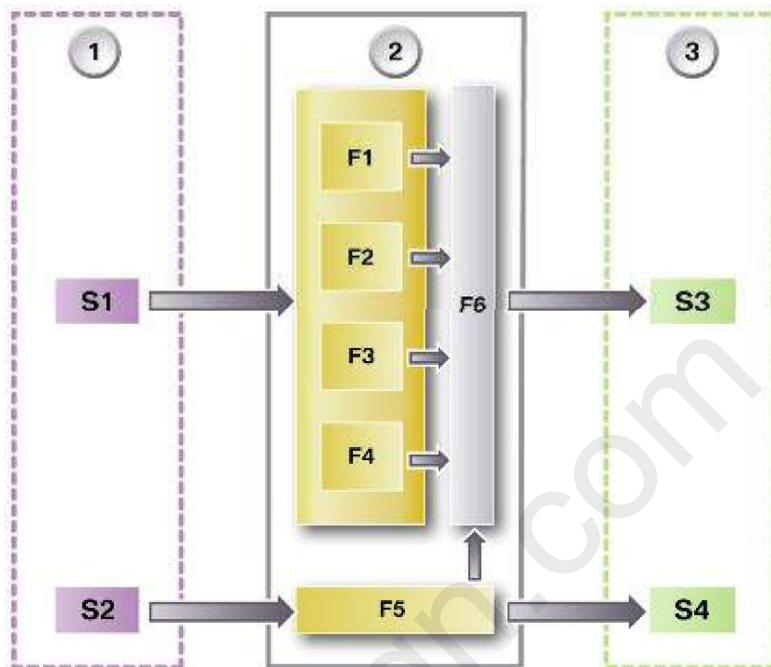


Principles of Operation

Overview of EPS functions



Index	Explanation
1	Input
2	EPS control unit
3	Output
S1	Input signals for EPS control and modulation functions - Steering force applied by driver - Road speed and other variables that describe the driving situation - Steering angle, steering angle rate of change
S2	Input signals for EPS status control - Terminal 15 on/off - Engine running/not running
F1	"Speed-dependent power steering assistance" function
F2	"Active steering wheel return" function
F3	"Active damping" function
F4	"Active roadwheel feedback" function
F5	"Status control" function
F6	"Co-ordination of specified settings" function
S3	Output signal of EPS control and modulation functions: control of electric motor
S4	Output signal of EPS status control: - Demand for higher cooling capacity - Control of warning and indicator lamps

EPS Input Variables

Steering Column Switch Cluster (SZL)	
Transmitter	Steering column switch cluster with steering-angle sensor
Signal	Steering angle set by driver
Transmitted via	PT-CAN
Receiver	EPS control unit
Function	Active steering-wheel return

Dynamic Stability Control (DSC)	
Transmitter	Dynamic stability control with DSC sensor
Signal	Road speed and other variables that describe the driving situation
Transmitted via	PT-CAN
Receiver	EPS control unit
Function	Steering power assistance, active roadwheel feedback

Digital Motor Electronics (DME)	
Transmitter	Digital motor electronics
Signal	Engine running
Transmitted via	PT-CAN
Receiver	EPS control unit
Function	Status control

Car Access System (CAS)	
Transmitter	Car Access System
Signal	Terminal 15 status
Transmitted via	PT-CAN
Receiver	EPS control unit
Function	Status control

EPS Output Variables

Digital Motor Electronics (DME)	
Transmitter	EPS control unit
Signal	Demand for greater cooling capacity
Transmitted via	PT-CAN
Receiver	Digital motor electronics
Function	Control of electric fan

Instrument Cluster (Kombi)	
Transmitter	EPS control unit
Signal	Request for failure message
Transmitted via	PT-CAN
Receiver	Instrument cluster
Function	Control of warning and indicator lamps

DME Functions Used by EPS

Intelligent Alternator Control

With the advent of "intelligent alternator control" (IGR) on the DME as an additional means of CO₂ reduction, the alternator voltage is adjusted according to the driving situation and battery charge level. Therefore, there will be periods in which the electrical system voltage is at the level that has been normal up to now (approximately 13.8 V). However, there will also be situations in which the voltage drops to around or just below 12 V.

The EPS components, and in particular the electric motor, are rated for a power supply of 12 V. At that level, the requirements in terms of maximum steering power assistance and speed are satisfied.

If the maximum EPS output were demanded at an alternator voltage of 12 V, the high current draw by the electric motor would produce a voltage drop on the EPS power supply line. The consequence would be an EPS input voltage of substantially below 12 V and, therefore, a reduced level of steering power assistance.

In order to prevent such an undesirable situation occurring, there is an additional IGR function for the EPS that is implemented without additional exchange of signals with the EPS and comprises the following features:

- Observation of whether an operating status exists in which high EPS output is required.
 - The bus signals indicating steering angle rate of change and road speed are monitored for that purpose. A high level of EPS output is identified when the steering angle rate of change is high at the same time as the road speed is low.
- Action: Increase of alternator output and temporary increase of electrical system voltage when high EPS output is detected.

This function ensures that the power supply at the EPS input terminals always provides at least the rated voltage of 12 V regardless, to a great extent, of other variables.

Note: Detecting statuses involving high EPS output and raising the electrical system voltage constitute a control cycle that is completed within 2 seconds at most. As it is also an infrequent situation, it is unlikely that it will be the subject of customer complaints. If a particularly observant customer complains of momentarily reduced power steering assistance, this control cycle may possibly be the cause. If there are repeated complaints, performing a diagnosis on the power supply is advisable.

Speed-dependent Power Steering Assistance

The Servotronic function that is only achievable by means of additional system complexity on hydraulic steering systems is implemented in the form of software on the electric power steering system and is therefore available with EPS.

The customer expects the lightest and smoothest steering movement possible when maneuvering or parking into spaces. Less sensitive steering setup is required when driving at high speed so that the vehicle can be kept on course more effectively.

Based on the sensor signals indicating the vehicle's road speed and the steering torque applied by the driver, the EPS provides a high level of power steering assistance at low speeds and when stationary (maximum convenience).

At high speeds on the other hand, the EPS demands greater steering force from the driver by reducing the level of power steering assistance. This helps the driver to hold a constant line.

As can be seen from the graph, the level of power assistance is computed on the basis not only of vehicle speed but also of the steering torque applied by the driver. If the driver applies a small amount of turning force to the steering wheel, the assistance from the EPS also initially remains at a relatively low level. This produces excellent self-centering characteristics, i.e. the steering does not react over-sensitively from the straight-ahead position.

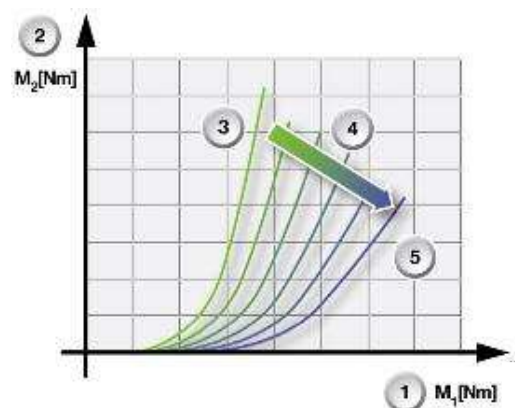
If the driver applies greater force to the steering wheel, there is a smooth transition to a steeper curve gradient. As a result, the driver obtains the expected high degree of assistance when making abrupt steering movements or tight maneuvers.

The characteristics described here have been adopted by the EPS from the familiar hydraulic steering systems.

The transition between the curves is not abrupt but progressive. The EPS calculates appropriate transitional levels where necessary.

The steering characteristics of the EPS is influenced by the driver as in other vehicles by pressing the driving dynamics button.

EPS speed-dependent power steering assistance



Index	Explanation
1	Steering torque applied by driver
2	Power assistance torque provided by EPS
3	Vehicle road speed equal to zero
4	Vehicle road speed increases
5	Vehicle road speed at maximum

Active Steering-wheel Return

In addition to the natural self-centering characteristics inherent in the steering and suspension systems, this function assists steering-wheel return by appropriate operation of the electric motor.

The following signals are required for this purpose:

- Road speed
- Steering torque applied by driver
- Steering angle and
- Steering angle rate of change

However, the steering angle signal is only required for calibration with the electric-motor position sensor in order to determine the target position for steering-wheel return (steering angle equal to zero). Thereafter, the active steering-wheel return function uses the electric-motor position sensor signal as it has a higher resolution than the steering angle sensor signal and thus enables more precise control.

If the steering-angle sensor signal is not available, e.g. due to a fault on the SZL, the active steering-wheel return function cannot operate. The other EPS functions remain active. Customers may possibly describe the resulting vehicle behavior as "pulling to one side" because the steering wheel does not return to the straight-ahead position as precisely as usual.

The necessity for activation of the active steering-wheel return function arises when, for example, the driver allows the steering wheel to slip when exiting a corner. The signal values reflecting that situation which the EPS uses to detect the situation are:

- Steering angle clearly not equal to zero and
- Steering torque applied by driver approximately equal to zero

The electric motor is then operated by the EPS so as to generate a return force that produces smooth return of the steering wheel to a position close to the straight-ahead position.

Note: If a customer complains of the car "pulling to one side" the possible causes to be considered include not only a mechanical problem with the suspension/steering but also a signal or communication fault between the EPS and the steering column switch cluster/steering-angle sensor. In such a situation, the EPS is unable to provide the active steering wheel return function and this may be perceived by the customer as the vehicle "pulling to one side".

Therefore, before checking the wheel alignment, the EPS fault memory should be checked and, if necessary, the stored testing sequence followed in order to make certain the signal from the steering-angle sensor is present.

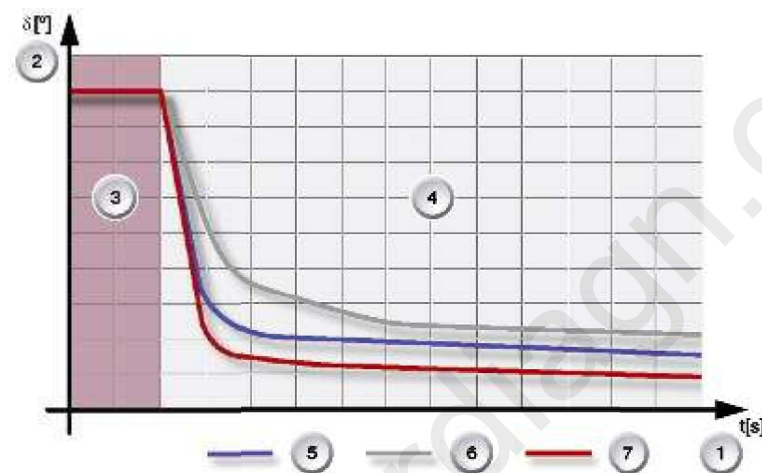
The clearly perceptible improvement compared with the self-centering characteristics of hydraulic power steering systems is evident from the graph below.

The electric power steering returns to the center position more dynamically and precisely. This applies to all electric power steering systems used by BMW because they all incorporate the active steering-wheel return function.

The self-centering characteristics of an EPS system without active steering wheel return shown on the graph are for comparison purposes only. They reveal themselves to be inferior to those of a hydraulic power steering system. This is due to the greater inertia of the electric motor and reduction gearing.

However, all EPS systems used by BMW incorporate active steering-wheel return and therefore offer the benefits described above.

Self-centering characteristics of various steering systems



Index	Explanation
1	Time
2	Steering wheel angle
3	Driver holds steering at a constant lock (cornering)
4	Driver lets steering wheel slip (exiting corner)
5	Self-centering characteristics of a hydraulic power steering system
6	Theoretical self-centering characteristics of EPS without active steering-wheel return
7	Self-centering characteristics of EPS with active steering-wheel return

Active Damping

The undesirable steering-wheel movements to be damped can be produced either by inadvertent steering input by the driver or feedback from the road/roadwheels.

■ Damping Roadwheel Feedback

The design of the front suspension (double link Macpherson strut suspension) on its own ensures that vertical wheel movements produce very little lateral force on the track rods.

Due to the low ratio of the reduction gear by which the electric motor is connected to the steering rack, the inertia of the electric motor also has a damping effect on the forces and movements transmitted from the roadwheels to the steering wheel. Those mechanical damping effects are supplemented by an electronic damping function on the part of the EPS. It analyses the movements of the steering rack (using the signals from the electric-motor position sensor) and operates the electric motor accordingly in response.

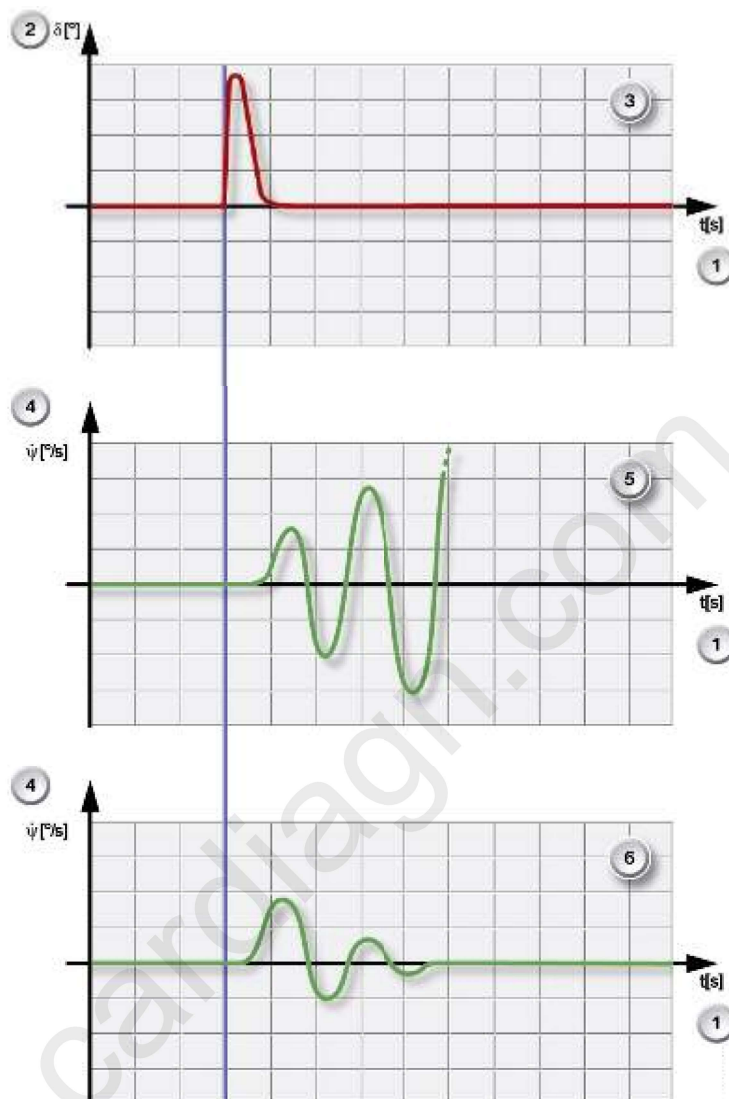
This means that feedback from external forces is transmitted in controlled amounts to the steering wheel so that, on the one hand, the driver obtains sufficient information about the nature of the road surface, but on the other, undesirably extreme steering wheel backlash is prevented.

■ Damping Steering Input from Driver

Particularly at high speeds, unintentional jerky movements of the steering wheel by the driver have a negative effect on vehicle handling stability. So-called "snatching" of the steering wheel can, under certain circumstances, cause the vehicle to start rocking, which can lead to snaking and the driver ultimately losing control of the vehicle if corrective action is not taken quickly enough.

The EPS detects such steering input and operates the electric motor so as to substantially damp the movements, particularly at high speeds. As a result, vehicle rocking is prevented.

Damping of Steering Input by EPS



Index	Explanation
1	Time
2	Steering wheel angle
3	Steering angle progression (steering input by driver, "snatching" the steering wheel)
4	Yaw rate
5	Theoretical vehicle response without active damping: the turning action following the steering input is progressively amplified at high vehicle speed.
6	Desirable vehicle response with active damping: the turning action is heavily damped even at high vehicle speeds.

Active Roadwheel Feedback

Partly due to the damping effect of the inertia of the electric motor, an EPS system can inherently not provide as direct feedback about the nature of the road surface as a hydraulic power steering system.

In order to obtain virtually identical roadwheel feedback characteristics on vehicles with EPS, the EPS analyses information that describes the vehicle's dynamic handling situation. From that information, the EPS computes additional "EPS road surface data". As a result, the driver obtains better roadwheel feedback characteristics which are very similar to those of a hydraulic power steering system.

Control

The EPS status control function makes the overriding decision as to whether operation of the electric motor is permissible or not. It produces a clearance signal that is sent to the EPS function that is co-ordinating the subordinate specified settings of the control and modulation functions.

The conditions for allowing operation are the following:

- Ignition must be switched on
- Engine must be running
- There must be no EPS input signal faults or EPS internal faults present

The response to detected faults described below represents an exception.

■ Status Shutdown in the Event of Faults

A primary aim in the development of the EPS was to ensure that vehicle response in the event of faults would remain manageable by the driver. Therefore, under no circumstances must a sudden high steering force in either direction be allowed to occur. For that reason, the EPS has numerous monitoring functions for detecting faults on the sensors, actuators and associated systems that are involved in EPS operation.

All fault statuses in which reliable and correct control of the electric motor is not possible result in the disabling of motor operation and, therefore, shutdown of the EPS functions.

The consequence of that is that the driver no longer benefits from the convenience of power-assisted steering. More importantly, however, incorrect control of the electric motor is prevented.

Note: The loss of power steering assistance in the event of faults constitutes an intended system response on the part of the EPS. Although such a response may be slightly unnerving for the driver, the vehicle remains fully steerable with greater physical effort.

Loss of power steering assistance in the event of faults occurs both with electric and hydraulic power steering. The two systems thus also behave in a similar manner in response to faults.

In such a fault situation, a yellow warning lamp lights up on the instrument cluster. The driver is also notified of the fact that power steering assistance from the EPS is no longer available by display of the appropriate Check Control symbol together with the explanatory message on the Central Information Display.



Co-ordination of Specified Settings

The specified settings for the control and modulation functions for operating the electric motor are co-ordinated at a central point by the EPS software. If a clearance signal from the status control function is present, the individual specified settings are normally added together and signalled as a total value.

In certain transitional situations the specified settings are filtered before they are signalled.

The following are examples of such cases:

- The EPS goes into operation after the engine is started. The power assistance torque is increased progressively until the desired level is reached.
- The EPS reduces the power steering assistance for function-related reasons (see also the section "Supplementary functions").

In the event of a fault the control signal for the electric motor is abruptly cancelled instead of being filtered in order to prevent incorrect operation as quickly as possible.

Supplementary Functions

The functions described below are encountered only rarely in special operating situations. The information given here can help to distinguish those special operating statuses, which do not require repairs, from genuine faults when handling complaints from customers.

■ Protection Against Overload

The EPS reduces the degree of power steering assistance if the temperature of EPS components becomes too high. By limiting motor operation, the amount of heat generated by the EPS itself is also limited, thereby protecting the components against excessive thermal stress.

This action starts to come into effect from a temperature of approximately 100°C and escalates to the point where power steering assistance is reduced to zero at a temperature of 115°C.

Upwards of a certain degree of function restriction, the warning light on the instrument cluster is switched on (see the section "Shutdown in the event of faults") and a fault registered in the fault memory.

In addition to reducing power steering assistance, the EPS also requests higher electric fan output from the DME in order to produce a greater cooling effect.

This type of overload can occur at high ambient temperatures combined with simultaneous high degrees of steering activity, especially when stationary.

Another overload situation can occur if an attempt is made to turn the front wheels against a solid obstacle (e.g. a kerbstone). If this situation occurs repeatedly at short intervals, the degree of power steering assistance is similarly reduced. This firstly protects the EPS components against excessive mechanical stresses, and secondly signals to the driver that there is a solid object preventing the wheels turning.

The EPS detects such situations by comparing the control signals to the electric motor with the motion of the motor.

Note: The EPS reduces the power steering assistance in overload situations. If customer complaints are received, the customer should be questioned as to the situation in which the symptoms occurred before commencing any repair work.

If necessary enlighten the customer as to the way in which these protective functions operate.

■ End Stop as Software Function

Although the EPS steering gear also incorporates mechanical end stops, there is a function that steeply reduces the level of power assistance shortly before the mechanical end stops are reached. Although the driver will perceive this as increased steering resistance, it makes turning the wheels to full lock much smoother overall.

In addition, this function reduces the stresses on mechanical and electrical components of the steering system and thus contributes to the achievement of long service life combined with reliable operation.