Service.

Self-Study Programme 275

The Phaeton
Air Suspension with Controlled Damping

Design and Function

Contact between the road and the vehicle is established by the components of the suspension system.
Requirements for maximum comfort for vehicle occupants, optimum driving safety and minimum noise transmission from the road to the vehicle interior place heavy demands on the suspension system's designers.

Vehicles expected to meet high standards of comfort therefore represent a special challenge which entails reaching a compromise between the various requirements on the suspension system.

One solution is a controlled running gear comprising ...

– a full load-bearing self-levelling suspension system 4-Corner Air Suspension (**4CL**)

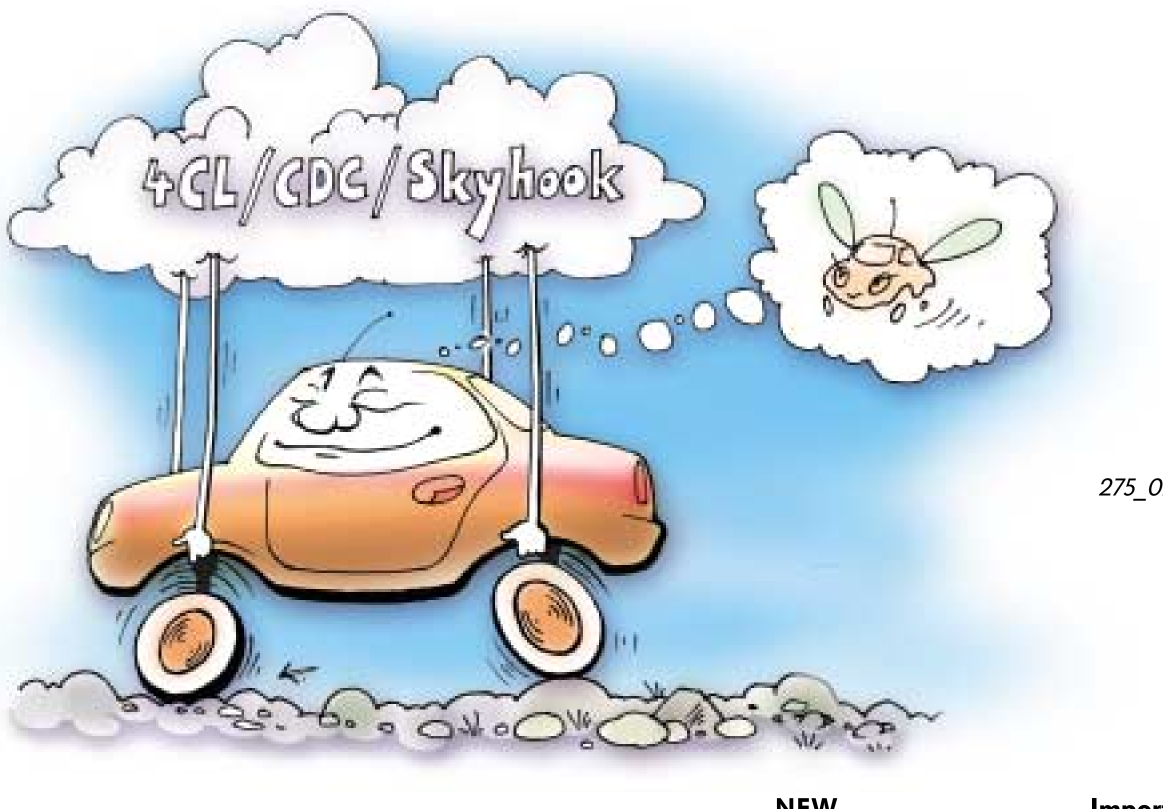
  in combination with

– **C**ontinuous **D**amping **C**ontrol (**CDC**).

  Control takes place based on the "skyhook control strategy".

A running gear design of this type is being used for the first time by Volkswagen in the Phaeton.

The system is described in this Self-Study Programme.



275_024

NEW

Important Note

This Self-Study Programme explains the design and function of new developments! The contents will not be updated.

Please refer to the relevant Service Literature for up-to-date inspection, adjustment and repair instructions.

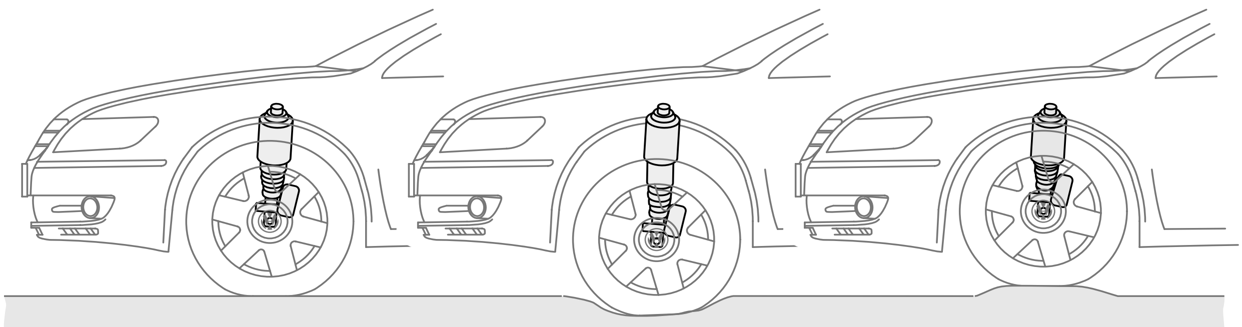
Contents

Basics of spring/damper system

Vehicle suspension

When moving, external forces and impacts act on the vehicle, producing movements and vibrations in the direction of the vehicle's three spatial axes (transverse, longitudinal and vertical axes). The aim is to minimise the impact of these forces on driving comfort, driving safety and operating safety by striking a good balance between the suspension system and the vibration damping system.

A basic distinction can be drawn between the suspension system and the vibration damping system.
The task of both systems is to absorb and reduce the forces produced and, if possible, to keep them away from the vehicle body.

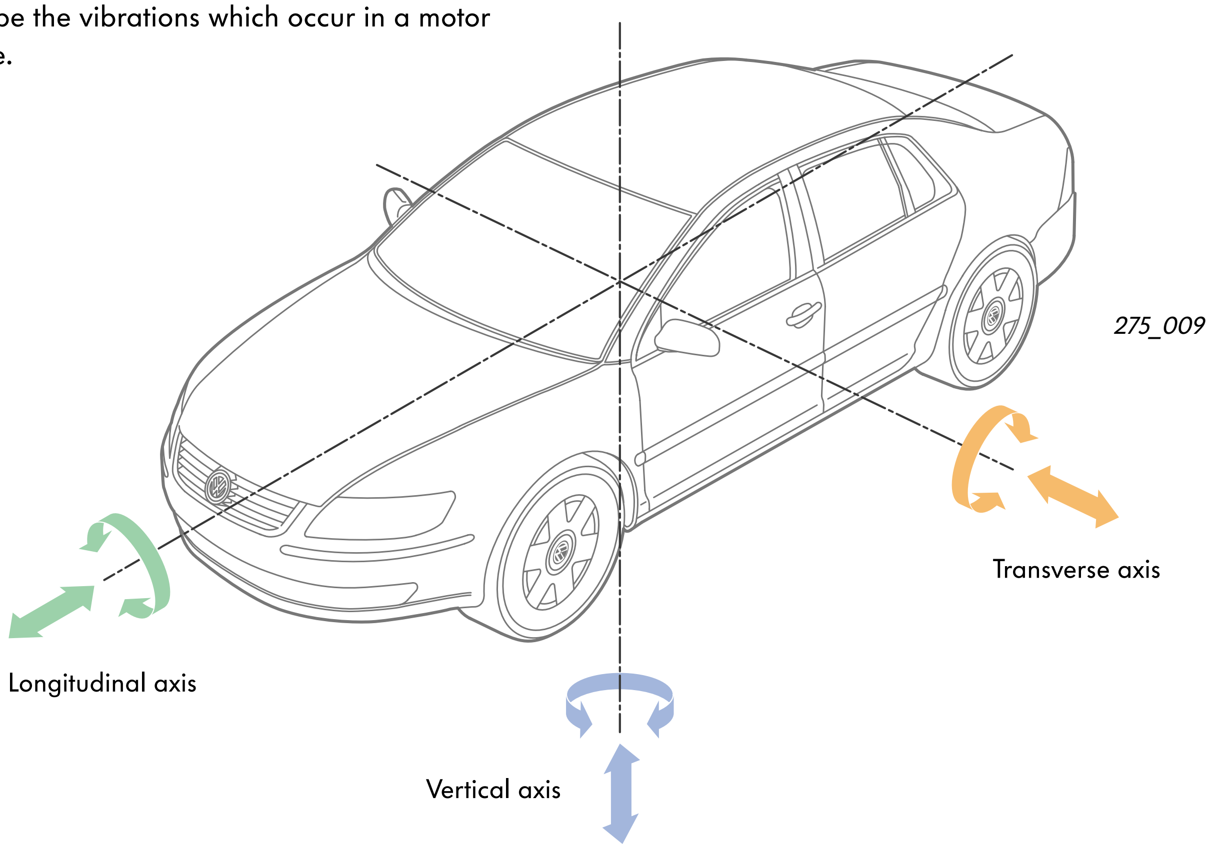


275_001

Driving safety	They maintain continuous contact with the road, which is important for steering and braking.
Driving comfort	Harmful or unpleasant vibrations are kept away from the passengers and the cargo remains intact.
Operational safety	The vehicle body and assemblies are protected against high impact and vibration loads.

Types of vibration acting on the motor vehicle

Apart from the upward and downward movement of the vehicle, vibrations occur about and in the direction of the three spatial axes (longitudinal, transverse and vertical axes) of the vehicle while travelling.
The following terms are generally used to describe the vibrations which occur in a motor vehicle.



Twitching	Vibration in the direction of the longitudinal axis (shudder)
Roll	Torsional vibration about the longitudinal axis (snaking, rolling, tilting)

Drifting	Vibration in the direction of the transverse axis
Pitching	Torsional vibration about the transverse axis (pitching)

Bouncing	Vibration in the direction of the vertical axis (impacts, vertical vibration)
Yawing	Torsional vibration about the vertical axis

Basics of spring/damper system

Vibrations

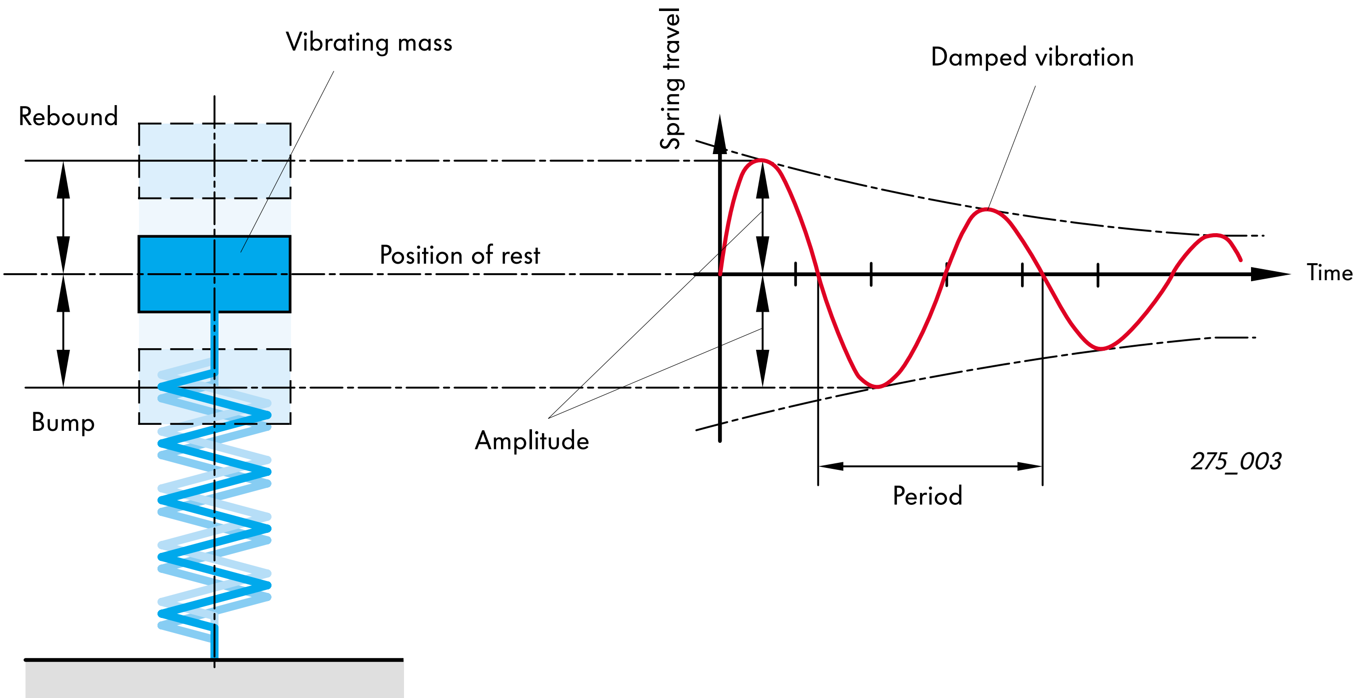
The tyres, suspension elements, body and vehicle seat forms a system which is capable of vibration, i.e. when an external force such as a bump on the road acts on this system, it oscillates back and forth about its position of rest.
These vibrations repeat themselves until they die away due to inner friction.

The vibrations are defined by their amplitude and frequency.

Intrinsic body frequency is self-levelling adjustment button.
An intrinsic body frequency of less than 1 Hz can cause nausea, depending on one's predisposition.
Frequencies above 1.5 Hz are detrimental to driving comfort, and frequencies higher than 5 Hz are perceived as shocks.
Intrinsic body frequency is essentially determined by the spring rate and the size of the sprung mass.

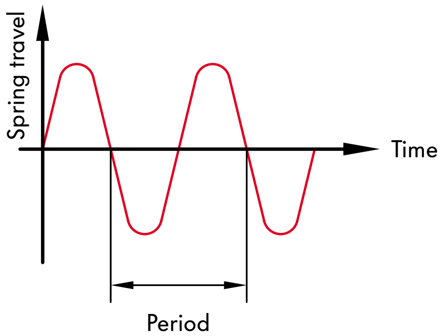
Definitions:

Vibration	Upward and downward movement of a mass (e.g. bump and rebound of the vehicle body)
Amplitude	Maximum distance of an oscillating mass from its position of rest (vibration displacement, spring travel)
Period	Duration of a single, complete vibration
Frequency	Number of vibrations (periods) per second 1 vibration per second = 1 Hz (Hertz)
Intrinsic frequency	Number of free vibrations of the sprung mass per second
Resonance	Occurs when a system capable of vibration requires a minimum of excitation to reach maximum amplitudes (rolling as intrinsic frequency approaches).
Shock abs.	Describes the decay of vibrations



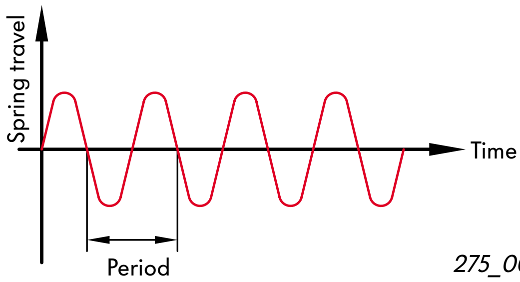
275_003

Larger masses or softer springs produce a lower intrinsic body frequency with increasing spring travel (amplitudes).

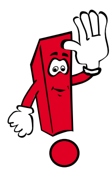


275_005

Smaller masses or firmer springs produce higher intrinsic body frequencies with decreasing spring travel.



275_004



The intrinsic wheel frequency (intrinsic frequency of unsprung masses) is approx. 10 to 16 Hz.

Basics of spring/damper system

Suspension system

The tyres, the springs and the seats with their cushioning effect collectively form the vehicle's suspension system.
As key components of this system, the spring damper elements are the link between the wheel suspension and the vehicle body.
Suspension elements include:

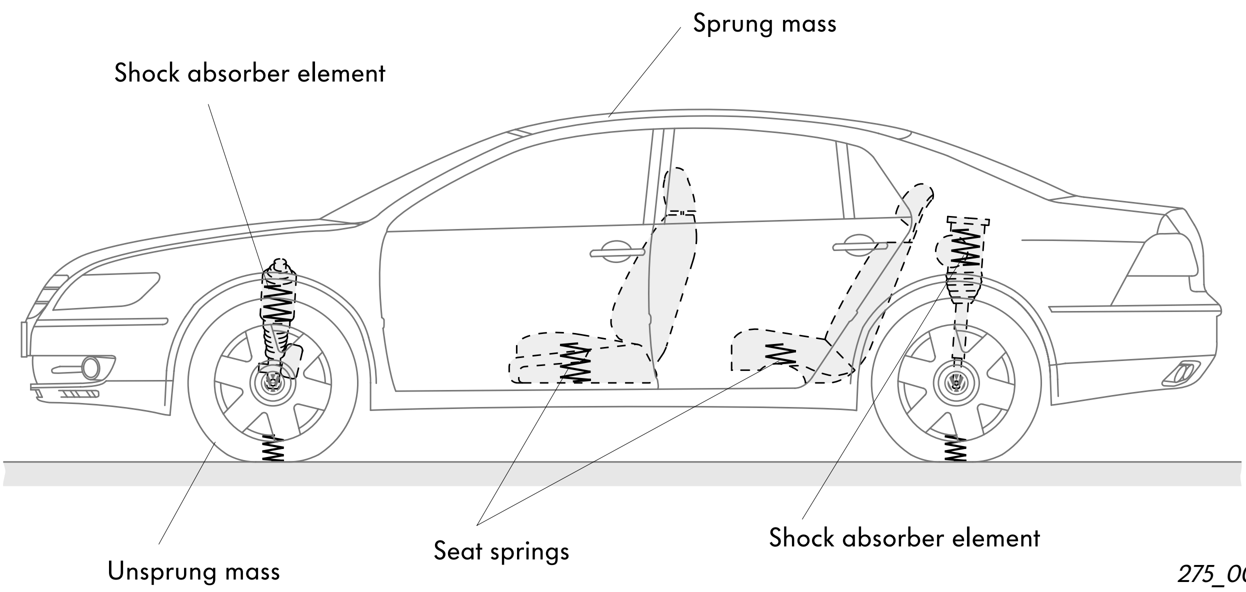
- steel springs (leaf springs, helical springs, torsion bar springs),
- air springs (gaiter springs and toroidal bellows springs),
- hydropneumatic springs (piston and diaphragm type hydraulic accumulators),
- rubber springs,
- anti-roll bars or
- combinations of these elements.

On the vehicle, a distinction is made between **unsprung masses** (wheels, brakes, final drive shafts, wheel bearings and wheel bearing housings) and
sprung masses (vehicle body with suspension and drive train parts).

The general aim of vehicle tuning is to keep unsprung masses to a minimum.
This minimises interference with the vibrational characteristics of the vehicle body and improves suspension response (and also driving comfort).

The following components contribute to reducing unsprung masses:

- light-alloy suspension parts,
- light-alloy brake calipers,
- light-alloy hollow-spoke wheels and
- weight optimised tyres.



275_002

Spring characteristics

The characteristics of a spring are obtained by applying a force of increasing magnitude to a spring in a spring press and plotting the change in spring travel against force applied.

The spring rate **c** is calculated from the ratio of change in force and change in travel.

c = force : distance [N/cm]

A "firm" spring has a steeper spring characteristic than a "soft" spring.
If the spring rate is constant over the full distance travelled by the spring, then the spring has a linear characteristic.
If the spring rate increases over the distance travelled by the spring, then the spring has a "progressive" characteristic.

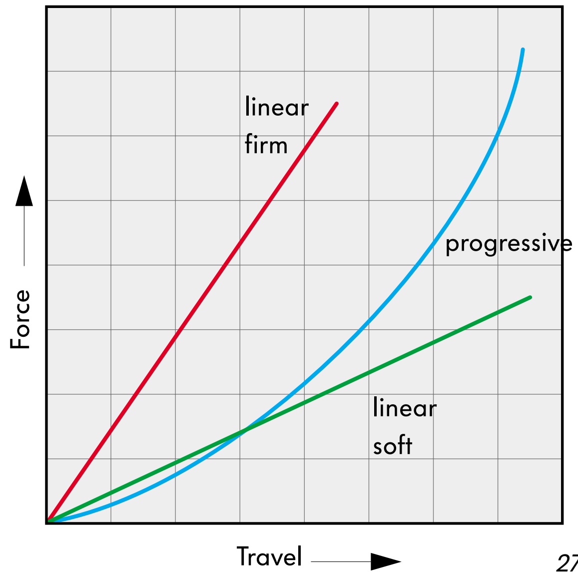
The characteristic of a coil spring can be influenced as follows:

- the spring diameter
- the spring wire diameter and
- the number of windings in the spring

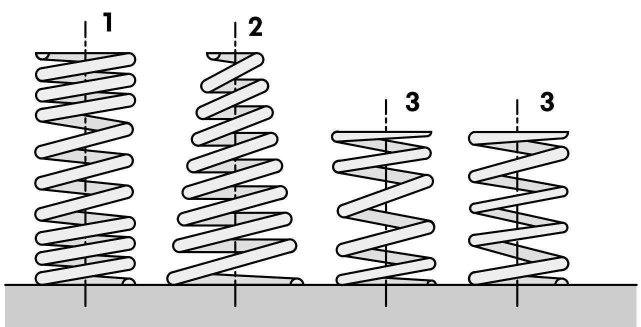
Characteristic features of springs with progressive characteristic include:

- uneven winding pitch (1),
- conical winding shape (2),
- conical wire diameter (3) and
- combinations of several suspension elements.

Examples of spring characteristics



275_006



275_007

Basics of spring/damper system

Spring travel

The necessary spring travel $\mathbf{s_{tot}}$ of a vehicle without self-levelling suspension comprises the static bump $\mathbf{s_{stat}}$ and the dynamic spring travel $\mathbf{s_{dyn}}$ resulting from vehicle vibration when the vehicle is fully laden and unladen.

$$s_{tot} = (s_{stat(full)} - s_{stat(unladen)}) + s_{dyn}$$

The static spring travel $\mathbf{s_{stat}}$ is the distance which the spring is compressed when stationary depending on payload. This is the difference between the static compression of the fully laden vehicle $\mathbf{s_{stat(full)}}$ and the static compression of the unladen vehicle $\mathbf{s_{stat(unladen)}}$.

$$s_{stat} = s_{stat(full)} - s_{stat(unladen)}$$

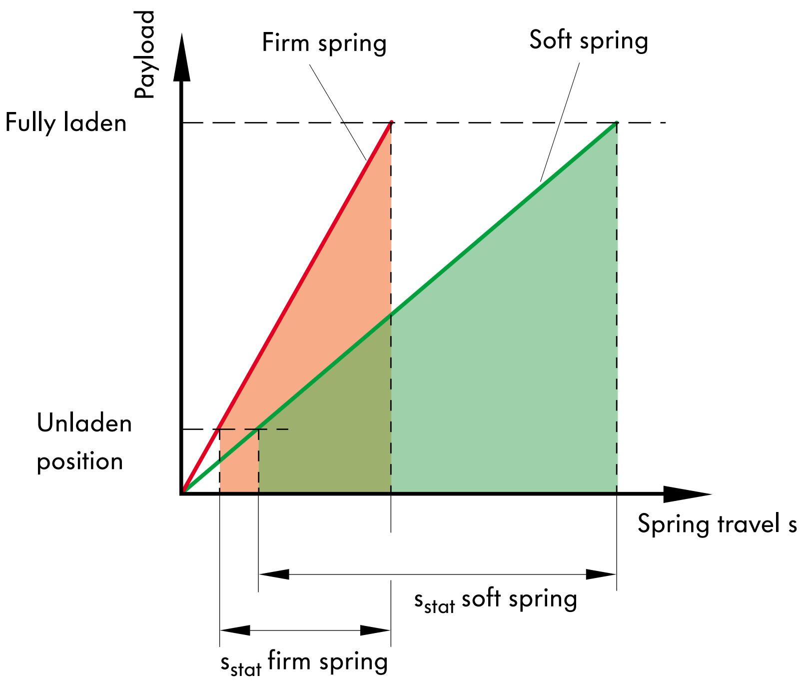
Where a spring characteristic is flat (soft spring), the difference, and so the static compression, between the unladen and fully laden vehicle is large.
Where spring characteristic has a steep gradient (firm spring), the static compression is small.

Definition:

The **unladen position** is the compression of the spring when the serviceable vehicle (incl. full tank of fuel, tool kit and spare wheel without driver) is standing on its wheels.

The **design position** is the position which the unladen vehicle adopts when additionally laden with three persons each weighing 68 kg.

The **controlled position** is the position in which the vehicle is held by the self-levelling suspension of the air suspension system, regardless of payload.



275_008

Air suspension

The air suspension is a variable-height vehicle suspension system and can be combined with controllable vibration damper systems.

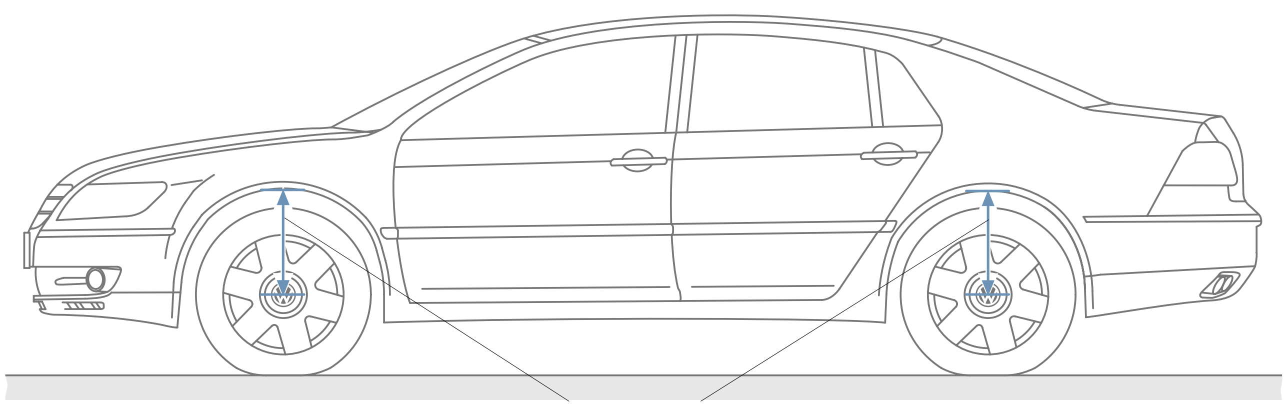
It is relatively easy to implement a self-levelling air suspension system.
The self-levelling suspension keeps the vehicle body at constant level (controlled position = constant distance between centre of wheel and lower edge of wing), i.e. at a pre-defined ground clearance.

The vehicle level is controlled by adapting the pressure acting on the air springs and the associated change of air volume in the air spring struts.

Static compression is always set to s_{stat} = 0, regardless of payload.

The advantages of a self-levelling suspension are:

- the vehicle can be sprung comfortably
- the static level of the vehicle is constant, regardless of payload
- reduced tyre wear
- no payload-dependent change of drag coefficient c_d
- maximum rebound and bump travel are maintained in all load states
- full ground clearance is maintained (even at maximum payload) and
- no changes of toe and camber due to changes in payload.



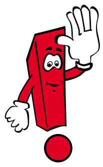
275_010

Basics of air suspension

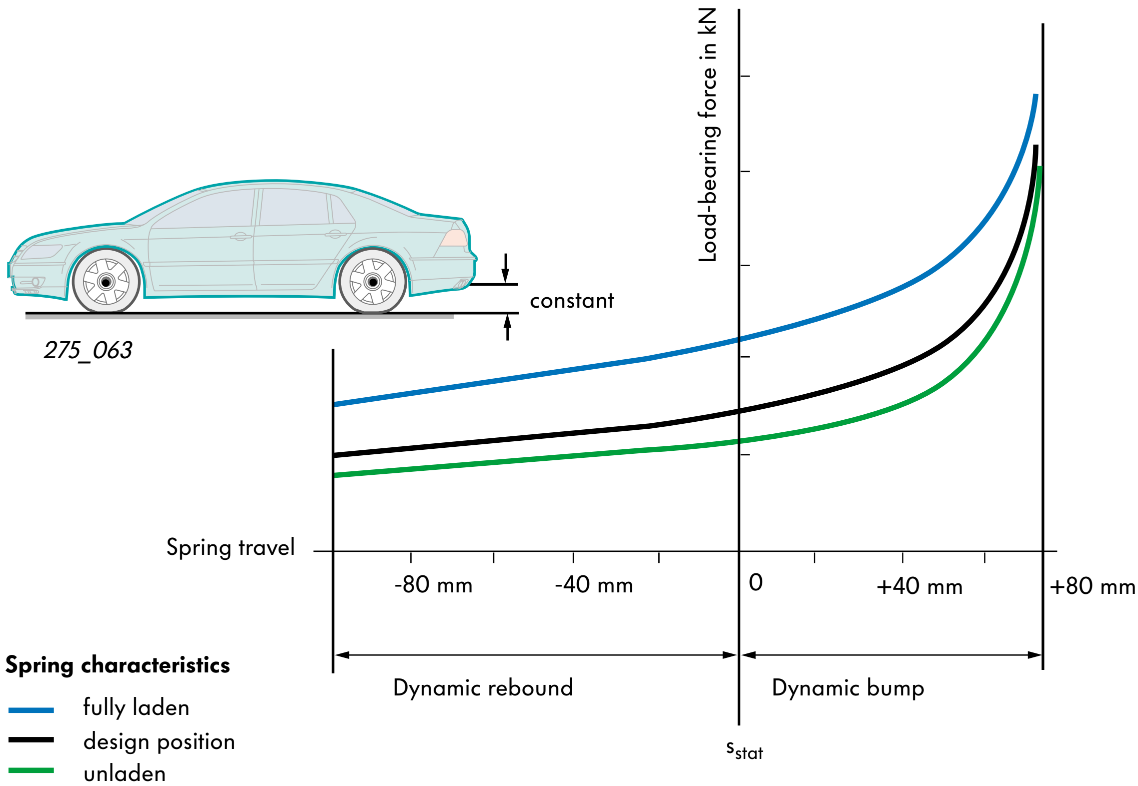
In addition to the basic advantages of variable-height, full load bearing air suspension as described above, it is also possible to set different vehicle level heights by means of the air suspension.

Three level heights have been implemented on the Phaeton:

- the normal suspension level
- a raised suspension level for poor road surfaces or rough terrain, and
- a low suspension level that is set automatically while travelling at high motorway speeds



"Full load-bearing" means that only air springs are used as load-bearing spring elements on all wheels. Combined suspension systems, which consist of a combination of hydraulically or pneumatically controlled steel and gas struts, are described as "partially load-bearing".



275_063

Characteristics of air springs

Spring force/spring rate

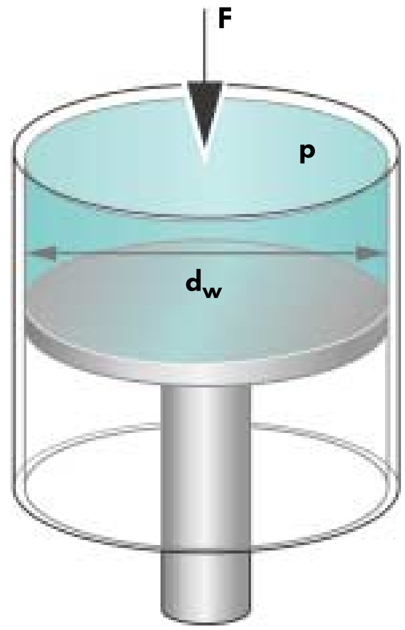
The spring force **F** (load-bearing force) of an air spring is defined by its geometric dimensions (the effective circular area $\mathbf{A_w}$) and the excess pressure acting on the air spring **p**.

$$\mathbf{F}\ [N] = \mathbf{A_w}\ [cm^2] \times \mathbf{p}\ [N/cm^2]$$

The effective circular area $\mathbf{A_w}$ is defined by the effective circle diameter $\mathbf{d_w}$.

$$\mathbf{A_w}\ [cm^2] = \boldsymbol{\pi} \times (\mathbf{d_w})^{\mathbf{2}} : \mathbf{4}\ [cm^2]$$

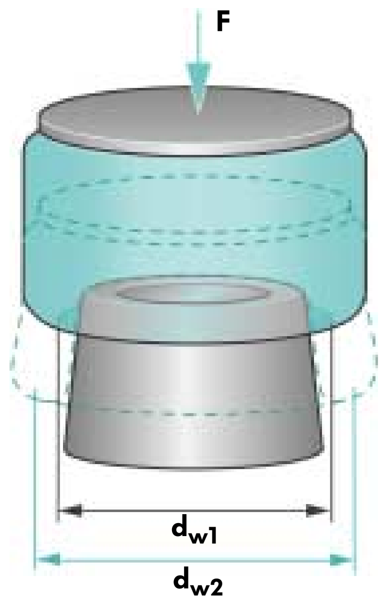
π = 3.14... constant "pi" for calculating the circle area



275_011

In a piston in the cylinder, the piston diameter corresponds to the effective circle diameter.

The effective diameter of the air spring gaiter is defined by the diameter at the lowest point of the gaiter ($\mathbf{d_{w1}}$ rebounded and $\mathbf{d_{w2}}$ compressed). Since this effective diameter $\mathbf{d_w}$ is squared in the equation for $\mathbf{A_w}$, minor changes in this diameter lead to relatively large changes in the area of the circle, and so the load-bearing force of the air spring.



275_012

Basics of air suspension

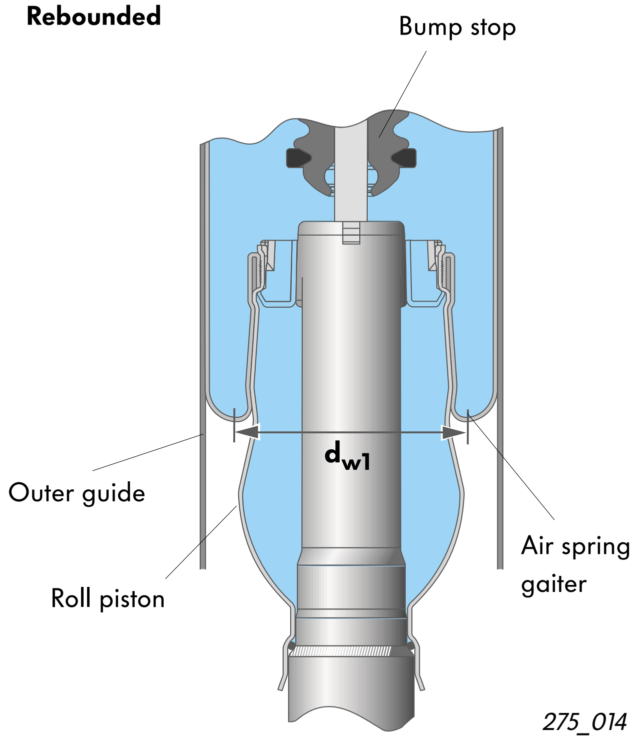
The load-bearing force of the spring can be adapted to the load situation by simply changing the effective internal pressure **p** in the air spring.

The different pressures - depending on payload - result in different spring characteristics or spring rates.
The spring rates do not change in direct proportion to total body weight.
The intrinsic body frequency, a key factor in handling performance, remains almost constant.

Spring compression changes the effective air spring gaiter diameter (**d_w** from **$d_{w\,1}$** to **$d_{w\,2}$**) because it rolls back on the roll piston.

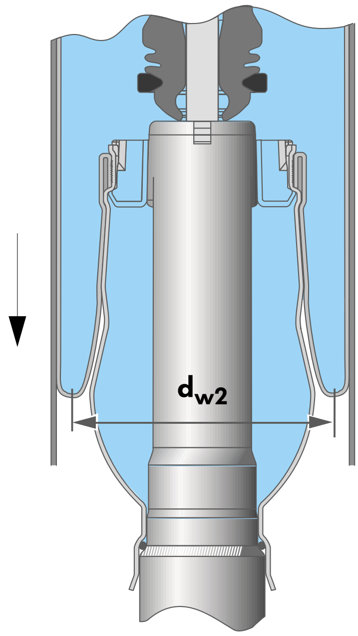
Example showing the effect of roll piston contour on effective diameter d_w

Rebounded



275_014

Compressed



275_014a

Spring characteristic

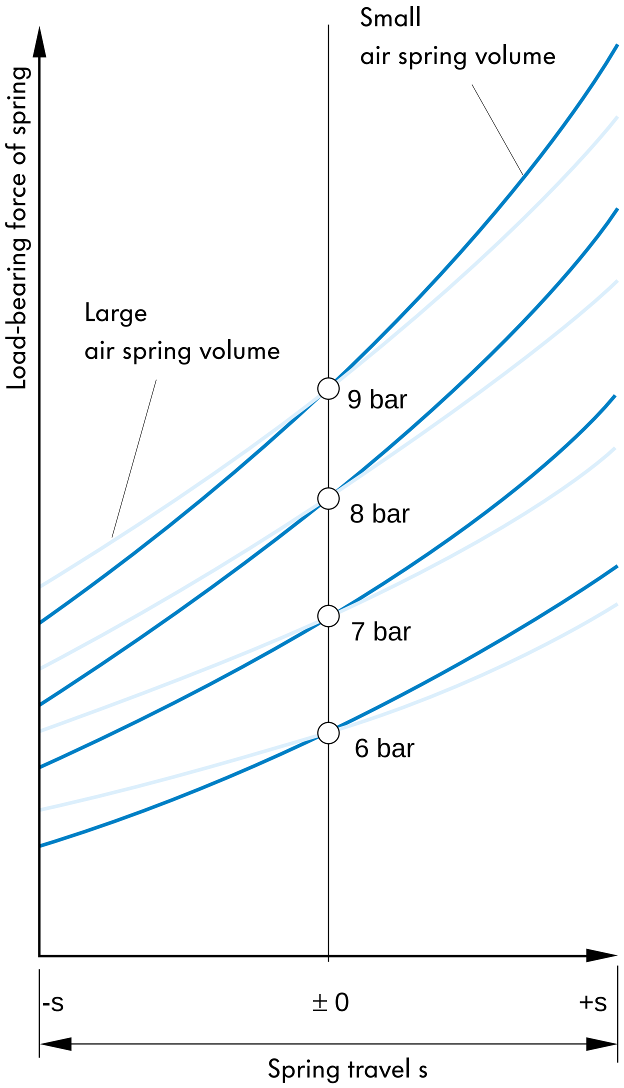
In principle, the spring characteristic of an air spring for cylindrical pistons is progressive.

The spring characteristic curve (steep or flat) is governed by the air spring volume.

The existing air volume is compressed by dynamic compression. Assuming that bump travel is constant, the pressures in a low volume system rise more rapidly than in a system with a large air spring volume.

A flat spring characteristic curve (soft spring) is produced by a large air spring volume.
A steep curve (firm spring), on the other hand, is produced by a small air spring volume.

The characteristic curve can be influenced by the roll piston contour.
Modifying the contour of the roll piston changes the effective diameter, and so the load-bearing force (spring force), of the air spring.



275_015

An air spring can be tuned for the required application by adjusting the following parameters:

- size of effective area A_w,
- size of air spring volume (air volume) and
- outer contour of roll piston.

Basics of air suspension

Design of an air spring

A distinction can be made between two air spring variants:

- "partial load-bearing" and
- "full load-bearing"

In partial load-bearing variants, a combination of steel and gas struts generates the load-bearing force of the air spring.

A full load-bearing variant as used in the Phaeton exists only when air springs function as load-bearing spring elements.

The air spring basically comprises

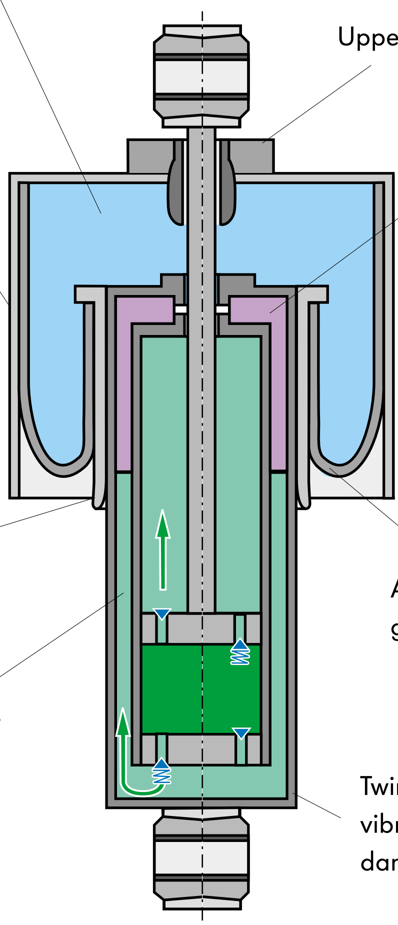
- an upper housing with an outer guide
- the air spring gaiter
- the roll piston (lower housing)
- an auxiliary accumulator (where required), and
- the integrated vibration damper (shock absorber)

Gaiter

The air spring gaiter comprises a special, high-quality multi-layer elastomer material with fabric inlays of nylon cord as reinforcing material.
The reinforcing material absorbs the forces arising in the air spring.
The inner overlay is specially designed for air tightness.
A special combination of individual layers lends good rolling characteristics to the air spring gaiter and precise response to the suspension.

The materials are resistant to all external influences in a temperature range from –35 °C to +90 °C.

Example of an air spring strut with outer guide (full load-bearing)



275_027

If the metallic sleeve of the outer guide used to absorb circumferential forces is left out, the air springs are referred to as "externally guided" as opposed to "unguided" air springs.

Vibration damper

The task of the vibration damper (often referred to as the shock absorber) is to reduce the vibration energy of structural and wheel vibrations as rapidly as possible by converting vibration energy to heat.

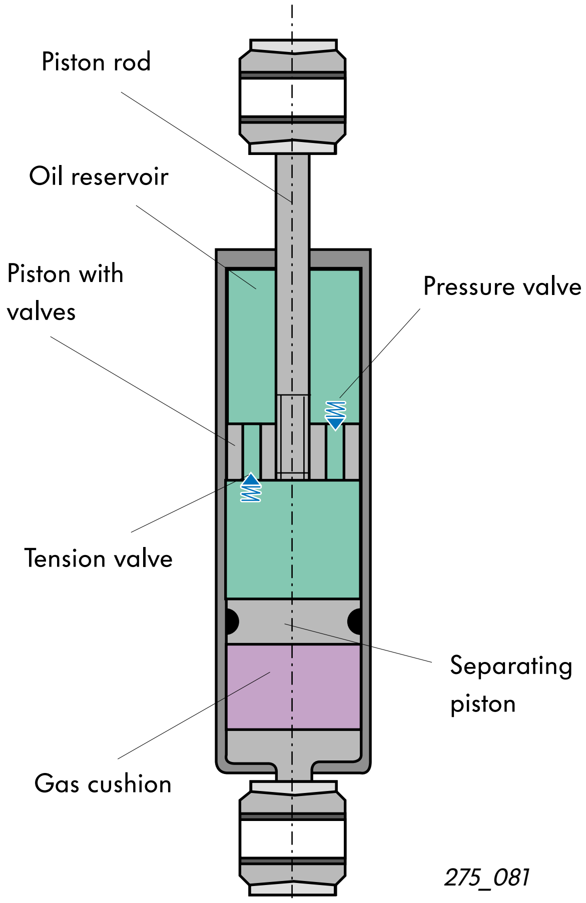
Without vibration dampers, the vibrations introduced into the vehicle would "build up" to the extent that the wheels could lose contact with the road surface. As a result, the vehicle would no longer be steerable.

There are several different types of vibration damper.

Single-tube gas pressure vibration damper

With this damper variant, the working and oil reservoirs are located in a single cylinder (single-tube damper).
Changes in oil volume, due to temperature effects and plunging of the piston rod when the springs are compressed, are equalised by the gas in the pressurised gas cushion (approx. 25 to 30 bar).

The damping valves for the compression and tension stages are integrated in the piston.



Schematic diagram of a single-tube gas pressure vibration damper

Basics of the damping system

Twin-tube gas pressure vibration damper

This damper variant has established itself as the standard vibration damper.

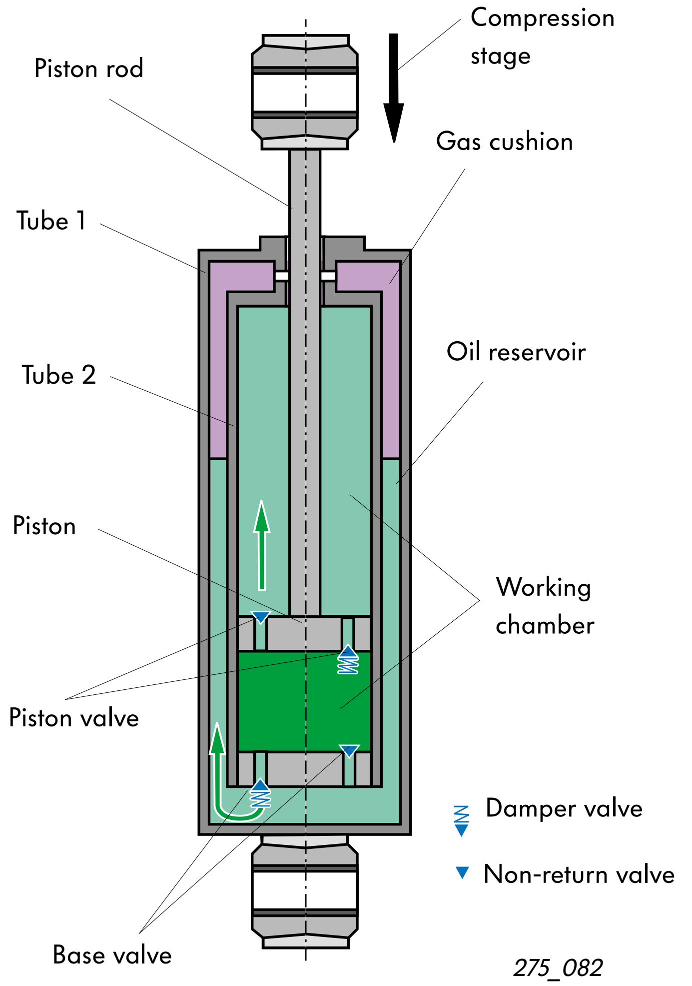
As the name indicates, it consists of two tubes fitted into each other (twin-tube damper).
The inner tube acts as the working chamber.
It is completely filled with hydraulic fluid.
The pistons together with the piston valves and the piston rod move up and down inside the working chamber.
The base of the working chamber comprises the base plate and base valves.
The outer tube surrounds the oil reservoir.
It is only partially filled with oil. There is a gas cushion above the oil filling.

The oil reservoir equalises changes in the volume of oil in the working chamber.

Vibrations are damped by the two damping valve units located on the piston and at the base of the working chamber.
They comprise a system of spring washers, coil springs and valve bodies with restrictor bores.

During a bump event (compression stage), damping is defined by the base valve and partly by the flow resistance of the piston.

During a rebound event (tension stage), vibrations are damped by the piston valve alone.
This valve produces a defined resistance to the oil as it flows downwards.



Schematic diagram of the twin-tube gas pressure vibration damper (compression stage)

Damper tuning

As regards damping, a distinction is made between the compression stage (bump) and the tension stage (rebound).

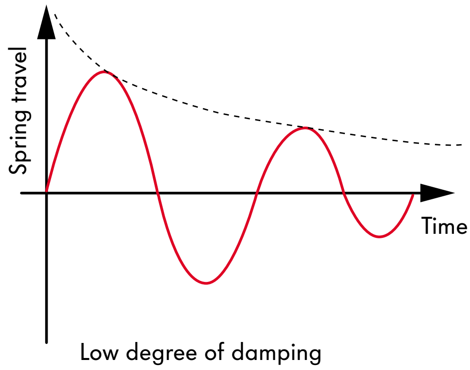
The damping force during the compression stage is less than during the tension stage.

As a result, jolts caused by rough road surfaces are transmitted to a lesser degree to the vehicle. Because the shock absorber tuning is fixed, there is a close relationship between driving comfort and driving safety.

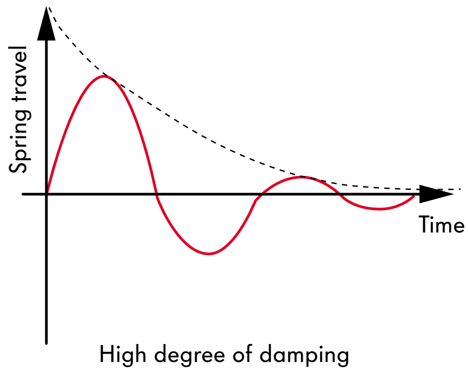
Dampers with adjustable damper tuning and continuous control are fitted to luxury vehicles. The control unit determines within a matter of milliseconds what degree of damping is required and for what wheel.

The **degree of damping** indicates how quickly the vibrations must be reduced.
It is dependent on the damping force of the vibration damper and the size of the sprung masses.

Increasing the sprung mass reduces the degree of damping, i.e. the vibrations are slowly reduced.
A reduction in sprung masses increases the degree of damping.



275_017



275_018

Basics of the damping system

Damping force

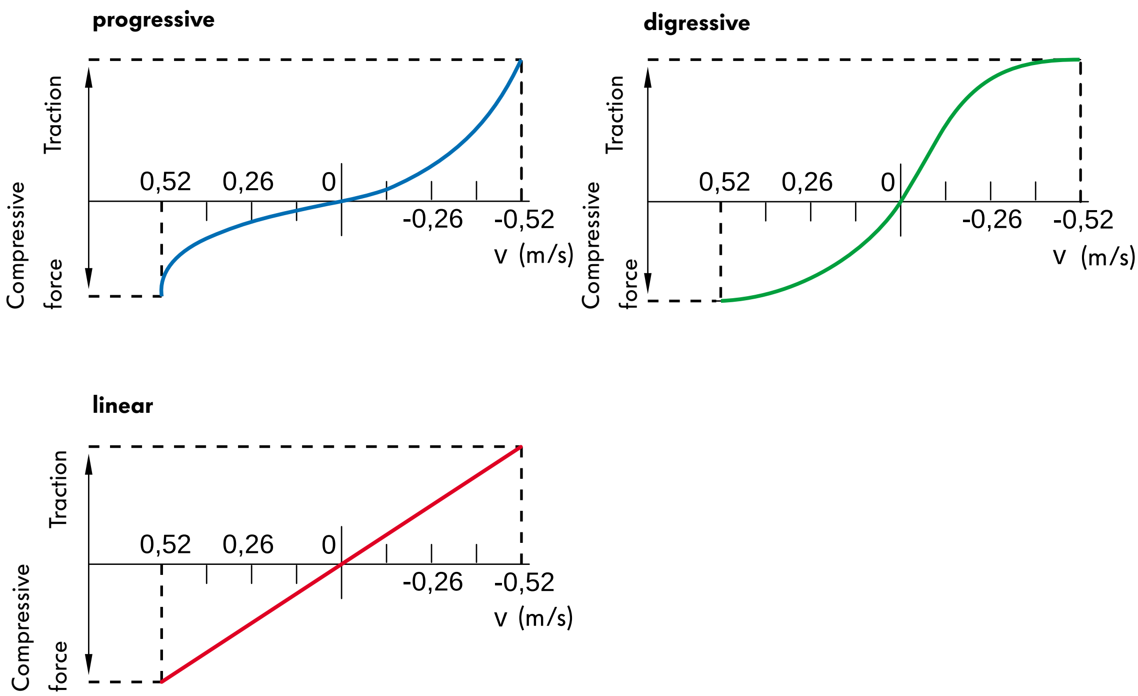
The damping force of a vibration damper is determined using a test apparatus.
The machine produces different engine speeds, and therefore different rebound and bump rates of the damper, whilst maintaining a constant stroke.

The values determined in this way can be represented in force-speed diagrams (F-v diagrams).

These diagrams clearly show the characteristic of the vibration damper.

A distinction is made between progressive, digressive and linear action vibration dampers.

F-v diagram showing characteristic curves



275_019

System description

The full load-bearing **4-C**orner air suspension (**4CL**) with Continuous Damping Control (**CDC**) keeps the vehicle at a constant level above the road, regardless of payload.
In other words, a constant, static ground clearance adapted to the driver's input or vehicle's road speed is maintained between the road and the vehicle floorpan.

The overall system comprises:

– a control unit for the 4CL/CDC

– an air spring and a vehicle level sender in each corner

– an adjustable vibration damper integrated into the air spring strut in each corner

– a compressor with air drier and temperature sender

– a solenoid valve block with 4 valves, a drain valve, a pressure accumulator valve, as well as an integrated pressure sensor,

– a pressure accumulator

– air lines from the compressor to the individual air spring struts and to the pressure accumulator

– a wheel acceleration sender on every air spring strut (measurement range ± 13 g) and

– three body acceleration senders (measurement range ± 1.3 g).

Three level heights have been implemented in the Phaeton (of which NN and HN are driver selectable):

– a **normal suspension level** (**NN**),

– a **high suspension level** (**HN**) which is 25 mm above NN and intended for driving on bad roads and

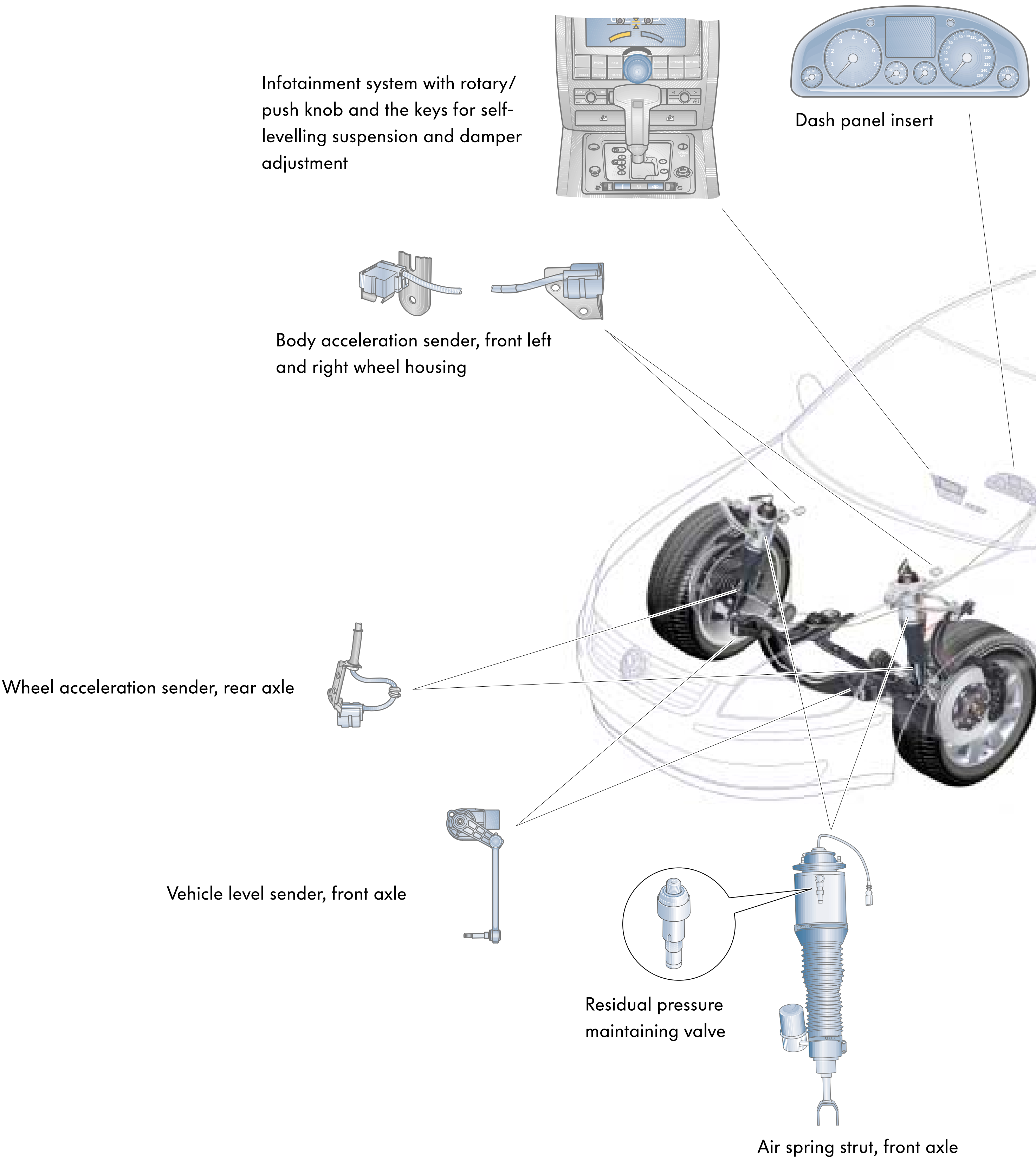
– a **low suspension level** (**TN**), 15 mm below NN. Ride height is selected automatically depending on road speed (while driving at high speeds on a motorway), and is also deselected automatically.

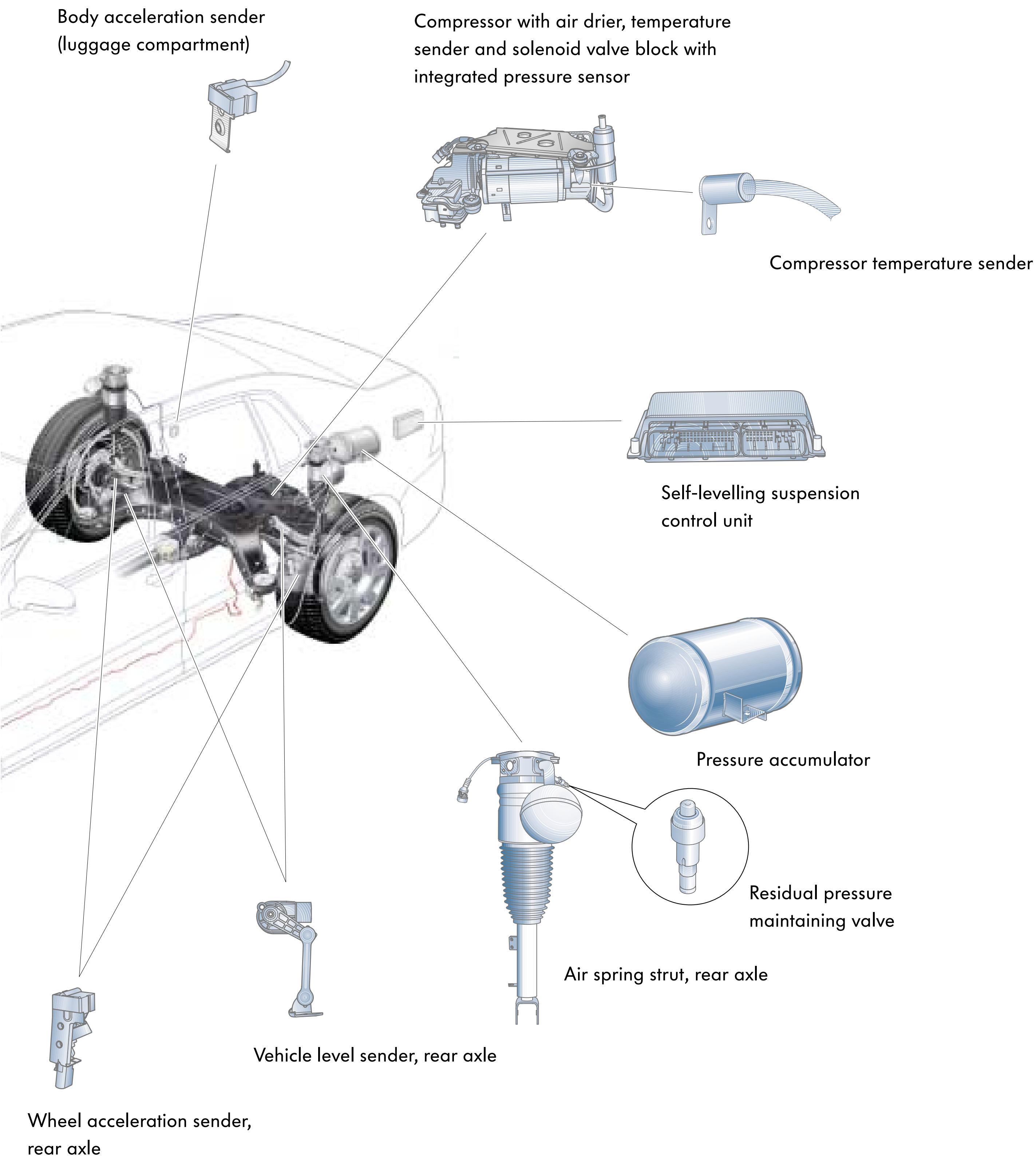
The system also switches automatically to other levels depending on the driving situation by means of a special control strategy. Ride height adjustments are made in the background and are not normally noticed by the driver.
When driving at high speeds, the ground clearance is automatically lowered from the high suspension level to the dynamically more stable normal suspension level. At even higher speeds, the ground clearance is automatically reduced to the low suspension level which is not selectable by the driver.
When a pre-determined road speed is undershot, the low suspension level is automatically deselected.

The "Comfort" damper setting is automatically adjusted in the direction of "sporty/firm" at higher speeds in order to ensure safe handling and track stability.

System description

The system and its components




Body acceleration sender
(luggage compartment)
Compressor with air drier, temperature
sender and solenoid valve block with
integrated pressure sensor
Compressor temperature sender
Self-levelling suspension
control unit
Pressure accumulator
Residual pressure
maintaining valve
Air spring strut, rear axle
Vehicle level sender, rear axle
Wheel acceleration sender,
rear axle

275_020

System description

Operation and display

The Phaeton is the first Volkswagen vehicle to be equipped with a self-levelling suspension.

For the front and rear axles, the system comprises a

– full load-bearing air spring with self-levelling suspension in combination with
– a continuously adjustable vibration damper

The central control unit for the system is self-levelling suspension control unit J197.

The system is operated by the damper adjustment button or the self-levelling suspension button as described in the operating manual.

These keys are located on the centre console behind the gear selector lever.
Pressing the appropriate key opens a pop-up menu in the Infotainment display select between

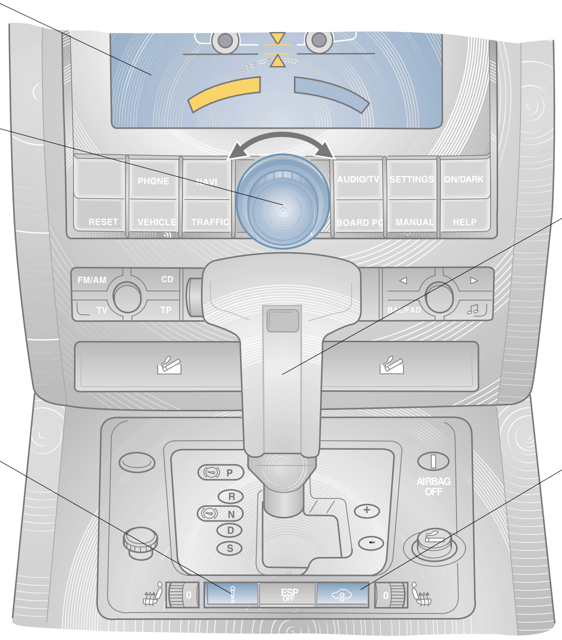
two suspension levels

– normal suspension level **NN** (preset) and
– high suspension level **HN**

and four **damper tunings**

– Comfort,
– Basic (preset),
– Sport 1 and
– Sport 2.

using the rotary/push knob.



275_038

Self-levelling suspension

The button for self-levelling suspension must be pressed to set the level.
By turning the rotary/push knob, the driver can select between high suspension level **HN** or normal suspension level **NN**.
The screen corresponding to the level selected is displayed.

When the high level is set, the self-levelling suspension button is lit.
The driver can exit the menu by pressing the rotary/push knob.

Normal level

275_034

High level

275_035

Damper tuning

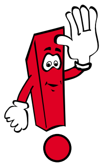
To select damper tuning, press the damper adjustment button.

Turn the rotary/push knob, the driver can select one of the following four damper tunings:

- Comfort,
- Basic (preset),
- Sport 1 and
- Sport 2.

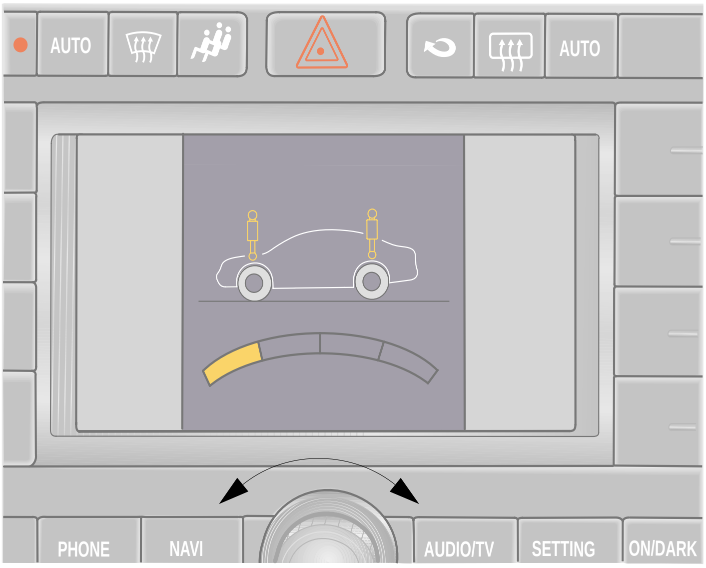
The corresponding screen is displayed.

The driver can exit the menu by pressing the rotary/push knob.
In the Comfort, Sport 1 and Sport 2 settings, the key is lit.



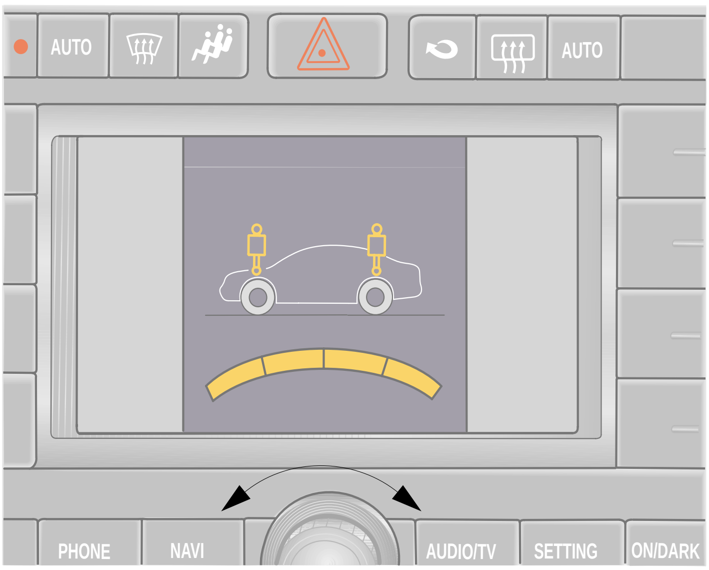
The level always resets from the "Sport 2" position to the "Basic" position when the ignition is turned off.

Comfort



275_036

Sport 2



275_037

Control strategy of the self-levelling suspension

The position of the vehicle body in relation to the wheel is measured by four vehicle level senders located between the axle carriers and the lower wishbones and compared with defaults for each wheel stored in the control unit.
The vehicle control unit must "learn" these defaults.

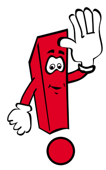
The air required for self-levelling is normally provided by the compressor (maximum pressure 16 bar).

At road speeds above 35 kph, adjustments are controlled by the compressor.
The pressure accumulator is also topped up as required.

At road speeds below 35 kph, adjustments are controlled by the pressure accumulator (5 litre capacity).
A sufficient pressure difference (approx. 3 bar) between the pressure accumulator and the air spring is required for this purpose.

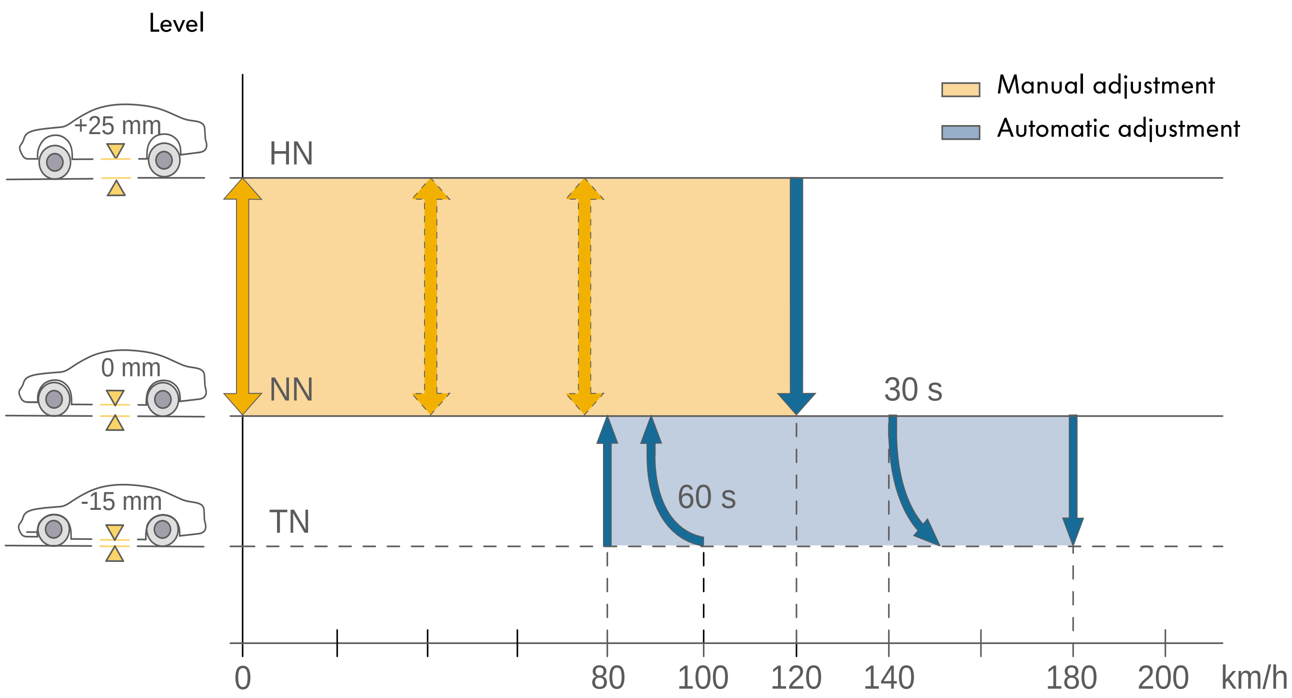
Loading and unloading

If the height of the vehicle changes in relation to the road surface due to loading or unloading processes, the control unit re-adjusts the vehicle's level height to the nominal level.
For this purpose, air is channelled via a solenoid valve into the air spring or discharged via the drain valve.



The compressor for topping up the pressure accumulator comes on independently of the levelling adjustments.

Schematic diagram of the automatic up/down adjustments



275_021

HN - high level
NN - normal level
TN - low level

Level is automatically **decreased** from

HN to **NN**: at v ≥ **120** kph

NN to **TN**: takes place at v ≥ **140** kph after 30 seconds and/or immediately at v ≥ **180** kph.

Level is automatically **increased** from

TN to **NN**: at v ≤ **100** kph after 60 seconds and/or immediately at v ≤ **80** kph.

Special modes of the self-levelling suspension

Deactivating self-levelling suspension system
In special situations, it may be necessary to deactivate the suspension, e.g. to change a wheel or to carry out work on the vehicle whilst raised on a lifting platform.
The self-levelling suspension can be deactivated by simultaneously pressing the keys for self-levelling suspension and damper adjustment for about 5 seconds.

A message indicating that the self-levelling suspension has been deactivated appears in the dash panel insert.

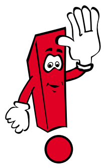
Activating the self-levelling suspension
The suspension system is re-activated by pressing both keys for approx. 5 seconds, or automatically when the control unit determines that the vehicle is travelling at a speed of $v \geq 10$ kph.

Lifting platform:
When the vehicle is raised on a lifting platform at the jack and lifting platform locating points, air is allowed to escape from all four air springs until the control unit determines that the vehicle is in elevated state.

The self-levelling suspension initially detects when the vehicle body is too high in relation to the wheels and adjusts the vehicle height accordingly by allowing air to escape from the springs.

As a result, the vehicle may have a very low ground clearance when it comes off the lifting platform.

The vehicle is automatically raised to the normal level (NN) again after the engine, and therefore the compressor, has been running for a short period of time.



To avoid this discharge of air, therefore, the self-levelling suspension must be deactivated before starting lifting platform activities.

Actions of air suspension after "ignition OFF"

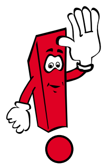
Loading and unloading

After "ignition OFF", the control unit remains active for approx. one minute and can execute suspension adjustments, e.g. to compensate for increases/decreases in payload, provided that sufficient pressure is available in the pressure accumulator.

The control unit always remains active for one minute until no further door or bonnet/bootlid operations are detected.

Gradual level changes

To compensate for gradual level changes, which can occur due to air in the air springs heating up during the trip and cooling down again at the end of the trip, three adjustments are made to achieve optimum ground clearance after " ignition OFF".



These adjustments are made after approx. two, five and ten hours, provided that sufficient pressure is available in the pressure accumulator.

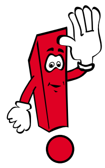
Vibration damper control

The damper control system registers the condition of the road surface and the movements of the vehicle via four wheel acceleration sensors and three body acceleration sensors.
The characteristics of the individual vibration dampers are adjusted according to the calculated damping requirements.
In this case, the dampers function as semiactive components during bump and rebound cycles.

Continuous damping control is based on vibration dampers whose characteristics are electrically adjustable.
These vibration dampers are integrated in the air spring struts.
Damping force can be set depending on the characteristic map via the proportional valve built into the vibration damper.
As a result, it can adapt the damping force to the driving situation and road condition within milliseconds.

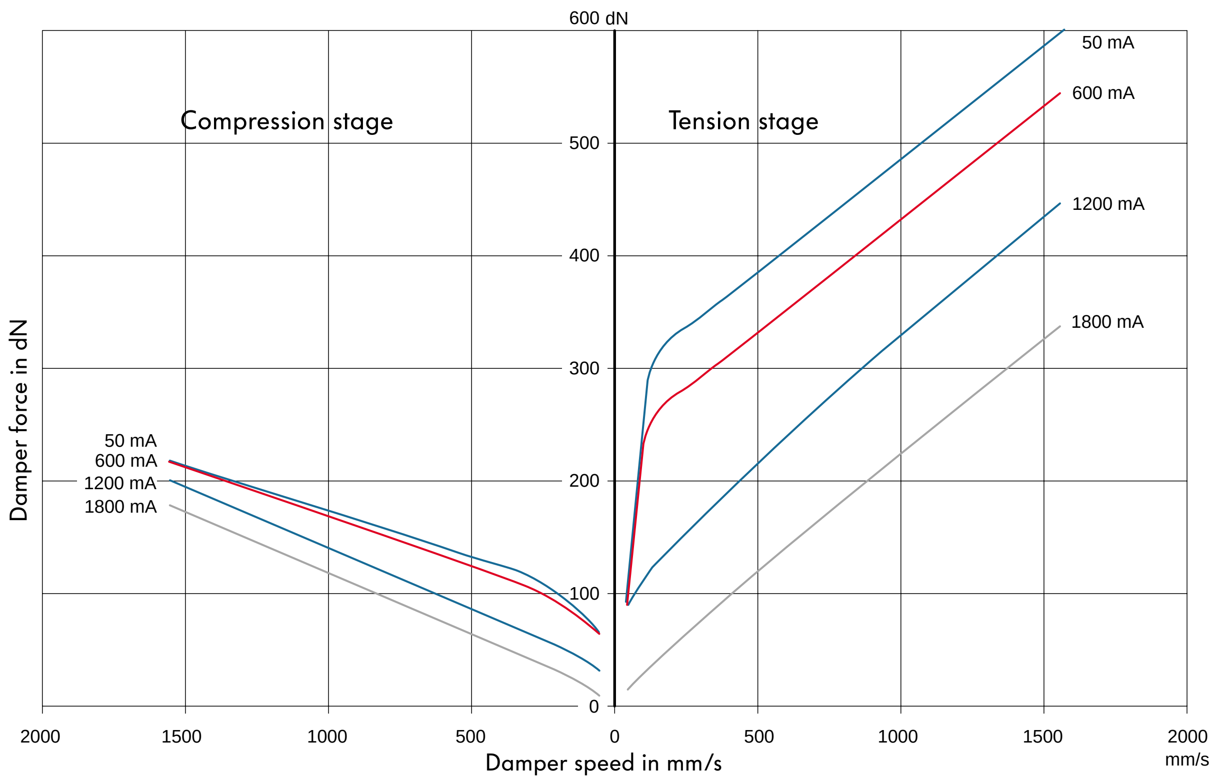
The control always attempts to set the damper force according to the so-called "skyhook control strategy".
The damper is adjusted depending on the vertical acceleration rates of the wheels and the vehicle body.
Ideally, damping would be controlled as if the vehicle body were suspended by a hook in the sky and were hovering above the road almost without any interfering movements.

Maximum driving comfort is achieved in this way.



Firm damping is achieved by low control rates.
Soft damping is achieved by high control rates.

Characteristic map of damper force in Phaeton front axle

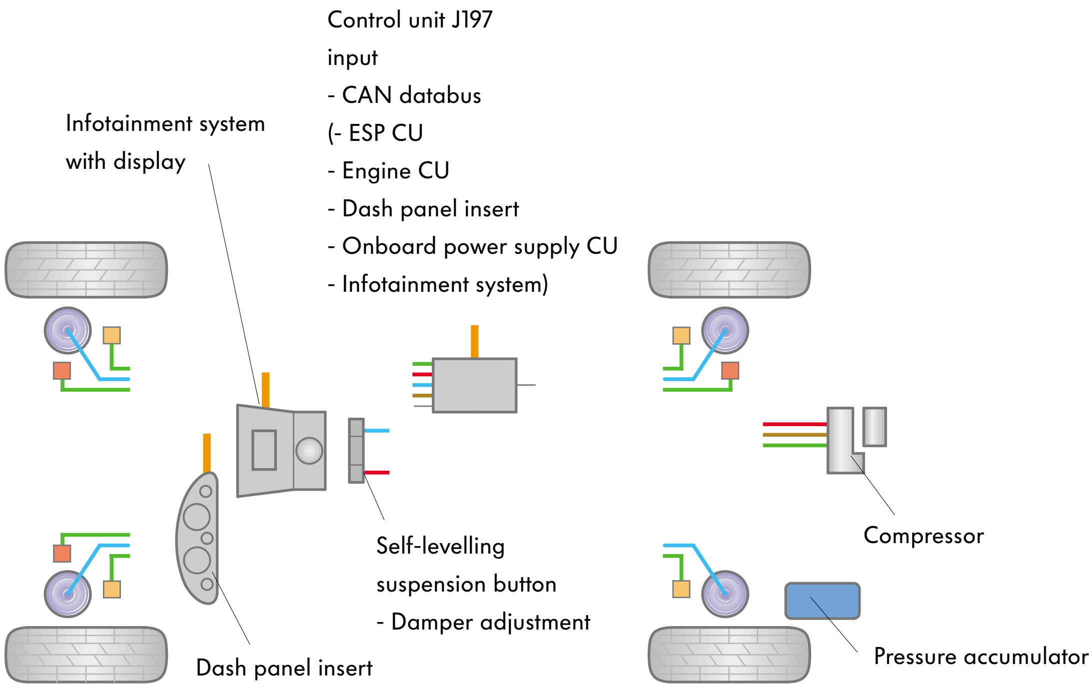


275_022

System description

Diagram of the suspension system with controlled dampers

The system diagram below highlights the relationships with other vehicle systems as well as display and operating elements.



275_025

Air spring strut with electrically adjustable damper

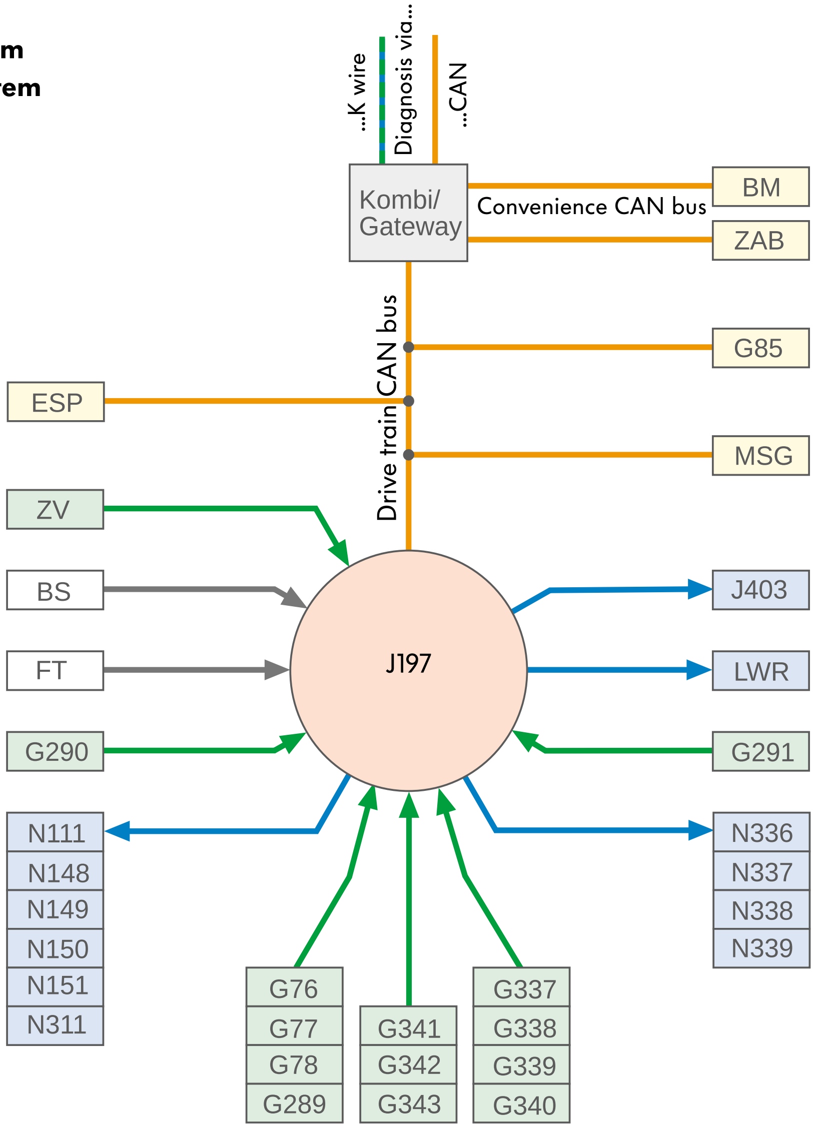
Wheel acceleration sender

Body acceleration sender

Connection via CAN bus

Connection via onboard power supply

Schematic diagram of the overall system



275_023

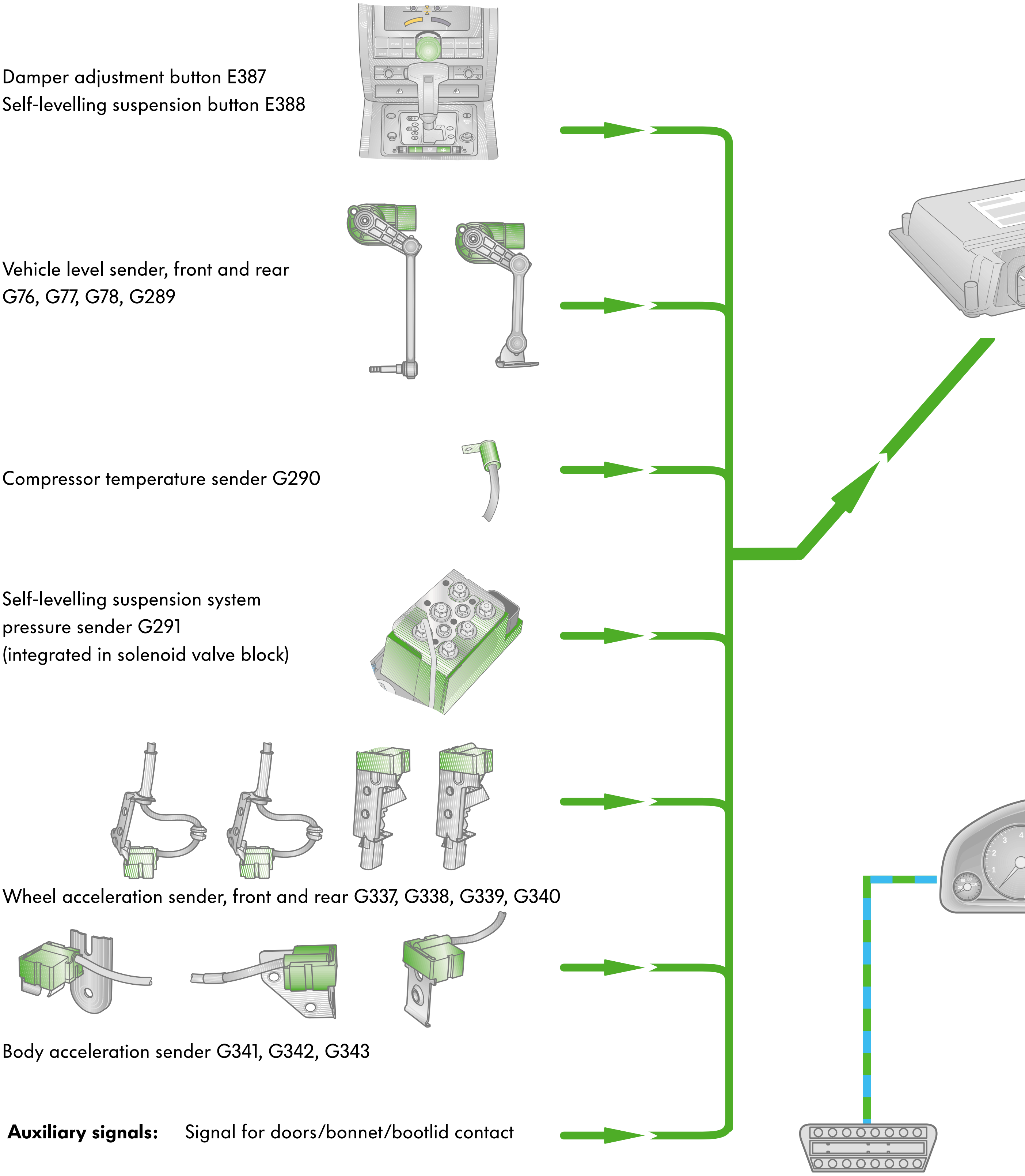
Legend

BM - Battery management
BS - Status signals T.30, T.15
ESP - Electronic Stability Programme
FT - Self-levelling suspension button and damper adjustment button
G76...78, ... G289 - Vehicle level senders
G85 - Steering angle sender
G290 - Compressor temperature sender, self-levelling suspension
G291 - Self-levelling suspension system pressure sender
G337 ... G340 - Wheel acceleration sender
G341 ... G343 - Body acceleration sender

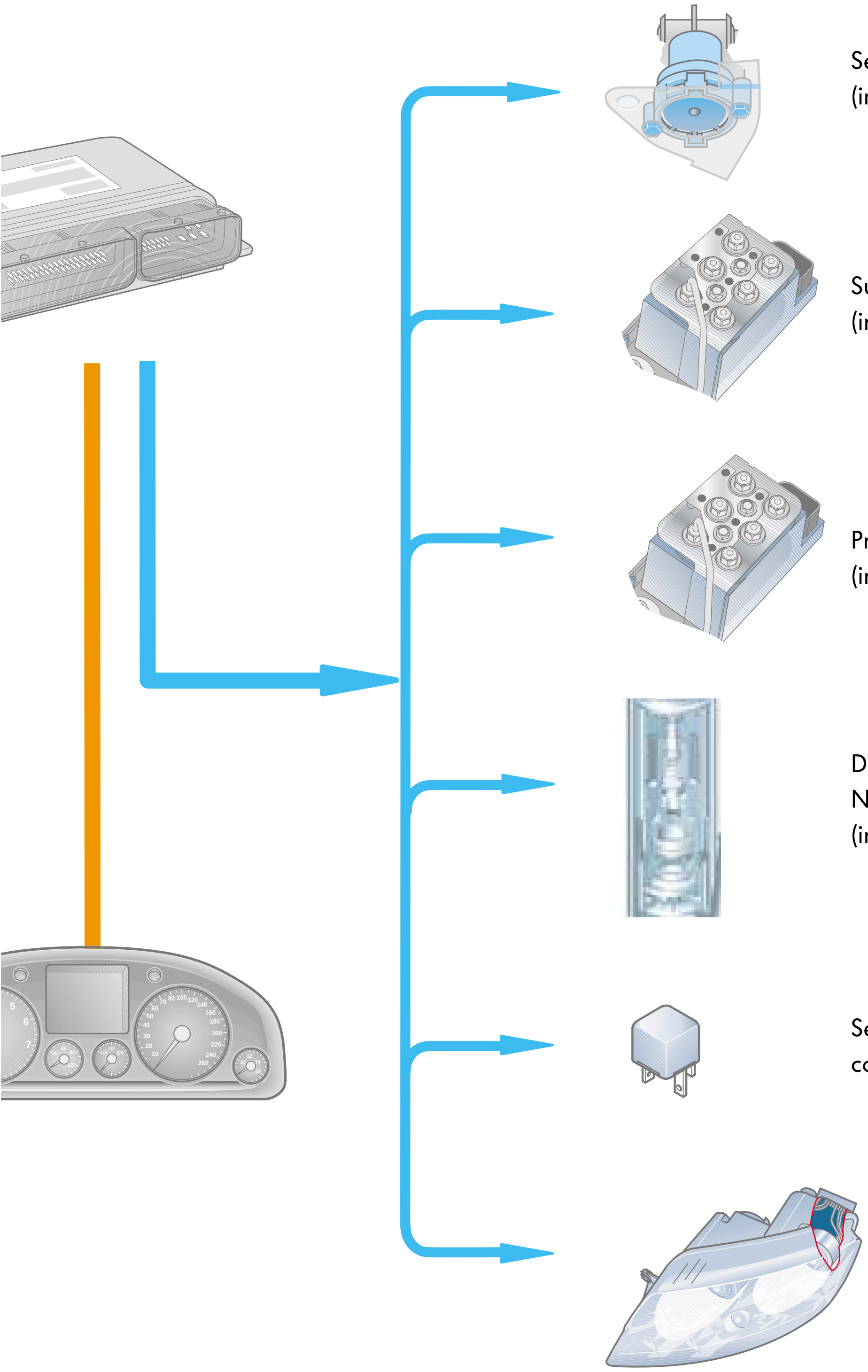
J197 - Self-levelling suspension control unit
J403 - Self-levelling suspension compressor relay
Combi - Dash panel insert
HRC - Headlight range control
MSG - Engine control unit
N111 - Drain valve
N148 ... N151 - Damper adjustment valve
N311 - Self-levelling suspension pressure accumulator valve
N336 ... N339 - Damper adjustment valve
ZAB - Infotainment
ZV - Door/bonnet/bootlid signal

System overview

Sensors



Actuators



Self-levelling suspension drain valve N111
(integrated in solenoid valve block)

Suspension strut valves N148, N149, N150, N151
(integrated in solenoid valve block)

Pressure accumulator valve N311
(integrated in solenoid valve block)

Damper adjustment valves
N336, N337, N338, N339
(integrated in air spring struts)

Self-levelling suspension
compressor relay J403

Gas discharge lamp control units with HRC
J567 and J568 integrated in the headlights

275_026

Design and function

Self-levelling suspension control unit J197

This control unit is located in the luggage compartment on the left-hand side behind the side trim. It is bolted behind the relay and fuse carriers.

As a central control unit, it has the following tasks:

- to control air suspension and the vibration dampers,
- to monitor the overall system,
- to diagnose the overall system, and
- to communicate via the CAN databus (drive train CAN databus).

275_083

The self-levelling suspension control unit has a redundant processor design (dual processors); the air spring algorithm runs primarily on the first processor and damping control runs primarily on the second processor.

Air spring struts

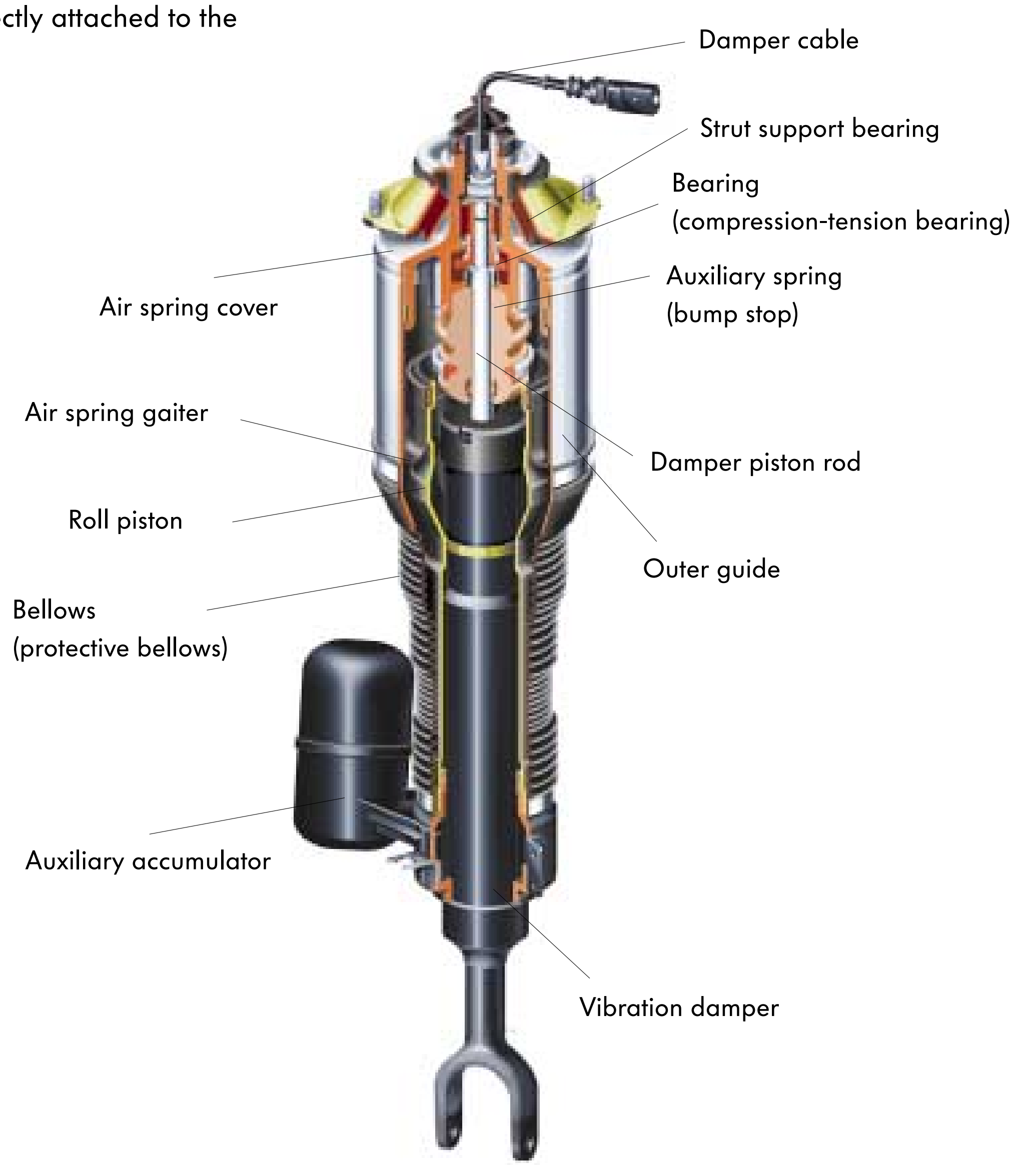
Air spring struts with externally guided, two-layer air spring gaiters are used on the front and rear axles.

The air spring gaiter is arranged concentrically around the gas-filled shock absorber (twin-tube gas-filled shock absorber).

The small wall thickness of the air spring gaiter provides excellent suspension response.
The desired spring rate is achieved by combining the roll piston contour, the outer guide and an auxiliary accumulator directly attached to the strut.

Different auxiliary accumulators are used on the front axle and rear axles.
The accumulator on the front axle - recognisable as a small cylinder - has a capacity of 0.4 litre and the ball accumulator on the rear axle has a capacity of 1.2 litre.

Strut, front axle



275_027a

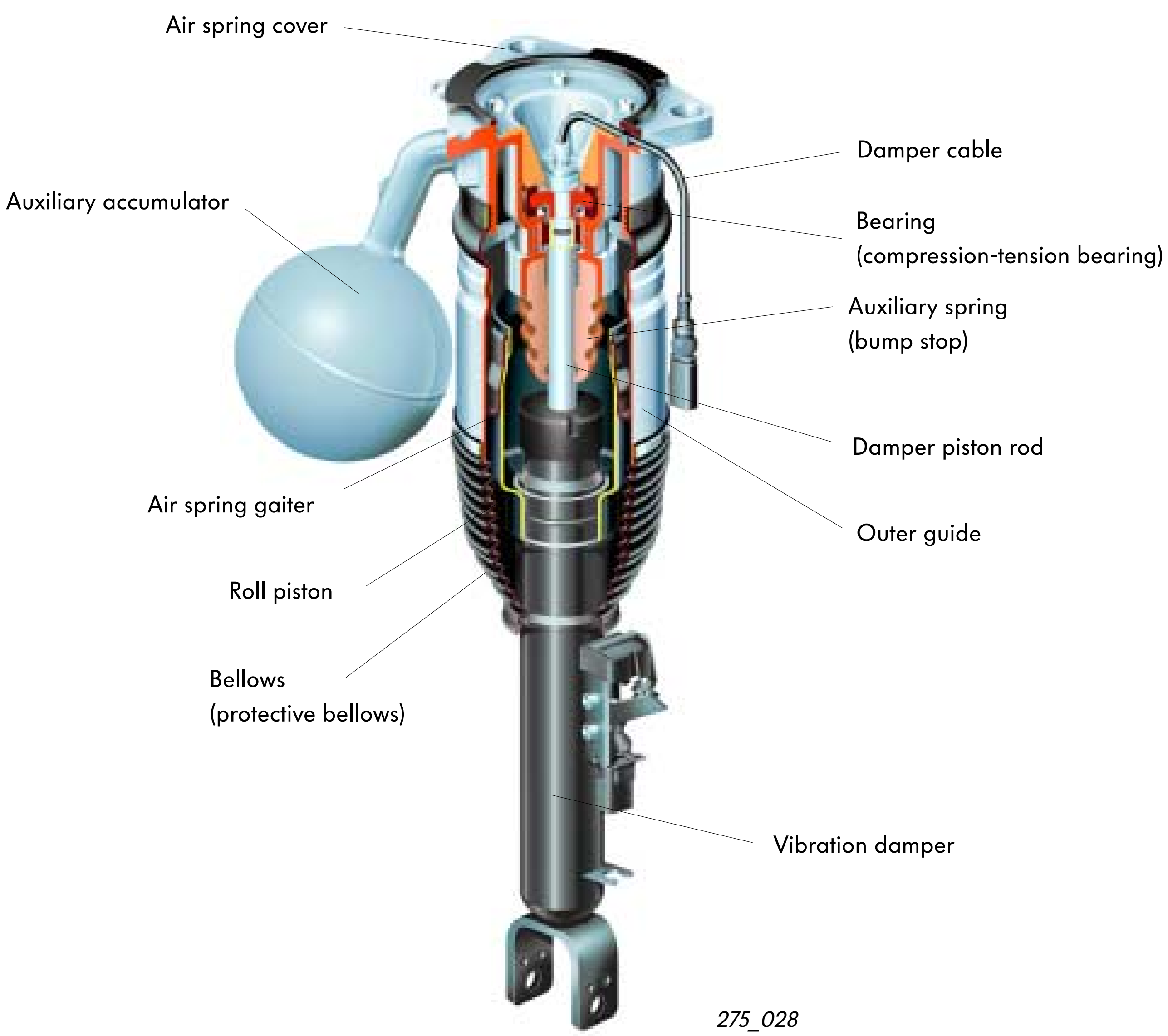
Design and function

The struts are designed to minimise the effect of transverse forces on the dampers. The special design of the strut support bearing on the front axle and the cardanic acting hydro-mounted version on the rear axle help reduce the effects of transverse forces on the dampers.

Residual pressure maintaining valves are mounted directly on the air connection of each air spring strut.
They maintain a residual pressure of about 3.5 bar in the air spring strut. This permits easy assembly and mounting of the components.

The outer guide protects the air spring gaiter against soiling and damage besides its function of guiding the air spring gaiter and bellows.

Strut, rear axle



275_028

Damper adjustment valve

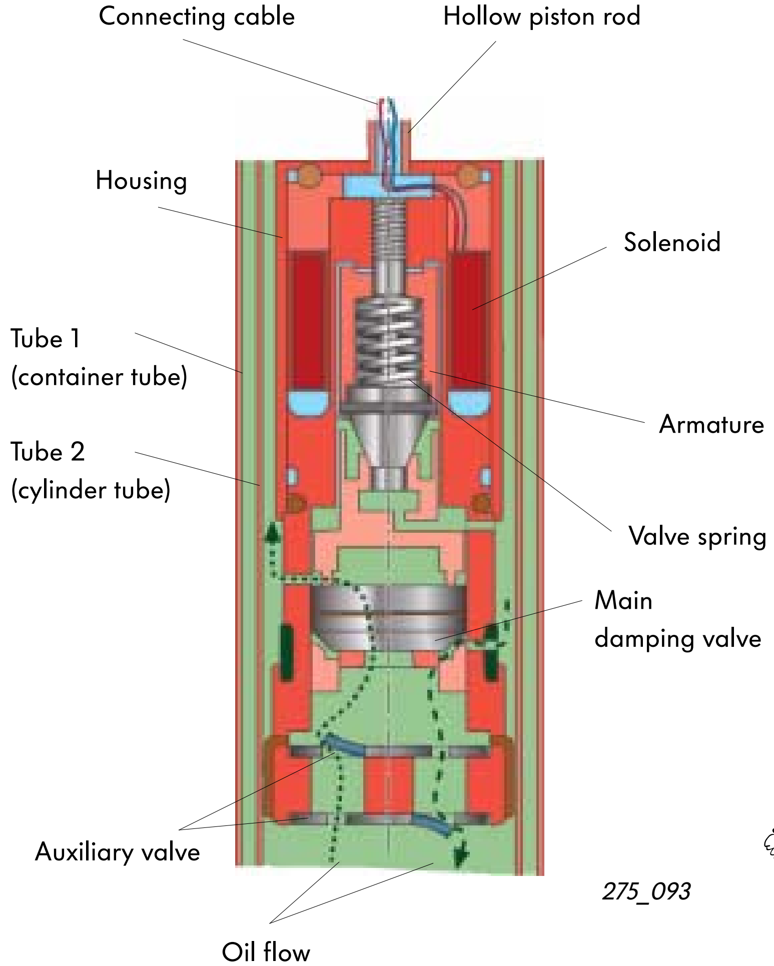
The CDC twin-tube gas-filled damper is adjustable over a wide range of damping forces via an electrically controlled valve integrated in the piston.
The oil flow through the piston valve, and hence the damping force, can be adapted to momentary demand within a few milliseconds by varying the electric current flowing through the solenoid.

The wheel acceleration senders mounted on each damper generate signals which, together with the signals supplied by the body acceleration senders, are used to calculate the required damper setting.

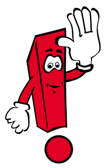
Since the system can rapidly detect and control tension and compression stages, it permits adjustment of the damping force required for the momentary driving situation.

The driving situation dependent maps are stored in the self-levelling suspension control unit.

Example of a piston valve



275_093

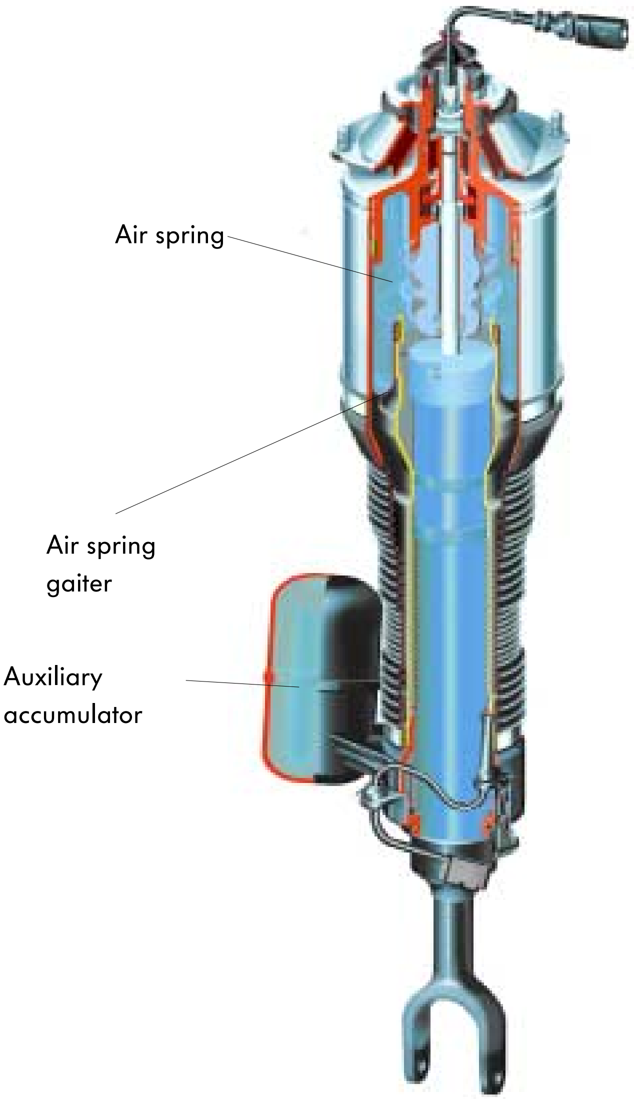


In certain driving dynamic states - e.g. longitudinal and/or transverse dynamics - the "skyhook control" is deactivated and the dampers are controlled by other dynamic modules.

Design and function

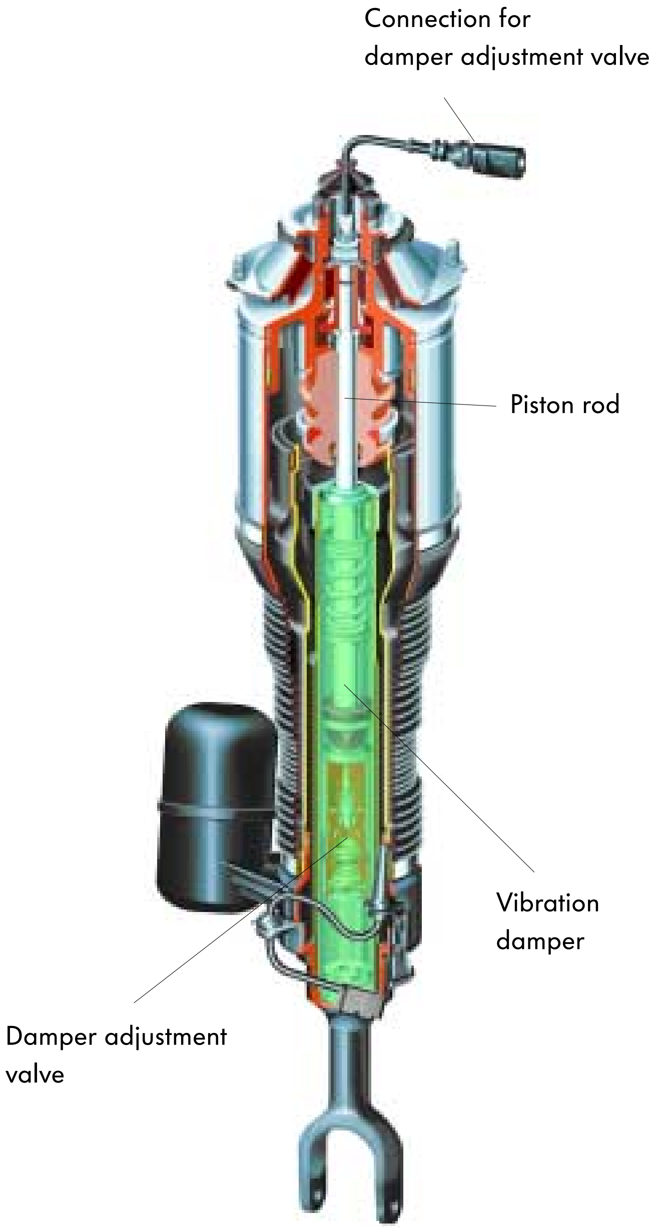
Air spring strut, front axle

Air spring part (blue)



275_086

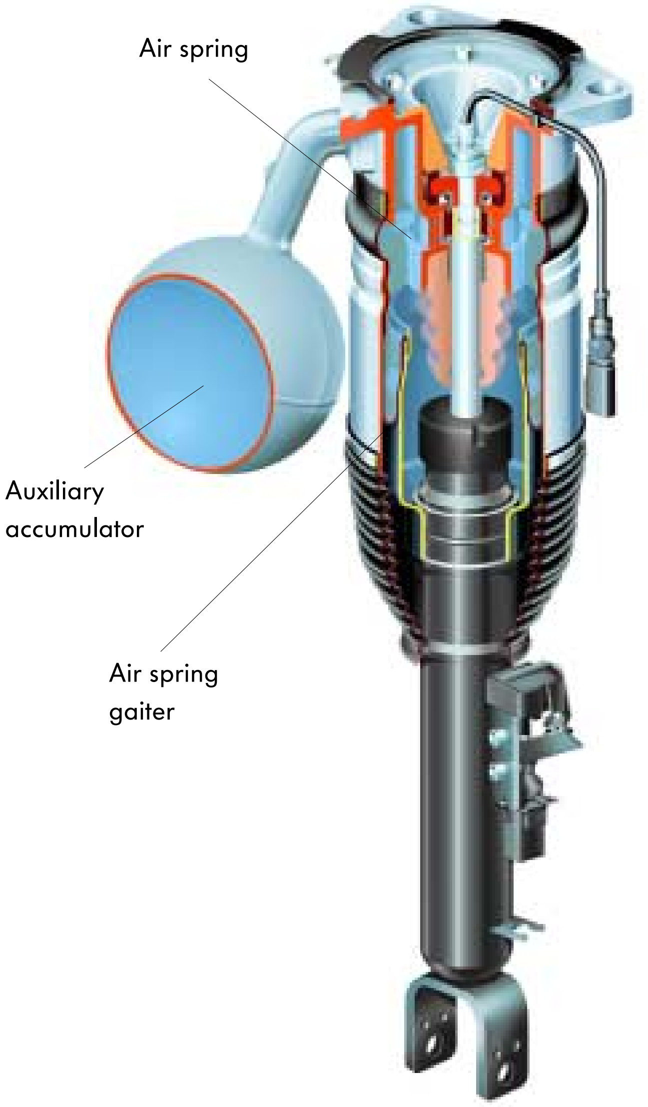
Damper part (green)



275_084

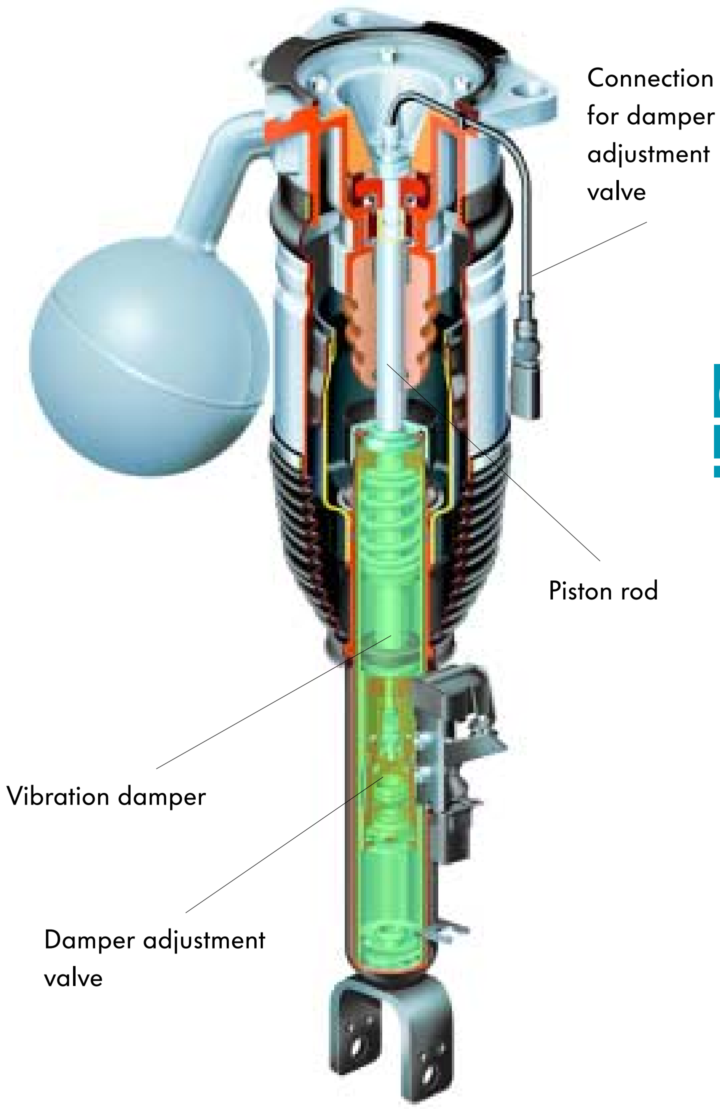
Air spring strut, rear axle

Air spring part (blue)



275_087

Damper part (green)



275_085

Design and function

Air supply unit

The air supply unit (ASU) is a compact unit. It is mounted to the underbody on an anti-vibration mounting in the spare-wheel well adjacent to the activated charcoal filter.

A plastic cover with vents provides protection against soiling.

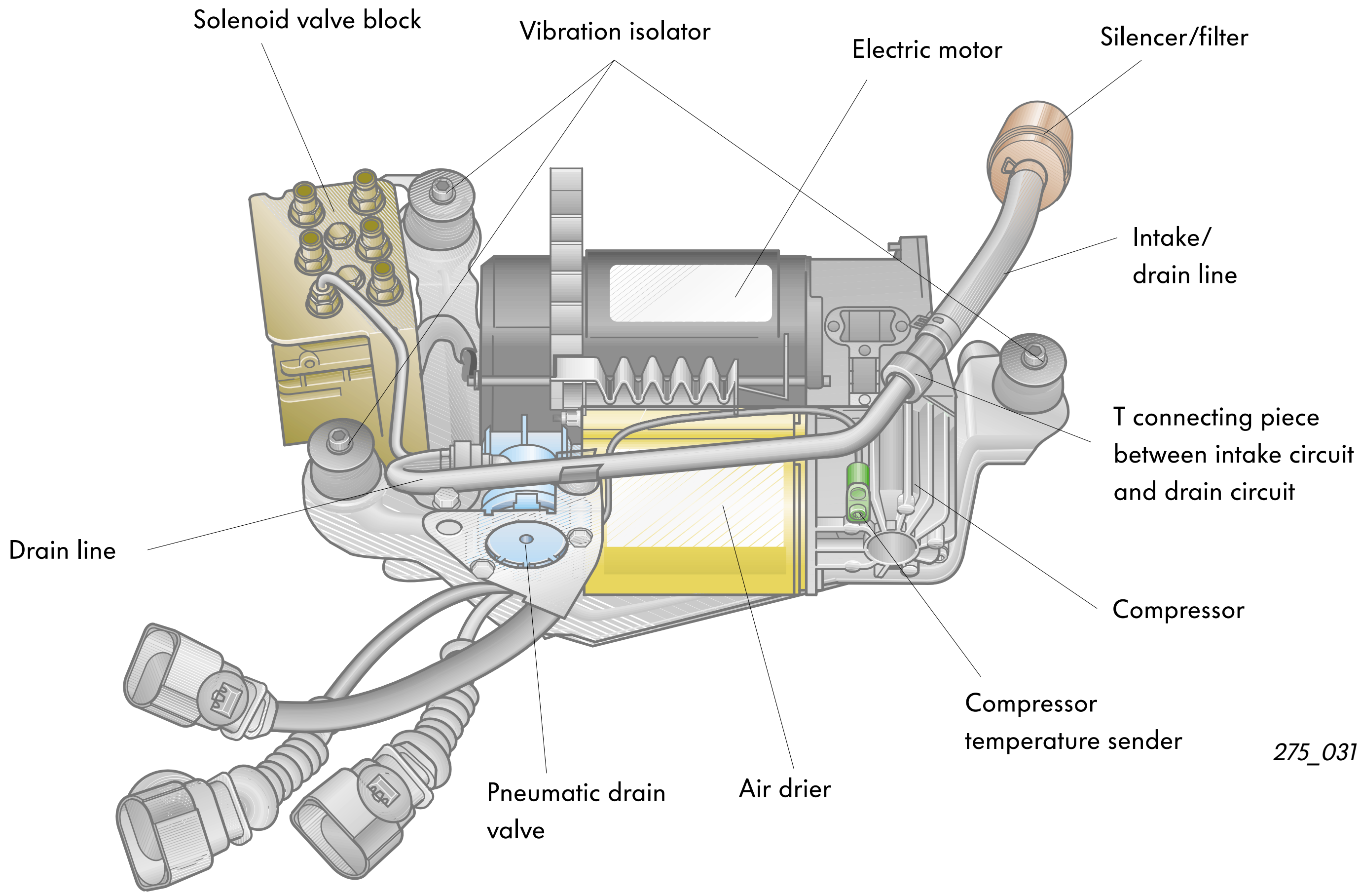
The compressor is supplied with air via the luggage compartment. Air is drawn in via the silencer/filter, cleaned and discharged.

A temperature sender protects the compressor against overheating and ensures availability of the air supply for the air suspension in all climatic and driving conditions.

The air supply unit comprises:

– the compressor unit with
  electric motor,
  dry-running compressor,
  air drier,
  residual pressure maintaining unit,
  maximum pressure limiter,
  drain circuit/valve,
  silencer with air filter,
  compressor temperature sender (temperature sender for overheating protection),
  pneumatic drain valve with pressure relief valve and

– the solenoid valve block with
  control valves for each air spring strut and for the pressure accumulator as well as
  an integrated pressure sender for monitoring the pressure accumulator.



275_031

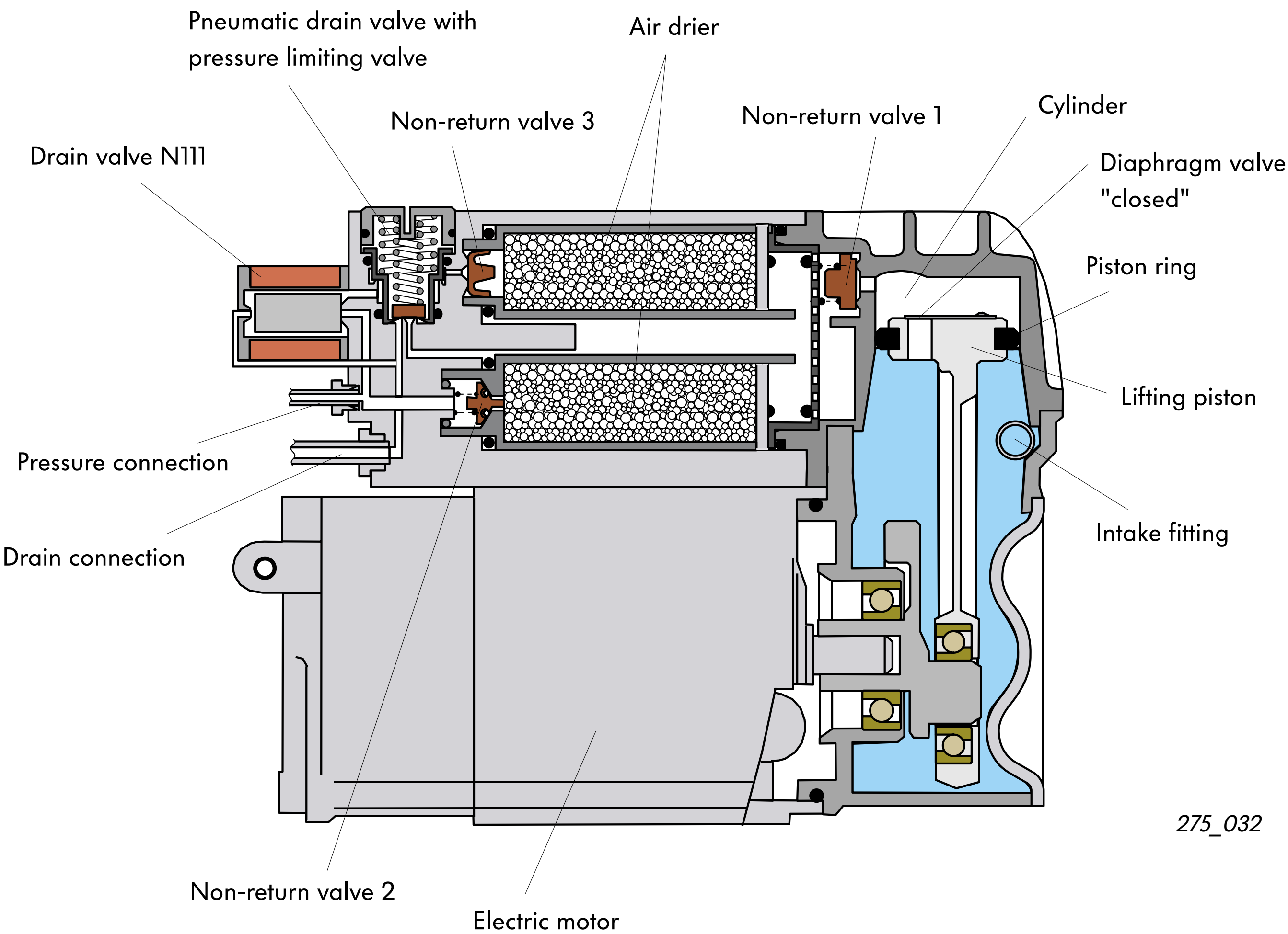
Compressor unit

Compressed air is produced by means of a single-stage piston compressor with integrated air drier.
To prevent soiling of the gaiters and the air drier (drier cartridge), the compressor is designed as a so-called dry-running compressor.

Lifetime-lubricated bearings and a piston ring made of PTFE (polytetrafluorethylene) ensure a long service life.

The drain valve N111, a pneumatic drain valve with pressure limiting valve and 3 non-return valves are integrated in the air drier housing.

To protect the compressor against overheating, it is switched off if excess temperature occurs.



275_032