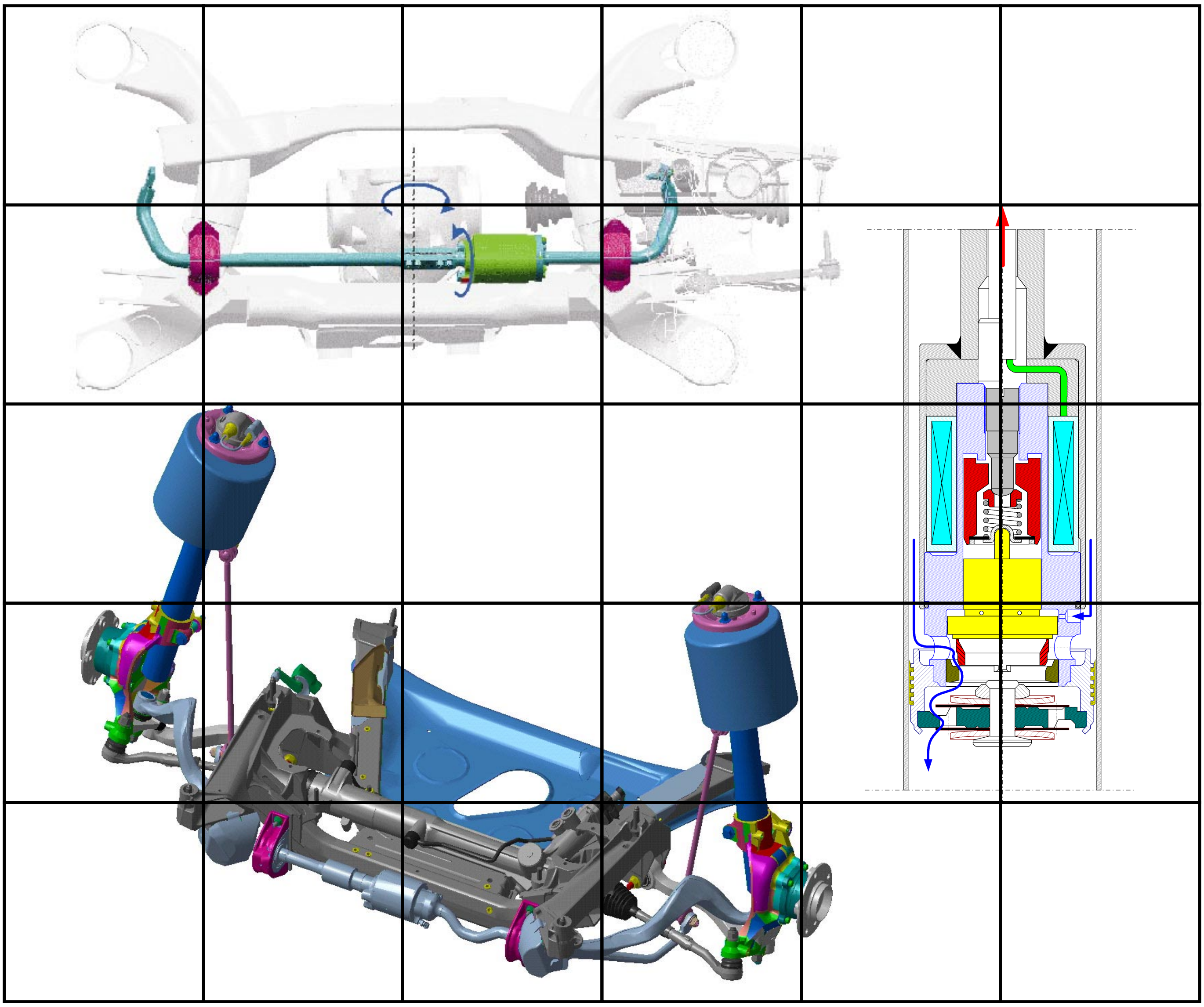
BMW
Service Training

E65 Driving Dynamics Systems
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.

VS-42 MFP-HGK-BRK-E65_0500

Contents

Introduction

Modern chassis and suspensions must offer drivers optimum driving comfort, high driving safety, a high degree of agility and simple handling. Furthermore, it must also be able to adapt to changed conditions (road and traffic conditions, ice, snow etc.).

The following movements of the vehicle body can occur as a result of the acting forces:

- About the transversal axis: pitching
- Around the longitudinal axis: rolling
- About the vertical axis: yawing

The task of the chassis and suspension is to suppress the effects of these forces as much as possible. Active driving-dynamics systems are integrated in the E65 which support the driver both actively and passively.

The driving-dynamics systems record the driving conditions using the sensors. These are transmitted to the control units which then convert the input signals and send output signals to the relevant actuators.

The driving-dynamics systems include:

- The Dynamic Stability Control (DSC) with subsystems
- The continually adjustable Electronic Damping Control system (EDC-K)
- The active roll stabilizer Dynamic Drive

ABS/ASC/DSC

Introduction

Bosch DSC 5.7 has been improved in detail and expanded to include new functions in order to achieve improved system operation.

The system is connected to the PT-CAN.

Functions (overview)

The DSC module controls by means of brake intervention or for individual situations by means of engine-load control. It consists of the following subsystems:

- ABS Anti-lock Braking System
- ASC Automatic Stability Control
- MSR Engine drag-torque control
- DSC Dynamic Stability Control
- DBC Dynamic Brake Control
- CBC Cornering Brake Control
- ECD Electronically Controlled Deceleration (with ACC only)
- FBS Fading Brake Support
- FLR Driving-performance control
- DTC Dynamic Traction Control
- Parking brake (hydraulic section)

In addition, the evaluation of the 2-stage brake-lining wear sensors has been integrated in the DSC control unit.

The setup and mode of operation of the brake-lining wear sensors is described in the Background Material "Brakes."

- DSC in bus network

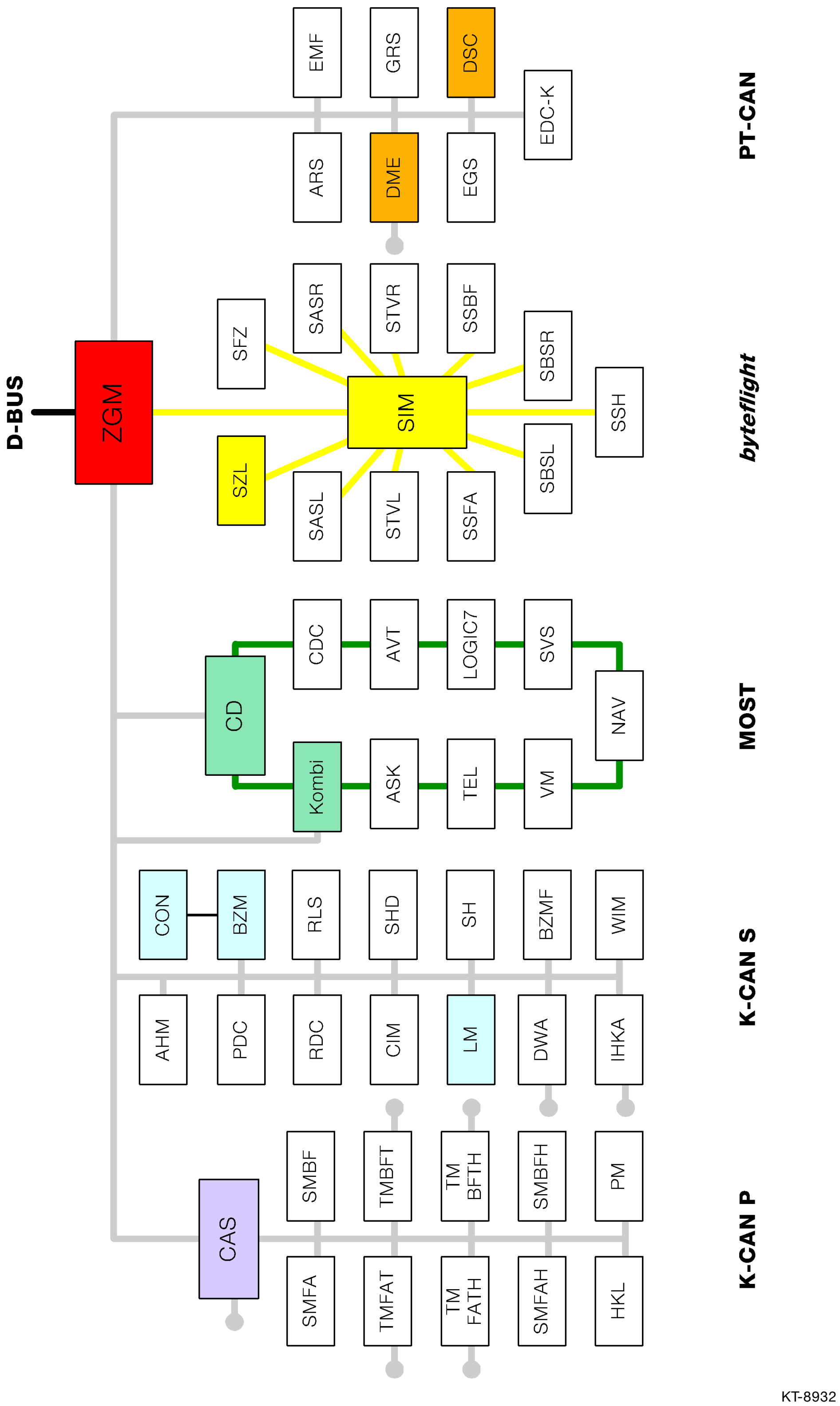


Fig. 1: BUS structure

Functional description

- ABS Anti-lock Braking System

  Notes:____________________________________

- ASC Automatic Stability Control

  Notes:____________________________________

- MSR Engine drag-torque control

  Notes:____________________________________

- DSC Dynamic Stability Control

  Notes:____________________________________

- DBC Dynamic Brake Control

Notes:__________________________________

- CBC Cornering Brake Control

Notes:__________________________________

- Electronically Controlled Deceleration (ECD)

ECD responds to the requests of the ACC (Active Cruise Control) signals.

DSC executes braking retardation when deceleration is requested by ACC.

This is performed by way of an automatic brake intervention at the four disc brakes, dependent on the vehicle speed, the distance and the speed of the vehicle travelling in front, with max. 3 m/s^2 deceleration.

On downhill gradients at a preselected driving speed, ECD maintains the driving speed continuously at the preset value by way of automatic brake intervention.

In the case of automatic braking, the brake lights are activated in line with legal requirements.

Only from a deceleration >1m/s^2 will a brake-light activation be performed by the light module (LM). This prevents the brake lights from coming on frequently and for brief periods.

- Fading Brake Support (FBS)

FBS is a new subfunction of DBC.

The FBS function compensates for the brake-force loss through an increase in temperature.

The diminishing braking effect when brakes are hot requires the driver to press the brake pedal more firmly. This increase in pressure is now assumed by an activation of the hydraulic pump.

The temperature measurement is a virtual value (temperature model), which is calculated using the input variables:

- Wheel speed
- Individual wheel brake pressure and
- Ambient temperature

- Driving-performance control (FLR)

FLR is a new function of DSC, which protects the brakes against overloading if they are misused.

If a temperature of over 600 °C is determined, the engine power is reduced (max. engine torque 330 Nm).

This reduction of the engine torque is stored as a fault (driving-performance control active). Should the customer find fault with the lack of engine power, this can be established by the garage/ workshop and explained as brake overloading.

- Dynamic Traction Control (DTC)

The DTC function can be activated by the controller. Thus the ASC slip thresholds for improving propulsion can be increased up to a speed of 70 km/h. Basically the permissible slip is doubled but there is a program map in the background. This function offers advantages when driving on poor roads and thick fresh snow. Driving is not safety- but rather traction-orientated. With increasing transversal dynamics, measured by the yaw-rate sensor, the slip thresholds are reduced back to the normal mode for stability reasons.

When the DTC traction mode is activated, the letters DTC are displayed above the permanent DSC safety lamp.

- Parking brake (hydraulic section)

DSC controls the hydraulic function of the parking brake. The comfort function "Automatic Hold" selected by the driver effects a hydraulic braking operation at the brakes on the front and rear axles. The function "Dynamic Emergency Braking" also uses the same activation.

For this purpose, the DSC control unit makes available the ECD interface, which is connected via the PT-CAN to the parking-brake control unit.

Note:

The hydraulic parking-brake functions are described in the Background Material "Brakes."

System structure (components)

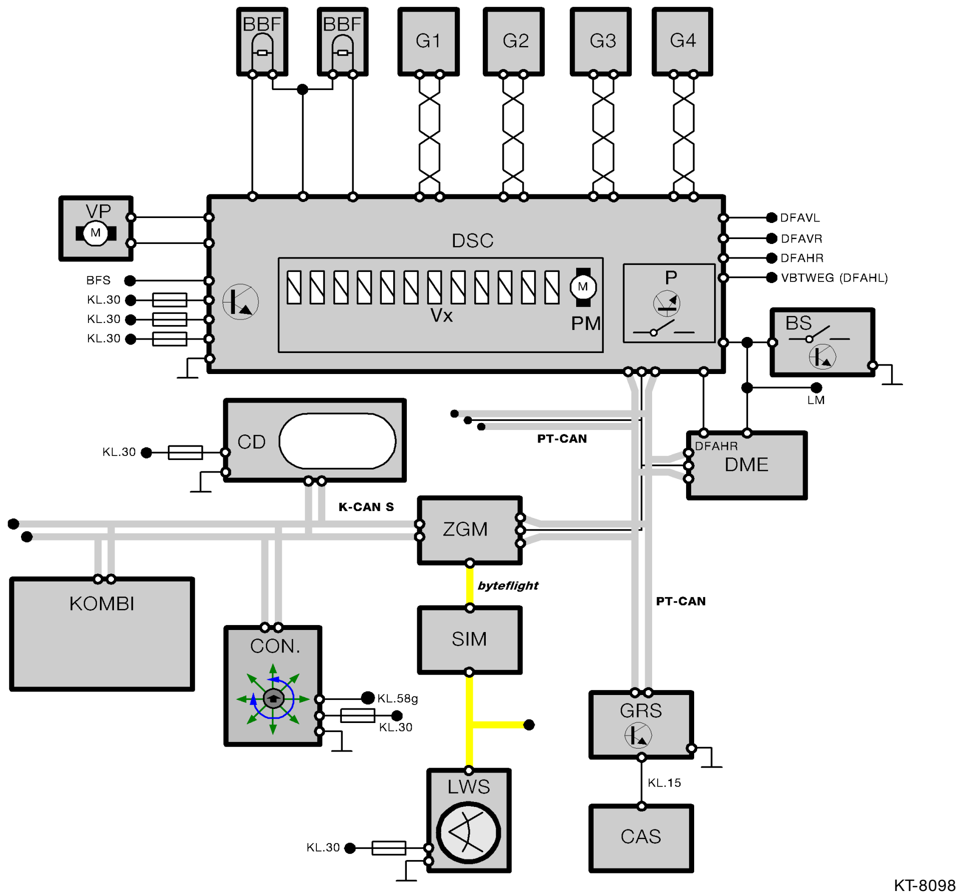


Fig. 2: Schematic DSC 5.7

Index	Description	Index	Description
BBF	Brake-lining sensor	G1-G4	Wheel-speed sensors
VP	Precharging pump	BFS	Brake-fluid sensor
DSC	DSC control unit	P	Pressure sensor
Vx	Hydraulic control valves	DF A	Speed-sensor output
VBTWEG	Mileage signal	BS	Brake-light switch
CD	Control Display	DME	Digital Motor Electronics
ZGM	Central gateway module	SIM	Safety Information Module
KOMBI	Instrument cluster	CON.	Controller
CAS	Car Access System	LWS	Steering-angle sensor
GRS	Yaw-rate sensor with integrated transversal-acceleration sensor		

- Components of hydraulic system

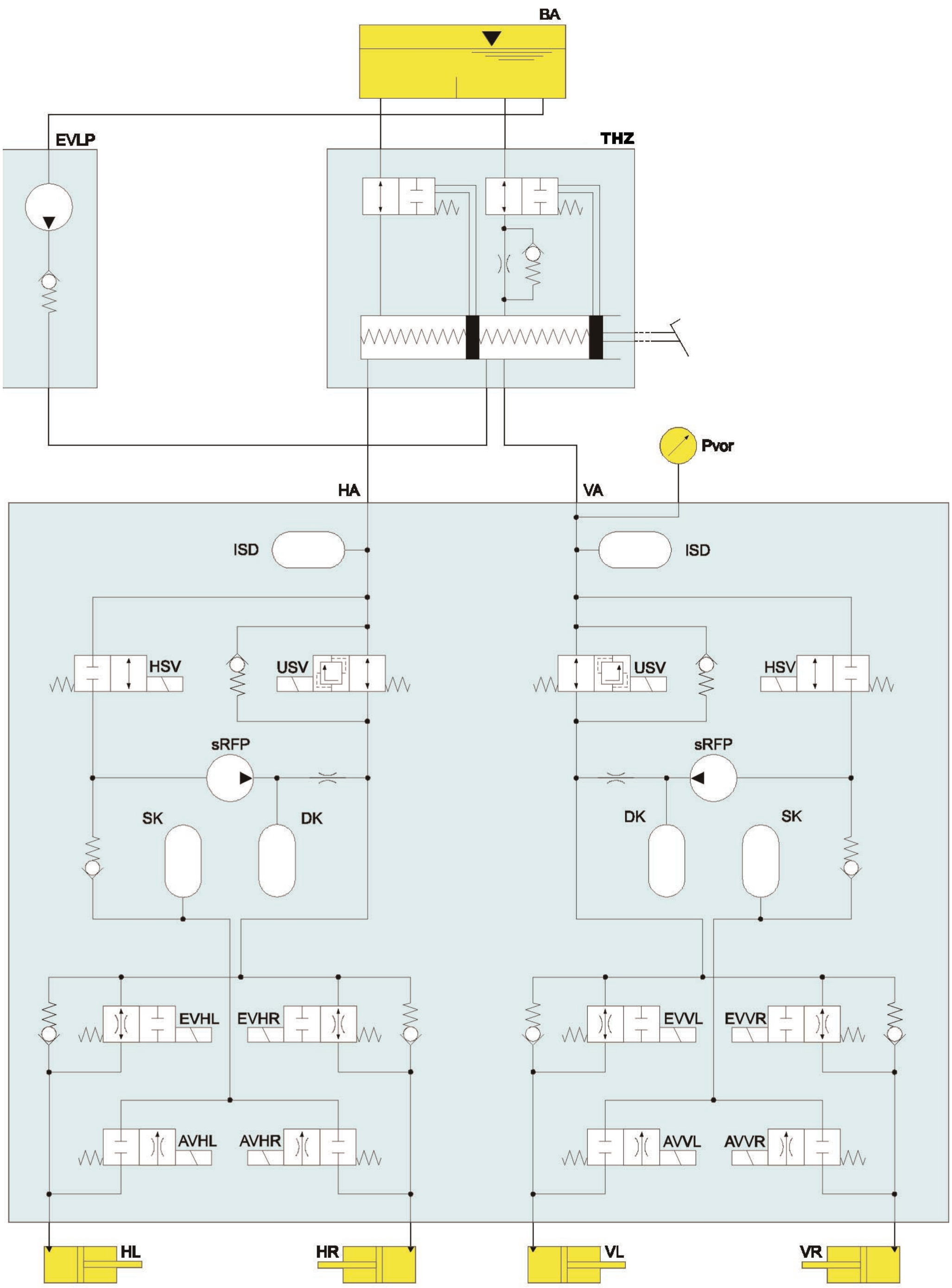


Fig. 3: Hydraulic schematic (DSC)

Index	Description	Index	Description
BA	Brake-fluid reservoir	sRFP	Self-priming return pump
THZ	Tandem brake master cylinder	ISD	Integrated flow damper
HA	Rear axle	EVHL	Inlet valve, rear left
VA	Front axle	EVHR	Inlet valve, rear right
Pvor	Admission-pressure sensor	EVVL	Inlet valve, front left
DK	Damper chamber	EVVR	Inlet valve, front right
EVLP	Single precharging pump	AVHL	Outlet valve, rear left
KOMBI	Instrument cluster	AVHR	Outlet valve, rear right
GRS	Yaw-rate sensor	AVVL	Outlet valve, front left
CAS	Car Access System	AVVR	Outlet valve, front right
HSV	High-pressure switching valve	HL / HR	Rear left / rear right
USV	Changeover valve	VL / VR	Front left / front right
SK	Accumulator chamber		

- Sensors

DSC 5.7 receives its input signals via the following sensors:

- Wheel-speed sensor (active wheel-speed sensor with direction-of-rotation detection)
- Rotation-rate sensor (with CAN interface as satellite of DSC on PT-CAN)
- Transversal-acceleration sensor (integrated in rotation-rate sensor)
- Pressure sensor (fitted at inlet of front-axle circuit; permanent zero-point determination with non-actuated brake-light switch)
- Steering-angle sensor (component part of steering-column switch centre (SLZ), made available via central gateway module on PT-CAN)
- Brake-fluid warning switch (level monitoring in brake-fluid reservoir)
- Brake-light switch (BS)

EDC-K

Introduction

Modern chassis and suspensions must offer drivers optimum driving comfort, high driving safety, a high degree of agility and simple handling.

Conventional, non-adjustable vibration dampers can only ever offer a compromise between the above-mentioned objectives. Manually adjustable vibration dampers can be set to either sporty or comfortable damping.

Engineers have developed electronically adjustable damper systems in order to virtually eliminate this conflict of objectives.

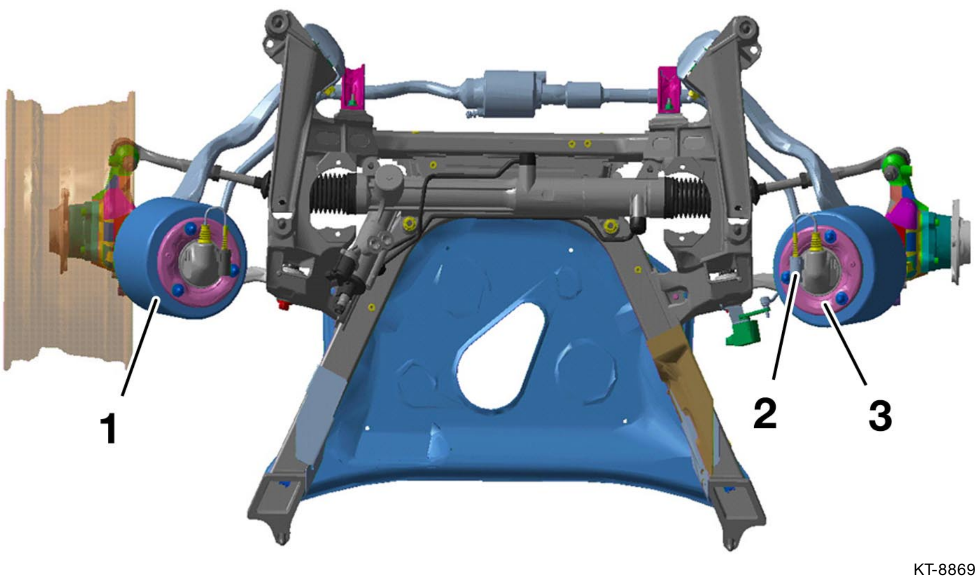


Fig. 4: View of front axle from above

Index	Description	Index	Description
1	Surround chamber, spiral spring	3	Upper support bearing
2	EDC-K plug connection		

- History

EDC III is a fully automatic adjusting system that adapts itself to the driving situation. Input parameters such as state of road surface, vehicle load and driving style are recorded by the system via sensors. One of the three curves (soft, medium or hard) is activated automatically.

The driver also has the option of selecting a comfort or sports program.

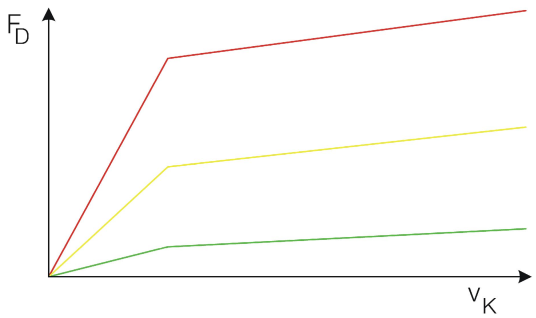


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Fig. 5: Curves of EDC III (pull stage)

EDC-K enables fully automatic damper adjustment over the entire map. The map itself is made up of an infinite number of curves. The dampers can be continuously adjusted as a damping force F_D can set for each piston speed V_K.

The driver also has the option of making a comfort or sports setting via the controller.

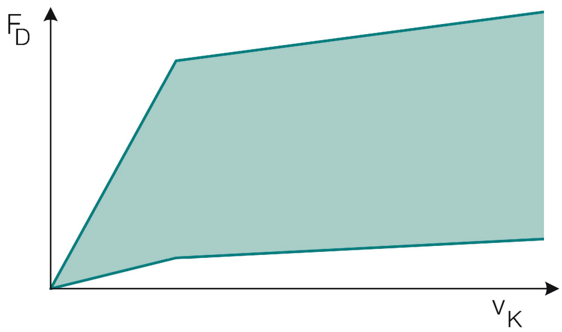

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Fig. 6: Curves of EDC-K (pull stage)

Function of system

As a component of the chassis and suspension, EDC-K assumes the function of compensating the dynamic forces acting on the vehicle during driving.

The following forces occur:

- Vertical forces (e.g. caused by uneven road surfaces)
- Transversal forces (centrifugal forces, crosswind)
- Longitudinal forces (acceleration, deceleration)

The following movements of the vehicle body can occur as a result of these forces.

- About the transversal axis: pitching
- About the longitudinal axis: rolling
- About the vertical axis: yawing

The function of the chassis and suspension is to intercept the transmission of these forces to the vehicle. The continuous adjusting dampers play a significant role in this function.

The primary function of EDC-K is to increase driving comfort while simultaneously maintaining a high degree of driving safety.

The objective of EDC-K is to drive for as long as possible with comfortable, soft damper adjustments. For safety reasons and because of the reduction of impaired comfort, the system switches as needed to harder damping in order to avoid major movements of the vehicle body.

The damper hardness is not adjusted in established stages but rather by a variable damper valve in a variety of activation options.

Sensors record the driving and road-surface conditions.

The driver can also use the controller to select between comfort and sports programs.

The input signals for the system are generated by:

Sensor/switch	Signal	Calculated variable	Location
Acceleration sensors front axle, rear axle	Vertical acceleration front, rear	Vertical velocity, compression/rebound travel	Spring-strut dome FR, FL, RR
Steering-angle sensor	Steering angle	Steering-angle velocity	Switch centre steering column
Wheel-speed sensors FL/FR	Wheel speed	Driving speed, acceleration/braking	Wheel hubs FL/FR
Program selection	Comfort/sports program		Controller

System overview

EDC-K in bus network

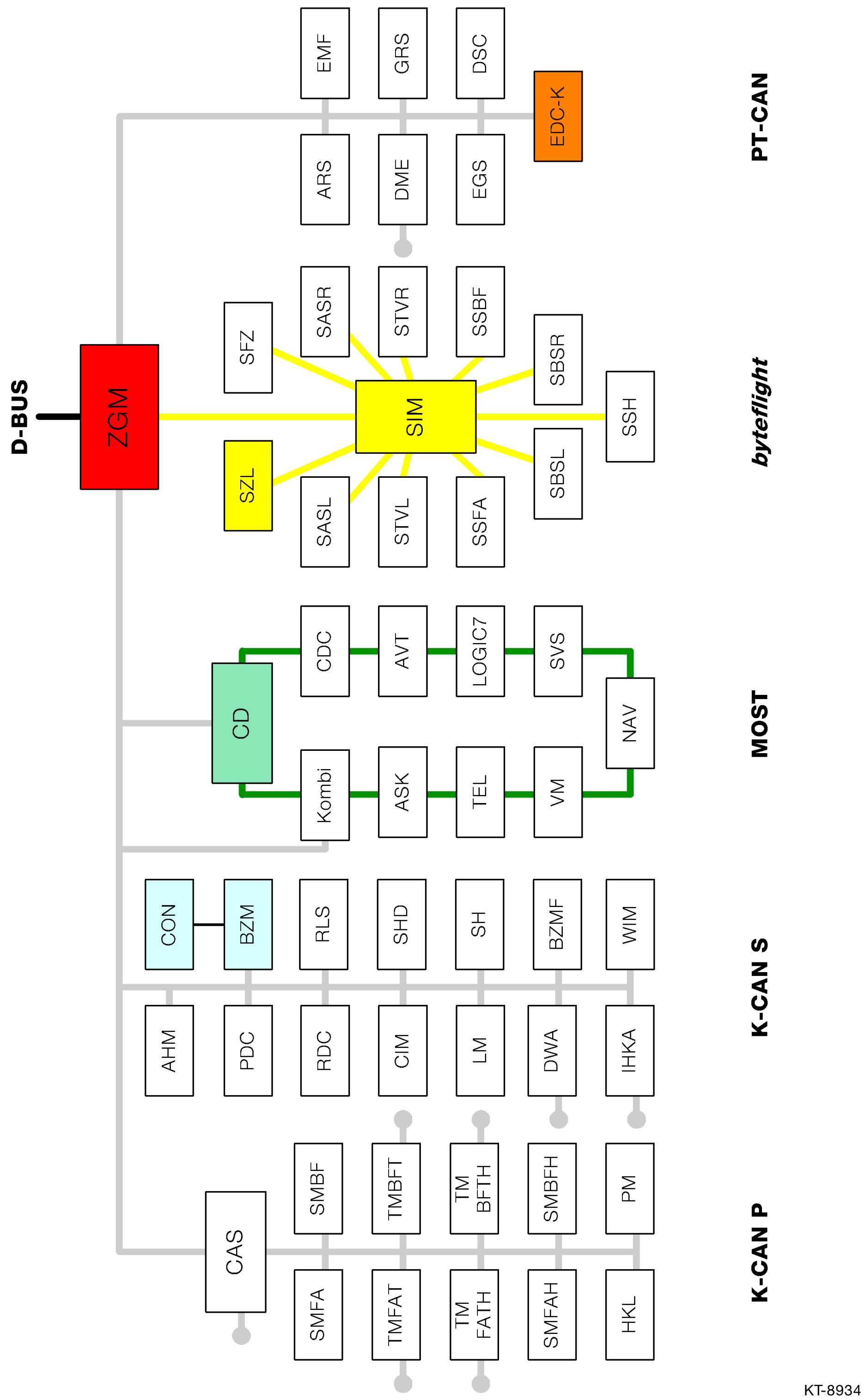

Fig. 7: Bus structure

System schematic:

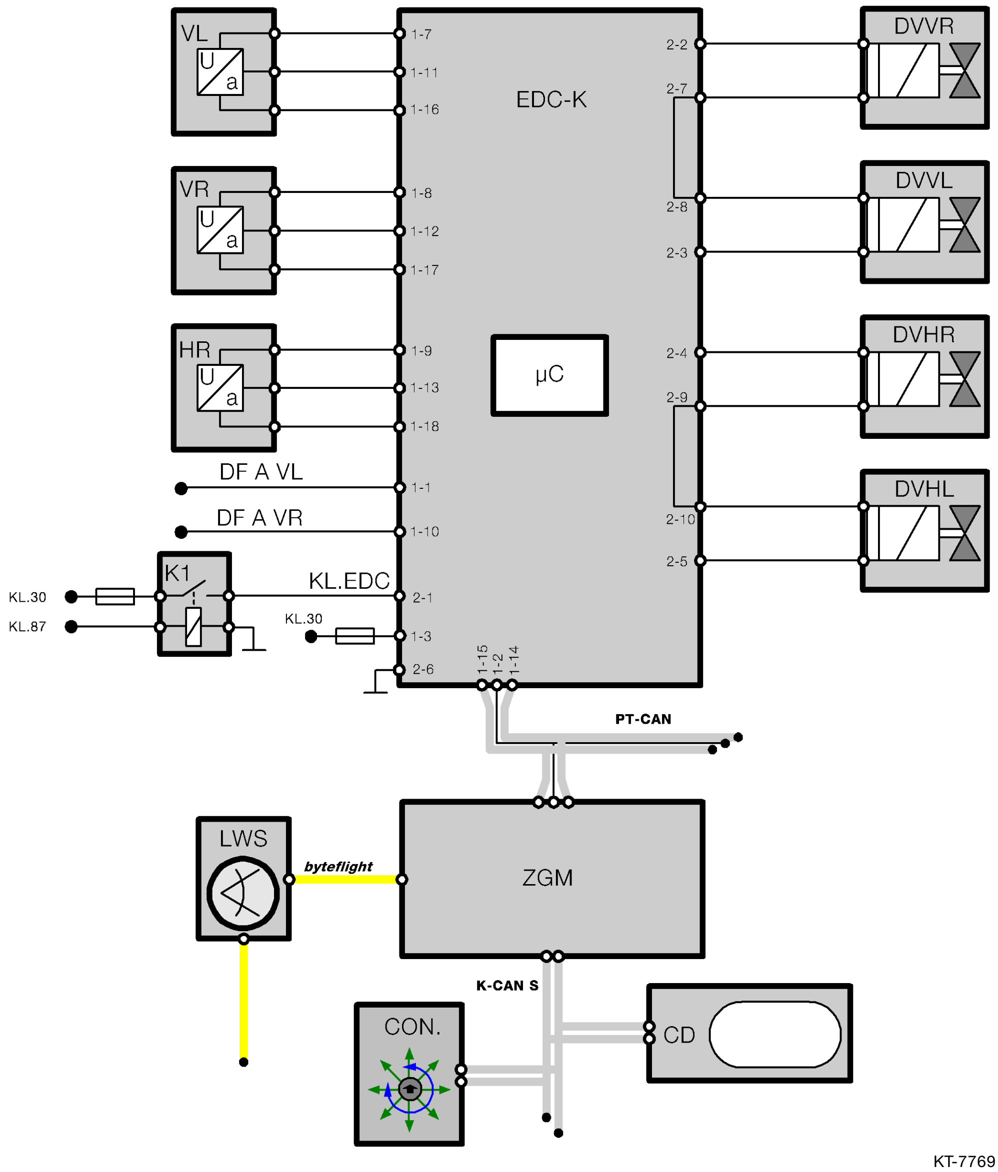

Fig. 8: Electronic system overview EDC-K

Index	Description	Index	Description
VL	Front left	CD	Control Display
VR	Front right	DVVR	Damper valve, front right
HR	Rear right	DVVL	Damper valve, front left
DF A	Analog speed sensor	DVHR	Damper valve, rear right
CON.	Controller	DVHL	Damper valve, rear left
LWS	Steering-angle sensor	ZGM	Central gateway module

Functional description of components

- Control unit

The control unit is supplied by the vehicle electrical system (terminal 30) via an unloading relay with integrated reverse voltage protection.

The control unit is fully operational within a range of + 9 V to + 16 V. In the event of undervoltage, the system shuts down for a defined period to prevent the vehicle battery from being excessively drained.

The control unit incorporates various controller functions which through a control strategy establish the direct current applied at the damper valves.

In accordance with the forces calculated in each case, there are vertical, longitudinal, transversal, copy and tolerance controllers.

The dampers are de-energized when the vehicle is stationary. They are energized initially from 5 km/h.

- Power supply

A low current at the valves results in hard damping while a high current results in soft damping.

The setpoint values for the output voltage are specified by the microprocessor via a pulse-width-modulated signal (PWM). Current limitation is ensured by a hardware overcurrent deactivation facility.

All analog inputs are protected by diodes against positive and negative overvoltage.

The following analog control-unit signals are processed by the microprocessor:

- Supply voltage from vehicle
- Output voltage from switching controller
- Voltage and current at valves

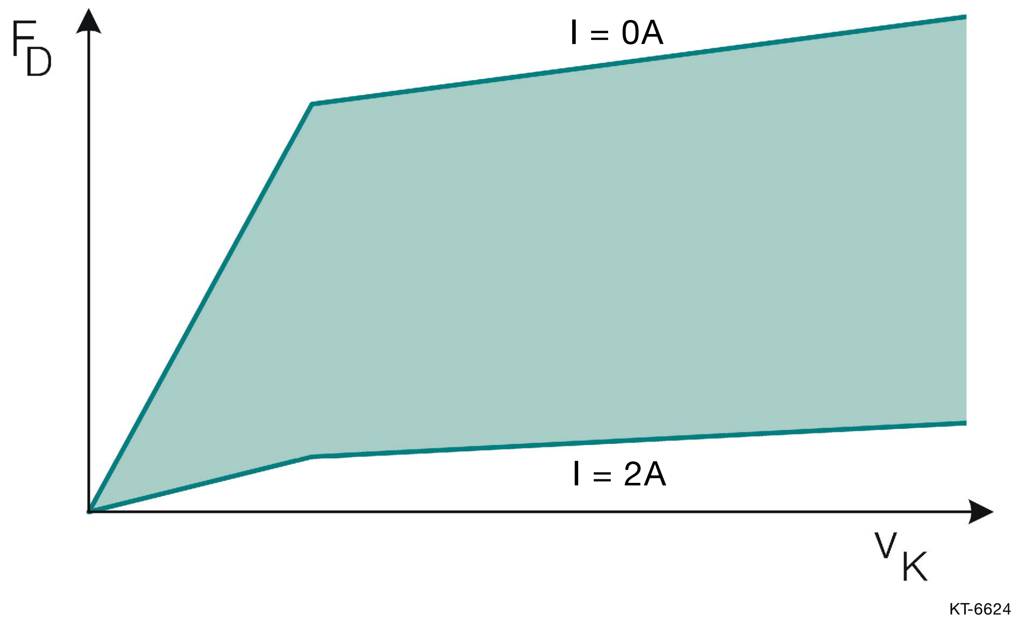

Fig. 9: Hard and soft damper curves (pull stage) and their currents

Valve activation/output-stage circuit

The actuators are jointly supplied by the control unit on the negative side.

The solenoid valves in the dampers demonstrate a relatively low resistance (approx. 2.2 ohms per valve at room temperature). The current to be set is in the range of 0 to 2 A depending on the desired damping force, i.e. a relatively high current is needed at a low voltage. The setpoint value must not exceed 2 A otherwise damage to the valves will be incurred. The solenoid valves are connected in series for each axle. The output current is a direct voltage.

The adjusting dampers are activated in series for each axle.

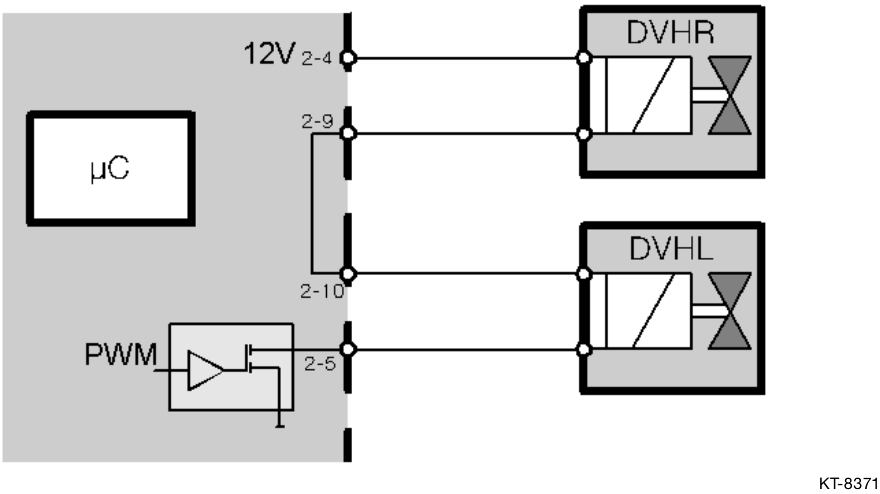

Fig. 10: Series connection of EDC-K valves on rear axle

Index	Description	Index	Description
µC	Microcontroller	DVHR	Damper valve, rear right
PWM	Pulse width modulation	DVHL	Damper valve, rear left

- Vertical-acceleration sensors

The three vertical-acceleration sensors have a measuring range of 2.5 g. They are fitted on the right and left spring-strut domes and on the right rear-axle dome in the wheel arch. The three sensors are identical, their only difference being the way in which they are mounted in the wheel arches. The front sensors (1) are mounted at the top of the wheel arch while the rear sensor (2) is mounted on the side of the wheel arch. The plug connection to the control unit points downwards in each case.

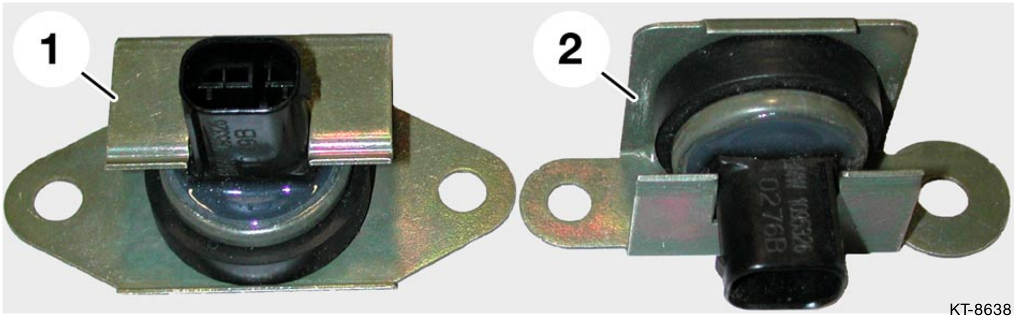

Fig. 11: Vertical-acceleration sensors, front/rear

Index	Description	Index	Description
1	Acceleration sensor, front	2	Acceleration sensor, rear

- Electronically adjustable vibration dampers

The front and rear axles are fitted with twin-tube gas-pressure dampers. The adjusting dampers have been developed by the company Mannesmann Sachs Boge.

The dampers are map dampers, i.e. there are no longer any fixed stages as was the case with EDC III.

Each damper incorporates an adjustable proportional control valve on the piston. Damper oil flows through this valve alternately during compression and rebound.

The control valve generates a pressure drop between the lower and upper piston sides depending on the oil flow admitted.

The electric supply lead for the integrated control valve passes through the hollow piston rod.

A base valve is axially arranged in parallel next to the controllable control valve. The primary function of this valve is to safeguard the minimum pressure-stage curve.

The minimum pull-stage curve is primarily created by a conventional piston valve connected in series with the control valve.

Activation takes place separately for both axles so as to guarantee an optimum body vibration response in all driving conditions.

The valves are not energized in the event of a control-unit failure or with ignition "off;" the dampers are automatically located in the hardest damper setting.

If the vehicle is equipped with dynamic drive, spring struts with different valve configurations are used on the front and rear axles.

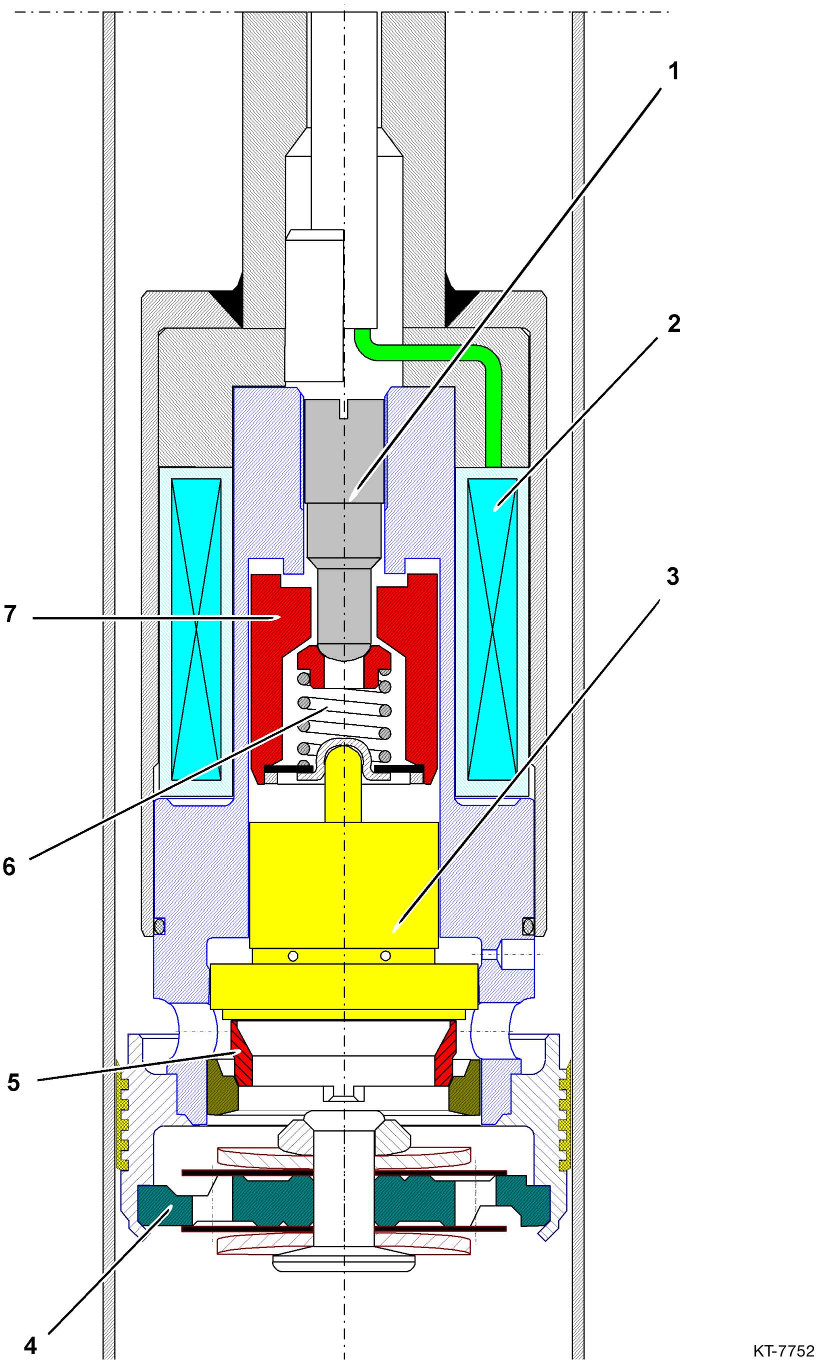

Fig. 12: Section through a damper

Index	Description	Index	Description
1	Screw	5	Floating seat ring
2	Solenoid coil	6	Valve spring
3	Main damper valve	7	Armature
4	Supplementary valve		

- Infinitely variable control valve

In de-energized operating state, the maximum hydraulic resistance is set by the manufacturer. This is effected by the screw (1), which pretensions the valve spring (6). This is the hardest damper setting, also known as the safety setting.

The valve spring acts with maximum force on the armature (7), which presses down on the main damper valve (3). This in turn presses down on the floating seat ring (5), which then rests at the bottom on the housing and offers resistance to the oil flow.

The energising of the solenoid coil (2) moves the armature against the valve-spring bias.

Together with the conventional base valve (not illustrated), the supplementary valve (4) creates the softest pressure damping.

Pull-stage operation:

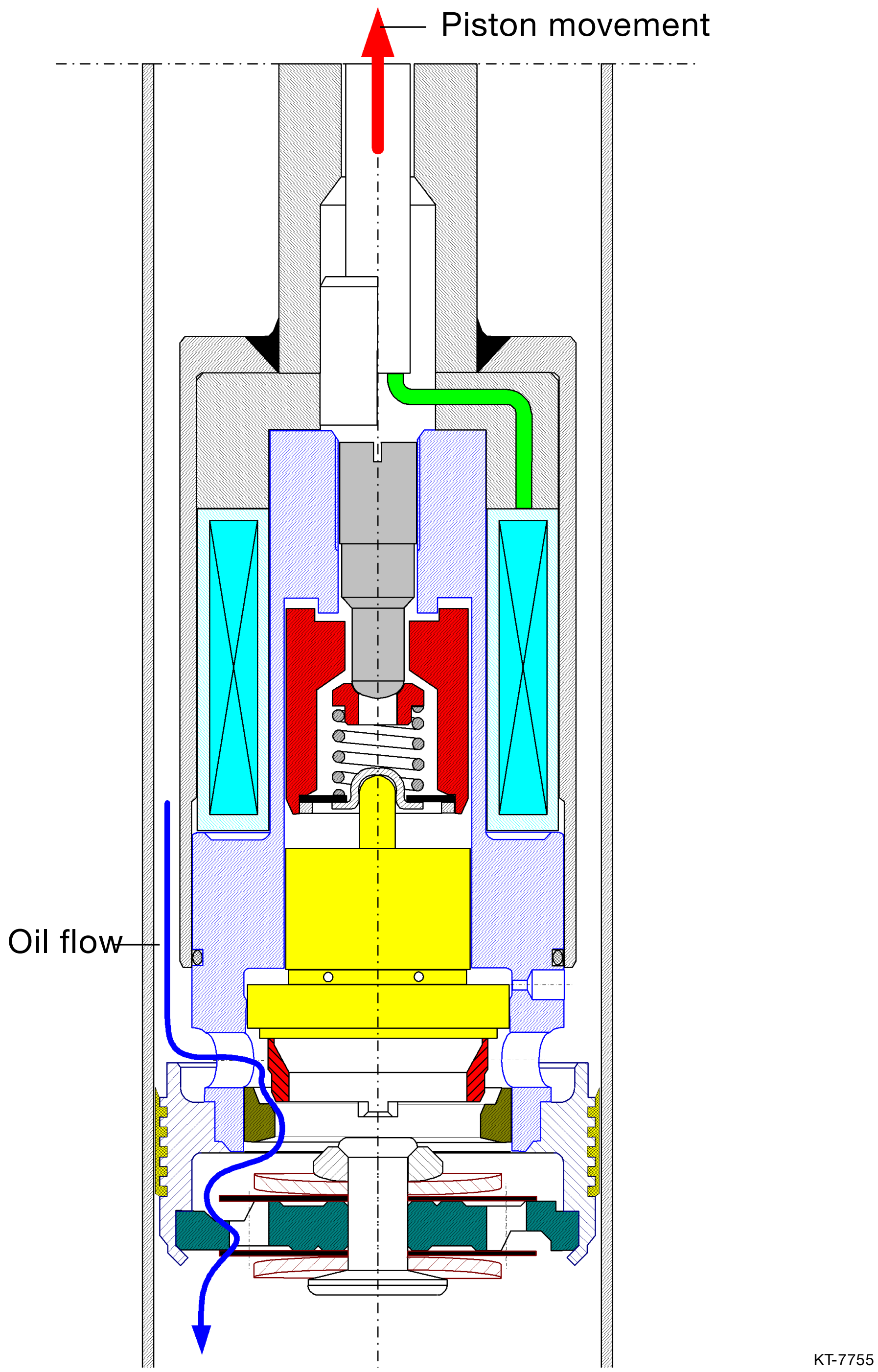

Fig. 13: Valve, pull stage

The piston is pulled upwards and the oil flows in the direction indicated by the drawn arrow. The floating seat ring forces the main damper valve upwards as a result of the hydraulic conditions.

Pressure-stage operation:

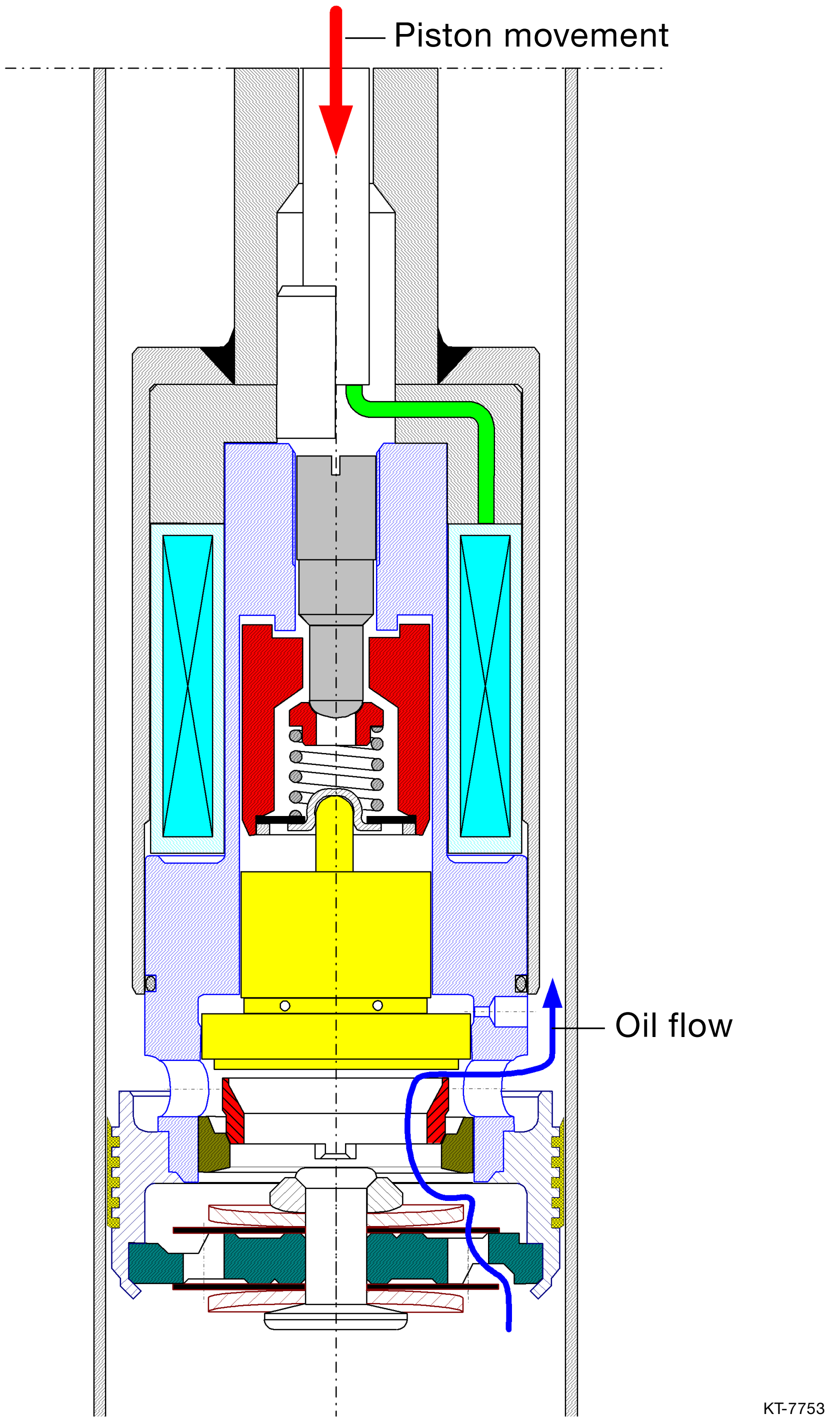

Fig. 14: Valve, pressure stage

The piston rod is forced downwards and the oil flows in the direction indicated by the drawn arrow. The main damper valve is forced upwards as a result of the hydraulic conditions. The floating seat ring rests at the bottom.

Operation

Controller and control display

Sports program:

The driver activates the sports program by way of the controller or from 03/02 the button combination on the multifunction steering wheel. A more rigid damping is set when the EDC-K switch is set to "SPORT."

EDC-K is always in the comfort program each time the engine is restarted.

Fig. 15: Control display

Diagnosis

System monitoring and plausibility

For safety reasons, faults at one valve will result in the power being cut to all the valves. Fault detection takes place on each axle. To ascertain which valve is faulty, use the DIS or measure the resistance of the individual valves. An operational valve will have a resistance of 2.2 ohms ±10% at room temperature (20 °C). Pay attention to the temperature-dependent change in resistance.

Acceleration sensors

There is no distinction between malfunction and real operating state in the EDC-K control unit. The power supply to the three sensors is connected in parallel in the control unit without isolation. A short circuit in the supply voltage to one of these electrical loads will thus also affect the supply to the other sensors.

Notes on Service

EDC diagnosis detects electronic damper faults on the complete axle only. Mechanical testing of individual dampers can be carried out on the damper tester.

Mechanical wear causes the dampers to weaken over the course of their service lives. A running-time memory shifts the damper curves towards a harder setting. Faulty dampers are normally replaced together on a single axle. Following such a replacement, the running-time memory for the front or rear axle must be reset with the DIS (life time reset).

Dynamic Drive

Introduction

Stabilizer bars on the front and rear axles

A rolling moment is built up over the car's roll axis as a result of the centrifugal force occurring at the centre of gravity. This force works such that the vehicle body leans towards the external wheel while cornering and thereby quickly draws the car closer to the limits of its driving dynamics. The tilt angle of the body and the resultant increased wheel load differential can be counteracted by the use of stabilizer bars.

When cornering, the wheel on the outside of the corner compresses its spring, while the inner wheel extends its spring. This causes the back of the stabilizer bar to turn. The forces occurring in the mounting points of the stabilizer bar generate a torque which counteracts the body angle and causes better load distribution on both the wheels on one axle.

The disadvantage is that when you are driving straight ahead and during one-sided compression, the basic suspension becomes harder. This reduces comfort.

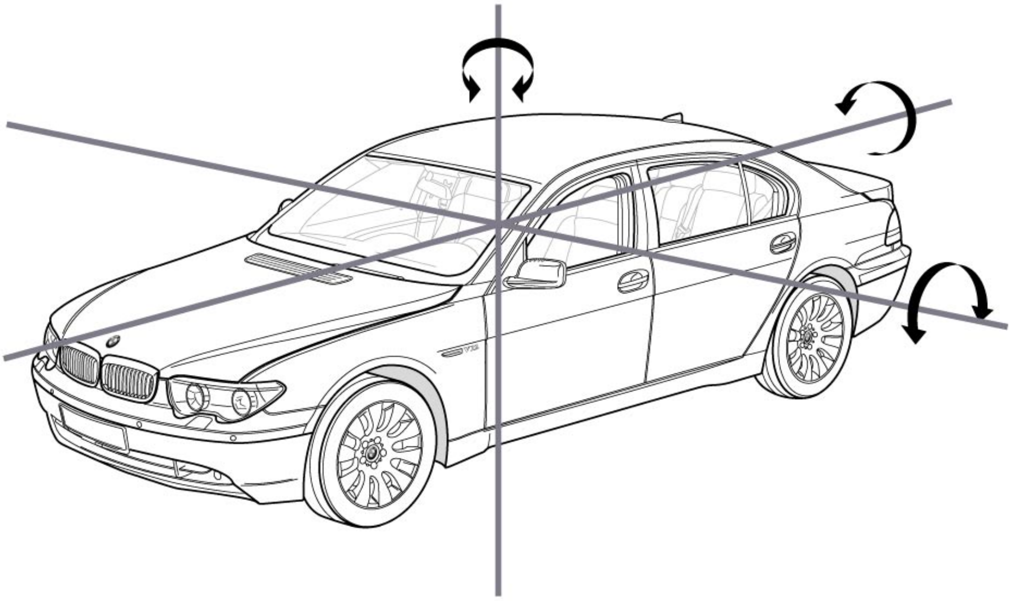

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Fig. 16: Roll, yaw and pitch axis

The active Dynamic Drive chassis system, also known as "Active Roll stabilizer bar" (ARS) represents a revolutionary step for chassis technology. Firstly, it goes a long way towards removing the conflict between handling/agility and comfort. This leads to a new kind of "Ultimate Driving Machine" typical of BMW.

The active roll stabilizer has two stabilizer bars which have a positive effect on the roll tilt angle and handling. Springs and dampers can be positioned better to increase comfort.

Dynamic Drive overview

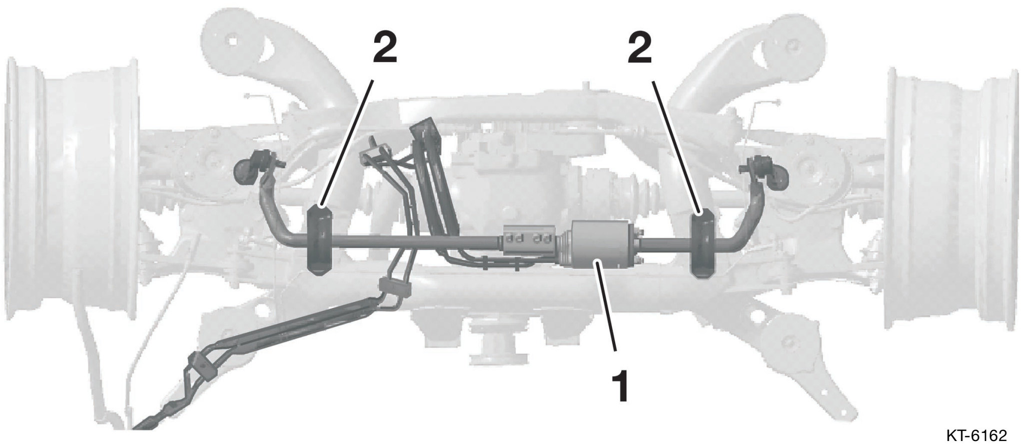

Fig. 17: Active stabilizer bar on the rear axle

Index	Description	Index	Description
1	Oscillating motor	2	Stabilizer bearing (roller bearing)

Dynamic Drive controls two active stabilizer bars depending on the lateral acceleration.

The Dynamic Drive is based on two separate stabilizer bars on the axles, the halves of which are connected via a hydraulic oscillating motor. One half of the stabilizer bar is connected to the oscillating motor shaft while the other is connected to the oscillating motor housing.

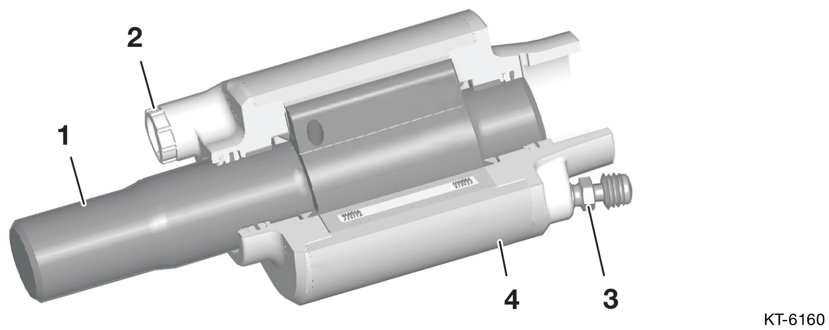

Fig. 18: Oscillating motor

Index	Description	Index	Description
1	Oscillating motor shaft	3	Ventilation connection
2	Pressure connection	4	Oscillating motor housing

These active stabilizer bars set the stabilizing torque,

- which minimizes or completely eliminates the rolling motion of the vehicle structure while cornering,
- which reduces the copy movement of the vehicle structure,
- which allows a high degree of agility and destination precision over the entire speed range,
- and produce optimum self-steering characteristics.

When you are driving straight ahead, the system improves suspension comfort because the stabilizer bar halves are non-interacting and therefore do not harden the basic suspension when suspension is used on one side.

Dynamic Drive consists of the following components:

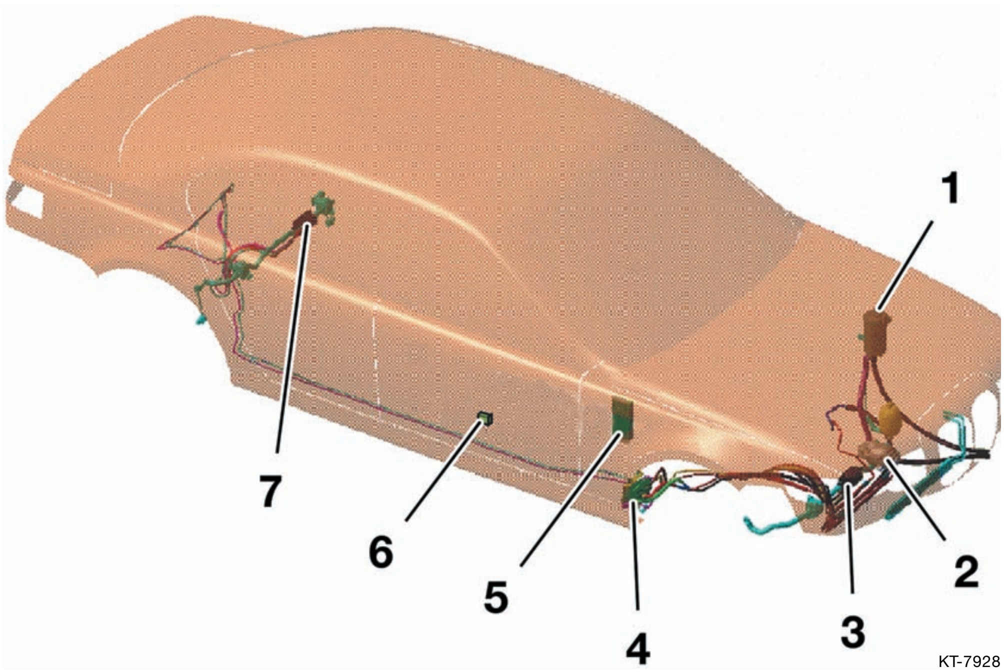

Fig. 19: Installation position of the components

Index	Description	Index	Description
1	Fluid reservoir	5	Control unit
2	Tandem pump	6	Transverse acceleration sensor
3	Front oscillating motor	7	Rear oscillating motor
4	Valve block		

Effect of the tilt behaviour

The car sets lateral acceleration while cornering (aq) which affects the vehicle body at the centre of gravity (SP). The body rolls around the roll axis (RA) which is predefined by the front and rear axle kinematics. This sets the roll angle φ (max. 5°). This produces a maximum change in level on the wheel housing of 10 cm.

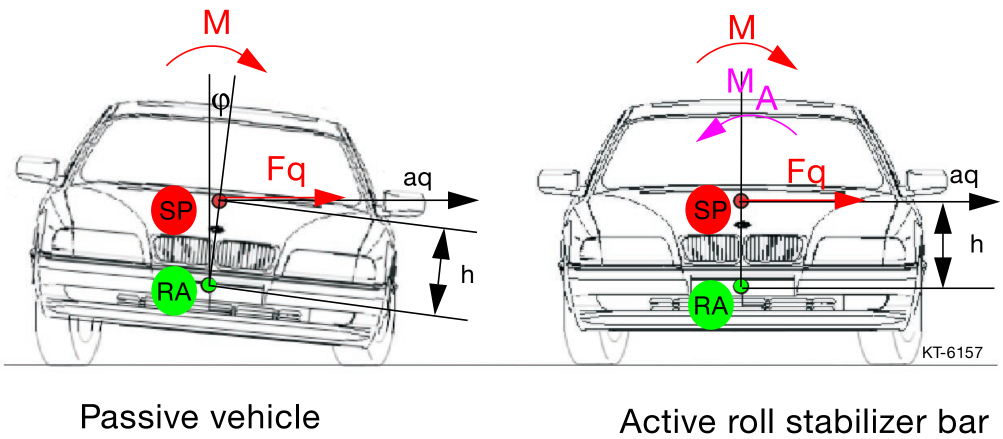

Fig. 20: Passive vehicle/ARS roll behaviour

Index	Description	Index	Description
M	Rolling moment	SP	Centre of gravity
aq	Lateral acceleration	RA	Roll axis
φ	Roll angle	Fq	Lateral force
M_A	Body torque	h	Lever arm centre of gravity height

On a passive vehicle with conventional suspension the rolling moment (M) is taken up by the stabilizer bars and springs. The springs which are external to the corner compress and the inner springs extend. The stabilizer bars also turn. A roll angle φ is formed between the perpendiculars and the body.

On vehicles with Dynamic Drive, the rolling moment (M) can only be compensated by the active stabilizer bars up to a specific lateral acceleration (aq). The roll angle does not form until the rolling moment (M) is larger than the moment set by the ARS (M_A). The remaining rolling moment (M) is then supported by the passive springs.

The active body torques (M_A) on the front and rear axle counteract the rolling moment (M). In this way the roll angle is compensated in accordance with the characteristic curve which is predefined in the control unit. The roll angle is completely compensated up to a lateral acceleration of approx. 3 m/s^2 (0.3 g). A roll angle is not formed by the ARS until there is increased lateral acceleration. The roll angle and increased understeer alerts the driver that the vehicle is approaching its stability limit.

Note: The tyre suspension created by the rolling moment (M) is not compensated for.

Roll angle diagram:

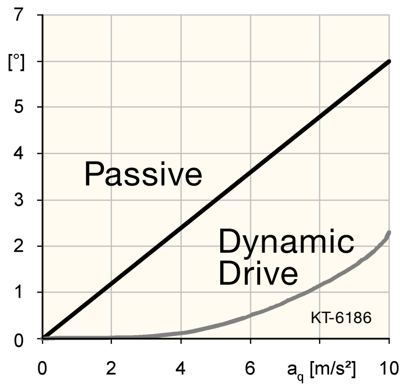

Fig. 21: Unladen vehicle

The roll angle shown is achieved when the vehicle is unladen and the driver is in the vehicle.

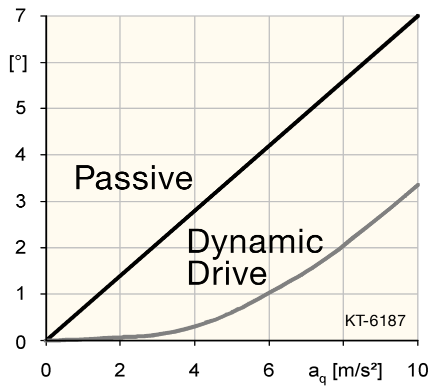

Fig. 22: Laden vehicle

When the vehicle is fully laden, the larger body mass effects a greater lateral force on the vehicle. The lever arm (h) may also change depending on the position of the load (in the vehicle or on the roof). In this case the a larger roll angle will form than as predefined in the control characteristic curve.

A fully laden passive vehicle still forms a larger roll angle.

Calculating the rolling moment (M)

The lateral force (F_q) effected on the body is calculated as follows:

$$\mathbf{F_q = m * a_q}$$

m (kg) = weight of the vehicle body

a_q (m/s^2) = lateral acceleration

The lateral force (F_q) causes the rolling moment (M) via the lever arm (h) (= distance between SP and RA).

$$\mathbf{M = F_q * h}$$

F_q (N) = lateral force

h (m) = lever arm

The distribution of the active body torque between the front and rear axle depends on the road speed. The next section describes the way in which it is distributed.

Effect of the self-steering behaviour

The self-steering behaviour can be decisively influenced by the distribution of the stabilizing torque on the axles. The greater the stabilizing torque on an axle, the lower the lateral forces transmitted on this axle.

Two cases are described below with different distribution of stabilizing torque on the axles:

1. Identical stabilizing torque on both axles

Handling is "NEUTRAL."

The front wheels can apply about the same amount of lateral force on the road as the rear wheels without drive torque. The handling conditions are neutral.

A vehicle which is tuned to neutral handling conditions provides very agile handling, the steering reacts very quickly. The driver experiences precise handling.

Even an inexperienced driver can control a vehicle which is tuned to neutral handling very well at low speeds.

2. Larger stabilizing torque on the front axle

Handling is "UNDERSTEERING."

The front axle wheels cannot apply the same amount of lateral force on the road as the rear axle wheels. The vehicle suffers understeer.

A vehicle with understeer can generally also be controlled well by an inexperienced driver at higher speeds and higher cornering speeds.

This very sensitive handling reduces the vehicle's agility.

Dynamic Drive sets the stabilizing torque on the front and rear axle such that a different handling characteristic is produced for low and high speeds.

Road speed	Handling
Low	Neutral
High	Understeering

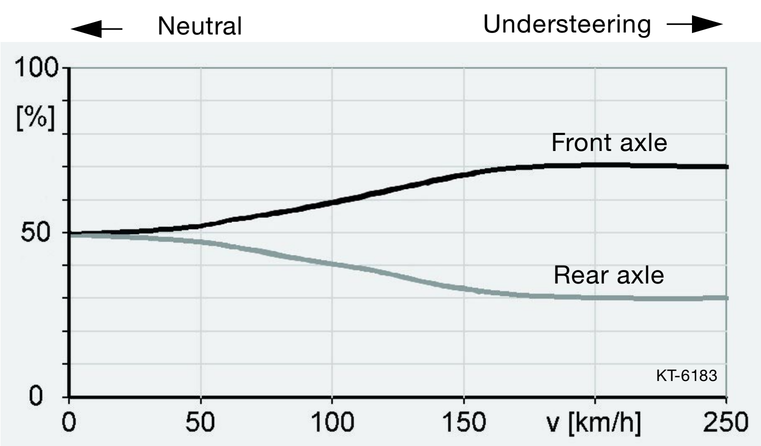

Fig. 23: Percentage distribution of the active body torque over the road speed

The hydromechanical concept is designed so that a larger active stabilizing torque cannot occur on the rear axle than on the front axle under any circumstances. This means that mechanically and hydraulically the vehicle with Dynamic Drive is safeguarded such that no oversteering and therefore for normal customers no critical handling characteristics can occur under any circumstances.

System dynamics

When the vehicle changes lane, corners or changes direction quickly on winding country roads, Dynamic Drive must react quickly as appropriate.

The Dynamic Drive system dynamics is determined by the time that the following steps take:

Process	Time
Signal detection by sensors, processing of sensor signals in the control unit, valve control	Approx. 10 ms
Change of direction, switching over the torque direction, direction valve	Approx. 30 ms
Pressure build-up (force per wheel) 0 --> 30 bar (0 --> 350 N) 0 --> 180 bar (0 --> 2100 N)	 Approx. 120 ms Approx. 400 ms

Comparison between the conventional stabilizer bar and the active stabilizer bar

Active stabilizer bars introduce fewer forces into the body which reduce comfort than passive stabilizer bars. In this case a differentiation must be made depending on the frequency with which the forces were introduced.

Road stimulus	Stabilizer bar behaviour
At approx. 1 Hz (body natural frequency)	At smaller strokes the active stabilizer bar is easier to turn than a conventional stabilizer bar. The forces introduced into the body are fewer, the vehicle becomes more comfortable and body sound is improved.
From 8 Hz (wheel natural frequency)	Both stabilizer bars behave in a similar way. On a vehicle with an active stabilizer bar this is because the fluid is not displaced so quickly.

- Dynamic Drive in the BUS combination

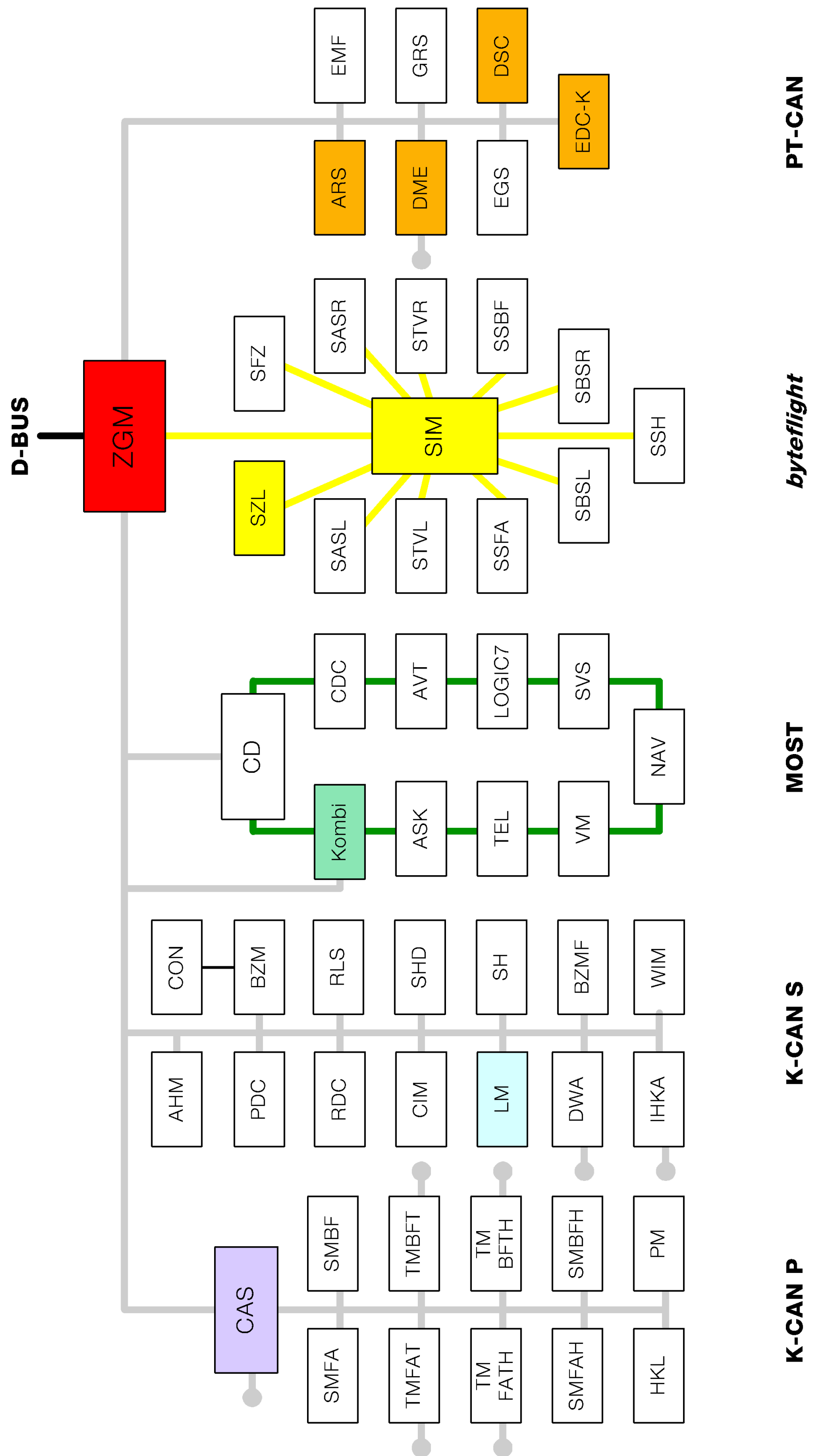

Fig. 24: BUS structure

Description of components

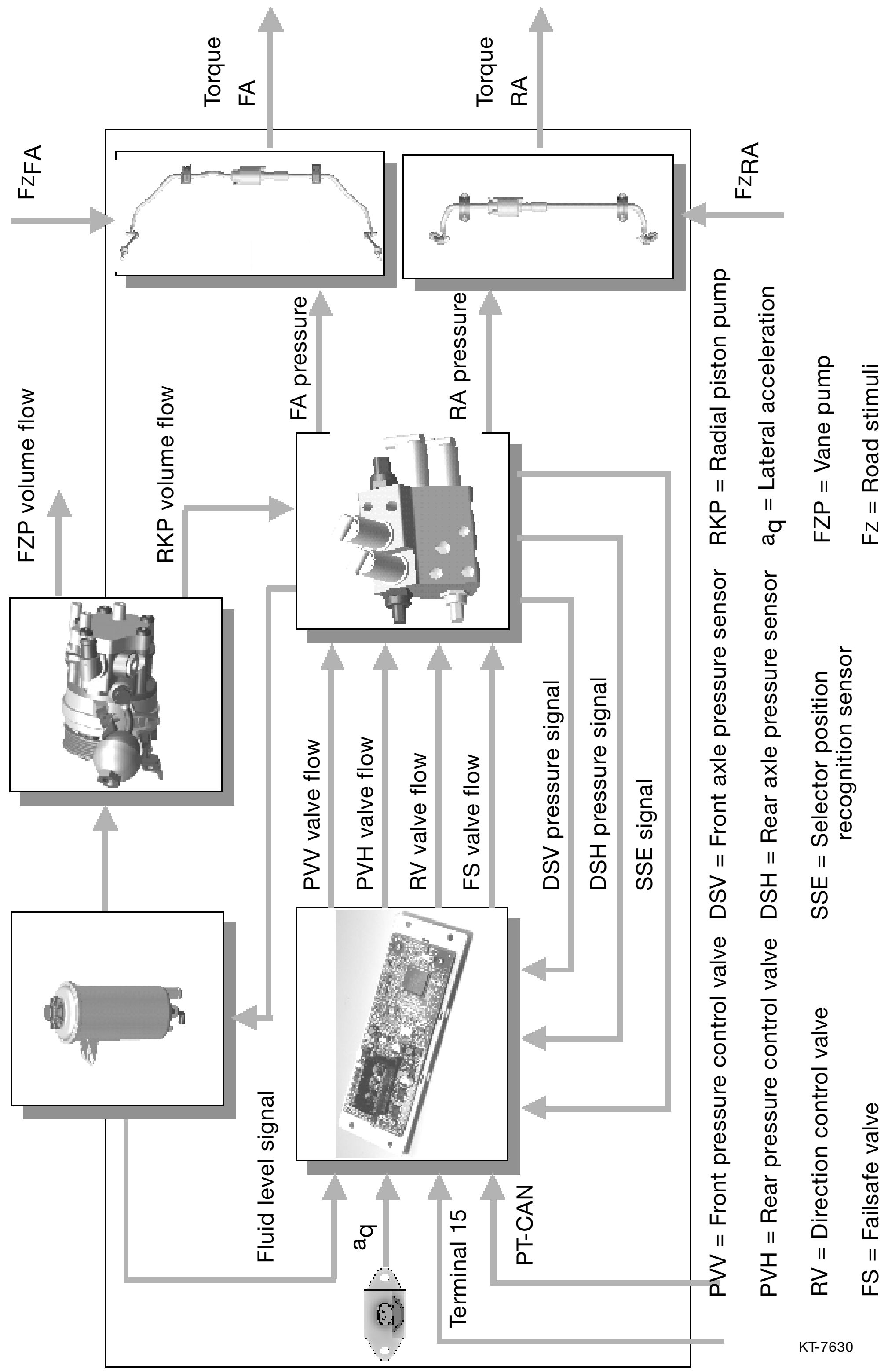

Fig. 25: Overview of the Dynamic Drive system

Control unit

The control unit is supplied with power via terminal 30 and is protected by a 10 A fuse. The control unit is only activated via a CAN alarm lead from the Car Access System (CAS) once the ignition is ON.

A vehicle authentication process takes place when the system is started. This compares the vehicle identification number from CAS with the vehicle identification number which is encoded in the Dynamic Drive control unit.

Then the control unit's hardware and software is checked.

All the outputs (valve magnets) are subjected to a complex check for short circuits and breaks. If there is a fault, the system switches the actuators into a safe driving condition.

The control unit switches off if there is undervoltage or overvoltage.

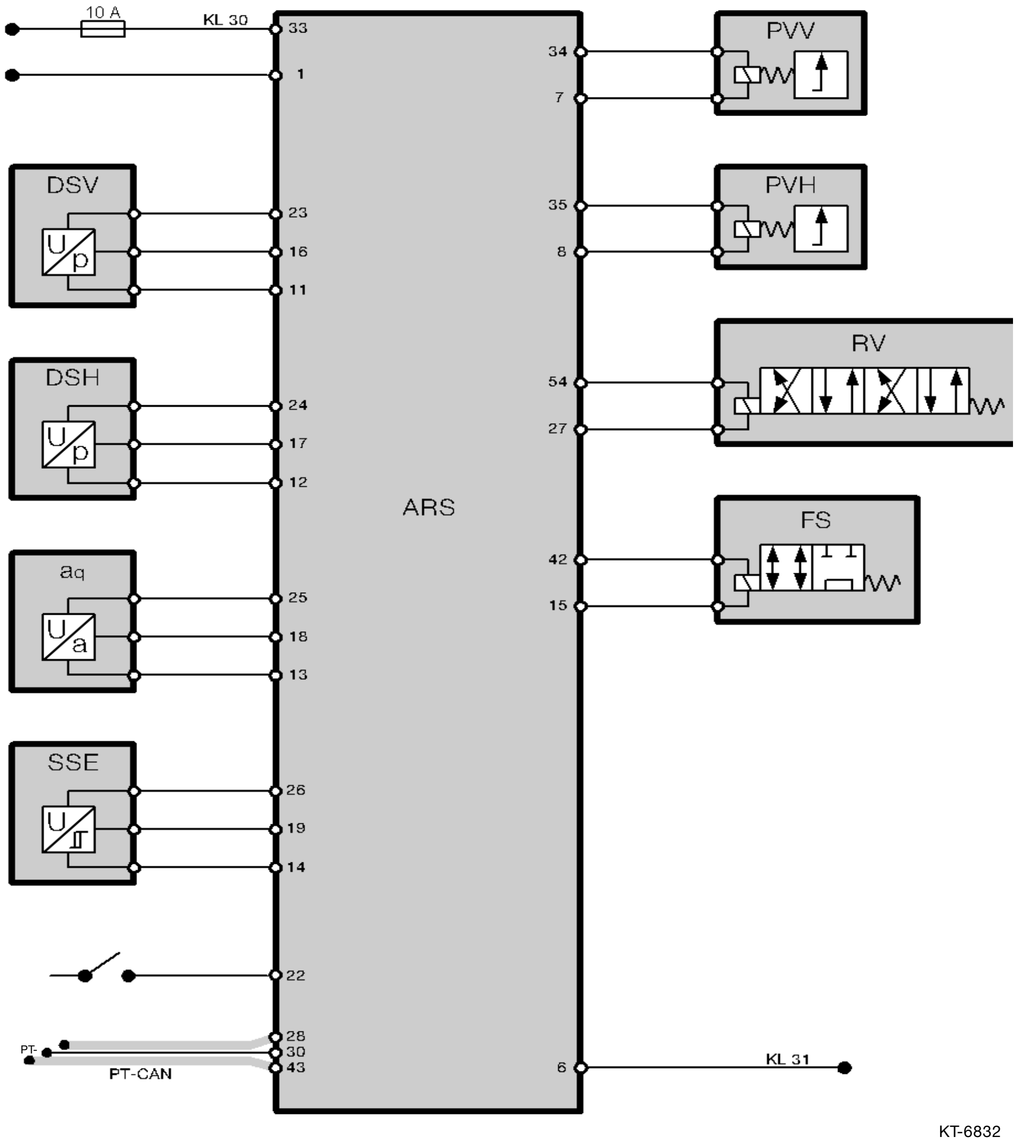

Fig. 26: ARS block diagram

Index	Description
aq	Lateral acceleration
ARS	Active roll stabilizer bar control unit
SSE	Selector position recognition sensor
DSV	Front axle pressure sensor
DSH	Rear axle pressure sensor
PVV	Front axle pressure control valve
PVH	Rear axle pressure control valve
RV	Directional valve
FS	Failsafe valve

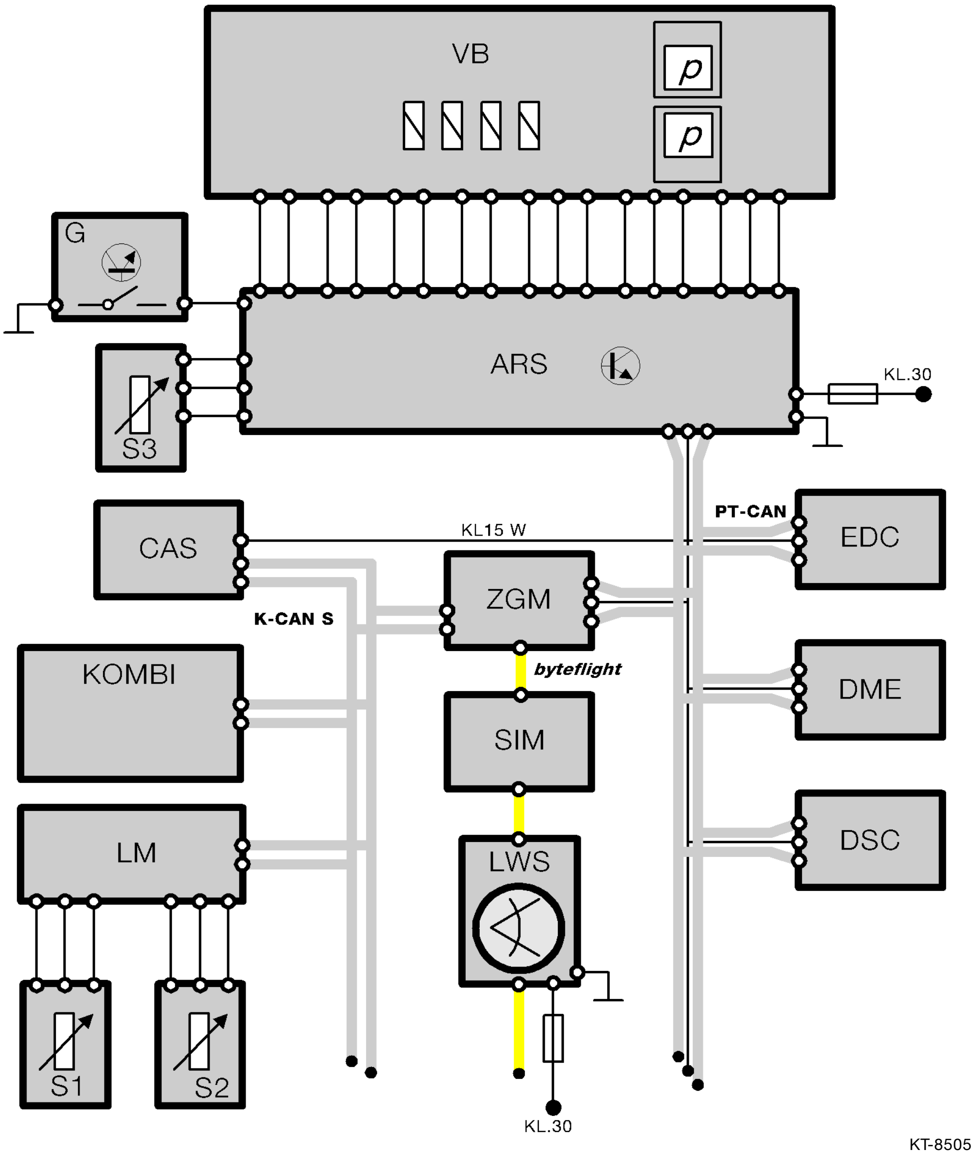

Fig. 27: Dynamic Drive system overview

Index	Description	Index	Description
ARS	Control unit	SIM	Safety integrated module
VB	Valve block	ZGM	Central gateway module
p	Pressure sensors	EDC	Electronic Damping Control
G	Fluid level sensor	DME	Digital engine electrics
CAS	Car Access System	DSC	Dynamic stability control
KOMBI	Instrument cluster	S1, S2	Ride level sensors
LM	Light switch centre	S3	Transverse acceleration sensor
LWS	Steering-angle sensor in SZL		

Inputs

The control unit has the following input signals:

- Lateral acceleration
- PT-CAN
- Front axle circuit pressure
- Rear axle circuit pressure
- Selector position recognition sensor
- Fluid level sensor signal

The measurement of the lateral acceleration is the Dynamic Drive's most important control signal. Additional information from the PT CAN, which characterize the lateral dynamics, are the road speed signal, steering wheel turning angle and the yaw velocity from the yaw sensor. This determines the stabilization requirement and the appropriate moments of inertia are set.

The system reaction time is also improved using the road speed and steering angle information.

Outputs

The outputs include the controls for the following:

- Pressure control valves for the front and rear axle
- Directional valve
- Failsafe valve
- 5 V voltage supply for the sensors

  Transverse acceleration sensor
  Pressure sensors on the front and rear axle
  Selector position recognition sensor (SSE)

The valves are controlled by current control using pulse width modulation. The current measurements for the individual coil currents are displayed in duplicate. The valve currents are constantly checked for plausibility.

The current measurement also makes it possible to set the pressure more precisely and the shift valves can be monitored electrically.

The PT CAN sends a telegram to the DME which states how much power the tandem pump requires to supply the active stabilizer bars. This means that the additional power required for the engine can be calculated.

A regular data signal (alive signal) is given and read by the other control units to detect whether the system is still active.

All signal faults are recorded and permanently stored.

Sensor system

There are 5 sensors which convey their signals directly to the control unit.

Transverse acceleration sensor:

The lateral acceleration sensor is the main controller output. When cornering, it measures the vehicle's lateral acceleration up to a measuring range of ±1.1 g. It is mounted beneath the right-hand front seat on the floor plate. The control unit can teach-in an offset during commissioning and during the journey.

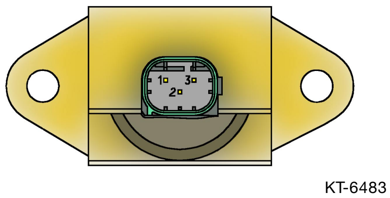

Fig. 28: Transverse acceleration sensor; natural colour connector, individual connector coding

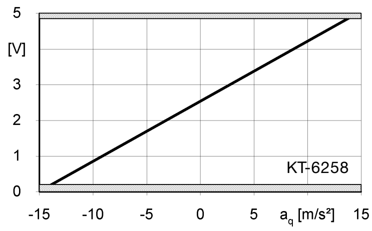

Fig. 29: Transverse acceleration sensor characteristic curve

Front and rear axle stabilizer bar pressure sensors:

The pressure sensors are responsible for detecting the front and rear axle stabilizer bar hydraulic pressures. The sensors are mounted on the valve block. The pressure sensor offset values are taught-in by the control unit once, during commissioning.

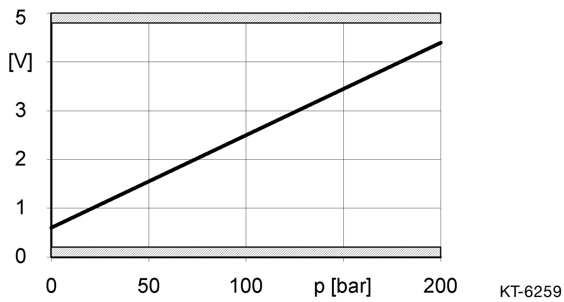

Fig. 30: Pressure sensor characteristic curve

Selector position recognition sensor (SSE):

The task of this sensor is to detect the specific position of the directional valve.

2 positions can be detected:

- Left-hand control
- Right-hand control

The SSE is mounted on the valve block.

Fluid level sensor:

The fluid level sensor detects the fluid supply in the fluid reservoir. The fluid level sensor detects any drops in fluid level which fall below a critical minimum level, and triggers a warning message. Normal fluid movement in the reservoir does not trigger a sensor.

The fluid level sensor is mounted on the fluid reservoir. Short circuits/open circuits cannot be detected by the fluid level sensor. A line break is interpreted as a loss of fluid.

Actuator systems

Pressure control valves:

There is a pressure control valve on both the front and rear axles. They both adjust the front and rear axle stabilizer bar actuation pressures.

When driving straight-ahead, the pressure control valves are de-energized and the throttle diameters are open. The fluid can flow freely to the reservoir.

The valves are energized when cornering. The pressure in the oscillating motors increases rapidly and is regulated to the setpoint value. Depending on the lateral acceleration and the speed, pressures of between 5 and 180 bar for the front axle and between 5 and 170 bar for the rear axle are regulated.

The pressure control valves are located in the valve block.

Directional valve:

The directional valve is electrically actuated. It specifies the direction of the high-pressure fluid for right-hand and left-hand bends.

It is located in the valve block.

Failsafe valve:

The failsafe valve (safety valve) is electrically actuated. It closes the front axle oscillating motor, de-energized. The system pressure is limited by the circulating position.

It is located in the valve block.

Check valve:

The check valves allow the fluid to be siphoned off, thus preventing cavitation in the oscillating motor.

They are located in the valve block.

Valve block:

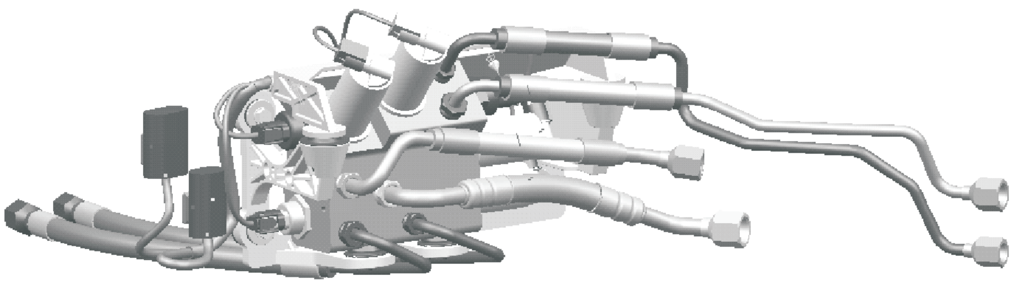

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Fig. 31: Valve block with cables

The valve block is located behind the right-hand front wheel arch trim, near the A-pillar.

It fulfils the following tasks:

- Distribution of fluid flow to the oscillating motors:
  The pressure at the front axle oscillating motor is greater than or equal to the pressure at the rear axle oscillating motor.

- Measuring the actual pressure of the high-pressure fluid:
  There is a pressure sensor for both the front and rear axle oscillating motors on the valve block outputs.

- Fast and precise regulation via pressure control valves:
  Additionally initiated pressure changes caused by road irregularities are passively regulated if possible. They can barely be detected.

- Adjustment of the volume flow direction (left-hand/right-hand bend) via a directional valve:
  The directional valve position is detected by a selector position recognition sensor (SSE).

- Transfer to failsafe mode in the event of power supply failure or if a fault is detected in the system:
  The front axle oscillating motor is sealed tight, a check valve makes siphoning using a tank cable possible.
  The rear axle oscillating motor is short-circuited and simultaneously joined with the tank cable.

- Limiting the system pressure in the event of a fault:
  The failsafe valve causes a circulating current.

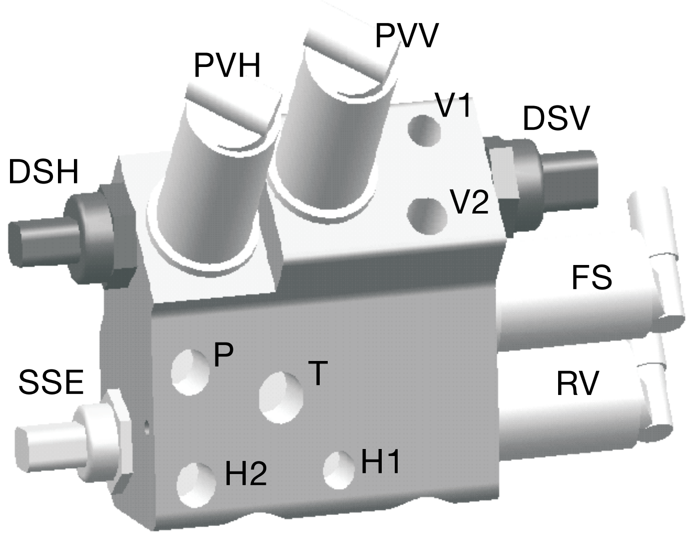

Fig. 32: Valve block

Index	Description
V1	Line 1, front axle oscillating motor
V2	Line 2, front axle oscillating motor
H1	Line 1, rear axle oscillating motor
H2	Line 2, rear axle oscillating motor
P	Pump
T	Fuel tank
RV	Directional valve
FS	Failsafe valve
RVV1	Check valve (in valve block)
RVV2	Check valve (in valve block)
PVV / PVH	Front axle/rear axle pressure limitation valve
SSE	Selector position recognition sensor
DSV / DSH	Front axle/rear axle pressure sensor

Valve block components:

Components	Description
Pressure control valves PVV, PVH	The pressure control valves are electrically actuated. The set the active pressure for the front and rear axle stabilizer bars. When driving straight-ahead, the pressure control valves are de-energized and the throttle diameters are open. The fluid can flow freely to the reservoir. The valves are energized when cornering. The pressure in the oscillating motors increases rapidly and is regulated to the setpoint value.
Directional valve RV	The directional valve is electrically actuated. It specifies the direction of the high-pressure fluid (active pressures) and the tank fluid pressure for right-hand and left-hand bends.
SSE	There is a selector position recognition sensor (SSE) for monitoring the directional valve position in the directional valve itself.
Failsafe valve FS	The failsafe valve is electrically actuated. It closes the front axle oscillating motor, de-energized. The system pressure is limited by the circulating position and causes a circulating current.
RVV1, RVV2 Check valves	The check valves are located in the valve block. They allow the fluid to be siphoned off and prevent cavitation in the oscillating motor.
Pressure sensors DSV, DSH	The stabilizer bar pressure sensor signals are used to monitor the hydromechanics. In addition, the pressure control pressure signals are used.

Active stabilizer bar

The active stabilizer bar consists of the oscillating motor (1) and the halves of the stabilizer bar with press-fitted roller bearings (2) which are mounted on the oscillating motor. The use of roller bearings ensures optimum comfort thanks to better response and reduced control forces.

The oscillating motor and the oscillating motor housing are joined by one half of the stabilizer bar.

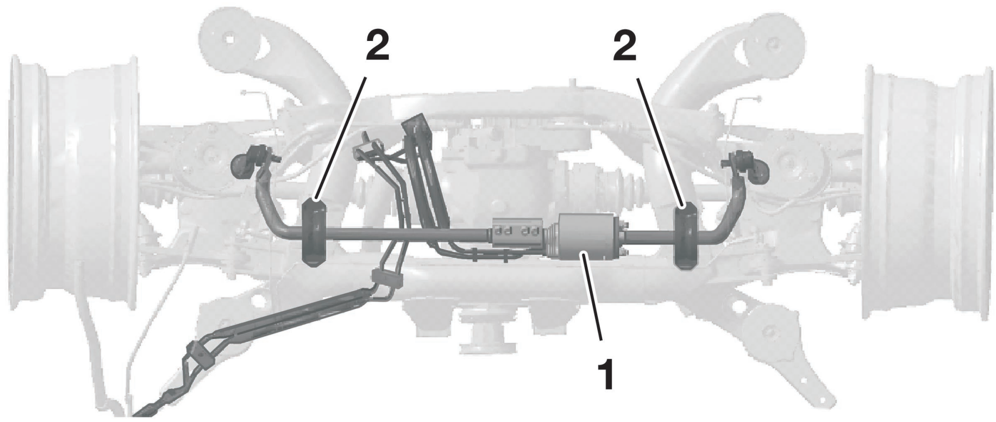

Fig. 33: Active stabilizer bar on the rear axle

Index	Description	Index	Description
1	Oscillating motor	2	Stabilizer bearing (roller bearing)

The active stabilizer bar has three tasks to fulfil:

- The oscillating motor guides the torque into the two halves of the stabilizer bar.

- The oscillating motor decouples the two halves of the stabilizer bar.

- In the event of system failure (failsafe mode), the front axle stabilizer bar creates sufficient damping via the oscillating motor hydraulic fluid (hydraulic locking). It now works like a conventional stabilizer bar.

  Exception: if the oscillating motor chambers no longer contain any fluid as a result of a leak, the front axle stabilizer bar can no longer create damping.

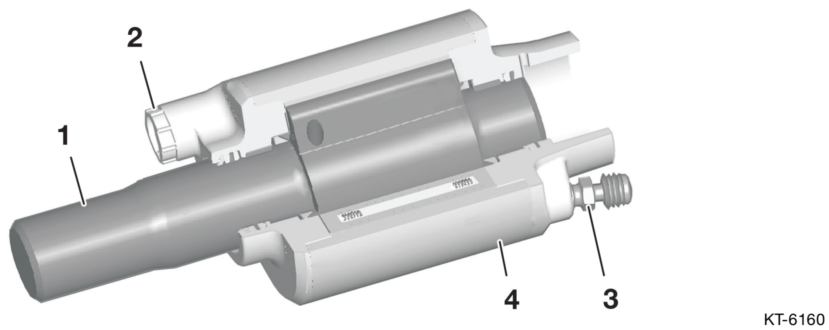

Fig. 34: Oscillating motor

Index	Description
1	Oscillating motor shaft
2	Oscillating motor housing
3	Pressure connection
4	Pressure connection (not visible)
5	Ventilation (x 2)

In the oscillating motor, opposite chambers are always connected with one another and have the same pressure. The two chambers are supplied with high-pressure fluid via a connection, the two other chambers are connected to the tank return line. The different pressures results in the forces F_H (High) and F_L (Low). Since F_H is greater than F_L, there is an M_S torque. As a result, the shaft turns opposite the housing.

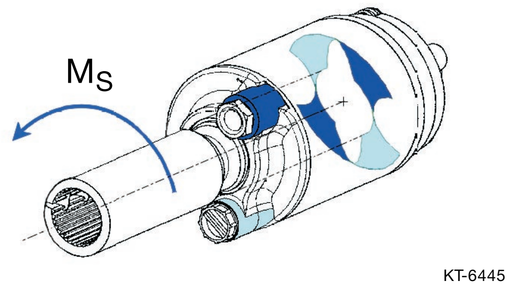

Fig. 35: Oscillating motor, generation of the M_S torque

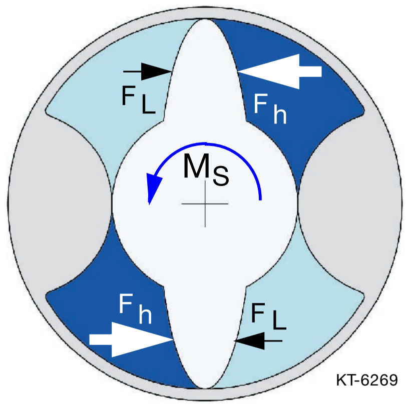

Fig. 36: Cross section of the oscillating motor

Since one half of the stabilizer bar is connected to the shaft, and the other with the housing, the two halves turn in opposite directions.

Via the stabilizer bar connection, this M_S torque generates the active moment M_A at the vehicle's longitudinal axis, against which rolling moment M works when cornering. The shell is forced upwards on the outside of a curve, and dragged down on the inside of a curve.

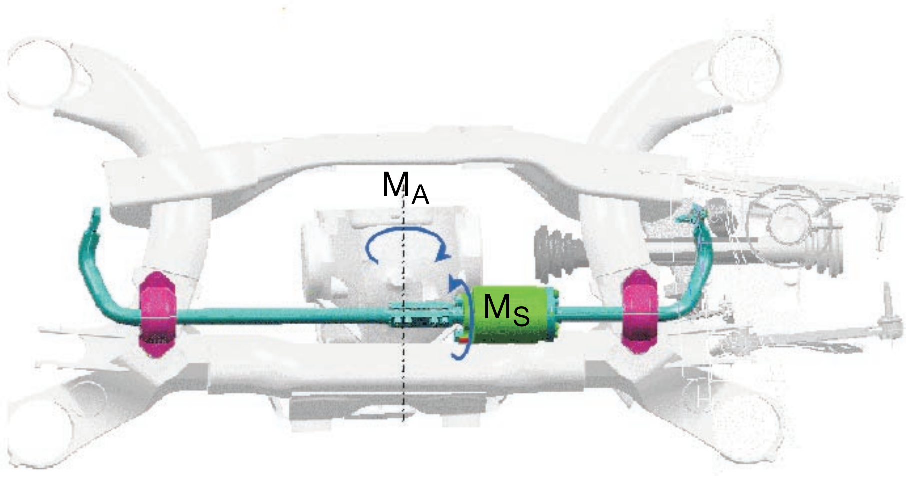

Fig. 37: Active moment M_A

The maximum body torque on the front and rear axle occurs when there is a high degree of lateral acceleration. The system pressure is then 180 bar at the front axle and 170 bar at the rear axle.

The front oscillating motor is smaller than the rear one. This means that the rear oscillating motor can build up a force of 800 Nm at 170 bar, and the front oscillating motor can build up a force of 600 Nm at 180 bar. Both oscillating motors have ventilation screws.

If the oscillating motor turns as a result of external forces (road problems e.g. uneven roads or road holes), it acts as a torsional vibration damper. This torsion means that the fluid is displaced from two chambers. The displaced fluid flows over the lines and the valve block, whose hydraulic resistance creates the damping.

With failsafe blocking (hydraulic blocking), the oscillating motor can only turn as a result of the hydraulic locking occurring in it.

Tandem pump

The tandem pump which is driven by the engine via a ribbed V-belt consists of a radial-piston part for Dynamic Drive and a vane part for the power steering.

When the engine is idling, the pump speed is approx. 750 rpm.

The pump's minimum fluid flow rate is 4.5 l/min at approx. 5 bar and 3.3 l/min at 200 bar. This means that sufficient system dynamics are also guaranteed when the engine is idling.

At a pumping speed of approx. 1165 rpm, the fluid flow rate is limited to 7 l/min.

Dynamic Drive and power steering have a joint fluid reservoir and fluid cooler.

Fluid reservoir

The fluid reservoir is identical on all vehicles, whether they have the Dynamic Drive function or not. The reservoir contains a fluid filter and a fluid level sensor to detect the minimum amount.

Cooler

The cooler ensures a long-term fluid temperature of < 120 °C and a short-term fluid temperature of < 135 °C in all hydromechanical components under all conditions.

Functional description

- Starting characteristics, entire Dynamic Drive system

With the ignition on, an internal control unit function test is first performed.

The electrical function of all the valves is then tested. Short circuits and open circuits in the valve connectors, cables and solenoid coils are detected.

The sensors can be checked for short circuits or open circuits in their cables, connectors or the electronics.

Finally, the hydraulics safety functions are checked before commencing a journey as part of the "Predrive-Check."

A test pressure of < 60 bar is set, between the pump and the failsafe valve only. This allows you to check whether the failsafe valve is actually in the required failsafe position in de-energized mode. The function of the front axle pressure control valve is tested simultaneously. No pressure is formed at the front axle stabilizer bar, the Predrive-Check can therefore not be detected in the vehicle.

The Dynamic Drive function is stopped completely when the vehicle is stationary, all the valves are de-energized. There are also no active moments of inertia when the vehicle is stationary.

If a vehicle which is resting on an incline (one-sided load, vehicle on a curb) therefore, there is no rollback, even though the lateral acceleration sensor gives off a signal.

At a road speed of 5 km/h, the ARS function is started, it becomes fully active at 20 km/h.

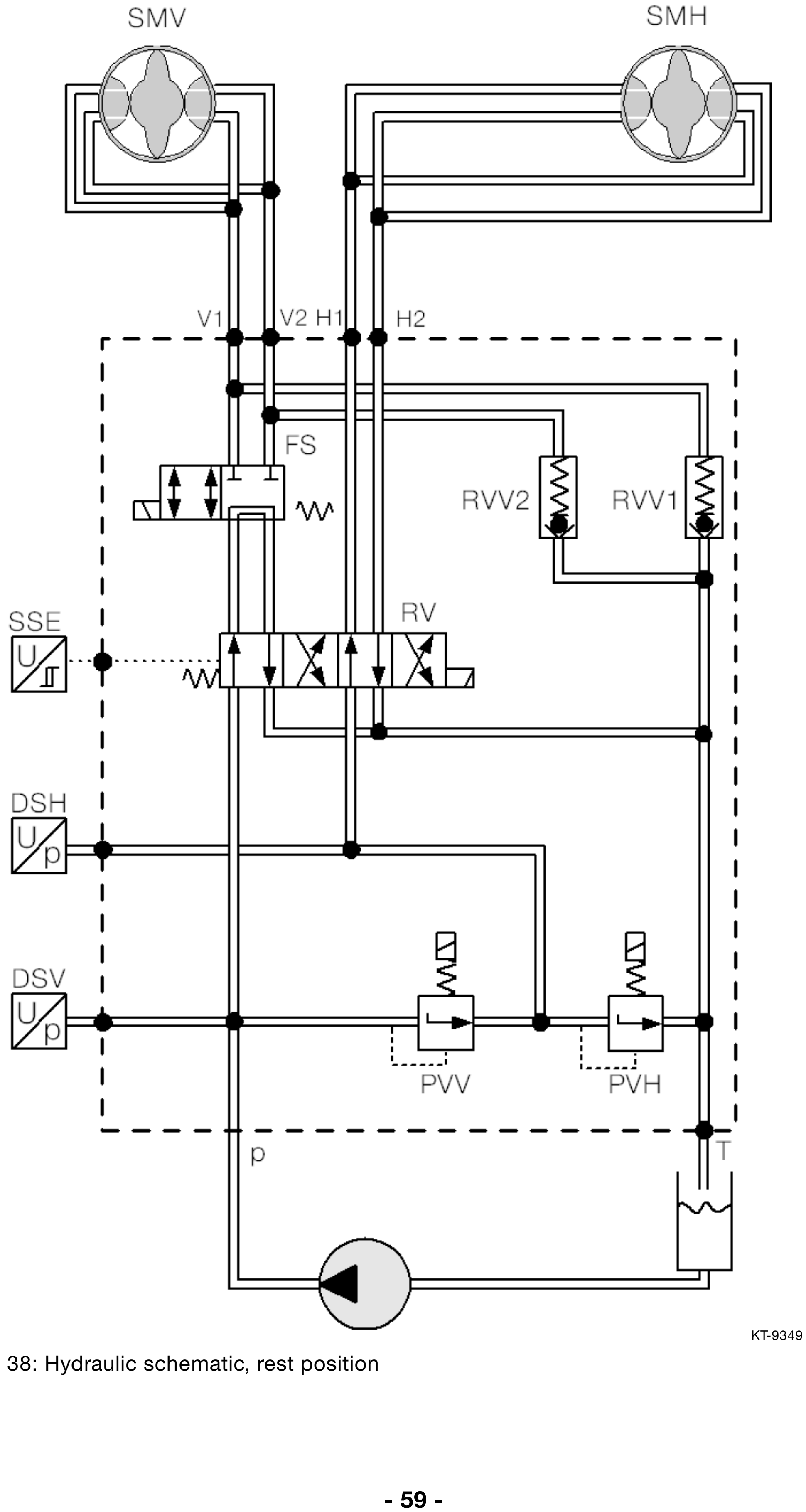

Fig. 38: Hydraulic schematic, rest position

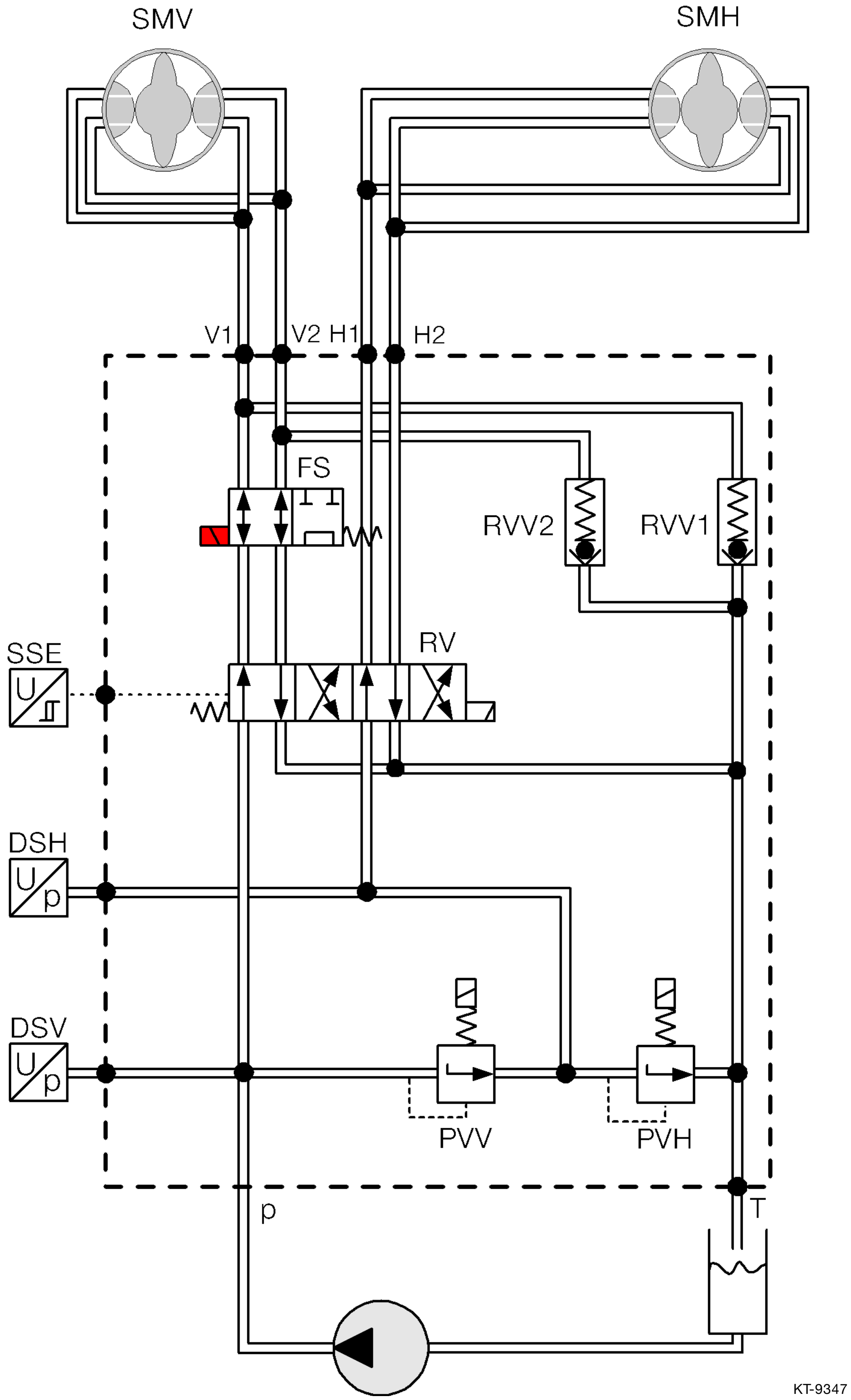

Fig. 39: Hydraulic schematic, normal function, driving speed over 5 km/h, failsafe valve pressurized/cornering left

- Operating conditions

Straight-ahead driving:

If the engine is started, the pump supplies hydraulic fluid to the system, a pressure of 3-5 bar is generated. The pressure acting on one side of the actuator has no effect on the stabilizer bar, which is weakened by the internal leak. The rear axle (PVV) and front axle (PVH) stabilizer bar pressure valves are de-energized and are therefore open. The hydraulic fluid can flow directly back into the reservoir. As long as the vehicle is driving straight ahead, this condition is achievable.

The system reaches its full functional speed at 20 km/h.

Cornering:

When cornering, the signals from the lateral acceleration sensor are conveyed to the Dynamic Drive control unit. The control unit then conveys a pulse width modulated signal (PWMS) to the front and rear axle stabilizer bar pressure valves. The stronger the lateral acceleration, the greater the signal (current). The stronger the valve current, the more often the valves close, and a correspondingly higher pressure is formed in the stabilizer bars. The pressure sensors (DSV, DSH) are used to measure the stabilizer bar pressures and to convey them to the control unit.

In order to reduce the build-up of pressure according to the corner (left-hand or right-hand bend), the directional valve (RV) is actuated by the control unit. A sensor (SSE) detects the directional valve selector position.

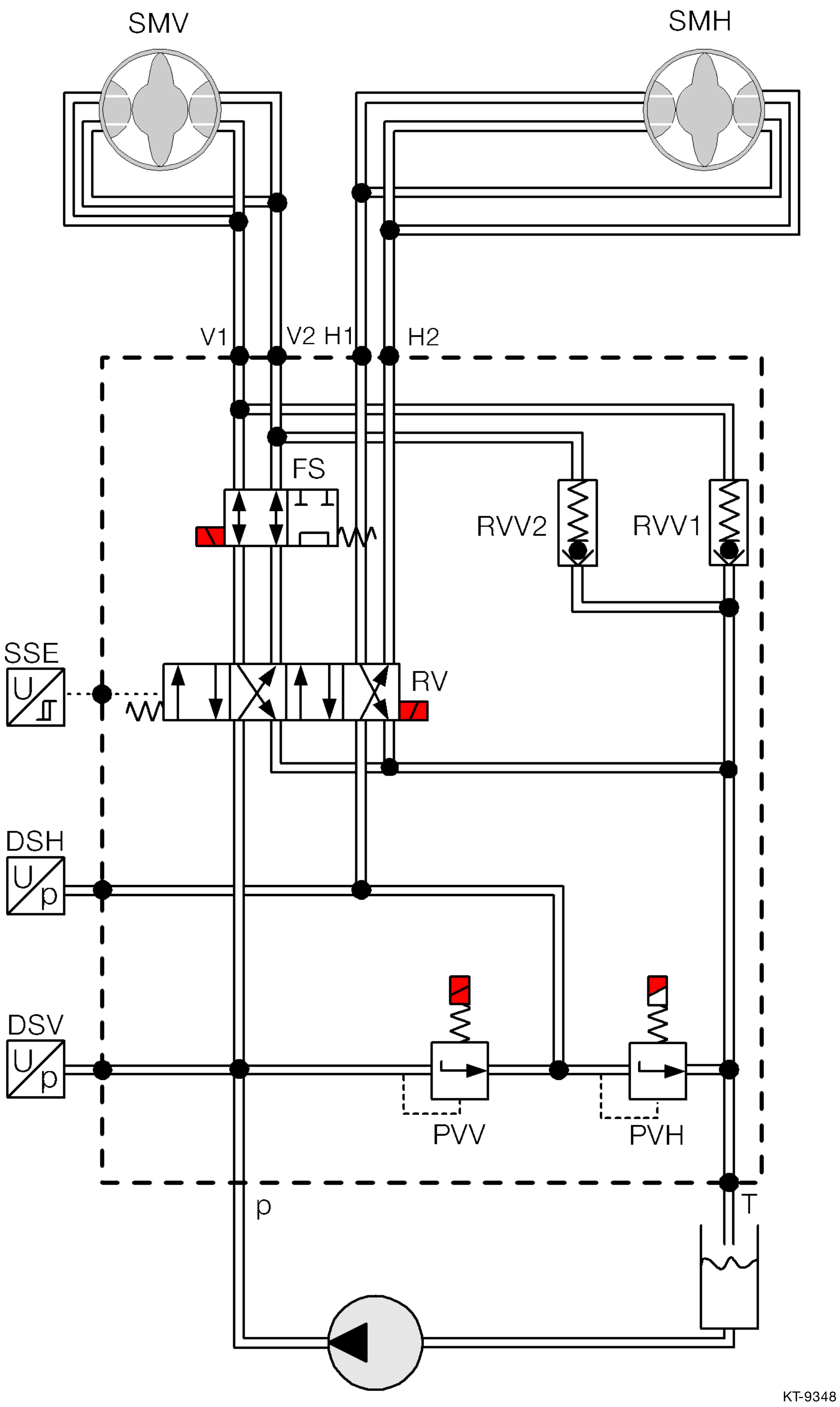

Fig. 40: Hydraulic schematic, cornering right; failsafe valve, directional valve and front-axle pressure valve pressurized, rear-axle pressure valve half pressurized

Restricted function:

The system reverts to failsafe mode if a fault is detected. The control unit documents the fault in the fault code memory and indicates failsafe mode on the instrument cluster. The failsafe mode remains available all the while commissioning has not been completed without faults.

The failsafe situation is shown in the following overview diagram of the hydraulics.

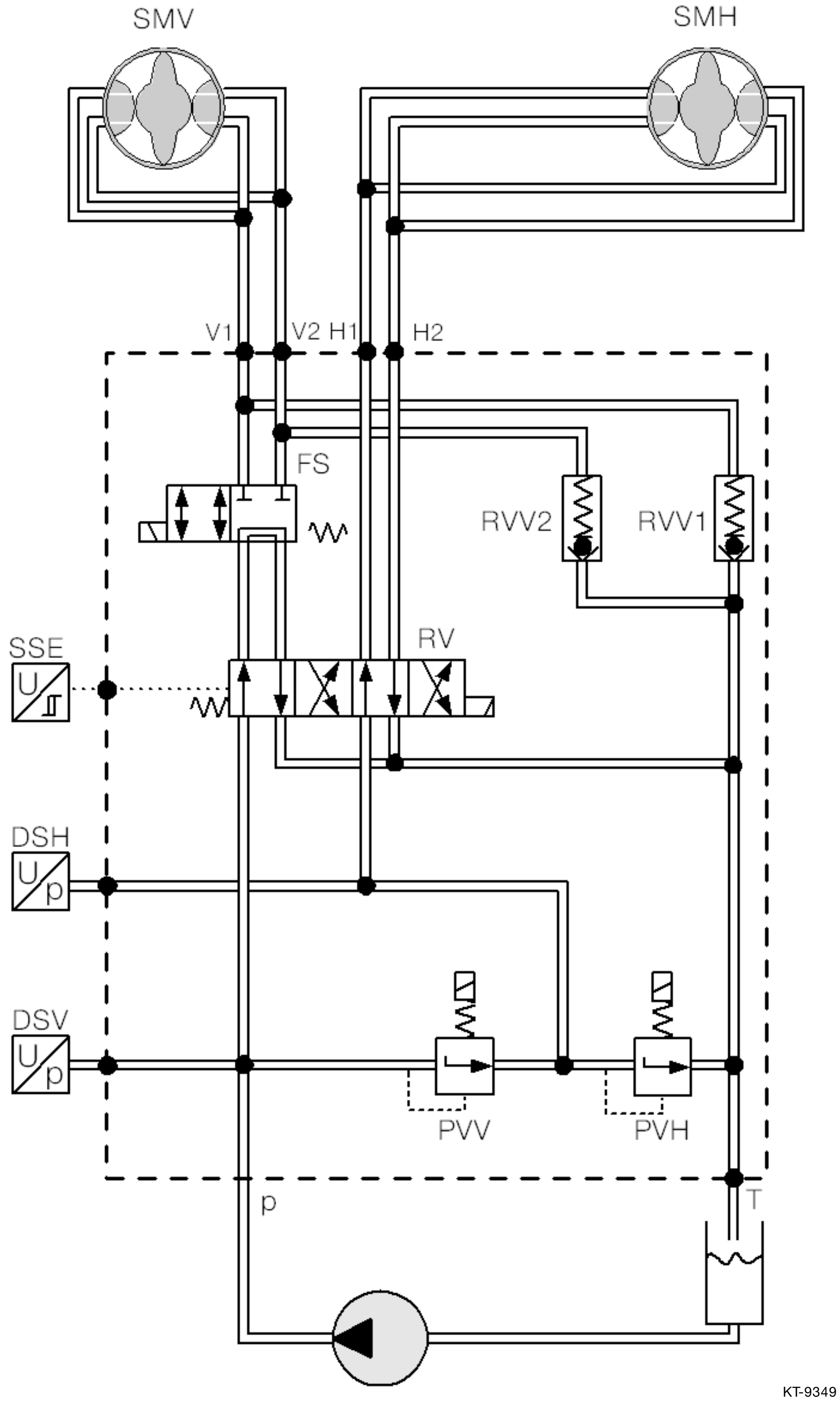

Fig. 41: Hydraulic schematic, failsafe function

In the event of system failure, the failsafe valve (FS) is closed by a spring. The hydraulic fluid in the front stabilizer bar is sealed in, ensuring the stability and understeer effect of a conventional chassis.

The check valves (RVV1, RVV2) make it possible to siphon off hydraulic fluid to prevent the formation of cavities in the oscillating motors.

External leakage:

External leakage is detected by the front or rear pressure sensors and leads to total system failure.

Notes on Service

If the Dynamic Drive fails, DSC can no longer be deactivated or if it is already deactivated it does not switch back on automatically.

The connections for all the hydraulic components are designed in different dimensions and lengths so that they cannot be transposed.

A faulty acoustic transmission in the vehicle interior predominantly occurs through the assembly and cable connections. The cables must not appear on the surface, they must lie correctly in the supports without any slack or tension. They are covered by the underbody covering.

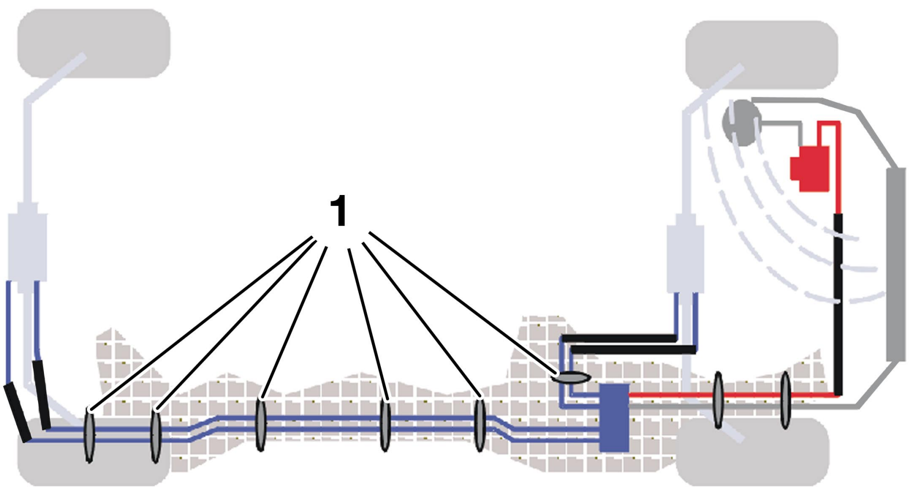

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Fig. 42: Sources of noise

Index	Description
1	Cable fastenings

- Dynamic Drive commissioning

The commissioning procedure must always be carried out once the system has been opened or a part has been replaced. This also applies after the lateral acceleration sensor has been replaced.

The following conditions must be guaranteed for matching the lateral acceleration sensor and the two pressure sensor offset values:

- The vehicle must be stand level on all four wheels
- The vehicle must be unladen
- The engine must be idling
- Rest status (doors closed, persons are not allowed in the vehicle)

No persons may remain within the vicinity of moving chassis parts during the commissioning (both in the factory and the workshop). In addition you must ensure that the basic commissioning conditions (temperature range, constant engine speed etc.) are maintained. The ground clearance must not be limited and the doors must be closed. The arms of the lifting platform may no longer be situated beneath the car.

The commissioning procedure is split into five stages which follow on from each other automatically:

I: direction valve test (from 3 to 3.4 s)	First the direction valve is tested by evaluating the SSE signals.
II: low-pressure test (from 3.4 to 4.3 s)	The failsafe and direction valves are without power during this stage. Then tests are carried out with pressure control valves with and without power on the front and rear axle. The body is then tilted. The sides of the vehicle must be clear.
III: front-axle high-pressure test (from 4.3 to 9.9 s)	Pressure of 180 bar is applied to the front axle oscillating motor. Air in the system, internal leaks and a blocked oscillating motor are detected.
IV: rear-axle high-pressure test (from 9.9 to 15 s)	Pressure of 170 bar is applied to the rear axle oscillating motor. Air in the system, internal leaks and a blocked oscillating motor are detected.
V: pressure-control-valve test (from 15 to 25 s)	The characteristic curves of the front and rear axle are checked. (Target/actual value comparison.) Faulty pressure control valves are detected.

- Dynamic Drive ventilation

A ventilation routine must be carried out using the diagnostics tester if the Dynamic Drive system was opened hydraulically. This ventilates the system at the oscillating motor ventilation screws.