

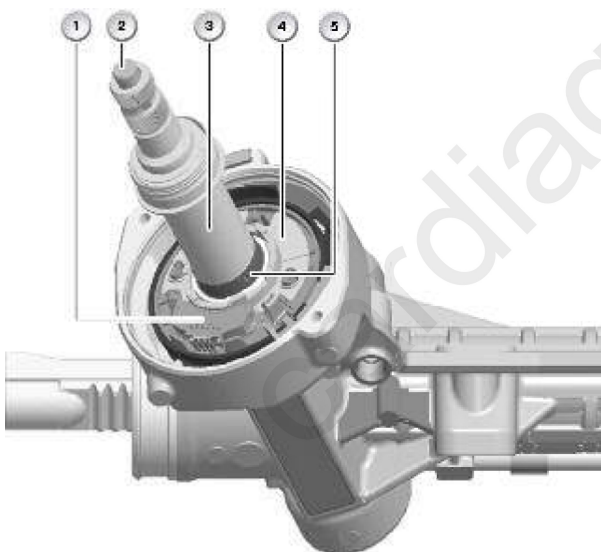
System Components

The main components of the EPS system are the:

- Steering torque sensor
- EPS control unit
- Electric motor with position sensor
- Reduction gear
- Steering rack

Steering Torque Sensor

The steering torque sensor provides the EPS control unit with information about the steering torque applied by the driver in the form of an input signal. The EPS control unit uses that signal and other input signals to calculate the power assistance torque and operates the electric motor accordingly. The torque produced by the electric motor is added by way of the reduction gear to the steering torque applied by the driver. The total torque is converted by the steering rack into steering force at the front wheels.



Index	Explanation
1	Sensor unit with analyzer circuitry
2	Torsion bar (top end) 5 Ring magnet
3	Input shaft
4	Coil spring
5	Ring magnet

Rotation of the input shaft (3) and ring magnet (5) is detected and electronically analysed by the sensor unit (1). The fundamental sensing principle applied is called the Hall effect.

As the rigidity of the torsion bar (2) inside the input shaft is known, the electronic circuitry can calculate the amount of torque applied from the degree of twist.

The steering torque is then digitally transmitted to the EPS control unit via a direct cable connection.

The sensor signal is provided with redundant back-up (a second identical sensor) so that system availability in the event of sensor failure is improved. If an unacceptable degree of divergence between the two sensors is detected during operation, the system continues to operate on the basis of the more plausible of the two signals and full EPS functionality is maintained.

If the fault status remains present at the end of the driving cycle, a fault memory entry is generated and the EPS does not operate when the next driving cycle starts.

EPS Control Unit

As well as the control circuitry, the EPS control unit also contains the power electronics for operating the electric motor.

The power electronics includes a multiple output relay that turns off the power supply to the motor windings in the event of a fault. Breaking the circuit allows the motor shaft to rotate freely. Fault conditions in which the motor would electrically lock up are avoided.

There is a temperature sensor integrated in the control unit that is required for detecting overload situations.

EPS control unit and electric motor housing



Index	Explanation
1	Electric motor housing
2	Steering torque sensor lead connection
3	Bus connection
4	Cable to steering torque sensor
5	Power supply connection
6	Diaphragm made of Goretex
7	EPS control unit housing

The housing of the EPS control unit (and the electric motor) is located in a position exposed to large temperature fluctuations and high external moisture levels. Therefore, there is a diaphragm made of Goretex on the housing that equalizes the pressure difference between the inside and outside of the housing but still prevents moisture intrusion at that point.

On the EPS control unit and electric motor housing there are also the following EPS electrical connections:

- Power supply for the EPS
- Bus connection (PT-CAN inc. wake-up line)
- Power supply and signal line for steering torque sensor

Electric Motor with Position Sensor

The essential function of the electric motor is to generate the required torque calculated by the EPS control unit.

The type of electric motor used is a brushless DC motor (made by Siemens).

Although it is powered by direct current, its method of operation is based on that of an AC synchronous motor. The power electronics in the EPS control unit convert the power supply voltage (DC voltage) into phase voltages so as to produce a rotating field at the phase windings.

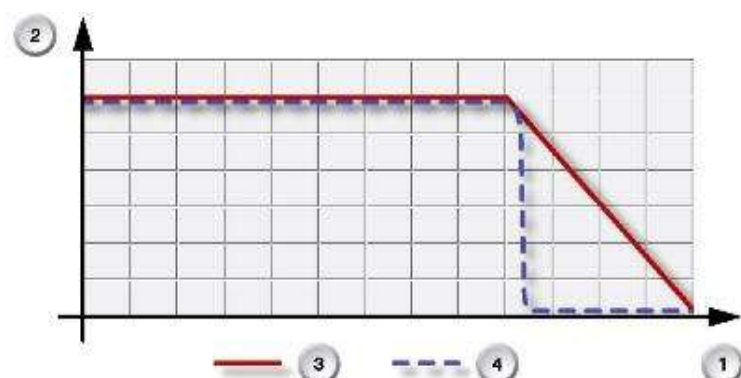
Only this type of motor combines the following characteristics that are decisive for use in an EPS system:

- High efficiency
- Low wear
- Long service life
- High thermal load capacity
- Small external dimensions
- Constantly high torque over a wide speed range

The electric motor is almost exclusively operated in the speed range throughout which its torque is constant. Only in rare cases involving extremely high rates of steering angle change applied by the driver does the speed briefly reach the point at which the torque curve falls away with increasing motor speed. Very aware drivers may perceive this as reduction of power steering assistance. In contrast with hydraulic power steering, where the drop is noticeable as an abrupt stiffening, the change is progressive with EPS, which is generally perceived as more pleasant.

The maximum power consumption (transient) is 85 A so that at a rated voltage of 12 V a peak output of approximately 1 kW results. The fuse in the trunk that protects the power circuit against shorting has an appropriately high rating for that high current draw.

Available torque versus rate of change of steering angle (EPS vs. Hydraulic Power Steering)



Index	Explanation
1	Speed of electric motor, equates to rate of change of steering angle
2	Torque
3	EPS electric motor - relationship of torque to motor speed
4	Hydraulic power steering pump - relationship of torque to steering angle rate of change

In contrast with the peak output, the average output required for delivery of EPS functions is very low. It is only between approx. 20 W and 40 W (depending on driving profile) because the electric motor is only supplied with power on demand, e.g. when cornering but not when travelling in a straight line (without having to use the steering).

Demand-based operation of the electric motor is the main reason why the fuel consumption of vehicles with EPS is around 0.2 l / 100 km less than that of vehicles with hydraulic power steering. And on the other hand, the power that would otherwise be required to constantly drive the power steering pump is now almost entirely available as additional motive power for the vehicle. Depending on the situation, there can be a linear dynamics gain of up to 2 kW.

A second important component is *actually on* the circuit board of the EPS control unit but is located directly adjacent to the electric motor shaft: the motor position sensor. In that way the motor position sensor can directly signal the electric motor's rotor position to the EPS control unit. As the electric motor is rigidly connected to the steering rack by means of the reduction gearing, the EPS control unit can deduce the position of the roadwheels and the steering angle from the rotor position.

After first calibrating the straight-ahead position with the aid of the signal from the steering angle sensor, the motor position sensor signal is subsequently used for the EPS functions (e.g. "active steering-wheel return"). The reason for this is the higher resolution of the motor position sensor signal.

The sensing principle applied by the motor position sensor is identical with that used by the steering torque sensor. Both consist of Hall-effect sensor units adjacent to which there is a rotating magnet. The steering torque sensor is designed to detect small degrees of twist, while the motor position sensor must detect large amounts of rotation (a complete revolution must be measurable). The motor position sensor is also duplicated, though in this case the duplicate unit has a different resolution in order to be able to pick up both fast and slow movements effectively.

Reduction Gear

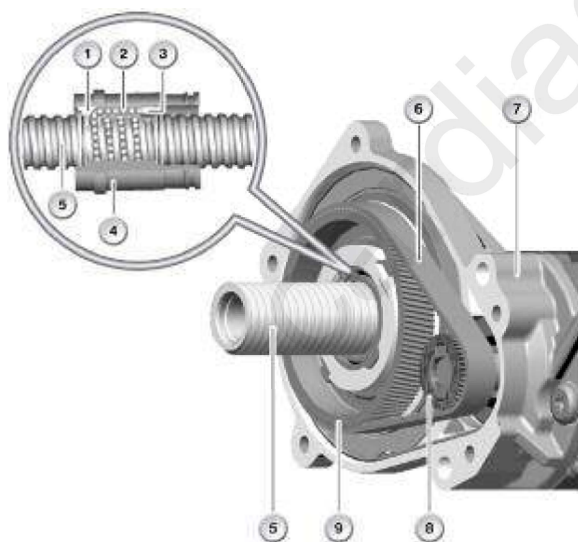
The reduction gearing transmits the torque generated by the electric motor to the steering rack, thereby applying steering force to the front wheels.

The overall transmission ratio is approximately 20 revolutions of the electric motor to one revolution of the steering wheel. That low gearing ratio combined with the high torque of the electric motor makes it possible to generate the required steering rack forces.

The low ratio combined with the rotating mass of the electric motor also has a damping effect on feedback from the road and roadwheels (as described in the section "Active damping").

The reduction gearing consists of the belt drive and reciprocating ball (screw) drive.

Reduction gearing for EPS with APA



Index	Explanation	Index	Explanation
1	Ball bearing outfeed mechanism	6	Toothed drive belt
2	Ball bearing return channel	7	Reduction-gear housing
3	Ball bearing infeed mechanism	8	Small gear wheel
4	Nut of ball screw drive	9	Large gear wheel
5	Ball screw thread on steering rack		

The electric motor shaft drives the small gear wheel (8) of the belt drive directly. Via the toothed drive belt (6) and the large gear wheel (9), the nut (4) of the ball screw drive is made to rotate.

That nut contains a return channel (2) and mechanisms at either end of the bearing race for feeding the ball bearings into (3) and out of (1) the ball screw thread of the steering rack (5). Thus, the ball bearings circulate within a "closed system".

As the nut cannot move along the steering rack, the ball bearings moving along the ball screw thread exert an axial force on the steering rack.

The reduction gearing is inseparably attached to the electric motor. Repairs or adjustments to it as a separate component are not possible.

The reduction gearing and its components (including the drive belt) are designed to last for the life of the vehicle.

If the gaiter at the end of the steering rack is damaged, water can get into the reduction gear housing and therefore into the steering gear as well. That water will cause corrosion and, over time, loud noises when steering.

Nevertheless, power steering assistance from the EPS continues to be provided even in such cases.

In order that large amounts of water do not remain in the steering gear (e.g. after driving through deep water), a water drain valve has been fitted at the lowest point of the reduction gear.

Note: If a defective bellows (boot) is discovered, it should be replaced so as to prevent water entering the steering gear. At the same time as replacing the gaiter, the water drain valve at the lowest point of the reduction gear should also be replaced and is included in the repair kit.

Steering Rack

The steering rack of the EPS system has the same function as that of a hydraulic power steering system.

It converts the steering force applied by the driver combined with the power steering assistance provided by the EPS into a force applied to the track rods. Ultimately, that results in steering movements by the front wheels.

The design and dimensions of the steering rack are such that the design of the other vehicle components only required marginal adjustments in order to enable the use of electric power steering.

In particular, the points of attachment to the wheels by way of the track rods and with the steering column are absolutely identical with those used up to now with the hydraulic power steering.

The track rod also has the same gearing ratio.

Accordingly, the gearing ratio of the steering system as a whole is identical regardless of the power assistance method used.

As with hydraulic power steering systems, there is a thrust piece at the point where the pinion engages in the rack. It guides the rack and also serves as a means of adjusting the entire unit at the factory.

The thrust piece in this EPS system acts purely as a spring mechanism without a hydraulic bearing.

Note: Adjustment of the steering rack and pinion using the thrust piece is a once-only operation carried out during production. That adjustment cannot and must not be performed at a dealership!