tube between the compressor and reservoir tank manually. Then only the air in the tank will be discharged as long as the air in the air springs are clogged by the solenoid valves. This means that the vehicle will not be rapidly lowered even if the mentioned tube is disconnected. However, disconnect the tube gently because the air will come out rapidly.



Inputs & Outputs



* ADM: Assistant door module

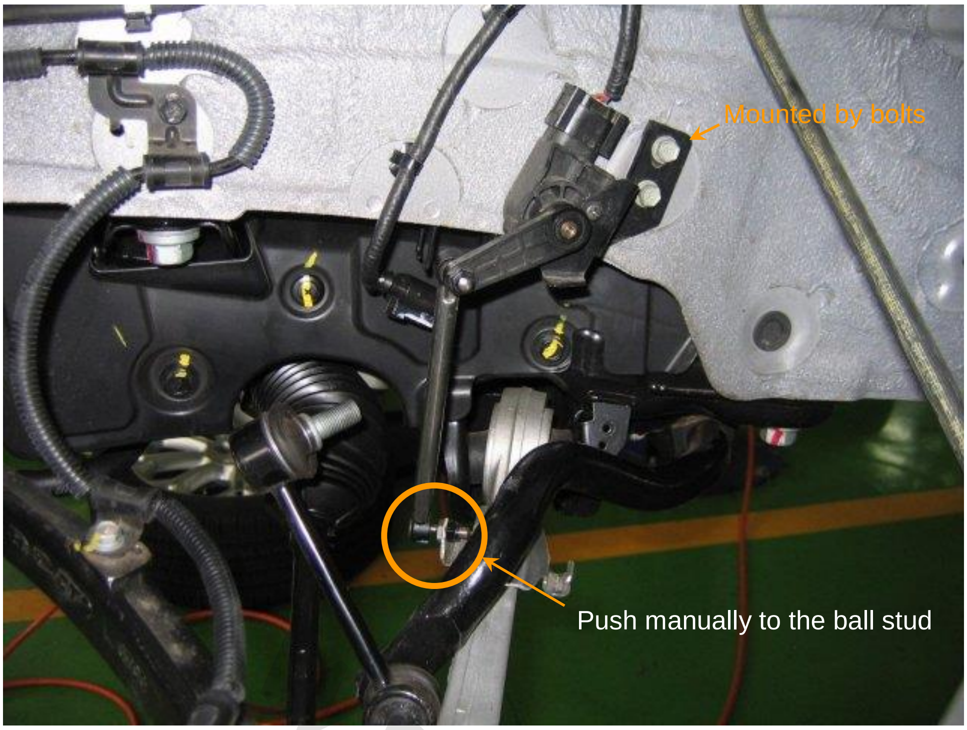
Door Lock / Unlock signal from ADM:

- This signal is used to shift the ECS mode such as ‘Sleep mode’ and ‘Wake-up’ & ‘Pre-run mode’. This signal is sent to ECS via not CAN but the independent serial communication line as shown in the picture.

Height Sensor
- Height sensor detects not only the vehicle height but also vehicle bouncing acceleration, so that it is also used for CDC damping control as well as air spring control. Therefore, if height sensor is failed, CDC current is fixed by 600mA for the failsafe.
- The height sensor values are shared with AFLS control module via CAN.

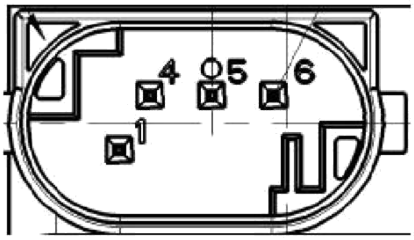
CAN signals
- If CAN bus off or CAN timeout is detected in the system, the vehicle level will be shifted to normal level immediately and the manual or automatic level control at normal level will not be available anymore. And the CDC damper is controlled by zero ampere so that the damping feeling will be hard.

Height sensor



Height Sensor (Front side)

[Connector layout]



PIN	Description
1	GND
4	Not used
5	+5V
6	PWM signal

Function

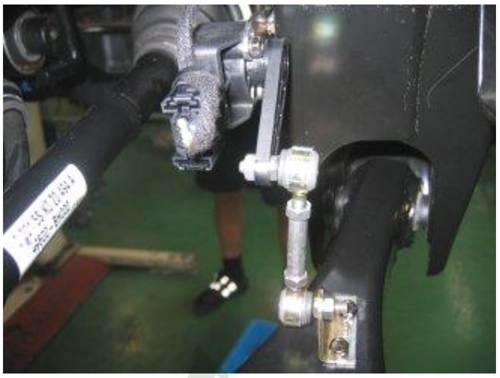
- Detects the level (for vehicle level control) and the bouncing acceleration (for damping force control).

Applying Hall IC, it detects the level and the bouncing acceleration of vehicle. Installed at each suspension(4EA). Even if the sensor bracket is different, 4 sensors in each corner can be interchangeable. Receiving these values, control module controls not only vehicle level but also damping force for the CDC damper. This signal is the main for vehicle level control.

Refer to the followings for the specification of height sensor.

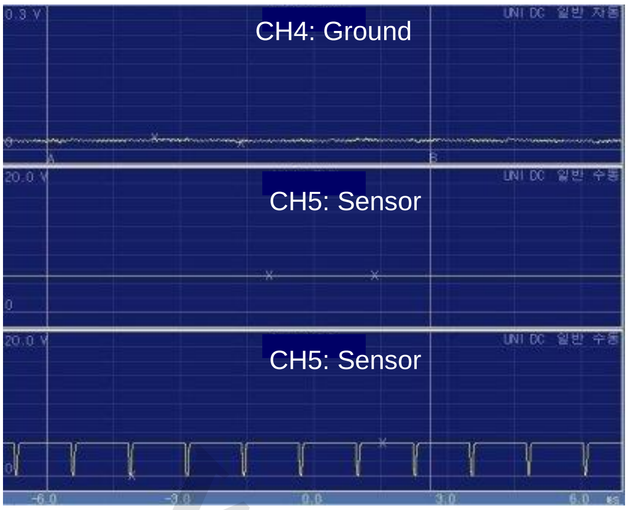
- Sensor power: 5V
- PWM frequency: 800Hz
- Range: 5% (-54°) ~ 95% (+54°)

While service for this sensor, any shock should be avoided. Especially inspect that any foreign materials are attaching on the sensor body because the rod portion of sensor rotates in relation to the vehicle body as shown in the picture.



Height sensor attached on rear axle

Height sensor signal

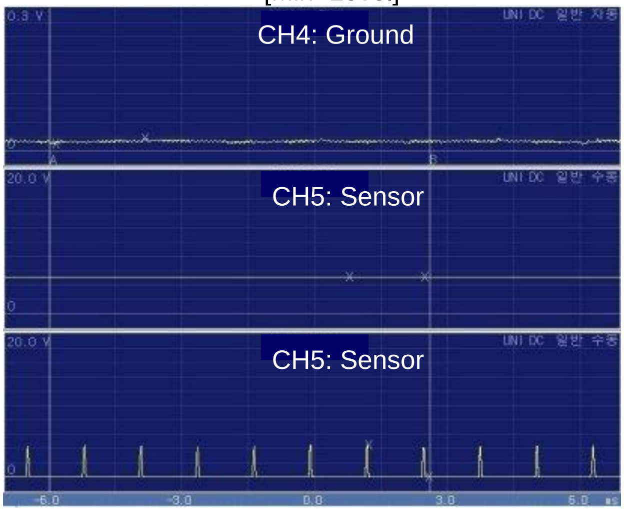


[Max. Level]

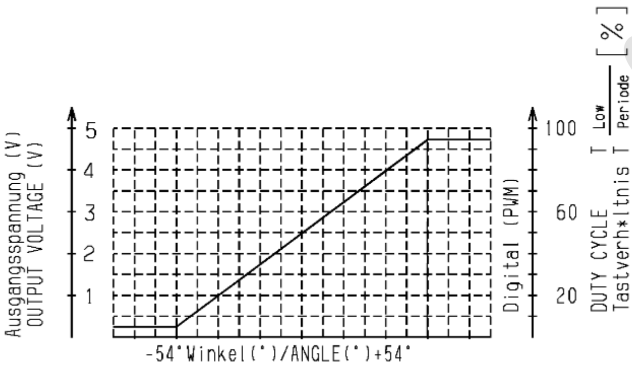
Duty(-): 6%
Frequency: 783Hz
Max.: 4.63V
Min.: 0.06V

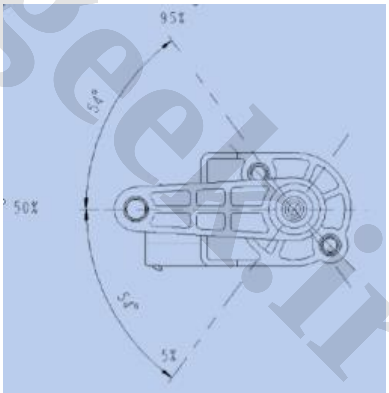
Duty(-): 97%
Frequency: 785Hz
Max.: 4.49V
Min.: 0.06V

[Min. Level]



As shown in the picture, it outputs PWM duty waveform for each level. Total 120 degree (maximum capable angle allowed in this sensor) is divided into 256 detection ranges and it outputs '128' in the scanner in case of 0 mm level (design height).





Applying the bracket for front and rear side, it offers full-proof to avoid wrong installation of sensor to the vehicle body.

If a height sensor is failed, vehicle level is controlled based on the data from the other 3 sensors. If two sensors are failed, vehicle level control will stop. For more detail features for failsafe of height sensor, please refer to the section of 'Air spring failsafe' in this slide

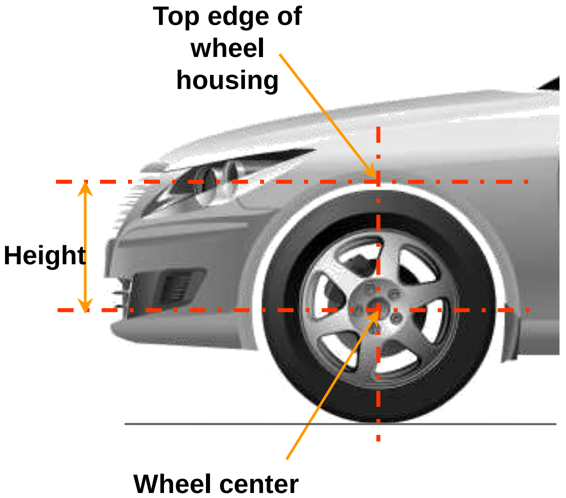
Height sensor calibration

❑ Height sensor calibration

- When? ☞After air filling, height sensor or ECS control module replaced.

❑ Calibration procedure

- IG ON (engine off or on) and keep 'Normal level'.
- Measure the height described in the right side picture.
- Input the measured value to the scanner.
  ※Order: FL, FR, RL, RR
- After calibration, confirm that the value is within the specification measuring the height again.



After filling the air, the actual vehicle level has to be renewed into ECS control module for more accurate control as well as after height sensor or control module replacement.
Just follow the procedure in below.

1) IG ON (engine running or stall doesn't matter). Keep the 'Normal level'.

   - Avoid doing on the lifter ! It should be done on the ground.

2) Connect the scanner and move to the relevant menu.

3) Follow the instruction and order (FL, FR…) in the scanner.

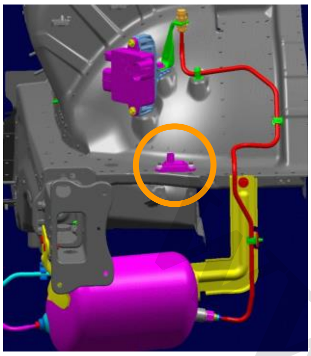
4) Measure the height using the tape ruler described in the slide and input the value in the scanner.

5) After calibration, measure again the height is within the specification or not.

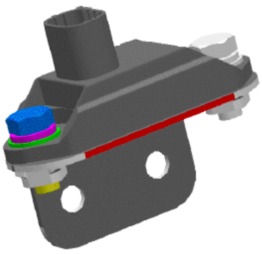
   Front: 394±5mm, Rear: 387±5mm.

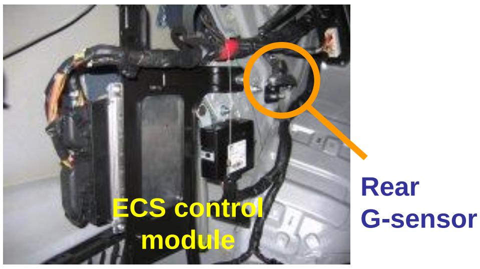
After completing this calibration, the memorized data is stored in ROM so that the height value will not be erased even if the vehicle battery is removed. If the height sensor calibration is not completed, DTC (C1620) is stored and warning lamp turns on. However, the air spring control and CDC damping control is available.
In case of replacement of ECS control module, the variant coding also is required. That is, the variant code should be done in advance to calibrate the height sensor.

G-sensor



G-sensor (FL)





Inside trunk

❑ Function
- It detects the bouncing acceleration of vehicle and installed at the front area (2EA) and rear area (1EA).

- Receiving G-sensor output value, control module controls the solenoid valve in the CDC damper.

Because this sensor signal is a main input for the CDC damping control, it is referred to as CDC sensor. The sensor power supply is 5V and output from 0.5 to 4.5V under normal driving condition. In case of vehicle stationary, it outputs 2.5V.

Totally 3 sensors are installed, one for rear left side (inside of trunk, nearby ECS control module) and other two sensors are for front side (left and right accordingly).

There is no other particular reason except for lower cost to have only one sensor in case of rear side. However, in case of front side, much more changes occurs comparing with the rear side so that two independent sensors are required. Three sensors have same part number so that it is interchangeable each other.

Failsafe for G-Sensor:

As it is explained this sensor is only for CDC damping control and there is no relation for air spring control. Therefore, if this sensor has a problem (any possible failures such as electrical short, open, invalid signal and out of range), the CDC damper will be controlled by fixing value of 600mA current flows in damper solenoid valve. As it is learned previously, the current flows in the damper solenoid valve varies from zero to 1.6A, therefore, 600mA means that the amount of stiffness of damper will be around half. However, don’t forget that the air spring is operated normally even if G-sensor is failed.

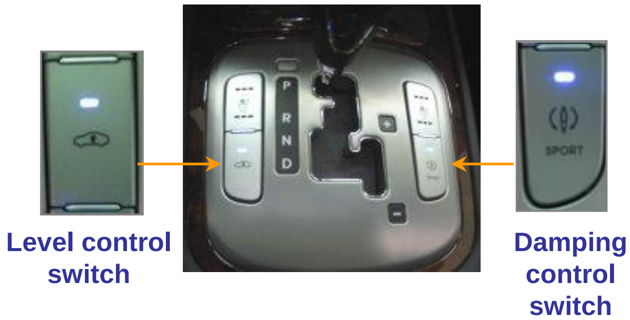
ECS switch

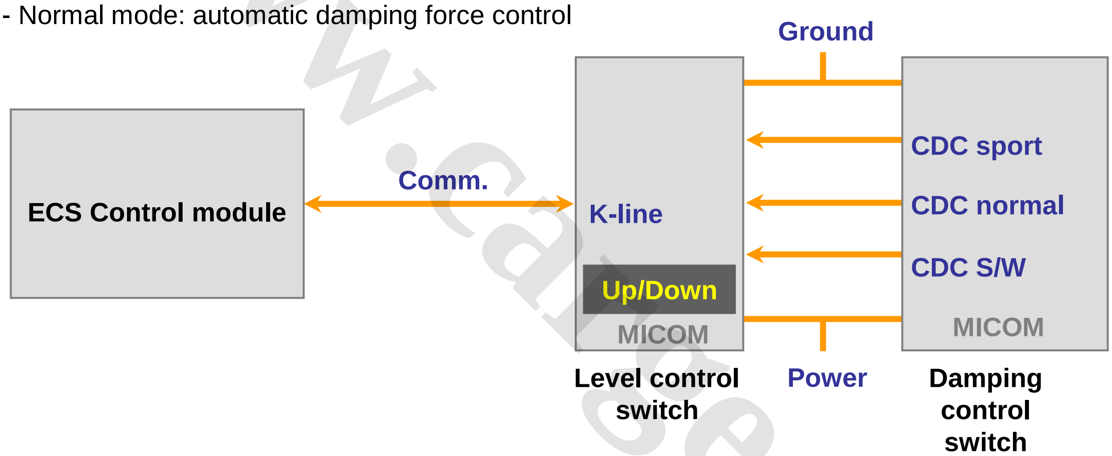
❑ Level control switch

- Manual Up: Normal → High
- Manual Down: High → Normal

❑ Damping control switch

- Sport mode: high damping force (hard)
- Normal mode: automatic damping force control



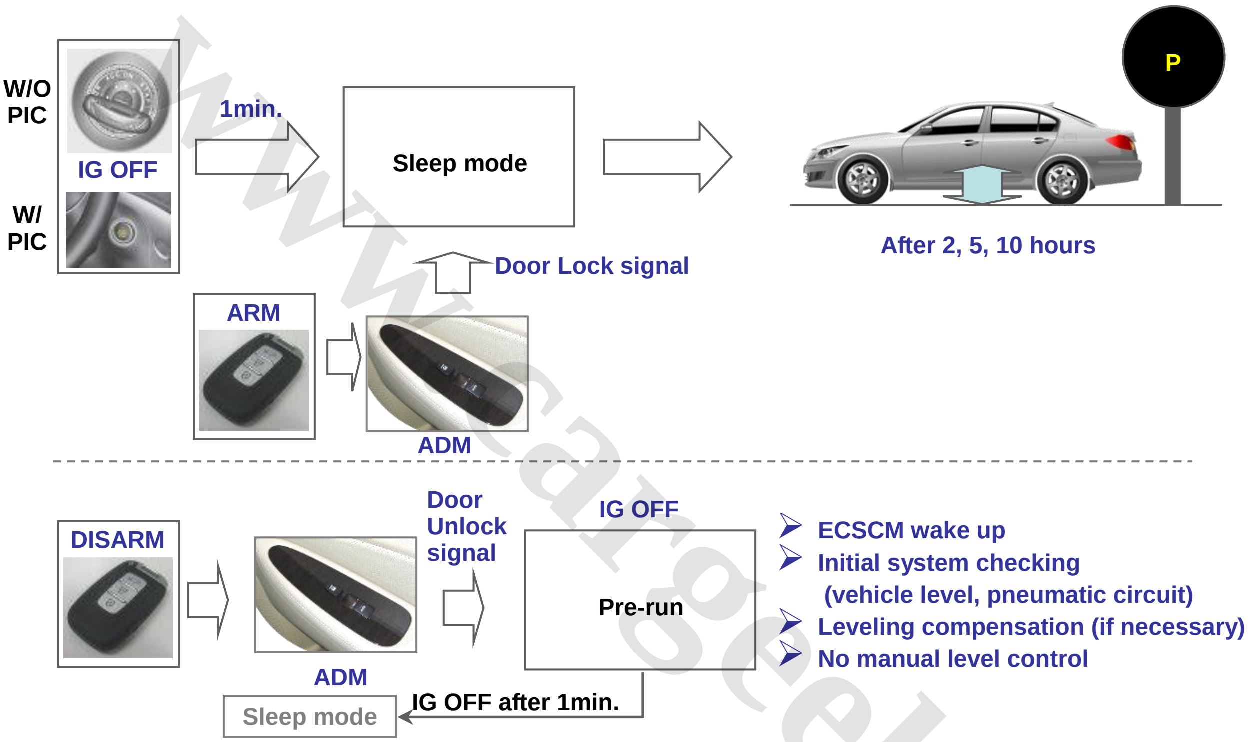


Two manual switches are applied in ECS switch. One is 'level control switch' in order to change the vehicle level manually. Be sure that there is particular condition to perform the level change successfully. As the high level is selected, the lamp will turn on.

The other one is 'damping control switch' in order to select the feeling of shock absorber. If sport mode is selected (lamp turns on), the current flows to the solenoid valves will be around 300-1,000mA so that the shock absorber feeling will be hard.
Oppositely, in case of normal mode (lamp turns off), the current in the solenoid valves is controlled by 800-1,600mA depending on the G-sensor and height sensor signals (road condition).

This switch assembly has a MICOM so that it communicates with ECS control module via K-line as shown in the picture and it is referred to as HMI (Human Machine Interface). All signals including of vehicle level request, CDC damper mode selection will be processed inside switch and will be sent to control module. If ‘K-line’ communication is failed or HMI has a electrical problem such as missing signal or internal error, only manual operation (level control manually, soft/hard control manually) will not be available but other automatic controls are activated normally. The warning lamp does not turn on but corresponding DTC will be stored.

Sleep mode & Pre-run mode



Sleep mode:

The control module has a low power consumption (less than 1mA). In this mode no manual level control is possible. The sleep mode will be quit, when the ECM recognizes a change on the ECM wake up status or when the ignition is switched on.

The ECM returns to sleep mode with a delay time (1min) after ignition is switched off. If the vehicle is armed by RKE, sleep mode will start immediately without time delay.

Under sleep mode (mostly while parking), the vehicle level is monitored and compensated automatically by ECS control module up to 3times (after 2, 5, 10hours)

However, the compressor will not be operated if the battery voltage is lower than 10V.

Pre-run mode:

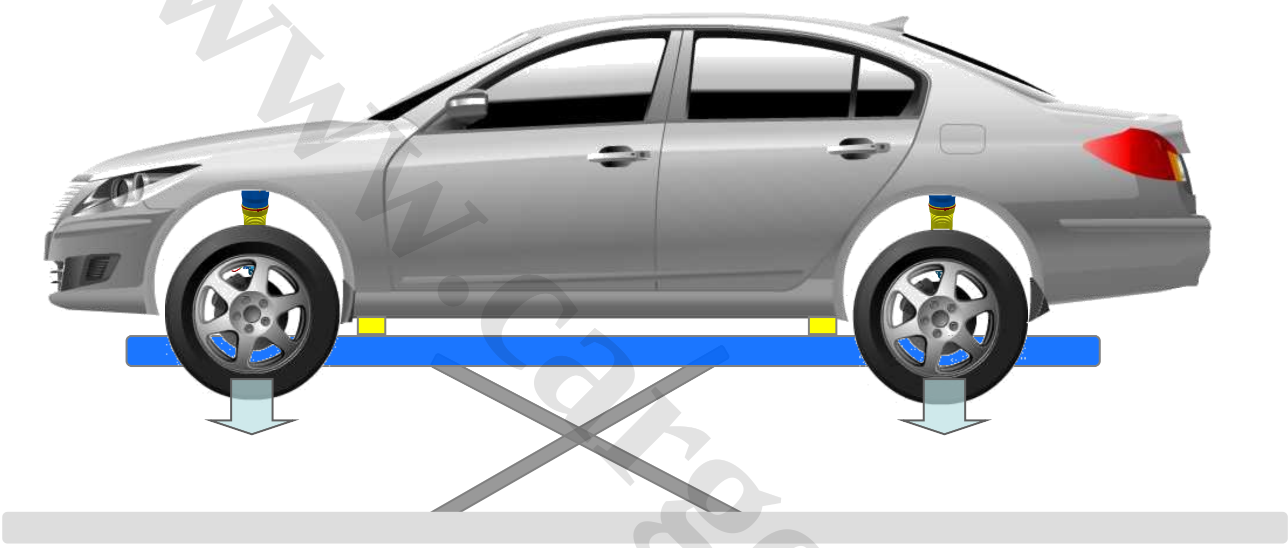
As the vehicle is disarmed, it wakes up the control module and Pre-run mode starts. Pre-run mode lasts for 1min after wake up. While Pre-run mode, the system is initially checked including of pneumatic circuit and the vehicle level is automatically adjusted if necessary. (That is, if the passengers or baggage are heavy weighed, the vehicle level may be compensated automatically even if the ignition switch is off ; while driver is preparing to start)

Don't forget that the manual level change is not allowed in this mode.

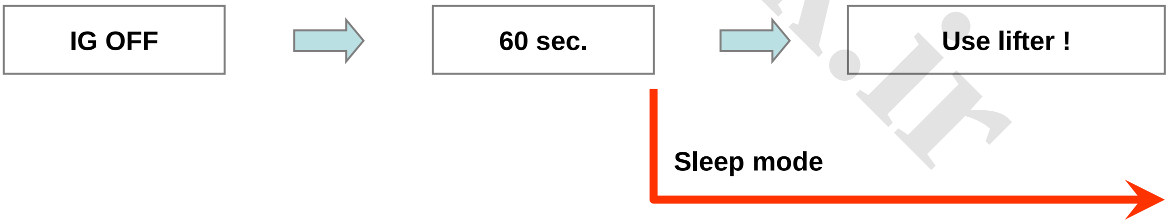
However, if the ignition switch still stays in off position after 1min, it will shift into 'Sleep mode'.

Oppositely, as soon as the ignition switch is on, the mode shifts into 'Stand 1'.

Vehicle on the lifter



Fully rebounded wheels on the lifter



Lifting-Platform mode:

For the vehicle to be lifted from normal level to high level, there is only one way; to push ECS button when vehicle speed is lower than 70kph. But what will happen if the vehicle is lifted up by external force without input of ECS switch ? For example, usually when the vehicle is lifted on the lifter, the vehicle level is rapidly increased without pushing of button.

At this time, ECSCM will neglect all the conditions of vehicle level down (70kph, 10s) and try to lower the vehicle discharging the air from the front two air springs. Even if the air comes out from the air springs, the vehicle level is not changed (no change of height sensor value) so that ECS control module will stop the air discharging considering the special vehicle condition. This is referred to as 'Lifting-Platform Mode'. Under this mode, the manual level control is not available.

As the vehicle lift down and touch on the ground, the vehicle level will be minimum (full rebound) because the air in the front springs already discharged on the lifter, but it will be restored to normal level by control module upon ignition switch ON ◊ OFF or vehicle speed is higher than 10kph for 5sec or more or manual request by switch.
In case of tire replacement at the workshop:
In order to replace the tire, mostly lifter will be used. The best way is that turn the ignition switch off and wait for 1min. Then system will shift into 'Sleep mode' automatically so that the wheel does not be rebounded (by system) even if the vehicle is lifted up by lifter. Because, under sleep mode, system will try first adjustment of the vehicle level after 2 hours enough to replace whole tires.

Summary:
Even though we have a lifting platform mode, it may affect to the lifetime of compressor because of unnecessary operation. Therefore we recommend that;

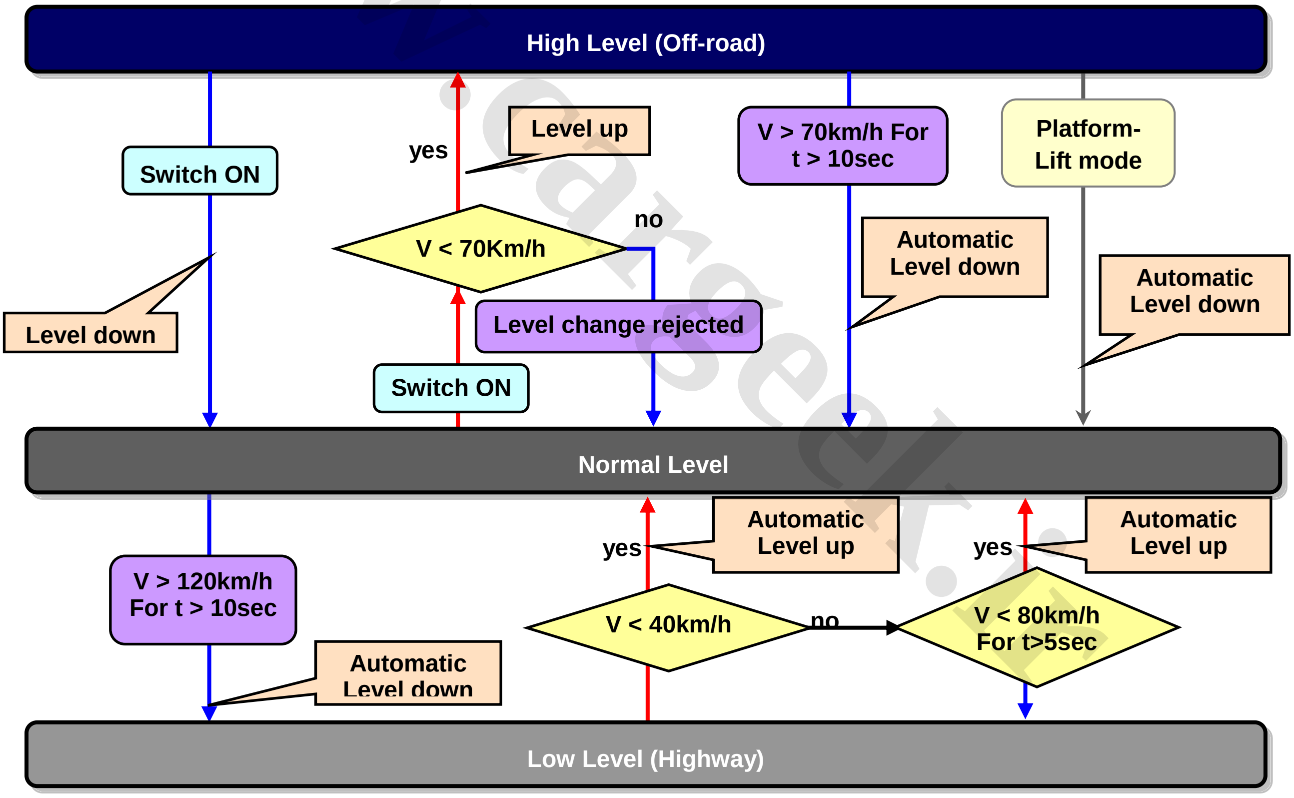
1) To lift up the vehicle, turn ignition key off and lift it after 60 seconds.

  → Do your job under sleep mode.

2) If you have to lift the vehicle for more than 2 hours (2HR: this is the FIRST timing of level compensation under sleep mode),

  → Remove the fuse of ECS control module or compressor relay.

Leveling control logic

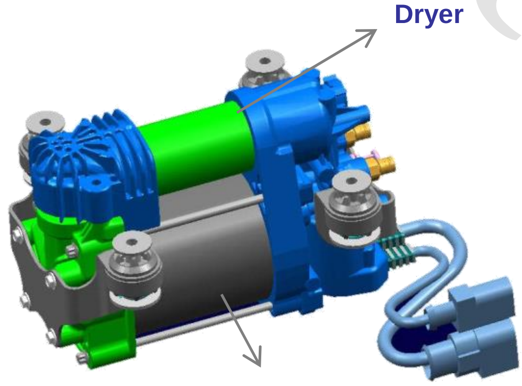


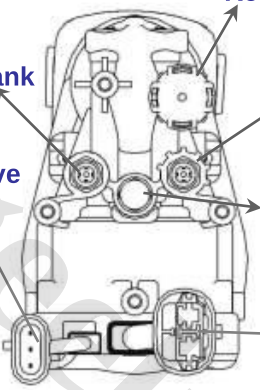
Leveling control logic:

The shown diagram is to explain the overall level control (both manual and automatic) accomplished by air spring. Be sure that the manual operation to low mode is not available as shown in the picture.

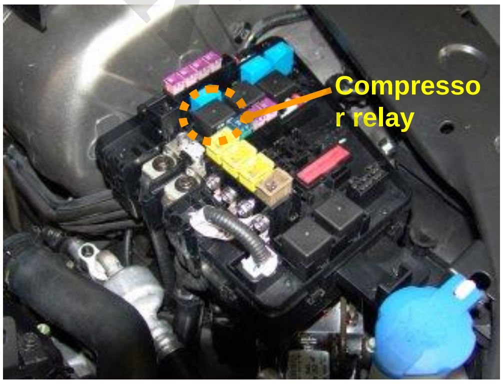
For details, please refer to the section of ‘Leveling control’ in this slide.

Compressor





- ❑ Components: Motor, Dryer
- ❑ Function:
  - Compresses the air in the system
  - Transfers the air
  - Perform the air dryness using the dryer



The compressor operates in all events except the system air filling and two solenoid valves (referred to as reverse valve, on-off control, normal open) are embedded.
Air dryer is maintenance free (permanent use)

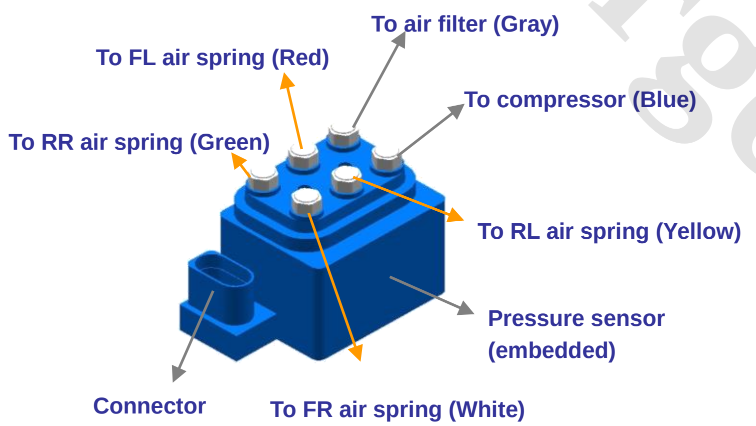
The relief valve opens upon the pressure of 20±3bar.

The compressor relay is monitored by control module in order to detect any failure in relay. If the compressor relay is failed (short to battery, short to ground or open circuit), the lifting is prohibited but down leveling is only available. However, the down leveling is done not by compressor but ambient valve.

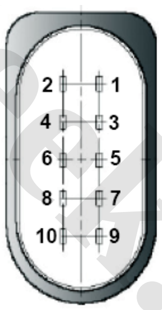
In case of compressor overheating: temperature is higher than 140℃ for more than 10 sec.

→ Level control is prohibited.

Solenoid valve block



Connector layout

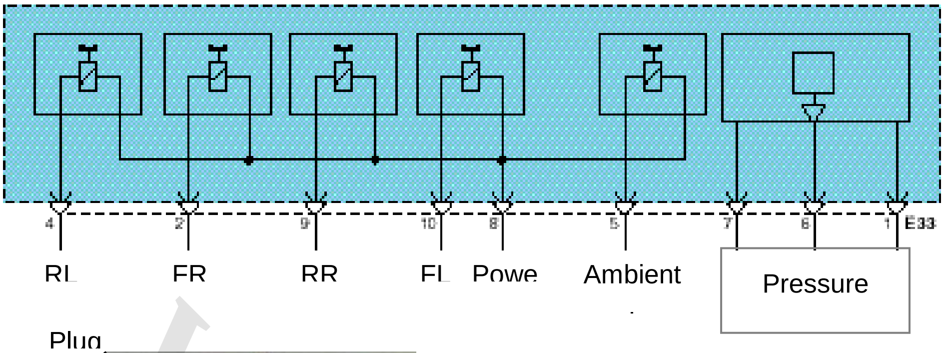


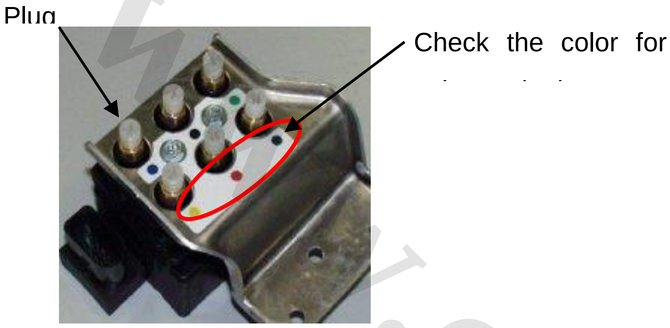
1. FL air spring SOL.
2. Ambient valve
3. RR air spring SOL.
4. RL air spring SOL.
5. Solenoid valve power
6. Solenoid valve power
7. Pressure sensor ground
8. FR air spring SOL.
9. Pressure sensor output
10. Pressure sensor power

- ❑ Components
  5 solenoid valves, Pressure sensor, Air port
- ❑ Function
  Air port open and close depending on the solenoid valve operation.

Four air spring solenoid valves ('-' control) and one ambient solenoid valve are embedded inside this solenoid valve block as shown in the circuit diagram below. When connecting the air tube to the solenoid valve block, carefully check the color dot which is marked on the valve and tube so that all colors should be matched each other.

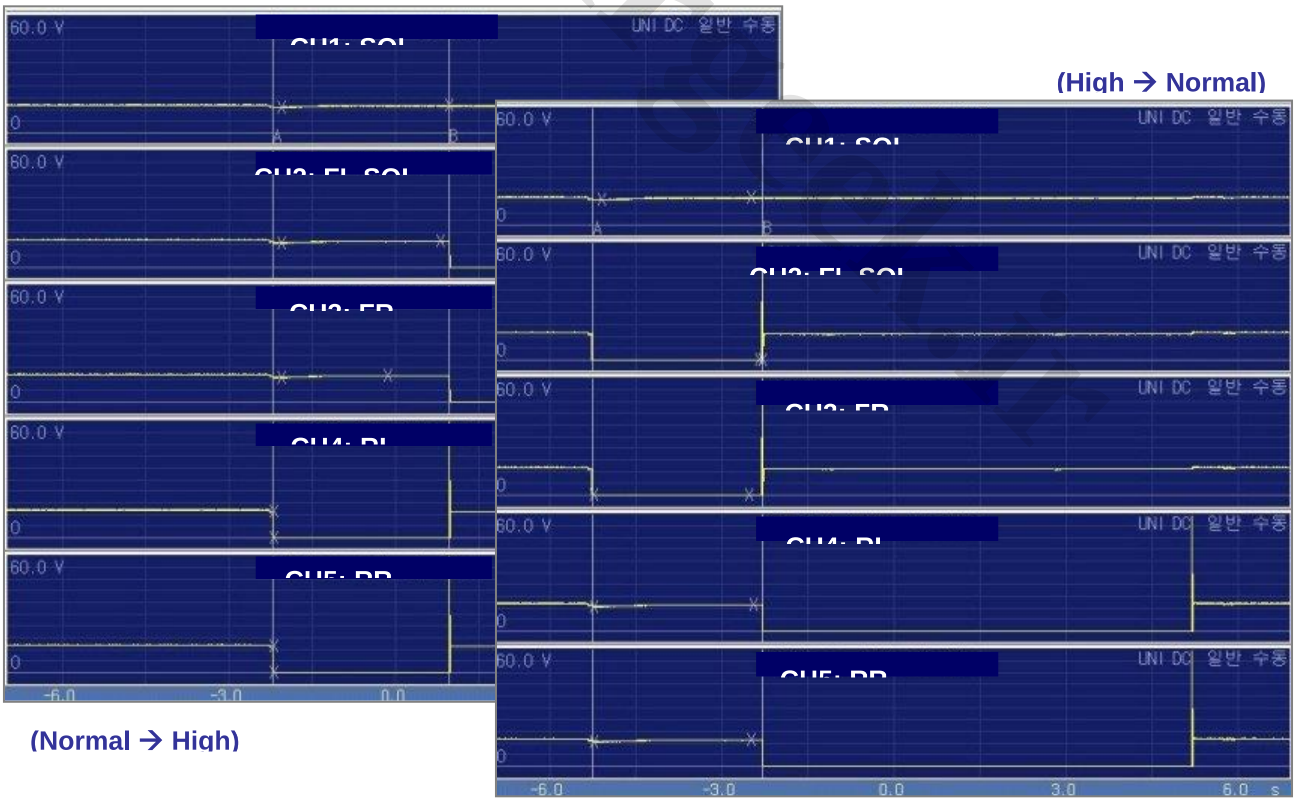
The pressure sensor is built in the solenoid valve block so that it detects the internal pressure when lifting or lowering the vehicle height. Also it senses the pressure of reservoir tank every 30 minutes when the vehicle is running.





If the pressure sensor is failed (lower than 0.2V or higher than 4.8V or no signal for more than 12times), the lifting control is prohibited but the down leveling only is available.

Solenoid valve operation

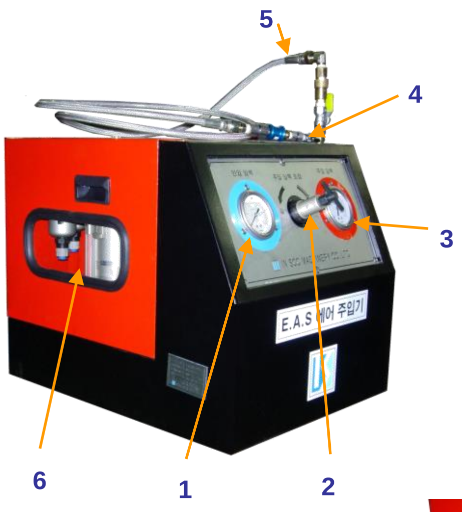


Normal level ◊ High level:

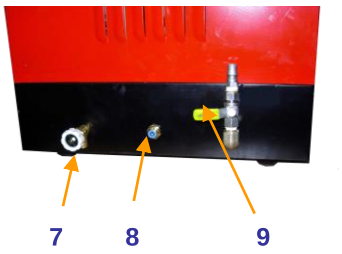
As it is explained previously, during lifting process the rear side air springs are expanded at first and then front side air springs are expanded later on. Therefore, RL and RR solenoid valves are grounded firstly ('-' control type) for around 3sec at the same time and then FL and FR solenoid valves are grounded accordingly. In case of front side, it starts as soon as the rear side is completed and it takes around 2sec as shown in the waveform.

High level ◊ Normal level:
Oppositely, during down-leveling process the front side air springs are expanded at first and then rear side air springs are expanded later on. Therefore, FL and FR solenoid valves are grounded firstly ('-' control type) for around 3sec at the same time and then RL and RR solenoid valves are grounded accordingly. In case of rear side, it starts as soon as the front side is completed and it takes around 7~8sec as shown in the waveform. Comparing with the lifting, the lowering is done mostly under the high vehicle speed so that more careful and slow motion is required to complete the lowering of vehicle level.

System air filling machine



- **Pressure gauge (inlet): around 5~8bar**
- **Pressure adjusting handle (set to 12bar)**
- **Pressure gauge (outlet)**
- **Filling nozzle: connected to the filling valve of vehicle**
- **Filling hose**
- **Air filter**
- **Air tank drain valve**
- **Water outlet (filtered water is automatically drained)**
- **Inlet nozzle: connected to the air supply line in workshop**



This machine is used to fill the system air at the factory or workshop, that is used to do a system air filling by externally. It receives the air from the supply line (5bar) at the factory or workshop and compressed the air into 12bar in order to fill the system line in the vehicle.

◊ There is no electrical motor and switch for driving the compressor on this machine. The air is compressed by the energy of compressed air (5~8bar) from the air line in workshop.

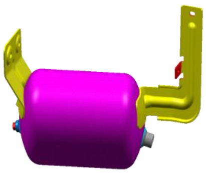
As the air is supplied to the machine, it starts to compress air automatically with operating noise and it stops automatically until the pressure reaches 12bar (if the pressure adjusting handle is set to 12bar). After that connect the outlet nozzle to the vehicle side then the compressed air will be transferred to the vehicle naturally.

In system air filling procedure, the dry condition of air must be strictly kept, because water in the air will affect the control parameter and result in the poor performance. Furthermore, it may give a damage to the compressor if it frozen in winter. For this reason, the dryer and filter are built in the machine.

System air filling procedure

Filling route

Filling valve



Reservoir

Front air spring

Rear air spring

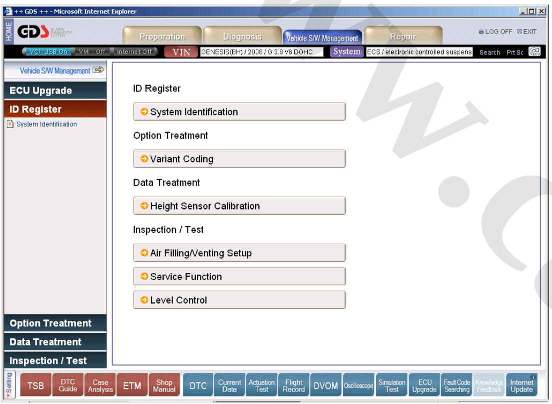
❑ **System air filling condition**

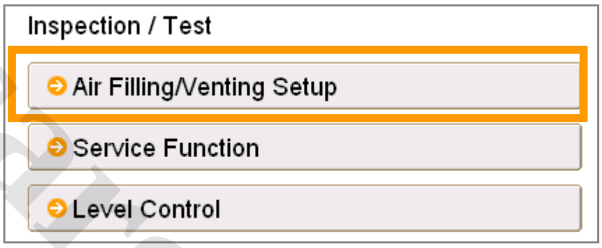
- The vehicle must be lifted up.
- External air supply pressure (from machine): **12 ± 2 Bar**

System air filling is done at the factory before delivering the vehicle. In case of workshop, it should be done after replacing the related parts or the system air was drained because of other repairing works. Follow the recommended procedure for system air filling.

1) Prepare the compressed air (12bar) using the air filling machine. (refer to the section of 'system air filling machine')
2) Connect the air outlet nozzle in the machine to the air filling valve (RH side of engine room) in the vehicle.
3) Ignition ON (engine off) and connect the scanner.
4) Lift up the vehicle (all wheels must be rebounded)
5) Opening the lever in the machine, starts to fill the air from filling machine to the reservoir tank in the vehicle until the whistle sound stops.
6) Enter the menu of system air filling in the scanner and follow the instruction in the scanner. The compressed air will be transferred to the front air spring and rear air spring accordingly by operating the compressor and solenoid valves.
7) Take down the vehicle after completing the air filling.

It will take around 40~60 seconds to complete this job.



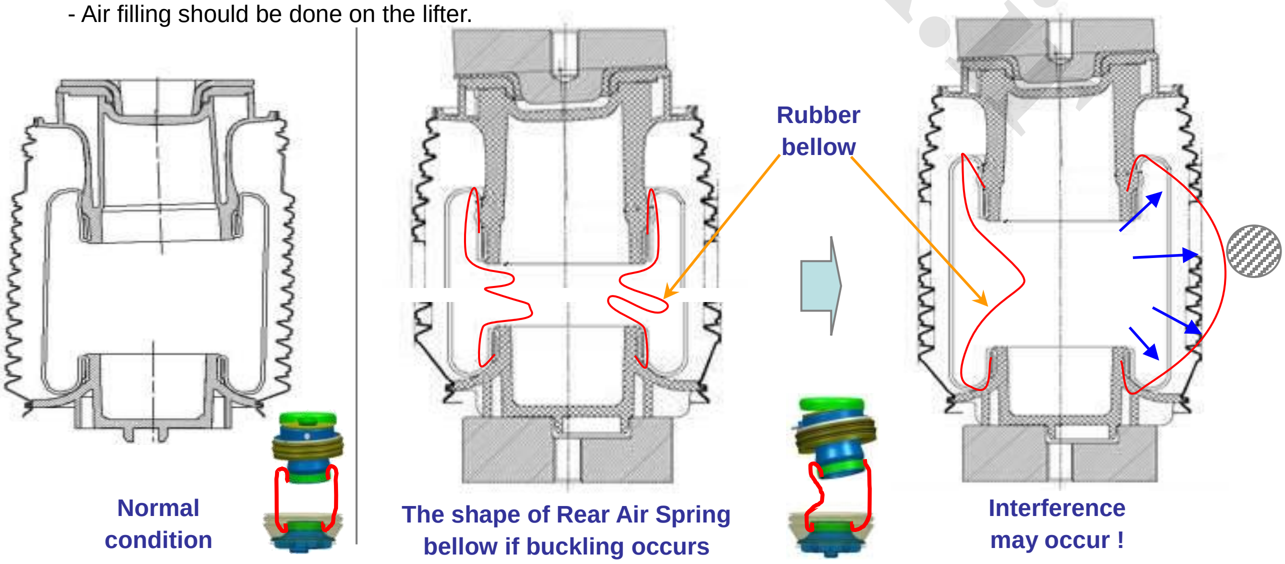


Cautions of handling

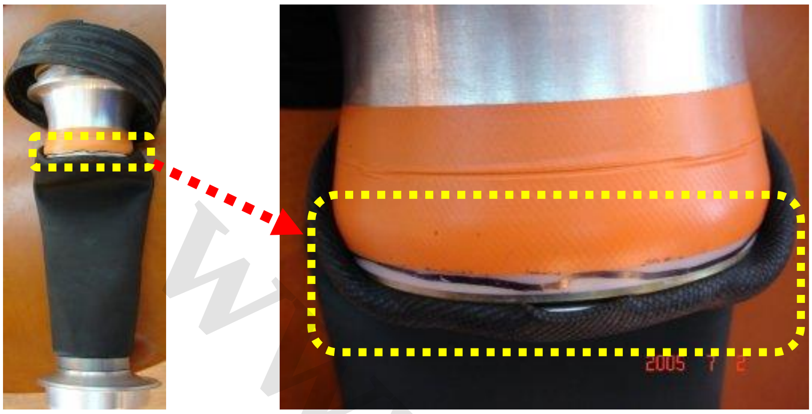
☐ When vehicle is on the ground with fully rebounded wheels.

▸ Cautions for system air filling

- Air filling should be done on the lifter.

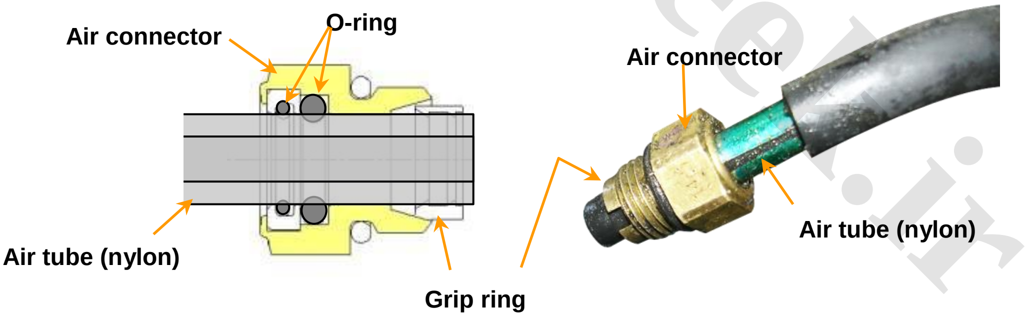


If the air is filled when the wheels are fully compressed on the ground, the air spring may be subject to buckling phenomenon as shown in the picture. Therefore it is strongly recommended to use a lifter when fill the air into the ECS system. If it was buckled accidentally, the air spring has to be removed from the vehicle and the buckled rubber bellow should be abstracted manually as well as the inspection of exterior damage on the rubber bellow, but it is not so easy.
Furthermore, buckling may result the third problem as shown in the picture below.

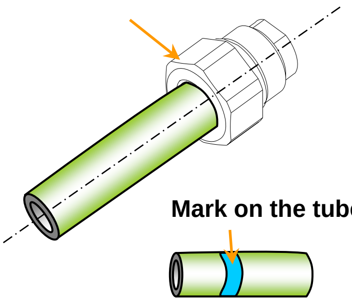


The upper clamping portion of bellows in rear air spring due to the buckling.

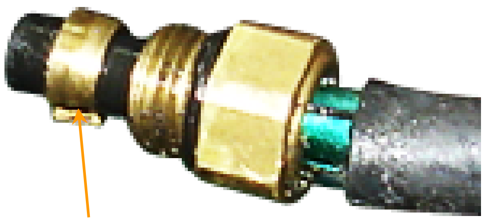
Air tube connection



Do not reuse the air connector



Recommended pliers for nylon tube cutting



Grip ring was protruded

- It is possible to disconnect the air connector that the tube is connected by rotating the air connector counter clockwise. The air connector will rotate freely due to the O-ring and grip ring.
- Pushing the air tube toward inside, make the grip ring protruded and then expand the grip ring in order to remove the tube from the air connector.

The air connector should not be reused.

- If the end of air tube was damaged, it can be repaired cutting the end of tube by 3mm. At this time, nylon tube must be cut off square. A saw may not be used for this purpose as the possible formation of burrs will affect the sealing capability of connection. For cutting nylon tubing to the correct length, the special cutting pliers which ensure that the tubing is cut squarely and cleanly as shown in the picture. (however, it is not listed in the official SST for BH)
- When tighten the air connector, excessive torque may result in the damage of housing so that tighten by hand carefully. (Torque: about 2.0Nm +/-0.5)
- If the air connector is new one, you may find the cover for connector. The cover should not be removed until the connection is completed in order to prevent the separation of grip ring.
- When you insert the tube at first, try to align the approaching angle with target female or male side, otherwise it may result in the damage of O-ring. Sometimes, the damaged end of tube may cause the damage on the O-ring.
- Insert with enough effort up to the marking which is indexed in the tube and then confirm the proper connection by pulling the tube 2 or 3 times.
- After completing the air tube connection, please check the any leakage by applying some soup liquid on the connecting portion and check that any bubble is generating or not after air filling.
- For more detail information for the cautions of air tube service, please refer to the workshop manual.

Service procedure

Here let's do a summary for the works for each event in ECS system applied in BH.

1) If control module replaced: Variant coding + Height sensor calibration should be done.
   : If the control module is new one, it may have C1702 (variant coding not completed) and C1620 (height sensor not calibrated) already.
2) If height sensor replaced: Height sensor calibration should be done.
3) Air spring replaced: System air filling + Height sensor calibration
4) Compressor replaced: System air filling + Height sensor calibration
5) Reservoir tank replaced: System air filling + Height sensor calibration
6) Solenoid valve block replaced: System air filling + Height sensor calibration
7) Steering angle sensor replaced: Nothing to do in ECS section but sensor has to be calibrated in ESC system. (Steering angle signal for ECS is transferred from ESC via CAN)

Cautions for variant coding:

It is only for distinguish the vehicle model (BH or VI). That is, there is no difference for area, engine volume and wheel size and so on. Because the main purpose for variant coding is to input the vehicle model into ECS control module, it is not possible just only to do the ignition on like other systems. It should be done using the scanner. **If the variant coding is not done properly, the air spring cannot be controlled anymore and CDC damper solenoid valve current will be fixed by zero ampere.**

Warning lamp:

Following picture shows the location of ECS warning lamp. Refer to the workshop manual for more details about warning lamp.

Current data

As for the concept (definition) of 'bar-liter'. for example 100 bar-liter means that the air with pressure 1bar is confined in the volume of 100 liter so that it is used to express the air mass in ECS system. It shows as an unit of 'barl' in the current data of scanner as shown in the picture.

Air Spring Failsafe

Mode	All SOL.	Comp. relay	Height sensor	Level control	Restore condition (if failure repaired)
A	OFF	OFF	OFF	OFF	Cannot be restored
B	OFF	OFF	ON	OFF	Next IG cycle
C	OFF	OFF	ON	OFF	Current IG cycle
D	ON	OFF	ON	Down leveling only (via ambient valve)	Next IG cycle
E	ON	ON	ON	Down leveling only	Current IG cycle
F	ON	ON	ON	Done by 3 height sensors	Current IG cycle
G	ON	ON	ON	Move to Normal level immediately and no more auto/manual level control at normal level	Current IG cycle

As for the failsafe mode of air spring control system, there are several modes depending on the failure type as shown in the table. Mode 'A' means a severe problem so that almost control is prohibited. Mode 'E' is valid when the most light failure is occurred.

Mode A: Actually mode A is not applied in BH.

Mode B:
- **Height sensor power supply error** (lower than 4V or higher than 6V)
- Air spring solenoid valves error (short to B+ or short to Ground)
- Reverse valves error (short to B+ or short to Ground or internal failure)
- Ambient valve error (short to B+ or short to Ground or invalid operation)
- Level control failure (if lifting or lowering time exceeds 20 sec.)
- Control module hardware error (ROM/RAM/EEPROM, etc)

Mode C:
- Vehicle battery voltage error (lower than 10V, higher than 16V)
- **More than 2 height sensors are failed** (abnormal frequency or invalid signal)
- Ambient valve out of control range
- **Variant coding error**

Mode D:
- Compressor relay error (short to B+ or ground, open circuit)
- Control module hardware failure (internal MICOM comm. error)

Mode E:
- Pressure sensor error (lower than 0.2V or higher than 4.8V or no signal more than 12times)

- Solenoid valve operating time is over. (Air spring sol.: exceeds 3min within 10min, Reverse valve: exceeds 5min within 10min) ◊ to avoid the over heating of solenoid valve.

- Compressor overheating: temperature is higher than 140℃ for more than 10 sec.

→ Exceptionally down leveling also is prohibited.

Mode F:

- One height sensor is failed (abnormal frequency or invalid signal)

Mode G:

- **CAN bus off, CAN timeout (EMS)**
- **CAN message failure (EMS)**
- Lop sided car could not be adjusted (VSS<10kph, left & right deviation of level cannot be corrected after 3 times try)

CDC damper Failsafe

Mode	Level control	Defect item	Restore condition (if failure repaired)
A	CDC Solenoid current: 0mA (Hard control)	- CDC solenoid valve - Control Module	Next IG cycle
B	CDC Solenoid current: 600mA (Fixing midway control)	- Height sensor + volt Low or High - G-Sensor	Next IG cycle
C	CDC Solenoid current: 600mA (Fixing midway control)	- Height sensor + short to ground	Current IG cycle
D	Reserved	Not Used	Reserved
E	Reserved	Not Used	Reserved
F	CDC Solenoid current: 0mA (Hard control)	- Battery voltage too low or high - One of height sensor error - Variant code error - CAN BUS Off DTC - CAN message failure (EMS,ESP or SAS)	Current IG cycle

As for the failsafe mode of CDC damper control system, there are several modes depending on the failure type as shown in the table. Mode 'A' and 'F' mean a severe problems so that almost control is prohibited. Mode 'C' and 'D' is valid when lighter failure occurs. Mode 'D' and 'E' are not used.

Mode A:

- CDC actuator (solenoid valve) failure: High side is shorted to ground.
- Control module hardware failure (internal MICOM comm. error)
- Control module hardware error (ROM/RAM/EEPROM, etc)

Mode B:

- Height sensor power supply error (lower than 4V or higher than 6V)
- G-sensor failure (short to B+ or short to Ground or open circuit or invalid signal or sensor power is less than 4.75 or higher than 5.25V)

Mode C:

Height sensor failure (short to ground or B+)

Mode D and E:

- It does not used in BH.

Mode F:

- Vehicle battery voltage error (lower than 10V, higher than 16V)
- One height sensor is failed (abnormal frequency)
- **Variant coding error**
- **CAN bus off**
- **CAN timeout (EMS or ABS/ESC or SAS)**
- CAN message failure (EMS or ABS/ESC or SAS)

Sometimes, you may encounter that ESC, ECS, EPB and SCC warning lamps altogether do not disappear after ignition on. At this time, please check that;

1) Check the battery cable or ground is correctly connected or not. If the battery connection is not good, ESC cannot perform to write the offset value of sensors and it may result in the warning lamp on in other systems also even though those systems have no problem.

2) Next, check ESC at first ! As it is mentioned, ECS shares various info via CAN and the problems from ESC can affect to other systems.