

# Comfort analysis of Modern Active Air Suspension System

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**ABSTRACT:** A new approach to constraint-based path selection for dynamic routing and wavelength allocation in optical Air ride suspension carries the load on each axle with a pressurized air bag much like a high pressure balloon. The job of a car suspension is to maximize the friction between the tires and the road surface, to provide steering stability with good handling and to ensure the comfort of the passengers. Air ride suspension systems have been in common use for over forty years and have proven to provide the smoothest and most shock-free ride of any known vehicle suspension system. Modern air bags are constructed using the same methods as a tire by using high strength cords which are then encapsulated in rubber. The first important feature of 'Air suspension system' is the system automatically adjusts air pressure in the air bag so that the trailer always rides at the same height, whether lightly loaded or heavily loaded. This allows the suspension system to always provide the maximum usable wheel travel independent of trailer load. In addition, the higher air bag pressure associated with higher trailer loads automatically provides a stiffer suspension which is exactly what is required for a smooth ride. The automatic control of the air bag pressure is accomplished by a solid state electronic control system specifically designed and packaged for vehicle use. This system continuously monitors the "ride height" of the trailer suspension and increases air pressure if the ride height is too low, by turning on an on-board air compressor.

**KEYWORDS:** Suspension System, Air Spring, Air Bag, Ride Comfort.

## I. INTRODUCTION

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 road holding 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, etc. If roads were perfectly flat, with no irregularities, suspensions wouldn't be necessary but they are not therefore these imperfections interact with the wheels of a car and apply some forces on them. A bump in the road causes the wheel to move up and down perpendicular to the road surface. The magnitude depends on whether the wheel is striking a giant bump or a tiny speck. Either way, the car wheel experiences a vertical acceleration it passes over an imperfection. Suspension consists of the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. The suspension systems not only help in the proper functioning of the car's handling and braking, but also keep vehicle occupants comfortable and make your drive smooth and pleasant. It also protects the vehicle from wear and tear.

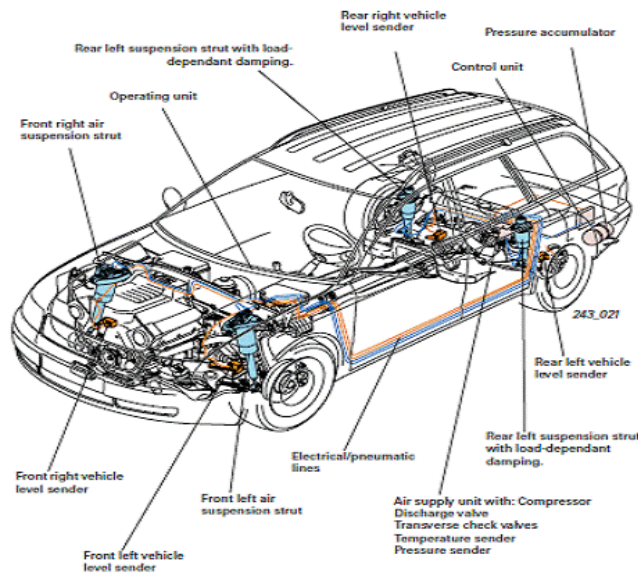


Figure 1: Locating Suspension Units

The air suspension system is an air-operated, microprocessor controlled suspension system. This system replaces the conventional coil spring suspension and provides automatic front and rear load leveling. The 4 air springs, made of rubber and plastic, support the vehicle load at the front and rear wheels. An air suspension supports the vehicle on the axles with an arrangement of air bags instead of some type of steel spring, leaf or coil, or some type of torsion spring arrangement. The air bags are sometimes referred to as air springs or bellows. Suspensions that have steel or torsion springs that are supplemented by the use of air bags are not considered air suspensions. There are combination systems that have both air and steel springs. Usually the air suspension components are used on the rear of the vehicle.

## II. PROBLEM DEFINITION

### GENERAL PROBLEMS WITHOUT SUSPENSION SYSTEM:

1. Unsprung Weight:  
Having a large beam connecting the two front wheels results in a lot of mass .This extra mass hinders the road holding capability of the suspension on rough road.
2. Wheel Movement:  
Since both wheels are tied together the force acting on each wheel are directed to the other wheel. Under the load this causes the wheels to shake and decrease the stability of the vehicle in corners.
3. Bad Bump Steer:  
Since it is difficult to locate the steering correctly with the help of a beam axle, therefore most of the solid axle suspensions suffer from an uncontrollable amount of bump steer and due to which the performance of the car decreases.
4. Size:  
Since solid axles are huge therefore the fitting them into the chassis requires a lot of space.
5. Ride Quality:  
Due to the high mass of the axle and the wheels being connected there is not much ride isolation between the springs and unsprung mass. This results in rough ride and decreases the road holding capacity.

### III. PROBLEMS IN AIR SUSPENSION SYSTEM

1. **AIR BAG OR AIR STRUT FAILURE:** It is usually caused by wet rot or moisture entering the air system and therefore damages it. Air ride suspension parts may fail because rubber becomes dry and punctures to the air bags can be caused by debris on the road. Improper installation can also cause the air bags to get rubbed against the vehicle's frame or other surrounding parts and therefore damaging it.
2. **AIR LINE FAILURE:** It is the failure of the tubes connecting the air bags or struts to the air system. This failure usually occurs when the air lines are rubbed against the sharp edges of the chassis member or moving suspension components and causes a hole.
3. **COMPRESSOR FAILURE:** This failure is due to the leakage in air springs or air struts. The compressor burns out maintain the air pressure in a leaking air system. Compressor burnout may also be caused by the moisture present in the air system coming in contact with its electronic parts.
4. **DRYER FAILURE:**  
Function of dryer is to remove moisture from the air system. But when it stops performing its function and becomes saturated the moisture develops resulting in burnout failure and damaging of air springs.

### IV. BASIC COMPONENTS OF ACTIVE AIR SUSPENSIONS

An air suspension has three basic components. The air supply, the height control valves, the air bags and the sensors. In the following section, we will discuss several different arrangements of these components.

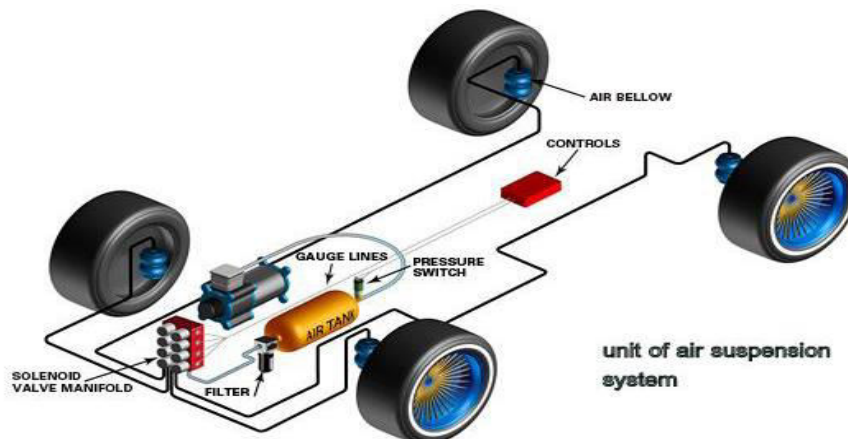


Figure 2: Advanced Air Suspension

#### 1. AIR SUPPLY

The air supply is engine air compressor, the air tanks, air valves and air lines. The engine air compressor supplies air for every piece of air equipment on the vehicle. The maximum pressure supplied by the compressor varies. For many years, the air supply was maintained around 120 to 125 psi but on some newer, larger vehicles this has been increased to 135 psi. There will be dash gauges that will supply system pressure information but all vehicles have what we refer to as a "pop off valve". One can hear the valve "pop off" when the system reaches the maximum air pressure.

The air supply is maintained through an arrangement of air tanks. Air tank arrangement is one thing that varies greatly between different air systems. There can be as many as 10 to 12 different tanks. The terminology for these tanks varies greatly also. There are primary tanks, secondary tanks, wet tanks, auxiliary tanks, front brake tanks, rear brake tanks. The only purpose of air tanks is to store air for the different systems on the vehicle.

## 2. HEIGHT CONTROL VALVES

The height control valves (HCV) are kind of the brains of the system. They dictate how much air is in the air bags. This dictates the height the vehicle sits at, therefore they are known as Height Control Valve. Most HCVs are mechanical valves but electronic HCVs are available. The HCV is mounted to the frame of the vehicle.

## 3. AIR BAGS

Air bags are simply a rubber bladder that holds air. Air bags are also referred to as air springs or bellows. The air bags are located between the frame of the vehicle and the vehicle axles. Air bags are rated for weight and pressure capacities. Air bag placement and arrangements vary amongst chassis manufacturers. At the very least, there will be one air bag for each side of each axle in the vehicle. There can be two air bags for each side of the axles but there is no system with more than one bag per side. Some manufacturers use two air bags for each side of the drive axle and some use two air bags for each side of the drive and front axles. Space between air bags for side to side placement also varies. Some place the air bags outboard as far as they can and some have the bags closer together. When two bags per side are used, one will be in front of the axle and the other behind the axle. Again, spacing can vary. Most air bags will have some device such as a cone that keeps the air bag from being crushed or damaged when fully deflated. Inflating air bags is limited to the available air pressure to the suspension system. This is why the relief setting of the engine air compressor should not be changed.

## 4. SENSORS

In active suspension systems, sensors are used to measure the accelerations of sprung mass and unsprung mass and the analog signals from the sensors are sent to a controller. The controller is designed to take necessary actions to improve the performance abilities already set. The controller amplifies the signals which are fed to the actuator to generate the required forces to form closed loop system (active suspension system) Fig.4.9 Some types of sensors used in active suspension system are as follows:

- Position sensor (LVDT position sensors)
- Height sensor
- Air bags pressure sensor
- Bumps sensor

## V. LAYOUT AND WORKING OF ACTIVE SUSPENSION SYSTEM

Active air suspension system consists of an air tank, 4-way air valve assembly (pressure solenoids), air compressors, the necessary pressure sensors, all wiring and air fittings, and an in-car electronic control module. In order to understand the working of active air suspension system, we need to understand functions of each component. Using the diagram below, we can find an in-car input of whether to raise or lower the car through the entire system. From the cabin of the vehicle, using the control module, an air pressure is selected for each corner. Once a pressure has been chosen, the signal travels to the computer, which sends the request to the pressure solenoids. The solenoids then either send air to the air springs to inflate them or bleed pressure from the air springs to deflate them. The air compressors are used to fill the air tank, which feeds air to the pressure solenoids. In order for the in-car control module to know the pressure in each air spring, pressure sensors are used in conjunction with the pressure solenoids. In other words, the in-car control module represents the gauge faces while the sensors are the gauges themselves. While the arrangement of components there is a need of attention to cutting the airlines straight and making sure to run the lines away from anything potentially harmful.

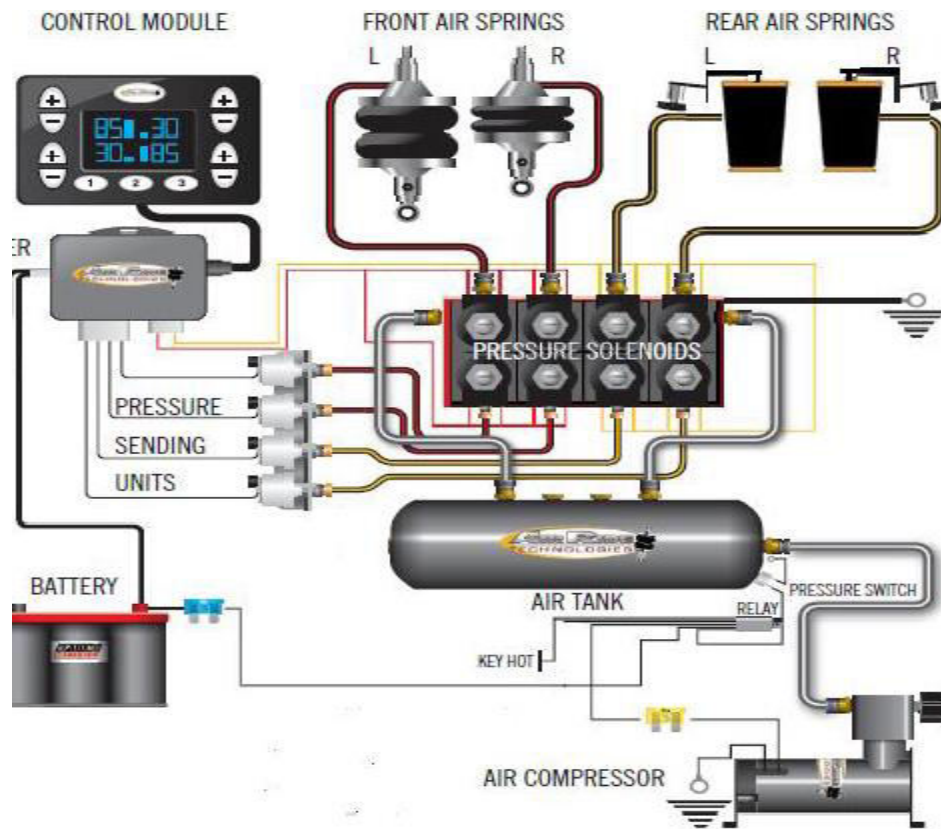


Fig.3 Arrangement of active air suspension system

## VI. WORKING

The working of this system can be explained in following steps:

1. The vehicle air system, engine air compressor, tanks, lines, etc., supplies air to the height control valves (HCV) mounted to the frame of the vehicle.
2. The height control valves are connected to the air bags with an air line. The linkage which connects the HCVs to the axles rotates the HCV as it moves up and down.
3. When weight is added to the vehicle or transferred through the suspension of the vehicle, the air in the air bag(s) is compressed, the frame moves closer to the axle. This forces the HCV linkage up. As the linkage moves up, the valving of the HCV connects the air supply to the air bag(s). The added pressure and volume inflates the air bag(s), causing the frame to move away from the axle. As the frame moves back to the proper ride height, the HCV linkage moves to the neutral position. This moves the valving away from the air supply and locks the air in the air bag to maintain the proper ride height.
4. As weight is removed from the vehicle or the suspension shifts weight away, the existing pressure in the air bag(s) can push the frame away from the axle. The HCV linkage is pulled down. This connects the air bag(s) to the HCV exhaust port. As air is exhausted from the air bag(s), the frame lowers back down towards the axle. As the linkage moves up to the neutral position, the exhaust port is closed and the air is again locked in the air bag(s), maintaining

proper ride height. These three drawings show a schematic example of the height control valve in the neutral position, inflate position and deflate or exhaust position.

**X. SPECIFICATION OF COMPONENTS**

**1. AIR-SPRING**

Air spring, load-carrying component of an air suspension system used on machines & automobiles. A system used on buses consists of an air compressor, an air-supply tank, leveling valves, check valves, bellows, and connecting piping. Basically, an air-spring bellows is a column of air confined within a rubber and fabric container that looks like an automobile tire or two or three tires stacked on top of one another. The check valves admit additional air to the bellows from the air-supply tank to maintain vehicle height when the load is increased, and the leveling valves vent excess air from the bellows when the vehicle rises because of unloading.

The vehicle thus remains at a fixed height regardless of load. Although an air spring is flexible under normal loads, it becomes progressively stiffer when compressed under an increased load. Three basic types of air springs are available: the double-convoluted, the tapered-sleeve, and the rolling-sleeve. The double-convoluted design looks like a large double cheese-burger and generally has more load capacity, a shorter stroke, and a more progressive spring rate that's best suited for use on most front suspensions where the spring sits considerably in board of the suspension's load point.



Fig.4 Air Springs

**2. FRONT SUSPENSION**

As air suspensions evolved, a higher-end installation was developed based on coilover shock/spring combos but with an airbag replacing the coilover's coil spring, these setups tend to be more expensive but offer the advantage of easier installation, better looks and more wheel-and-tire clearance. For front suspension system, double-convoluted air bags are used as it is having greater load carrying capacity. The front springs are connected with the pressure solenoids controlled by the pressure sensors in order to avoid the bump by supplying the suitable amount of air in the air bags.

**3. REAR SUSPENSION**

In Rear suspension system, tapered sleeve or rolling sleeve air springs are generally used which are connected with the pressure solenoids. Removing several leaves from each spring pack and install air springs between the axle housing and the vehicle frame. Residual leaves are still needed to locate the rear axle but airbags now perform the primary load-bearing function.



#### 4. COMPRESSORS

A compressor and reservoir tank allow quick in-vehicle altitude adjustments. Airsprings can be inflated using compressed air just like an oldair shock, but that obviates oneof the main benefits of this typeof suspension: in-use adjustability to compensate for changing road conditions, vehicleloads, or intended use.



Fig.5 Compressor with reservoir tank

An on-board air system consists of at least one air compressor, a storage tank and control system. A cost-effective and relativelysimple solution that providesreasonable ride and handlingbenefits would be a 2-gallontank kept full by a single compressor. On the other hand, ifthe car has to go up anddown in two seconds; on aheavy car it could take as muchas a pair of 150-psi compressorsand two or more 5-gallontanks, huge industrial air valves,and 3/4-inch feeder lines.

#### 5. AIR LINES

Plastic air lines originally developed for big trucks are standard which provides aneasy, affordable solution to connecting the compressors to theair springs. Typical operatingpressures range from about 75to 150 psi, well within the capabilities of such tubing.

Stainless hard line can be used, justas in a brake or fuel system, connecting it using typical a flare nuts and pipe adapters. Atsuspension travel points, flexible hose would be needed in another wise hard-lined system,just as it is in a brake system.Also like in a brake system,braided stainless steel Teflon-core hose is preferred overbraided synthetic rubber-core fuel/oil-line hose.

#### 6. CONTROL SYSTEM

Manual setups typically use pneumatic valves mounted to a panel with a pressure gauge. A more sophisticated approach with less under dash clutter is to use electric solenoids controlled by a switch or computer. The last 3-4 years have seen the introduction of various aftermarket active electronic height-control systems that attempt to maintain a set ride height as the vehicle drives down the road. An electronic height-control system adds a computer plus sensors to control the electric solenoids. Both pressure-based and ride-height-based electronic control systems are available.

### XI. PROS AND CONS OF AIR SUSPENSION SYSTEM

Do you have a truck and it sags more than you like when towing a trailer or a hauling a bed full of supplies? Ever wonder what is the best solution to get rid of the suspension sags, so your truck drives Normally?

- Air springs or non-air suspension kits?
- Air Lift or Timbren?
- Firestone air springs or Firestone work-rite non-air suspension kits?

These are common questions and we will touch on a few of the pros and cons of each to make your buying decision a little easier. Which is better? In our experience over the years, we've found that both air suspension kits and kits that don't use air will reduce suspension sag. If you search the web, you'll find to friends. Rather than ask which is better, perhaps a better question is "Which suspension kit is better for me?"

Firestone Ride-Rite  
Firestone Coil-Rite  
Firestone Sport-Rite  
Air Lift Load-Lifter 5000  
Air Lift 1000  
Air Lift Ride-Control  
Hellwig Air Springs

**Pros:**

**Air adjustable:**

A little obvious, but this is the major plus that a non-air kit can never overcome, the ability to adjust your truck to the desired ride height. Hook up your trailer, truck sags a few inches, no problem. Inflate the air springs until your truck is level. Done towing and just using the truck for the daily commute? Simply remove the air pressure until air springs are at the minimum required air pressure, and your good to go.

**Level Side-to-Side:**

Have a motor home with a tank full of water on one side, or a pickup with a slide incamper and your leaning to one side? With air springs, you have the option of running a "T" fitting and inflating both the air springs equally, or running the airlines separately to each bag which allows you to increase the pressure on one side over the other. This allows you to level out the side with the water tank, etc.

**Cons:**

Using air to level your truck is a major plus, and the advantages do outweigh the disadvantages, but air does require more attention and opens the door for cons that a non-air load leveling kit will never experience. When dealing with air, you have the potential to run into leaks, damaged airline, holes in air springs etc. These problems can all be easily repaired, and are not very common in the big picture, but they do happen. If you're planning on extensive travel, it's never a bad idea to have a spare air spring and some airline. Replacement air springs and airline are readily available and not very expensive.

## XII. INSTALLATION

Air-suspension systems address all the issues of air-spring installed height, shock installed height, ball-joint travel, driveline angles, ground clearance, tire clearance, and other parameters that must be considered when building a safe, functional system.

Fundamentally, it's no different from engineering traditional suspension, except air springs replace metallic springs. It may actually be easier because air springs have a greater operating envelope in terms of ride height and load capability than traditional metallic springs. It is important to match the air spring to the vehicle's weight capacity and suspension travel. Identical springs and shocks may not always yield identical results in two different applications, even if the weight and installed height are similar. As mentioned earlier, on a front suspension, the spring-mount location on the control arm exerts a leverage effect, multiplying the theoretical spring rate as seen at the wheel. Just like an engine rocker arm, increasing the distance of the mount from the arm's pivot point (moving it closer to the ball joint) yields a higher ratio, which multiplies the spring rate. Increasing the angle of the shock also requires more spring to maintain an equivalent ride height.



Once the air spring has been selected, it must be mounted in the vehicle. Every air spring has an optimum design ride height where it delivers maximum performance. This spring-height dimension should be synchronized with the intended ride height to determine how to mount the air spring in the car. The mounting point must also allow for sufficient suspension travel, tire clearance, ground clearance, and appropriate driveline angles. Maintain adequate clearance between the air spring and other components—abrasion is death to these otherwise very durable units. A variety of premade universal brackets are used that mount like a coilover shock and are easier to install with proper geometry than separately mounting a conventional separate air spring and shock absorber.

The vehicle should be mocked up at its intended highway ride height. At this point, you should maintain at least 4 1/2 inches of ground clearance and have adequate suspension travel—at least 3 inches in compression and 2 inches in rebound. Be sure the air spring's end plates are aligned and parallel at ride height.

Double-convoluted air springs don't require a bump stop to avoid damage; however, specific application may need a bump stop to maintain safe ground clearance when deflated. For tapered- or rolling-sleeve air springs, a bump stop and an extension strap (either a limiting strap or a shock absorber) must be used to prevent the air spring from exceeding its design compressed or extended dimensions or the spring will fail. Finally, set wheel alignment at the car's normal running ride height, understanding that it will change slightly when the suspension is in the raised or lowered position.

### XIII. CONCLUSION

Air suspension is today mainly a feature for luxury vehicles. It offers a lot of features for compact class. Cost or price level will be more attractive. Integration & smart design is key. The Air Suspension System has the ability to change the load-carrying capacity simply by changing the air pressure. From the whole discussion in air suspension system, it is observed that the system is like a white blood cell. As a white blood cell provides energy to our body to fight against diseases or viruses which try to destroy or try to decrease our life, in a similar way air suspension system provides the energy to a vehicle to protect itself from damaging, increasing the life of the vehicle, increasing the handling, increasing the comfort of passengers and many more.

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