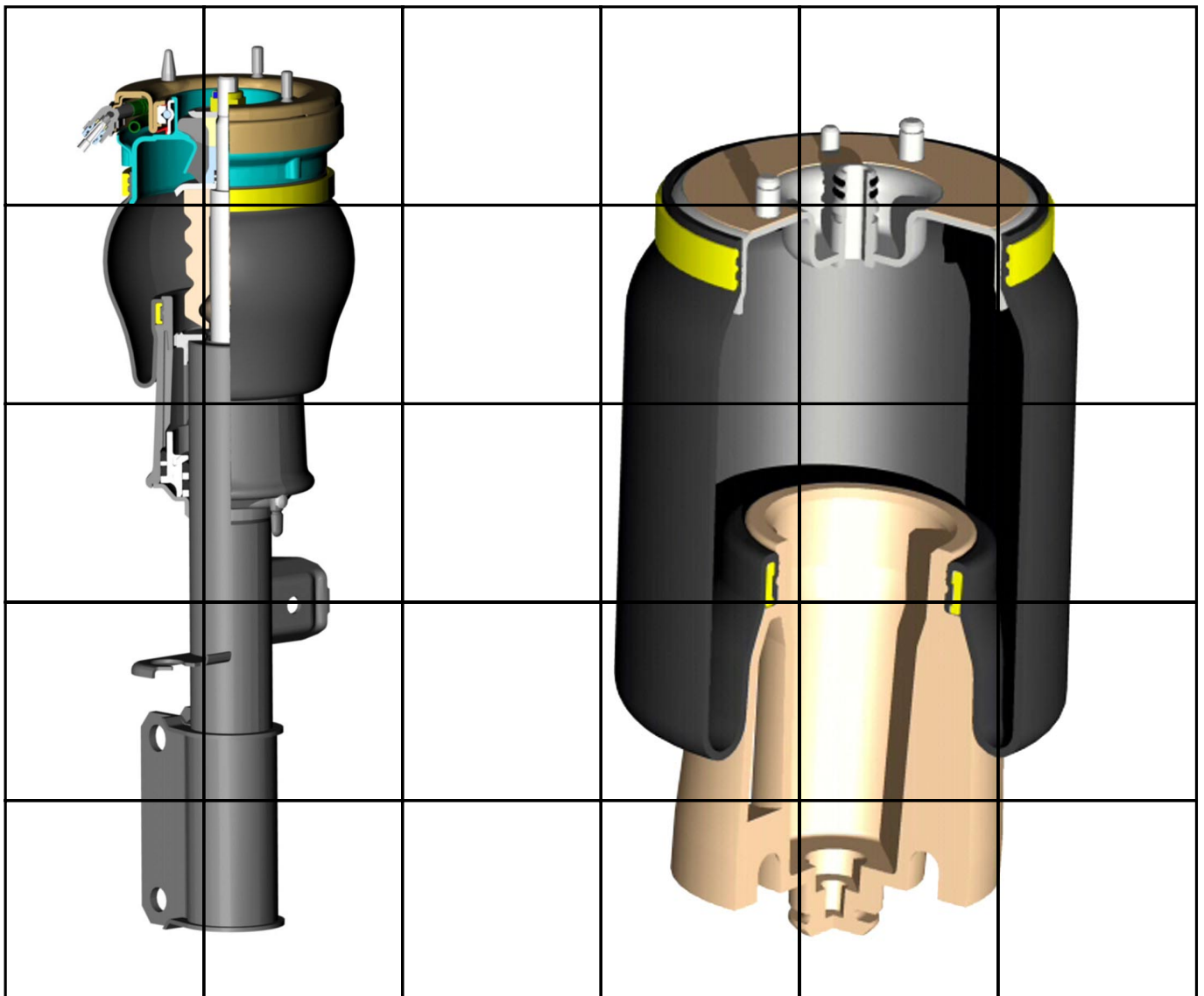




Air Suspension Level Control System

Seminar Working Material



NOTE

The information contained in this training course manual is intended solely for participants of the BMW Service Training course.
Refer to the relevant "Technical Service" information for any changes/supplements to the Technical Data.

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Air Suspension Level Control System

History

- General

The function of the level control system is to maintain the height of the vehicle body as closely as possible at a prespecified level under all load conditions.

Thanks to the extensively constant level, the geometric wheel suspension data (e.g. wheel camber, toe-in) remain unaltered by the load. The ride comfort is also not dependent on the load.

The headlight range remains extensively constant over the entire load.

BMW previously supplied level control systems as both special equipment and, in part, as standard equipment on the BMW 7 Series - E23/E32, 6 Series - E24 and 5 Series - E12/E28.

Hydropneumatic suspension

Partially loaded hydropneumatic rear-axle suspension forms the basis of these systems.

It is similar in its basic principle to pure air suspension. However it operates with a volume of gas which is permanently contained in the pressure accumulator (i.e. constant).

The gas used is nitrogen. The internal chamber of the pressure accumulator is divided by a diaphragm into individual gas and hydraulic fluid chambers.

Air Suspension Level Control System

With each compression and rebound movement of the rear wheels, the hydraulic fluid displaced by the piston rods of the dampers is moved back and forth between the spring strut and the pressure accumulator.

The gas cushion in the pressure accumulator is alternately compressed and expanded. This gas cushion thus acts as a gas spring, which is connected in parallel to the steel spring in the spring strut.

The level control system then begins to operate in the event of static (e.g. as a result of persons getting into the car) or quasi-static (e.g. as a result of the fuel tank emptying during driving) compression or rebound.

Level control system with electro-hydraulic pump

This type of level control system is used in the BMW 5 Series - E12, 7 Series - E23, 6 Series - E24 and 5 Series - E28.

A control switch mounted on the rear axle and actuated by the stabilizer continually compares the ride height with the set desired value and sends an electrical signal to the hydraulic control unit.

This unit essentially consists of an electric motor, a pump and an expansion tank and is connected by hydraulic lines to the two rear spring struts and the pressure accumulators.

Level control is disabled during the mostly prolonged dynamic wheel movements during cornering and acceleration or braking procedures. These drive states are recorded by a mercury acceleration sensor or by evaluation of activation of the brake lights.

Air Suspension Level Control System



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KT-10259



KT-10256

Fig. 1: Top left, E12; top right, E24; bottom left, E28; bottom right, E23

Level control system with engine-driven piston pump

In the 7 Series - E23, 7 Series - E32, 5 Series - E34 and 7 Series - E38, the suspension system was converted to a circulation system with an engine-driven piston pump (joint fluid circuit with power steering on the suction side). It was thus possible to dispense with the hydraulic control unit (increased space in the luggage compartment).

The accumulator is used together with the power steering. An expansion tube is used after the tandem pump to compensate pressure fluctuations.

Air Suspension Level Control System

The control valve on the rear axle assumes control of the fluid flow for raising or lowering the car or controls the circulation flow. It is actuated via a linkage which is connected to the stabilizer, i.e. the control valve switches continually in the event of changes in the ride height during driving. This goes unnoticed by the car passengers on account of the inertia of the overall system.

The control valve maintains a minimum pressure of 30 bar, which must be reduced to 0 bar via the drain valve in the event of repair work. If a pressure of 130 bar is reached, the system switches to fluid circulation, which results in a lowering of the rear end in the event of further loading (overload).



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Fig. 2: Top left, E23; top right, E32; bottom left, E34; bottom right, E38

Introduction to air suspension

- General

Air suspension was used for the first time in the BMW Group in the E39 and is also fitted in the E53 and E65/E66 models.

The entire axle load is borne by the air suspension.

This system is controlled automatically under all operating conditions and in the case of single-axle air suspension (air suspension at the rear axle) without the possibility of driver intervention.

The underlying control philosophy of this self-levelling suspension system is:

"Control only when absolutely necessary." This means that brief changes in the ride height are not compensated (potholes). Unnecessary control operations are thus avoided.



Fig. 3: Top left, E39; top right, E53; bottom, E66

Air Suspension Level Control System

Advantages of air suspension:

- Control is independent of the vehicle engine
- Single-wheel control is possible
- Lateral locking is effected
- A distinction is made between load and drive states
- An inclined load is identified and corrected
- However an inclination is not compensated
- Self-diagnosis is performed
- Activation of diagnosis with the Tester is possible
- An automatic interruption of control takes place in the case of
 - cornering
 - wheel changes

Pneumatics diagram

- Single-axle air suspension

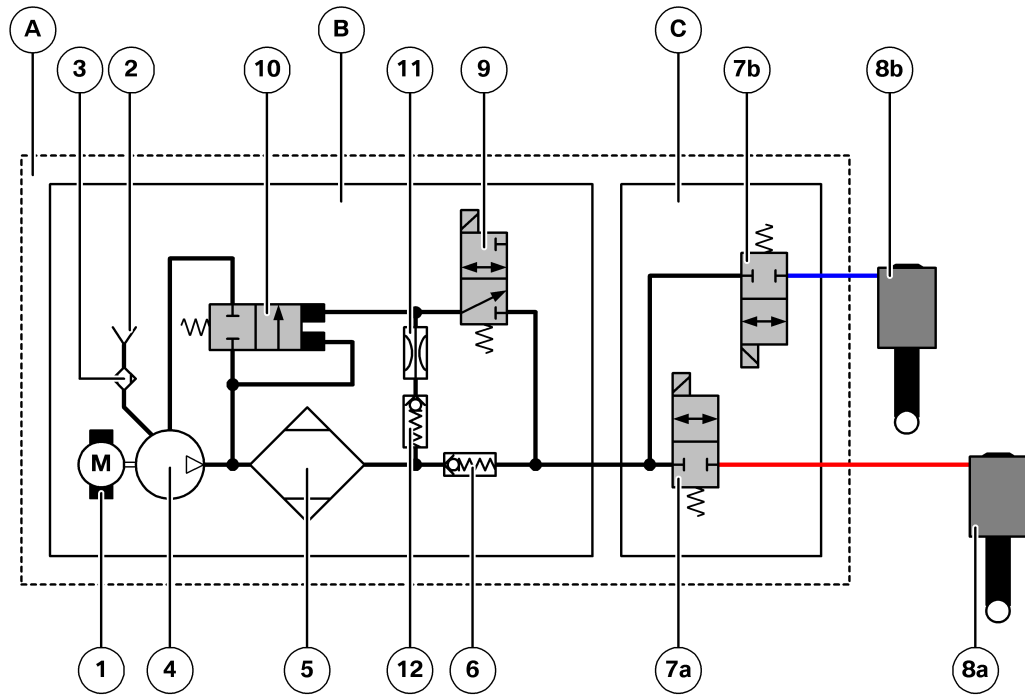


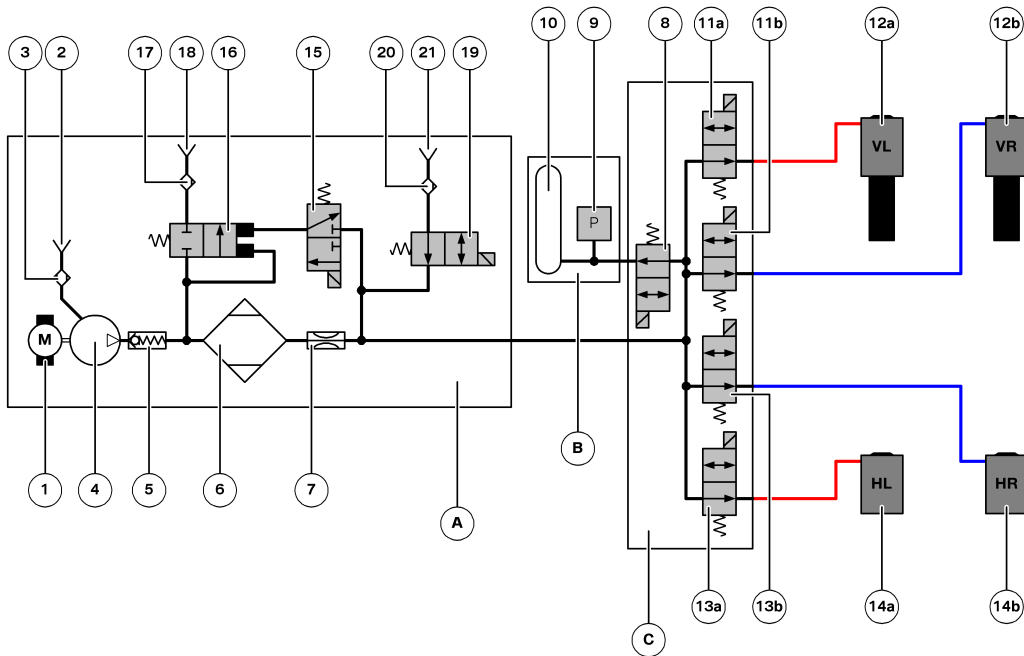
Fig. 4: Pneumatics diagram E39

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Index	Explanation	Index	Explanation
A	Air supply unit (LVA)	7a	Solenoid valve, left side
B	Compressor unit	7b	Solenoid valve, right side
C	Solenoid valve block	8a	Air spring strut, left side
1	Electric motor	8b	Air spring strut, right side
2	Intake opening	9	Drain valve
3	Filter	10	Pressure limiting/holding valve
4	Piston compressor	11	Restrictor
5	Air drier	12	Non-return valve
6	Non-return valve		

Air Suspension Level Control System

- Twin-axle air suspension



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Fig. 5: Pneumatics circuit diagram E53 twin-axle air suspension

Index	Explanation	Index	Explanation
A	Air supply unit	11b	Solenoid valve, right side, front
B	Pressure accumulator	12a	Air spring strut, left side, front
C	Pressure accumulator valve unit	12b	Air spring strut, right side, front
1	Electric motor	13a	Solenoid valve, left side, rear
2	Intake opening	13b	Solenoid valve, right side, rear
3	Filter	14a	Air spring, left side, rear
4	Piston compressor	14b	Air spring, right side, rear
5	Non-return valve	15	Pilot valve (electric)
6	Air drier	16	Drain valve (pneumatic)
7	Restrictor	17	Sintered filter
8	Pressure accumulator valve	18	Outlet opening
9	Accumulator pressure sensor	19	High pressure vent valve
10	Pressure accumulator	20	Sintered filter
11a	Solenoid valve, left side, front	21	Outlet opening

System overviews

- E39 electrical system schematic high (MY 2002)

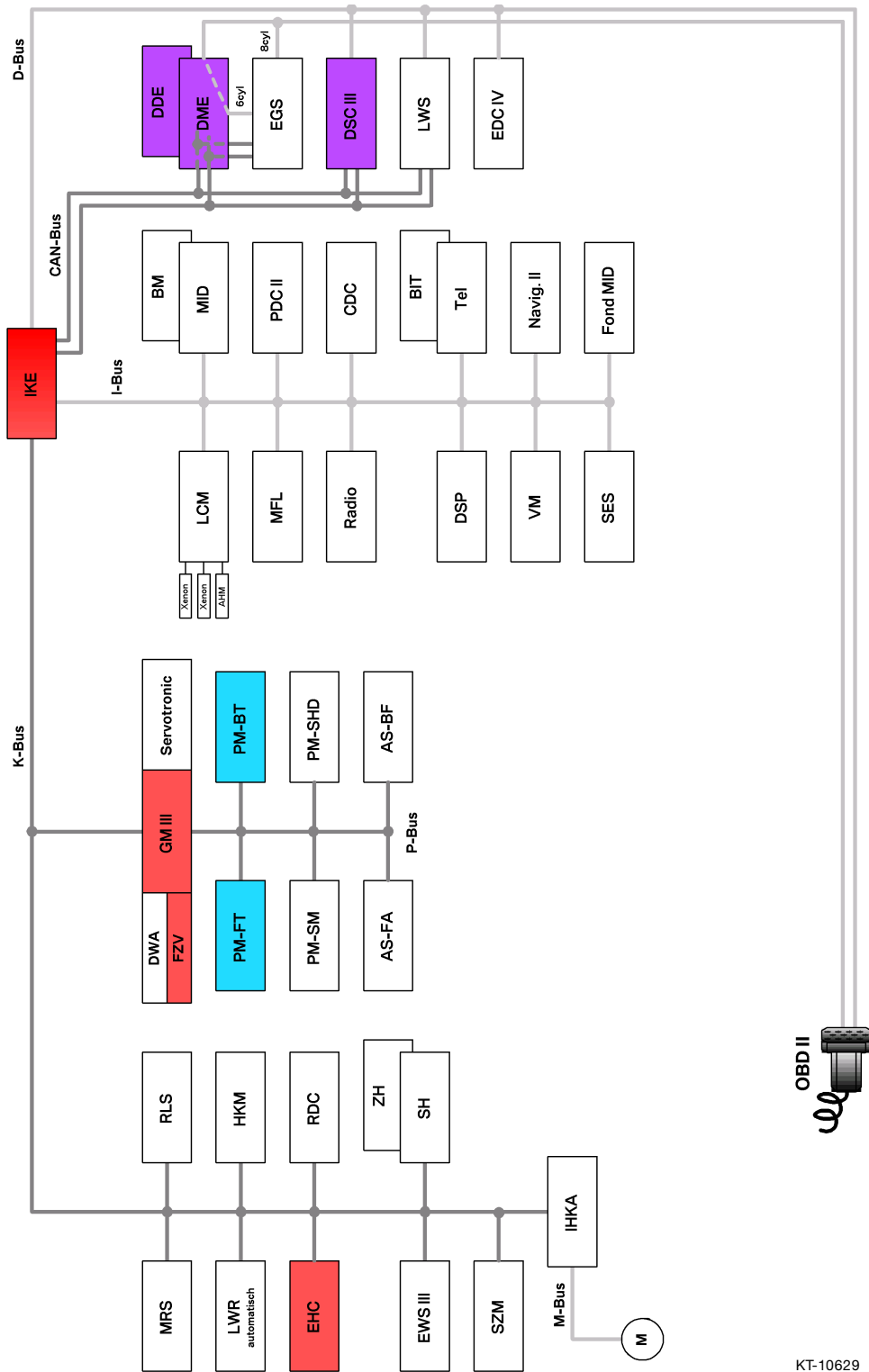
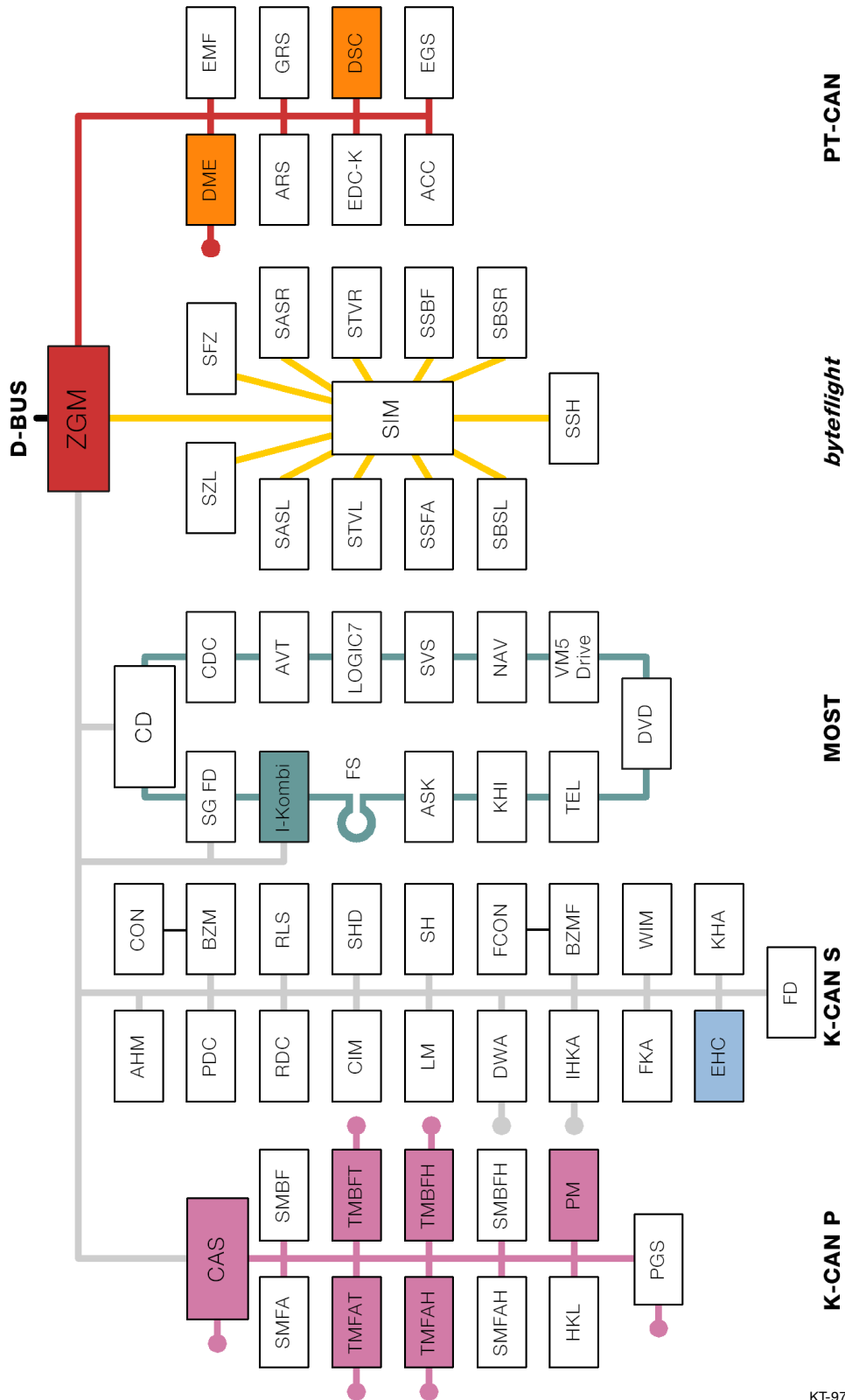


Fig. 6: Incorporation of the level control system E39 (EHC) in bus system

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Air Suspension Level Control System

- E65/E66 electrical system schematic (MY 2002)

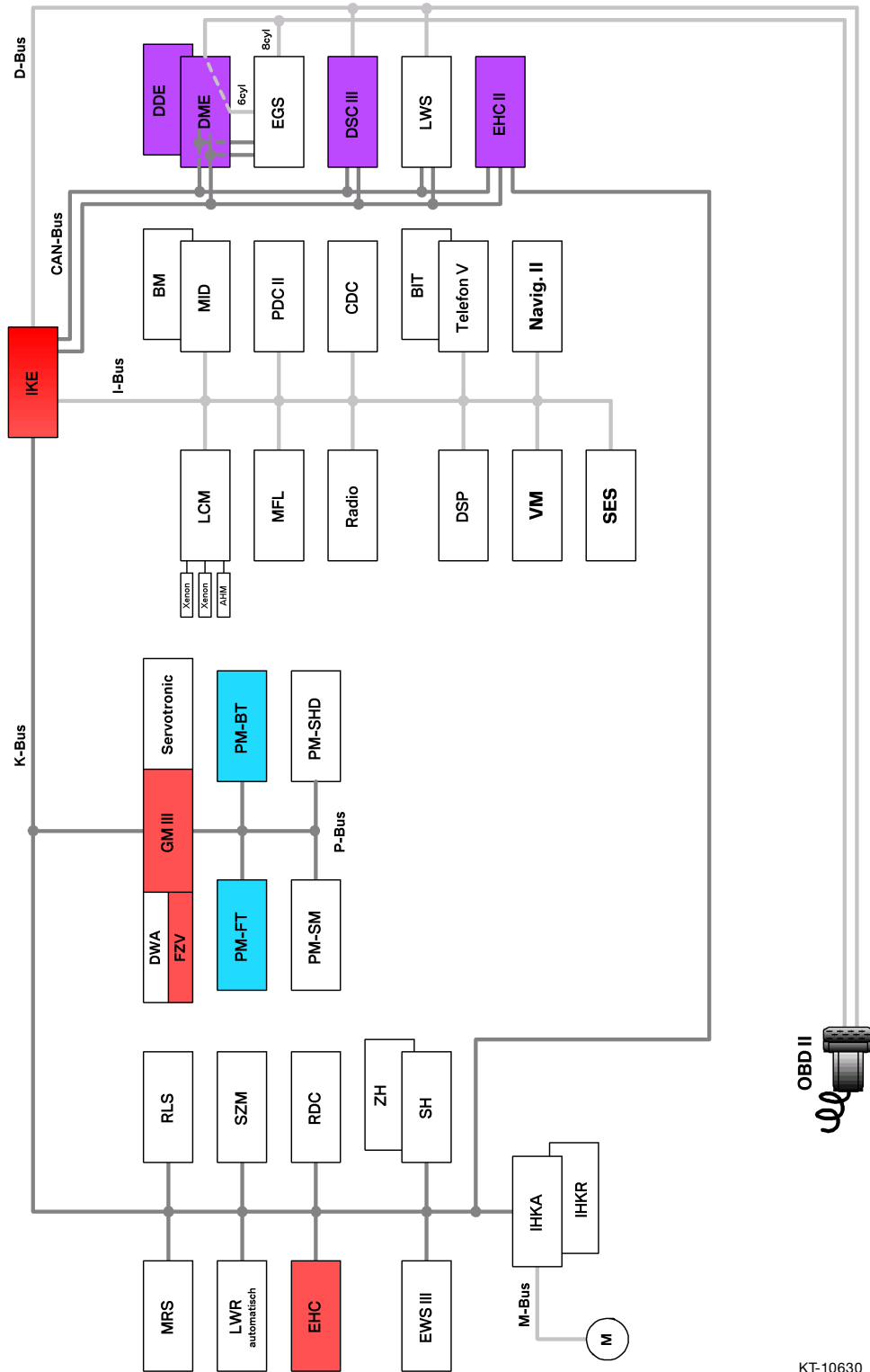


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Fig. 7: Incorporation of the level control system E65/E66 (EHC) in bus system

Air Suspension Level Control System

- E53 electrical system schematic high (MY 2002)



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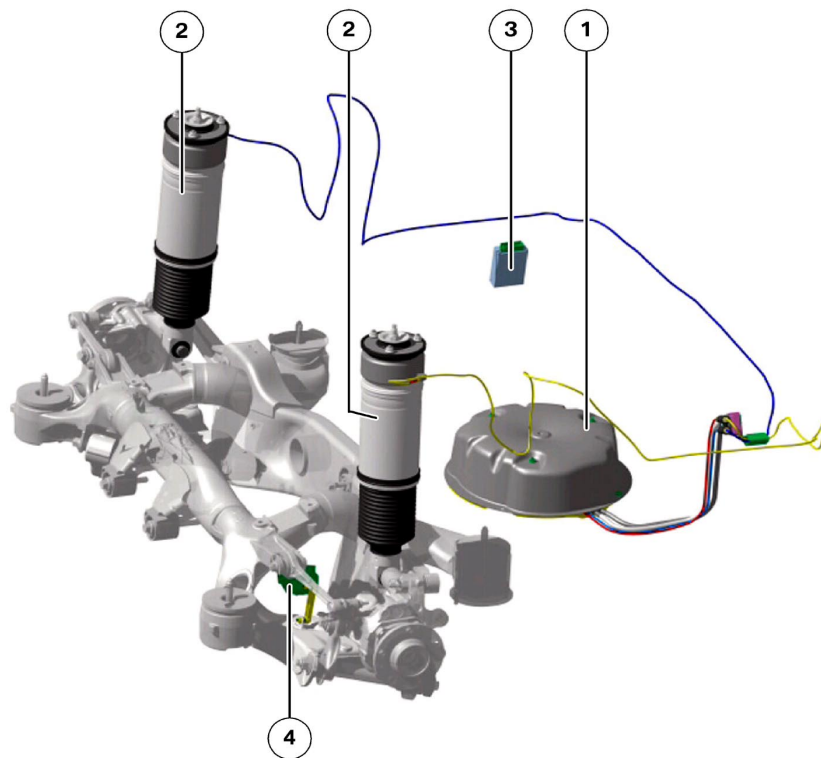
Fig. 8: Incorporation of the level control system E53 (EHC) in bus system

Air suspension components

- Graphical system overview

Single-axle air suspension

- Air supply unit (LVA)
- Control unit (EHC)
- Two air springs
- Two ride height sensors
- Telltale or CC display



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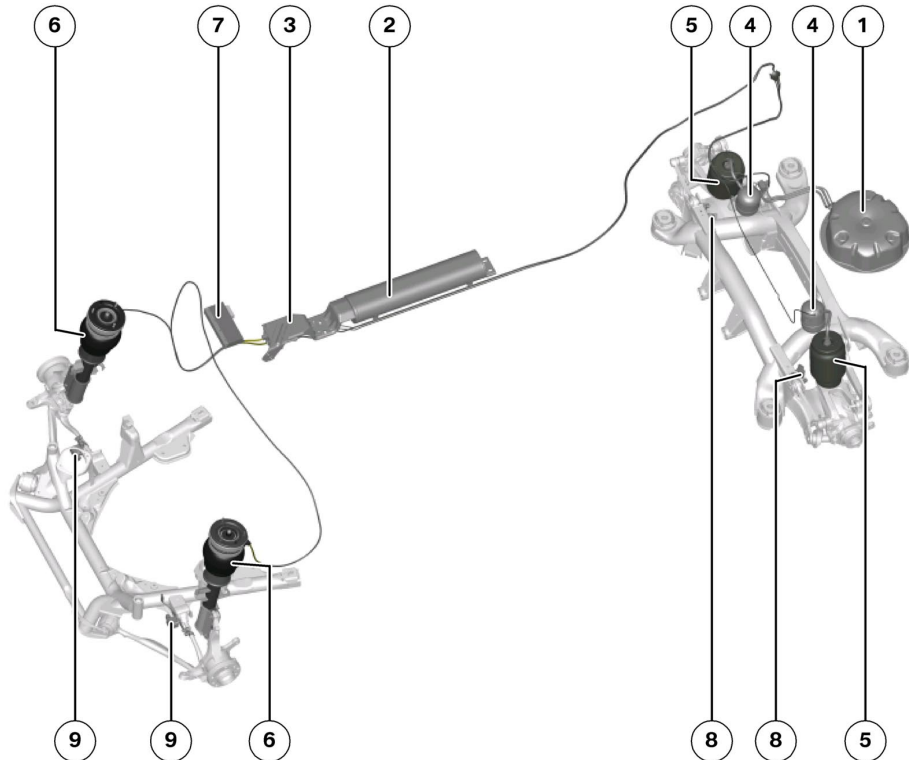
Fig. 9: Overview of E65/E66 single-axle air suspension

Index	Explanation	Index	Explanation
1	Air supply unit (LVA)	3	EHC control unit
2	Air spring strut	4	Ride height sensor

Air Suspension Level Control System

Twin-axle air suspension

- Air supply unit (LVA)
- Control unit (EHC)
- Four air springs
- Four ride height sensors
- Pressure accumulator valve unit
- Telltale or CC display



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Fig. 10: Overview of E53 twin-axle air suspension

Index	Explanation	Index	Explanation
1	Air supply unit (LVA)	6	Air spring strut, front
2	Pressure accumulator	7	EHC control unit
3	Pressure accumulator valve unit	8	Ride height sensor, rear
4	Additional air volume	9	Ride height sensor, front
5	Air spring, rear		

Air Suspension Level Control System

- Air supply unit (LVA)

The air supply unit is fitted in the spare wheel recess and consists of the following components:

- Protective cover with internal acoustic insulation
- Lid
- Rubber-mounted component carrier
- Compressor unit
- Compressor relay
- Solenoid valve block

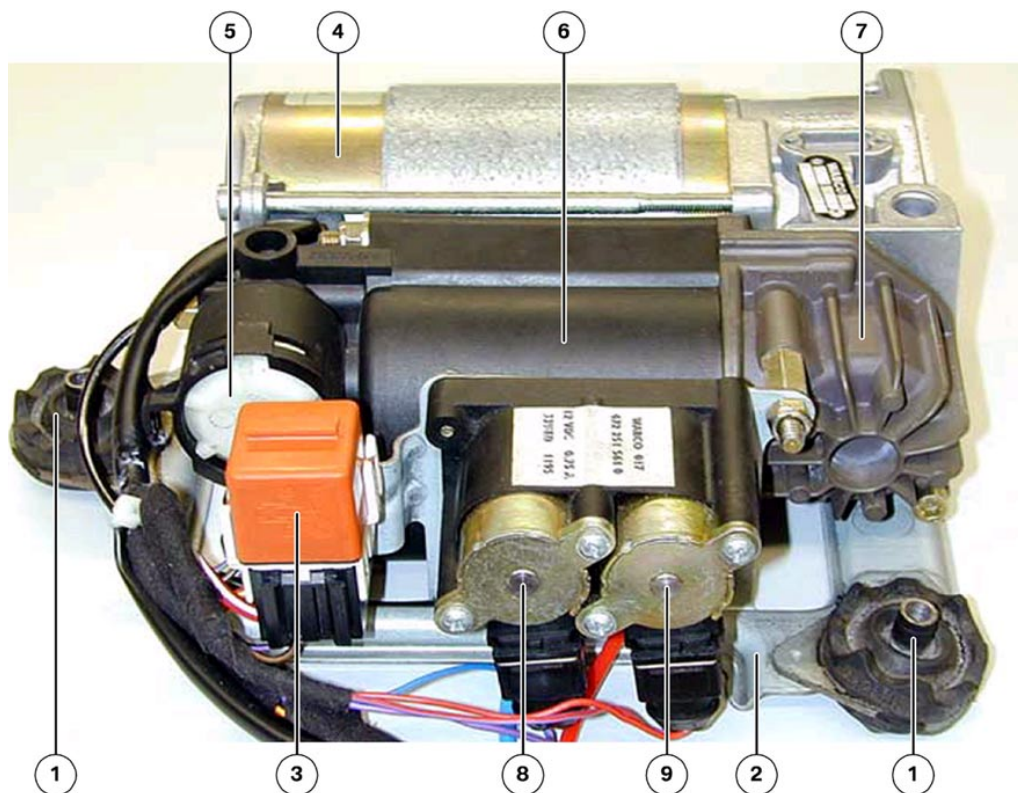


Fig. 11: Air supply unit, single-axle air suspension

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Index	Explanation	Index	Explanation
1	Rubber mount	6	Air drier
2	Component carrier	7	Compressor
3	Compressor relay	8	Solenoid valve, right valve
4	Electric motor	9	Solenoid valve, left valve
5	Air cleaner		

Air Suspension Level Control System

- Control unit (EHC)

The control unit for single-axle air suspension is fitted in the module box on the rear right of the luggage compartment.

In the E53 with twin-axle air suspension, the control unit is fitted in the module carrier behind the glovebox.

Signals

The EHC control unit receives the following information:

- Vehicle ride height
- Load cutout signal
- Terminal 15 ON/OFF
- Vehicle speed
- Lateral acceleration
- "Engine running" signal
- Flap status

The control unit decides on a case-by-case basis whether a control operation is required in order to compensate changes in load. It is thus possible to adapt the frequency, specified height, tolerance thresholds and battery load optimally by means of the control operation to the relevant situation.

The control unit has full diagnostic capability.

- Air suspension

E39

The air spring strut is a combination of a gas pressure damper and an air spring. The air spring consists of an air reservoir, a U-type bellows and an additional air volume.

The bellows forms the airtight and moving connection between the air reservoir and the damper. The bellows bears the relevant vehicle load with its effective inner surface via the prevailing air pressure.

If the air spring fails, an elastomer auxiliary spring assumes temporary suspension of the vehicle.

Important: The spring strut must be replaced after the air spring has failed.

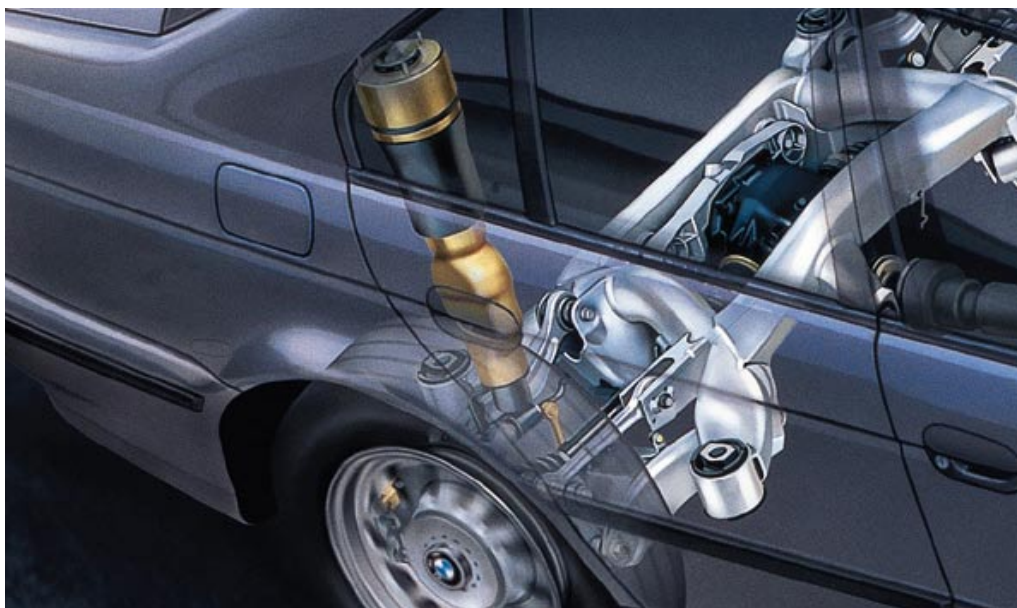
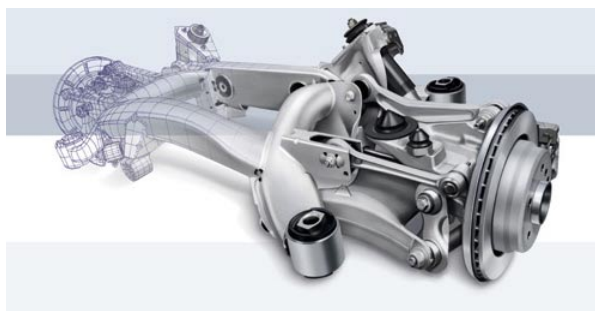


Fig. 12: Rear axle E39 saloon with EHC

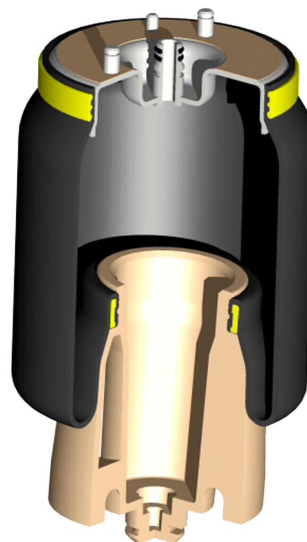
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Air Suspension Level Control System

The air spring and the damper are separate on the E39 touring rear axle. The air spring is installed in place of the steel spring.



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Fig. 13: Rear axle E39 touring, left; air spring E39 touring rear, right

E65/E66

An identifying feature of the E65/E66 air spring strut is the internally guided axial air bellows. Internally guided means that the bellows is guided in an aluminium casing. The bellows is supported on this casing. This prevents the compression forces from weighing heavily on the bellows.

It has thus been possible to manufacture the bellows from a thin, flexible diaphragm which can react to minimal shocks and in this way provide a more comfortable suspension.

The diaphragm is composed of only one fabric layer embedded in rubber whose fibres run longitudinally along the spring strut (axially). The bellows is therefore also known as an axial air bellows.

Air Suspension Level Control System

The bottom end of the air spring strut is enclosed in a bellows in order to protect the diaphragm against the mechanical effects of fouling (sand, particles, etc.). The lower end of the bellows incorporates small holes for pressure compensation in the space between the bellows and the roll piston. The action of the bellows rolling in this space produces pressure differences.

The bellows together with the roll piston contains a volume of air that is sufficient for optimum suspension.

A residual pressure holding valve on the air spring strut prevents it from being depressurized. The air spring strut remains under pressure in the event of a loss of pressure in the system. The residual pressure is 3.25 ± 0.75 bar. This ensures that the bellows diaphragm is not damaged when the car is still being moved.

The residual pressure holding valve is secured with Loctite and must **not** be removed!

The air spring strut is initially filled at the manufacturer to 10 bar. This pressure is reduced to 3.5 bar when the spring strut is to be stored. Under this pressure, the strut is extended to its maximum length.

The connection of the air spring struts to the air supply unit (the distributor block) is located on the left of the luggage compartment under the flap on which the wheel nut wrench is mounted.

Air Suspension Level Control System

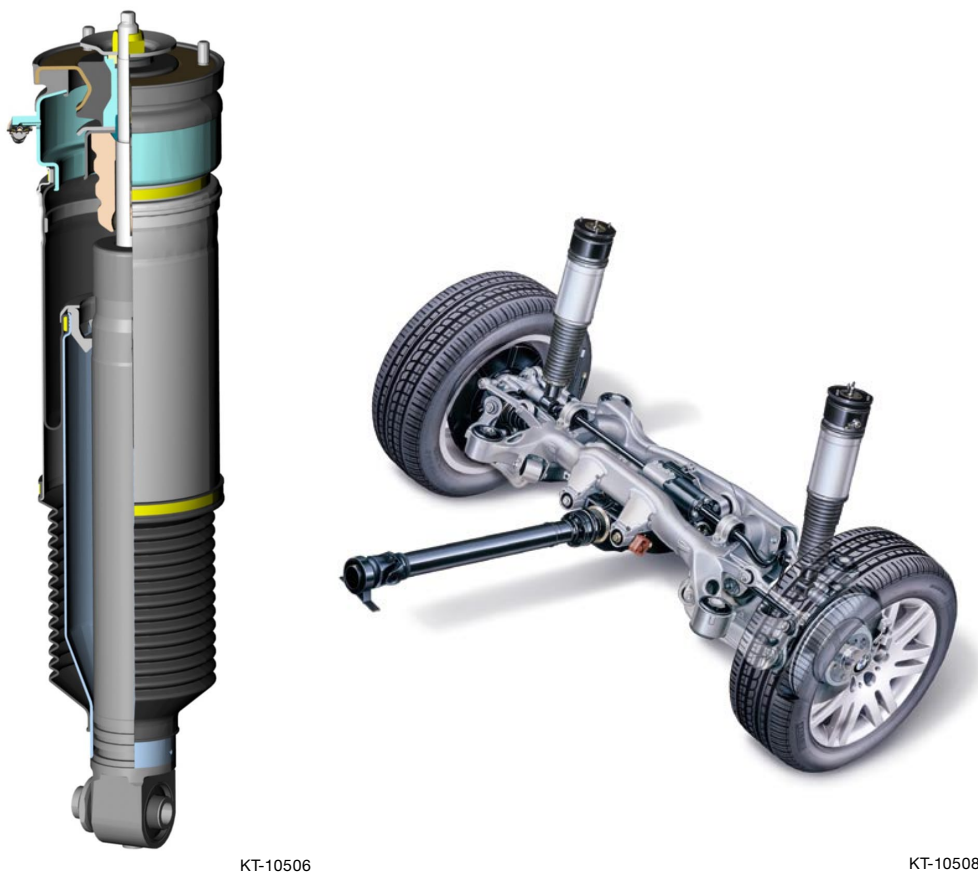


Fig. 14: Air spring strut E65/E66, left; graphic of rear axle, right

E53

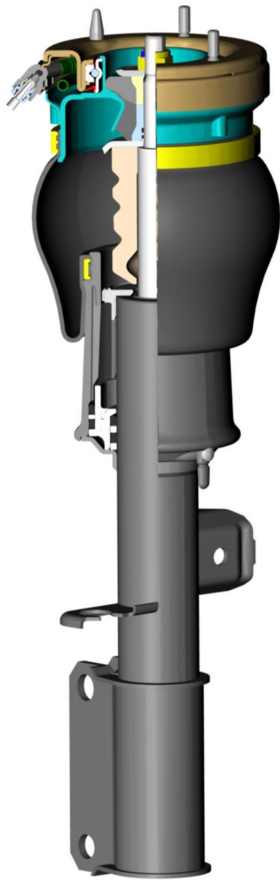
Single-axle air spring

The rear-axle air spring is identical to its counterpart in the E39 touring.

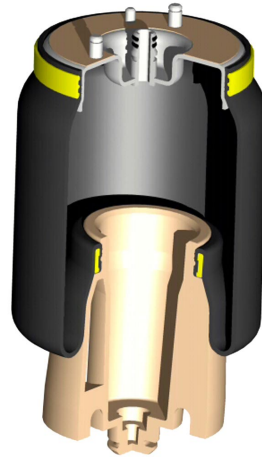
Twin-axle air spring

In addition to the air spring on the rear axle (identical to the single-axle air spring E53), the steel spring strut is also replaced by an air spring strut on the front axle.

Air Suspension Level Control System



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Fig. 15: Air spring strut E53 front, left; air spring rear, right

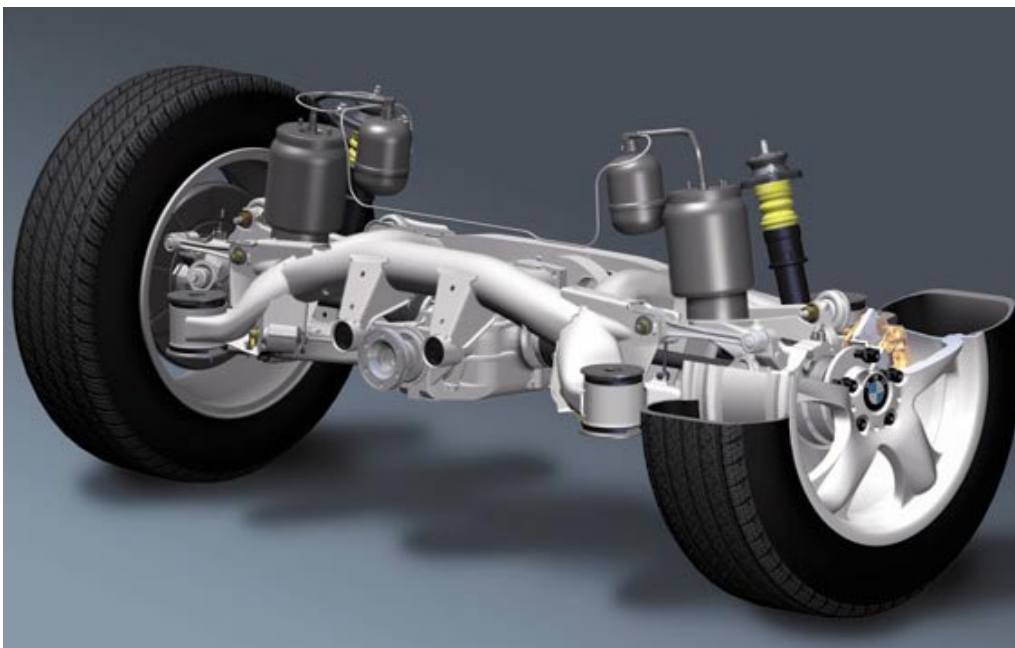
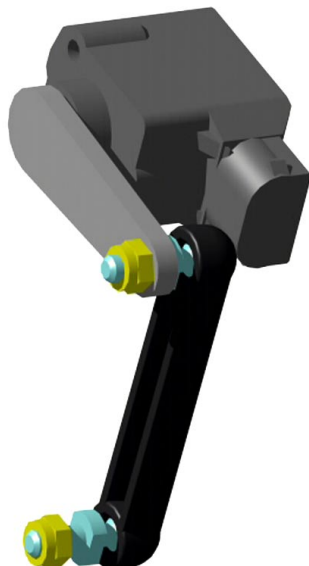


Fig. 16: Rear axle E53 with air suspension

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- Ride height sensor



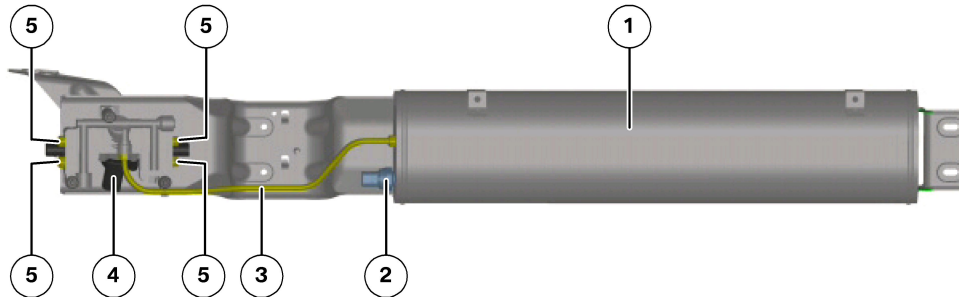
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Fig. 17: Ride height sensor

A ride height sensor is fitted for each air-sprung wheel. Refer to the overview graphics for the single-axle and twin-axle air suspension for details of the installation position. The ride height sensor is articulated by a coupling rod and sends a signal to the EHC control unit.

The ride height sensor operates according to the magnetoresistive principle. In the E38 and the following cars, the car is fitted with automatic headlight vertical aim control and the right-hand ride height sensor is designed as a double sensor.

- Pressure accumulator valve unit



KT-10649

Fig. 18: Pressure accumulator valve unit

Index	Explanation	Index	Explanation
1	Pressure accumulator	4	Pressure accumulator valve
2	Pressure sensor	5	Air line connection
3	Connecting line from valve unit to pressure accumulator		

With the pressure accumulator, it is possible to achieve the at times large height differences more quickly than with a compressor system only.

Internal pressure is gauged by a sensor attached to the pressure accumulator. Normal system pressure is 15.7 ± 0.7 bar. Minimum pressure is 9 bar.



The charge of the pressure accumulator is theoretically sufficient to fill the four spring struts once from the Access position to the normal position and also to load the unladen vehicle in the normal position up to the maximum permissible gross weight at normal temperatures.

In the valve unit, four bellows valves and the pressure accumulator valve are activated. The bellows valves and the pressure accumulator valve are solenoid valves, which are closed under spring pressure when deenergized.


Air Suspension Level Control System

- Check Control messages

E65/E66 single-axle air suspension




Control unit	Cause	Variable telltale	Check Control message	Information in control display
EHC	Alive failure or loss of functionality; transport or belt mode set	 KT-9793	Level control system failure!	"Level control system failure" Ground clearance and driving comfort reduced. Avoid high speed cornering. Have checked by BMW Service as soon as possible.
EHC	Level control system sensor failure	 KT-9793	Level control system fault!	"Level control system fault" Possible reduction in driving comfort. Have the problem checked by BMW Service.

E39 and E53 single-axle air suspension

Control unit	Cause	Variable telltale	Check Control message	Information
EHC	Level control system sensor failure Transport or belt mode set Malfunction	 KT-9793	Level control system inactive	Ground clearance and driving comfort possibly reduced. Avoid high speed cornering. Have the problem checked by BMW Service.

Air Suspension Level Control System

E53 twin-axle air suspension

Control unit	Cause	Variable telltale	Check Control message	Information
EHC	<p>Faults in the system or on the control unit which are only detected by the instrument cluster, e.g. disconnected control unit</p> <p>Level control system sensor failure</p> <p>Transport or belt mode set</p>	 <small>KT-9793</small>	Level control system inactive	Ground clearance and driving comfort possibly reduced. Avoid high speed cornering. Have the problem checked by BMW Service.
EHC	For safety-critical faults (vehicle too high or at inclination)	 <small>KT-9793</small>	Level control system inactive + max. 60 km/h	Ground clearance and driving comfort possibly reduced. Avoid high speed cornering. Have the problem checked by BMW Service.
EHC	Trailer mode	 <small>KT-9793</small>	Trailer mode	A coupled trailer is identified via the trailer socket. No other levels can be selected. System switches automatically from other modes to Normal mode when the conditions are exceeded.

Air Suspension Level Control System

- Control button

A control button is fitted in the E53 with twin-axle air suspension. The driver can set three different vehicle ride heights using the control button.

- Off-road (+25 mm), high ground clearance
- Normal, normal level
- Access (-35 mm), for entry and exit, loading and unloading



Fig. 19: Control button E53

KT-9068

Light emitting diodes indicate the current ride height setting.

Ride height can be adjusted from terminal 15 on and with the doors closed. The bonnet and/or boot lid may be open.

Air suspension function

- Model overview table

Control modes	Single-axle air suspension		Twin-axle air suspension
	E39/E53	E65/E66	E53
Sleep	x	x	x
Wake-up			x
Post		x	
Pre	x	x	x
Terminal 15 On			x
Normal	x	x	x
Drive	x	x	x
Kerb	x	x	x
Curve	x	x	x
Lift	x	x	x
Twist			x
Trailer			x
Off-road			x
Access			x

Air Suspension Level Control System

- Control mode flow charts

The following flow charts demonstrate the control sequences of the individual models.

E39/E53 single-axle air suspension

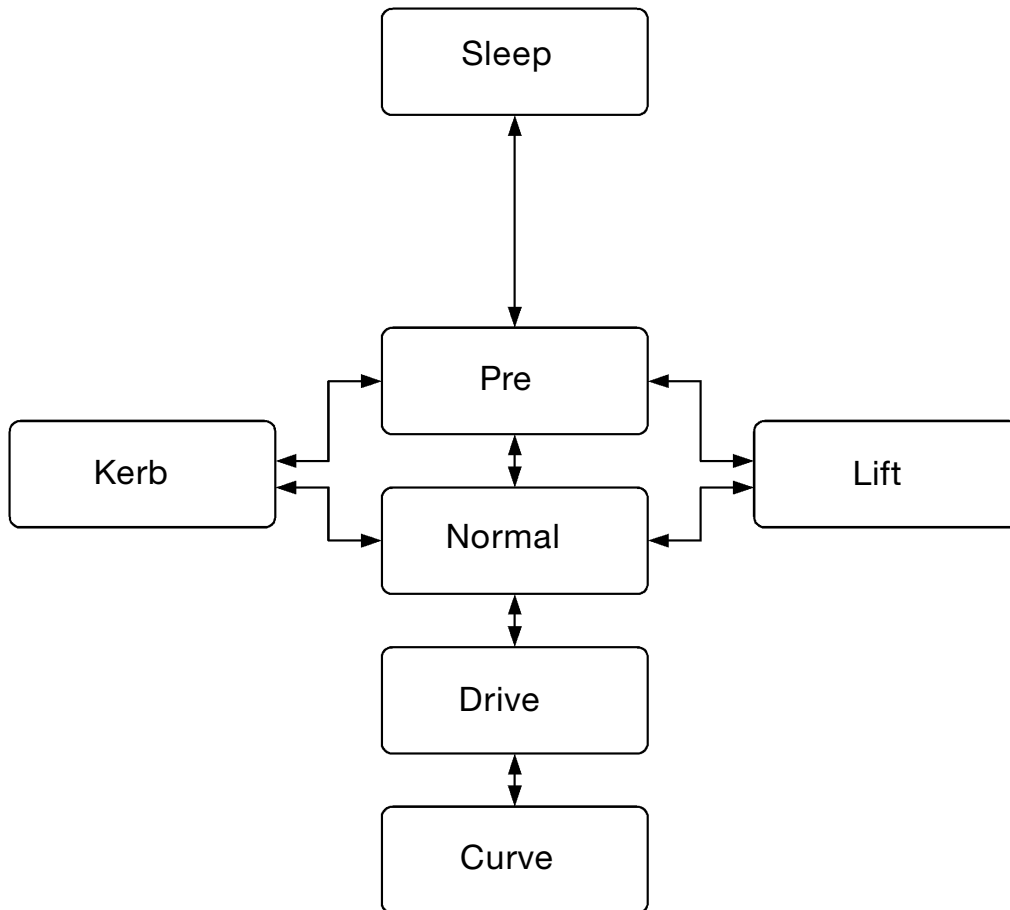
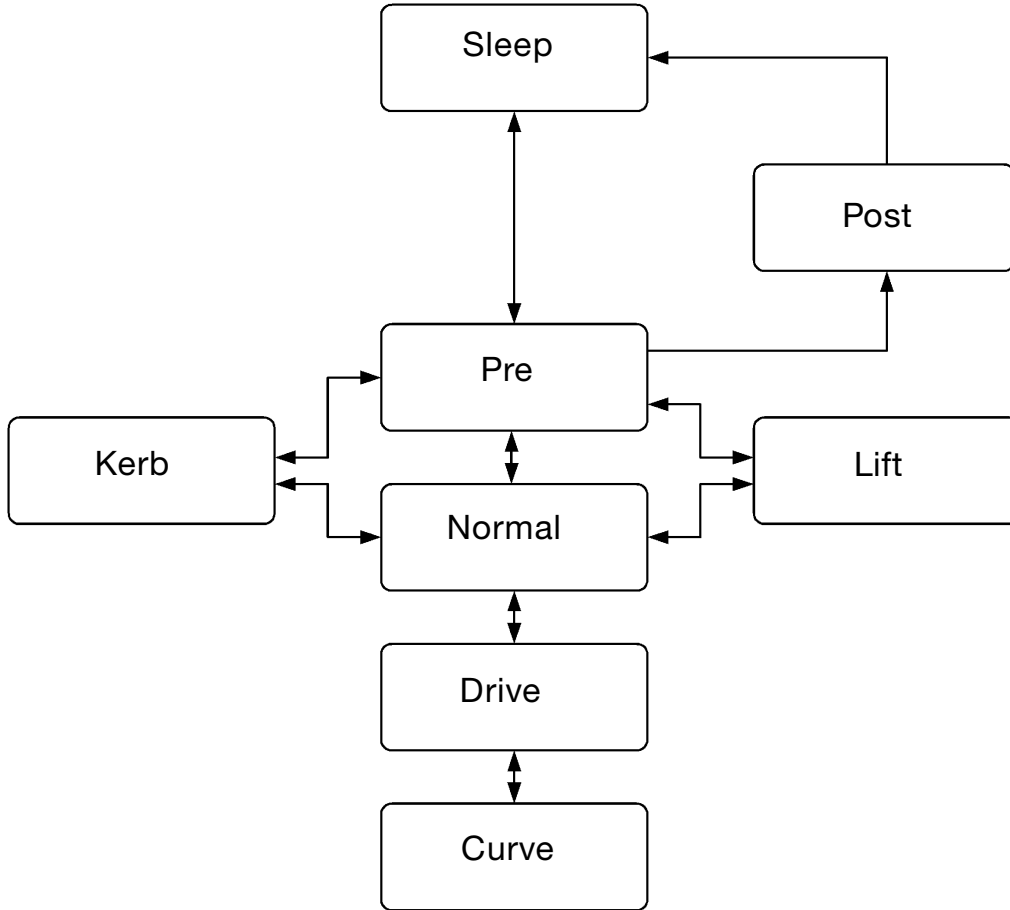


Fig. 20: Flow chart E39/E53 single-axle air suspension

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Air Suspension Level Control System

E65/E66 single-axle air suspension

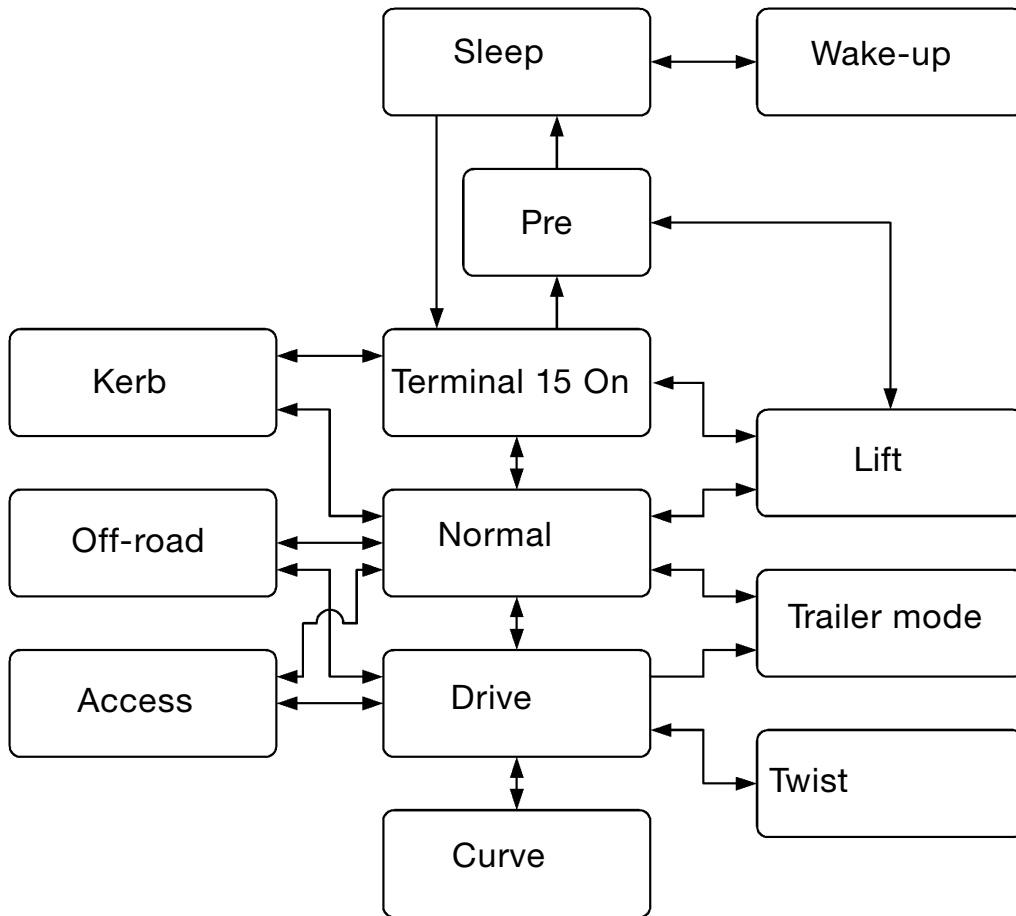


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Fig. 21: Flow chart E65/E66 single-axle air suspension

Air Suspension Level Control System

E53 twin-axle air suspension



KT-10802

Fig. 22: Flow chart E53 twin-axle air suspension

Air Suspension Level Control System

- Control mode overview table

Model/ mode	E65/E66 Single-axle air suspension	E39/E53 Single-axle air suspension	E53 Twin-axle air suspension
Sleep	No control, load cutout off	Same as E65/E53 twin-axle air suspension	Same as E65 and E39/E53 Single-axle air suspension
Wake-up	Not available	Not available	Load cutout off. The control unit wakes up every 6 hours to set the vehicle straight. Tolerance band ± 20 mm. The vehicle is only lowered to the Access ride height. If the vehicle is parked in Access, the system also adjusts to $- 50$ mm
Post	Approx. 1 minute fast filter (2 s), very narrow tolerance band $< - 6 / > 6$ mm, control ends at $< - 4 / > 4$ mm	Not available	Not available
Pre	Approx. 16 minutes fast filter 2 s, wide tolerance band Control up at $< - 40$ mm, control down at mean value > 0 mm and one side > 10 mm	Same as E65	Approx. 16 minutes fast filter 2 s, wide tolerance band Control up at $< - 20$ mm, control down at > 15 mm
Terminal 15 On	Not available	Not available	Fast filter, narrow tolerance band with ± 10 mm, accumulator filling not permitted; level change selection down by the driver permitted
Normal	Engine running Fast filter 2 s, narrow tolerance band ± 10 mm	Same as E65	Engine running Fast filter 2 s, narrow tolerance band ± 10 mm Level change by driver permitted provided no door is open; pressure accumulator is filled
Drive	$v > 1$ km/h, slow filter 1000 s, narrow tolerance band ± 10 mm	$v > 4$ km/h, slow filter 1000 s, narrow tolerance band ± 10 mm	Same as E65
Kerb	On at: Difference between left and right sides of vehicle > 32 mm, longer than 0.9 s changeover from single-wheel control to axle control Off at: Difference between left and right sides of vehicle < 28 mm, $t \geq 0.9$ s or $v > 1$ km/h	On at: Difference between left and right sides of vehicle > 24 mm, longer than 1 s changeover from single-wheel control to axle control Off at: Difference between left and right sides of vehicle < 19 mm, $t \geq 1$ s or $v > 4$ km/h	On at: Stationary vehicle and total twist (also over both axles) > 45 mm, changeover from single-wheel control to axle control Off at: Vehicle movement or drop below a total twisting of < 30 mm
Curve	On at: Lateral acceleration > 2 m/s ² Off at: Lateral acceleration > 1.5 m/s ²	On at: $v > 50$ km/h and difference between right and left sides > 30 mm Off at: $v < 50$ km/h or difference between right and left sides < 25 mm or $t > 280$ s	Same as E65

Air Suspension Level Control System

Lift	<p>On at: Rebound travel > 55 mm at one or more wheels</p> <p>Jack on at: Lowering speed drops below the value 2 mm/s for 3 s, ride height storing</p> <p>Off at: Level change < - 10 mm, ride height drops below stored setting by more than 10 mm</p>	<p>On at: Rebound travel > 90 mm at one or more wheels</p> <p>Off at: Level change < - 10 mm</p>	<p>On at: Rebound travel > 70 mm at all wheels or lowering speed drops below the value 2 mm/s for 3 s</p> <p>Jack on at: Lowering speed drops below the value 2 mm/s for 3 s, ride height storing</p> <p>Off at: Switch operation or $v = 40$ km/h for more than 3 s or setting drops below stored value by more than 10 mm</p>
Twist	Not available	Not available	No control in event of twisting of more than 200 mm
Trailer	Not available	Not available	<p>On at: Identification via trailer connector, action: change to Off-road or Access no longer possible</p> <p>Off at: Disconnect trailer connector</p> <p>See also User's Handbook</p>
Off-road	Not available	Not available	<p>On at: Off-road button and $v < 50$ km/h</p> <p>Off at: Button operation to "Normal" or $v > 50$ km/h</p>
Access	Not available	Not available	<p>Preselection on at: Button to "Access" and $v < 80$ km/h and accumulator pressure > 11 bar</p> <p>On at: Preselection Access and $v < 25$ km/h</p> <p>Preselection off at: $t > 60$ s or button operation to "Normal", or compressor temperature > 110 °C</p> <p>Off at: Button operation to "Normal" or $v > 35$ km/h</p> <p>Preselection only possible: Compressor temperature between 95 °C and 110 °C</p>

- Faults

Bus failure

If the control unit no longer receives any bus signals, the signals received last (doors, speed,...) continue to apply and the control unit remains in the mode that was set last until deactivation by the load cutout signal.

During the next restart or always during any restart with failed communication, the control unit remains in Pre-mode and the driver is alerted to the existing fault by the fault display in the instrument cluster. System availability is retained. But there may be increased control activity.

- Explanation of terms

Tolerance band

The tolerance band of the level control system specifies when the control electronics identifies the need for a control operation. The width of the tolerance band is adapted to the different operating modes and the relevant vehicle model. Thus the E65 in Normal mode already identifies the need for a control operation in the event of a deviation of 10 mm from the normal ride height. In Pre-mode, the need for a control operation is only identified from a lowering of more than 40 mm.

Low-pass/high-pass filters

A filter is an electronic circuit which influences specific frequency ranges. In the analogue range, a filter consists of an inductance (a coil) and/or a capacitance (capacitor). The configuration of the components determines the so-called cutoff frequency. Different filter characteristics can be created through appropriate configuration of the components.

In the digital range, the inductance, the capacitance and the characteristic can be replaced by suitable digital evaluation circuits. The low-pass filter allows through all frequencies below the cutoff frequency and suppresses the frequency above the cutoff frequency. The high-pass filter suppresses all frequencies below the cutoff frequency and allows through the frequencies above the cutoff frequency.

For example, the air suspension of the E65 evaluates by means of a low-pass filter in Normal mode only those ride height changes with the cutoff frequency 0.001 Hz (1/1000 1/s). Therefore only ride height changes which last longer than 1000 seconds are controlled (e.g. emptying of fuel tank).

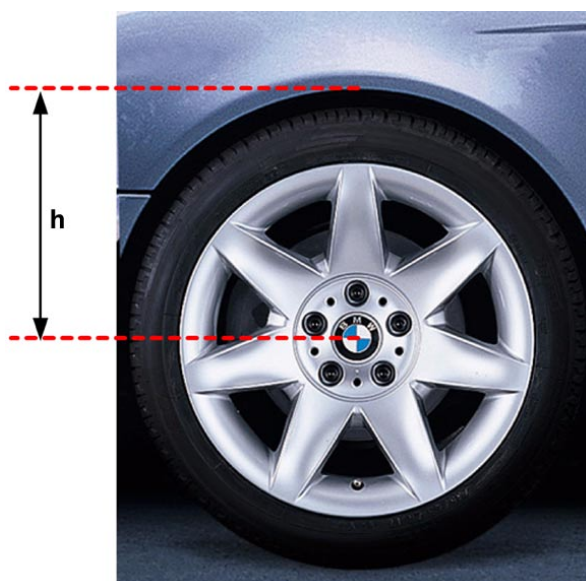
The combination of low-pass and high-pass filters is widely distributed in two-way loudspeaker systems. The low-pass filter in the supply lead to the woofer filters out the height component of the applied audio signal. The high-pass filter in the supply lead to the tweeters blocks all the low-frequency components of the applied audio signal and thus protects the tweeters against overloading.

Vehicle level

The vehicle level is the ride height of the vehicle. Inclination of a vehicle with single-axle air suspension is immediately visible with the eye. If the rear end on the right/left shows a different ride height in comparison (i.e. the vehicle is leaning on one side), the air suspension may possibly be malfunctioning.

If the rear end of the vehicle is clearly lower than the front end, the ride height is incorrectly set or the air suspension may possibly be malfunctioning on the rear axle.

To adjust the level, it is necessary for the EHC (electronic ride height control/self-levelling air suspension) to be activated and air to be discharged from or introduced into the relevant air spring. The actual value is recorded with a tape measure at the point illustrated below and corrected until the desired value is obtained. The actual value of the sensor is stored as the normal position in the EHC control unit.



KT-10804

Fig. 23: Ride height measurement (h)

- Control modes

Ongoing control operations are not affected by transitions from one mode to another. However, in the case of load cutout OFF, control operations are always concluded in order to safeguard system deactivation. The control unit then sets the Sleep mode.

Sleep

The vehicle is in Sleep mode at the latest when it has been parked for longer than 16 minutes without a door or bonnet/hood/rear lid being operated or the terminal status changing. This is the initial state of the control system. No control operation is performed in Sleep mode.

The control system goes into Pre-mode when a wake-up signal is received by the control unit.

Wake-up

The control unit becomes active every 6 hours for several minutes (Wake-up mode) in order to compensate any possible inclination. Inclination of the vehicle can be caused by large temperature differences or by minor leaks. The adjustments to the front and rear axles ensure that the vehicle is visually level. To minimize power consumption, the vehicle is lowered only. The level of the lowest wheel serves here as the nominal level for all the other wheels. The lowest level to which the vehicle is lowered is the Access ride height level (-35 mm).

Exception: If the vehicle has already been parked at Access level, it is lowered in Wake-up mode down to max. -50 mm. Further loss of pressure can no longer produce a change of ride level since the weight of the body is borne by the auxiliary springs and the residual tyre pressure.

Air Suspension Level Control System

Post

The Post-mode is adopted in order to compensate any inclination or to adjust the ride height after driving and between the Pre-mode and Sleep mode.

The Post-mode is limited in time to 1 minute. The Post-mode is only executed if the engine has been running before the system switches into this mode. If the engine has not been previously running, the system switches directly from Pre-mode into Sleep mode.

The control operation is performed in a narrow tolerance band of ± 6 mm and is terminated at ± 4 mm. The fast signal filter is used.

In the event of an inclination (Kerb mode), the control operation takes place for the nominal heights applicable in this situation.

Pre

The Pre-mode is activated by the "Load cutout off" signal (e.g. by opening the door or unlocking with the radio remote control). The Pre-mode then stays set for 16 minutes and is restarted with a change in status.

The ride height of the vehicle is monitored and evaluated with a wide tolerance band.

Air Suspension Level Control System

In Pre-mode, the vehicle is only controlled up to the nominal height if the level is significantly below the nominal height. The control tolerance band is - 40 mm from the mean value for single-axle air suspension or - 20 mm for twin-axle air suspension. This control tolerance ensures that the vehicle is only controlled up in the case of large loads in order to increase the ground clearance prior to departure. Small loads give rise to small compression travel and this is compensated only when the engine is started. This control setting helps to reduce the battery load.

With single-axle air suspension, the vehicle is controlled down when the mean value derived from both ride height signals is > 0 mm and one side is in excess of $+ 10$ mm. With twin-axle air suspension, the vehicle is controlled down when one side is > 15 mm.

In this mode, only the mean value of the two height signals (fast filter) is considered when deciding whether there is a need for a control operation.

The control operation is executed as long as pressure is available in the accumulator. When the accumulator is empty and the engine is turned off, the control operation is driven directly by the compressor. User-activated changes of ride level and filling of the accumulator are not possible.

Control operations which were started in other modes are continued with the inner tolerance bands applicable to these modes.

There is no inclination identification in Pre-mode.

Air Suspension Level Control System

Terminal 15 On

As soon as the ignition is turned on (terminal 15), the user is allowed to lower the ride level as required.

However, it is still not possible to raise the ride level or fill the accumulator.

Ride level is compensated outside a narrow tolerance band of ± 10 mm.

Normal

The Normal mode is the starting point for the vehicle's normal operating state. It is obtained by way of the Engine running signal.

Ride level compensation, changing the vehicle's ride height and filling the accumulator are possible. The compressor starts up as required.

A narrower tolerance band than that in Pre-mode can be used because the battery capacity does not have to be protected. The fast filter is used with a narrow tolerance band of ± 10 mm. In this way, ride level compensation takes place outside a narrow tolerance band of ± 10 mm. The faster filter allows the system to respond immediately to changes in ride level. Evaluation and control are performed separately for each wheel.

Air Suspension Level Control System

When a speed signal is recognized, the control unit switches into Drive mode. When the vehicle is stopped, the control unit remains in Drive mode. The system switches back into Normal mode only when a door or the boot lid is also opened. If none of the doors or the boot lid is opened, the vehicle logically cannot be loaded or unloaded.

This prevents a control operation happening when the vehicle for example is stopped at traffic lights and the ride height is above the mean axle due to the pitching motion on the rear axle.

Drive

The Drive mode is activated for E39/E53 single-axle air suspension when a speed signal of > 4 km/h is recognized. The Drive mode is recognized from > 1 km/h for E65/E66 single-axle air suspensions and for E53 twin-axle air suspension.

Low-pass filters are used. In this way, only changes in ride height over a prolonged period of time (1000 seconds) are corrected. These are merely the changes in ride height, caused by vehicle compression and a reduction in vehicle mass due to fuel consumption. The high-pass filter (fast filter) is used during the control operation. The slow filters are reinitialized at the end of the control operation. The markedly dynamic height signals caused by uneven road surfaces are filtered out.

Air Suspension Level Control System

Kerb

The Kerb mode prevents the inclination caused by the vehicle mounting an obstacle with one wheel from being compensated. Compensation would cause a renewed inclination of the vehicle and result in a renewed control operation after the wheel comes off the obstacle.

The Kerb mode is activated when the height difference between the left and right sides of the vehicle is > 32 mm for the E65/E66 with single-axle air suspension and > 24 mm for the E39/E53 with single-axle air suspension and lasts longer than 0.9 s. Twisting (also over both axles) > 45 mm must occur for the E53 with twin-axle air suspension.

There must be no speed signal for all vehicles. The system switches from single-wheel control to axle control.

The Kerb mode is quit when the difference between the left and right sides of the vehicle is < 28 mm for the with single-axle air suspension and lasts longer than 0.9 s or when the speed is > 1 km/h.

For the E39/E53 with single-axle air suspension, the Kerb mode is quit when the difference between the left and right sides of the vehicle is < 19 mm and lasts longer than 1 second or a speed signal of > 4 km/h is applied.

For the E53 with twin-axle air suspension, the Kerb mode is quit when a vehicle movement takes place or the twisting drops below 30 mm.

If the system switches from Kerb mode to Sleep mode, this status is stored in the EEPROM.

Air Suspension Level Control System

If the vehicle is loaded or unloaded in Kerb mode, the mean value of the axle is calculated by the control unit. The value is calculated in the control unit from the changes in ride level of the spring travel on the left and right sides.

A change in ride level is initiated if the mean value of compression or rebound at the axle is outside the tolerance band of ± 10 mm. The left and right sides of the vehicle are raised or lowered in parallel. The height difference between the two sides is maintained.

Curve

Since rolling motions have a direct impact on the measured ride levels, an unwanted control operation would be initiated during longer instances of cornering with an appropriate roll angle in spite of the slow filtering of the Drive mode. The control operations during cornering would cause displacement of the air volume from the outer side to the inner side of the curve. Once the curve is completed, this would produce an inclination which would result in a further control operation. The Curve mode prevents this control operation whereby when cornering is recognized slow filtering is stopped and a potential control operation that has started is terminated.

The Curve mode is activated for E65/E66 single-axle air suspension and for E53 twin-axle air suspension from a lateral acceleration of $> 2\text{m/s}^2$ and deactivated at $< 1.5\text{m/s}^2$.

Air Suspension Level Control System

For the E39/E53 with single-axle air suspension, the Curve mode is only activated from a speed > 50 km/h and a difference between left and right wheelbases of > 30 mm. The Curve mode is quit when the speed is < 50 km/h or the difference between left and right wheelbases is < 25 mm or longer than 280 seconds.

The lateral acceleration is recorded by the rotation rate sensor.

Lift

The Lift mode is used to prevent control operations when a wheel is changed or during work on the vehicle while it is on a lifting platform.

This mode is recognized when the permitted rebound travel at one or more wheels is exceeded. For the E65/E66 with single-axle air suspension > 55 mm, for the E39/E53 with single-axle air suspension > 90 mm and for the E53 with twin-axle air suspension > 70 mm. The Lift mode is also set when the lowering speed for the E53 with twin-axle air suspension drops below the value of 2 mm/s for 3 seconds.

A car jack situation is also recognized for the E65/E66 single-axle air suspension and for the E53 twin-axle air suspension. The ride level is stored and a car jack situation is recognized if the lowering speed drops below the value of 2 mm/s for 3 seconds.

If the vehicle is raised slightly and the permitted rebound travel has not yet been achieved, the control operation attempts to readjust the ride height. If the vehicle is not lowered, a car jack situation is recognized after a specific period of time and this ride height is stored.

Air Suspension Level Control System

A reset is performed if the vehicle is again 10 mm below this stored ride height.

A reset is also recognized for the E53 with twin-axle air suspension if a speed signal of > 40 km/h is applied for longer than 3 seconds or the control button is operated.

Twist

The twist mode is recognized when e.g. a wheel is driven up onto an embankment and the difference between the front axle levels plus the opposing difference between the rear axle levels is greater than 200 mm.

All control operations are inhibited in Twist mode because a control operation is no longer beneficial in these circumstances.

Trailer

A coupled trailer is identified via the trailer connector. To avoid damaging the trailer and the vehicle, changes of vehicle level are generally avoided. The standard level is "frozen." If the trailer is coupled at a level other than the Standard level, the vehicle ride level is not changed to Standard unless a button is pressed or the speed threshold for automatic change-over is reached. The standard level is then "frozen" until the trailer connector is disconnected.

Air Suspension Level Control System

Off-road

The Off-road mode is selected using the control button and only set when the engine is running and the speed is below 50 km/h.

In Off-road mode, the vehicle ride height is raised by 25 mm.

The LEDs of the control button indicate the current ride level and a change of ride level.

LED permanently lit:
Indication of the vehicle level.

LED of the target level flashes, LED of the starting level lit:
A change of level has been initiated by pressing the button or automatically by a specific driving condition. When the target level is reached, the flashing LED starts to light up permanently and the LED of the previous level goes out.

LED of the current level flashes for approx. 3 seconds when the button is pressed:
Change of level is not possible.

Access

The Access mode is selected using the control button. This mode can be selected from terminal 15 on and is only set when the speed is below 25 km/h.

Preselection of the Access mode is ignored at a speed in excess of 80 km/h. The LED of the current level flashes for 3 seconds:

Air Suspension Level Control System

The system goes into a preselection mode below 80 km/h. This mode can be quit by pressing the button upwards. It is also quit if the speed rises above 80 km/h or the time since it was activated exceeds approx. 60 seconds.

The LEDs of the control button indicate the current ride level and a change of ride level.

LED permanently lit:
Indication of the vehicle level.

LED of the target level flashes, LED of the starting level lit:
A change of level has been initiated by pressing the button or automatically by a specific driving condition. When the target level is reached, the flashing LED starts to light up permanently and the LED of the previous level goes out.

LED of the current level flashes for approx. 3 seconds when the button is pressed:
Change of level is not possible.

Transport

The Transport mode is set and cleared by means of diagnosis activation. It serves to increase the ground clearance in order to ensure safe transportation of vehicles on transporter trucks. The nominal height of the vehicle is raised in this mode by 30 mm.

When the Transport mode is activated, the air suspension symbol is indicated in the variable telltale in the instrument cluster and a text message is output in the Check Control display to alert the driver to this special mode.

Control operations do not take place in this mode because the vehicle mass does not change during transportation.

Air Suspension Level Control System

Belt

The Belt mode is set for mounting on the belt in order to avoid control operations.

When the Belt mode is activated, the air suspension symbol is indicated in the variable telltale in the instrument cluster and a text message is output in the Check Control display.

The Belt mode is cleared by means of diagnosis activation only. The Belt mode can no longer be set.

New control units (spare part) are supplied with the set Belt mode.

Control operations are not performed, the safety concept only operates with limited effect.

Operating principle

Initialization/reset performance

When the control unit is powered up after a reset (triggered by an undervoltage [$< 4.5 \text{ V}$] or also by load cutout off), different tests and initializations are performed. The system is only enabled after the tests have been successfully completed and starts to execute the control programs on a cyclical basis. Occurring faults are stored and displayed.

Air Suspension Level Control System

Control sequence

In an ongoing control operation, the high-pass filter (fast filter) is always used to prevent the controlled height from overshooting the nominal value. If a low-pass filter (slow filter) were used to calculate the ride height, brief changes of ride height would be consumed. The low-pass filter is used while the vehicle is driven (see Normal mode here). This type of filtering filters out vibrations which are excited by the road surface.

The high-pass filter is used to respond quickly to ride level deviations from setpoint. These take place while the vehicle is stationary in the event of large load changes (see Pre-mode here).

Both sides of the vehicle are controlled individually, i.e. even the setpoint/actual-value comparison for both sides is carried out individually. Exception: Check for undershooting of the minimum height in Pre-mode and Kerb mode: consideration of the left/right mean values in each case.

The following stipulations are applicable here:

- Raising before lowering
- Activation of all valves with control in the same direction
- Individual wheel deactivation

To ensure safe closing of the non-return valve in the air drier, the drain valve is actuated (by the control unit) briefly for 200 ms after the control up operation is ended.

The permissible ON period of the components is monitored while control up operations are executed.

Air Suspension Level Control System

Safety concept

The safety concept is intended to inhibit any system malfunction, particularly unintentional control operations, through the monitoring of signals and function-relevant parameters. If faults are detected, the system is switched over or shut down depending on the affected component. The driver is informed of existing faults via the display. Detected faults are stored for diagnostic purposes.

In order to ensure high system availability, existing faults, as far as possible, are cleared with terminal 15 ON. This is done by resetting the fault counter to zero. However, the fault memory content in the EEPROM is retained and can be read out for diagnostic purposes. The system is then operational again. The fast troubleshooting helps to detect existing faults before control operations can take place.

Only lowering is permitted if:

- The permissible supply voltage of 9 volts is undershot
- The permissible compressor running time of 480 seconds is exceeded

A reset takes place if the voltage is in the OK range of 9 to 16 volts or after the compressor pause time of 100 seconds has elapsed.

Only raising is permitted if:

- The permissible control down period of 40 seconds is exceeded
- The reset takes place the next time the vehicle is driven or after the next control up operation.

No control operations take place if:

- The permissible supply voltage of 16 volts is exceeded

The reset takes place as soon as the voltage is in the OK range.