ProVQ™

CHASSIS DIAGNOSIS

PHASE THREE

Contents

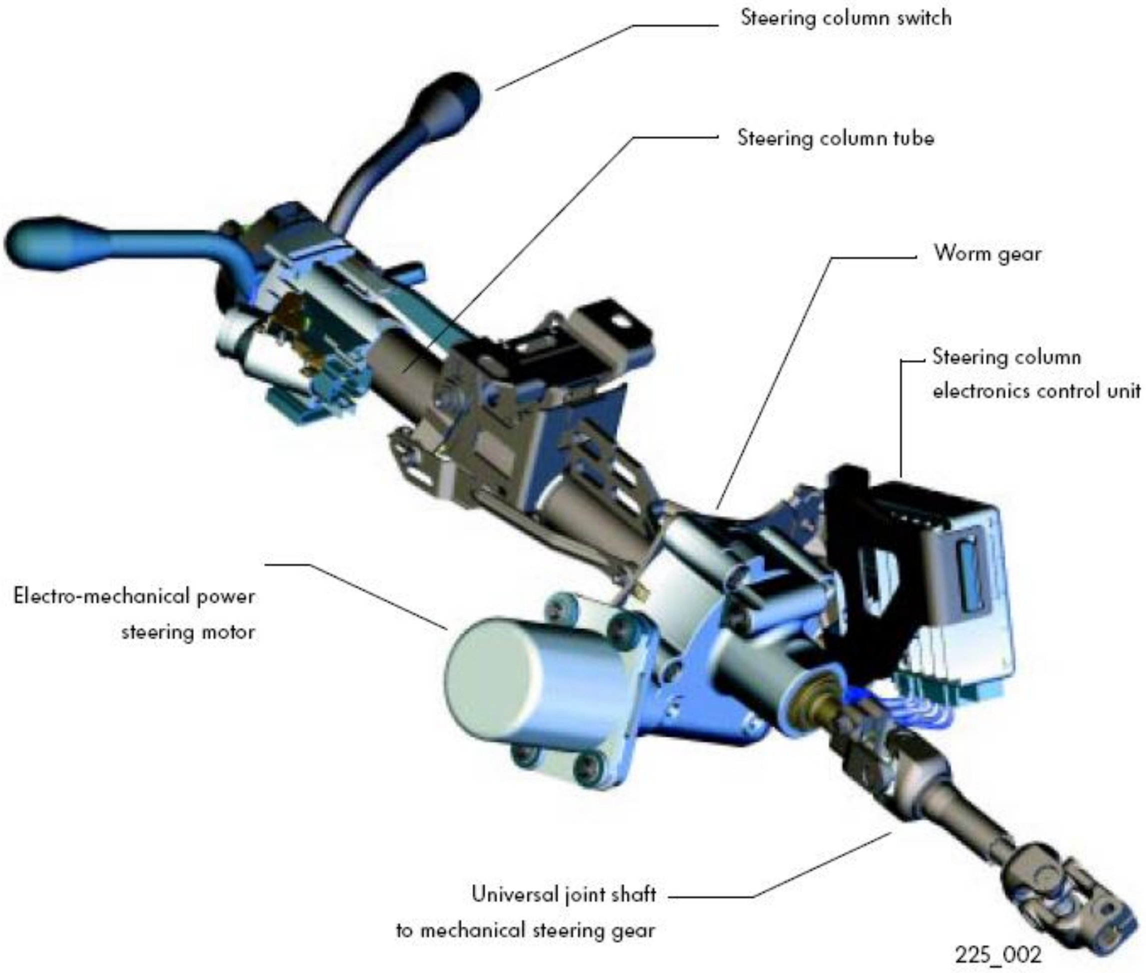
Electronic power steering

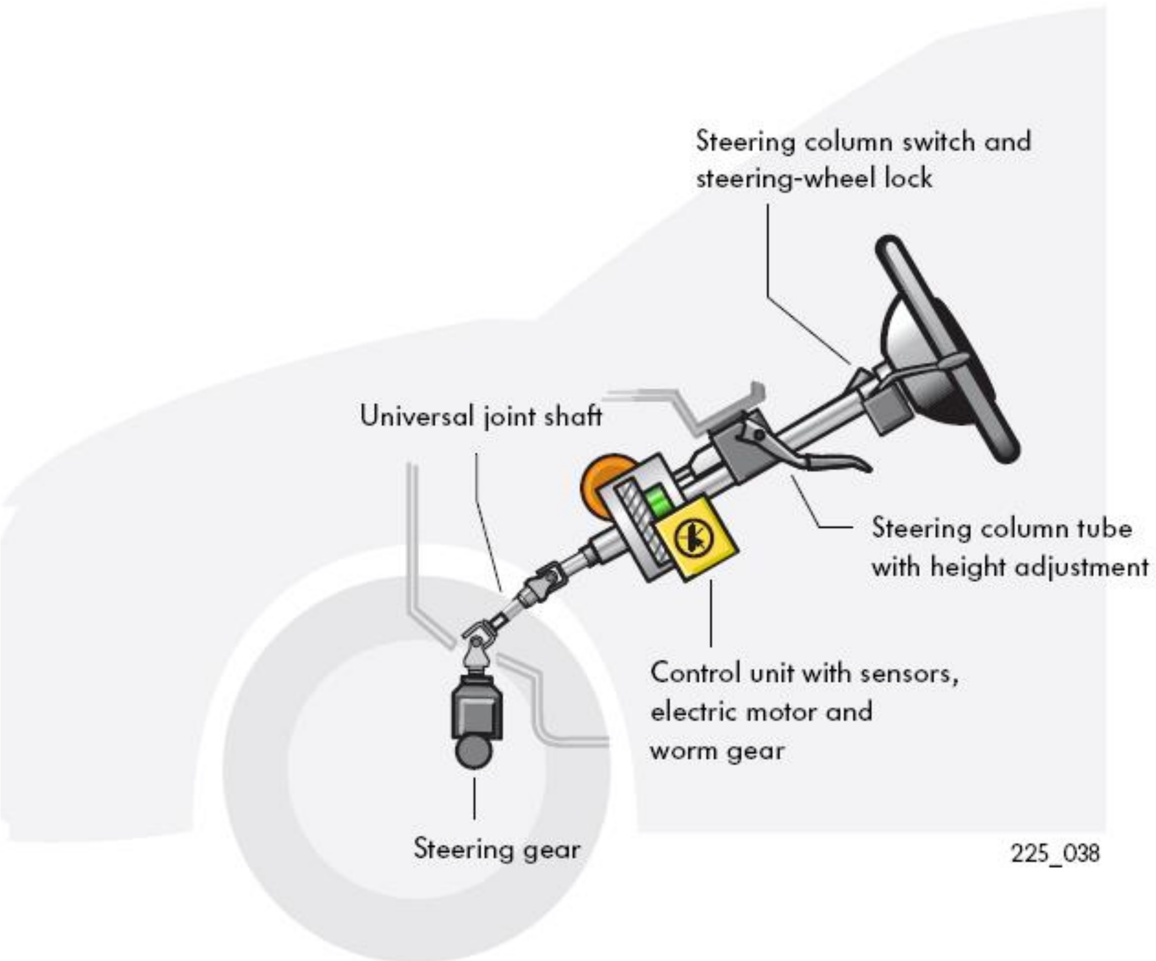
The electro-mechanical power steering system assists the steering movement performed by the driver by means of an electric motor. This motor, in turn, drives a worm gear. The speed dependent steering system conveys a direct steering feel, without any annoying feedback from the road to the driver.

The component parts of the steering column

The main components of the new power steering system are:

- the steering column switch,
- the steering column tube,
- the worm gear, steering position sender, and steering moment sender
- the electro-mechanical power steering motor
- the steering column electronics control unit
- the universal joint shaft to the mechanical steering gear.



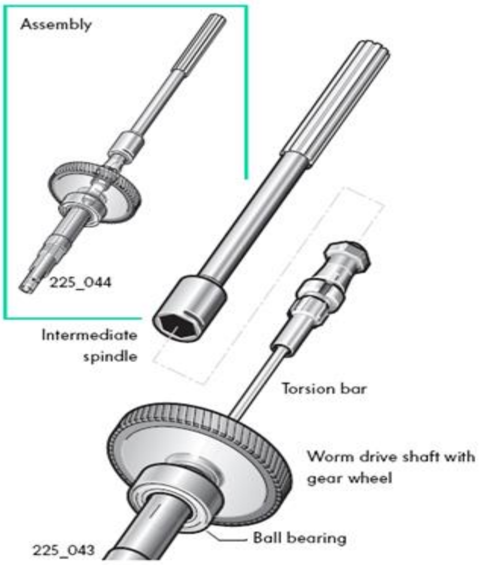


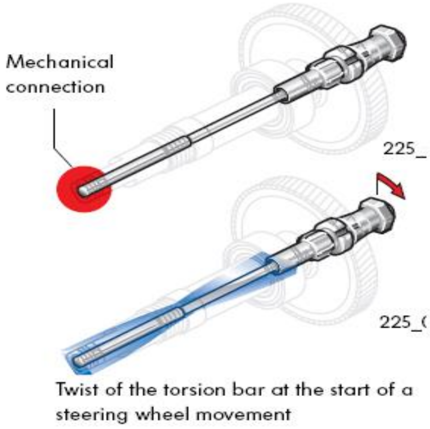
The entire electro-mechanical power steering system is integrated in a compact unit. This unit comprises all component parts of the steering gear, e.g. control unit, electric motor and the sensors required for control. Hence, there is no longer any need for complex wiring arrangements.

The steering column and its component parts

The key component parts of the electro/mechanical power steering system are:

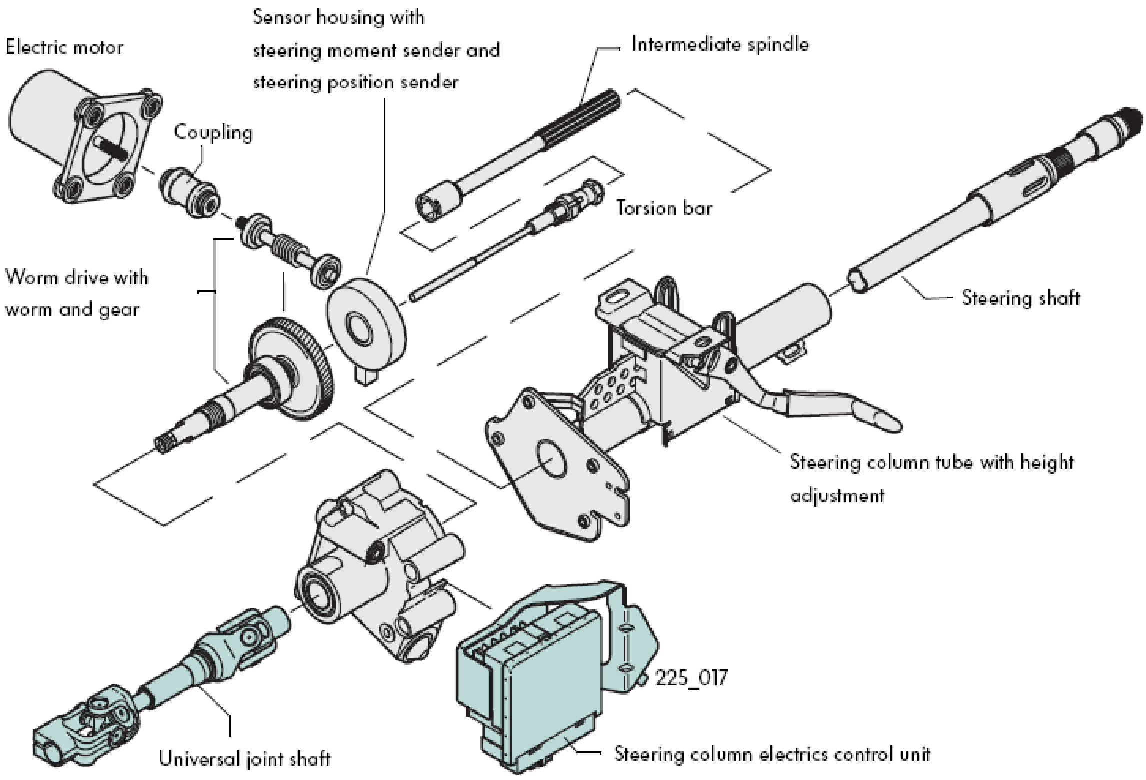
- Steering shaft
- Steering column tube with height adjustment
- Intermediate spindle
- Torsion bar
- Sensor housing with steering moment sender and steering position sender
- Electric motor and coupling
- Worm drive with worm and gear
- Gearbox housing
- Steering column electronics control unit and
- universal joint shaft





The torsion bar

The central component part of the electro/ mechanical power steering system is the torsion bar. It is made from tempered steel, which allows the bar to rotate about its longitudinal axis. The torsion bar mechanically connects the intermediate spindle to the worm drive shaft.

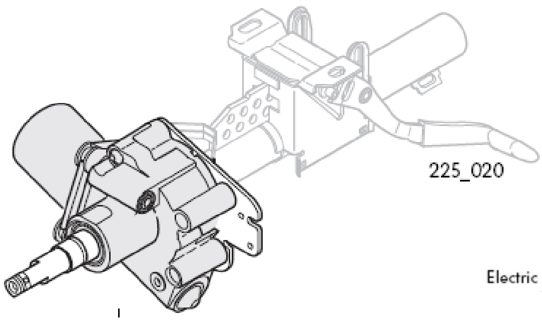


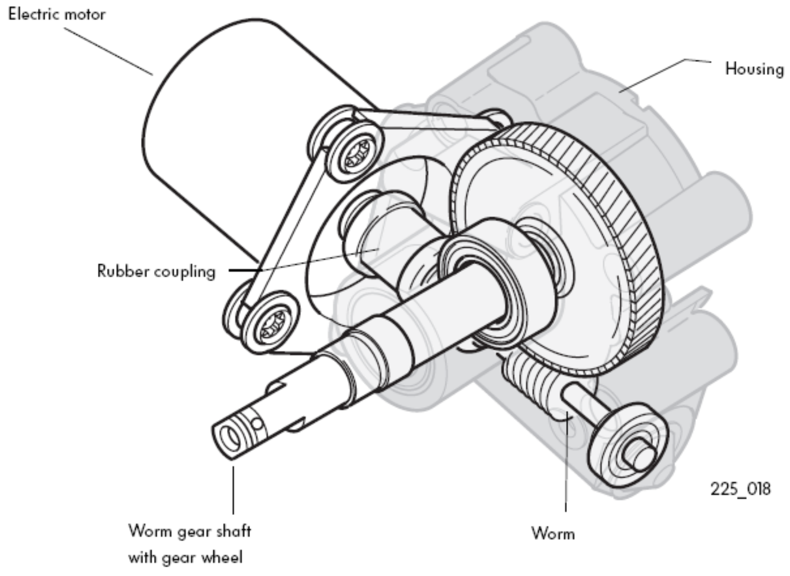
Operation

Through this connection, the intermediate spindle and the worm drive shaft are able to counter-rotate about a narrow angle. This narrow angle is enough for the system to detect the start of a steering operation.

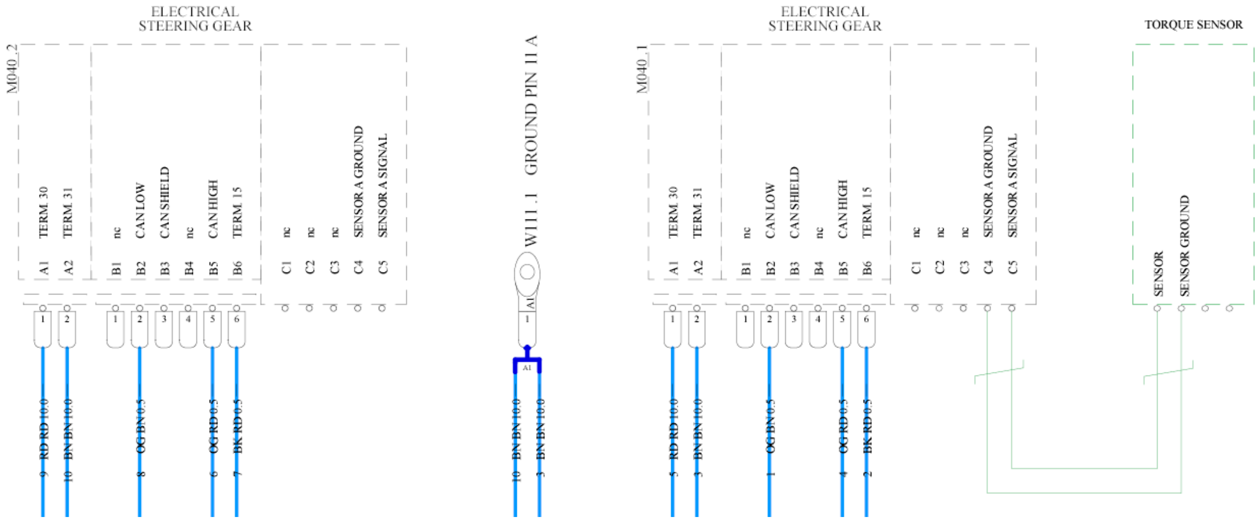
Worm gear assembly

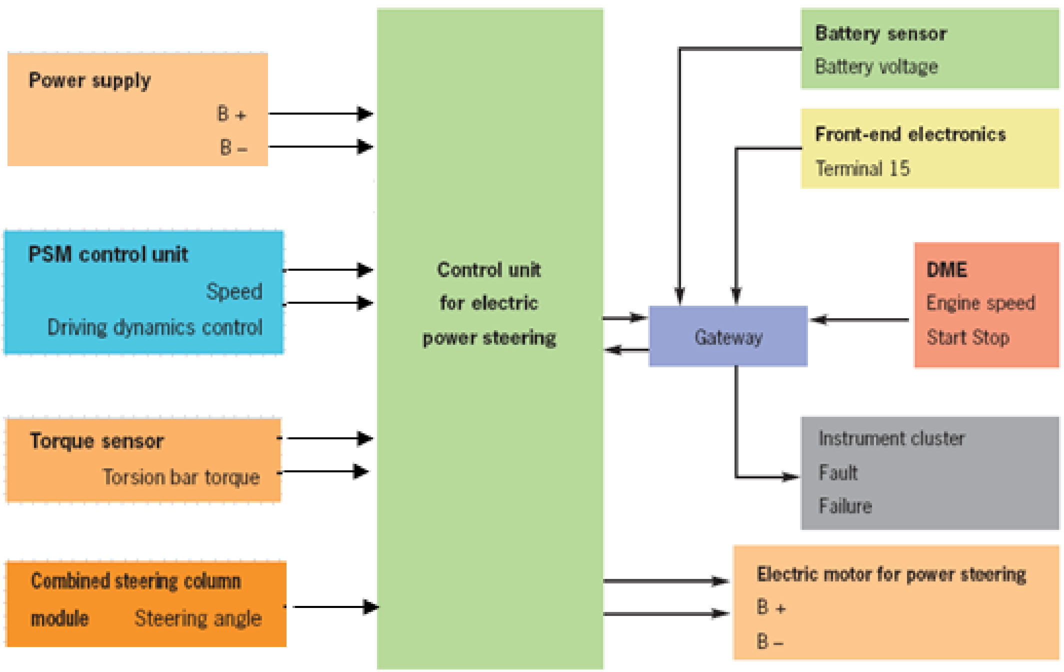
The worm gear assembly is located in an aluminium gear case where the electric motor is also mounted. A worm on the motor shaft meshes with the gear on the steering shaft. The gear ratio in this example is 22:1. The gear body and the worm are made of metal. The gear ring is manufactured from plastic to reduce mechanical noise.





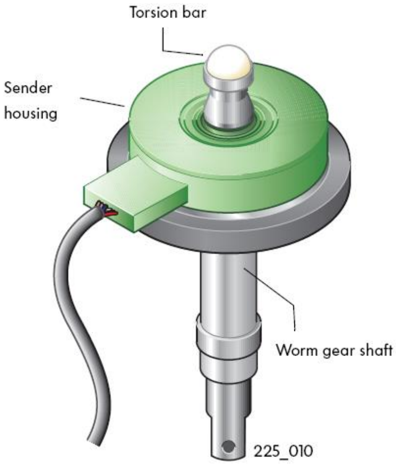
Electronic control





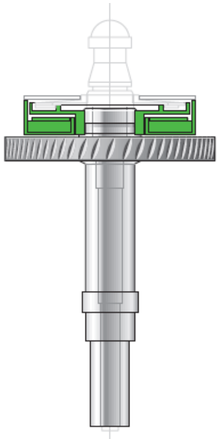
Sensors

Steering position sender and steering moment sender are located in a housing. The sensor housing is mounted on the worm gear shaft above the gear. The sensor housing is connected to the control unit via a connector.



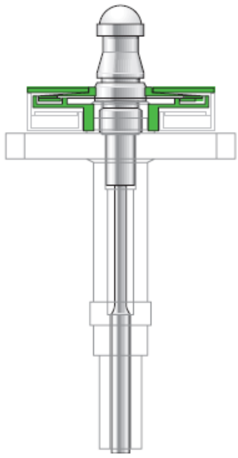
Steering position sensor

The steering position sensor is connected to the worm gear shaft. It registers the steering wheel lock and/or the current position the steering.



Steering moment sensor

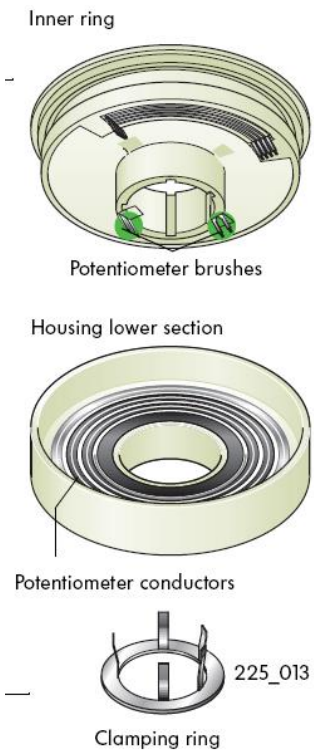
The steering moment sensor is connected to the torsion bar. It registers a rotation angle of the torsion bar in relation to the intermediate spindle. The control unit calculates a torque from this signal. If the calculated torque exceeds a value of 0.01 Nm, the control unit assumes that a steering assistance is required.

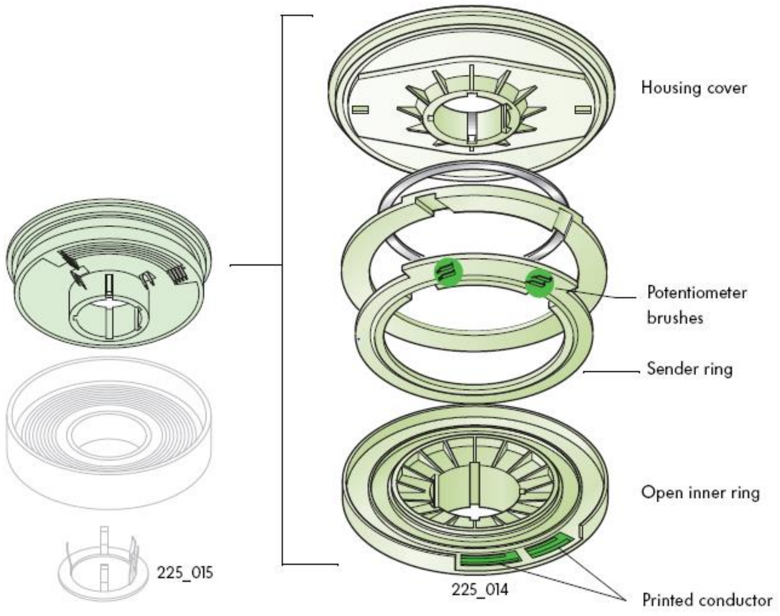


Sensor design

The two sensors are sliding contact potentiometers. The steering position sender registers the steer angle of the steering system through rotation of the inner ring in relation to the housing lower section. The steering moment sender registers the rotation of the torsion bar. The housing has an inner ring. This ring is mounted on the worm drive shaft with a clamping ring and can rotate relative to the housing. Two pairs of potentiometers scan the brushes of the inner conductor on the PCB in the housing. This part is the steering position sender. The other conductors transfer the signal from the steering moment sender.

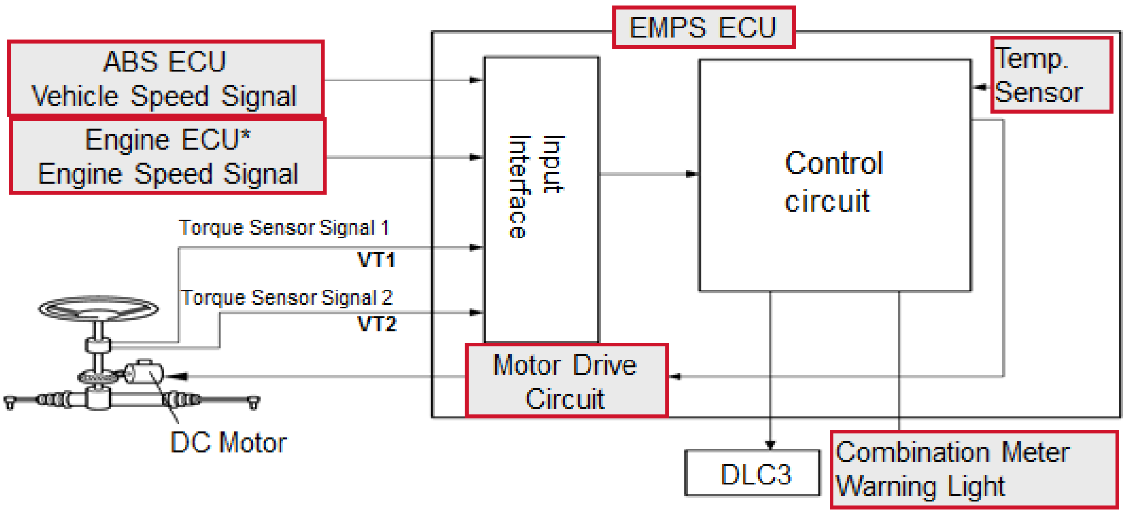
The steering moment sender is mounted in the inner ring. The inner ring is a plastic ring with two pairs of potentiometer brushes. These brushes scan the four conductors in the inner ring. The sender ring is connected to the housing cover. It fits exactly on the head of the torsion bar. When the torsion bar rotates, the cover also rotates relative to the inner ring. This movement is detected by the potentiometer brushes and transferred to the control unit as a signal along the printed conductors in the base of housing.





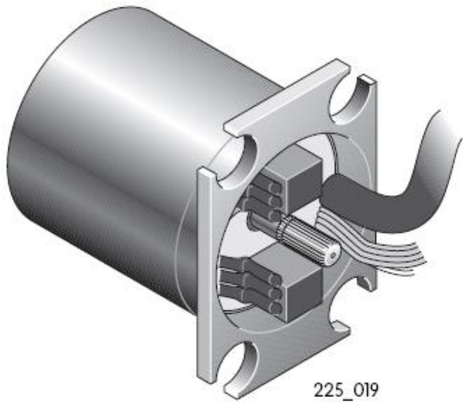
Control unit

The EPS control unit detects the twist of the torsion bar with torque sensor and controls the electrical current to the DC motor.



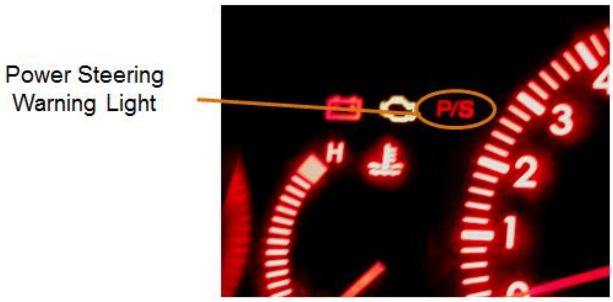
Actuators

This motor is bolted to the housing of the worm gear by means of rubber buffers so that no vibrations can be transmitted between the motor and steering column. The motor shaft is connected to the worm shaft via a flexible rubber coupling in such a way that motor starting torque is transmitted softly to the worm gear. The motor itself has a maximum power consumption of 720 W and develops 2 Nm of torque. It has an extremely short response time which allows it to assist steering wheel movements quickly.



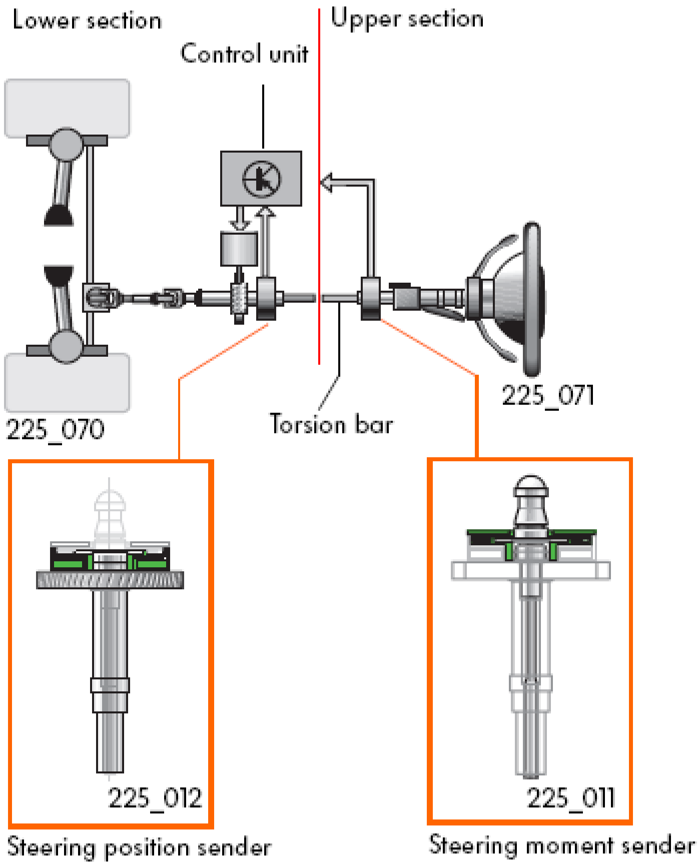
Warning lamp

This warning lamp is located in the dash panel insert. If the control unit detects a fault in the power steering system, it activates the warning lamp in the display unit in the dash panel insert.

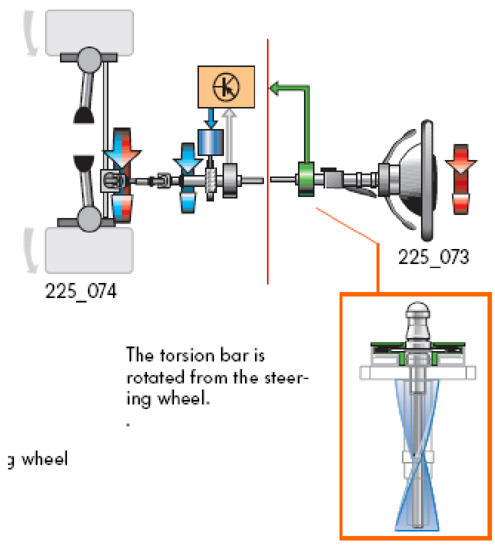


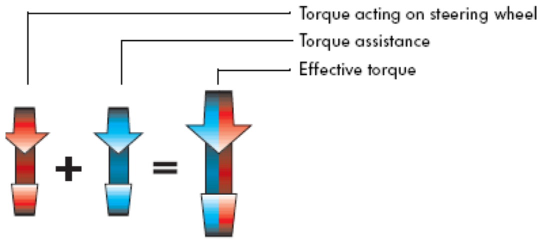
Operation

The diagram below shows a steering column which is split into an upper section and a lower section. The steering moment sender is integrated in the upper section, while the steering position sender is located in the lower section.

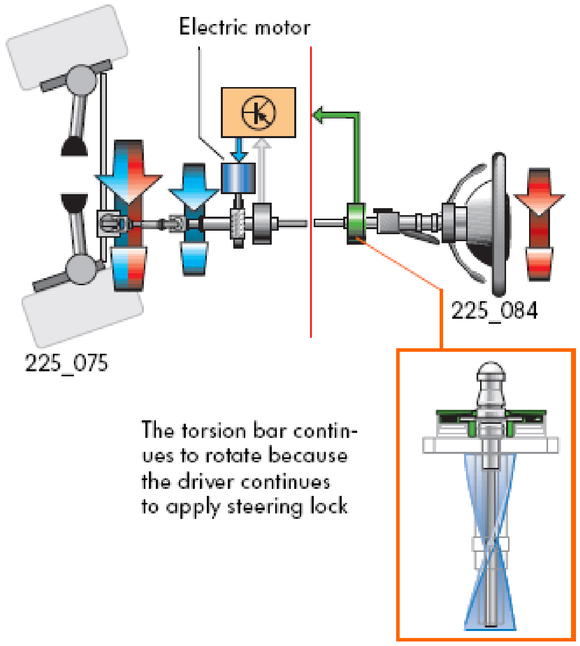


The driver starts to turn the steering wheel. The torsion bar is rotated at the same time. The steering moment sender, which rotates together with the torsion bar, supplies the control unit signals indicating the magnitude and direction of rotation of the torque acting on the steering wheel. The control unit calculates the torque assistance required from the signals and activates the electric motor. The aggregate of torque acting on the steering wheel and torque assistance is the effective torque acting on the steering gear.

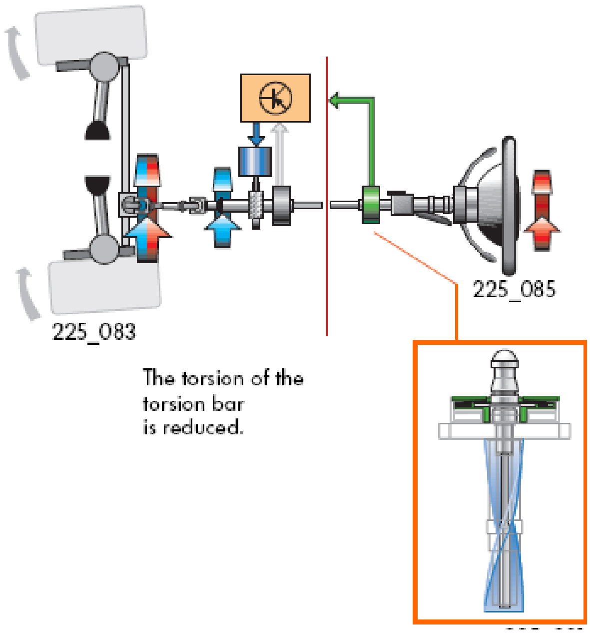




If the driver increases the torque applied to the steering wheel, the electric motor increases torque assistance. This allows the steering gear to rotate easily.

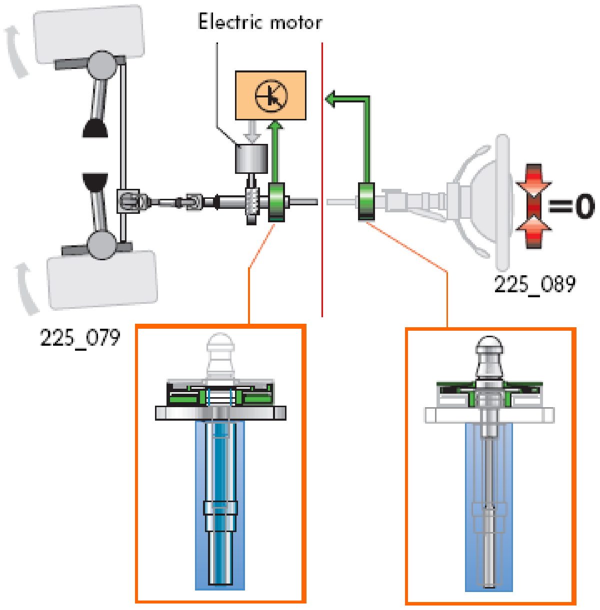


If the driver reduces the torque applied to the steering wheel, the torsion of the torsion bar is reduced. As a result, the steering moment sender supplies a lower signal to the control unit. The control unit reduces the torque assistance by activating the electric motor. Due to the wheel alignment, the steering system tries to restore the wheels to the straight-ahead position. If resultant restoring moment via the steering gear is greater than the aggregate of the torque acting on the steering wheel and the torque
assistance, the system begins to turn the steering back to the straight-ahead position.

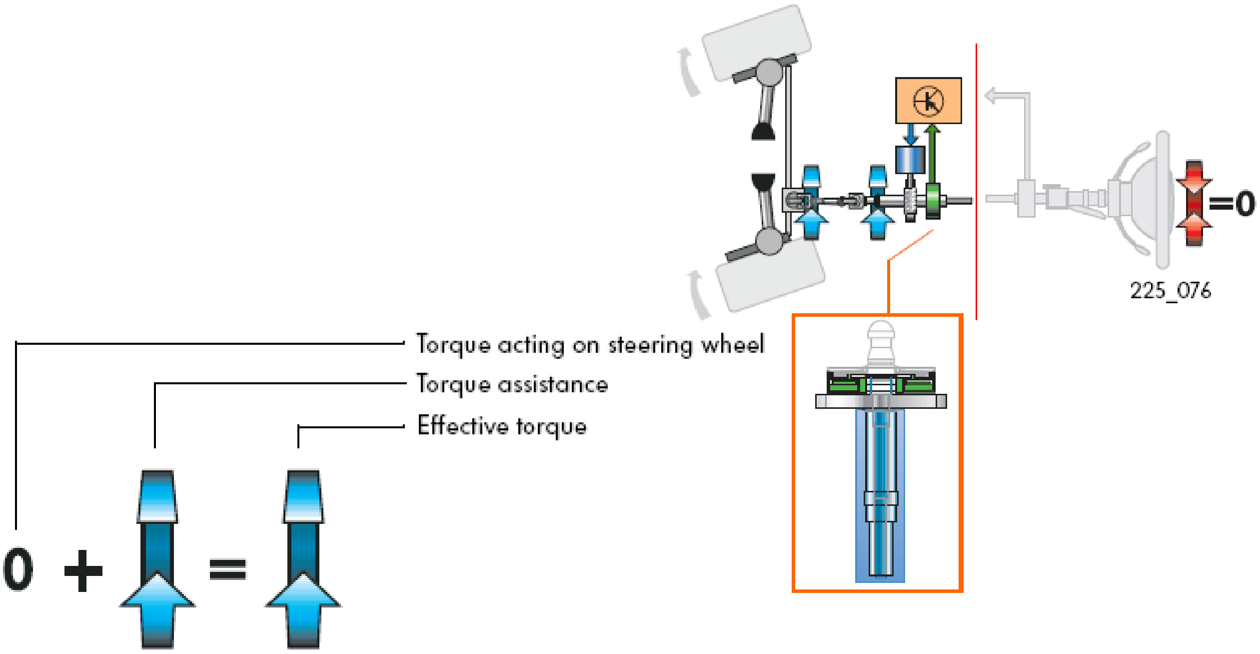


Active self-alignment

If the driver releases the steering wheel when cornering, the tension on the torsion bar is relieved. At the same time, the electronics deactivate the electric motor. As a result, torque assistance is no longer required.



If the vehicle is still not travelling straight ahead, this is registered via the steering position sender. The electric motor is now activated so that the steering is actively turned to the straight-ahead position.



Summary

The system offers the driver power-assisted steering in dependence on actual driving conditions

The steering movement of the driver is transmitted to the worm gear and steering gear via the steering shaft and an intermediate spindle.

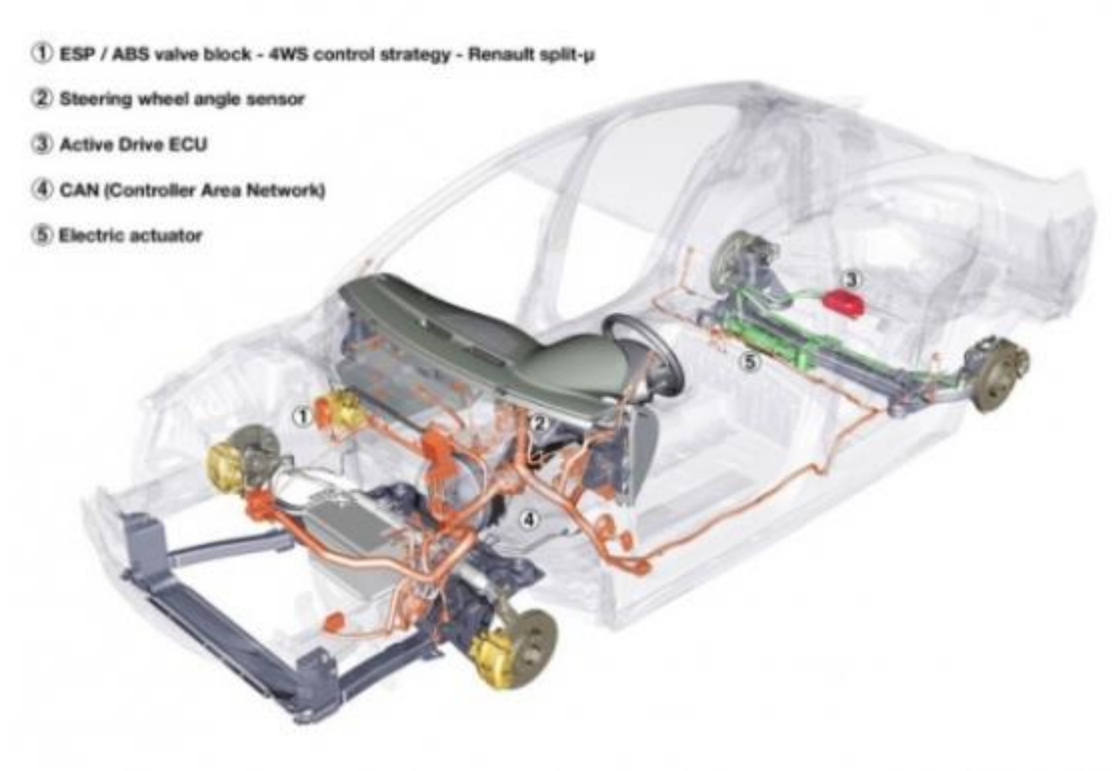
Self-alignment of the steering wheel in the straight-ahead position is assisted by the electro-mechanical power steering system.

The system conveys the feeling of contact with the road to the driver. The system monitors the input and output signals, as well as operation of the component parts of the steering system.

The safety steering column is adjustable for height, and incorporates the proven crash concept. It provides anti-theft protection through a lock on the steering shaft.

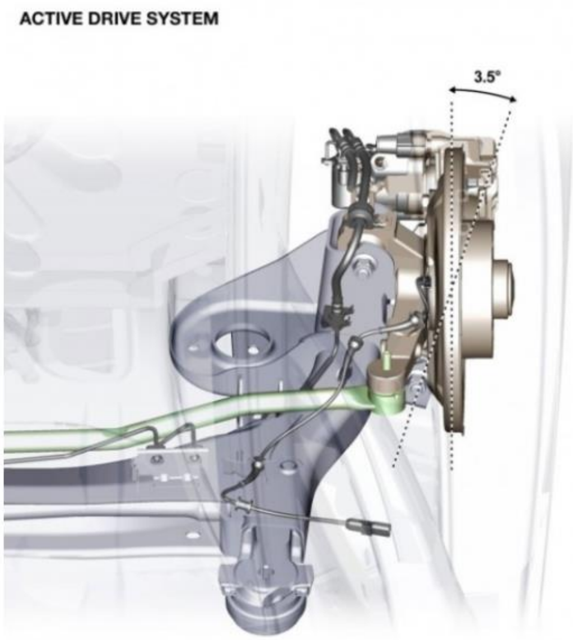
Four wheel steering

Four-wheel steering systems of the 1980s were essentially mechanical, with the wheels linked at pre-determined angles to make up for a vehicle's tendency to understeer. Such systems were gradually superseded by the advent of ESP. Towards the end of the 1990s, manufacturers such as Nissan were beginning to develop solutions based on electrically- and even hydraulically-operated actuators to take the dynamic performance of their vehicles forward. Electronic control of rear wheel steering has enabled handling to be fine-tuned even further, notably in the case of rear-wheel drive vehicles. We look at the new Renault system …



Developed jointly by Renault and Renault Sport Technologies, the Active Drive chassis with four-wheel steering brings many benefits, starting with improved manoeuvrability, sharpened dynamic response, and unrivaled steering precision giving the driver superb control over the cornering line, achieving new heights in driveability and active safety. In town and on country roads, the car is easy to drive: highly manoeuvrable and precise. Laguna GT corners with very little body roll and a precise line is achieved with small steering inputs. The Active Drive chassis with four-wheel steering also excels in active safety, both under difficult braking conditions (with a good control over asymmetrical grip and with the ESP matched to a more sporting driving style), and during avoidance manoeuvres at speed ('elk' test).

The Active Drive system builds on this approach by ensuring a more dynamic and more reactive response to make the most of the inherent qualities of Laguna GT's chassis and consequently deliver even greater driving enjoyment. In addition to the complex modelling of the vehicle's handling, real-time response to the driver's instructions (every 10 milliseconds) and its ability to adapt to different conditions, Laguna GT's Active Drive four-wheel steering system means that active safety systems are only required as a very last resort, which means drivers benefit from more efficient and even more reassuring reactions when faced with an unexpected hazard.



The Active Drive chassis with four-wheel steering makes Laguna GT exceptionally easy to handle in town and agile on winding roads. At speeds of less than 38mph, the rear wheels turn in the opposite direction to the front wheels, up to an angle of 3.5°. This brings two advantages: a smaller turning circle, for easy manoeuvring; and reduced steering wheel input required thanks to the more direct, specially calibrated steering.

With four-wheel steering on the Active Drive chassis, Laguna GT has a 10 per cent smaller turning circle than with two-wheel steering: 10.80 meters, incredibly the same as Clio, instead of 12.05m. Enhanced manoeuvrability is especially noticeable in tight parking situations.

With front and rear wheels turning in opposite directions, the car effectively pivots, which means smaller steering angles are needed for the same turning effect. Whereas it takes a 16° steering wheel angle to produce a 1° turn in the front wheels on New Laguna, it takes just 13.5° with the Active Drive chassis. And this drops to 12° when the rear wheels are turned at the maximum 3.5° angle in the opposite direction to the front wheels. Because the steering is more direct, with less need for large steering wheel angles, the impression of manoeuvrability and agility is greatly enhanced. For any given bend, the driver will need less input on the steering wheel, making for more effective avoidance.

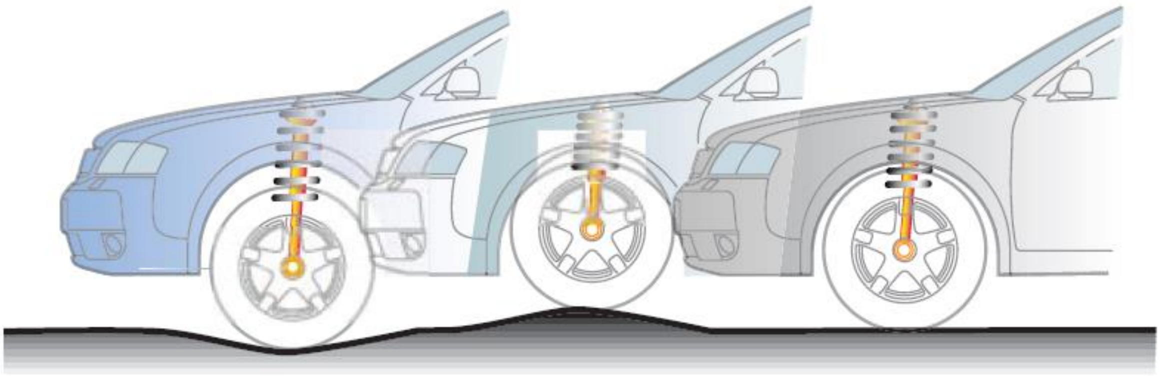
From 38mph, the emphasis is on steering precision. The rear wheels turn simultaneously in the same direction as the front wheels, to enhance stability. The Active Drive system with four-wheel steering counters the centrifugal force that tends to push the rear end outwards round bends, and thus raises the safe cornering speed. The rear axle is set on the ideal trajectory, with a rear-wheel angle of less than 2° in most situations, for stability. The Active Drive chassis with four-wheel steering enhances dynamic handling, with a reassuring response for outstanding driving pleasure.

The Active Drive chassis with four-wheel steering also improves safety for heightened reassurance during avoidance manoeuvres. In an emergency situation, the rear-wheel angle can rise to 3.5°. The involvement of the ESP system, specially configured for a more sporting driving style, is delayed, so that the manoeuvre can be performed both safely and more swiftly. ESP only deploys when necessary, and is applied gradually because it is synchronized with the rear-wheel turn action. Via the ESP/ABS unit, the four-wheel steering control unit also detects asymmetrical braking situations, such as on mixed surfaces, adapting the rear-wheel turn angle automatically to keep the car stable with no driver action required. This helps the driver keep control during critical situations, and ensures uninterrupted peace of mind during every day driving conditions.

The Active Drive chassis implements electronic control of the vehicle dynamics. A sensor on the steering column sends steering wheel angle information via the CAN (controller area network) to the four-wheel steer control unit, located behind the rear axle. The four-wheel steer control unit also inputs vehicle speed from the ESP/ABS unit and tracks steering wheel angle information to detect sharp steering wheel movements symptomatic of a sporting driving style or avoidance situation. All these parameters are analysed to determine the required rear-wheel turn angle, which is implemented by means of an electric actuator on the rear axle. Dynamic vehicle behaviour is precisely modelled to set the ideal vehicle trajectory at each instant, on the basis of the driver’s input and the actual situation of the vehicle. The controller and electric actuator are supplied by Aisin, a Japanese equipment supplier reputed for its experience in four-wheel steering systems

Self levelling suspension

When a vehicle travels over irregular road surfaces, impact forces are transmitted to the wheels. These forces pass to the bodywork via the suspension system and the wheel suspension. The purpose of the vehicle suspension is to absorb and reduce these forces.
When we talk about the vehicle suspension
we can basically distinguish between the **suspension system** and the **vibration damping system** By means of the interaction of the two systems, the following is achieved:



Driving safety

Wheel contact with the road surface, which is essential for braking and steering, is maintained.

Driving comfort

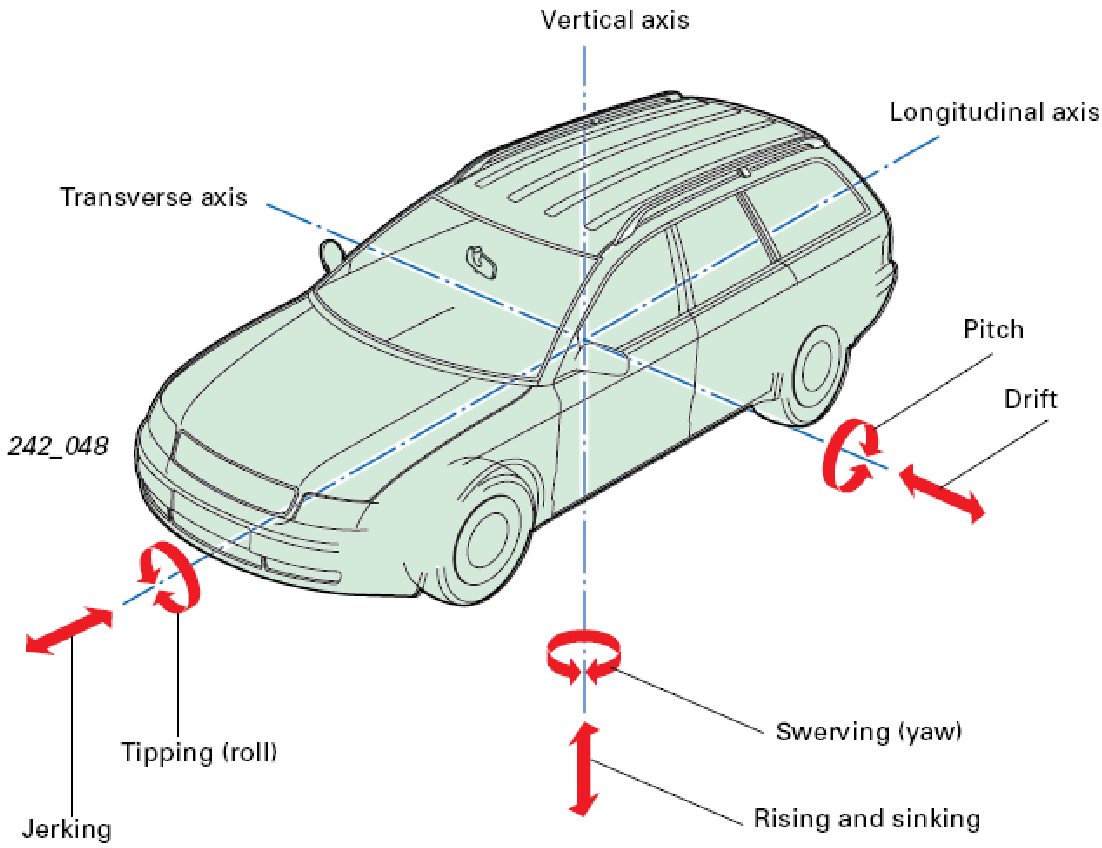
Unpleasant and unhealthy stresses to vehicle passengers are minimised, and damage to fragile loads is avoided.

Operating safety

The vehicle components are protected against excessive stresses.

During driving operation, the vehicle body is subject not only to the forces which cause the upward and downward motion of the vehicle, but also the movements and vibrations in the direction of the three spatial axes. Along with the axle kinematics, the vehicle suspension has a significant influence on these movements and vibrations.

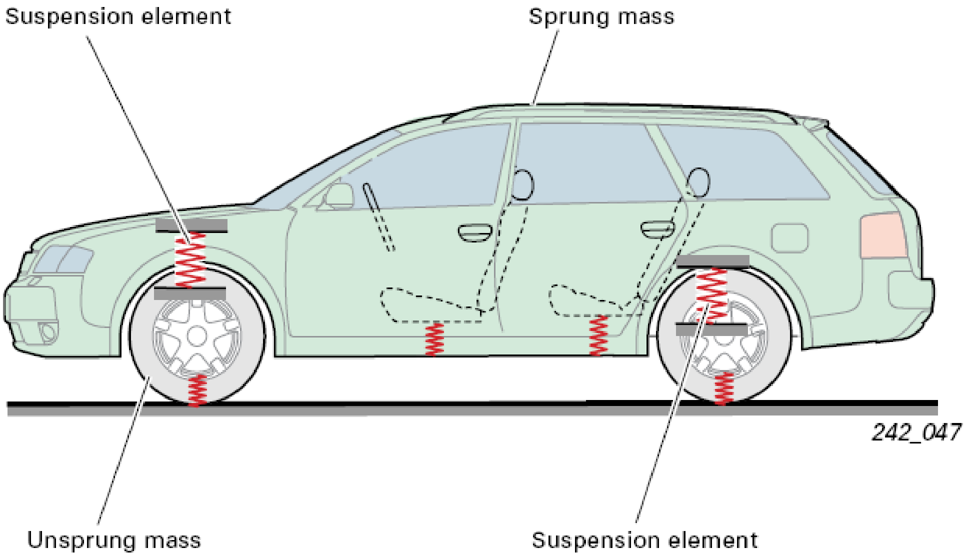
The correct matching of the springs and vibration damping system is therefore of great significance.



The suspension system

As ”supporting” components of the suspension system, the suspension elements form the connection between the wheel suspension and the bodywork. This system is complemented by the spring action of the tyres and vehicle seats. The suspension elements include steel springs, gas/air and rubber/elastomers or combinations of the above. Steel spring suspensions have become well established in passenger vehicles. Steel springs are available in a wide variety of designs, of which the coil spring has become the most widespread. Air suspension, which has been used for many years in heavy goods vehicles, is finding increasing application in passenger vehicles due to its system-related advantages.

In the case of the passenger vehicle we can differentiate between **sprung masses** (body with drive train and parts of the running gear) and **un-sprung masses** (the wheels, brakes and parts of the running gear and the axle shafts). As a result of the suspension system, the vehicle forms an oscillatory unit with a natural frequency of the bodywork determined by the sprung masses and the matching of the suspension system



The un-sprung masses

The aim in principle is to minimise the volume of un-sprung masses and their influence on the vibration characteristics (natural frequency of the bodywork). Furthermore, a low inertia of masses reduces the impact load on the un-sprung components and significantly improves the response characteristics of the suspension. These effects result in a marked increase in driver comfort.

Examples for the reduction of unsprung masses:
• Aluminium hollow spoke wheel
• Running gear parts (swivel bearing, wheel carrier, links etc.) made of aluminium

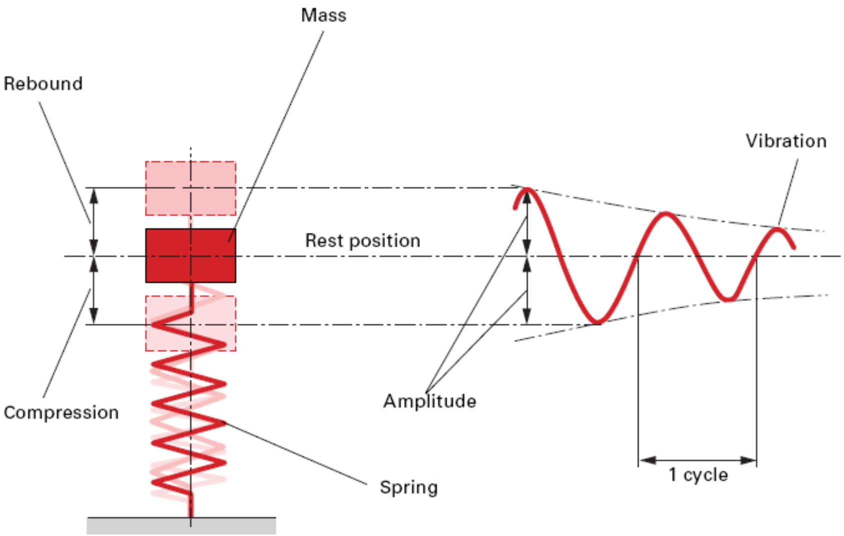
• Aluminium brake callipers
• Weight-optimised tyres
• Weight optimisation of running gear parts (e.g. wheel hubs)

Vibration

If a mass on a spring is deflected from its rest position by a force, a restoring force develops in the spring which allows the mass to rebound. The mass **oscillates** beyond its rest position which results in a further restoring force being exerted. This process is repeated until air resistance and the internal friction of the spring causes the vibration to cease.

The frequency of the bodywork

The vibrations are defined by the degree of amplitude and its frequency. The natural frequency of the bodywork is particularly important during matching of the suspension. The natural frequency of unsprung parts is between 10 Hz and 16 Hz for a medium-size vehicle. Appropriate matching of the suspension system reduces the natural frequency of the bodywork (sprung mass) to between 1 Hz and 1.5 Hz.



The natural frequency of the bodywork I essentially determined by the characteristics of the springs (spring rate) and by the sprung mass. Greater mass or softer springs produce a lower natural frequency of the bodywork and a greater spring travel (amplitude). Smaller mass or harder springs produce a higher natural frequency of the bodywork and a lesser spring travel. Depending on personal sensitivity, a natural frequency of the bodywork below 1 Hz can cause nausea. Frequencies above 1.5 Hz impair driving comfort and are experienced as shudders above around 5Hz.

Definitions

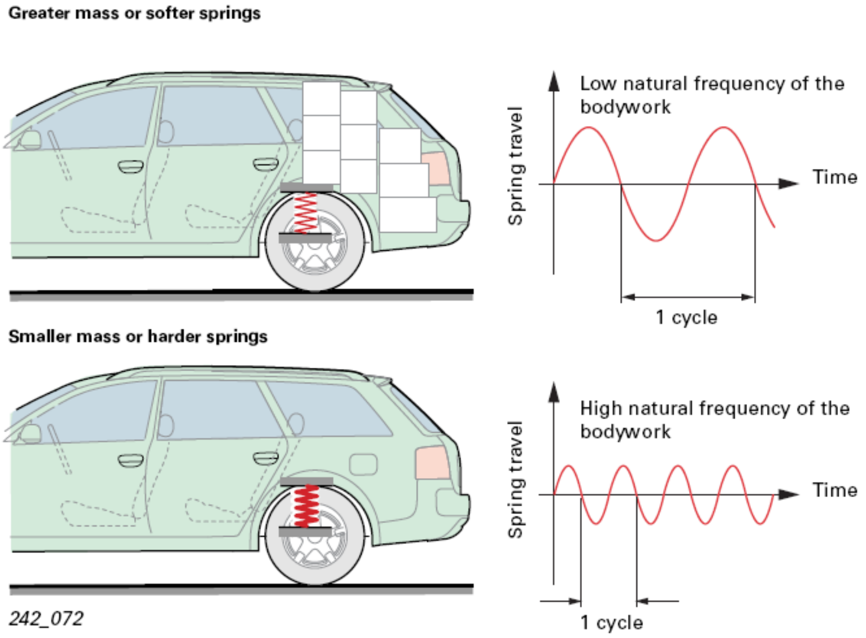
Vibration - Upward and downward motion of the mass (body)

Amplitude - The greatest distance of the vibrating mass from the rest position (vibration extent, spring travel)

Cycle - Duration of a single vibration

Frequency - Number of vibrations (cycles) per second
Natural frequency of the bodywork - Number of vibrations of the sprung mass (body) per second

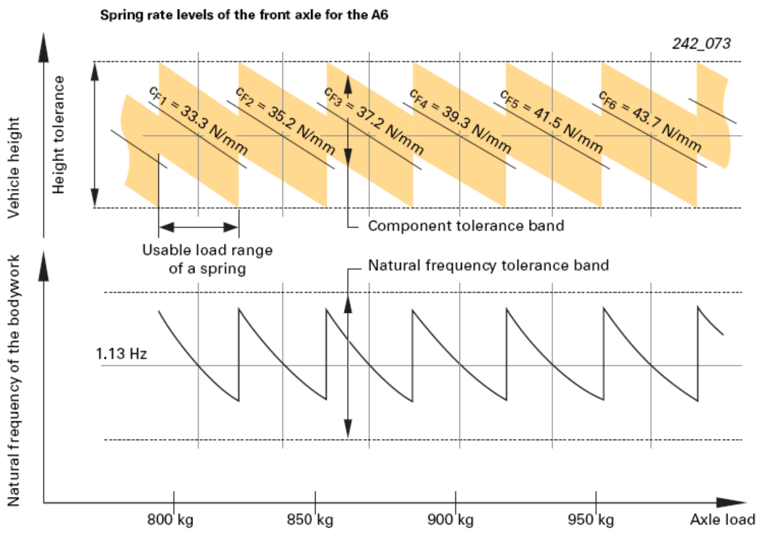
Resonance - The mass is disturbed in its rhythm by a force which increases the amplitude (build up).



Matching of the natural frequency of the bodywork

The axle loads (sprung masses) of a vehicle vary, at times considerably, depending on the engine and equipment installed. To ensure that the bodywork height (appearance) and the natural frequency of the bodywork (which determines the driving dynamics) remains practically identical for all vehicle versions, different spring and shock absorber combinations are fitted to the front and rear axles in accordance with the axle load. For instance, the natural frequency of the bodywork of the Audi A6 is matched to 1.13Hz on the front axle and 1.33Hz on the rear axle (design position). The spring rate of the springs therefore determines the value of the natural frequency of the bodywork. The springs are colour-coded to differentiate between the different spring rates.

The degree of damping of the vibration damper has no significant influence on the value of the natural frequency of the bodywork. It influences only how quickly the vibrations cease (damping coefficient). It is worth noting that For standard running gear without self- levelling, the rear axle is always matched to a higher natural frequency of the bodywork because when the vehicle is loaded, it is principally the load to the rear axle which increases, thus reducing the natural frequency of the bodywork.

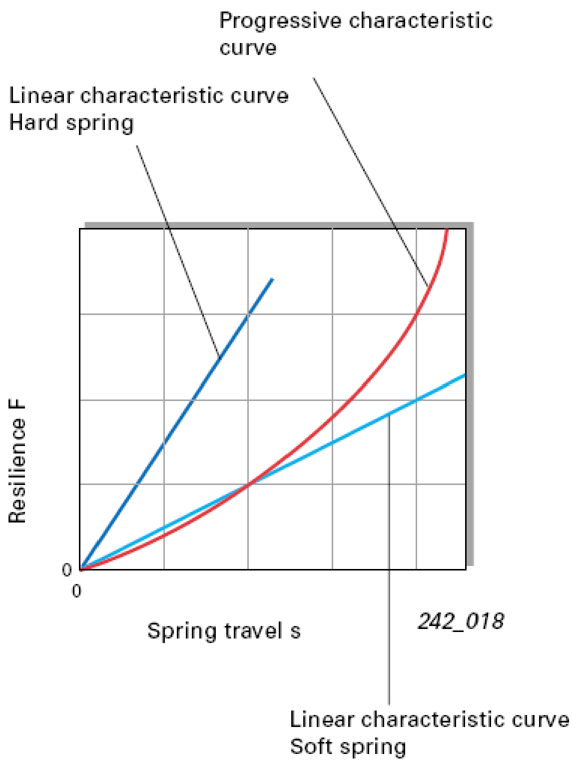


Characteristics of Road springs

Characteristic curve/spring rate of springs

We can obtain the characteristic curve of a spring by producing a forces/travel diagram. The spring rate is the ratio between the effective force and the spring travel. The unit of measurement for the spring rate is N/mm. It informs us whether a spring is hard or soft. If the spring rate remains the same throughout the entire spring travel, the spring has a linear characteristic curve. A soft spring has a flat characteristic curve while a hard spring has a steep curve. A coil spring is harder due to:

- a greater wire diameter
- a smaller spring diameter
- a lower number of coils



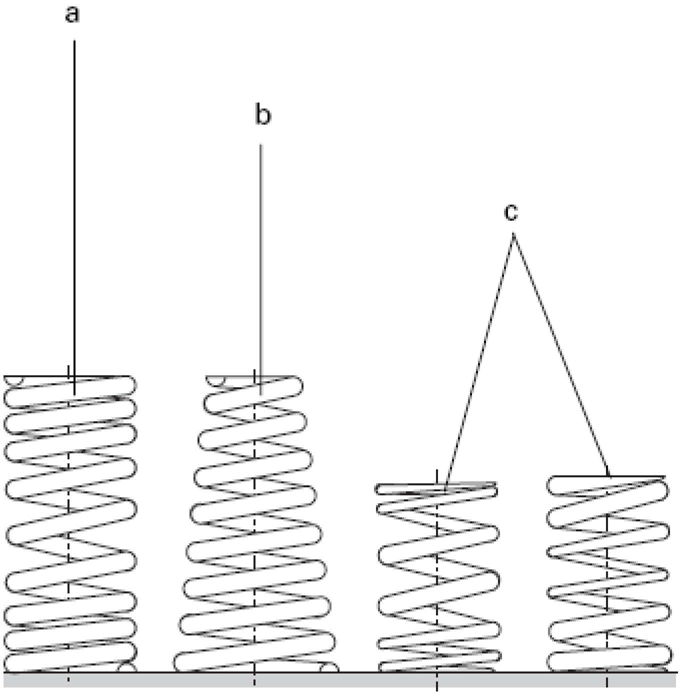
If the spring rate becomes greater as the spring travel increases, the spring has a progressive characteristic curve. Coil springs with a progressive characteristic curve can be recognised as follows:

a) uneven coil pitch

b) conical coil shape

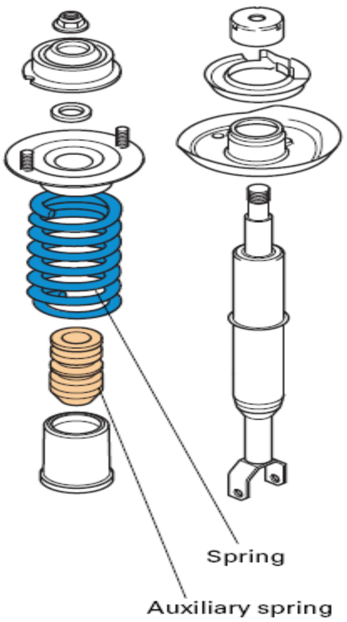
c) conical wire diameter

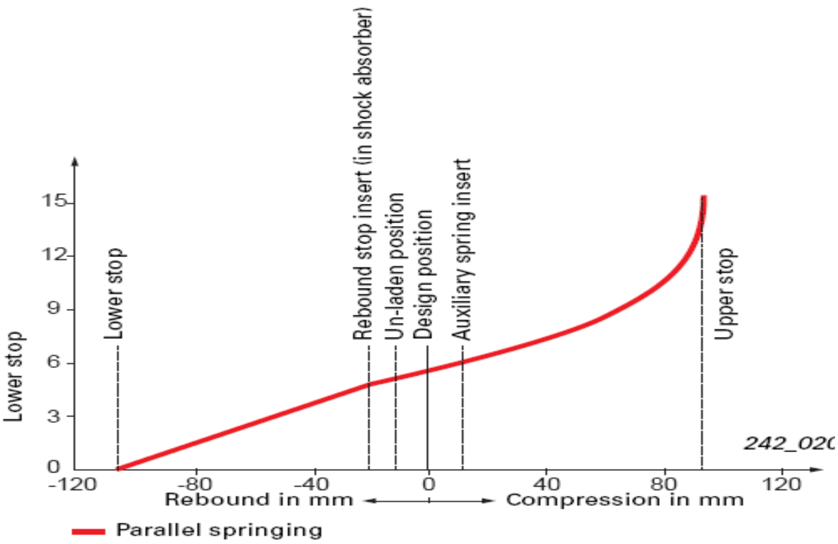
d) combination of two spring elements



Example of an auxiliary spring

Advantages of progressive characteristic curve of spring:





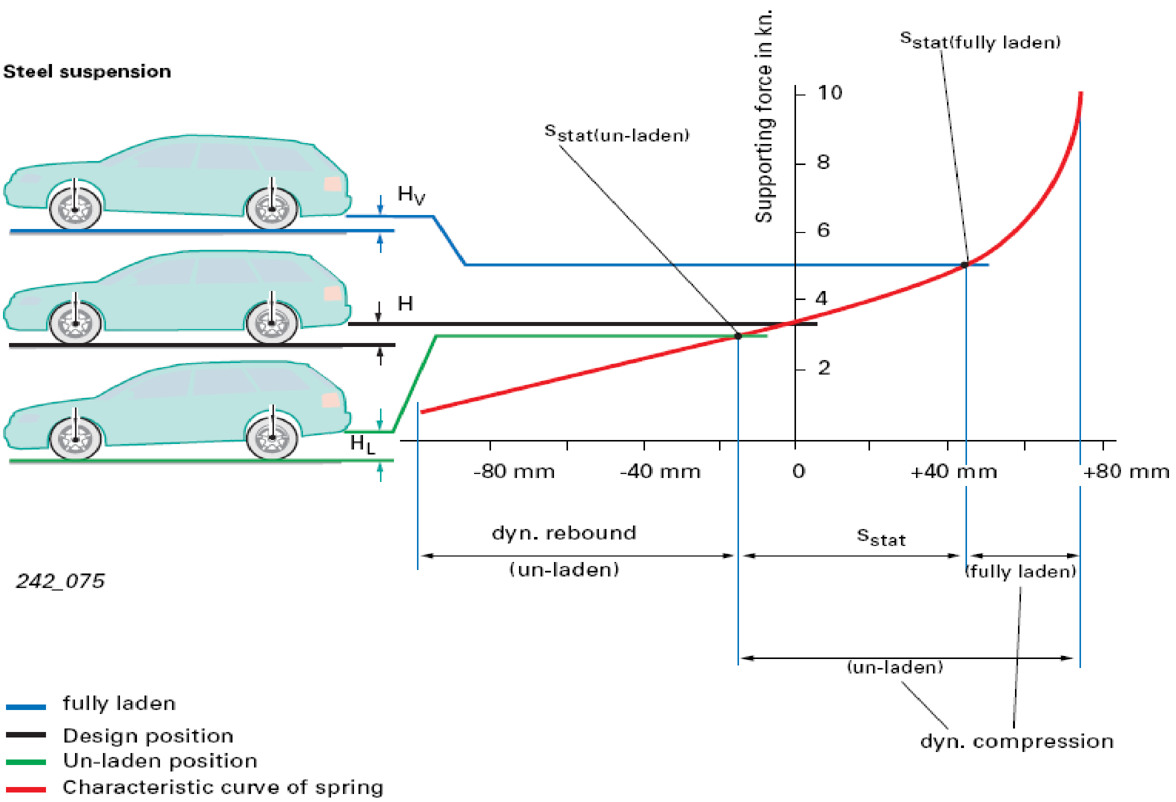
- Better matching of the suspension system from normal to full load.
- The natural frequency of the bodywork remains practically constant during loading.
- The suspension is not so prone to impacts in the case of significant irregularities in the road surface.
- Better use of the available spring travel.

Conventional running gear (steel springs)

The overall spring travel stot required for running gear without self-levelling is comprised of the static compression sstat and the dynamic spring travel caused by vehicle
Vibrations sdyn for both laden and un-laden vehicles.

Stot = sstat + sdyn(un-laden) + sdyn(fully laden)

When the vehicle is stationary, the vehicle body retracts by a certain spring travel depending upon the load. In this case, we speak of static compression: sstat.
The disadvantage of conventional running gear without self-levelling is its reduced spring travel at full load.



Static compression

Static compression is the starting point (zero) for the dynamic spring movements, compression travel (plus) and rebound travel (minus). It is dependent upon the spring rate and the load (sprung masses). Static compression results from the difference between the
static compression when un-laden sstat(un-laden) and the static compression when fully laden sstat(fully laden).

Sstat = sstat(fully laden) - sstat(un-laden)

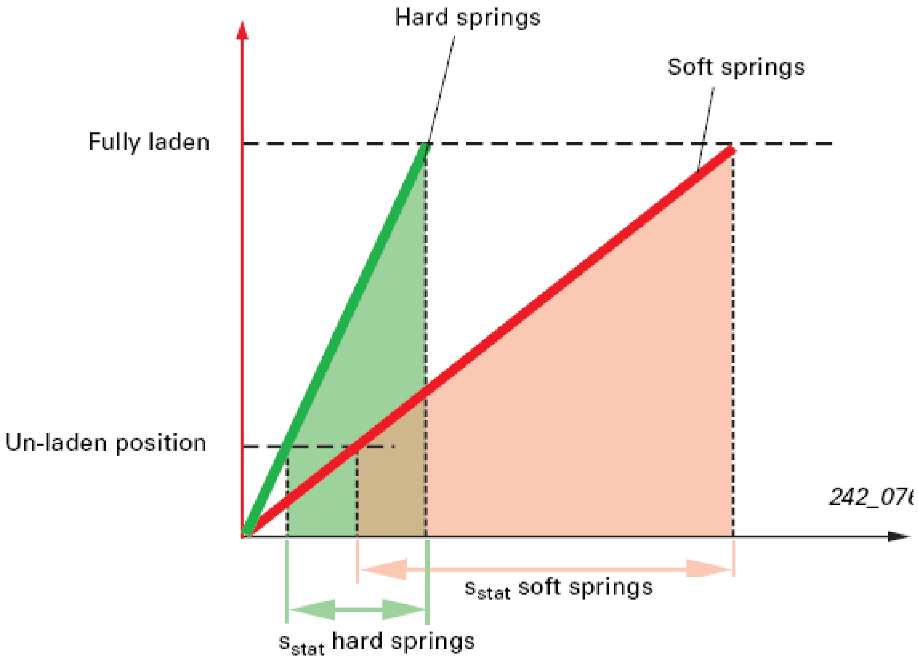
The un-laden position

The un-laden position is the compression exerted onto the wheels when the vehicle is ready for the road (fuel tank completely filled, spare wheel and vehicle tools present).

The design position

The design position is defined as the un-laden position plus the additional load of three persons, each weighing 68 kg.

In the case of a flat characteristic curve (soft springs), the difference and thereby the static compression between full and un-laden is very great. In the case of a steep characteristic spring
curve, this state of affairs is reversed and is coupled with an excessive increase of the natural frequency of the bodywork.



Self-l

Levelling suspension

Air suspension is a controllable form of vehicle suspension. With air suspension, it is simple to achieve self-levelling and it is therefore generally integrated into the system.

The basic advantages of self-levelling are:

Static compression remains the same, irrespective of vehicle loads. The space requirement in the wheel arches for free wheel movement kept to a minimum, which has benefits for the overall use of available space.

• The vehicle body can be suspended more softly, which improves driving comfort.

• Full compression and rebound travel is maintained, whatever the load.

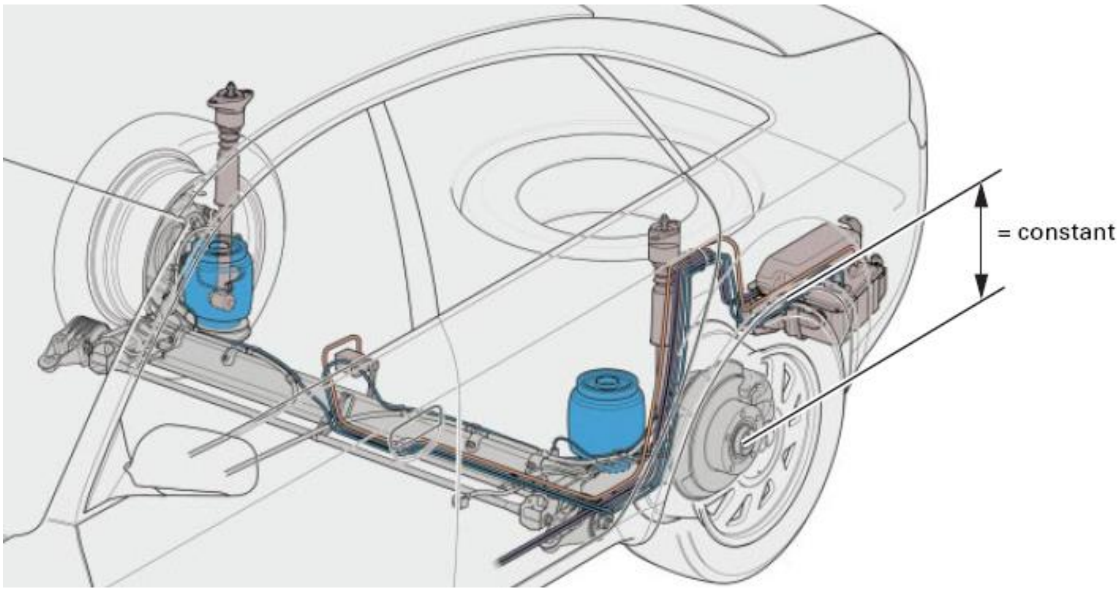
• Ground clearance is maintained, whatever the load.

• There are no track or camber changes when vehicle is laden.

• The cw value is maintained, as is the visual appearance.

• Less wear to ball joints due to reduced working angle.

• Greater loads are possible if required.



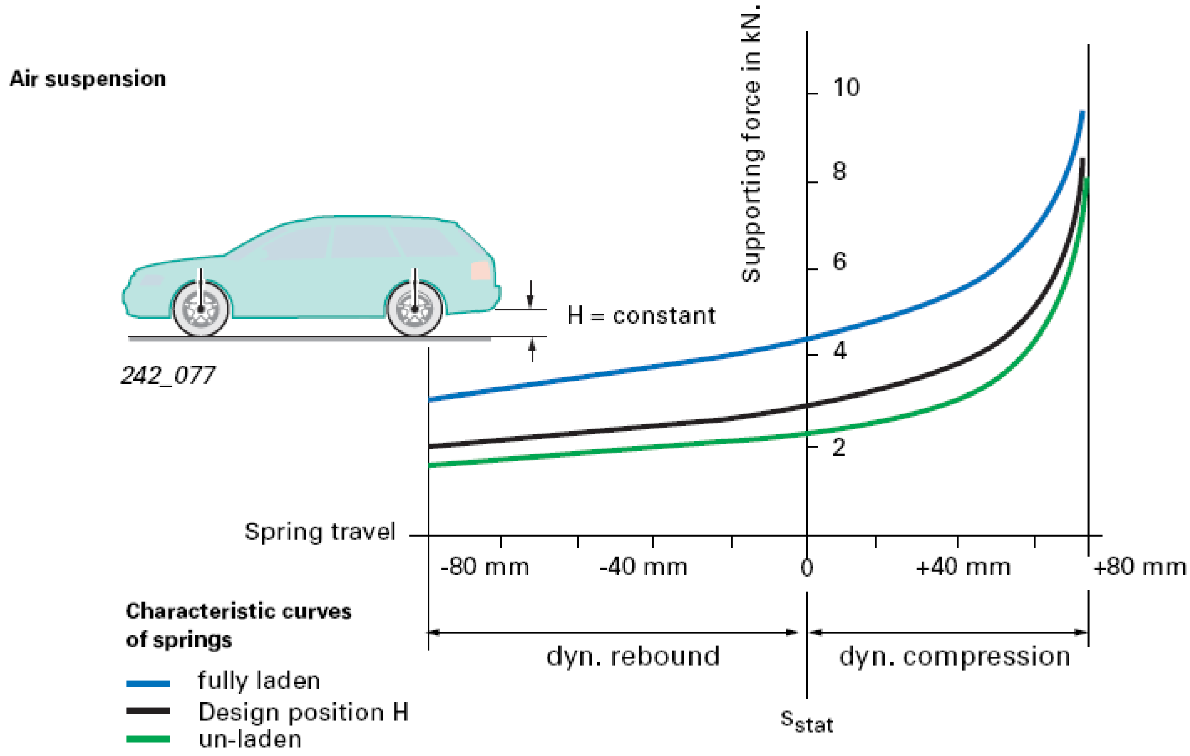
With the aid of self-levelling, the vehicle (sprung masses) remains at one level (design

position) because the air spring pressure is adapted accordingly. Static compression is thus the same at all times thanks to the self-levelling system and need not be accounted for when designing the wheel clearances.

sstat = 0

Another feature of self-levelling air suspension is that the natural frequency of the bodywork is kept virtually constant between un-laden and full-load.

In addition to the main advantages offered by self-levelling, its realisation by means of air suspension offers another significant advantage. As the air pressure in the air springs is adapted in accordance with the load, the spring rate alters proportionally to the sprung mass. The positive outcome is that the natural frequency of the bodywork and thereby driving comfort remain virtually constant, irrespective of the load.



Another benefit is the principle-related progressive characteristic curve of an air spring. With **fully supporting** air suspension on both axles, different vehicle levels can be set, e.g.:

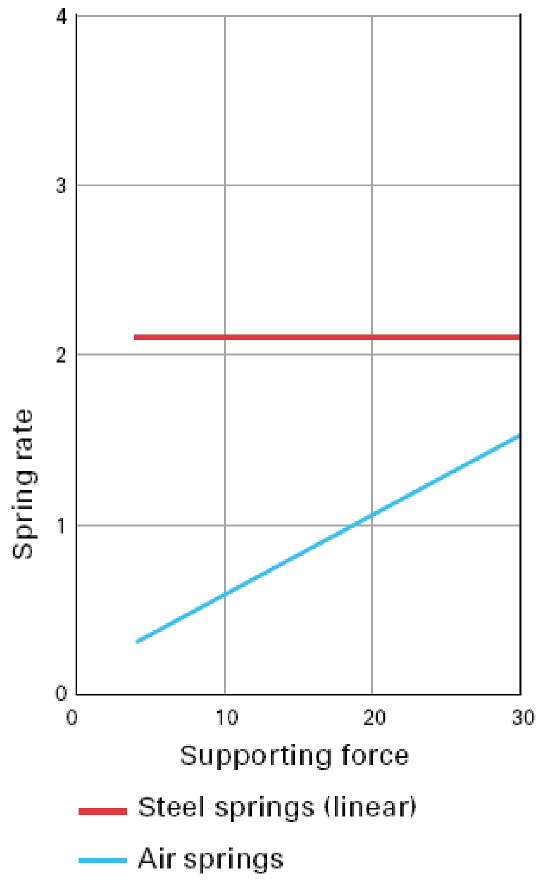
• Normal driving position for city driving.

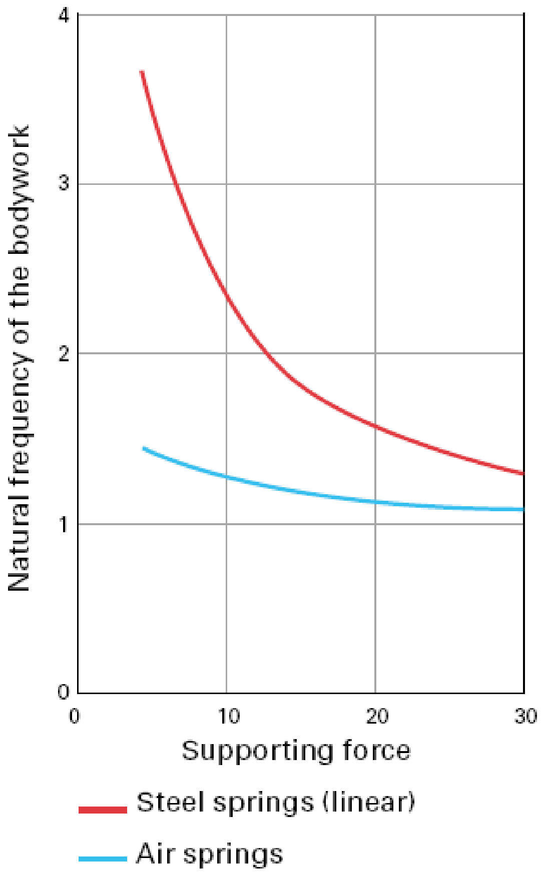
• Lowered driving position for high speeds to improve driving dynamics and air resistance.

• Raised driving position for travel off-road and on poor road surfaces.

Fully supporting

Self-levelling systems are often combined with steel or gas-filled spring devices with hydraulic or pneumatic control. The supporting force of these systems results from the sum of both systems. We therefore call them “partially supporting” In the self-levelling suspension systems such as in the Audi A6 (on the rear axle) and in the Audi allroad quattro (rear and front axles) air springs are the only supporting suspension elements and these systems are therefore described as “fully supporting”.





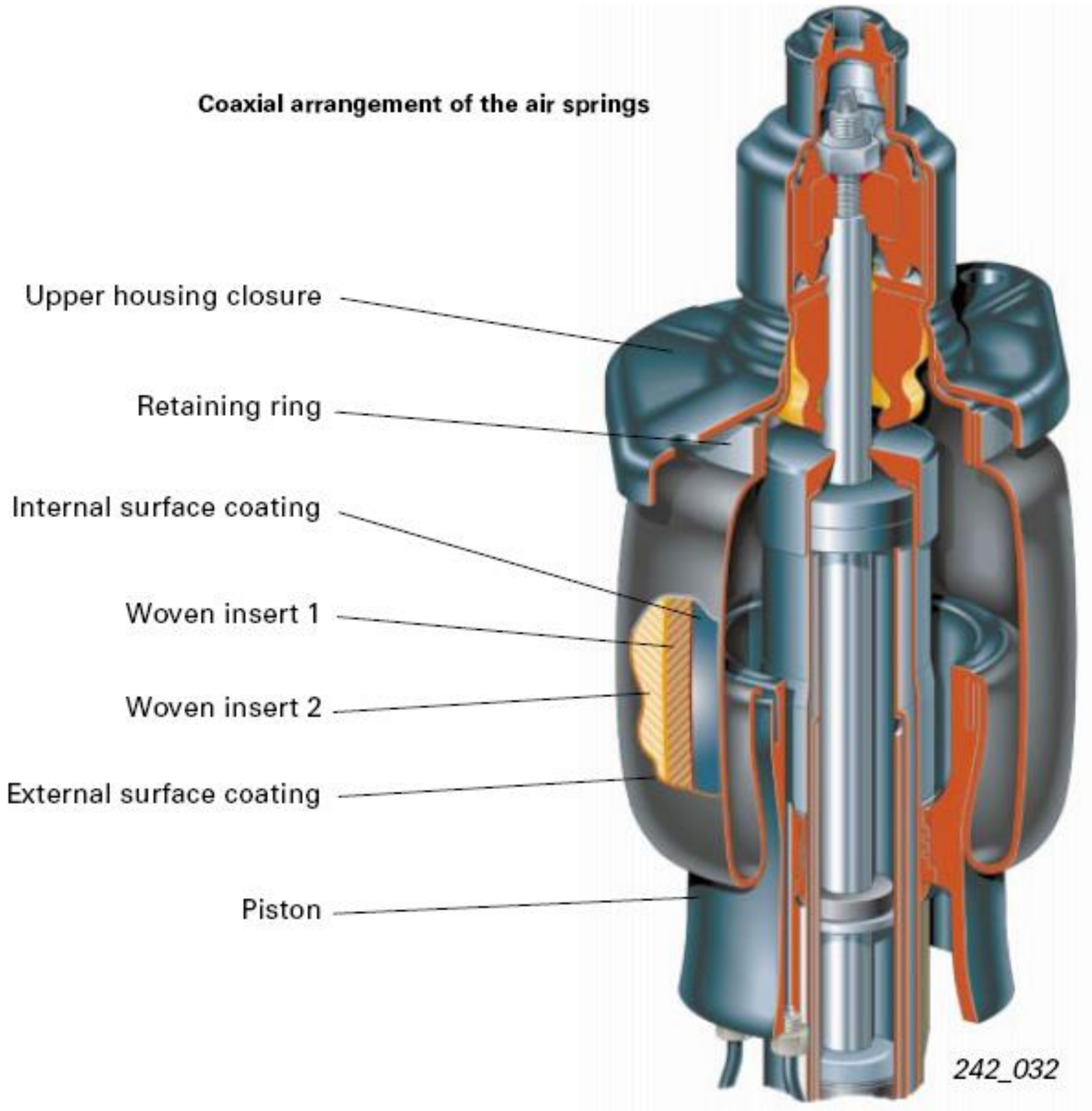
Design of air springs

In passenger vehicles, air springs with U-bellows are used as suspension elements. These allow greater spring travel in restricted spaces.

The air springs consist of:

- Upper housing closure
- U-bellows
- Piston (lower housing closure)
- Retaining rings

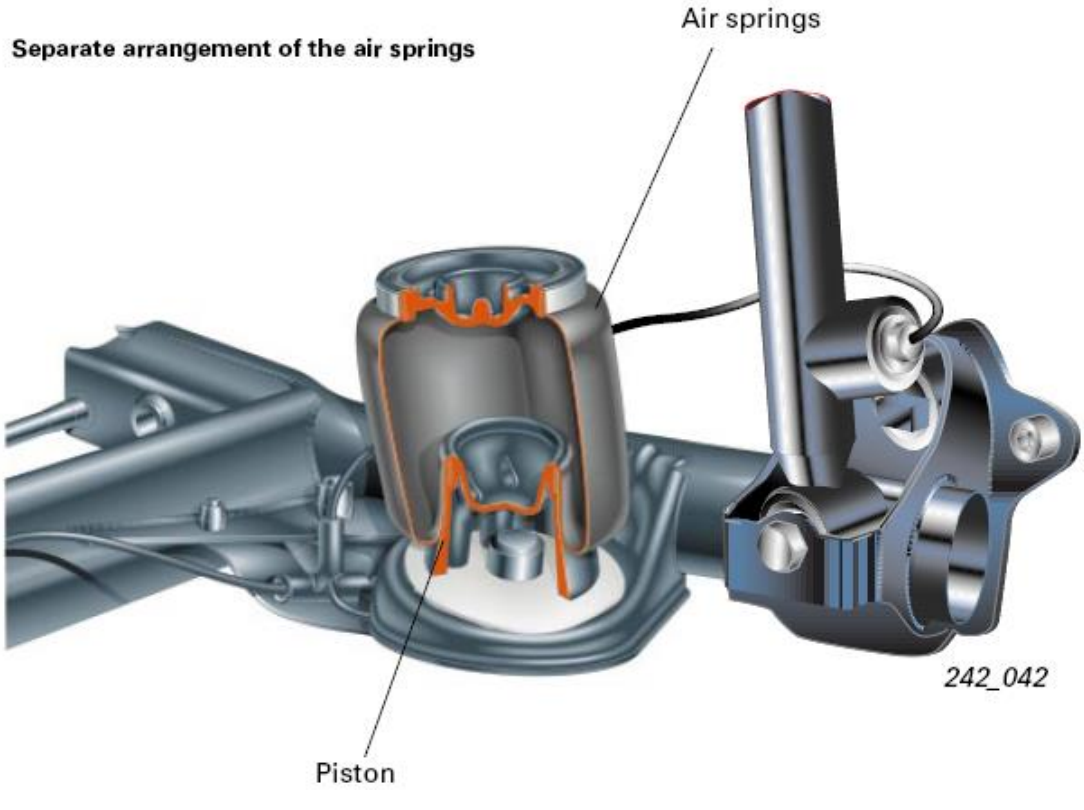
The outer and inner surfaces are made of an elastomer material. The material is resistant to all weather influences and is largely oil resistant. The inner surface finish is designed to be particularly air-tight. The stability supports absorb the forces produced by the internal pressure in the air springs.



High-quality elastomer material and polyamide cord woven inserts (stability supports) provide the U-bellows with good unrolling characteristics and a sensitive response of the spring system. The necessary properties are ensured over a wide temperature range between -35 °C and +90 °C.

Metal retaining rings tension the U-bellows between the upper housing closure and the piston. The retaining rings are machine pressed by the manufacturer. The U-bellows unrolls onto the piston. Depending on the axle design, the air springs are either separate from the shock absorbers or combined as a suspension strut (coaxial arrangement).

Air springs must not be moved in an unpressurised condition since the air bellows cannot unroll on the piston and would be damaged. In a vehicle in which the air springs are unpressurised, the relevant air springs must be filled with the aid of the diagnostic tester (see Workshop Manual) before raising or lowering the vehicle (e.g. vehicle lifting platform or vehicle jack).



Air springs

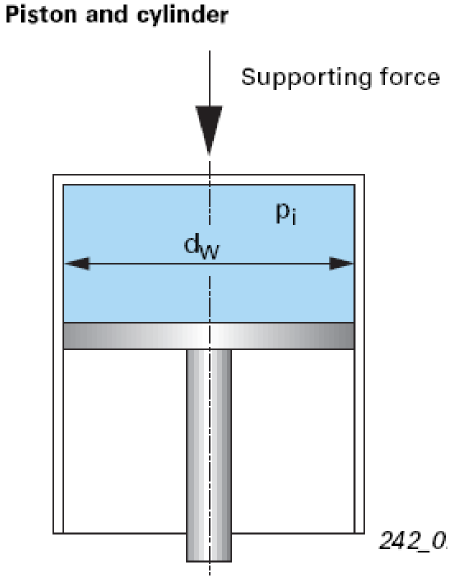
Resilience/spring rate

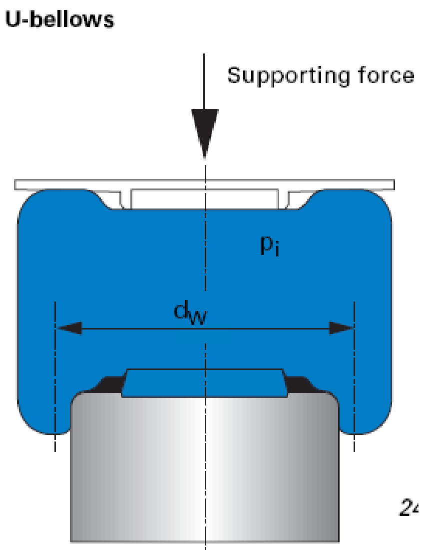
The resilience (supporting force) F of an air spring is determined by the effective surface Aw and the excess pressure in the air spring pi.

F = pi x Aw

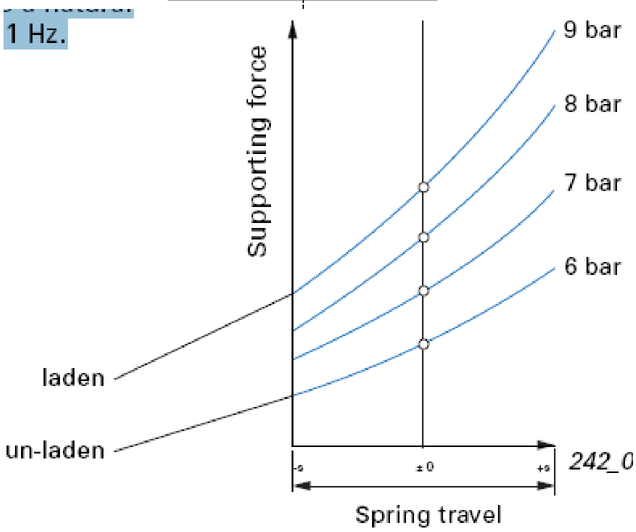
The effective surface Aw is defined by the effective diameter dw.

In the case of a rigid structure, such as piston and cylinder, the effective diameter corresponds to the piston diameter. In the case of air springs with U-bellows, the effective diameter is determined by the lowest point of the fold.

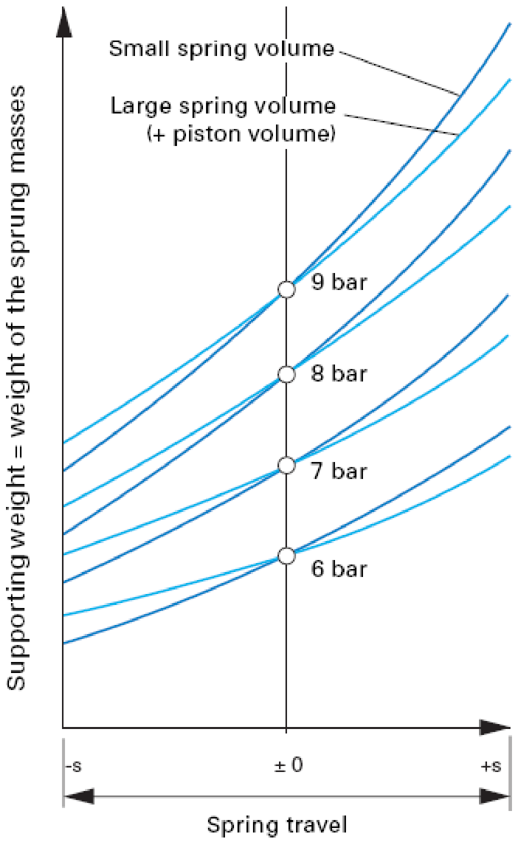




In the case of air springs with U-bellows, the effective diameter is determined by the lowest point of the fold. As the formula shows, the supporting force of an air spring is in direct relation to the internal pressure and the effective surface. It is very easy to alter the supporting strength (resilience) statically (no movement of the bodywork) by varying the pressure in the air spring. The various pressures, depending on the load, result in the relevant characteristic curves of the springs and/or spring rates. The spring rate alters at the same rate as the bodywork weight, while the natural frequency of the bodywork which determines the handling characteristics remains constant. The air suspension is adapted to a natural frequency of the bodywork of 1.1 Hz.

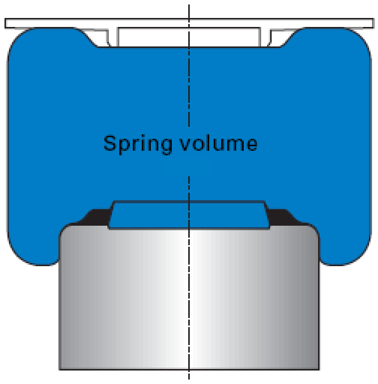


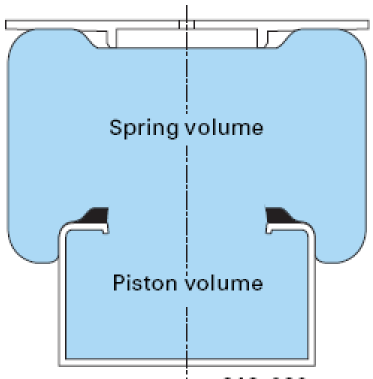
Owing to the functional principle, the characteristic curve of an air spring is progressive (in the case of cylindrical pistons). The progress of the characteristic curve of the spring (flat/steep inclination) is determined by the spring volume. A large spring volume produces a flat progression of the characteristic curve (soft springs), a small spring volume produces a steep progression of the characteristic curve (hard springs). The progression of the characteristic curve of a spring can be influenced by the contour of the piston. Changing the contour of the piston alters the effective diameter and thereby the resilience.

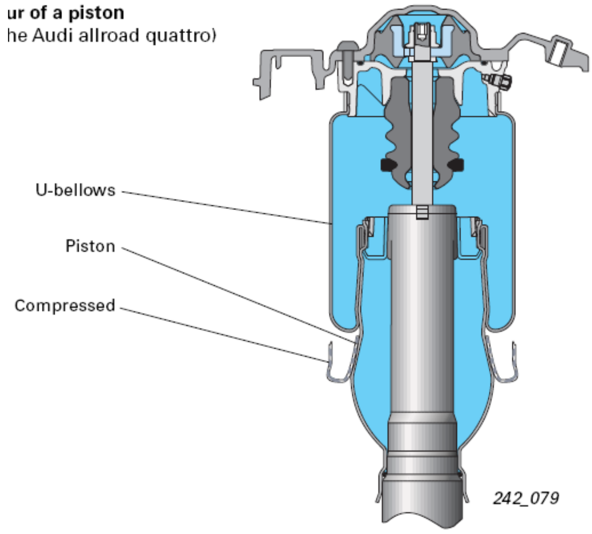


The following options are available for matching the air springs using U-bellows:

- Size of the effective surface
- Size of spring volume
- Contour of the piston

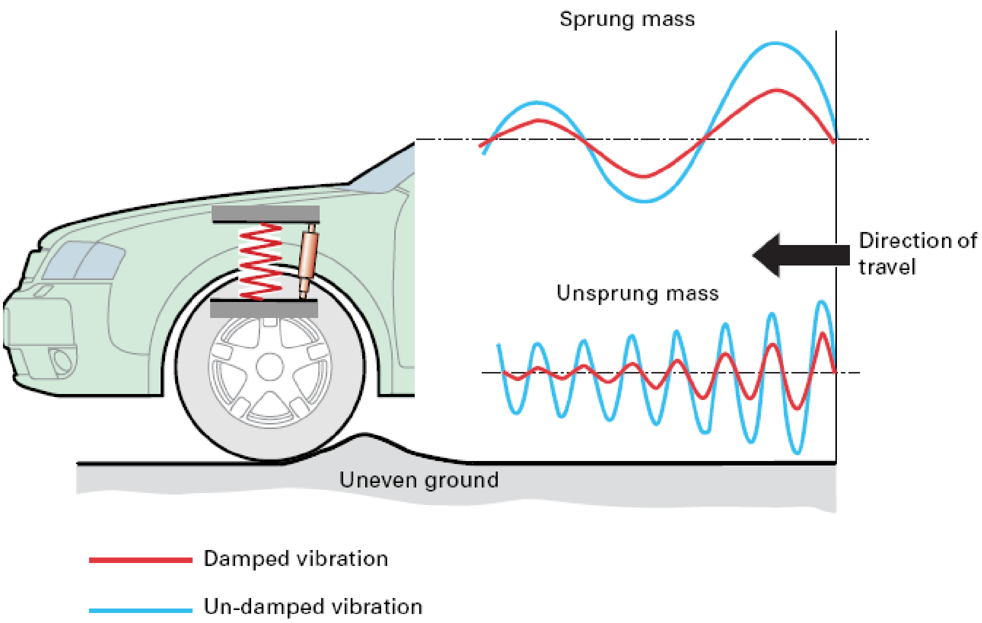






Vibration damping

Without vibration damping, the vibration of the masses during driving operation would be increased to such an extent by repeated road irregularities, that bodywork vibration would build up increasingly and the wheels would lose contact with the road surface. The purpose of the vibration damping system is to eliminate vibrations (energy) as quickly as possible via the suspension. For this purpose, hydraulic vibration dampers (shock absorbers) are located parallel to the springs.
Vibration dampers are available in different designs but their basic function and purpose are the same. Hydraulic/mechanical damping has found widespread application in modern vehicle design. The telescopic shock absorber is now particularly favoured due to its small dimensions, minimum friction, precise damping and simple design.



As previously mentioned, vibration damping has a fundamental effect on driving safety and comfort. However, the requirements of driving safety (driving dynamics) and driving comfort are conflicting.

Within certain limits, the following applies in principle:

• A higher rate of damping improves driving dynamics and reduces driving comfort.

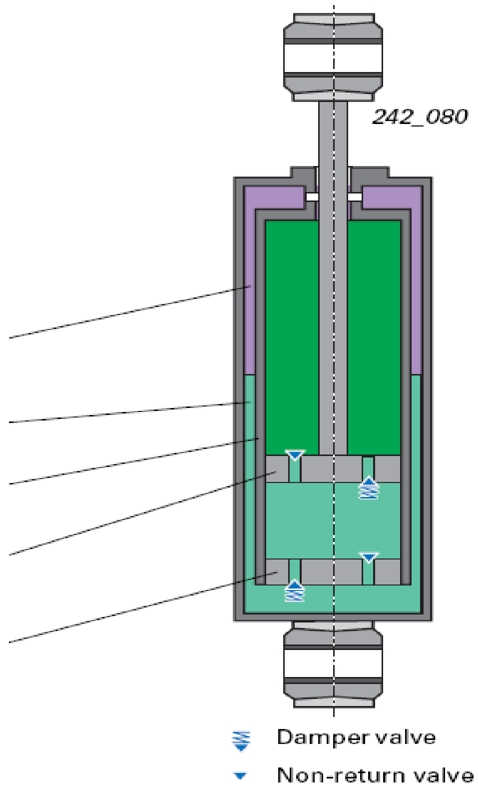
• A lower rate of damping lessens driving dynamics and improves driving comfort.

Note

The term “shock absorbers” is misleading as it does not precisely describe the function. For this reason we shall use the term “vibration damper” instead.

Dual pipe gas-pressure shock absorber

The dual pipe gas-pressure shock absorber has become established as the standard damper. In the dual pipe gas-pressure shock absorber, the working cylinder and the housing form two chambers. The piston and piston rod move inside the working chamber, which is completely filled with hydraulic oil. The ring shaped oil reservoir between the working cylinder and the housing serves to compensate volumetric changes caused by the piston rods and temperature changes in the hydraulic oil. The oil reservoir is only partially filled with oil and is under a pressure of 6 - 8 bar, which reduces the tendency towards cavitation. Two damping valve units are used for damping; the piston valve and the bottom valve. These comprise a system of spring washers, coil springs and valve bodies with throttle bores.



Note

Cavitation is the formation cavities and the creation of a vacuum in a rapid liquid flow.

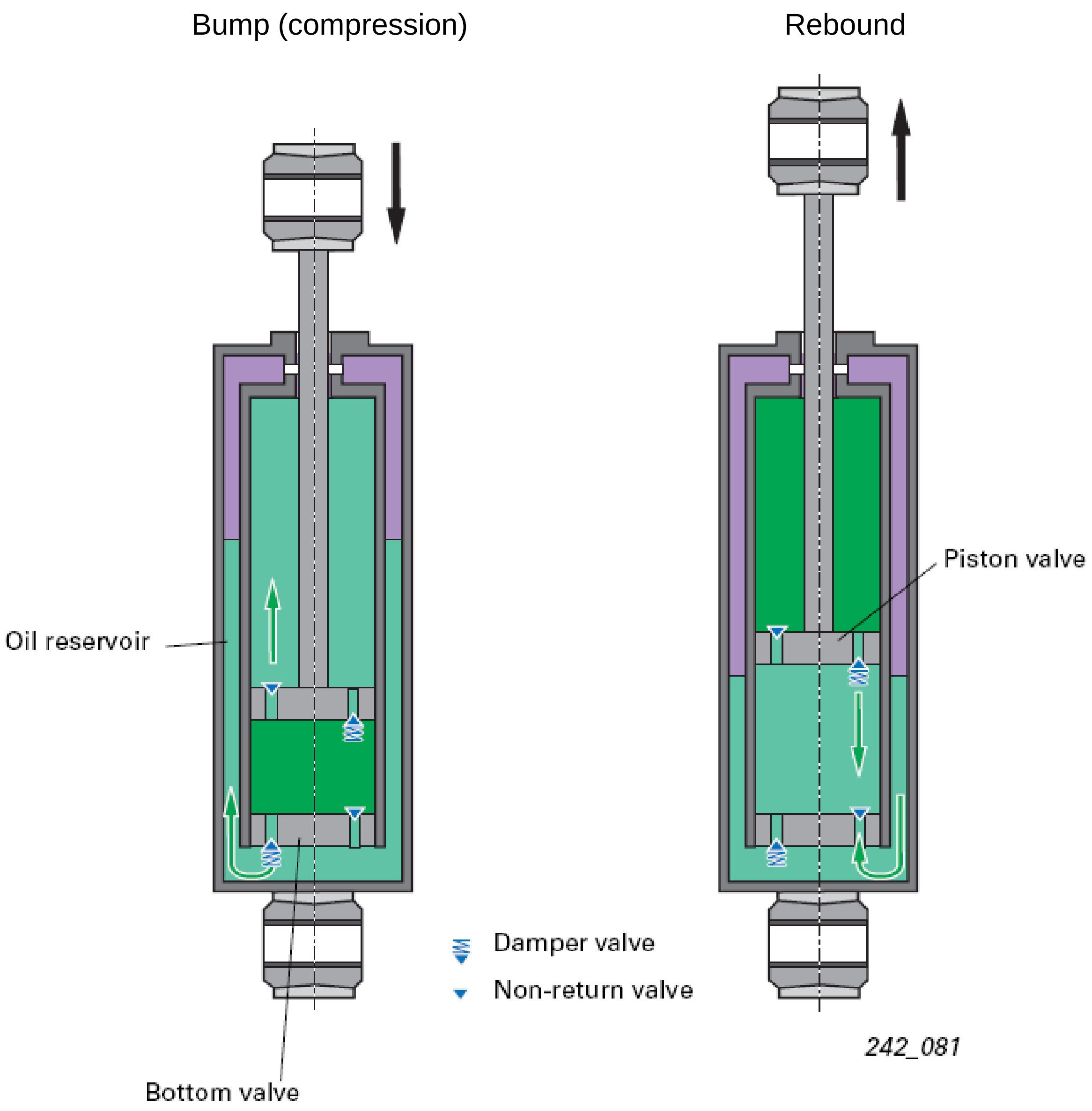
Operation

Bump (compression)

During compression, damping is determined by the bottom valve and to a certain extent by the return flow resistance of the piston. The oil displaced by the piston rod flows into the oil reservoir. The bottom valve exerts a defined resistance against this flow, thereby braking the movement.

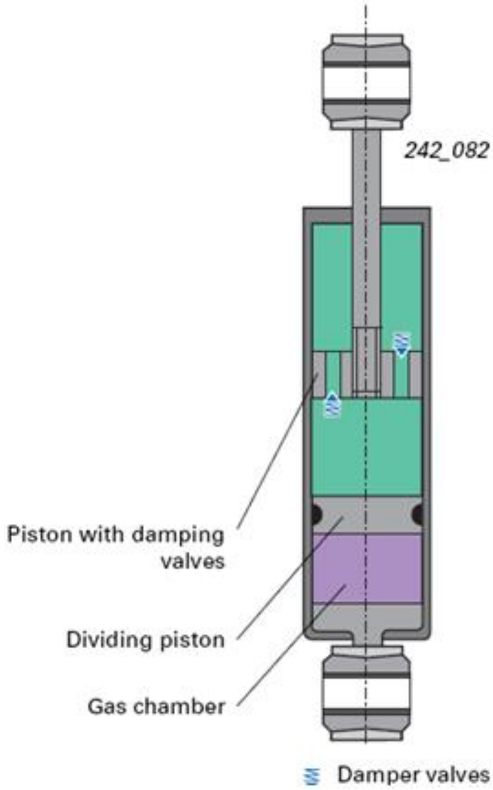
Rebound

During rebound, the piston valve alone carries out the damping action and exerts a predetermined resistance against the oil flowing downwards. The oil required in the working chamber can flow back unhindered via the non-return valve in the bottom valve.



Single pipe gas-pressure shock absorber

With the single pipe gas-pressure shock absorber, the working chamber and the oil reservoir are located in a single cylinder. Volumetric changes caused by the piston rod and the temperature changes in the oil are compensated by another gas chamber which is separated from the working cylinder by a dividing piston. The level of pressure in the gas chamber is approx. 25 - 30 bar and must be able to sustain the damping forces during compression. The damping valves for compression and rebound are integrated into the piston.



Comparison of single/dual pipe gas-pressure shock absorbers

	Dual pipe gas-pressure shock absorber	**Single pipe gas-pressure shock absorber**
Valve function	The tendency towards cavitation is reduced by the gas pressure in the oil reservoir	Minimal tendency towards cavitation thanks to high gas pressure and separation of oil and gas
Characteristic curves	Any, due to separate valves for compression and rebound	Dependant on the gas pressure during compression
Short damping strokes	Good	Better
Friction	Low	Higher due to seal under pressure
Design	Greater diameter	Longer due to gas chamber in the cylinder
Installation position	Approximately vertical	Any
Weight	Heavier	Lighter

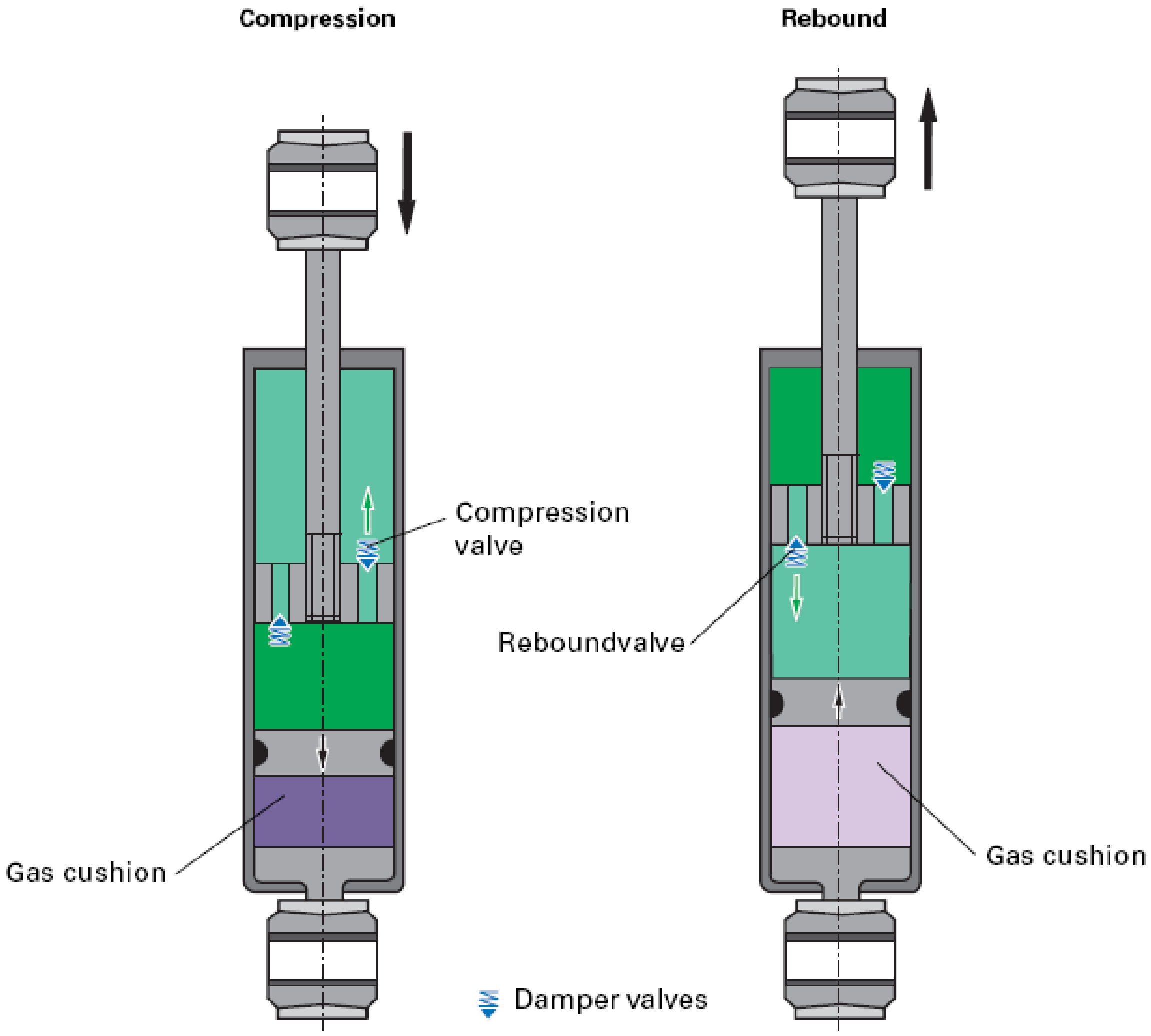
Operation

Bump (compression)

During compression, oil is forced out of the lower chamber through the discharge valve integrated into the piston which exerts a defined resistance against the oil. The gas cushion thereby compresses by the amount of the piston rod volume inserted.

Rebound

During rebound, oil is forced out of the upper chamber through the suction valve integrated into the piston which exerts a defined resistance against the oil. The gas cushion thereby expands by the amount of the emerging piston rod volume.

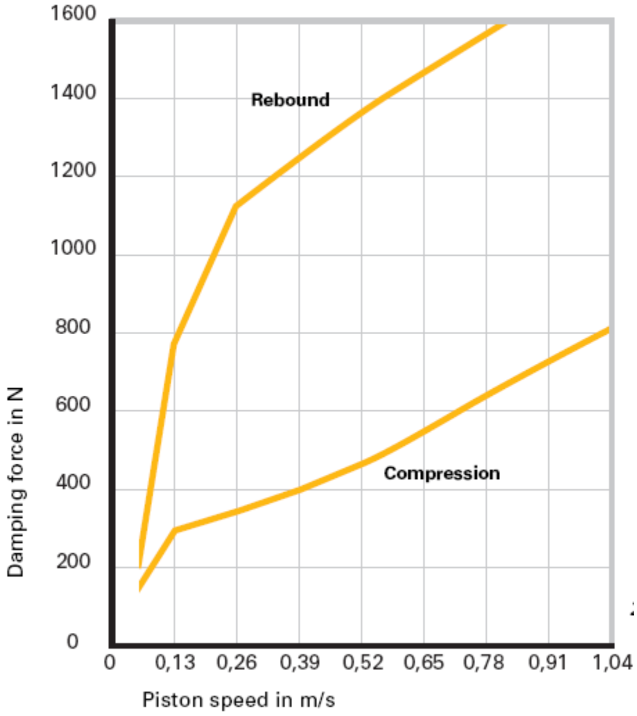


Damping matching

We can basically distinguish between compression and rebound in the damping process. The damping force during compression is generally smaller than during rebound. Consequently, irregularities in the road are transmitted to the vehicle bodywork with diminished force. The spring absorbs the energy which is quickly dissipated during rebound by the more efficient action of the shock absorber.

Advantage of this matching:

Good response of the vehicle suspension ensures greater driving comfort. The disadvantage of this matching occurs in the case of a quick succession of irregularities in the road. If the time between the individual impacts is no longer sufficient for rebound, the suspension can “harden” significantly in extreme cases, impairing driver comfort and driver safety.



The degree of damping

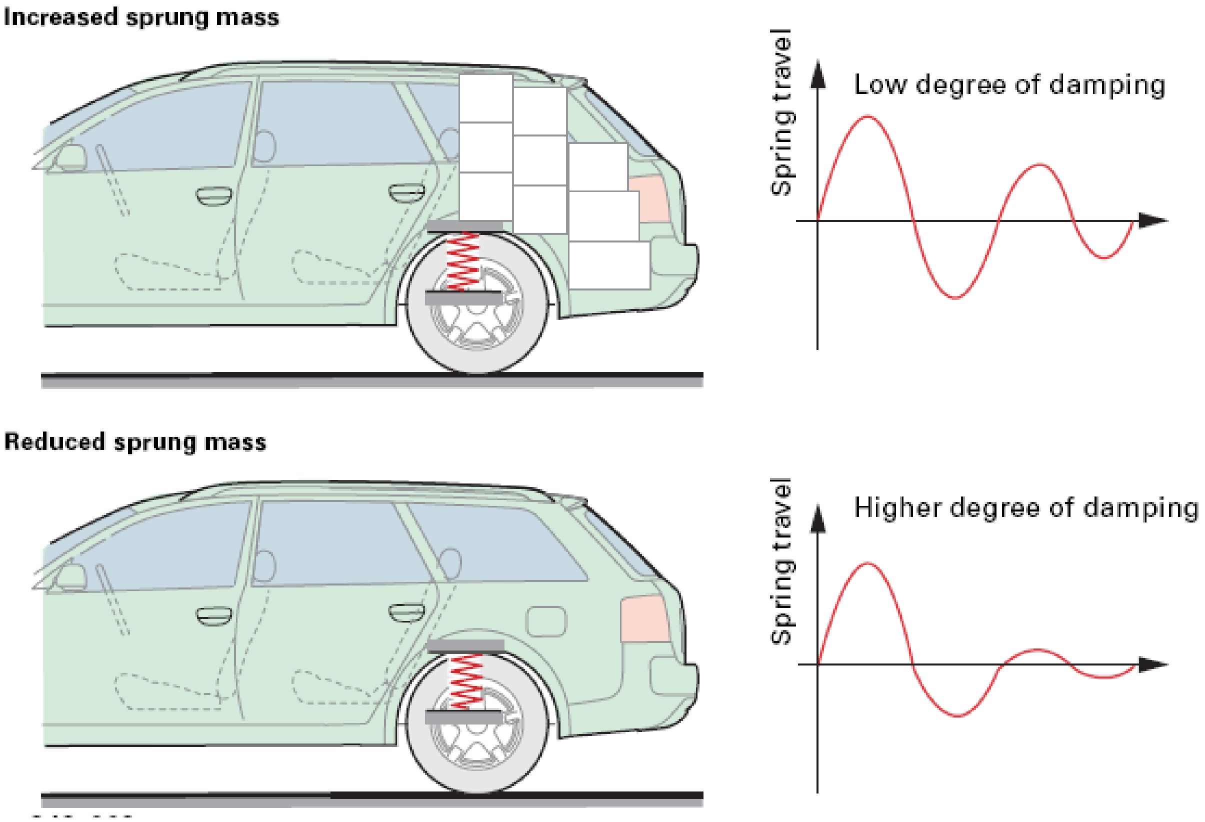
The degree of damping (the factor which determines how quickly the vibrations are eliminated) of the vehicle body is dependent on the damping force of the shock absorber and the sprung masses.

If the damping force is unchanged, the following applies:

An increase of the sprung masses reduces the degree of damping. This means that the vibrations are eliminated more slowly. A reduction of the sprung masses increases the degree of damping. This means that the vibrations are eliminated more rapidly.

Note

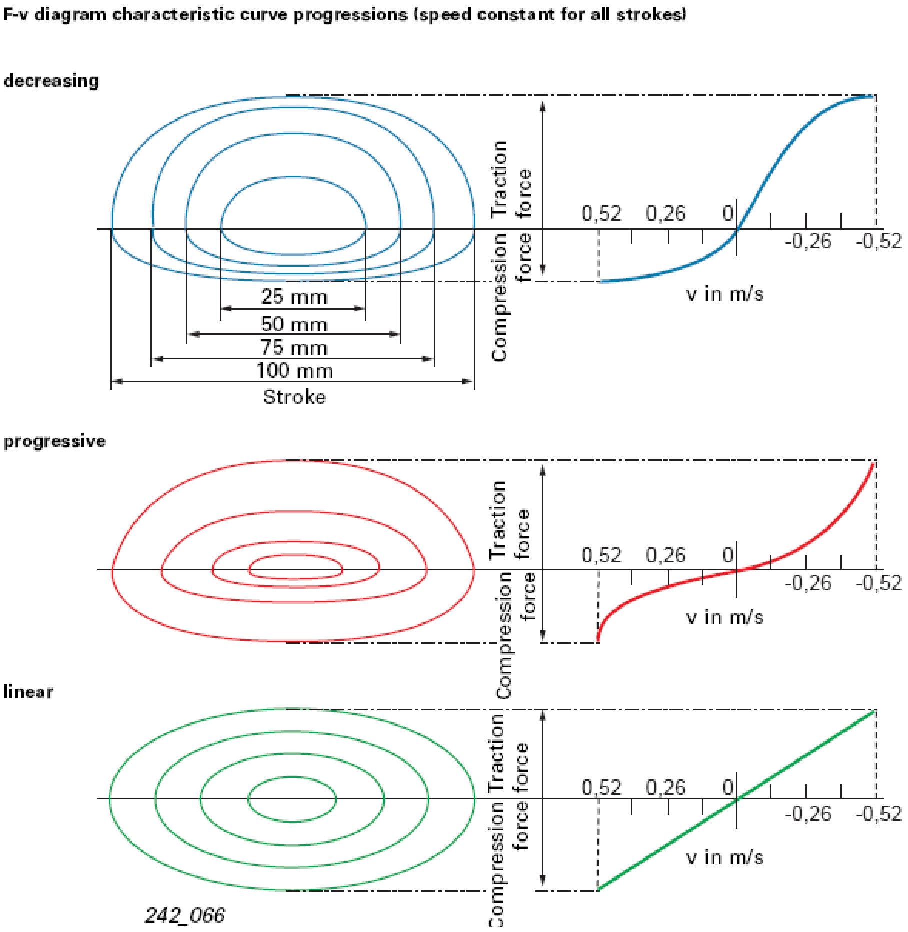
The **degree of damping** describes how much kinetic energy a vibration system been dissipated between two vibration cycles as a result of damping. The **damping coefficient** is just another term for degree of damping.



Damping force

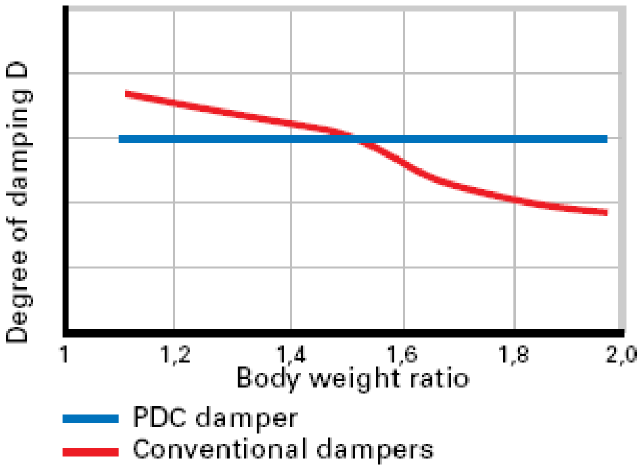
The damping force depends upon the oil volume to be displaced (surface of the damping valve), the flow resistance of the damper valves, the speed of the damper piston and the viscosity of the damping oil. The damping force is determined with the aid of a test machine. At a constant speed, this machine produces various rebound and compression strokes thereby producing differing rebound and compression speeds in the damper.

The force/stroke diagrams thus obtained can be converted into force/velocity diagrams (f-v diagrams). These characteristic curves show the relationship between the damping force and the piston speed, thereby indicating the shock absorber characteristics. We differentiate between linear, progressive and decreasing characteristic curves.



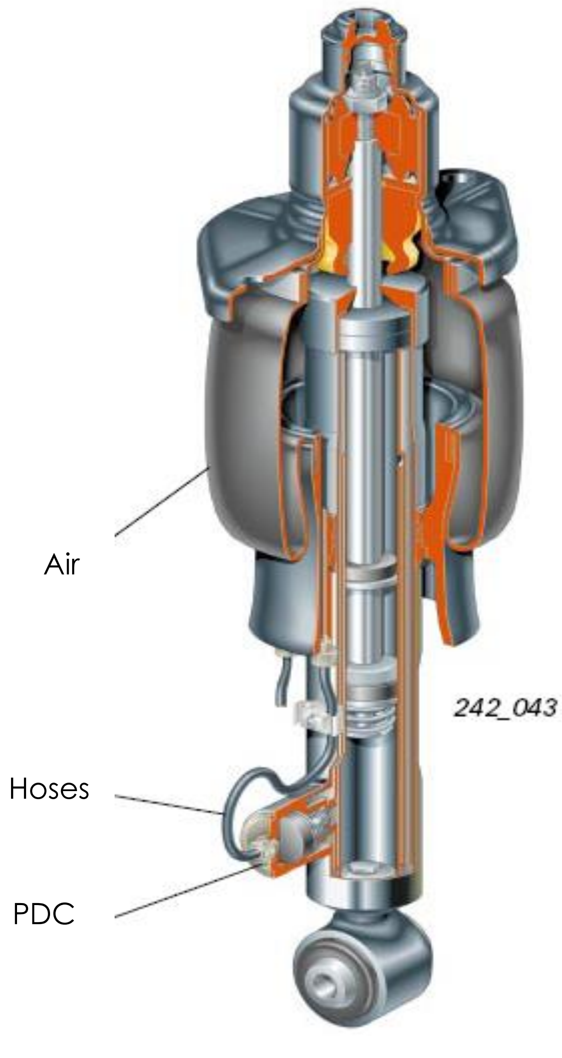
Measures are taken during the design stage to adapt the characteristic curves to the requirements of suspension matching. Shock absorbers with decreasing characteristic curves are normally used. Normal shock absorbers have predetermined characteristic curves. They are adapted to normal bodywork weights and can cope with a wide range of driving situations in a well matched running gear. Running gear matching is always a compromise between driving safety (driving dynamics) and driving comfort. The degree of damping (damping effect of sprung masses) is lessened as the load increases, which affects the driving dynamics. In contrast, the degree of damping is greater when the vehicle is un-laden, which lessens driving comfort.

The pneumatic damper

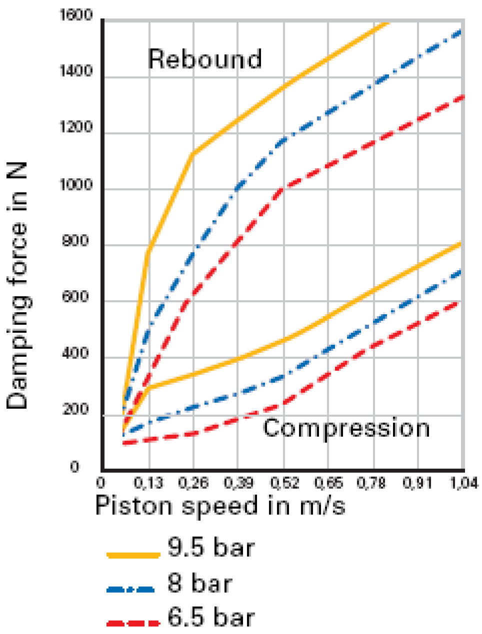


In order to maintain the degree of damping and thereby the handling characteristics at a constant level between partially and fully laden, the self-levelling air suspension and the 4-level air suspension both have a continuously variable load recognition system fitted to the rear axle. Along with the constant natural frequency of the bodywork, the vehicle bodywork maintains virtually constant vibration characteristics irrespective of the load thanks to the air springs. When the vehicle is partially-laden, good driving comfort is achieved and body movements are damped sufficiently firmly at full load. The PDC damper (Pneumatic Damping Control) is responsible for this. The damping force can be varied according to the air spring pressure.

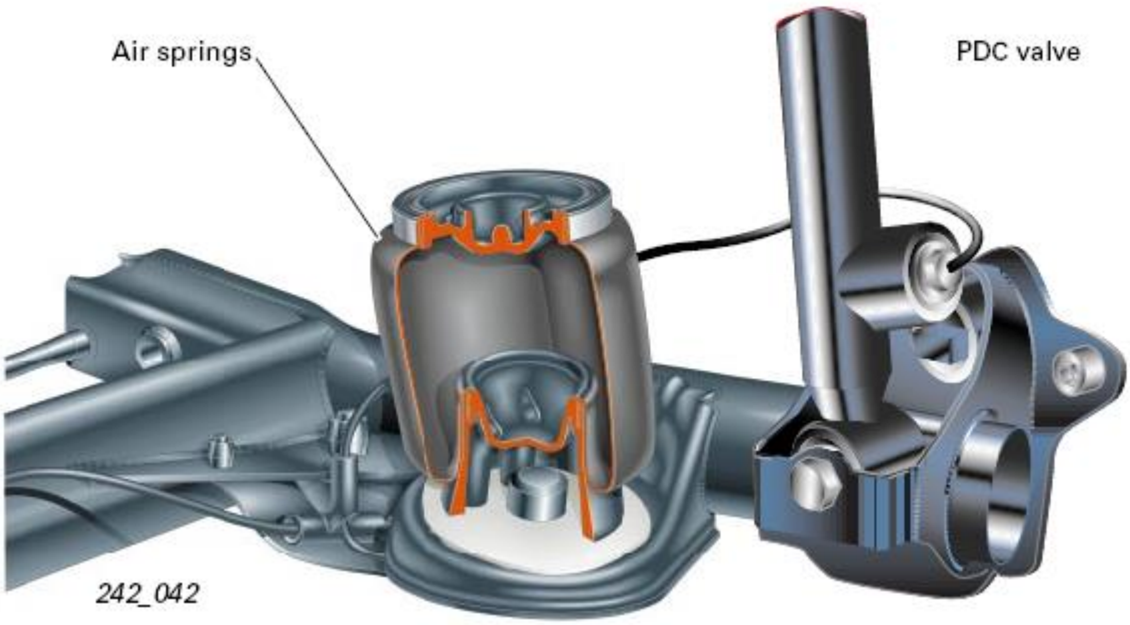
Coaxial arrangement of air springs/PDC damper



The damping force is altered by means of a separate PDC valve integrated into the damper. It is connected to the air springs via a hose. A variable throttle in the PDC valve is controlled by the air spring pressure acting as a control variable proportional to the load. This influences the flow resistance and thereby the damping force during rebound and compression. The air connector in the PDC valve is fitted with a throttle to counteract the undesirable influence of the dynamic pressure changes (compression and rebound) in the air springs.



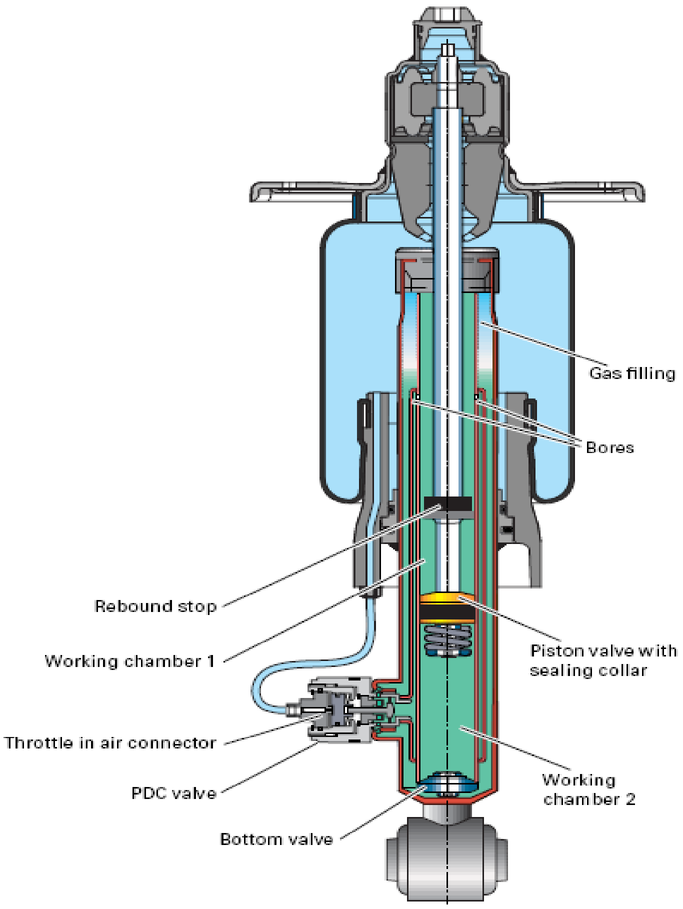
Separate arrangement of air springs/PDC damper



Operation

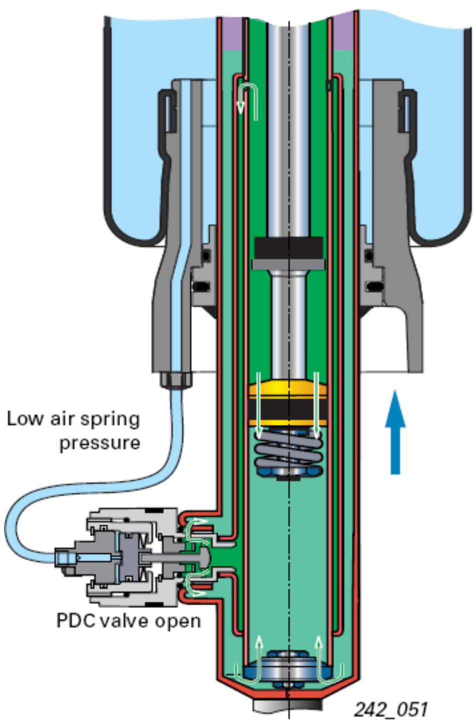
Design and function

The PDC valve influences the flow resistance of the working chamber on the piston rod side (working chamber 1). Working chamber 1 is connected to the PDC valve via bore holes. The PDC valve has a low flow resistance when the air spring pressure is low (no load or small partial load). Part of the damping oil bypasses the damping valve, thereby reducing the damping force. The flow resistance of the PDC valve has a fixed relation to the control pressure (air spring pressure). The damping force is dependent on the flow resistance of the relevant damping valve (compression/rebound) plus that of the PDC valve.

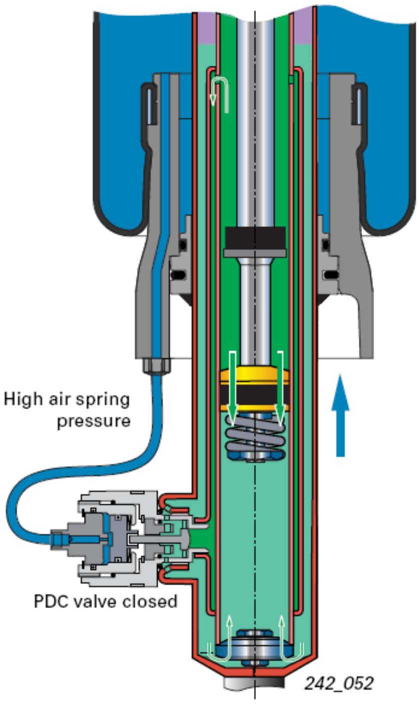


Function during rebound at low air spring pressure

The piston is drawn upwards, part of the oil flows through the piston valve, the remainder flows through the bore holes in working chamber 1 to the PDC valve. As the control pressure (air spring pressure) and consequently the flow resistance of the PDC valve is low, the damping force is reduced.



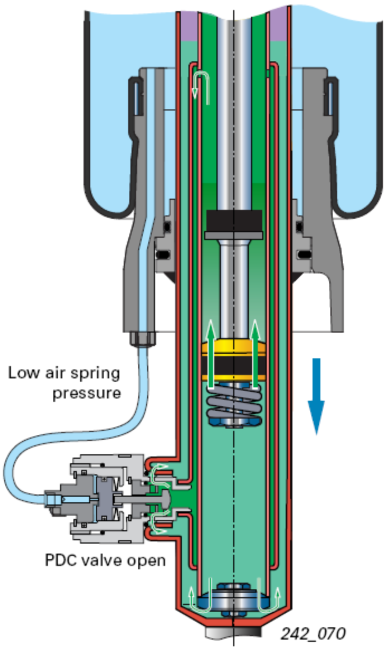
Function during rebound at high air spring pressure



The control pressure and consequently the flow resistance of the PDC valve is high. Most of the oil (depending on the control pressure) is forced to flow through the piston valve, thereby increasing the damping force.

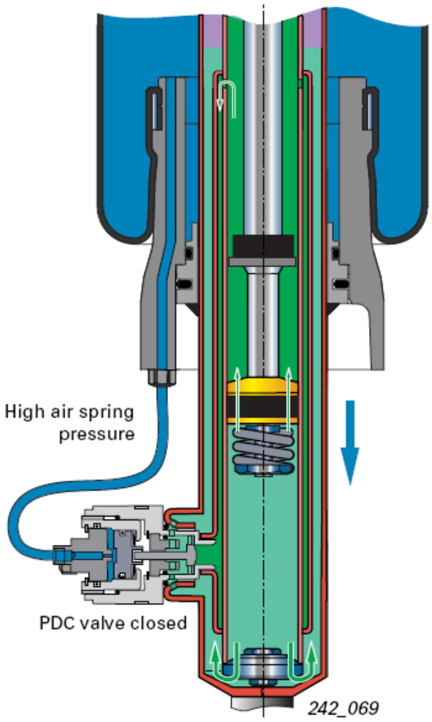
Function during compression at low air spring pressure

The piston is pushed downwards and damping is determined by the bottom valve and to a certain extent by the flow resistance of the piston. The oil displaced by the piston rod flows partly via the bottom valve into the reservoir. The remainder flows through the bore holes in working chamber 1 to the PDC valve. As the control pressure (air spring pressure) and consequently the low flow resistance of the PDC valve is low, the damping force is reduced.



Function during compression at high air spring pressure

The control pressure and consequently the flow resistance of the PDC valve are high. Most of the oil (in relation to the control pressure) must flow through the piston valve, thereby increasing the damping force.



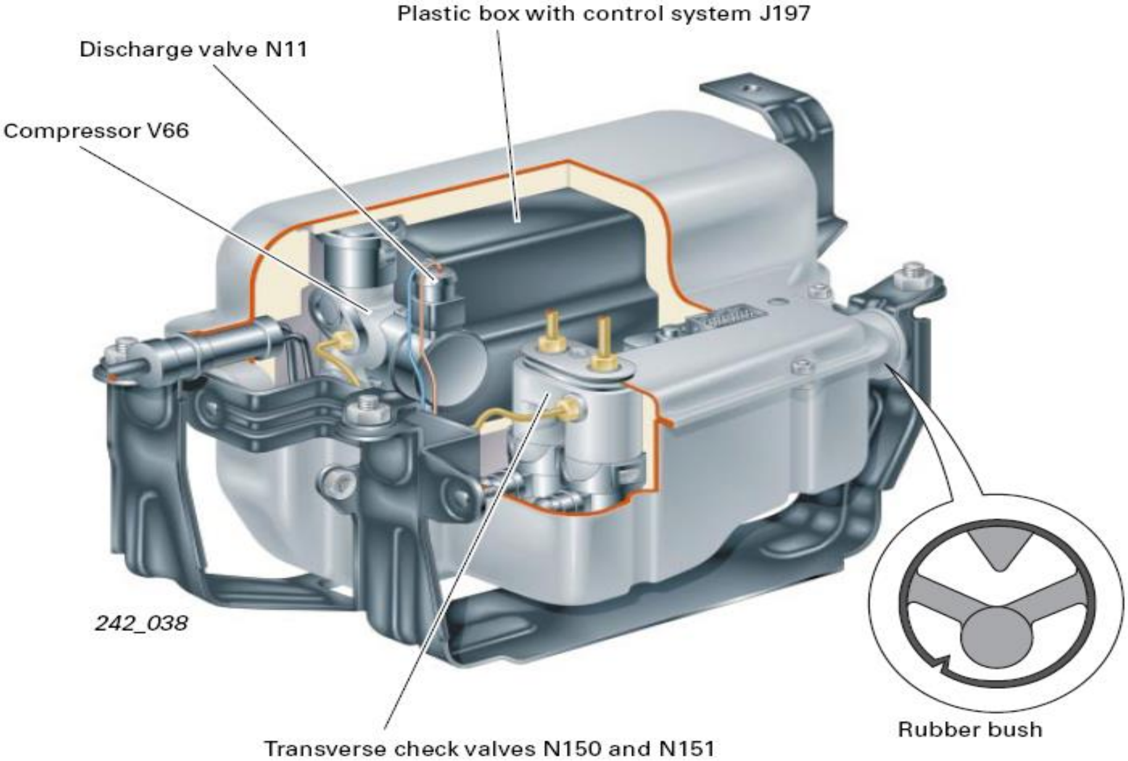
Air supply unit

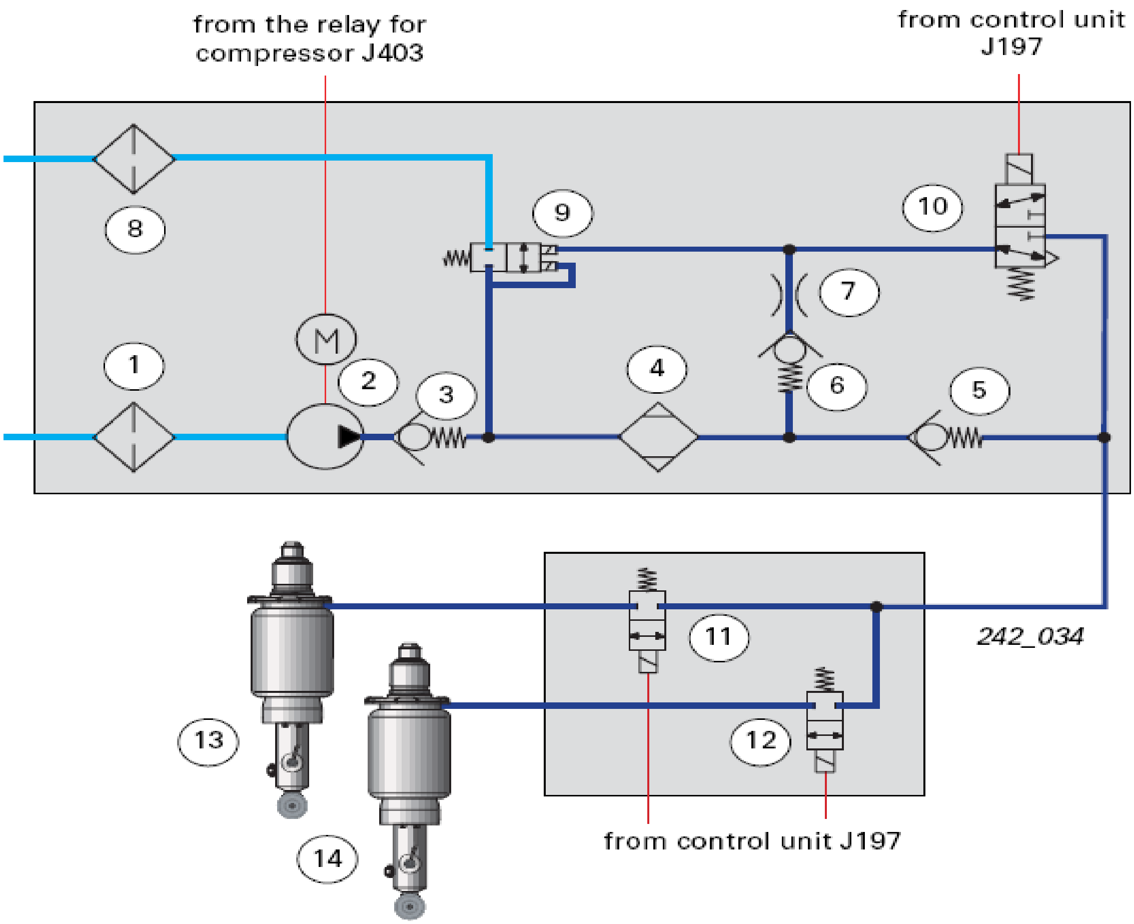
The following components are contained in a metal box inside the air supply unit:

- V66 compressor with integrated air dryer and discharge valve N111,
- transverse check valves N150 and N151,
- control unit J197
- relay for compressor J403

The components listed above are housed in a special polyurethane foam (PUR foam) insulation mat to ensure vibration and acoustic damping. The insulation mat is designed to fix the positions of the individual components within the metal box.

The air circuit

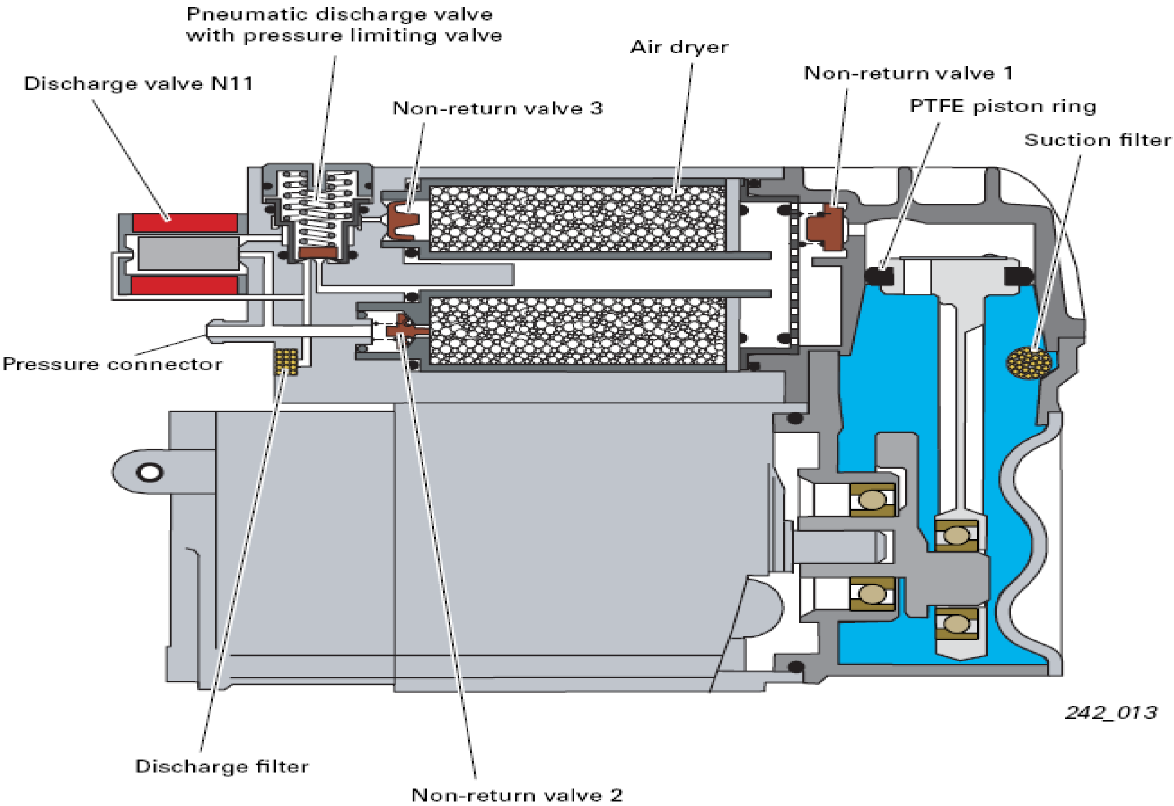




1	Suction filter	10	Discharge valve N11
2	Compressor with motor V66	11	Valve for suspension strut HL N150
3	Non-return valve 1	12	Valve for suspension strut HL N151
4	Air dryer	13	Rear left air spring
5	Non-return valve 2	14	Rear right air spring
6	Non-return valve 3		
7	Throttle		
8	Discharge filter		
9	Pneumatic discharge valve		

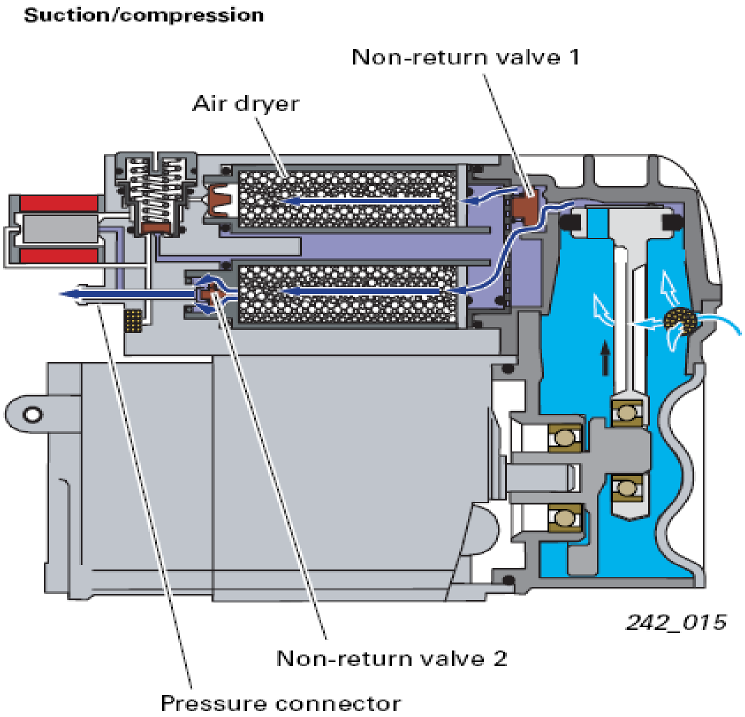
The air compressor

The compressed air is generated by means of a single stage piston compressor with integrated air dryer. In order to avoid oil contamination of the U-bellows and the dryer cartridge, the compressor is a so-called dry running compressor. Permanently lubricated bearings and a PTFE (polytetrafluoroethylene) piston ring ensure a long service life.
The discharge valve N111 and the pneumatic discharge valve are integrated into the dryer cartridge housing. In order to protect the compressor from overheating, it switches off at excess temperatures



Suction/compression

When the piston moves upwards, air is sucked into the crankcase via the sinter filter. The air is compressed above the piston and enters the air dryer via non-return valve 1. The compressed and dried air passes via non-return valve 2 to the pressure connector which leads to the transverse check valves.

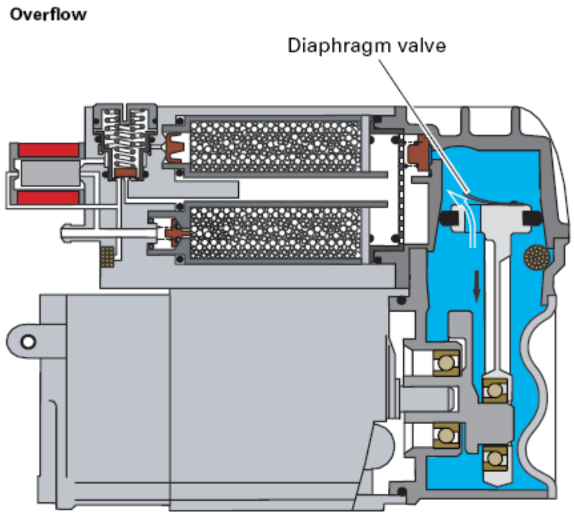


Overflow

When the piston moves back, the air which has been sucked into the crankcase passes via the diaphragm valve into the cylinder.

Filling/lifting

The relay for the compressor and the air spring valves are controlled simultaneously by the control unit for filling



Discharge/lowering

The air spring valves N150 and N151 and discharge valve N111 open during compression. The air spring pressure flows to the pneumatic discharge valve and out of the system from there via the air dryer and the pressure limiting valve.

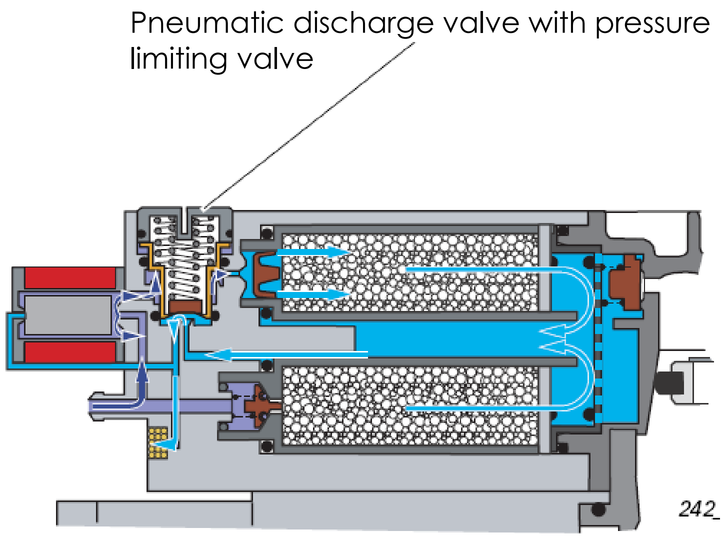
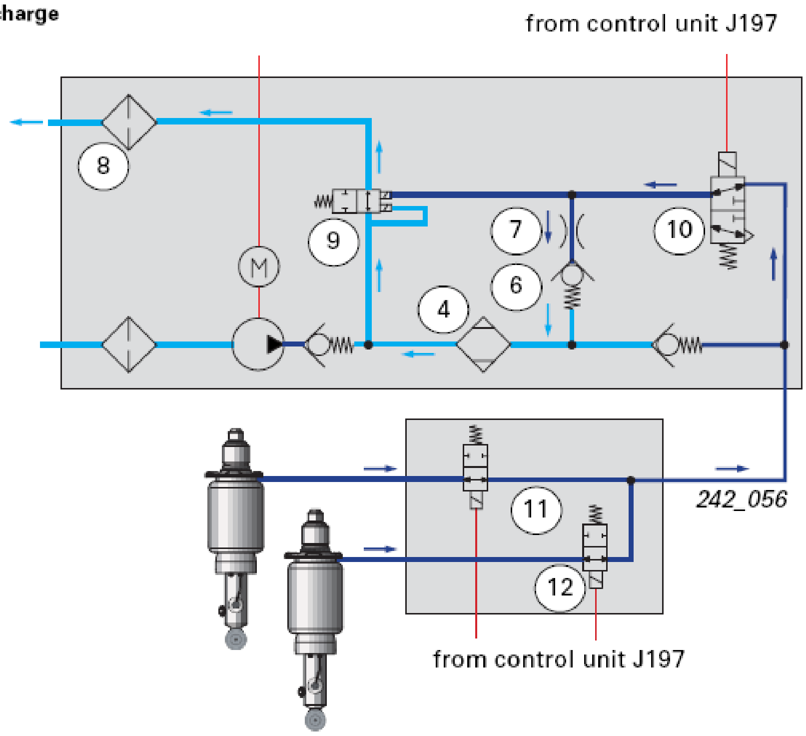


Diagram of pneumatic system, discharge

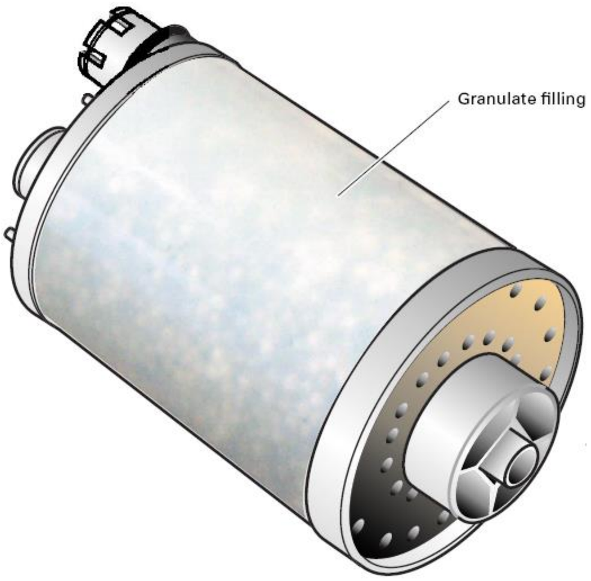
4	Air dryer
6	Non-return valve 3
7	Throttle
8	Discharge filter
9	Pneumatic discharge valve
10	N111
11	N150
12	N151



Air Drier

The air must be dehumidified in order to prevent condensate and the associated problems of corrosion and freezing. The system used here is a so-called regenerative air dryer system. A synthetically manufactured silicate granulate is used as the drying agent. This granulate can, depending on the temperature, store up to 20% of its own weight in water. As the air dryer operates generatively, and is only operated with oil-free, filtered air, it is not subject to replacement intervals and is therefore maintenance-free.

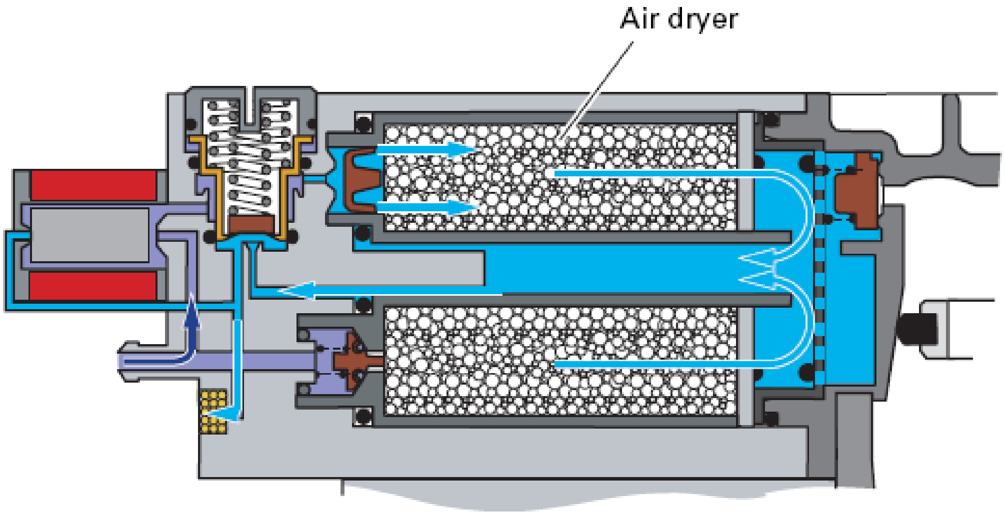
Note



Because the air dryer is regenerated only with waste air, the compressor cannot be used to fill any other components. As this compressed air is not fed back via the air dryer, no regeneration can take place. For this reason, the manufacturers do not fit a pressure connection for external components. Water/moisture in the system indicates a fault in the air dryer or the system.

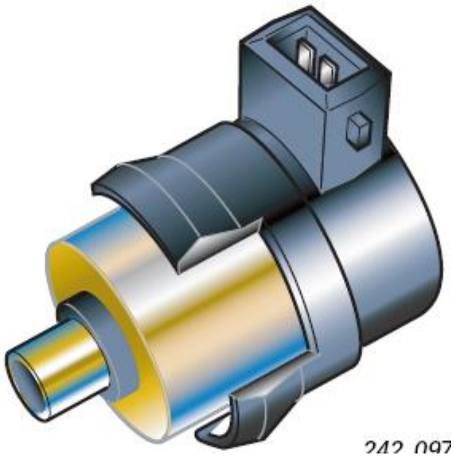
Regeneration

The compressed air is initially fed through the air dryer and dried. The moisture is temporarily stored in the air dryer and the dried compressed air passes into the system.
The air dryer is regenerated during discharge (lowering). During discharge, the dried compressed air (“waste air”) is fed back into the air dryer where it re-absorbs the moisture stored there and discharges it into the ambient air.



Discharge valve

The discharge valve is a 3/2 way valve (three connections and two switching positions) and is closed without current. The N111 is used only for discharge purposes (lowering). For lowering, the discharge valve is controlled by the control unit together with valves N150 and 151.



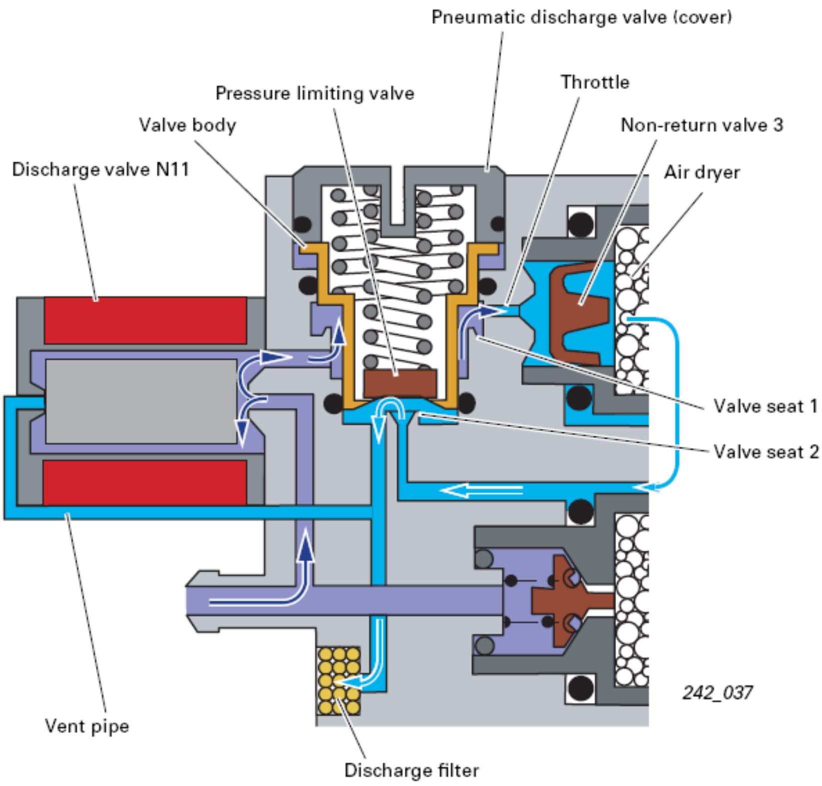
242_097

Pneumatic discharge valve

The pneumatic discharge valve performs two tasks:

- It is a residual pressure retaining device
- a pressure limitation device

A predefined minimum pressure (>3.5 bar) is necessary to prevent damage to the air springs (U-bellows). The **residual pressure retaining device** ensures that the pressure in the air suspension system does not fall below 3.5 bar during de-pressurisation (except in the case of leaks upstream from the pneumatic discharge valve).



242_037

At an air spring pressure of >3.5 bar, the valve body lifts against the resilience of both valve springs and opens valve seats 1 and 2. The air spring pressure then passes to the air dryer via the throttle and non-return valve 3. Once it has passed through the air dryer, the air flows through the valve seat of the pressure limiting valve and the discharge filter into the ambient air. The significant drop in pressure downstream from the throttle results in the uptake of the relative air humidity whereby the moisture uptake of the “waste air” is increased.

Pressure limiting

The **pressure limiting function** protects the system against inadmissible high pressure e.g. when the compressor fails to switch off due to a defective relay contact or defective control unit.
In such cases, the pressure limiting valve opens against the resilience from approx. 13.5 bar upwards, and the pressure is discharged via the discharge filter.

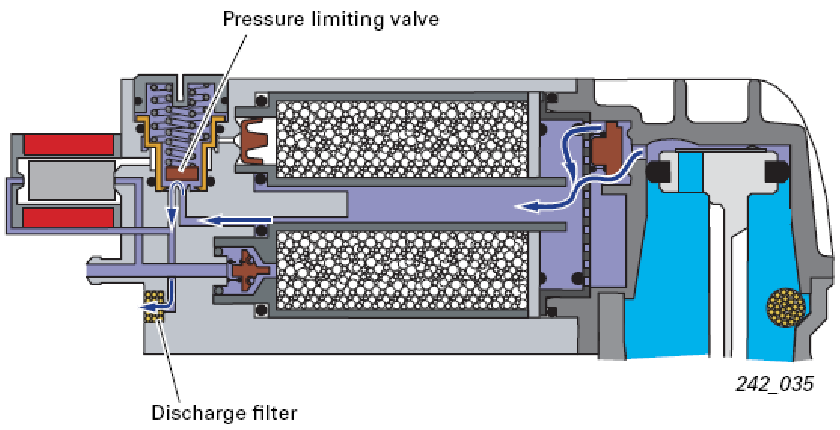
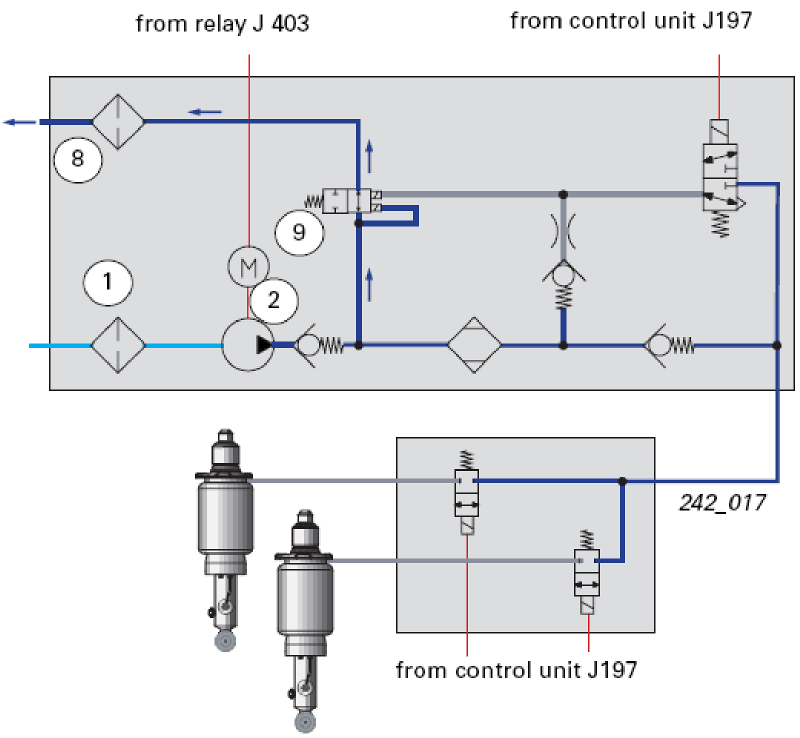


Diagram of pneumatic system, pressure limiting function

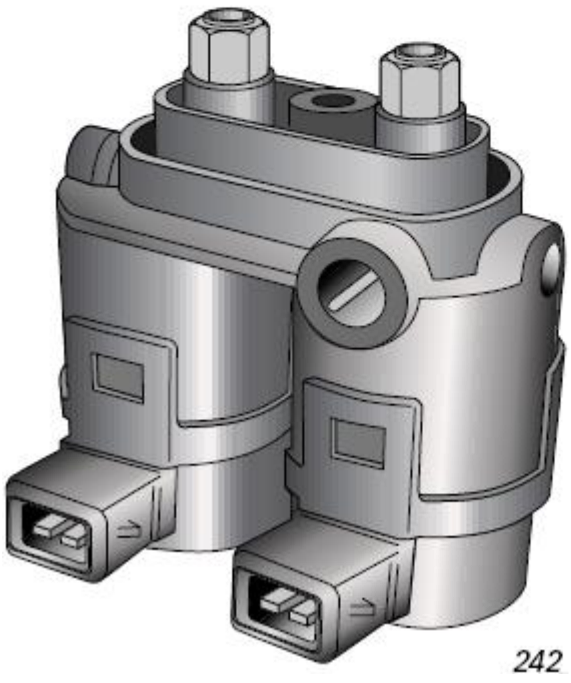
1	Suction filter
2	Compressor
8	Discharge filter
9	Pneumatic discharge valve

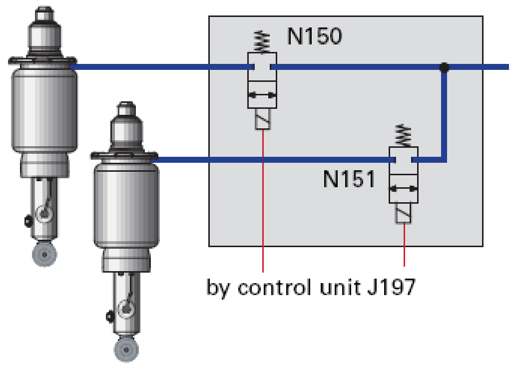


Valve for suspension strut

The valves are best described as transverse check valves and are combined in one housing. Both transverse check valves are so-called 2/2 way valves (2 connections and 2 switching positions). The transverse check valves are used to fill and discharge the air springs. The valves are closed without current and prevent an undesirable pressure equalisation between the left and right-hand air springs. This prevents the air spring pressure of the outer wheel (higher air spring pressure) escaping to the inside wheel (lower air spring pressure) when cornering. This would result in a momentary tilt of the vehicle. The transverse check valves are always controlled in unison during raising and lowering as adjustment can only be performed for the whole axle (see level sensor).

Following a control process while the vehicle is in driving operation (v >10km/h) the transverse check valves are opened three times for approx. 3 seconds at intervals of approx. 12 seconds in order to equalise the pressure between the left and right-hand air springs. If, for example, a control process takes place while cornering, this will cause the rear axle to tilt. The tilt is compensated by the opening of the transverse check valves, as described above (not in the case of a one-sided load).

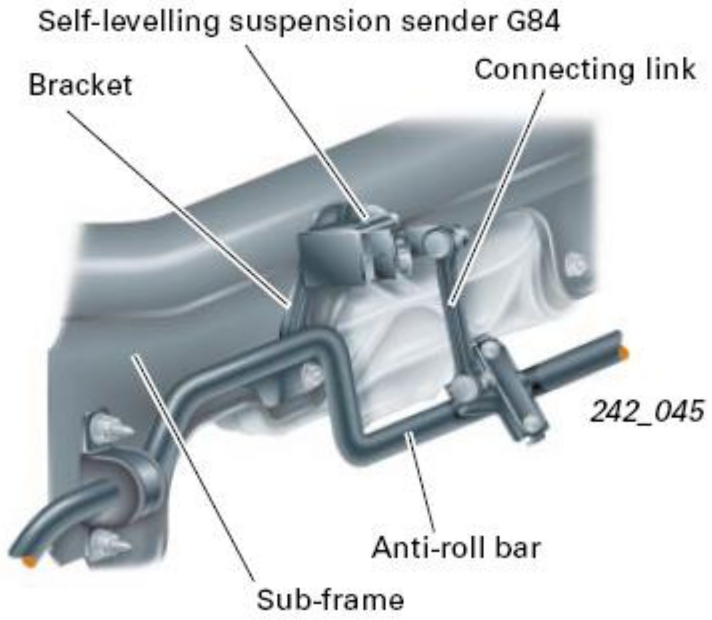




Self-levelling suspension sensor

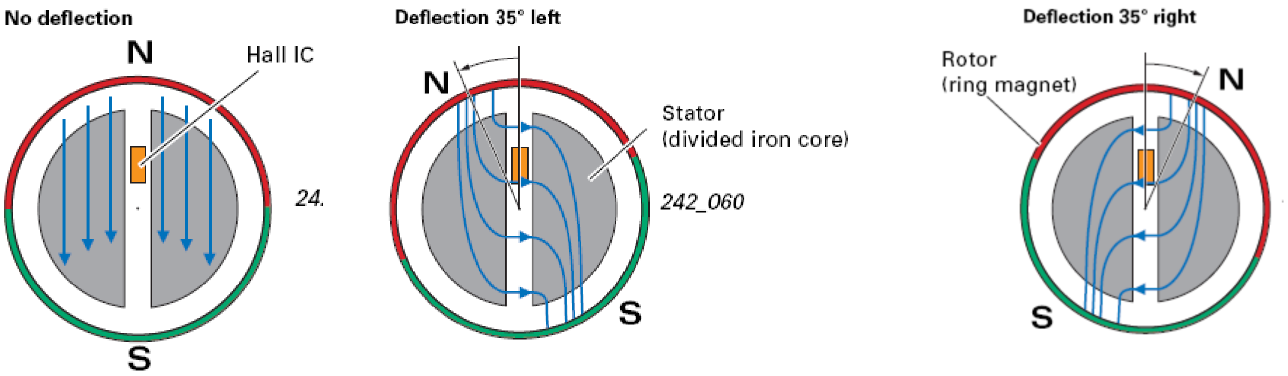
The vehicle level is detected by the self-levelling sensor. A contact-free angle sensor is used to determine the spring compression between the rear axle and the bodywork with the aid of the connecting link kinematics unit. The connection of the connecting link kinematics unit is designed to largely compensate for one-sided compression. This connection allows self-levelling to operate using only one level sensor. The self-levelling system in the example shown is not able to compensate for different levels on the left and right-hand sides (e.g. due to one-sided loads).

The angle sensor operates according to the Hall principle. Evaluation electronics integrated into the sensor convert the signal of the Hall IC into a voltage signal proportional to the angle (see diagram below).

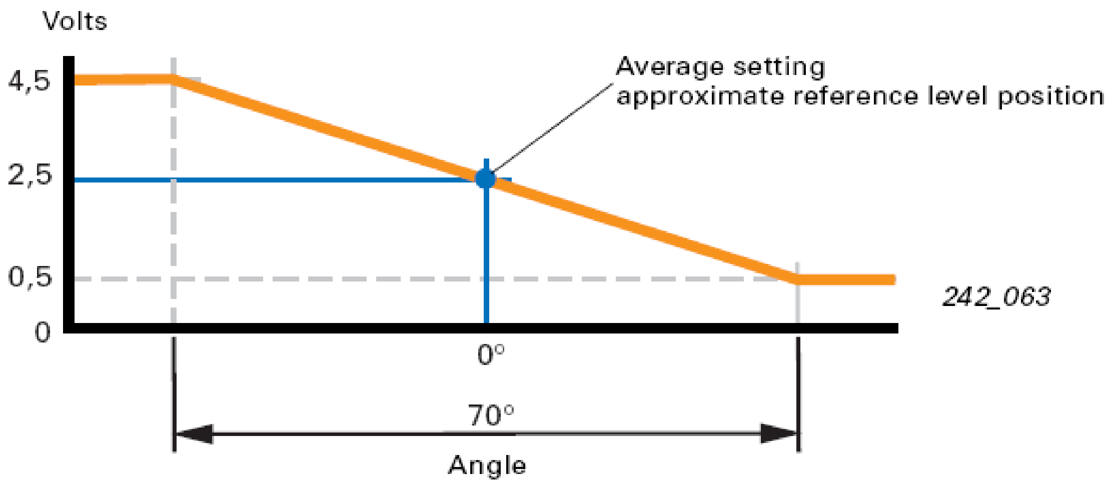


Operation

A ring magnet is connected to the axle of the sensor crank (rotor). A hall IC is positioned eccentrically between a two-piece iron core (stator). It forms a single unit together with the evaluation electronics. Depending on the position of the ring magnet, the magnetic field which penetrates the Hall IC changes. The resulting Hall signal is converted by the evaluation electronics into a voltage signal proportional to the angle. The control unit uses this analogue voltage signal to determine the current vehicle level.

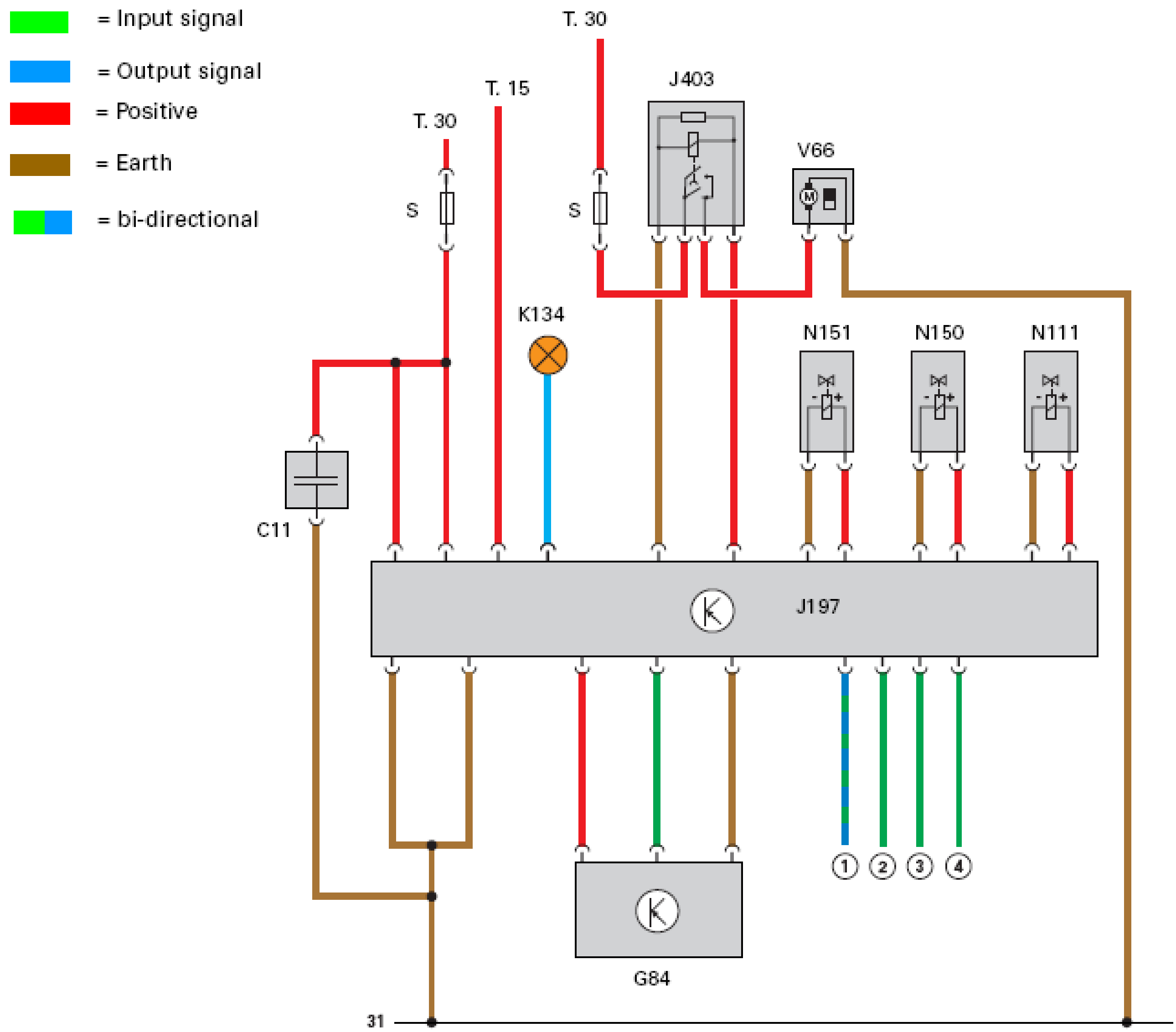


No deflection
N
Hall IC
S
24.
Deflection 35° left
N
Stator
(divided iron core)
242_060
S
Deflection 35° right
Rotor
(ring magnet)
N
S



Volts
4,5
2,5
0,5
0
Average setting
approximate reference level position
242_063
0°
70°
Angle

The electrical circuit



C11	Condenser	1	Diagnostic interface
G84	Self-levelling suspension sender	2	Driving speed signal
J197	Self-levelling suspension control unit	3	Door contact signal
J403	Relay for self-levelling suspension compressor	4	Terminal 50 signal
K134	Self-levelling suspension warning lamp		
N11	Discharge valve		
N150	Rear left strut valve		
N151	Rear right strut valve		
S	Fuse		
V66	Compressor motor		

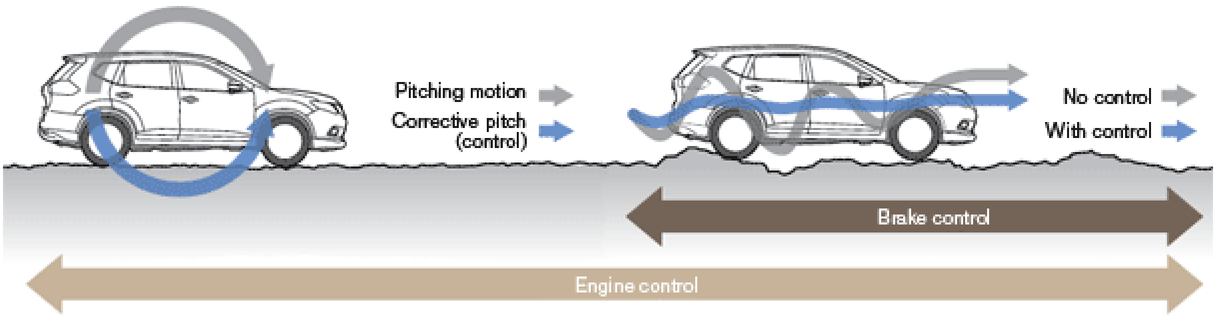
Active Ride Height

What is Active Ride Height.

When driving, a vehicle will encounter large and small bumps on the road. As the vehicle passes over certain bumps, passengers may feel a before and after pitching motion. The Intelligent Ride Control moderates this by controlling the engine and brakes, delivering a smoother driving experience.

Functionality
When the driver depresses the accelerator pedal and engine torque is increased, the front half of the vehicle rises slightly. Conversely, when the foot is taken off the accelerator pedal and engine torque is reduced, the front of the vehicle lowers back down. The raising and lowering of the front of the vehicle results in the vehicle exhibiting pitch behaviour.

The advantage ride height control is to counteract the pitching caused by bumps. The engine torque is varied slightly according to the bumps in the road surface, which decreases the pitching motion of the vehicle and allows the vehicle's occupants to have a more enjoyable driving or riding experience.



In addition, the vehicle suspension is fitted with shock absorbers which dampen the vertical and pitch motions of the vehicle. When dampening is strong, the motion caused by bumps on the road surface is quickly reduced. Conversely, with weak dampening, the motions caused by bumps can continue for a long time.

Manufacturers discovered that when the brake is applied, it has the effect of strengthening the dampening of body motion. Active Ride Control includes technology developed to reduce vehicle pitching when passing over a bump by automatically applying a very small amount of braking. The amount of braking is not enough to slow the vehicle down appreciably, but still results in faster dampening of the pitch motion than the vehicle using shock absorbers alone. With Active Ride Control, the pitching that follows when a vehicle passes over a bump is decreased in amount and duration, and the driving experience becomes more comfortable.

Technology Configuration
When a vehicle passes over a bump, the wheels speed fluctuates slightly when compared to the same vehicle driving on a flat surface. Using sensors to detect the change in the speed of the wheels, the system determines when the vehicle is moving up and down.

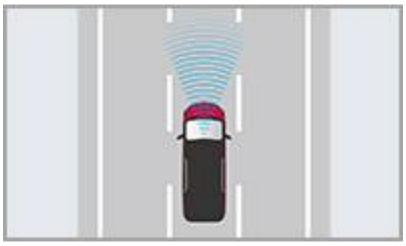
When the pitching is minor, ride quality can be improved by increasing or decreasing the engine torque. When the pitching is greater, the system applies the brakes, and this helps minimize the body motion of the vehicle. The engine torque variations and the brake applications are small and smooth. They calm the vehicle body motion but do not result in appreciable increases or decreases in vehicle speed. This allows drivers and passengers to simply enjoy a more comfortable driving and riding experience.

Significantly reduces driver stress when driving on highways in several kinds of traffic conditions, making long drives more comfortable and enjoyable is a revolutionary autonomous drive technology designed for highway use in single-lane traffic. Manufactures are now introducing a combination of steering, accelerator and braking that can be operated in full automatic mode, easing driver workload in heavy highway traffic and long commutes.

Employing advanced image-processing technology, the car's system understands road and traffic situations and executes precise steering enabling the vehicle to perform naturally. technology is extremely user-friendly, thanks to a switch on the steering wheel that allows the driver to easily activate and deactivate the system.

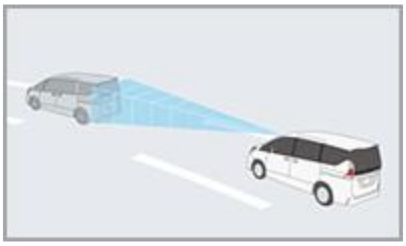
1. Maintains speed

Automatic speed control at pre-set speed



2. Follows, Stop and Maintains Stop

Automatically controls the throttle and the brakes to maintain a safe distance from the car in front. Completely stops in traffic situations and continues to apply brakes until released by the simple push of a button.

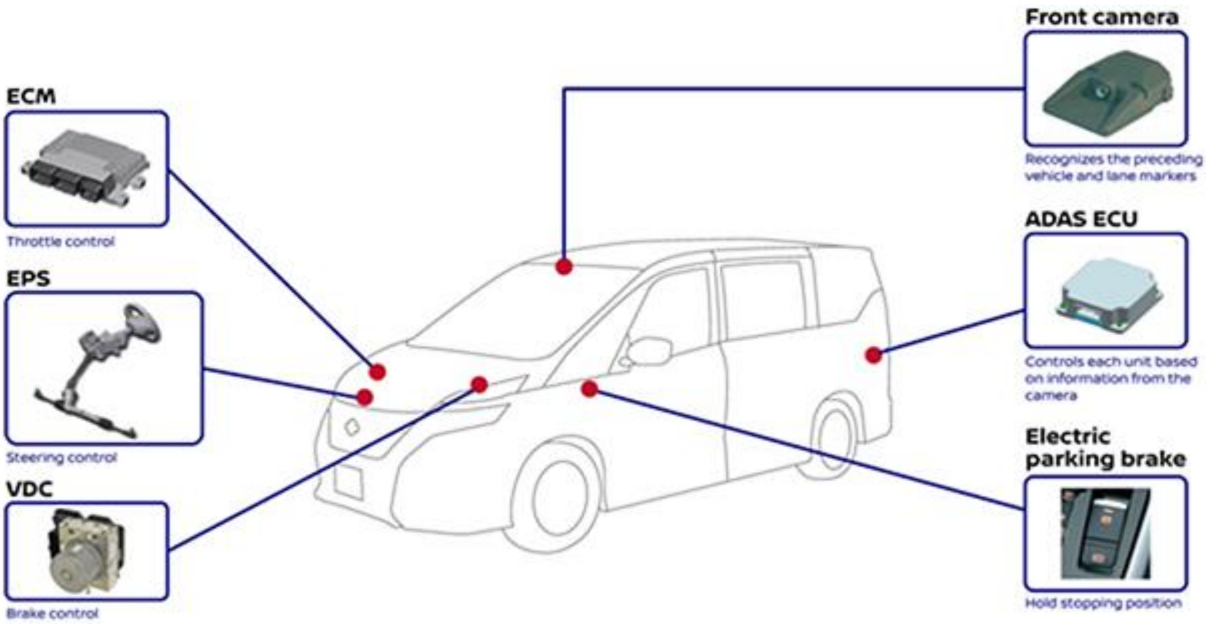


3. Steering control

Keeps the car in the middle of the driving lane on straight roads and even through corners. Applicable in slow moving traffic or on open highway roads.

System Configuration

The accelerator, brakes and steering are controlled based on information obtained through a mono camera equipped. The camera can quickly recognize in three-dimensional depth both preceding vehicles and lane markers.



ABS

A vehicles brakes work to stop a vehicle by utilising two types of resistance. These types are:

- The resistance between the brake pads and the brake discs (or brakes shoes and drums).
- The resistance between the road surface and the vehicle tyres.

Braking can be controlled in a stable manner if the relationship between the two resistances exists where the braking system resistance is *smaller* than the resistance between the road surface and tyre. If the relationship is reversed then the vehicle's tyres will lock up and start to skid.

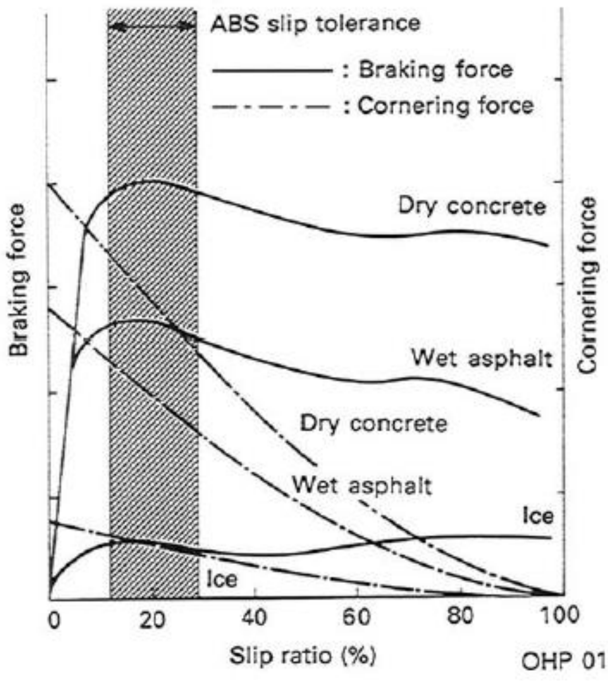
When a vehicle is driven at a constant speed i.e. the speed of the vehicle and road wheels are the same there is no slip taking place. When the driver depresses the brake pedal in order to slow the vehicle down, the speed of the wheels gradually decreases and no longer matches the speed of the vehicles body which is now travelling along under its own inertia (a small amount of slippage may occur). The difference between the vehicle body speed and the speed of the wheels is referred to as "slip ratio"

Slip ratio can be calculated in the following way:

$$\text{SLIP RATIO} = \frac{\text{VEHICLE SPEED} - \text{WHEEL SPEED}}{\text{VEHICLE SPEED}} \times 100\%$$

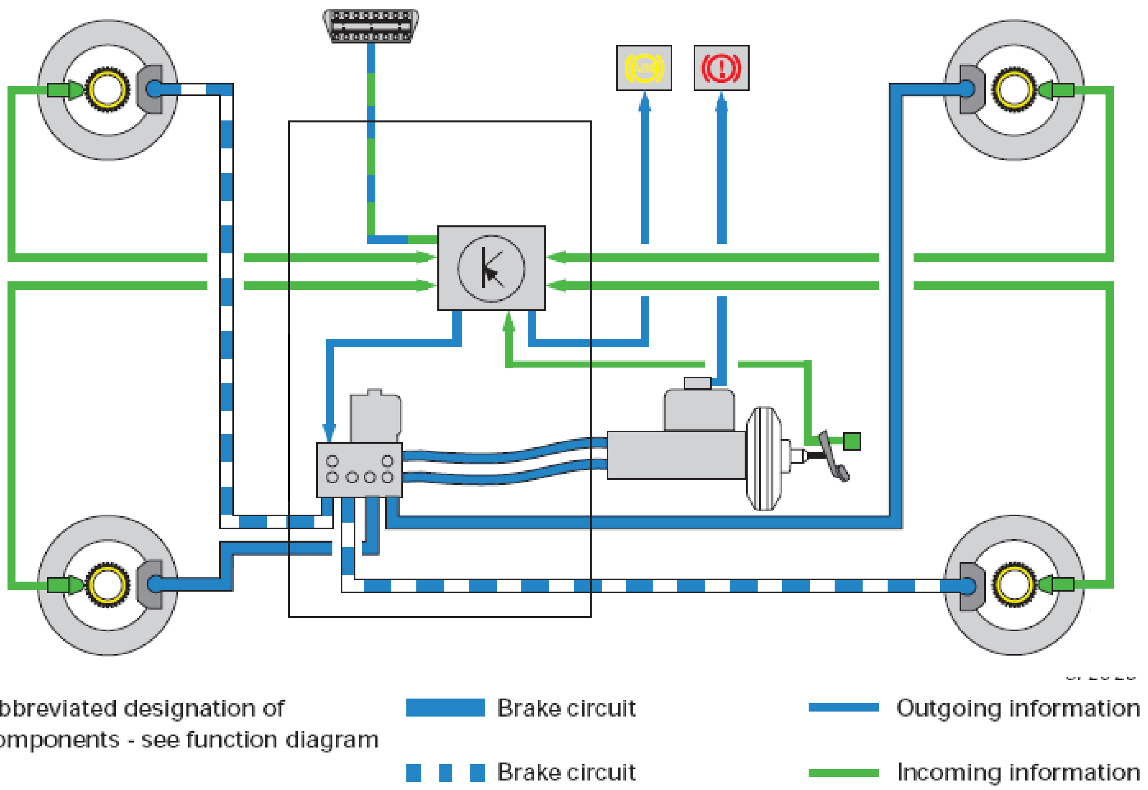
If the slip ratio is 0% then this means that the road wheels are turning freely with no resistance. If the slip ratio is 100% then this means that the wheels are completely locked up and skidding along the road surface.

Braking force is not necessarily proportional to the slip ratio. It reaches its maximum when the slip ratio is between 10% - 30%. Any higher and the braking force starts to decline. In order to maintain maximum braking force, the slip ratio should be maintained within that percentage range.



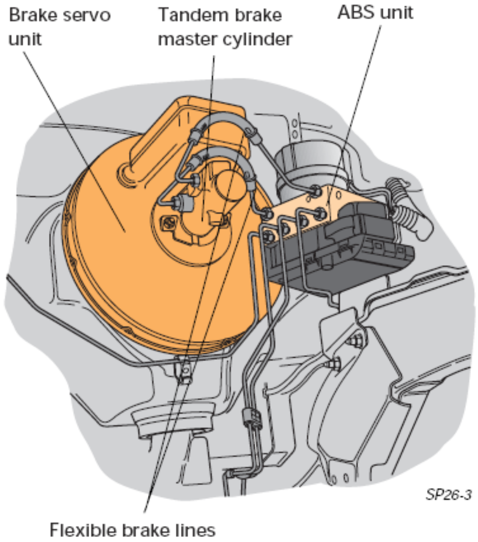
Basic operation

Wheel speed sensors detect the rotational speed of the road wheels and send a signal to the ABS control unit. The ABS control unit monitors the condition of the wheels by calculating the vehicle speed and any changes in the wheel speed from the rotational speed of the wheel.
During an emergency braking situation, the ABS control unit will control the systems actuators to provide the optimum brake pressure to each individual brake. The hydraulic control unit operates on commands form the ABS control unit by holding, increasing and reducing hydraulic pressure as required in order to maintain the braking force at the optimum operating range (slip ratio 10% - 30%).



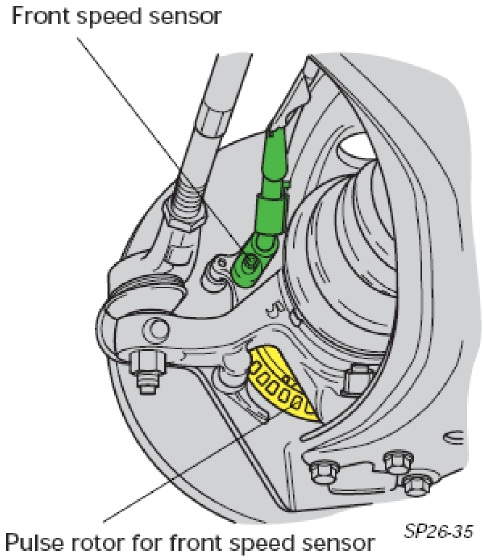
Components

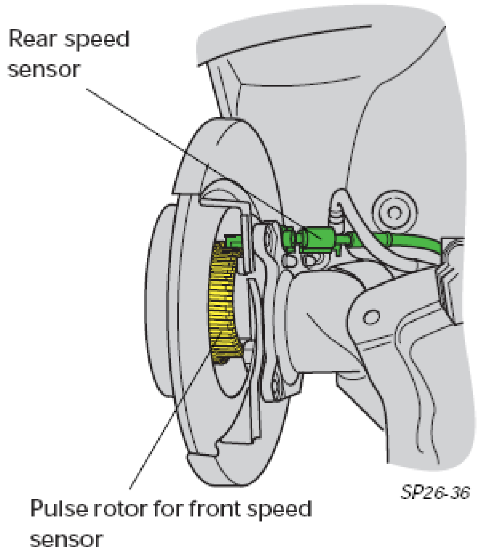
The brake servo unit with tandem brake master cylinder and the ABS unit are two separate components. The tandem brake master cylinder is connected to the ABS unit by flexible brake lines.

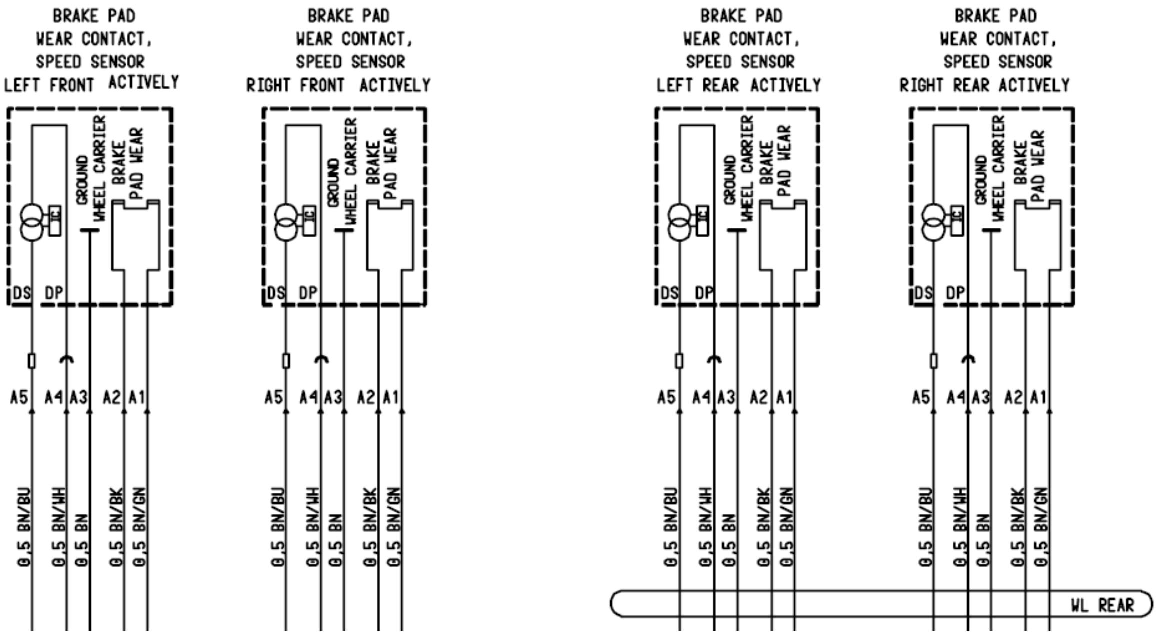


Sensors

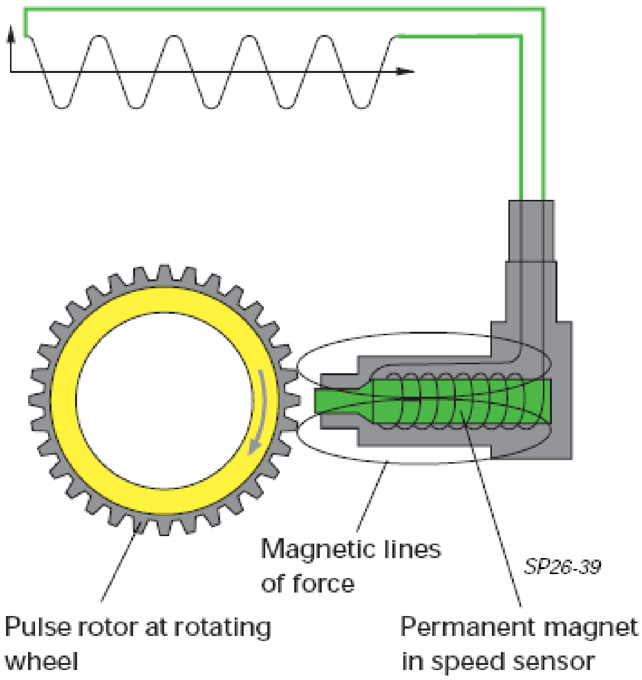
ABS speed wheel speed sensors are used to allow the ABS control unit to calculate road wheel speed.





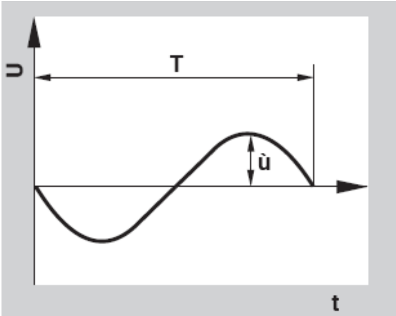


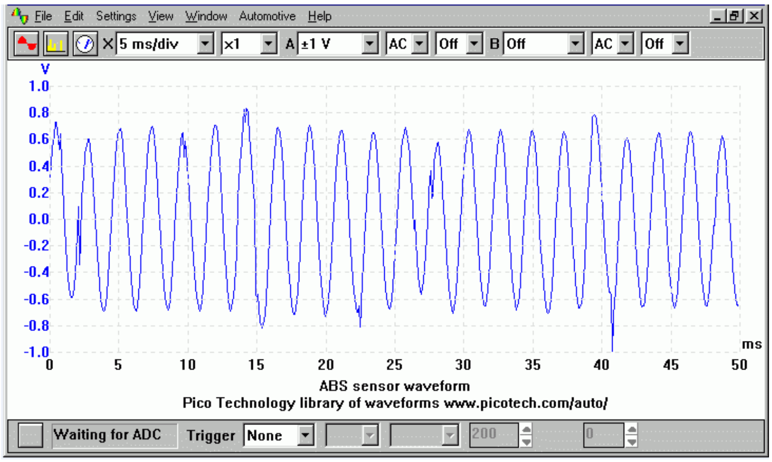
The speed sensor consists of a permanent magnet and a coil. This is connected to the control unit. The speed sensor operates on the principle of a generator, in other words when the gearwheel of the pulse rotor rotates in front of this sensor, a sinusoidal alternating voltage is generated in the coil. The frequency is depending on the wheel speed. The control unit converts the sinusoidal speed sensor signals and calculates the momentary wheel speed.



The gap between the pulse rotor and the speed sensor is of major significance for proper operation of the ABS system (the signal amplitude ù is influenced by this). When driving, the wheel bearing play and the movement of the suspension result in a slight movement of the wheel speed sensor. The size of the gap alters. That is why, it is important to check the gap as specified in the Workshop Manual when carrying out installation work. If an excessive gap exists, the control unit switches off the control at this wheel. Dirt which can clog the teeth gap in the pulse rotor are also sources of faults in the ABS system.

Sinusoidal alternating voltage
T = Period of oscillation
t = Time
U = Voltage
ù = Signal amplitude





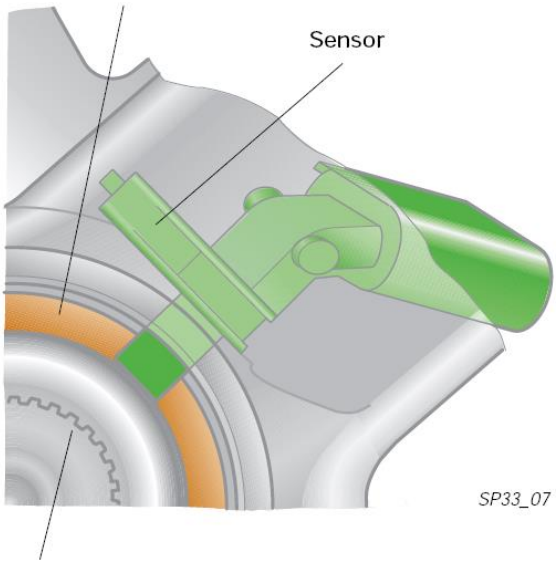
Typical inductive trace using an oscilloscope.

Active speed sensors

A system is termed as active if it requires an external voltage supply for its operation. Without this, it is not able to supply a signal. To enable the active sensor of the ABS, which is firmly located in the wheel bearing housing, to measure a wheel speed, it needs a matching piece which rotates with the wheel hub. This matching piece is known as the pulse rotor or signal rotor. A magneto-resistive element (semiconductor) in the wheel speed sensor alters its resistance as a function of the magnetic lines of forces intersected by the pulse rotor.

Reader track

Sensor



Wheel bearing

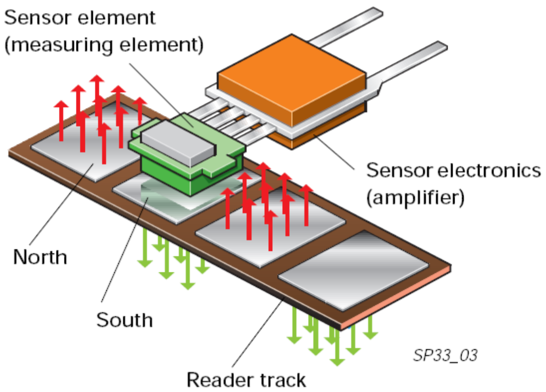
The active sensor is installed in the wheel bearing housing, and integrates the measuring element and amplifier.

The advantages of this system are:

- it is possible to measure the wheel speed from 0 km/h and down to the moment where the wheel is stationary
- a compact design
- high resistance to corrosion
- low level of mechanical interference as the gap remains practically constant
- less susceptible to spurious signals
- it is possible to detect the direction of rotation of the wheel

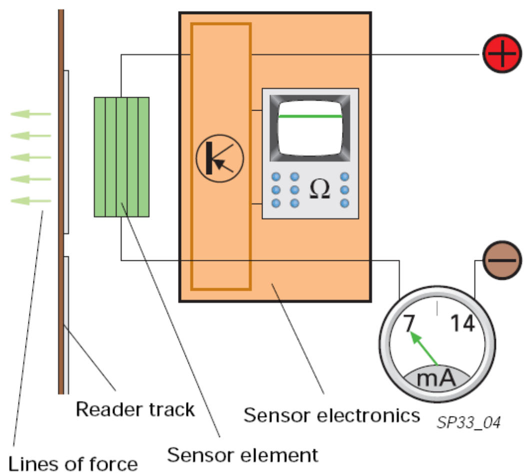
operation

The design of this system can be presented in a simplified form: The reader track contains small areas one next to the other, which are differently magnetised according to North pole and South pole. When the wheel bearing rotates, these areas pass close to the active sensor.

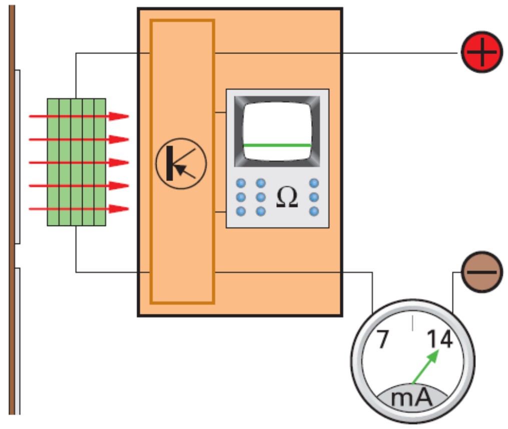


Operation of the active sensor

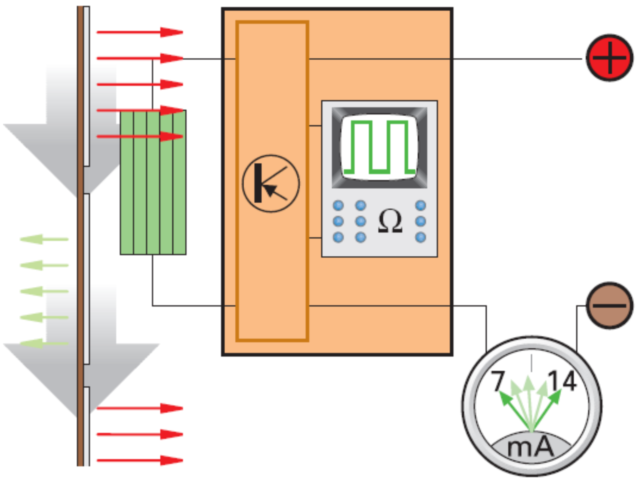
In the immediate vicinity of the magnetised areas, the magnetic lines of force are positioned vertically on the reader track. Depending on the polarity, they either run away from the track, or toward it. As the reader track moves past very close to the sensor, the lines of force also penetrate the sensor and influence its resistance. An electronic amplifier/trigger circuit integrated in the sensor, converts the changes in resistance into two different current levels. What this means is, if the resistance of the sensor element becomes greater because of the direction of the magnetic lines of force which run through it, the current drops.



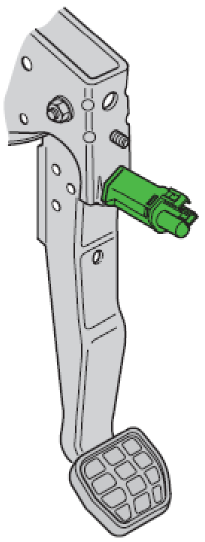
If the resistance becomes less as the direction of the lines of force is reversed, the current rises.



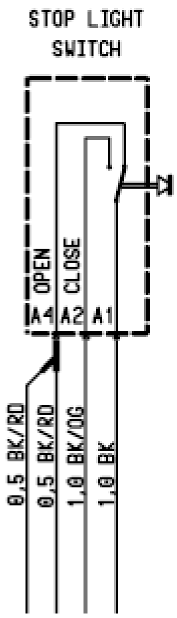
As the North and South poles on the reader track alternate, this produces a square-wave pulse as a result of the trigger circuit, the frequency of which is a measure for the wheel speed.



Brake light switch



The brake light switch is located at the pedal assembly. It operates as a normally-open (NO) contact,
its main function being to switch on the brake lights. The function is used at the same time for transmitting a signal to the ABS control unit.

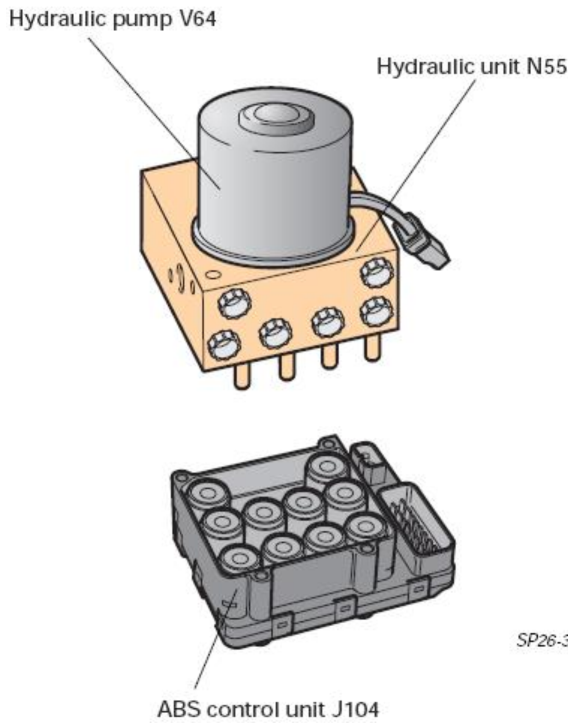


Use of signal

The “Brake operated” signal is required in the ABS control unit for achieving improved comfort during an ABS/EBD control (the brake
pedal pulsates less if the control is more accurate). In the absence of these signals, it would be possible, for example, that the control unit interprets a deceleration of a wheel caused by an uneven road surface as a braking manoeuvre.

Actuators

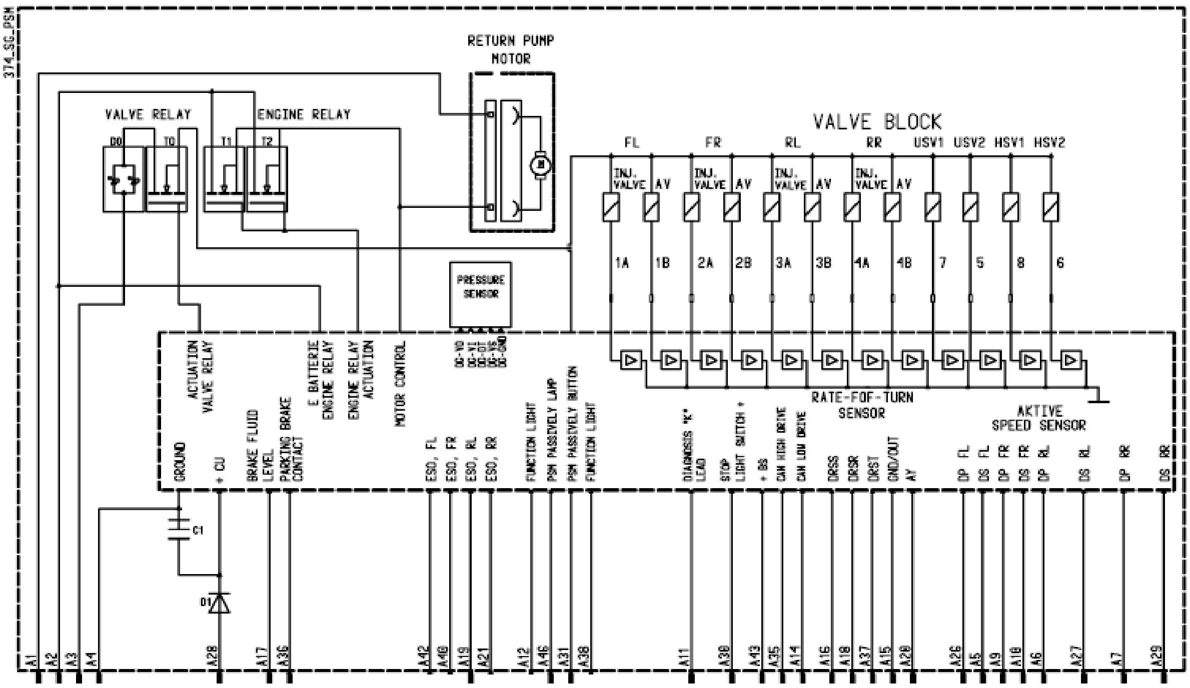
Hydraulic pump



The hydraulic unit contains the control valves of the ABS system which are used to perform the ABS control cycle. The hydraulic ABS energy supply is provided by the hydraulic pump. This operates when a control cycle is detected, draws in brake fluid and pumps it through the open inlet valve to the wheel brake in order to produce the pressure required.

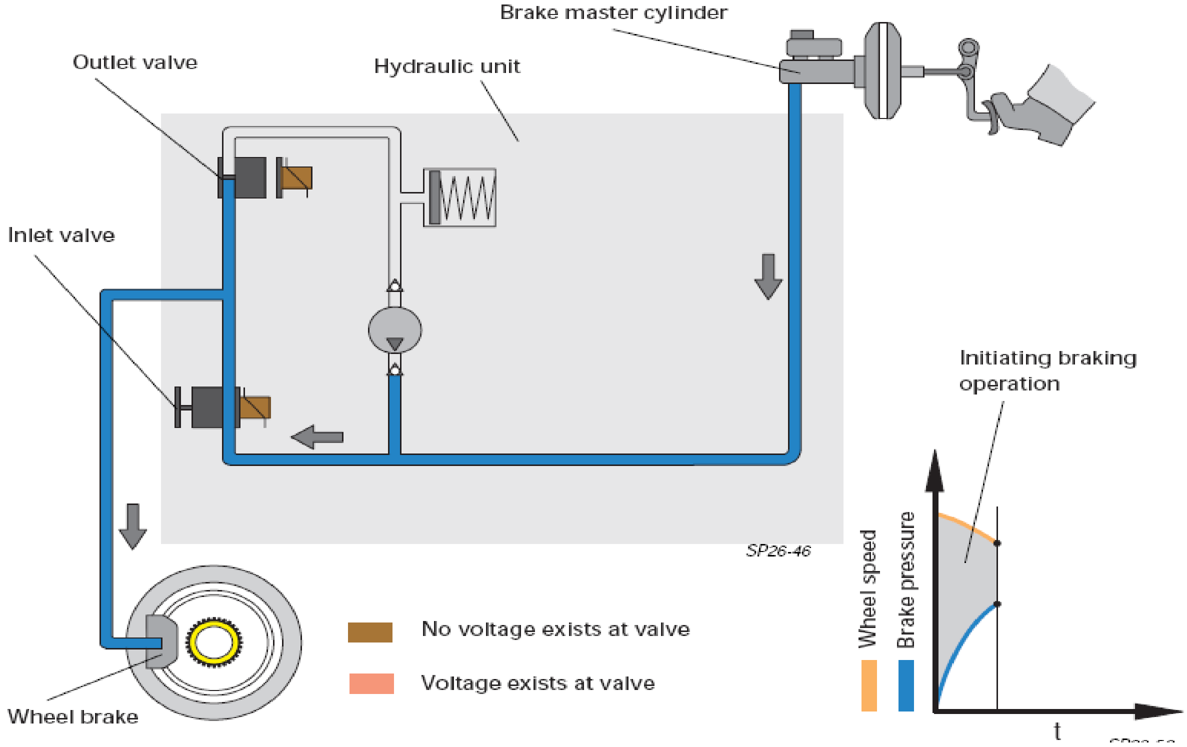
The ABS control unit often forms part of the hydraulic unit.

ABS control unit circuit



Operation – (normal braking phase)

Braking function with antilock control

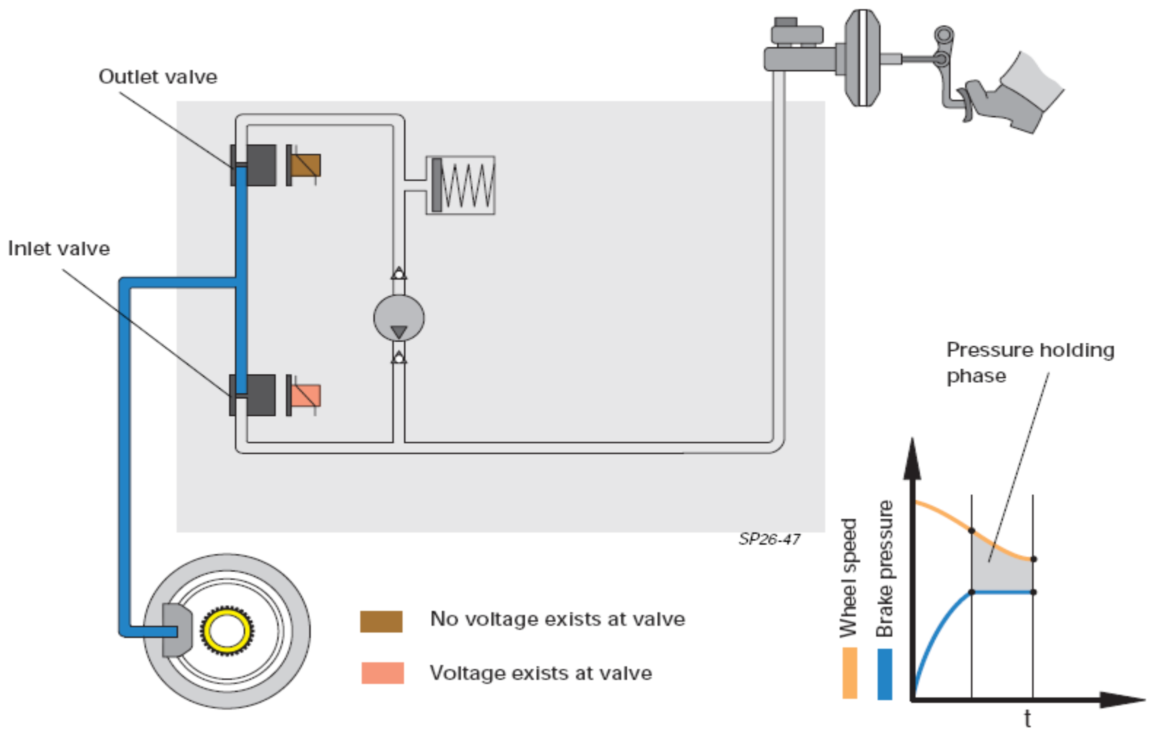


The brake pressure is increased by the brake master cylinder during a brake application. The brake pressure passes through the open inlet valve (de-energised) to the wheel brake. The outlet valve is closed (likewise de-energised).

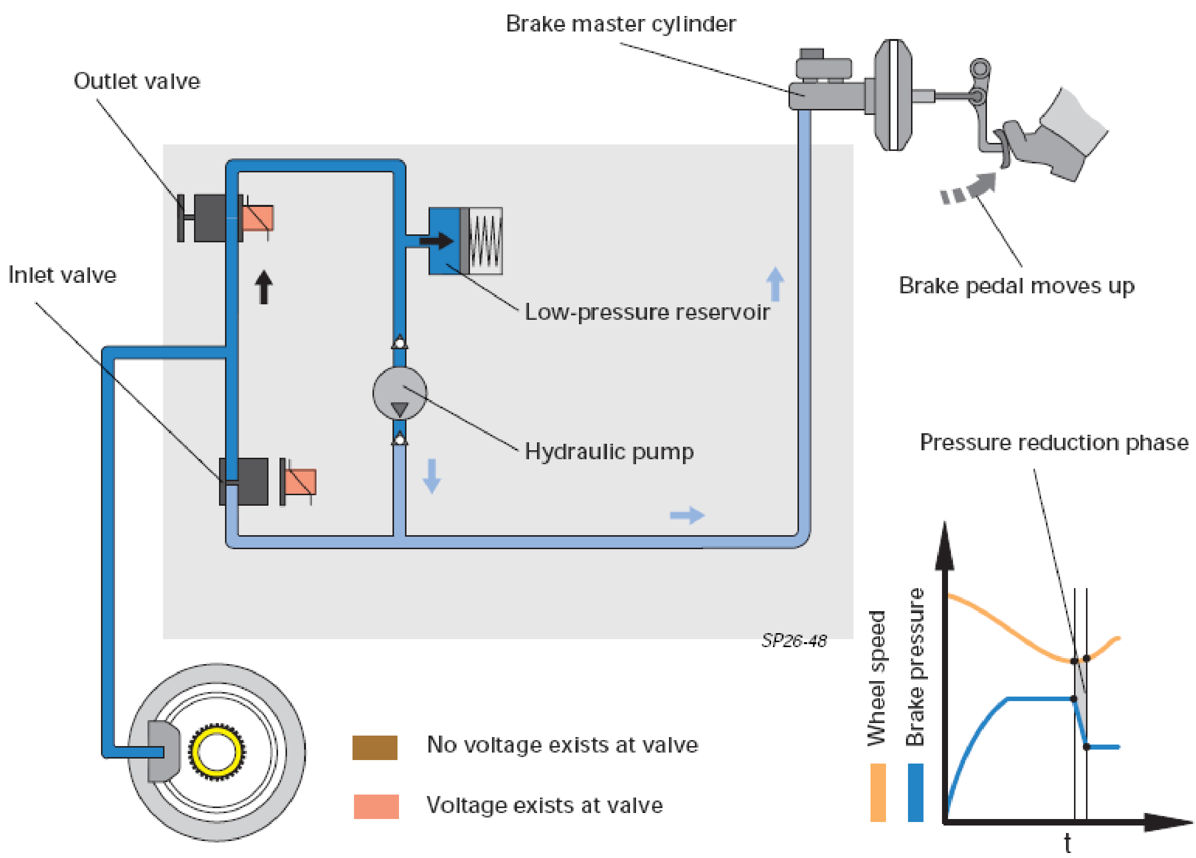
The speed of the wheel continues to reduce until the ABS control unit detects a tendency for the wheel to lock from the signal supplied by the wheel speed sensor.

Operation - (holding Phase)

If a wheel is tending to lock, voltage is applied first of all to avoid any further increase in the brake pressure at the inlet valve. As a result of this, the valve is closed. The outlet valve remains de-energised and is thus also closed.
The brake pressure between the inlet valve and outlet valve remains constant during this phase (pressure holding phase).

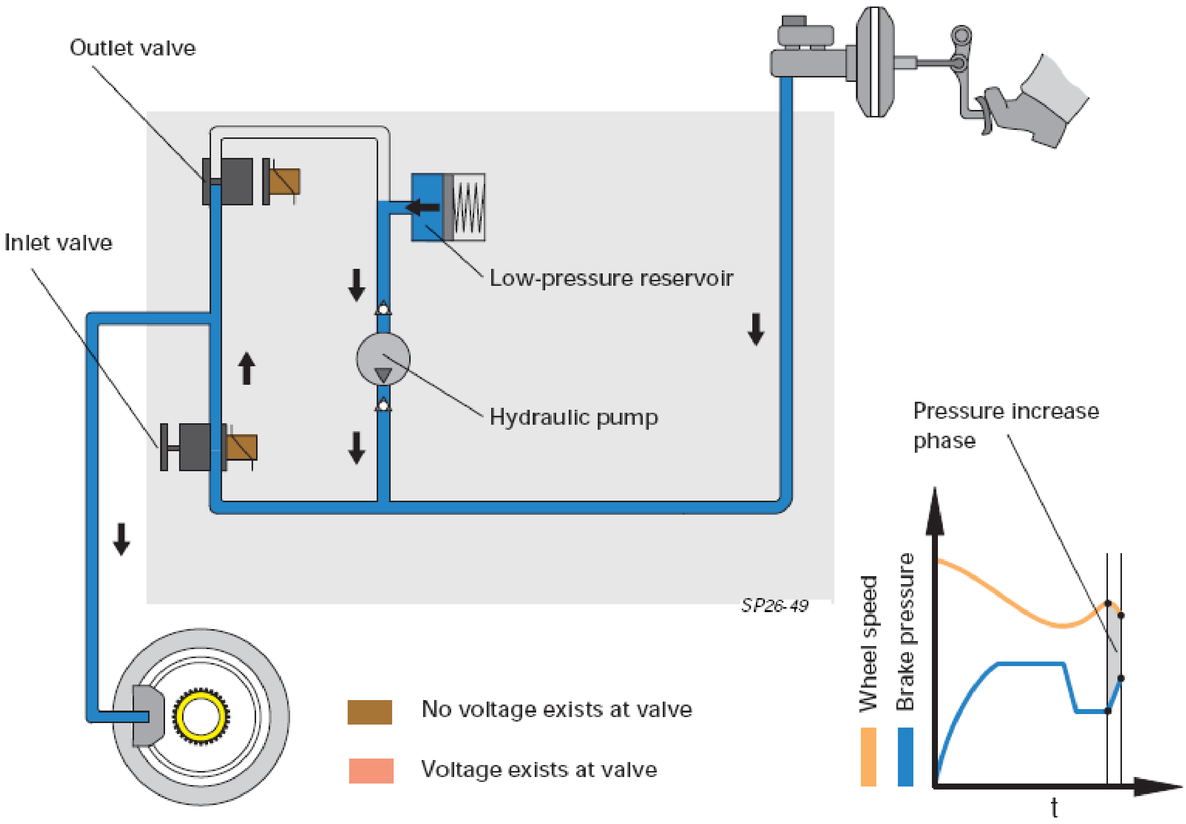


Operation – (pressure reduction phase)



If the speed of the wheel continues to drop although a constant brake pressure exists and the tendency for the wheel to lock also exists, the brake pressure must then be reduced. Voltage is applied to the outlet valve for this purpose. As a result of this, the valve is opened. The brake pressure is reduced through the low-pressure reservoir. The inlet valve continues to be energised and is thus closed.
The hydraulic pump operates and pumps brake fluid out of the low-pressure reservoir into the brake master cylinder. The brake pedal moves slightly up as a result of this. The wheel which is at risk of locking is again is accelerated and gains speed.

Operation – (pressure increase phase)



An increase in the pressure is necessary from a certain wheel speed in order to achieve optimum braking. The inlet valve is de-energised for this purpose. As a result, the valve is opened. The outlet valve is likewise de-energised and is thus closed.
The hydraulic pump continues operating, draws the remaining brake fluid out of the low-pressure reservoir and pumps it into the brake circuit (hydraulic brake servo assistance). The wheel is once again braked as the brake pressure rises. The wheel speed is reduced.

Note:

These control phases of the antilock brake system are repeated several times a second and wheel. They are detectable from a pulsating movement at the brake pedal!

Ongoing technical advances in the motor vehicle industry have seen vehicles with increasing performance and power output come onto the market. Even in the early days, designers were confronted with the question of how to keep this technology manageable for the average driver. In other words: What systems would be required to ensure maximum braking safety and assist the driver? Purely mechanical precursors to the modern-day anti-lock braking system were first conceived as long ago as the 1920s and 1940s. However, these systems were not suited to the task in hand because they were too slow. The electronics revolution in the 1960s made antilock braking systems feasible. Such systems have become more and more efficient with the further development of digital technology. Today, we regard not only ABS, but also systems such as EBD, TCS and EBC, as everyday technology.

What is ESP

The electronic stability programme is one of the vehicle's active safety features. It is also known as a "driving dynamic control system". Expressed in simple terms, ESP is an anti-skid programme. It recognises when the vehicle is in danger of skidding and compensates when the vehicle breaks out.

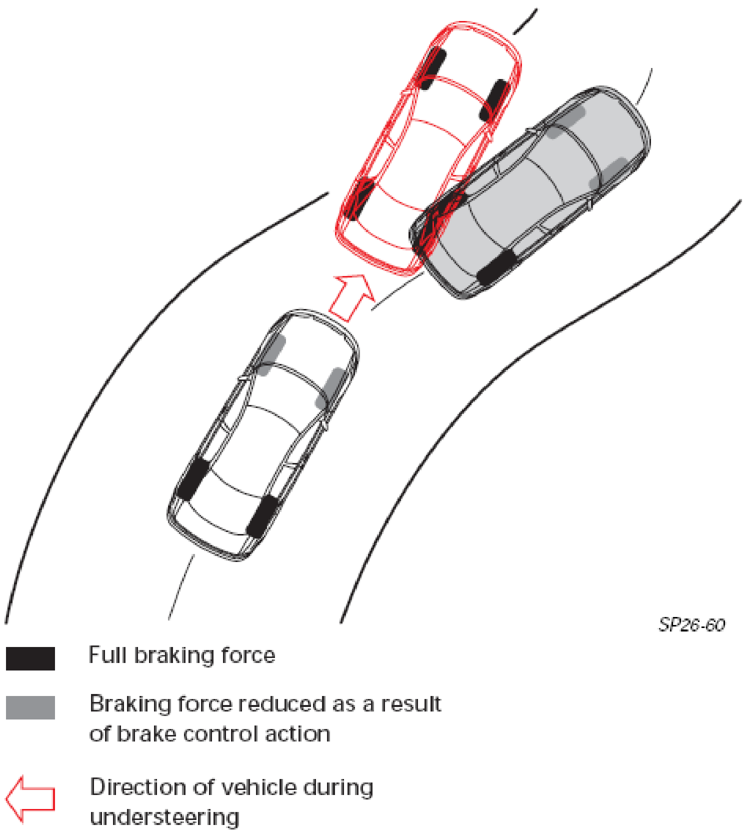
ESP is not an independent system. In fact it is based on other traction control systems. That is why it also includes the performance features of these systems.

- It relieves the burden on the driver.
- The vehicle remains manageable.
- It reduces the accident risk if the driver
- overreacts.

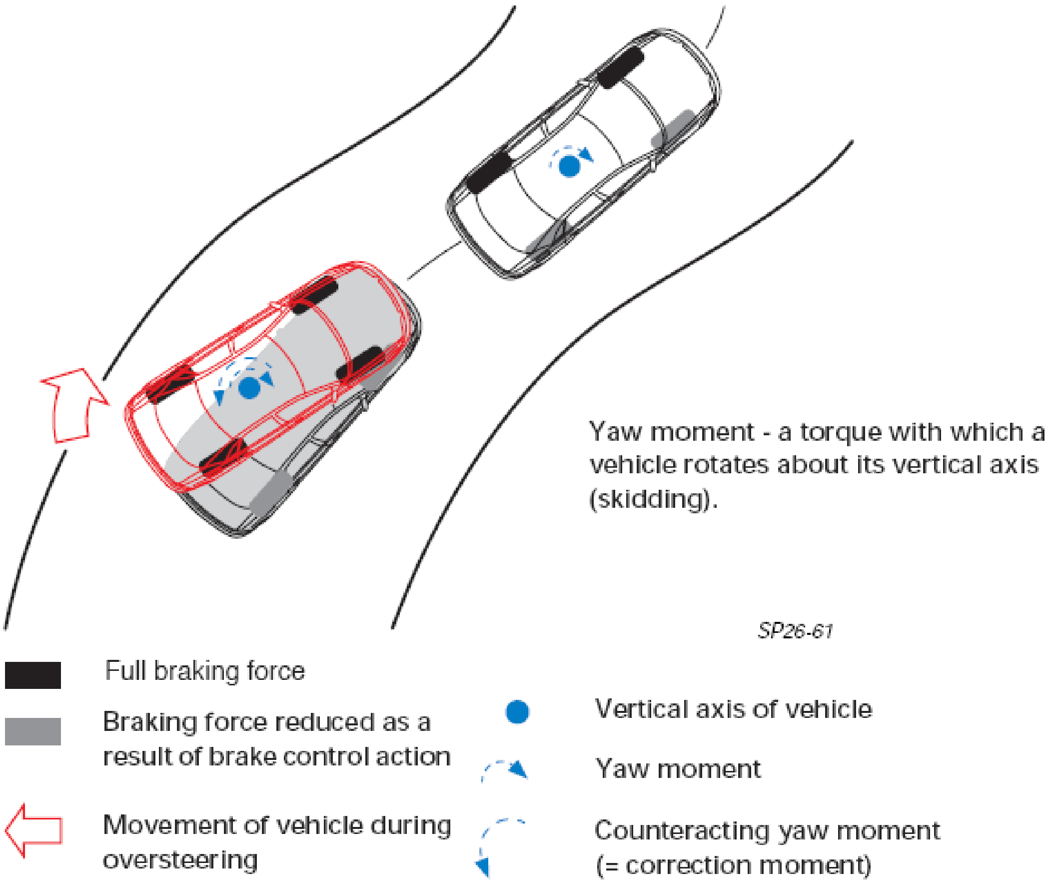
The electronic stability brake system improves directional stability and the steer ability of the braked vehicle by specific control actions at the brakes. It makes use of the sensors and actuators which are familiar from the ABS system.

Understeer

If the vehicle understeers, it is pushed by the front wheels to the outside of the curve (typical for front-wheel drive vehicles).
If a vehicle understeers during a brake application, the maximum cornering force of the front wheels is exceeded. The vehicle is pushed by the front wheels to the outside of the curve.
The ABS control unit detects this situation on the basis of the circumferential velocity of the wheel. Based on this, the braking force at the front wheels is reduced in order to in turn
increase the cornering forces. The vehicle is
stabilised and follows the desired steered direction.



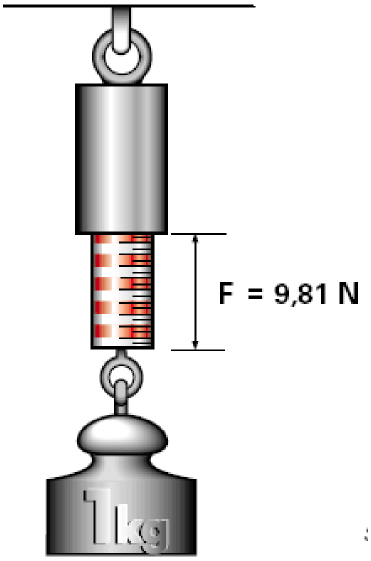
Oversteer



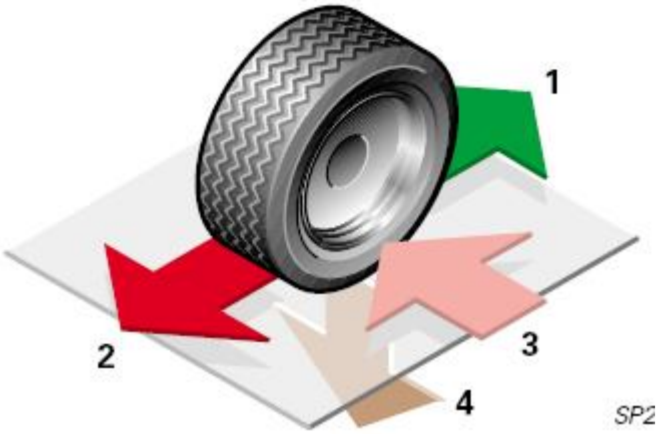
When a vehicle oversteers, the rear of the vehicle breaks away to the outer edge of the corner (typical for rear-wheel drive vehicles). If a vehicle oversteers during a brake application, the maximum cornering force of the rear wheels is exceeded. The vehicle breaks away at the rear wheels to the outside of the corner. The ABS control unit detects this situation on the basis of the reduced rotational velocity at the rear wheels and reduces the braking force at the inside wheels. The cornering forces at the inside wheels are increased; this reduces a counteracting yaw moment and the vehicle is thus stabilised.

Forces and moments

A body is subjected to different forces and moments. If the total of these forces and moments acting in the body is equal to zero, the body is at rest. If the total is not equal to zero, the body is then moved in the direction of the force resulting from the total.
The force with which we are most familiar is the force of gravity of the Earth. It acts in the direction of the centre of the Earth. If we suspend a mass weighing one kilogram from a spring balance in order to measure the forces which exist, what is indicated for us is a value for the force of attraction of 9.81 Newton.

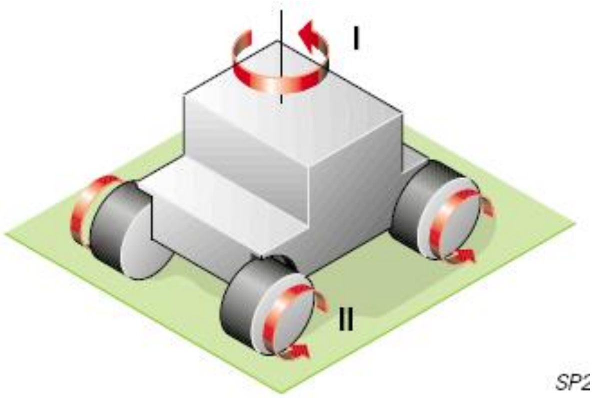


The forces which act on a vehicle, are:
1 the driving force
2 the braking force, which acts in the opposite direction of the driving force
3 cornering forces, which maintain the steerability of the vehicle, and
4 weight (wheel load), which, in combination with the friction, enable the other forces to be active.

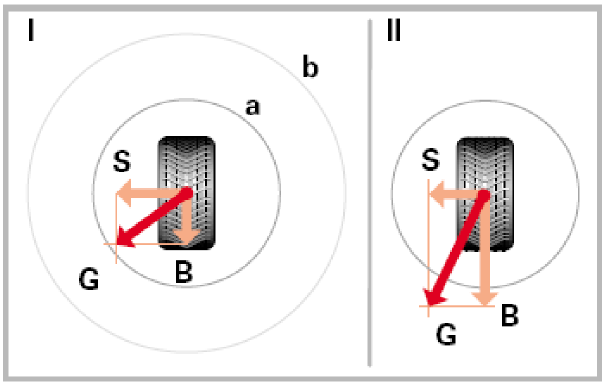


In addition to this, there are the following forces which occur at a vehicle:

– moments, which attempt to turn the vehicle about its vertical, transverse and longitudinal axis
Example I - yaw moment and
– steering moments and moments of inertia, which attempt to maintain a direction of movement once adopted
Example II - wheel moments of inertia as well as other forces such as
– aerodynamic drag, wind force (cross wind), centrifugal force

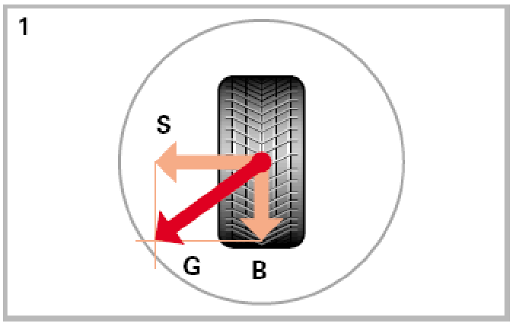


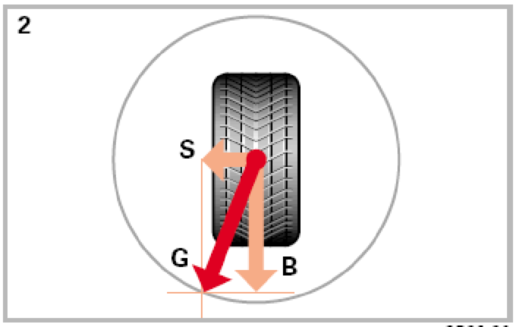
The interaction of certain of these forces can be described with the aid of the friction circle. The radius of this circuit is determined by the adhesion between the surface of the road and tyre. In other words, if adhesion is low, the radius is less than **a**, if adhesion is good, it is greater than **b**. Let us take a look at a wheel of the vehicle for this purpose.



The principle of the friction circle is a force parallelogram made up of the cornering force **S** , the braking or driving force **B** and a resulting total force **G**.
So long as the total force remains within the circle, the vehicle is still within a stable state **I**. The moment the total force extends beyond the circle, the vehicle is now in the state **II** which can no longer be controlled.

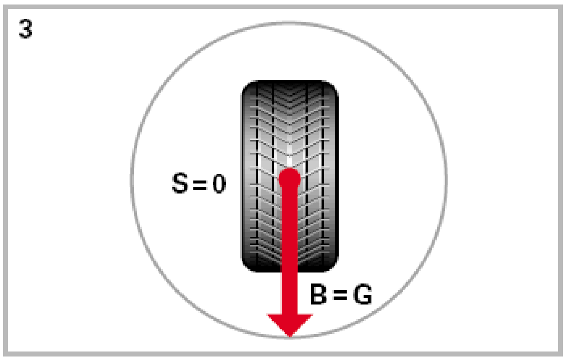
In diagram 1 braking force **B** and cornering force **S** are dimensioned in such a way that the total force **G** is contained within the circle. In this situation it is possible to properly steer the vehicle.



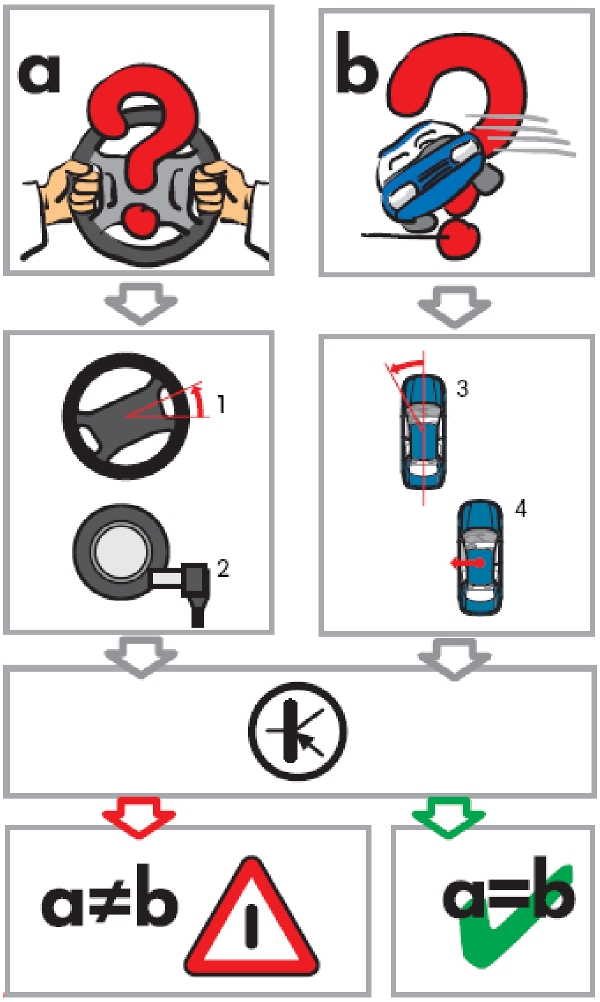


If we increase the braking force **B**. The cornering force **S** will reduce.

In this situation if the total force **G** is equal to the braking force **B**. The wheel locks. In the absence of a cornering force, it is no longer possible to control the vehicle. A similar situation exists between driving force and cornering force. If the cornering forces are reduced to zero by fully exploiting the driving force, the driving wheels spin.



System operating process

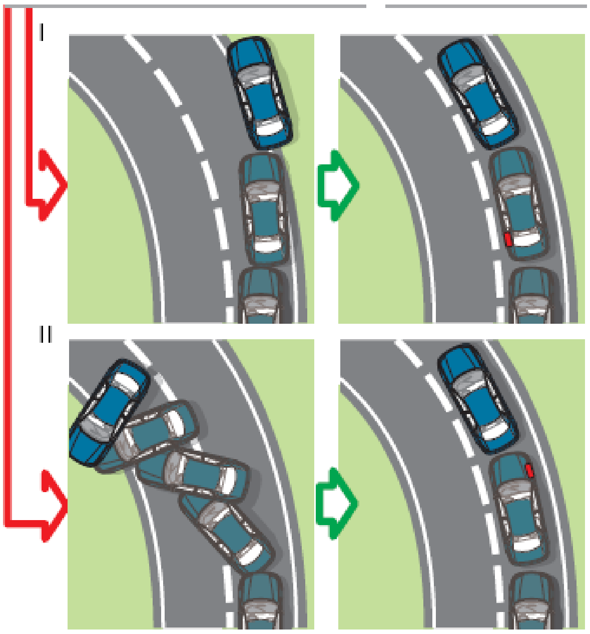


Before ESP can respond to a critical driving situation, it must answer two questions:

a - In what direction is the driver steering?
b - In what direction is the vehicle moving?

The system obtains the answer to the first question from the steering angle sensor (1) and the speed sensors at the wheels (2). The answer to the second question is supplied by measuring the yaw rate (3) and lateral acceleration (4).

If the information received provides two different answers to questions a and b, ESP assumes that a critical situation can occur and that intervention is necessary.



A critical situation may manifest itself in two different types of behaviour of the vehicle:

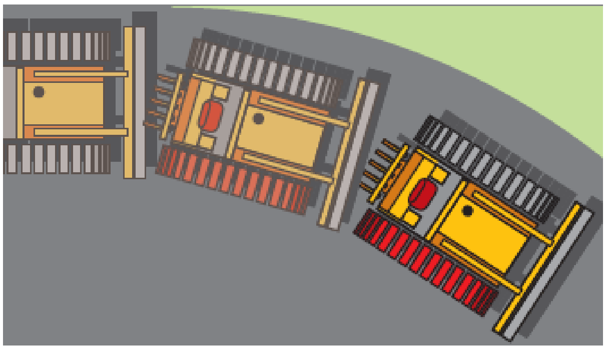
I. The vehicle threatens to understeer.
By selectively activating the rear brake on the inside of the corner and intervening in the engine and gearbox management systems, ESP prevents the vehicle from overshooting the corner.

II. The vehicle threatens to oversteer
By selectively activating the front brake on the outside of the corner and intervening in the engine and gearbox management systems, ESP prevents the vehicle from skidding.

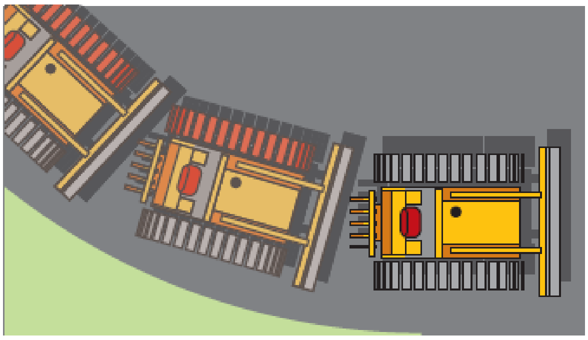
As you can see, ESP can counteract both oversteer and understeer. For this purpose, it is also necessary to initiate a change of direction without direct intervention in the steering.

The basic principle is the same as for tracked vehicles.

When a bulldozer wants to negotiate a left-hand bend, the track on the inside of the corner is braked and the outer track is accelerated.

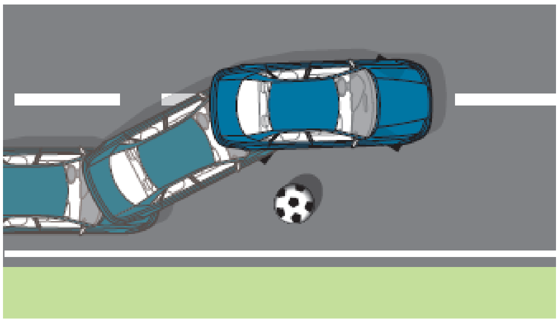


To return to the original direction of travel, the
track which was previously on the inside of the corner and now on the outside of the corner is accelerated and the other track is braked.

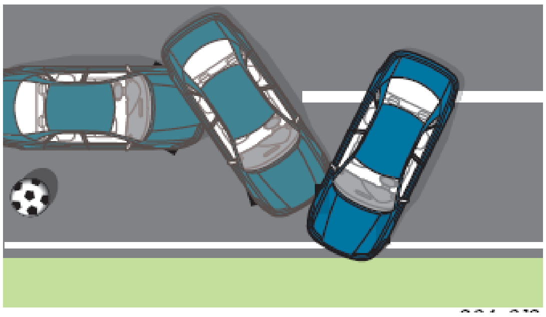


ESP intervenes along much the same lines. Here is an example of how such a situation is handled by a vehicle without ESP.

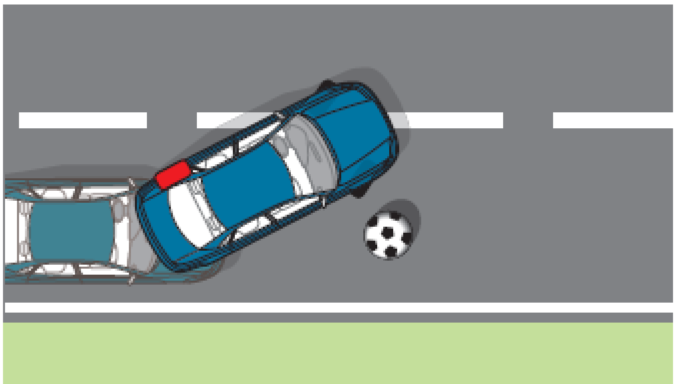
The vehicle must avoid an obstacle which suddenly appears. At first, the driver steers very quickly to the left and to then immediately to the right.



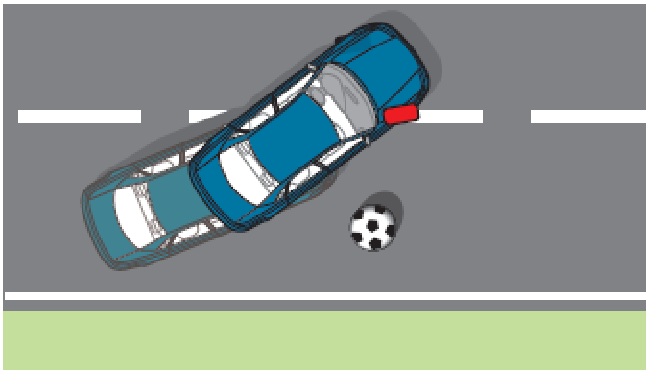
The vehicle swerves due to the drivers steering wheel movements and the rear end breaks away. The driver is no longer able to control the resulting rotation about the vertical axis.



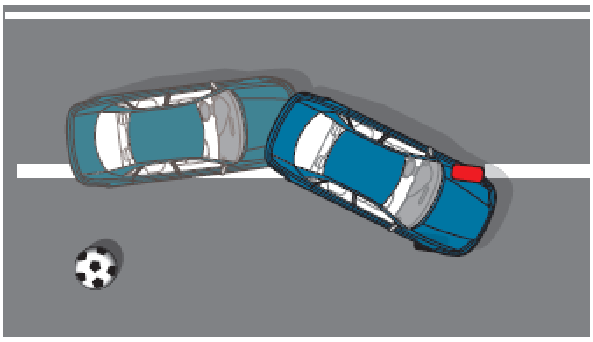
In the following situation the vehicle attempts to avoid the obstacle. From the data provided by the sensors, ESP recognises that the vehicle is losing stability. The system calculates its counteraction measures: ESP brakes the left-hand rear wheel. This promotes the turning motion of the vehicle. The lateral force acting on the front wheels is retained.



As the vehicle swerves to the left, the driver steers to the right. To help the driver steer into the over-steer, the front right wheel is braked. The rear wheels roll freely in order to ensure an optimal build-up of lateral forces acting on the rear axle.

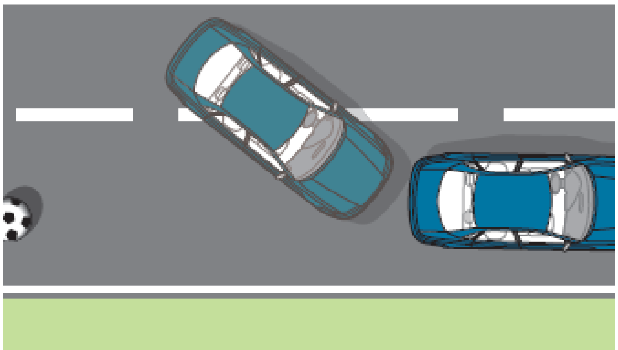


The preceding lane change can cause the



vehicle to roll about its vertical axis. To prevent the rear end from breaking away, the front left wheel is braked. In highly critical situations, the wheel may be braked very heavily in order to limit the build-up of lateral forces on the front axle.

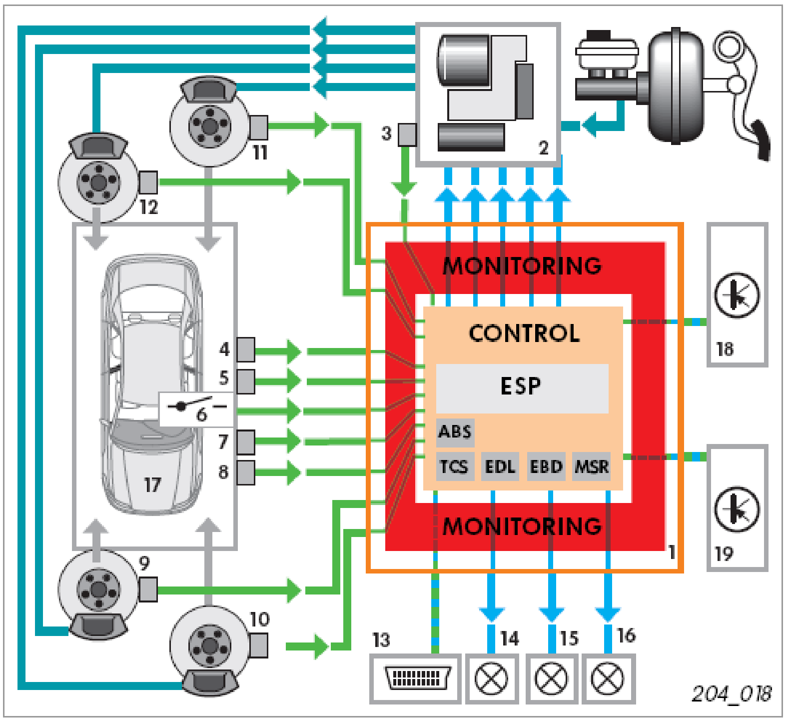
Once all instable operating states have been corrected, ESP ends its corrective intervention.



The system and its components

As mentioned already, the electronic stability programme is based on the proven traction control system.

The system can recognise and compensate for instable vehicle operating states at an early stage, such as skidding.



1 ABS control unit with EDL/TCS/ESP
2 Hydrualic unit with charge pump
3 Brake pressure sender
4 Lateral acceleration sender
5 Yaw rate sender
6 Button for TCS/ESP
7 Steering angle sender
8 Brake light switch

9-12 Speed sensor
13 Diagnosis wire
14 Warning lamp for brake system
15 ABS warning lamp
16 TCS/ESP warning lamp
17 Vehicle and driver behaviour
18 Intervention in engine management
19 Intervention in gearbox control unit (vehicles with automatic gearbox only)

The speed sensors provide a continuous stream of data on speeds for each wheel. The steering angle sensor is the only sensor which supplies data directly via the CAN bus to the control unit. The control unit calculates the desired steering direction and the required handling performance of the vehicle from both sets of information. The lateral acceleration sensor signals to the control unit when the vehicle breaks away to the side, and the yaw rate sensor signals when the vehicle begins to skid. The control unit calculates the actual state of the vehicle from these two sets of information. If the nominal value and actual value do not match, ESP performs corrective intervention calculations.

ESP decides:

- what wheel to brake or accelerate and to what extent,
- whether engine torque is reduced and
- whether the gearbox control unit is activated on vehicles with automatic gearbox.

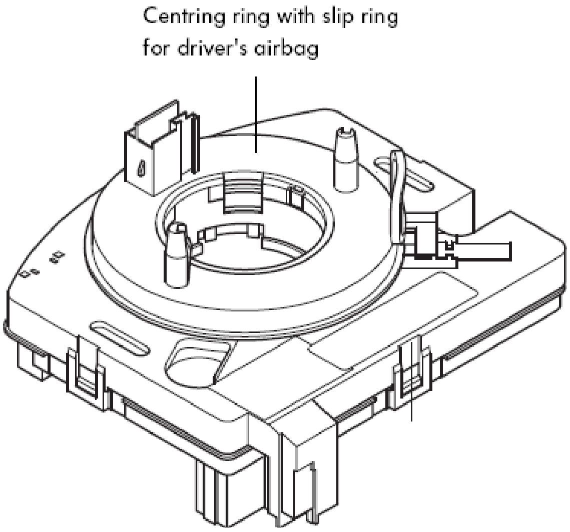
The system then checks to see if intervention was successful from the data it receives from the sensors. If this is the case, ESP ends intervention and continues to monitor the vehicle's handling characteristics. If this is not the case, the intervention cycle is repeated.
When corrective intervention is taking place, this is indicated to the driver by the flashing ESP lamp.

Additionally required sensors

Steering angle sensor

is mounted on the steering column between the steering column switch and the steering wheel. The centring ring with slip ring for the airbag is integrated in the steering angle sender and located on the base of the steering angle sender. Task
The sender transfers the steering wheel lock angle to the ABS control unit with ESP.

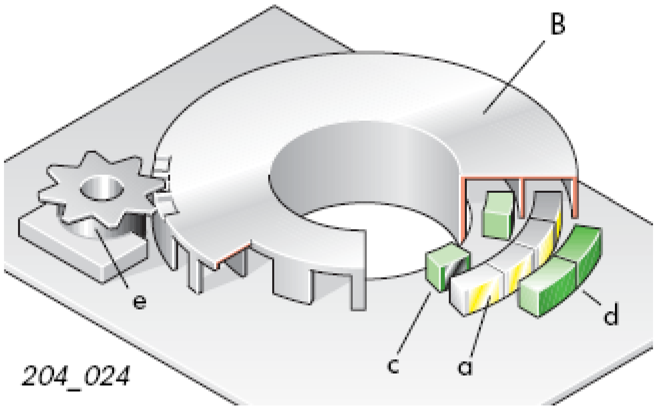
An angle of ±720 ° corresponds to four full turns of the steering wheel.



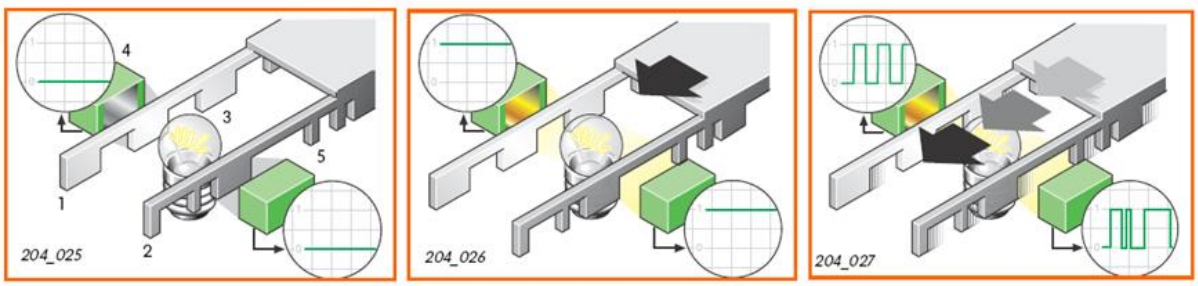
The angle is measured using the principle of the light barrier.
The basic components are:

- a light source (a)
- an encoding disc (b)
- optical sensors (c+d) and
- a counter (e) for full revolutions

The encoding disc comprises two rings: the absolute ring and the incremental ring. Both rings are scanned by two sensors each.



We can simplify the setup by arranging an incremental hole template (1) and an absolute hole template (2) side by side. The light source (3) is positioned in between the hole templates.
The optical sensors (4+5) are located on the outside. Light impinging on a sensor through a gap generates a signal voltage. If the light source is covered, the voltage breaks down again. Moving the hole templates produces two different voltage sequences. The incremental sensor supplies a uniform signal, since the gaps follow each other at regular intervals. The absolute sensor generates an irregular signal, since light passes through the gaps in the template at irregular intervals. By comparing both signals, the system can calculate how far the hole template has moved. The absolute part determines the starting point of the movement. Designed for only one turning motion, the steering angle sender uses the same principle.

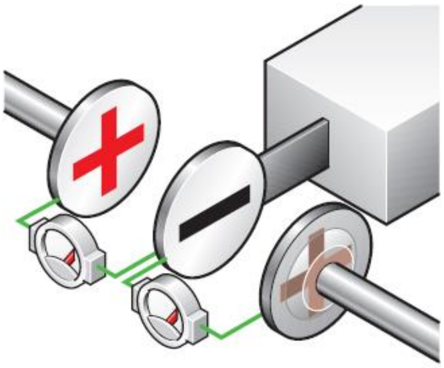


Lateral acceleration sender

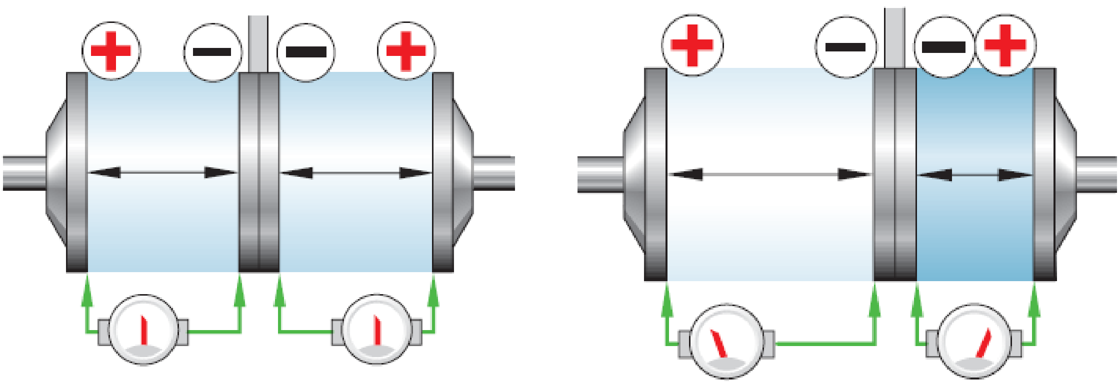
For physical reasons, this sensor should be as close to the centre of gravity of the vehicle as possible. Under no circumstances may the fitting location and alignment of the sensor be changed. Without the measurement of lateral acceleration, the actual vehicle operating state cannot be calculated in the control unit. The ESP function fails.

The lateral acceleration sender operates according to a capacitive principle. What does this mean?

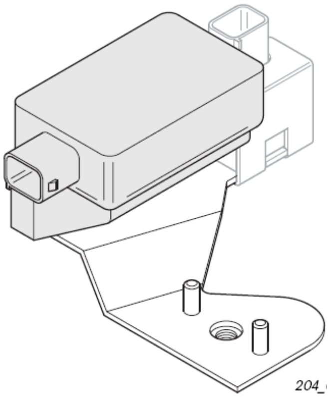
Imagine that the sensor comprises two capacitors connected in series. The common, central capacitor plate can be moved by applying a force. Each capacitor has a capacitance, i.e. it can absorb a certain amount of electric charge.



As long as no lateral acceleration is acting on the central plate, the gap between the central plate and the outer plates remains constant, with the result that the electrical capacitance of the two capacitors is equal. If lateral acceleration acts on the central plate, the one gap increases and the other decreases. The capacitance of the partial capacitors also changes. The electronics can determine the direction and quantity of lateral acceleration from a change in capacitance.



Yaw rate sensor

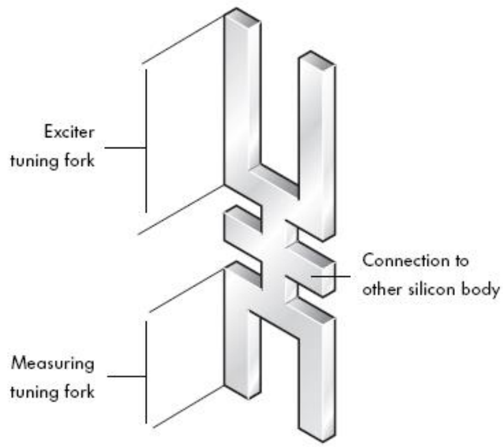


This sensor is also installed as close to the vehicle's centre of gravity and is often fitted with the lateral acceleration sensor, on a bracket.

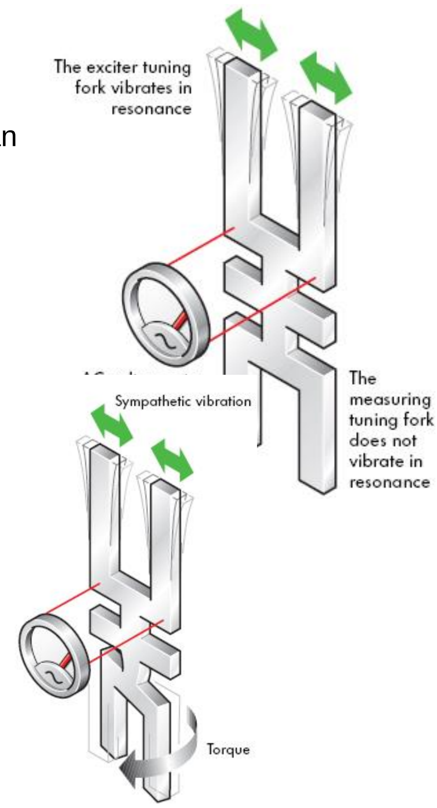
Operation

The yaw rate sensor ascertains whether torque is acting on a body. Depending on the installation position, it can detect rotation about one of the axes in space. In the ESP, the sensor must determine whether the vehicle has rotated about its vertical axis. This process is known as measuring the yaw rate.

Without the measurement of the yaw rate, the control unit is unable to ascertain whether the vehicle has begun to swerve. The ESP function fails.
The yaw rate sensor is a fundamental component of ESP. It is a micromechanical system with a double tuning fork comprising a silicon crystal housed in a small electronic component on the sensor board. below is a simplified drawing of the double tuning fork. Its mid-section is connected to the other silicon element which we have ommited here for the sake of clarity.
The double tuning fork comprises an exciter tuning fork and a measuring tuning fork.



Applying an AC voltage induces a sympathetic voltage in the silicon tuning fork. The two halves are matched so that the exciter tuning fork has a resonance vibration at exactly 11kHz and the measuring tuning fork at 11.33kHz. Applying an AC voltage at a frequency of exactly 11 kHz to the double tuning fork induces sympathetic vibration in the exciter tuning fork, but not in the measuring tuning fork. A tuning fork vibrating in resonance reacts more
slowly to the application of force than a non-oscillating mass.



This means that, whereas angular acceleration causes the other half of the double tuning fork and the remainder of the sensor together with the vehicle to move, the oscillating part of the double tuning fork lags behind this movement. As a result, the double tuning fork becomes twisted like a corkscrew. The twisting effect changes the charge distribution in the tuning fork. This is measured by electrodes, evaluated by the sensor electrics and transmitted to the control unit in the form of a signal.

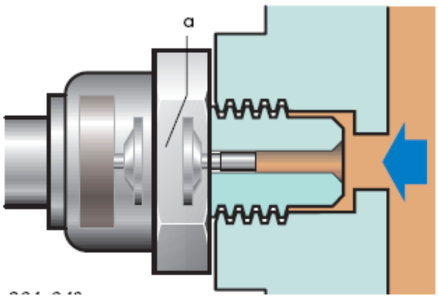
Brake pressure sender

This system features two sensors that are bolted to the tandem master cylinder.

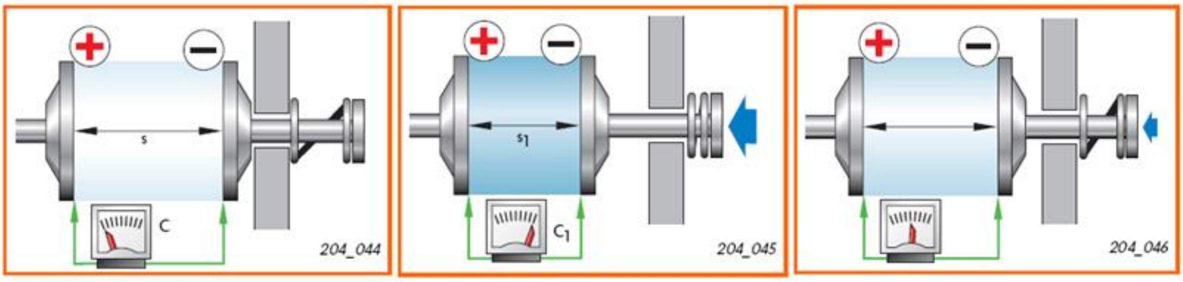
operation

To ensure maximum safety, there are two brake pressure senders. As with the BOSCH ESP system, the task of this system is to supply measured values for calculating the braking force and for controlling the pre-charging function.

Both sensors are capacitive-type sensors. For the sake of clarity, we are using here a simplified diagram of the plate capacitor in the interior of the sensor (a) on which brake fluid pressure can act.



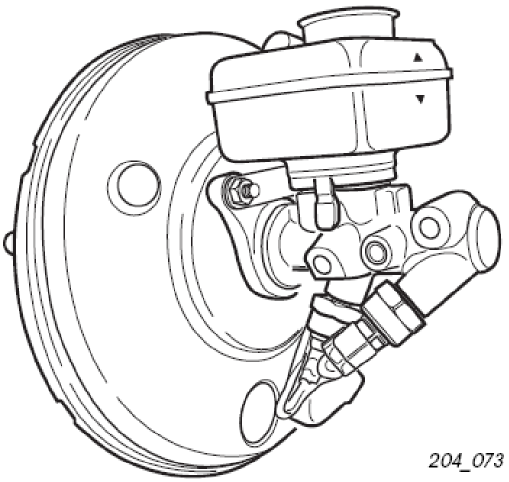
Due to the gap (s) between the two plates, the capacitor has a defined capacitance C. This means that it can absorb a certain amount of electric charge. Capacitance is actually measured in Farads (named after Michael Faraday)
One plate is fixed, the other can be moved by brake fluid pressure.

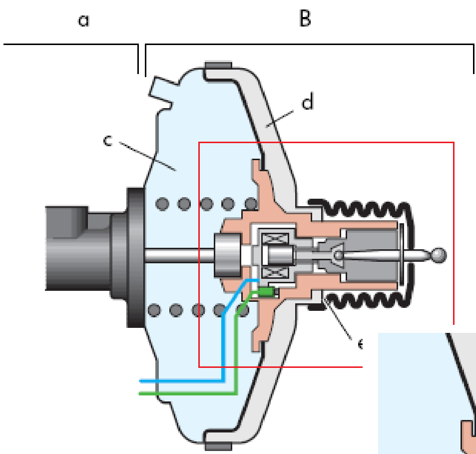


When pressure acts on the movable plate, the gap (s1) between the two plates becomes smaller and the capacitance C1 increases. If the pressure drops again, and the plate moves back. The capacitance is again low. A change in capacitance is therefore a direct measure of pressure change.

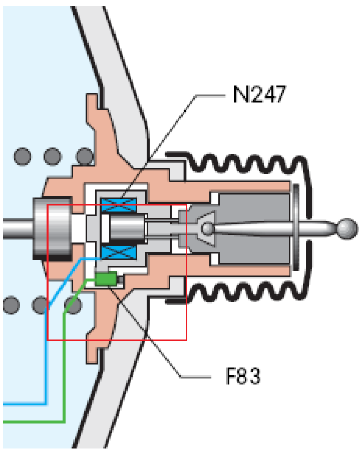
Active brake servo

The active brake servo or booster differs fundamentally from the previous model. Over and above the usual function, i.e. increasing the foot pressure on the brake pedal by means of a partial vacuum which is generated by the intake manifold or from a vacuum pump, the active brake servo assumes the task of building up the pre-pressure for ESP intervention. This is necessary since the intake capacity of the return flow pump is not always sufficient to generate the required pressure. The reason for this is the high viscosity of the brake fluid at low temperatures.





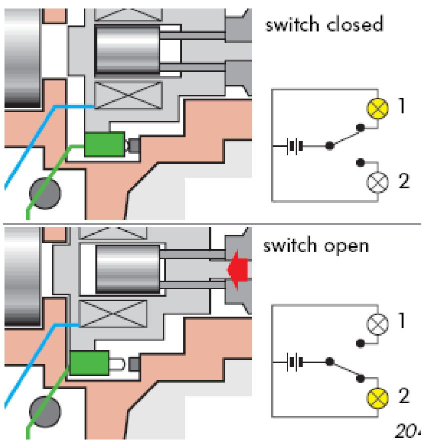
The booster comprises a modified tandem master cylinder (a) and the brake servo (b). The brake servo is subdivided into a vacuum part (c) and a pressure part (d) which are separated by a diaphragm. It also has a valve piston and magnet unit (e).



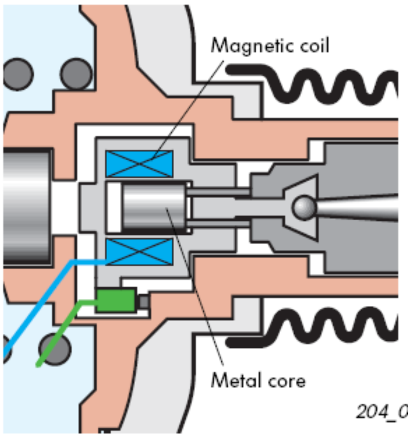
The valve piston and magnet unit is electrically connected to the ESP system.
It comprises:

- ESP brake recognition switch
- magnetic coil for brake pressure
- various air ducting valves

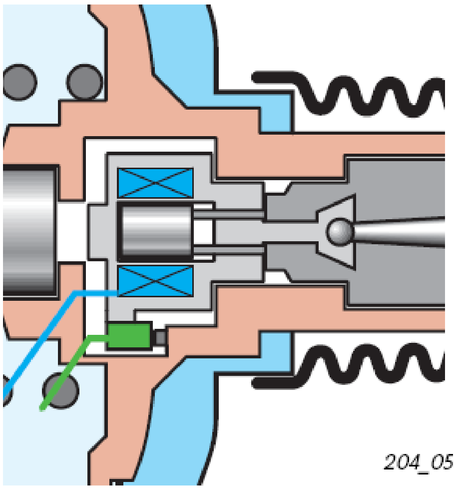
The ESP brake recognition switch is also known as the "release switch". It is a two-way switch.
If the brake pedal is not activated, the mid position contact is connected to signal contact 1. If the pedal is activated, signal contact 2 closes. Since only one contact is always closed, the signal which the switch generates is always clearly defined.
The release switch therefore offers a high level of intrinsic safety.



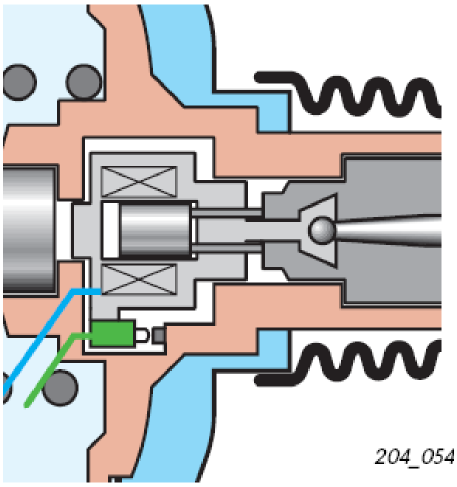
Operation of valve piston and magnet unit



The valve piston and magnet unit produce the pre-pressure of 10 bar which is required on the suction side of the return flow pump even if the brake pedal is not operated by the driver.
If the system recognises that ESP intervention is necessary and that the driver has still not activated the brake pedal, the control unit for ABS/TCS and ESP activates the magnetic coil for brake pressure.



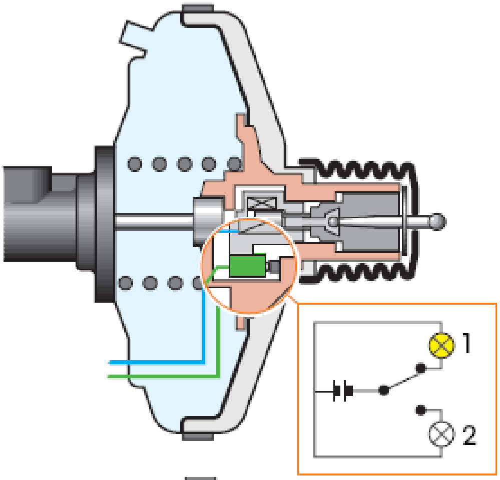
A magnetic field is built up inside the magnetic coil and draws a metal core into the coil. This movement causes the valves within the valve piston and magnet unit to open. A quantity of air sufficient to build up the required pre-pressure of 10 bar then flows into the brake servo.



If the nominal pre-charging pressure is exceeded, the electric current supply to the magnetic coil is reduced. The metal core retracts from the coil and the pre-pressure drops. On completion of the ESP control cycle or when the brake is operated by the driver, the control unit switches the magnetic coil off.

Function of ESP brake recognition switch

The brake recognition switch informs the ESP system when the driver applies the brakes. If the mid-position contact in the switch is closed at signal contact 1, the system assumes that it has to generate the necessary pre-pressure by itself.



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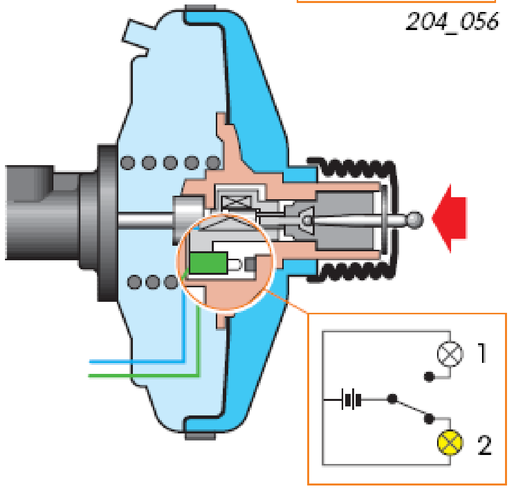
When the driver operates the brake pedal, the magnetic coil is moved in the direction of the master brake cylinder. This causes the mid-position contact in the switch to change over from signal contact 1 to signal contact 2, indicating to the system that the driver has applied the brake. Since the required pre-pressure is now generated by the driver depressing the pedal, the magnetic coil need not be activated.



Electronic parking brake systems (EPB)

An excellent example of this new use of technology, is the parking brake, although originally known to most of us as a "handbrake", (the name "parking brake" was required to encompass the fact that this method of locking the wheels, could be achieved by the use of a foot operated lever in addition to the hand controlled mechanism). Most manufacturers now include an electronic parking brake system on at least one of their current models, the primary purpose of which, is to ensure that the driver has total confidence in the ability of the parking brake to "hold" the car securely on any incline regardless of the total load being carried by the vehicle.

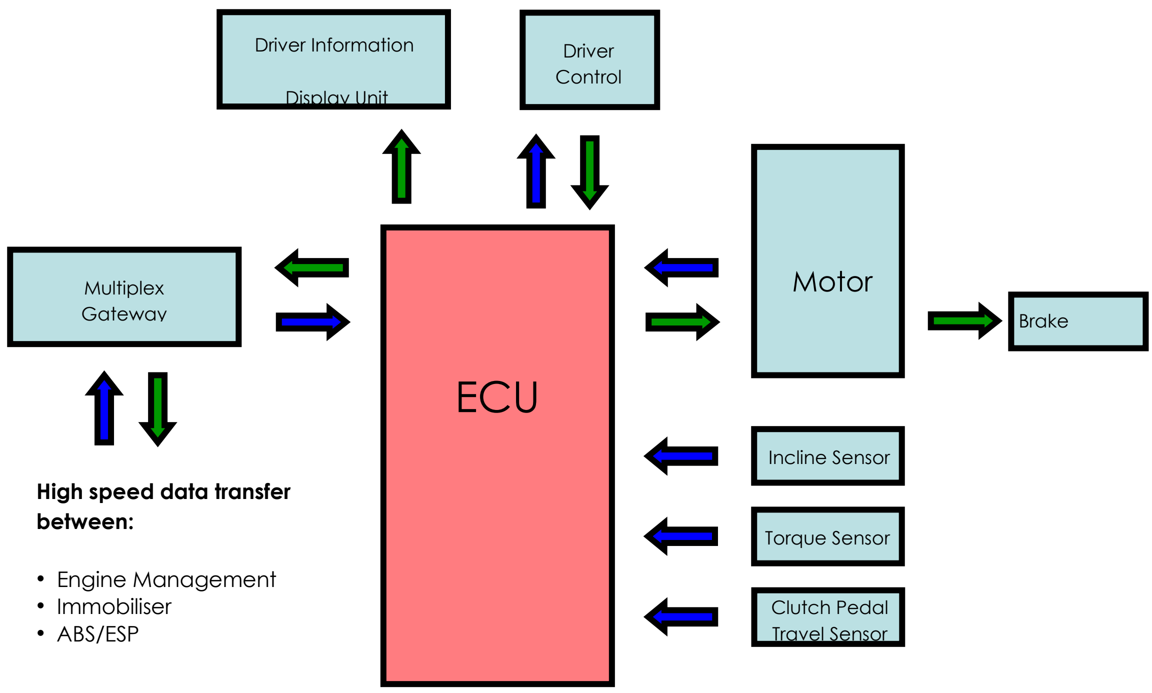
EPB systems enable the driver to apply and disengage the parking brake by the simple touch of a button, additional features can include:

- hill start assistance (automatic release)
- automatic operation in stop-go traffic
- application of parking brake when the ignition is turned off (automatic application)
- brake pad wear indication
- links to vehicle immobiliser function
- re-application of tension as the brake discs cool down
- manual override to allow the driver to apply maximum tension to the parking brake

whilst by no means exhaustive, this list gives us a clear indication of how sophisticated EPB systems can be.

EPB system overview

Depending upon the specific vehicle layout (below) and the different features that have been included by the OEM, the EPB will use an electronic control unit (ECU), an electric motor, brake cables, a cable tension or torque sensor, a vehicle incline sensor, driver application/release control switch and an emergency release mechanism.



EPB system operation

Beginning with the most basic type of EPB, the system operation is very simple. When the driver starts the engine, the EPB controller receives a " wake up" signal from the engine management ECU, at this stage the EPB is ready to operate. As the driver increases the engine revs and begins to release the clutch pedal the EPB motor gradually releases the tension on the park brake cables until the wheels are free to turn. The engine speed information comes from the engine management ECU, via the multiplex network, whilst clutch movement data can come directly from a clutch pedal travel sensor. For vehicles fitted with an automatic transmission (AT), the clutch pedal travel sensor input is replaced by a " point of drive" signal from the AT controller.

Once the vehicle comes to rest, the park brake will either be applied automatically, or the driver will be required to apply it by manually operating the EPB switch.

In some vehicles, the park brake is always applied to a maximum torque, that is somewhere in the region of 1500 Newtons. Other systems though, are far more sophisticated and will only apply a very precise torque value, that has been calculated by the EPB controller. This calculation is carried out by using data pre-programmed to the ECU (the total unladen weight of the vehicle) along with voltage signal inputs from a vehicle incline sensor and the park brake cable torque sensor, both of which are usually located inside the EPB motor assembly.
For those vehicles that are capable of varying the amount of torque applied to the cables, the driver is provided with the ability to manually apply maximum torque, simply by holding the EPB switch for a longer period of time (normally about 3 seconds). This facility would become necessary when towing a trailer, or if the vehicle was being parked on a car ferry where the vehicle's inclination value would vary with the movement of the sea.

The ECU will be linked to all of the other relevant electronic systems via a CAN bus (Controller Area Network) or similar high speed multiplex network, this will ensure that when the engine is turned off and the immobiliser is enabled, the park brake can be held securely on, until the EPB controller receives a “release” command from the engine immobiliser.

Other such high speed data links will include a connection to the ABS controller where wheel movement can be monitored for up to 24 hours. This will ensure that even the slightest amount of vehicle creeping, is detected and then countered immediately by commanding the EPB motor to increase the torque value that has been applied to the parking brake cables.

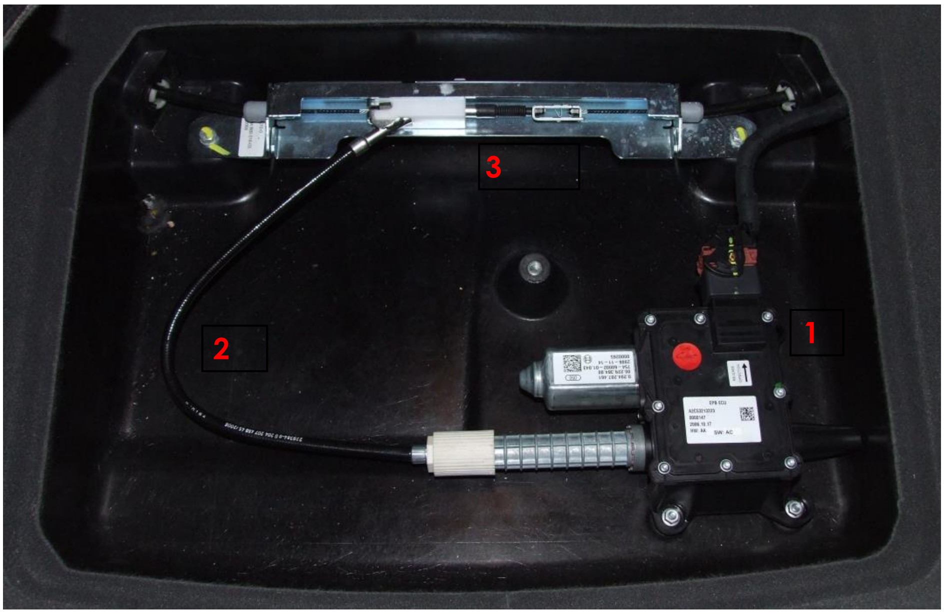
Having now seen how the system operates on different vehicles, it is easy to understand the ways in which drivability can be increased by simple changes to the EPB controller software. For example it could be programmed to apply the park brake as soon as the vehicle has been stationary for more than 3 seconds, thus providing automatic assistance in traffic.

EPB emergency release

In the unlikely event of a vehicle failure, such as a flat battery, it will be necessary to manually release the park brake cable tension to allow the car to be moved to safety.
Whilst on some systems it is possible to wind the calipers back, others provide a mechanical release cable that enables, even the driver to effectively unhook the park brake cables.
Whichever method is employed on the system that you are working on, it will need to be reset. This will be carried out, either by the dealer or automatically as the system initiates a reset procedure whilst the vehicle is being driven down the road.

MASERATI EHB System

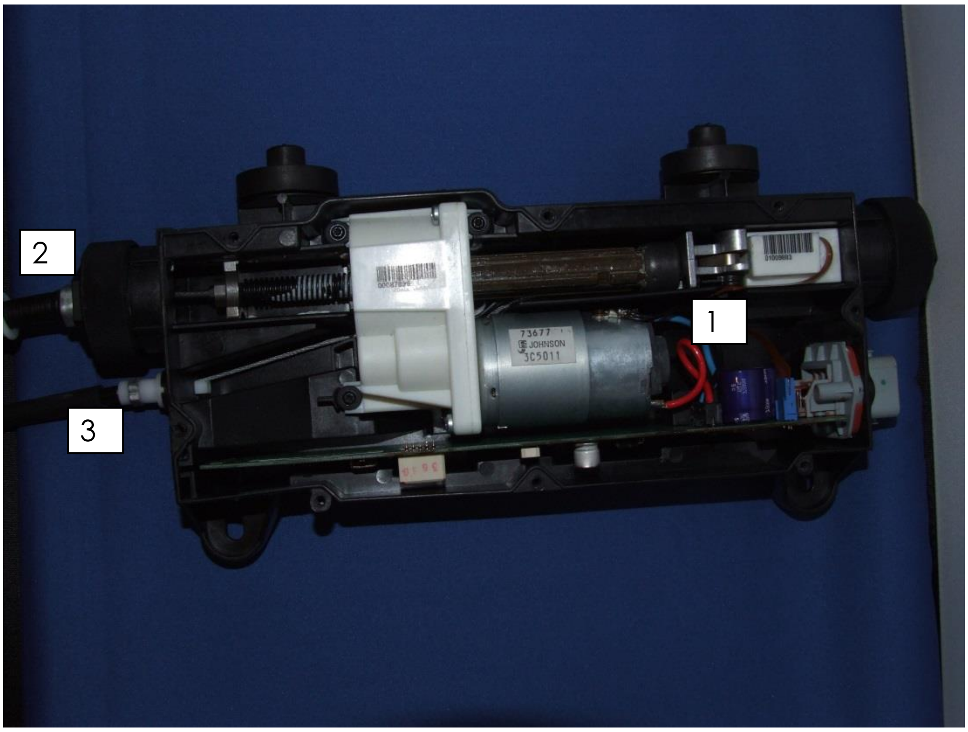
This is a basic system that provides the driver with an automatic release function whilst application of the park brake is via manual control of the EHB switch. Manual release of the calipers has to be carried out by the dealer.



1 = EPB controller and motor assembly
2 = EPB actuation cable
3 = Park brake cable compensator unit

Renault EHB System

This is a more sophisticated system that applies a variable torque to the cables, it also provides the driver with a manual over-ride that allows maximum torque to be applied. It has an emergency release mechanism that can also be operated by the driver.



1 = EPB controller and motor assembly (including cable torque sensor and vehicle incline sensor).

2 = EPB actuation cable

3 = Park brake emergency release cable