The function can be split into two areas:
- Steering without power assistance
- Steering with power assistance

The steering gear converts the rotary movement of the steering wheel to pivoting of the wheels and increases (boosts) the driver’s manual force.
In the case of rack-and-pinion steering gear, a pinion engages in a rack. The pinion is actuated via the steering shaft by the steering wheel. The steering tie rods which, in turn, transfer the movement to the steering-knuckle arms and onto the wheels move together with the rack.
The force applied by the driver (steering wheel torque) and the ratio of angle of rotation at the steering wheel to wheel steer angle result from:
- The diameter of the steering wheel
- The transmission ratio between pinion and rack
- The length of the steering-knuckle arms
- The friction between tyre and roadway

Basically, direct steering is desirable. However, this necessitates appropriate force on the part of the driver. However, since a steering force of 250 N at the steering wheel should not be exceeded, a power-assisted steering system is used.
Power-assisted steering system

Principle of the steering system with rack-and-pinion steering gear without power assistance

On a power-assisted steering system, an hydraulic cylinder assists the force applied by the driver. The cylinder acts in parallel with the rack. There is a steering valve, a rotary slide valve, fitted between steering shaft and pinion. It controls the cylinder.

Principle of the steering system with rack-and-pinion steering gear and power assistance
The steering forces through the valve are transmitted via a torsion bar. When steering, the valve body and rotary slide valve initially turn together. This does not cause the valve to open.

However, if steering resistances occur, the torsion bar twists as a function of the steering force. This deflects the rotary slide valve with respect to the valve body and causes the corresponding ducts to open. Pressure is thus applied to the corresponding side of the cylinder.

When the valve is in centre position (torsion bar not twisted), the entire volume of the hydraulic pump is routed unpressurised into the tank. This avoids unnecessary heating of the oil and a high energy consumption.

If the power assistance fails (e.g. if the pump is defective or if the engine is switched off), steering is still possible. However, with no power assistance, the force required at the steering wheel is far higher.

From the configuration of the power-assisted steering system, we can see that the power assistance is performed by a differential cylinder. This means that there is a problem since the forces in the case of a retracting piston are lower than when the piston extends. If the area ratio is 1:2, the force when extending is twice as high as when retracting.

A vehicle steering system with differing steering assistance forces would, however, be dangerous and difficult to handle. Two measures may be used to prevent this disadvantage of a differential cylinder.
One chooses a piston rod with a small diameter. This means that the area ratio nears the value 1:1 of a non-differential cylinder. This is possible only to a restricted extent owing to the associated risk of kinking of the piston rod. Consequently, in practice, the second measure is used. A circuit on which the same pressure obtains at the piston rod end as on the piston end when the cylinder extends is used. This means that only the differential force acts, i.e. half the force. On retraction, the pressure is applied only to the piston rod end. This means that the force is of equal magnitude both when retracting and when extending.

This special circuit is achieved thanks to the steering valve. On deflection to the right, the valve shuts off the connection from the pump to the full piston side and opens the connection to the piston rod side. In the opposite direction, the connection is open both to the full piston side and to the piston rod side. This circuit also compensates for the disadvantage of the higher flow rate demand at the piston side since the oil flows out of the ring chamber to the other side.
The configuration is subdivided into three parts:

a) The power-assisted steering system with the steering valve and the working cylinder.

b) The load with the two load cylinders and the required circuit configuration.

c) The circuit for producing two pressure sources with the flow divider.
The configuration is similar to that in the single-circuit system but there is no flow divider.

The assisting action of a power-assisted steering system can be felt only if there is a counter-force acting on it, e.g. owing to the friction of the tyres when steering. In addition, the steering system does not return to centre position of its own accord. This is ensured by a corresponding wheel-suspension system (steering geometry). These influences are shown by the two load cylinders with corresponding circuit configuration.

The following can be simulated:
- Resetting forces
- Steering forces and
- Influence of the power assistance
If the steering system is in straight-ahead position, the working cylinder is **half** extended. Both load cylinders are in their extended end position. If the steering wheel is turned, the rack and the piston rod of the working cylinder move. A driver forces one of the load cylinders out of its end position, depending on direction of rotation.

The piston diameter and the set pressure determine the resetting force of the load cylinders. The resetting force can be set with a **pressure-relief valve**. The setting acts on both cylinders (directions) equally. The load cylinders are used only as single-acting cylinders. The piston rod end is thus kept unpressurised.

**Flow control valves** are fitted in the supply lines to the load cylinders. This avoids excessively fast resetting. If the flow control valve is fully closed or if the driver steers more quickly than the oil can drain from the load cylinders, a pressure builds up and this results in a resistance when steering.

Since the working cylinder has a far larger diameter than the load cylinders, this results in pressure intensification. Without the second pressure-relief valve, this would lead to dangerously high pressures and destruction of the mechanical system if the flow control valve is closed. The set pressure on the pressure-relief valve influences the load pressure if the load pressure is set approximately the same or higher.

The assistance effect of the power-assisted steering can be influenced by the supply pressure. It is changed at the related pressure-relief valve.

The steering valve features a tank circulation setting. In this setting, the system pressure drops to a very low value. If the load cylinders are fed from the same pressure source, they do not have the pressure available in order to build up a pressure allowing them to steady the system. This means that the steering valve cannot open either. Consequently, what is necessary is either two pumps or a circuit which prevents this.

This is shown in the circuit diagram with **one** pressure source. Owing to the flow divider, the flow rate is half. This means that an outlet cannot receive more than 50% of the available flow. The flow rate at the outlets of the current divider does, however, depend on the smaller load. This means that if no flow is tapped in the load section, the working circuit (steering system) does not receive any flow either. Consequently, it is important that the pressure at the load pressure-relief valve be lower than the pressure of the supply system. The same applies to the working circuit.
Safety information

- Ensure that the system pressure of 6 MPa is not exceeded.
- Ensure that the relief valve of the load cylinders is connected.
- Ensure that the tank lines of the steering valve and the pressure-relief valves are connected.
- Set the relief valve of the load cylinders to maximum 7 MPa. Owing to the pressure intensification from the working cylinder to the load cylinder, dangerously high pressures are reached. The mechanical loading would also otherwise be too high and would do damage to the system.
- It is not permitted to operate the system without a cover.
- The flow control valve in the connection to the load cylinder limits the resetting speed. If the flow control valve is open, high resetting speeds are reached and this could lead to injury. Consequently, restrict the speed to a safe level when commissioning!
- When placing the system into operation for the first time, please note that uncontrolled behaviour may occur. The load cylinders will extend and move the steering system to centre position.
- Oil will escape when the steering wheel is moved if the tank line is not connected.

Commissioning

- Secure the slotted assembly board to a firm base surface.
- Check the working pressure of the hydraulic supply system.
- Ensure that the hydraulic connections of the power-assisted steering system and of the load circuit are connected.
- Reduce the settings of the pressure control valves to a minimum.
- Fully close the flow control valve.
- Switch on the pressure supply system.
- Set the pressure-relief valve for the load cylinders.
- Carefully open the flow control valves a little.
  **Caution:** If the pressure is adequate, the power-assisted steering system will return to centre position.
- Set the pressure-relief valve for the load cylinders. In order to do this, close the flow control valve fully again. Turn the steering wheel and, when doing this, limit the pressure produced to maximum 7 MPa. However, the pressure should be higher than that of the pressure-relief valve in the load branch. But it may be higher than the supply pressure.
- Set the pressure for the steering valve. In order to do this, turn the steering system as far as it will go mechanically. This causes the load valve to fully open. You can now set the pressure on the pressure-relief valve.
  **Caution in the case of single-circuit systems:** In this case, the pressure must be set lower than the pressure of the supply system owing to reasons dictated by the circuit. Otherwise, the flow divider will be blocked when loaded.
## Technical data

### Power-assisted steering system – steering valve

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System pressure</td>
<td>6 MPa</td>
</tr>
<tr>
<td>Design</td>
<td>Rotary slide valve (centre position: H)</td>
</tr>
<tr>
<td>Connection P</td>
<td>Pressure supply system, with quick connection coupling, $p_{\text{max}} = 6$ MPa</td>
</tr>
<tr>
<td>Connection L</td>
<td>Leakage oil connection, plug-in coupling <strong>not</strong> self-closing</td>
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</tbody>
</table>

### Power-assisted steering system – working cylinder

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>160 mm</td>
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<tr>
<td>Piston diameter</td>
<td>33 mm</td>
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<tr>
<td>Piston rod diameter</td>
<td>23.4 mm</td>
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<td>Area ratio</td>
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### Loading – load cylinders

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>System pressure</td>
<td>6 MPa</td>
</tr>
<tr>
<td>Maximum pressure of the cylinders</td>
<td>12 MPa</td>
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<tr>
<td>Maximum load pressure resulting from the working cylinder</td>
<td>7 MPa</td>
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<tr>
<td>Stroke</td>
<td>100 mm</td>
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<tr>
<td>Piston diameter</td>
<td>16 mm</td>
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<tr>
<td>Piston rod diameter</td>
<td>10 mm</td>
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<tr>
<td>Connections</td>
<td>A and B with quick connection couplings</td>
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</tbody>
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