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Lateral Dynamics Systems

Model: E70

Production: From Start of Production

OBJECTIVES

After completion of this module you will be able to:

- Describe changes to the Active Steering System
- Understand Servotronic operation in the E70

Lateral Dynamics

Nowadays, dynamic driving systems are subdivided according to their mode of operation within the three axis co-ordinates and classified according to function.

In the E70, there are two systems which count as lateral dynamics systems. Lateral dynamics systems (effective direction mainly along the y or lateral axis):

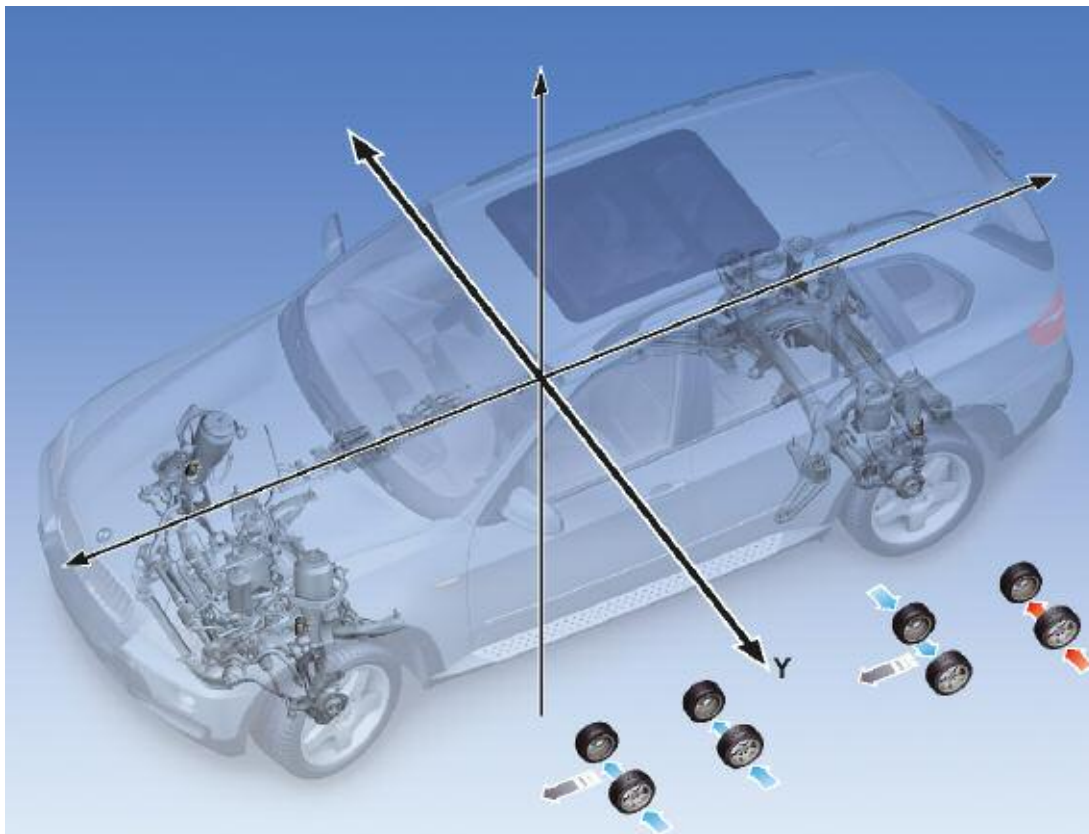
- Servotronic - Speed-dependent hydraulic steering torque assistance
- AS - Active Steering (previously AFS, Active Front Steering)

The E70 is the first all-wheel-drive vehicle to be offered with Active Steering (AS). Servotronic is only offered in conjunction with the Active Steering.

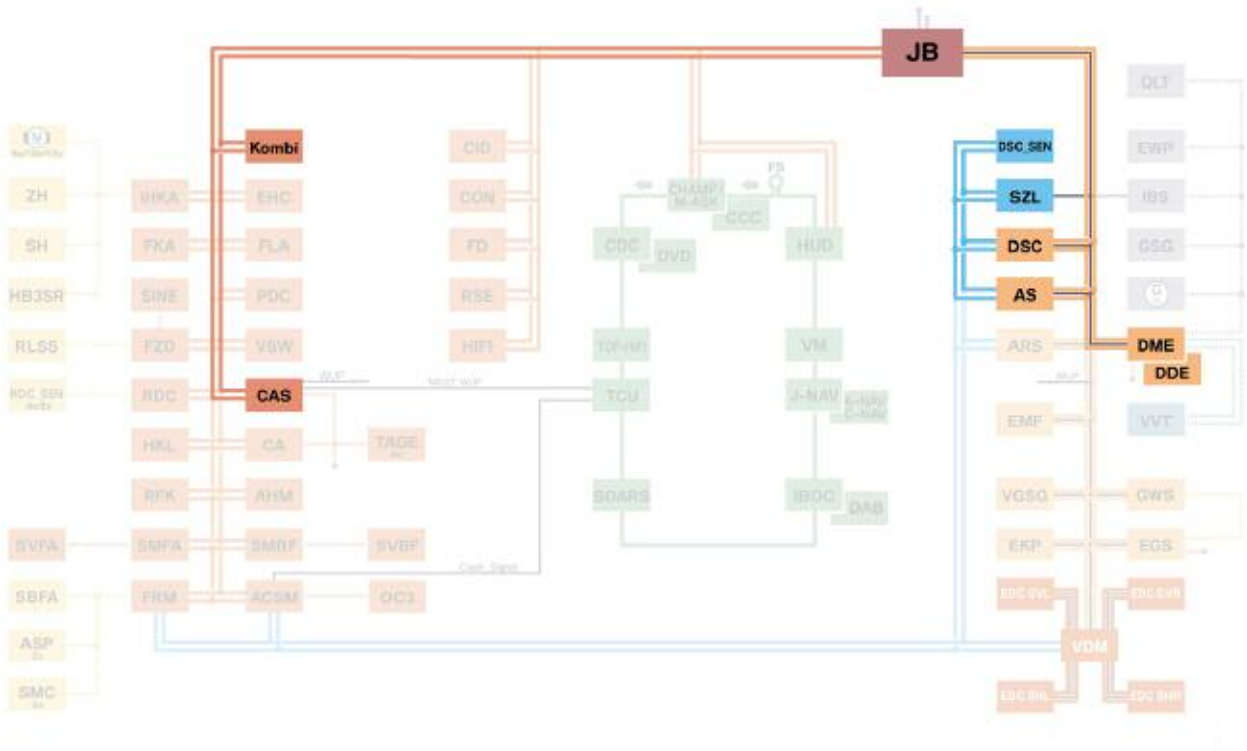
Active Steering (AS)

Active Steering was initially offered in the E60 (5 Series). Since then, a large proportion of BMWs in the 3 and 6 Series now have Active Steering. It is only the X models and other all-wheel-drive vehicles that have not yet been provided with this for reasons of space.

This innovative steering system is now being offered in an all-wheel-drive vehicle for the first time at BMW, namely in the E70.

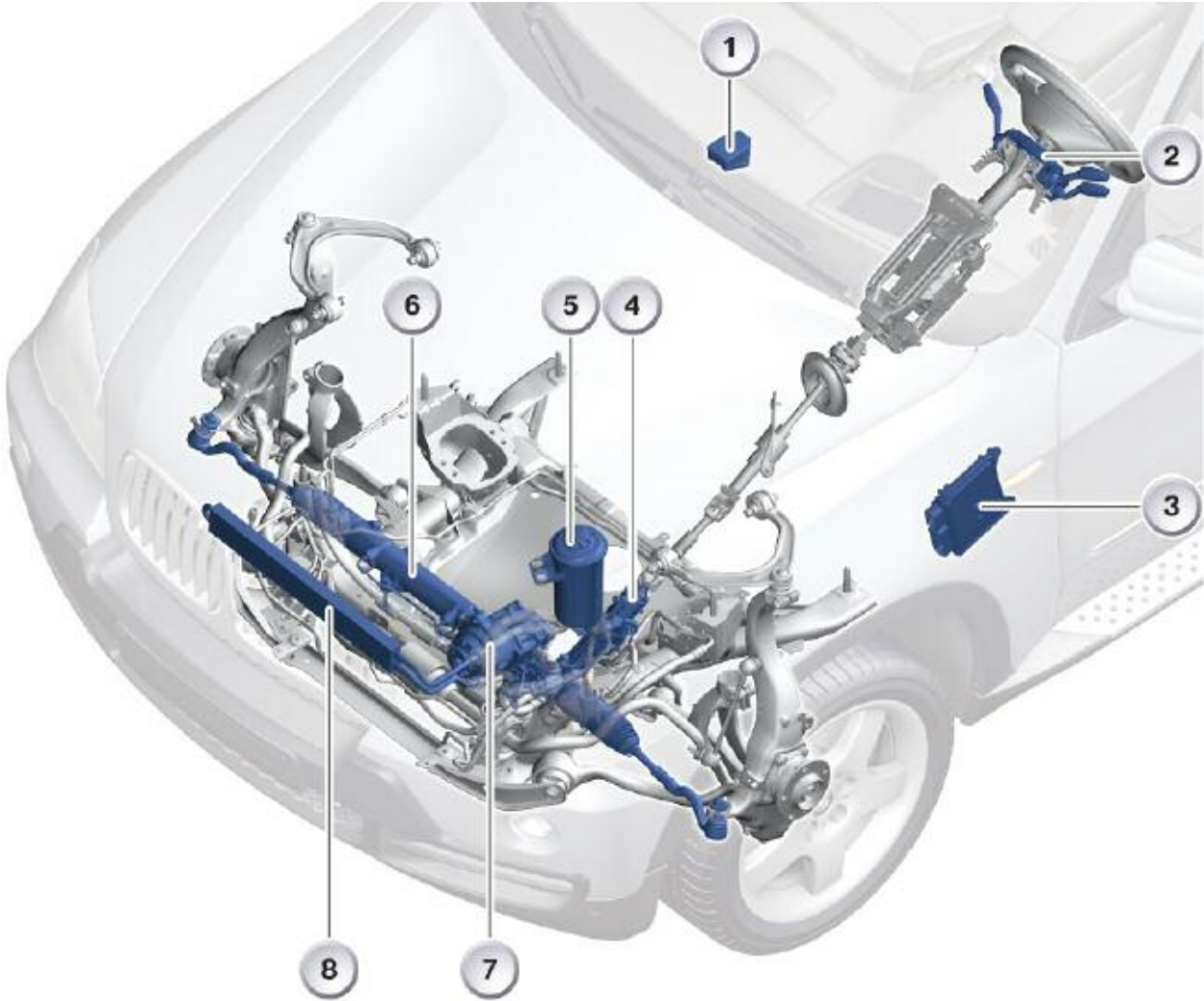


AS Bus Overview



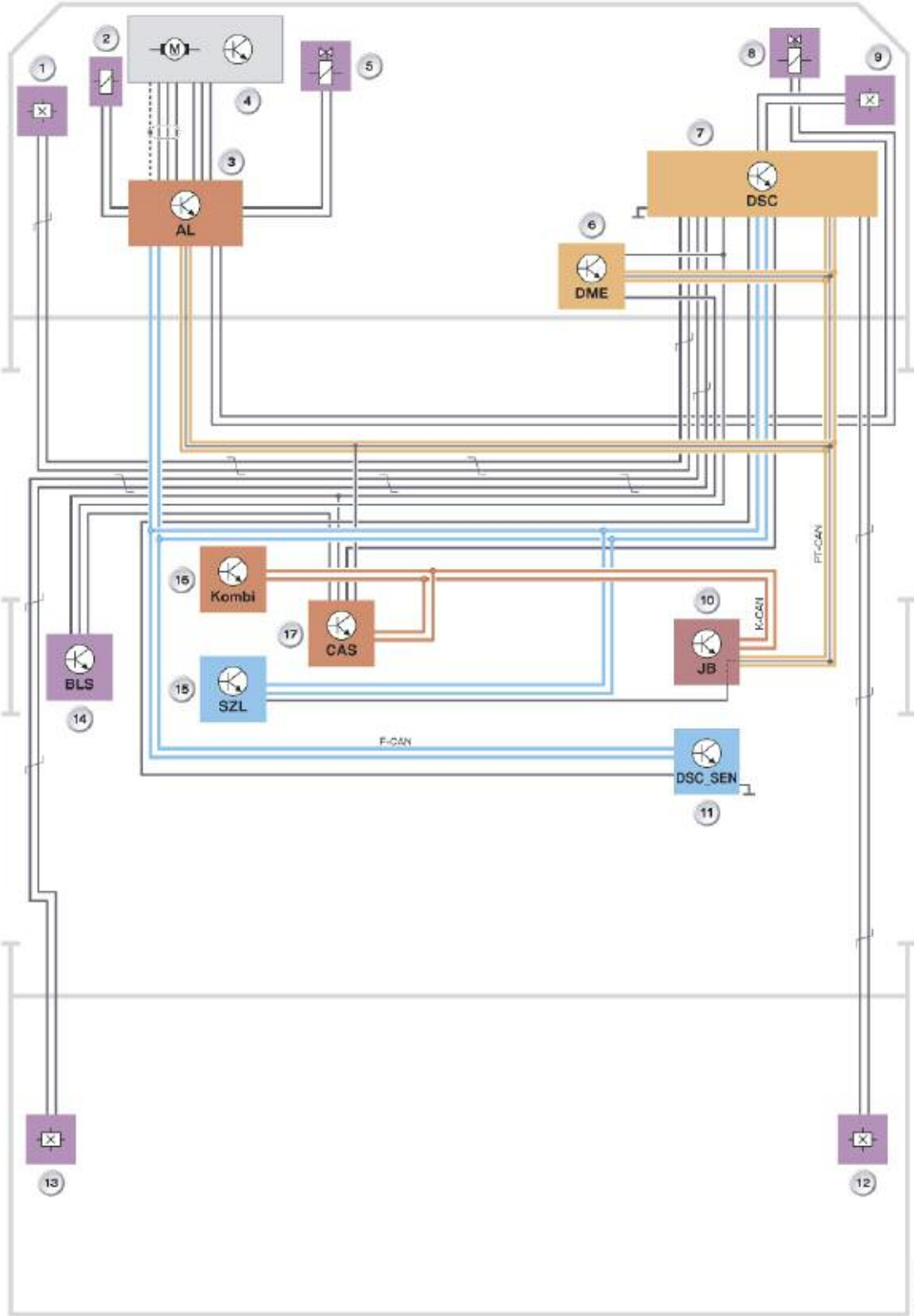
Index	Explanation	Index	Explanation
CAS	Car Access System	SZL	Steering Column Switch Cluster
KOMBI	Instrument Cluster	DSC	Dynamic Stability Control
JB	Junction Box	AS	Active Steering
DSC_SEN	DSC Sensor	DME	Digital Motor Electronics

AS System Components E70



Index	Explanation	Index	Explanation
1	DSC Sensor	5	Fluid reservoir
2	Steering Column Switch Cluster	6	Steering gear
3	AS control unit	7	Hydraulic pump
4	AS actuating unit	8	Power steering cooler

AS System Overview



Legend for AS System Overview

Index	Explanation	Index	Explanation
1	Wheel speed sensor, front left	9	Wheel speed sensor, front right
2	Solenoid lock	10	Junction box
3	AS control unit	11	DSC sensor
4	AS actuating unit	12	Wheel speed sensor, rear left
5	EVV (Electronically Controlled Bypass Valve)	13	Wheel speed sensor, rear right
6	Digital Motor Electronics	14	Brake light switch
7	Dynamic Stability Control	15	Steering column switch cluster
8	Servotronic valve	16	Instrument cluster

Active Steering Features

Previous Active Steering Systems at BMW

The dynamic steering system known as Active Steering was used for the first time in the world by BMW in the E60. The "variable steering-transmission ratio" is adjusted to the optimum ratio for all road speeds. During this process and depending on the road speed, an electric motor uses a worm drive to mesh with a special planetary gearbox with over-ride function and gear into the steering chain.

This allows the steering system to generate a greater or reduced steering angle at the front wheels depending on the driving situation. Since it was implemented in the E90, Active Steering is also able to intervene in critical dynamic driving situations (braking with different friction coefficients on the left and right) by correcting the steering angle if the vehicle starts to become unstable using so-called yaw moment compensation.

This stabilizes the vehicle more quickly than the driver could. Active Steering thus reduces intervention in the lower DSC control range and thereby provides optimum:

- Agility
- Comfort
- Active safety

■ Increased Agility

Due to the direct transmission ratio, the vehicle is perceived as having a greater agility and handling performance up into the mid driving speed range (approximately 100 km/h).

The driver also has far greater control when swerving, for example - this combined with considerably enhanced steering precision and reduced steering effort. Direct contact with the road via the steering wheel is maintained throughout.

■ Increased Convenience

Some previous steering systems have required more than 3 full steering-wheel turns to achieve a full wheel lock from the far left over to far right. Active Steering reduces this at low speeds to less than 2 steering-wheel turns from lock to lock.

The benefit: less steering effort is required when turning in city traffic or maneuvering in narrow parking spaces. On twisting roads in mountainous regions, for example, the reduced steering wheel angle also ensures that hands always remain in the optimum position on the steering wheel, which means that crossing of hands, or even arms in some cases, is no longer necessary. The multifunction buttons on the steering wheel or the gearshift paddles for the sequential manual transmission (SMG) therefore always remain conveniently within reach during every road situation.

■ Increased Active Safety

At higher speeds, the transmission ratio of the Active Steering is more indirect. This means that a rotational movement of the steering wheel generates a smaller steering angle than at lower speeds.

This results in more comfortable directional stability. The effects of "snatching" the steering wheel, e.g. in a frightening situation, are considerably lessened by this. An assisting intervention by the Active Steering counteracts yawing forces and rotational movements of the vehicle around its vertical axis when they first occur by correcting the steering angle of the wheel. Yawing forces (without active brake intervention) occur when the vehicle changes lane or swerves or when the load changes under cornering.

Active Steering electronically controls the stabilization function at all speeds without the driver being aware of this. It also assists the driver by actively counter-steering when there are different friction coefficients under braking.

Active Steering System Changes (as compared to E6X/E9X)

For the first time, the customer can choose between standard power steering and the innovative Active Steering system in a BMW all-wheel-drive vehicle.

Details in which the Active Steering in the E70 differs from those which are familiar in other series:

- No physical cumulative steering-angle sensor
- Virtual cumulative steering angle provides the same information as cumulative steering-angle sensor
- Virtual cumulative steering angle describes the exact position of the rack and pinion
- Virtual cumulative steering angle as reference for adjustment of track alignment (virtual steering angle "0" = rack and pinion exactly centered)
- Virtual cumulative steering angle is calculated from the driver steering angle and motor position angle
- If the motor position angle is lost or discarded, the position of the rack and pinion is unknown and must be relearned, i.e. initialize the Active Steering.
- Instead of yaw moment compensation, the E70 has yaw-rate control plus (GRR+)
- Initialization has changed
- There is no longer an ECO valve on the hydraulic pipe. It has been replaced by a new valve: Electronically Controlled Bypass Valve (EVV)
- The wheel alignment check with KDS has a new feature that must be taken into consideration.

Special Functions

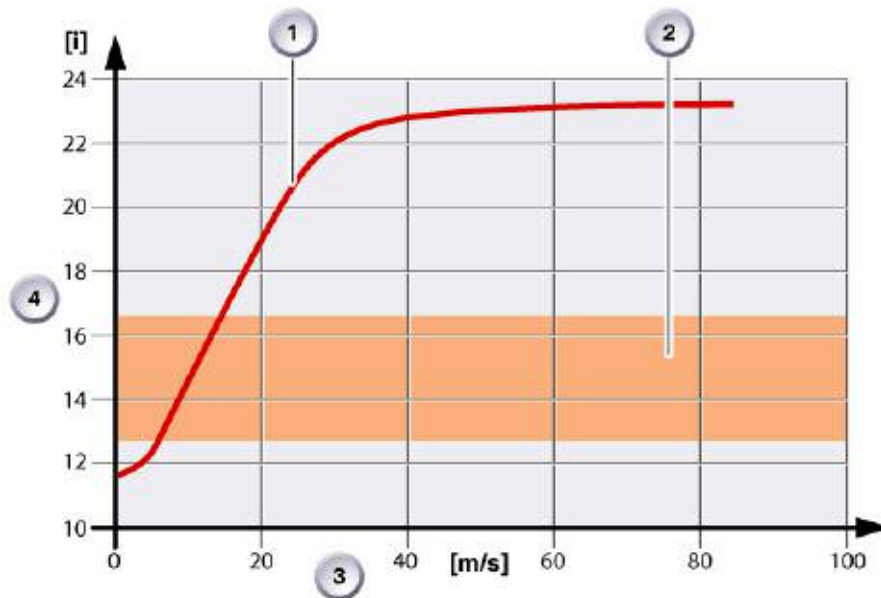
Active Steering Transmission Ratio

The Active Steering varies the steering-gear ratio as a function of the road speed and the steering angle requested by the driver. The steering is designed to be indirect at high speeds. At lower speeds, the steering is more direct.

The ease of handling the vehicle at low speeds or when parking is greatly increased by the Active Steering actuating unit. It is no longer necessary to grapple with the steering wheel.

Just two turns of the steering wheel when the vehicle is stationary are enough to move the steering wheel from one lock to the other. At high road speeds (> 120 km/h), the Active Steering allows a more indirect transmission ratio than in conventional steering systems. The electric motor operates against the steering wheel angle at high speeds.

Together with the elevated steering torque level (Servotronic), this has the effect of considerably improving the vehicle's directional stability.



Index	Explanation	Index	Explanation
1	Active steering design	3	Road speed
2	Conventional design	4	Ratio

Yaw Rate Control

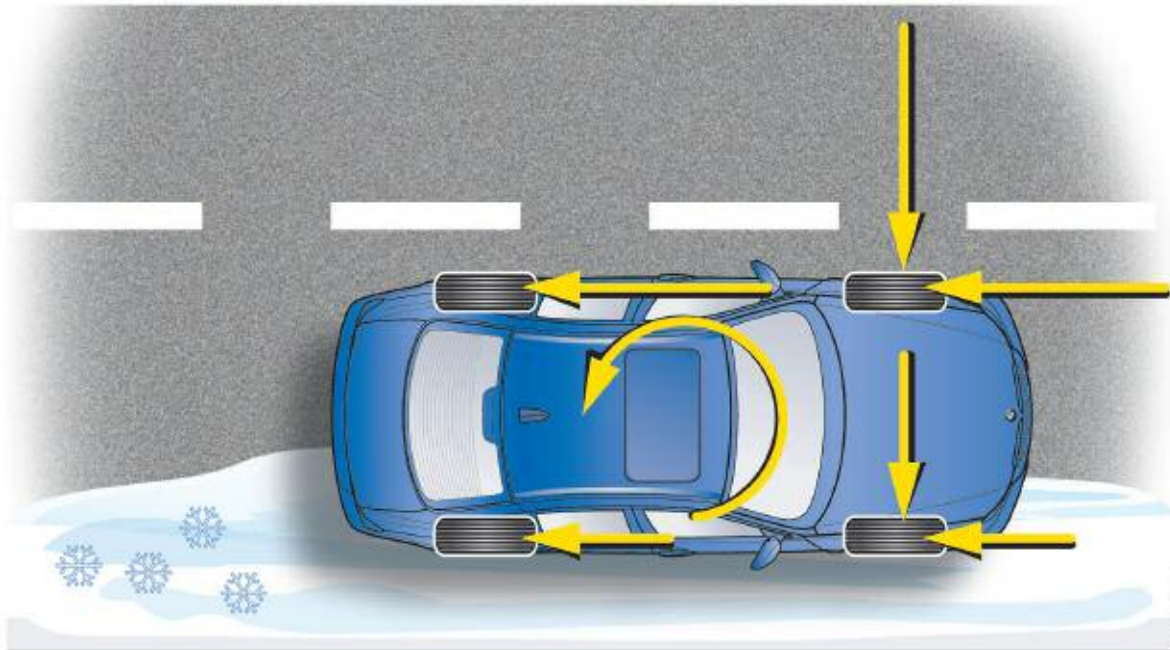
If the vehicle is threatening to oversteer, the Active Steering stabilizes the vehicle with a slight correction to the angle of attack of the front wheels.

Example: The driver initiates a rapid lane change. This change in direction causes a certain tendency to oversteer in the vehicle.

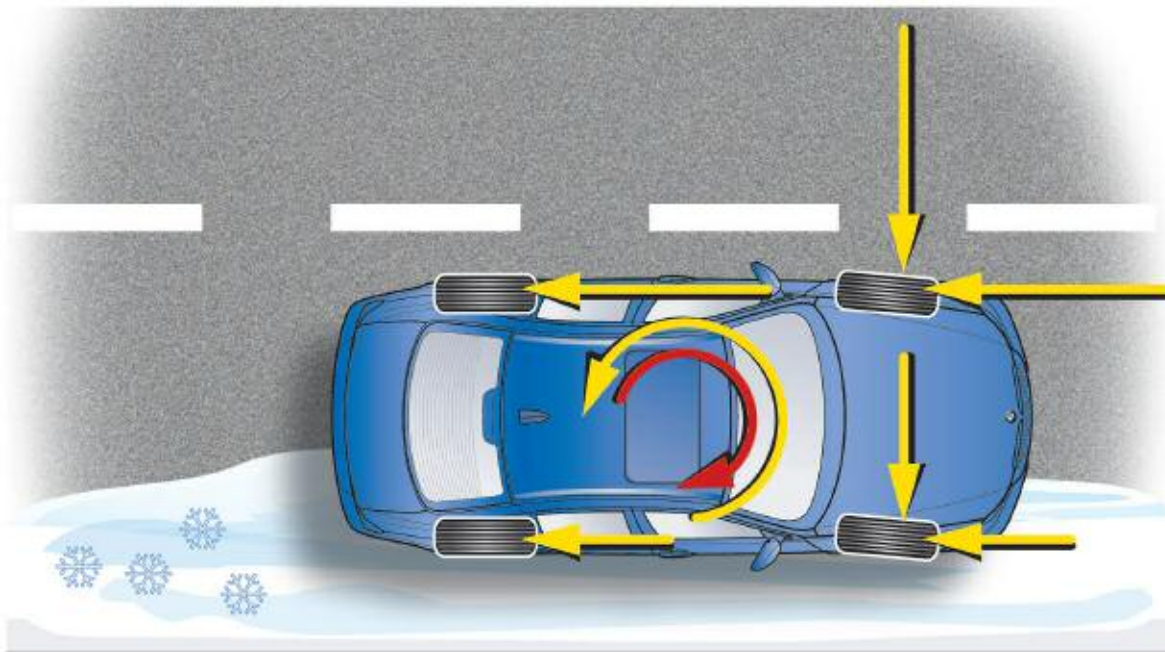
As the control thresholds for a DSC stabilization intervention are not yet reached in this case, the angle of attack of the wheels is slightly adjusted (maximum $\pm 4^\circ$) by the Active Steering. The vehicle is stabilized by this active damping, but the driver does not feel it through the steering wheel.

Yaw-rate Control Plus (GRR+)

The "yaw-rate control plus" function assists the driver when he is braking on roads with varying friction coefficients, in a similar way to the yaw moment compensation. This function represents a significant safety feature.



In the case of braking on different surface friction coefficients (asphalt/ice or snow), a moment builds up about the z or vertical axis (yaw moment) rendering the vehicle unstable. In this special case, the Active Steering control unit calculates the steering angle (maximum $\pm 4^\circ$) required for the front wheels to keep the vehicle stable using the actual yaw rate and the longitudinal and lateral acceleration.



This active counter-steering creates counter-torque about the z or vertical axis (red arrow) which compensates for the earlier acting yawing force (yellow arrow).

In this way, the vehicle is stabilized by clever interaction between the DSC braking and the AS function, resulting in a new safety aspect, unique in this class.

■ Special Feature

This function shortens the braking distance because the yaw-rate control plus allows higher braking pressure on the high friction coefficient side.

■ Difference to Yaw Moment Compensation:

With yaw moment compensation, an important calculation principle for automatic early counter-steering was the difference between the front wheel braking pressures that were detected by the DSC and based on which the DSC calculated the angle for attack of the front wheels and transmitted to the AS control unit.

This shared functionality of the DSC and AS control unit is now fully integrated into the AS control unit with yaw-rate control plus and, due to the high communication rate, precise interaction between the two units has now been achieved.

Power Steering Assistance

Servotronic

Power steering assistance is implemented by conventional hydraulic rack and pinion power steering.

The magnitude and direction of the auxiliary hydraulic forces acting on the rack depend on the rotational angle of the torsion rod. The torsion rod is located between the steering shaft and pinion.

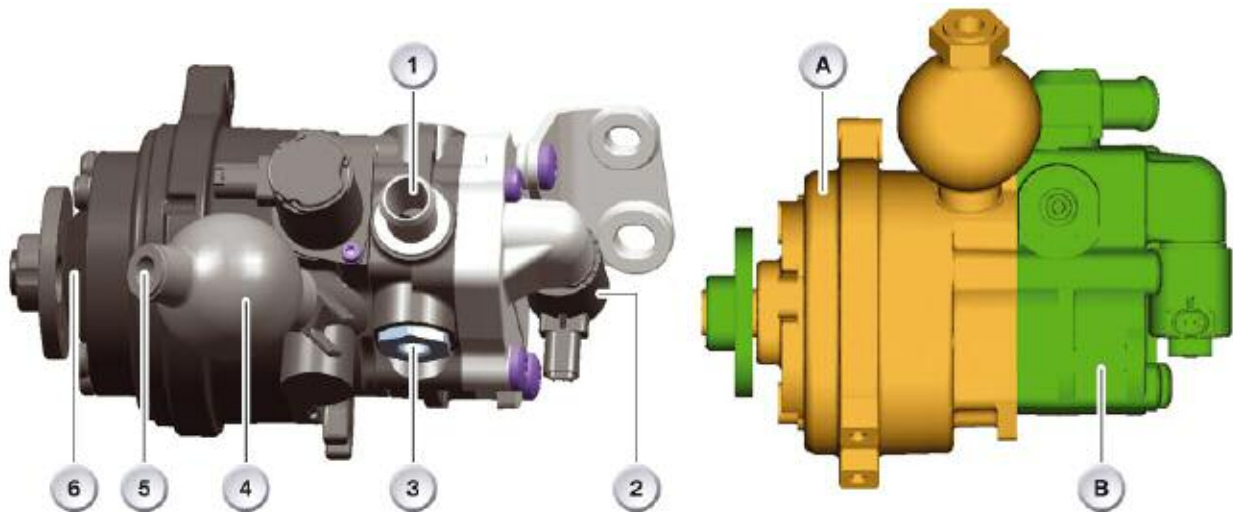
Servotronic, the speed-dependent power steering assistance, is only available as an option with Active Steering.

The output stage for Servotronic and its software are located within the AS control unit. The output stage for actuating the EVV is also within the Active Steering control unit.

Tandem Pump

The hydraulic pumps fitted in the E70 were developed according to a modular design principle. Depending on the engine and equipment specification, an appropriate hydraulic pump is located in the same installation space on the engine.

If only the optional Active Steering is fitted, there is a mono-pump that consists only of a vane section.



Index	Explanation	Index	Explanation
A	Radial piston section of pump	3	Steering pressure connection
B	Steering pressure connection	4	Accumulator
1	Suction connection	5	ARS Pressure connection
2	Proportional valve (EVV)	6	Input flange

System Safety

Unintentional "self steering" by the system would be a safety critical feature of Active Steering and is prevented by the following measures:

The safe system status (fail-safe) is when the actuator motor of the actuating unit is without power. Regardless of whether the system enters fail-safe mode as a result of a loss of power or an intentional system shutdown, it must be ensured that there is no possibility of the actuating unit intervening in the steering.

The actuating unit is arrested by a lock that engages in the worm gear of the actuating unit. The lock is pre-tensioned by a spring and held against this pretension by the power supply. The actuating unit is locked by an interruption in the power supply.

The arrested superimposed gear unit ensures that it is still possible for steering wheel movements input by the driver to be transferred along the steering column.

The steering then responds in the same way as conventional steering. The purely mechanical transmission between the steering wheel and the front wheels is retained.

The electric motor of the Active Steering actuating unit is connected to 3 phases. A short circuit to earth will therefore prevent the electric motor from completing a full turn, the maximum possible being only 120° ($360^\circ : 3$).

The Servotronic valve switches under no electrical load to the fast driving characteristic curve. The power steering assistance is reduced accordingly. When the EVV is de-energized, the volumetric flow is 7 l/min.

Steerability is fully guaranteed in this situation. Fault statuses in the system are indicated to the driver via an indicator lamp system and Check Control messages in the instrument cluster.

The Check Control message may read:

"Active Steering failure! Steer with care."

The following or similar message will appear in the Control Display:

"Steering behavior altered! Possible to continue the journey. Steering wheel may be at an angle. Have the problem checked by the nearest BMW Service."



Activation Conditions

The activation conditions for the Active Steering system are terminal 15 ON and a running engine.

After the engine is started, the system synchronizes the position of the steering wheel and the wheel lock. This ensures that steering wheel movements are detected when the system is deactivated (passive).

The steering wheel position and the wheel lock always match.

AS Control Unit

The AS control unit (1) is located under the wheel arch trim on the A-pillar at the front left of the vehicle.



The AS control unit is integrated into the vehicle electrical system by the PT-CAN and the F-CAN. The AS control unit calculates the control signals for the AS actuating unit from various input signals.

Every time the ignition is switched on, the system starts the pre-drive check. This includes initializing the AS control unit. The AS actuating unit is not activated during the initialization. The sensor signals are checked and, if necessary, calibrated. If errors are detected, either the "Error" fault status is activated immediately or, if the "Fail" status is present, the yaw-rate control (GRR+) is deactivated, depending on the positioning.

The actuating unit cannot be operated when the "Error" fault status is active. This is not the case if "Fail" is active. If initialization is successful, the "Drive" status is activated.

The volumetric flow required for the power steering assistance is calculated in the AS control unit from the following input variables:

- Steering angle speed
- Road speed
- Calculated cumulative angle
- Engine speed.

The AS control unit is directly connected to the EVV in the hydraulic pump and adjusts the flow according to the required volumetric flow using a PWM signal.

The AS control unit contains 2 processors that are asynchronously clocked and ensure a specific system reliability. It is connected to the AS actuating unit by conventional electrical lines.

The function algorithms for calculating the target values for controlling the AS actuating unit are stored in the AS control unit. The electronics in the AS control unit supply current to the electric motor of the AS actuating unit via three alternating phases.

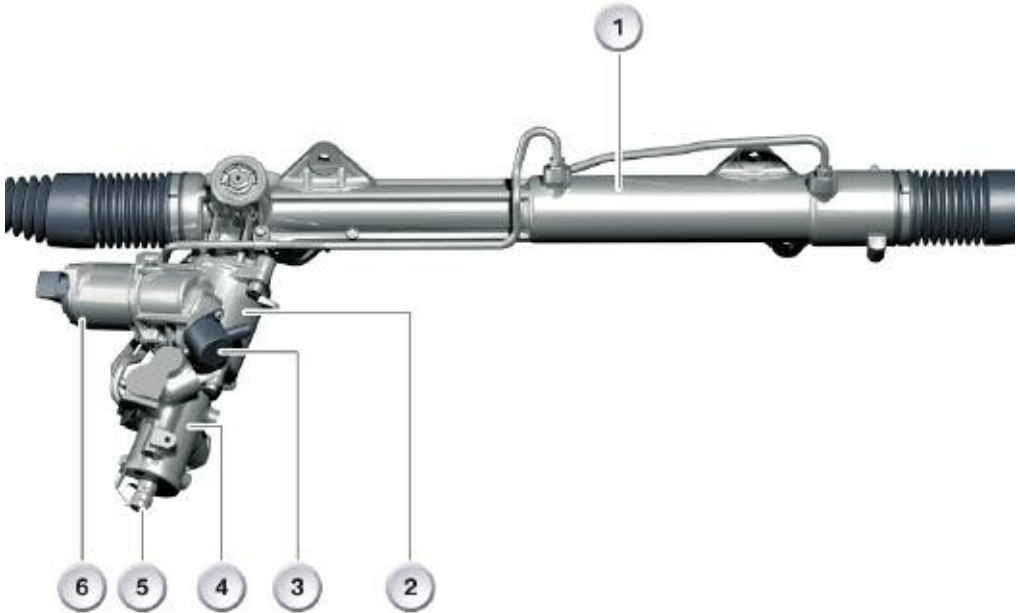
The following function groups are available to the AS control unit:

- Variable steering gear ratio
- Yaw-rate control (GRR+)
- Servotronic
- Electronically Controlled Bypass Valve (EVV)
- Safety monitoring
- Sensor plausibility monitoring
- Actuator monitoring
- Vehicle authentication
- Pre-drive check
- Commissioning
- On board diagnostics
- Fault code memory
- Coding
- Programming

The AS control unit uses various input signals to calculate the signals for controlling the AS actuating unit.

AS Actuating Unit

The AS actuating unit is located on the steering gear and is integrated into the split steering column between the Servotronic valve and the rack and pinion.



Index	Explanation	Index	Explanation
1	Rack and pinion steering unit	4	Servotronic valve
2	Planetary gear train housing	5	Steering spindle
3	Solenoid lock	6	Electric motor

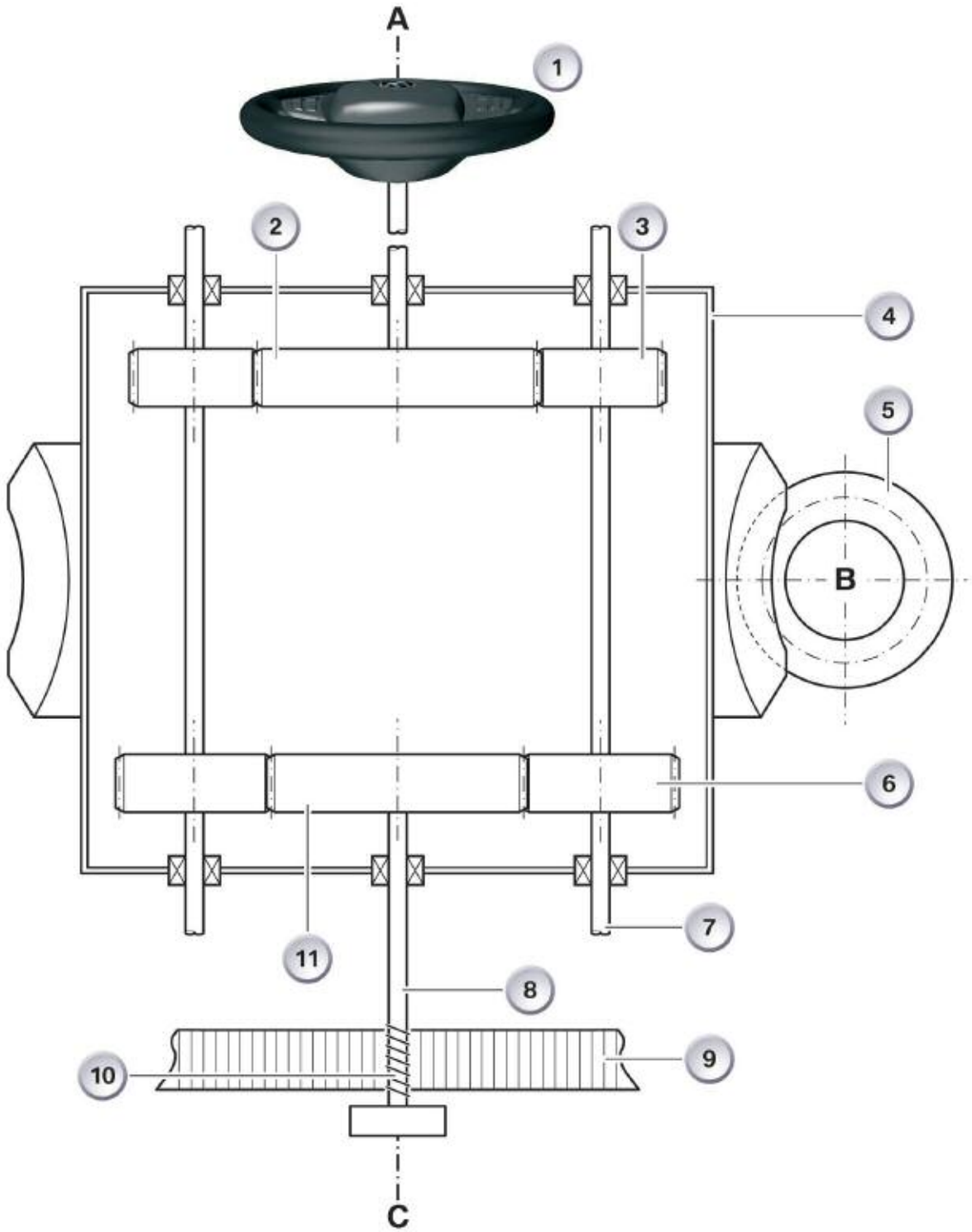
The AS actuating unit consists of a brushless synchronous DC electric motor and the planetary gearbox with override function (dual stage planetary gearbox).

The core component of the AS actuating unit is a planetary gearbox with two input shafts and one output shaft. The input shaft is connected to the lower steering spindle as with standard Servotronic. The steering valve is located in between. The second input shaft is formed by the electric motor, which is driven by a self-regulating reduction worm drive.

The self-regulating feature of the worm drive and the lock ensure that the worm is only turned by the electric motor. The worm drive drives a worm wheel that transfers the wheel steering angle input by the driver at the steering wheel.

The brushless synchronous DC electric motor is permanently connected to the worm drive and engages with the worm wheel without any play. The direction of rotation, the speed and the duration of the electric motor movement are monitored by a motor-position sensor attached to the AS actuating unit in order to calculate the steering angle redundantly.

AS Actuating Unit Overview



Legend for AS Actuating Unit Overview

Index	Explanation	Index	Explanation
1	Steering wheel	8	Lower steering spindle
2	Sun gear input	9	Rack
3	Planetary gear	10	Pinion
4	Planetary cage with worm wheel (ring gear)	11	Sun gear output
5	Electric motor worm wheel	A	Input shaft I
6	Planetary gear	B	Input shaft II
7	Planetary gear carrier shaft	C	Output shaft

The overriding drive or planetary gear train basically consists of the following main components: a planet cage with worm wheel [4], the three planetary gear carrier shafts [7] with two planetary gear carriers [3, 6] on each, the sun gear input [2] and the sun gear output [11].

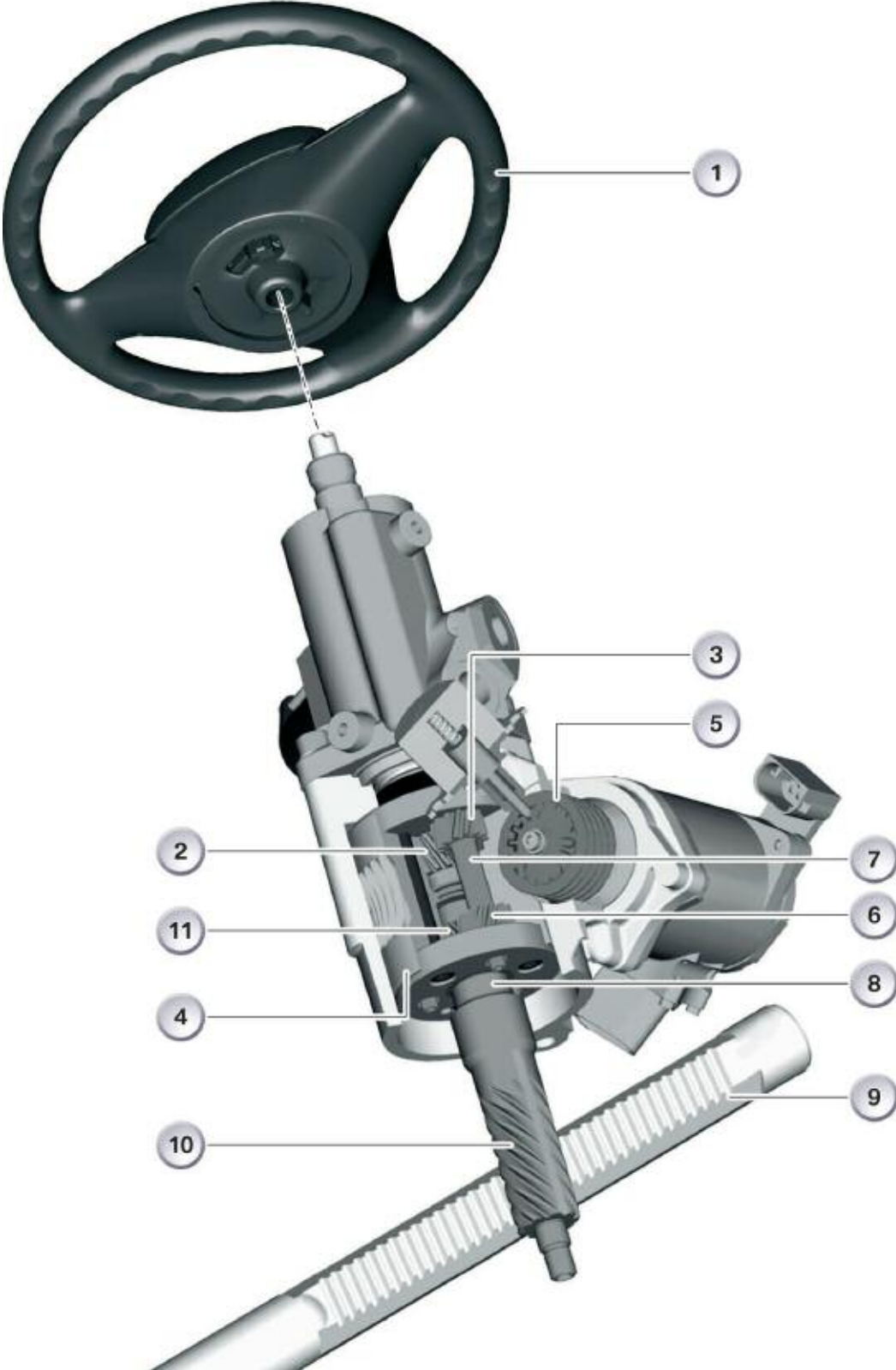
The planetary gear carriers form the mechanical connection between the sun gear input (input shaft I) and the sun gear output (output shaft). If the electric motor worm wheel [5] is stationary (input shaft II), the planet cage with worm wheel [4] (ring gear) is also fixed in position and the power is directed through the mechanical connection, both from the steering wheel to the rack and pinion and in the opposite direction.

As the two planetary gears on a shaft are of different sizes, there is a gear ratio of 1:0.76 from the steering wheel to the rack and pinion. As soon as the electric motor worm gear turns in one of the two directions, the planet cage and the planetary gears also turn.

This means that, if the rotation is in one direction, there is positive overriding of input shafts I and II and, if rotation is in the other direction and the shafts are counter rotating, there is a negative overriding.

The sum of the rotational movements between the steering wheel and the rack and pinion influences the angle of attack of the front wheels. In one case, the angle of attack is thus greater and, in the other case, it is smaller than the angle input at the steering wheel.

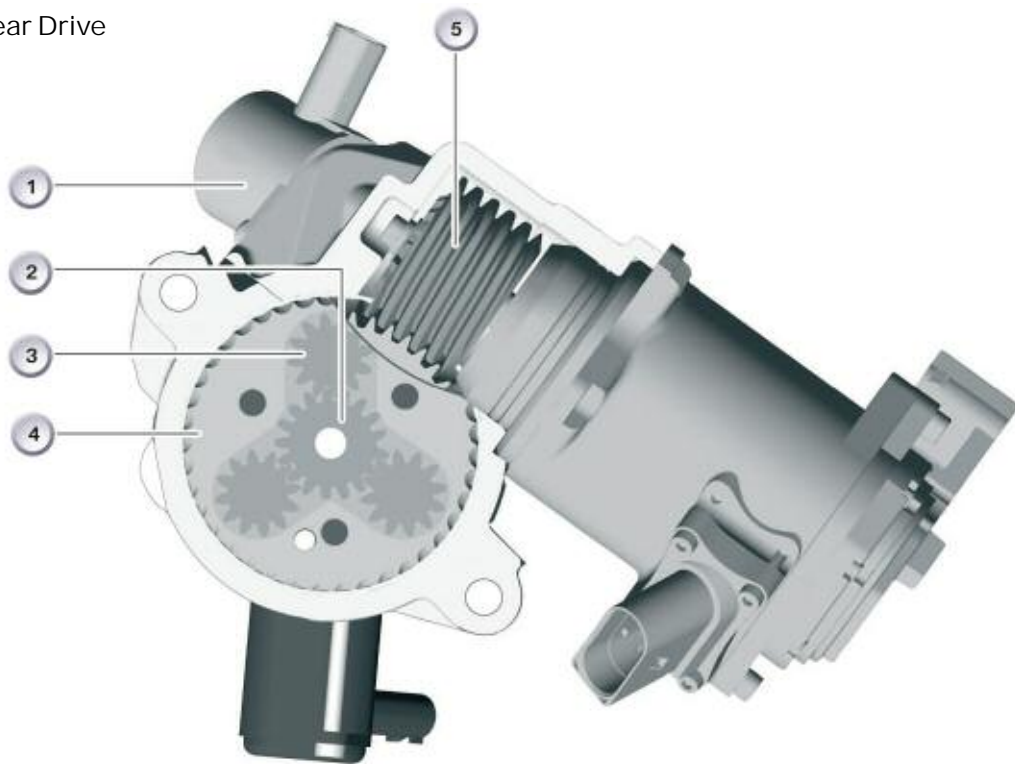
AS Actuating Unit Cut-away



Legend for AS Actuating Unit Cut-away

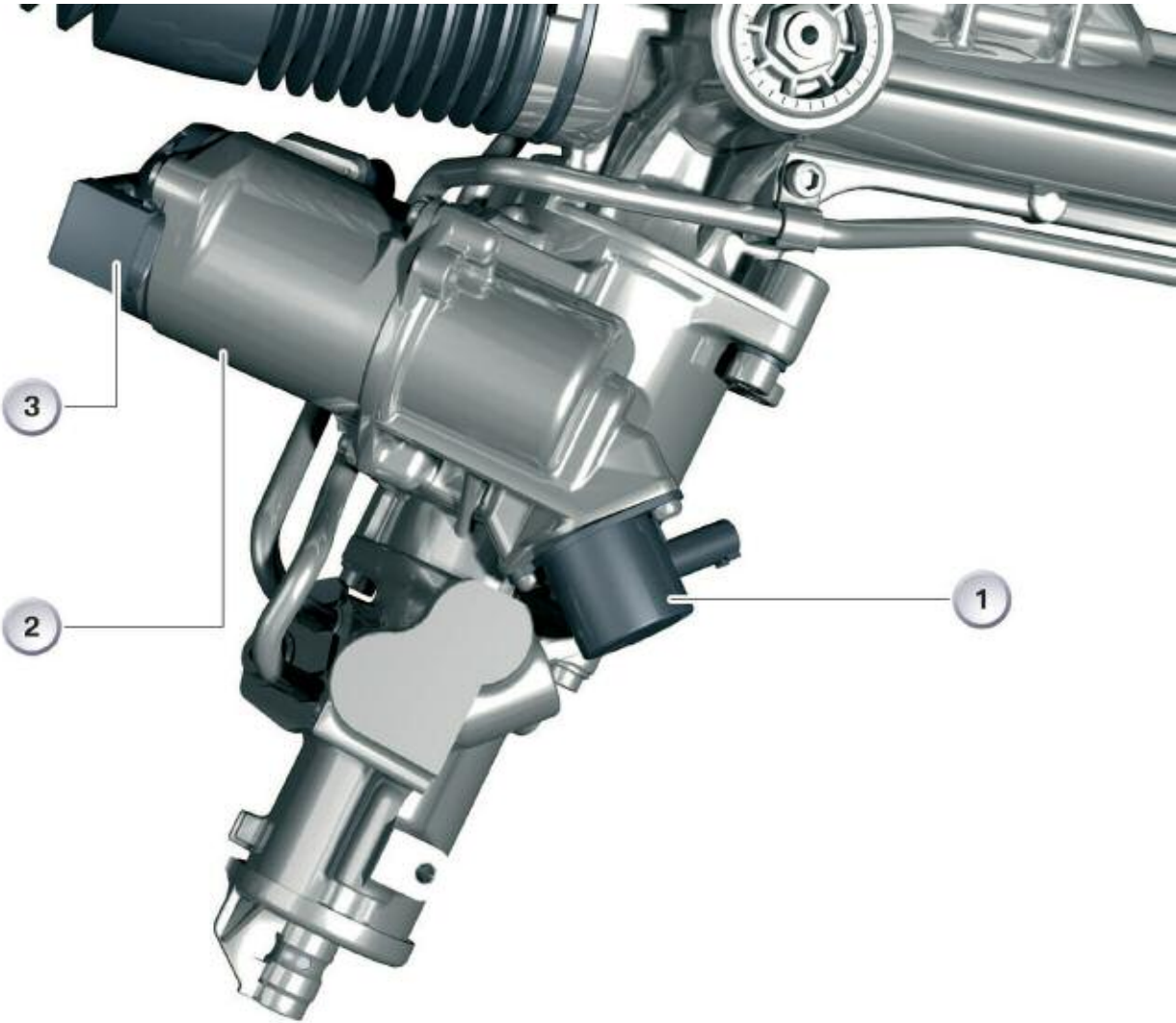
Index	Explanation	Index	Explanation
1	Steering wheel	7	Planetary gear shaft
2	Sun gear input	8	Lower steering spindle
3	Planetary gear	9	Rack
4	Planetary cage with worm wheel (ring gear)	10	Pinion
5	Electric motor worm wheel	11	Sun gear output
6	Planetary gear		

Worm Gear Drive



Index	Explanation	Index	Explanation
1	Solenoid lock	7	Planet cage with worm wheel (ring gear)
2	Sun gear input	8	Worm gear drive
3	Planetary gear		

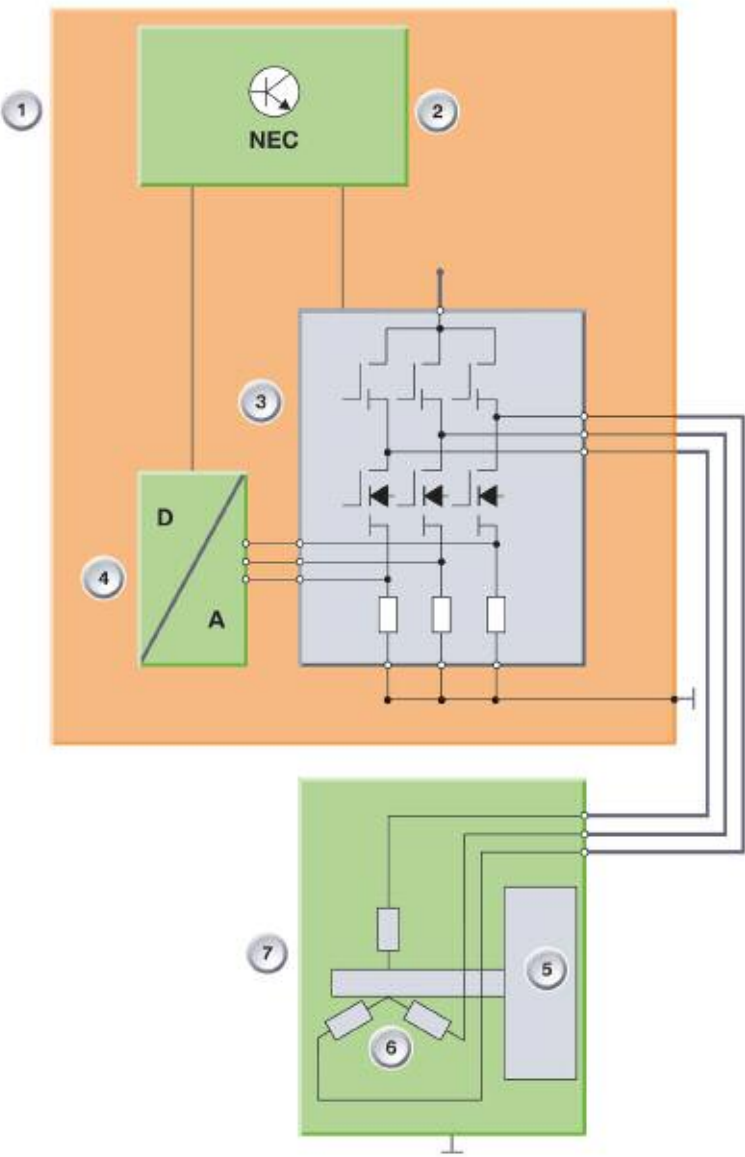
AS Actuating Motor



Index	Explanation	Index	Explanation
1	Solenoid lock	3	Motor position sensor
2	Electric motor		

The position of the electric motor rotor is detected by the motor position sensor on the actuating unit. The power supply of the electric motor has 3 phases. These are supplied with current by the electronics of the AS control unit such that a rotating field is generated. An earth connection in the electric motor connector provides shielding.

AS Actuating Motor Schematic



Index	Explanation	Index	Explanation
1	AS control unit	5	Motor stands (armature)
2	Processor	6	Motor coils
3	Circuit in the control unit	7	Electric motor
4	Analog/digital converter		

The actuating forces for turning the wheels are not produced by the electric motor, however, but by the separate hydraulic power steering assistance as with conventional steering.

Motor Position Sensor

The motor position sensor for the actuating unit is located at the rear of the AS actuating unit electric motor and consists of a sensor chip (magneto resistive element) and a magnet.

The motor position sensor in the actuating unit detects the rotor position of the electric motor in accordance with the magneto resistive principle.

The sensor chip receives signals along the vertical and horizontal from the measurement of the magnetic field direction. The sensor chip digitizes this angle information and transfers this square-wave signal through the two-wire connection to the AS control unit, on which the motor position sensor, in turn, receives its 7.5 V power supply. The motor position sensor in the actuating unit has a measuring range of 180°.

The number of half turns is counted by the AS control unit and stored when the ignition is switched off. The information about the rotor position is sent by the AS control unit via a direct line as a pulse-width-modulated signal.

Steering Column Switch Cluster

The SZL steering column switch cluster consists of the following components:

- SZL electronics
- Steering angle sensor
- Cruise control steering column switch
- Turn indicator steering column switch
- Wipers steering column switch
- Flat spring cassette.

The SZL can only be replaced as a complete unit. The flat spring cassette is attached to the steering column switch cluster. The flat spring cassette can be removed and replaced separately.



Index	Explanation
1	Turn signal indicator switch
2	Cruise control switch
3	Code disc
4	Steering column switch cluster with optical sensor
5	Wiper switch

SZL Electronics

The SZL electronics include a processor, a power supply and the following interfaces:

- F-CAN
- Optical switches
- Electrical switches

The optical sensor for measuring the steering angle is integrated into the control unit circuit board.

Steering Angle Sensor

The steering angle sensor is designed as a contact-free, optical angle measurement system. The system consists of a code disc and an optical sensor. The code disc is directly connected to the steering wheel via a driver. If the steering wheel is moved, the code disc turns within the optical sensor.



■ Code Disc

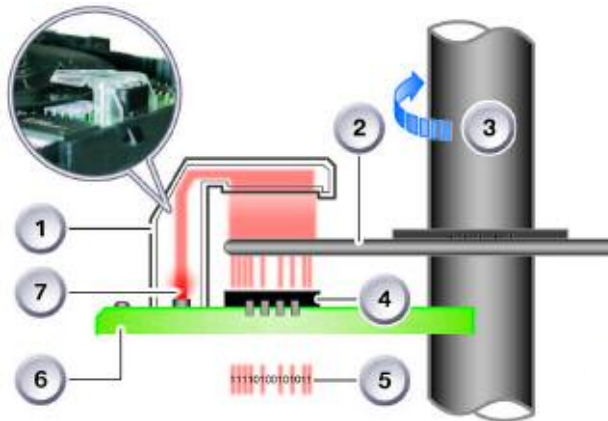
The code disc is black and has a pattern of lines. This pattern consists of two continuous lines on the outside and inside of the code disc.

Between the two continuous lines, there are discontinuous lines at certain distances from each other. These represent the digital range of the sensor. The digital code changes every 2° .

The diagonal lines around the outside represent the analogue range of the sensor. These lines allow a more precise measurement (0.1°) of the steering angle.

■ Optical Sensor

The optical sensor is structured as follows:



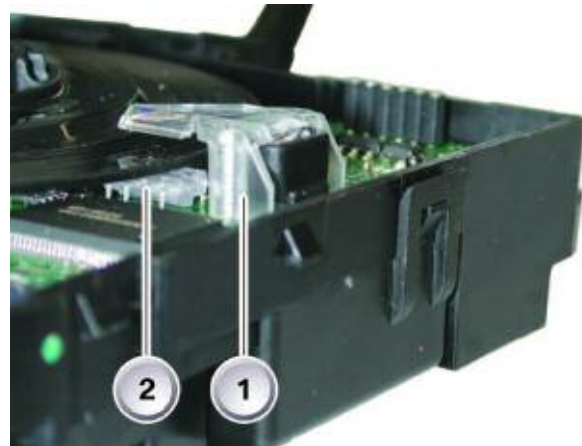
Index	Explanation	Index	Explanation
1	Light guide	5	Output: conversion into electrical signals
2	Code disc	6	Circuit board
3	Steering column	7	LED
4	Line camera		

■ LED and Light Guide

The function of LED and light guide is to project light onto the code disc from above. The light diode is soldered directly onto the SZL circuit board. The light guide is fixed to the circuit board with two screws. The LED and light guide form the optical sensor together with the line camera.

■ Line Camera

The line camera is fitted under the code disc. The line camera converts optical signals that penetrate the code disc into electrical signals.



Index	Explanation
1	Line camera
2	Light guide and LED

Hydraulic Pump

Electronically Controlled Bypass Valve (EVV)

The EVV regulates the volumetric flow of hydraulic fluid in the hydraulic pump to ensure that only the volumetric flow currently required to provide power assistance is made available.

Example:

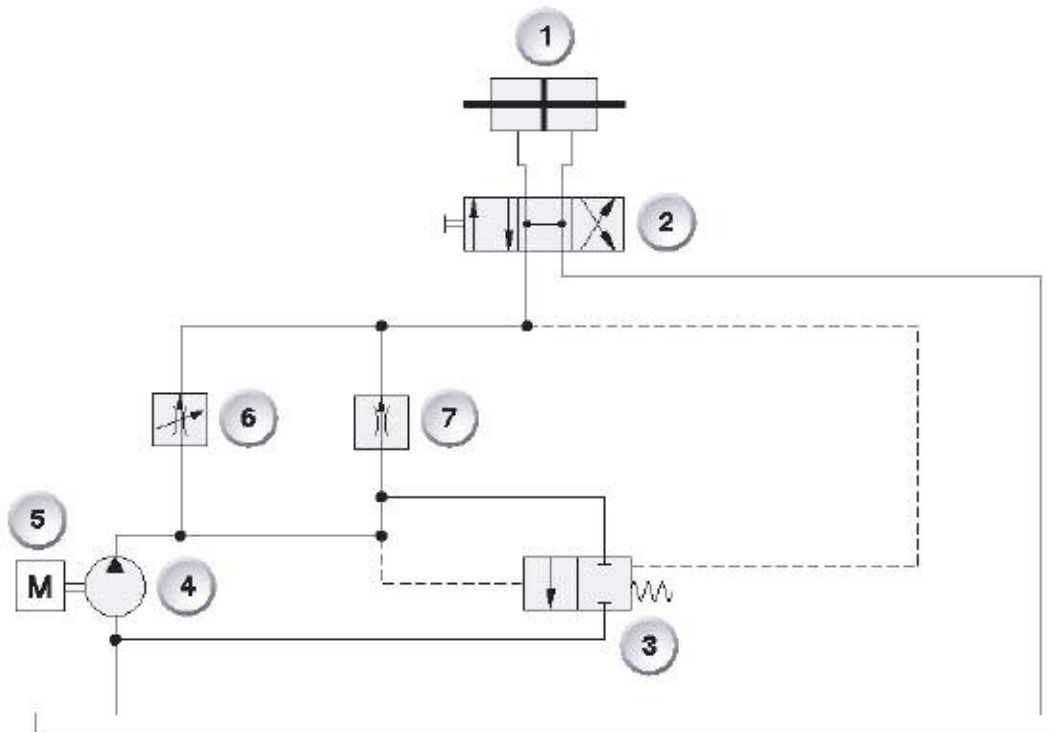
When the vehicle is being driven straight ahead without power assistance, the circulation pressure in the steering hydraulic circuit drops, thus reducing the circulation pressure and the power consumption. If a steering movement is required, the volumetric flow is immediately raised again and the usual steering-angle speed is ensured.

The EVV therefore controls the power consumption of the hydraulic pump, thus reducing the fuel consumption and the CO₂ emissions of the combustion engine.



Index	Explanation
1	Proportional valve (EVV)

Power Steering Hydraulic Circuit Diagram



Legend for Power Steering Hydraulic Circuit Diagram

Index	Explanation	Index	Explanation
1	Rack and pinion steering unit	5	Combustion engine
2	Steering valve	6	Electronically controlled bypass valve (EVV)
3	Flow regulating piston in the vane-cell pump	7	Throttle (restriction)
4	Vane-cell pump		

Power Steering Cooler

The power steering cooler is located in the engine cooling module. The power steering cooler consists of a continuous pipe with soldered rectangular fins.

