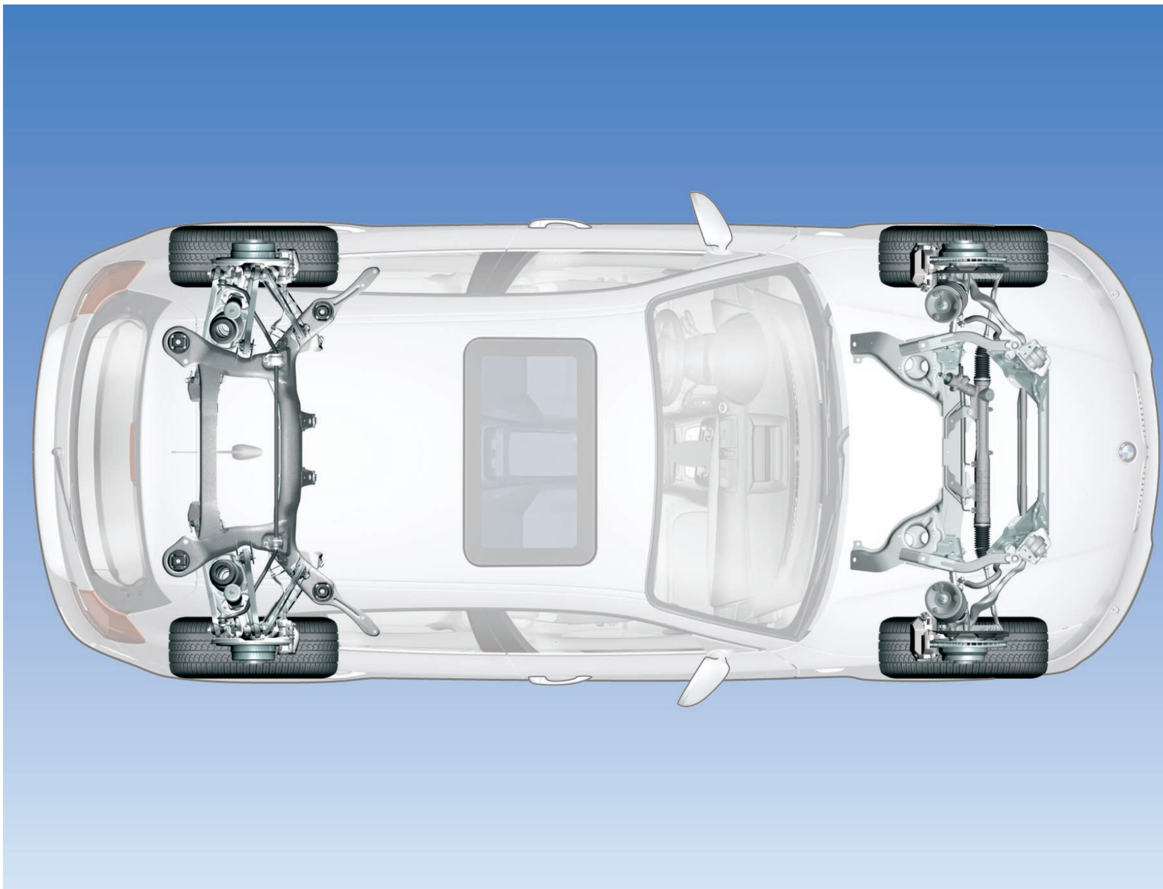
Participant's Manual

Vehicle Chassis, Suspension and Dynamic Driving Systems E87



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Aftersales Training

The information contained in this Participant's Manual is intended solely for the participants of this seminar run by BMW Aftersales Training.

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Vehicle Chassis, Suspension and Dynamic Driving Systems E87

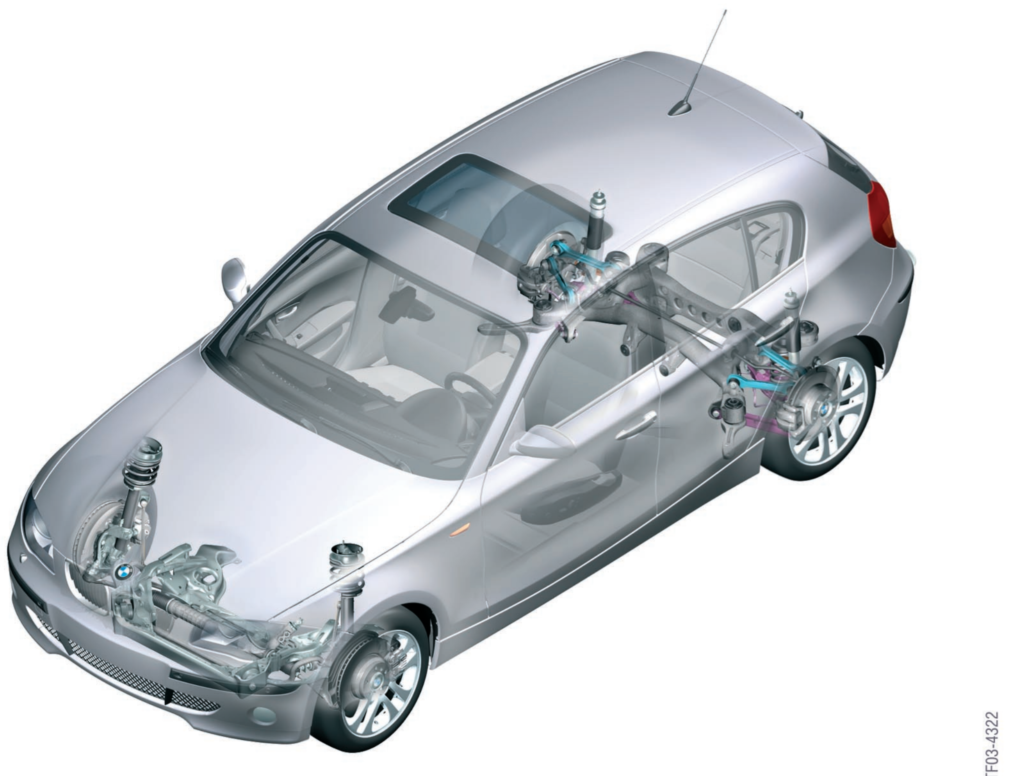
Front axle

Rear axle

Electric steering lock

Suspension and damping

Adaptation of dynamic driving systems



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Vehicle Chassis, Suspension and Dynamic Driving Systems E87

The Ultimate Driving Machine

This Participant's Manual is intended to provide fundamental information on the subjects of the vehicle suspension and the, in part, known, dynamic driving systems.

With its balances rear-wheel drive, the E87 is also characterized by BMW's brand-name standards.

By working through this Participant's Manual, you will gain fundamental knowledge of the following areas:

- E87 Front axle
- E87 Rear axle
- Electric steering lock (ELV)
- E87 Suspension and damping
- E87 Adaptation of chassis and suspension control systems

Development of BMW rear axles

BMW chassis and suspension systems and therefore the sportive and dynamic character of the individual models have long been based on the special axle designs and, of course, on the integral optimum chassis and suspension tuning.

The following table shows the development history of BMW rear axles:

Designation	Distinguishing features	Model
HA 1	Semi-trailing arm axle	E3, E9, E12, E21, E28, E30, E36/5, E36/7, E114
HA 2	Screw-link axle	E23, E24, E32, E34
HA 3	Central-link rear axle	Z1, E36/2, E36/3, E36/4, E36/C, E46, E83, E85
	Double lateral control arm axle	E26
HA 4	Experimental study	
HA 5	Dispersed double control arm axle	**E87**
Integral I	Experimental study	
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Integral III		E31
Integral IV	Steel, spring, damper tower	E38
Integral IV	Aluminium, spring, damper tower	E39
Integral IV	Aluminium, spring on body and damper on axle carrier	E39/2
Integral IV	Steel axle carrier, aluminium link and steel wheel carrier, spring and damper separated but both supported on body	E53
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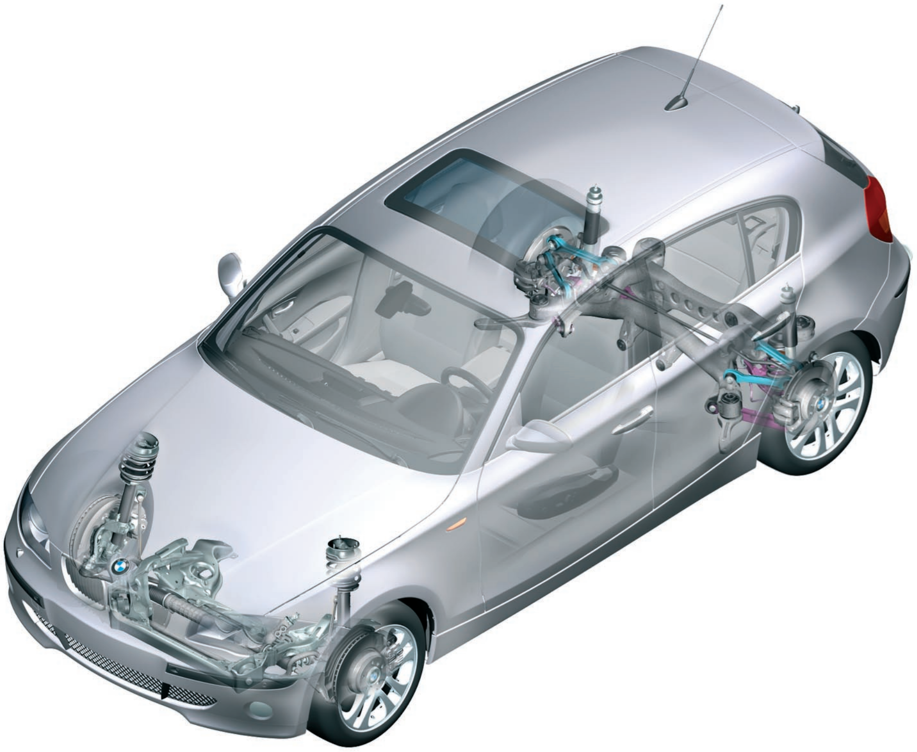
Integral IV	Aluminium axle carrier with cast node technology and cast swing arm, spring strut shock absorber tower	E6x

E87 Chassis and suspension



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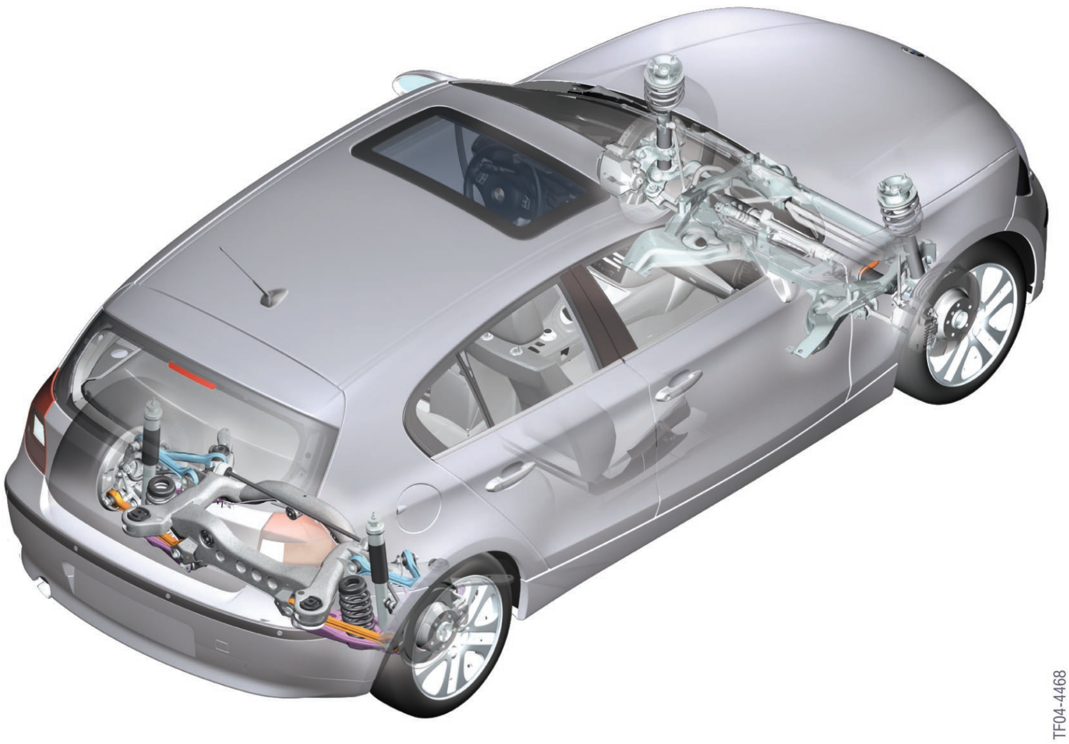
1 - E87

As can already be seen from the illustration, the chassis and suspension of the E87 represent a new step forward in the compact class both at the front axle as well as at the rear axle. The front axle is designed as a double pivot spring strut axle (MacPherson strut) in aluminium.

The design principle of the double pivot spring strut front axle of the E87 was installed in the E23 as early as 1977. At that time, however, it was installed with recirculating ball-and-nut steering behind the axle. The E87 on the other hand features a front-positioned rack and pinion steering system as was used on the E39 basic axle. The design of the front axle in the 1 Series is generally very similar to that of the E39 not least because all its components are made of aluminium.



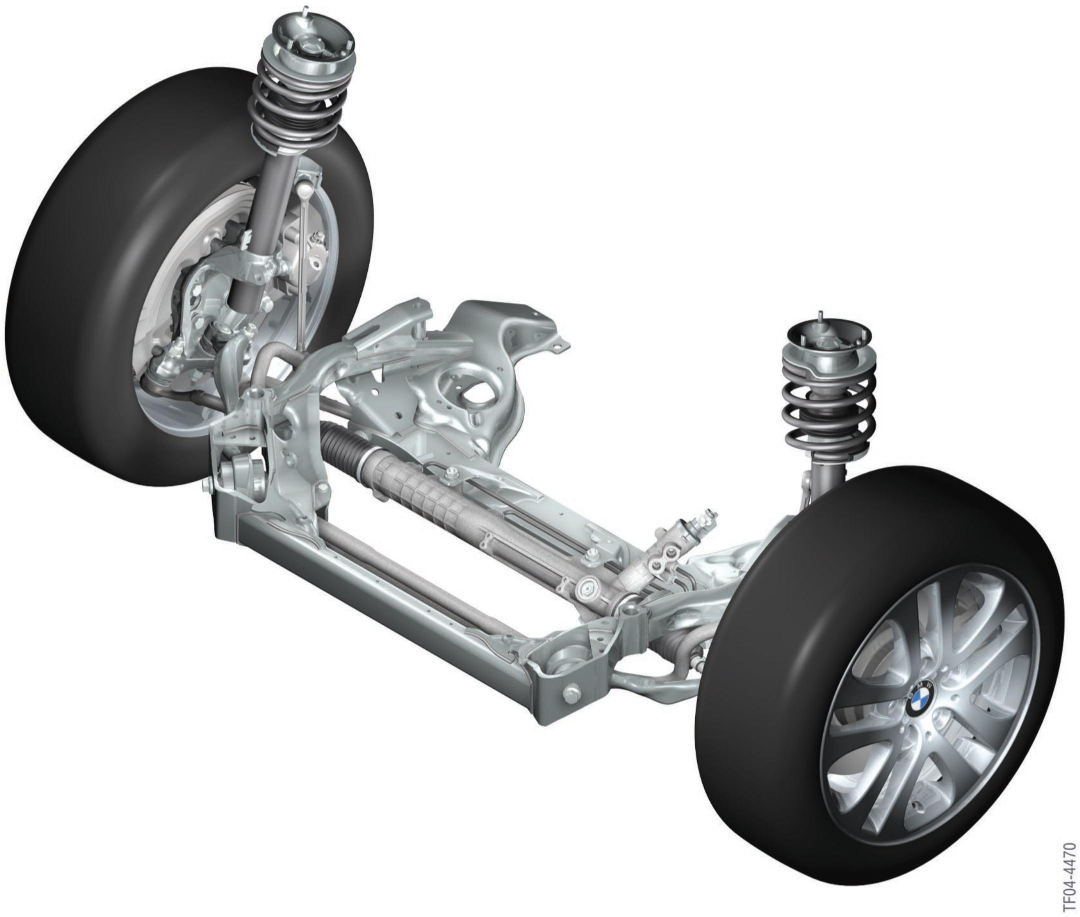
2 - E87

The rear axle was completely redesigned as a five-link axle for the E87. The properties of the E87 front and rear axle are described in the following.

E87 Front axle

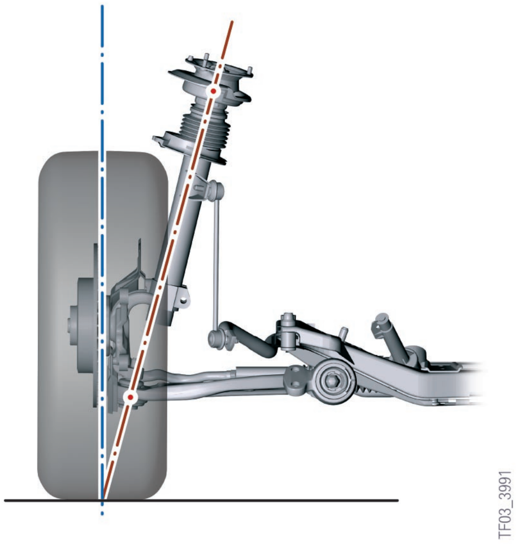
Double pivot spring strut axle

Although a tension strut version of the double pivot spring strut axle has been used in BMW vehicles for over 25 years, some of the advantages, specifically compared to the single-joint or pivot axle, are listed in the following.

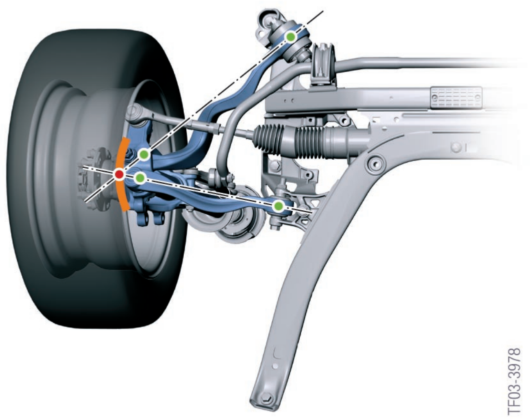


1 - E87 Front axle

Both a positive (+) as well as a negative (-) kingpin offset can be achieved by realizing the virtual "pivot axle" (also known as "spreading axle", "steering pivot" or "steering axle").



2 - Pivot axle/steering axle



3 - Double pivot spring axle/determining the lower pivot point

Initially, it was thought that a negative kingpin offset should always be selected.

However, when taking into consideration the self-stabilizing effect of a negative kingpin offset in connection with asymmetrical breaking forces, this presumption is justified only under uniform deceleration conditions (in the stationary or steady range). In the unsteady case, i.e. at the start of the breaking procedure, an implausible steering wheel movement occurs that could convey to the driver a false impression of the driving situation.

In addition, driving tests have shown that a stabilizing effect is also achieved at a small positive kingpin offset.

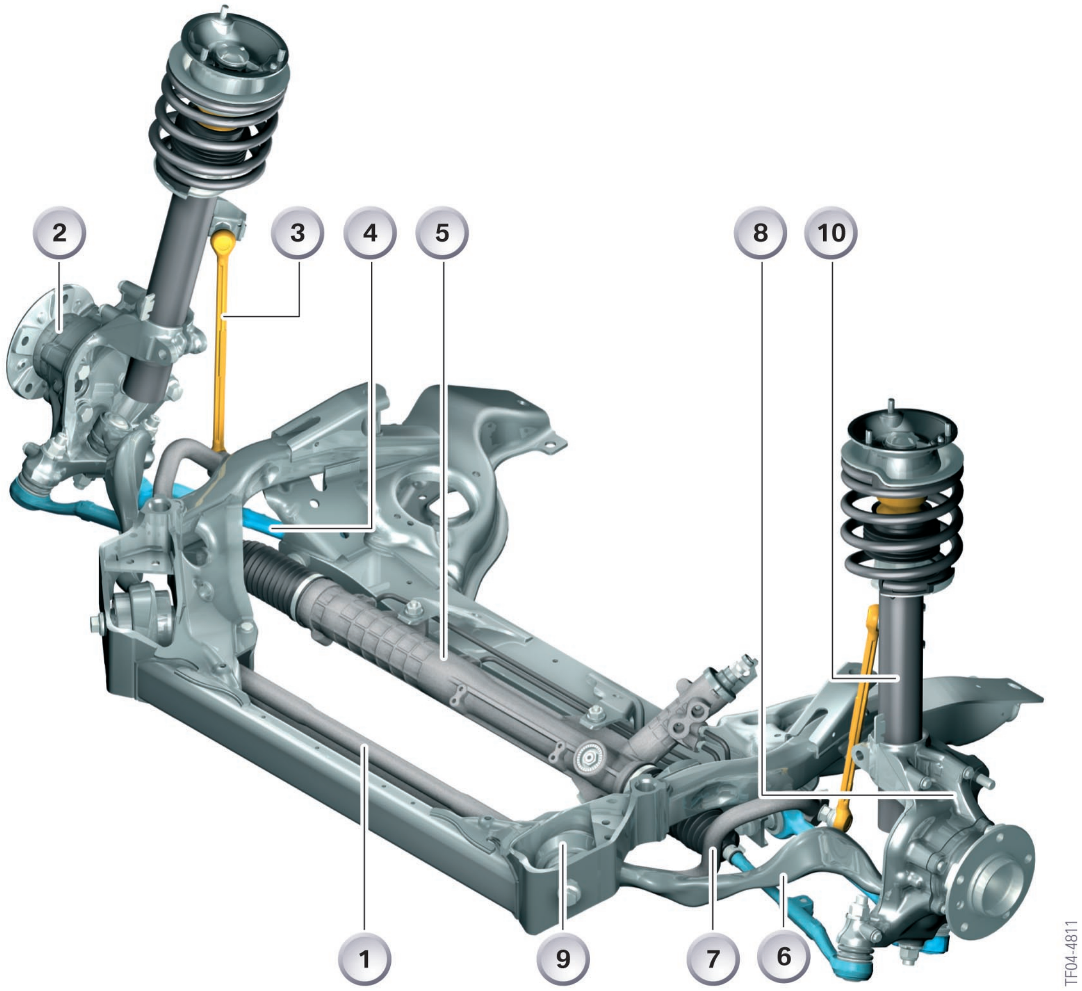
In view of the many other influencing factors such as the castor angle, moment of inertia of the vehicle, width of the tyre contact surface, etc. a fundamental explanation of this characteristic is provided.

The overall vehicle handling is also considerably more harmonious with the double pivot spring strut axle designed with slightly positive kingpin offset.

Likewise, realization of the virtual "pivot axle" has a favourable effect on the package space for the brake discs and brake callipers.

In the case of the single-joint or pivot axle, the wheel control joint is largely determined by the size of the kingpin offset. Since the kingpin offset should be as small as possible, the wheel control joint must be located as far towards the outside as possible. This however results in problems concerning the package space for the brake disc and brake calliper. On the double pivot spring strut axle the position of the control arm and tension strut with respect to each other determine the size of the kingpin offset.

The pivot points of the control arm or wishbone and tension strut at the swivel bearing can therefore be selected such that no space problems are encountered for the brake system.



4 -

Index	Explanation	Index	Explanation
1	Front axle carrier	6	Tension strut
2	Wheel hub	7	Stabilizer bar
3	Stabilizer link	8	Swivel bearing
4	Control arm	9	Hydraulic mount
5	Rack-and-pinion steering	10	Spring strut

Both tension struts are mounted with hydraulic mounts in the front axle carrier.

In addition, the distance of the tension strut and control arm pivot points at the swivel bearing largely determines the vertical force lever arm.

The greater the joints of the tension strut and control arm are from each other at the swivel bearing, the greater the weight reset force.

On the single-joint axle, the distance is generally zero as the two joints of this axle have, as it were, merged to form one. The resulting advantage of the double pivot or joint spring strut axle is improved directional stability in the high speed range and a lower tendency to steering instability in the lower sped range (insignificant for LDS).

Compared to that of the control arm, the ball joint (guide joint) of the tension strut is raised at the swivel bearing, thus providing effective anti-dive control. A further advantage of this arrangement is that this tension strut mount on the axle carrier can be arranged at approximately the same level with respect to the mounting at the swivel bearing and does not have to be lowered. This is of particular benefit to a large overhang angle. In addition, it is possible to lower the control arm mount on the axle carrier side, thus enabling a lower roll centre.

The single-joint axle features only one type of cross brace as the axle carrier.

The double pivot spring strut axle on the other hand features a frame which additionally provides significant stiffening of the front end.

Technical data

Description	Value	Description	Value
Total toe-in	14’	Kingpin offset	4 mm
Track width	1493 mm	Wheel lock	41° 22’
Camber	-12’	Wheel lock, outer	33° 29’
Kingpin inclination	13° 56’	Press-in depth	37 mm
Caster angle	7° 2’	Tyre size	185/60 R 16
Caster	19.5 mm		

E87 Rear axle

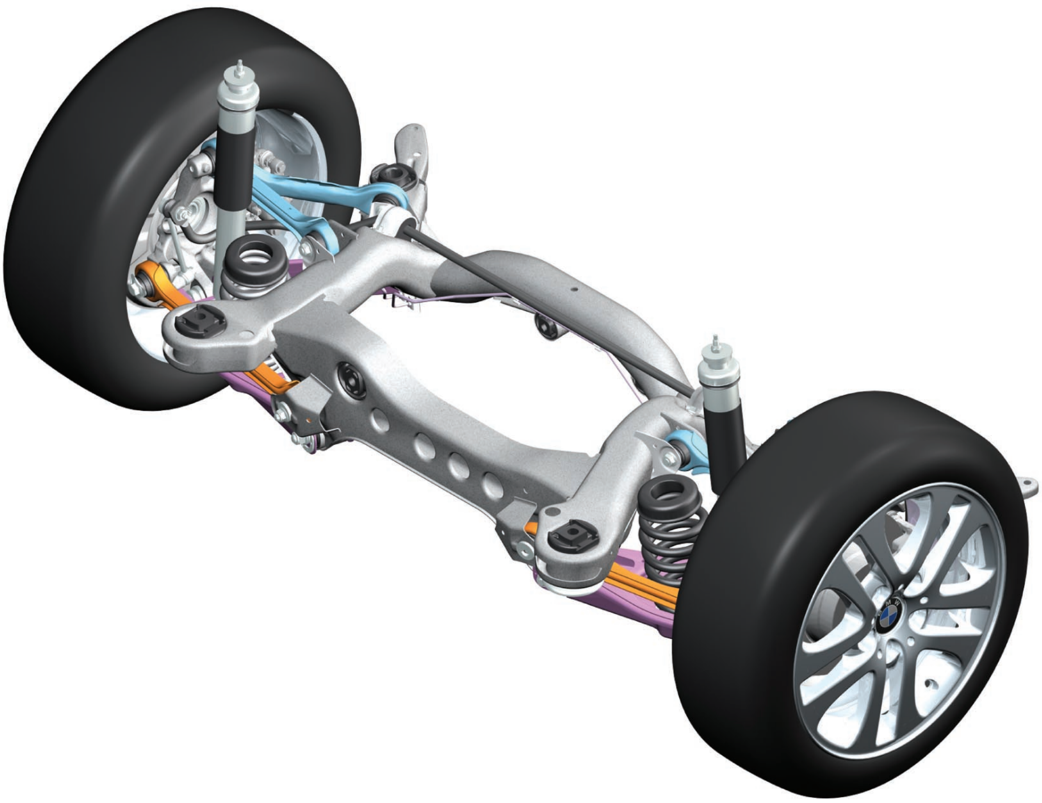
General

The newly developed rear axle with the development designation "HA 5" is used for the first time in the E87.

It is designed as a multi-link independent rear suspension axle with 5 different link arms.

The designation "HA 5" does not refer to the five links but rather represents the consecutive development designation used at BMW (see models).

Advantages



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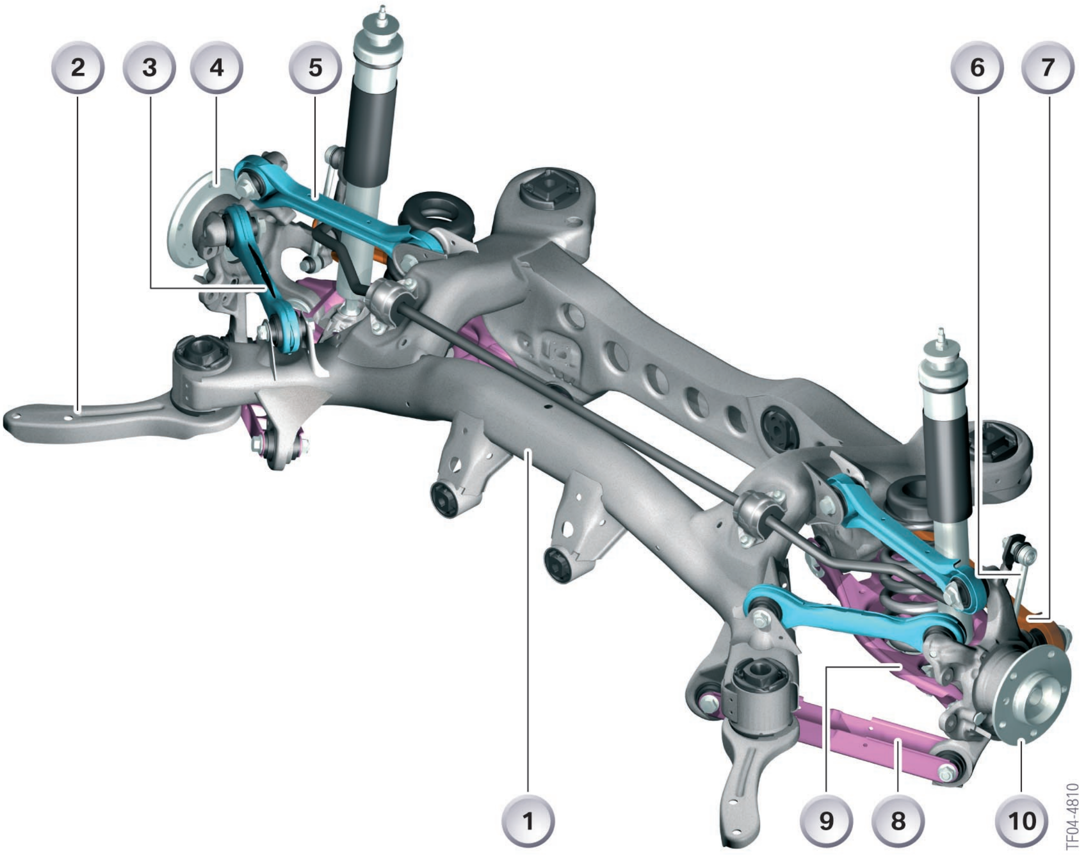
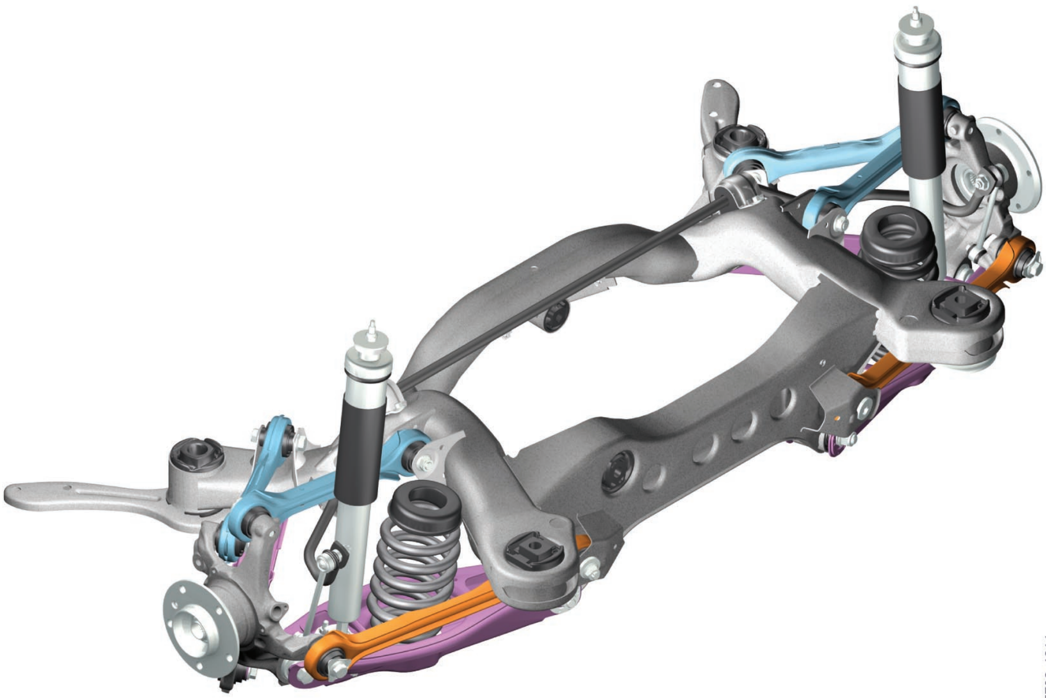
5 - E87 Rear axle

The names of the individual links are defined in the following graphic.

Components of the rear axle



Index	Description	Index	Description
1	Rear axle carrier	6	Stabilizer link
2	Thrust rod	7	Track link
3	Traction strut	8	Semi-trailing arm
4	Wheel hub	9	Camber link
5	Control arm	10	Wheel carrier



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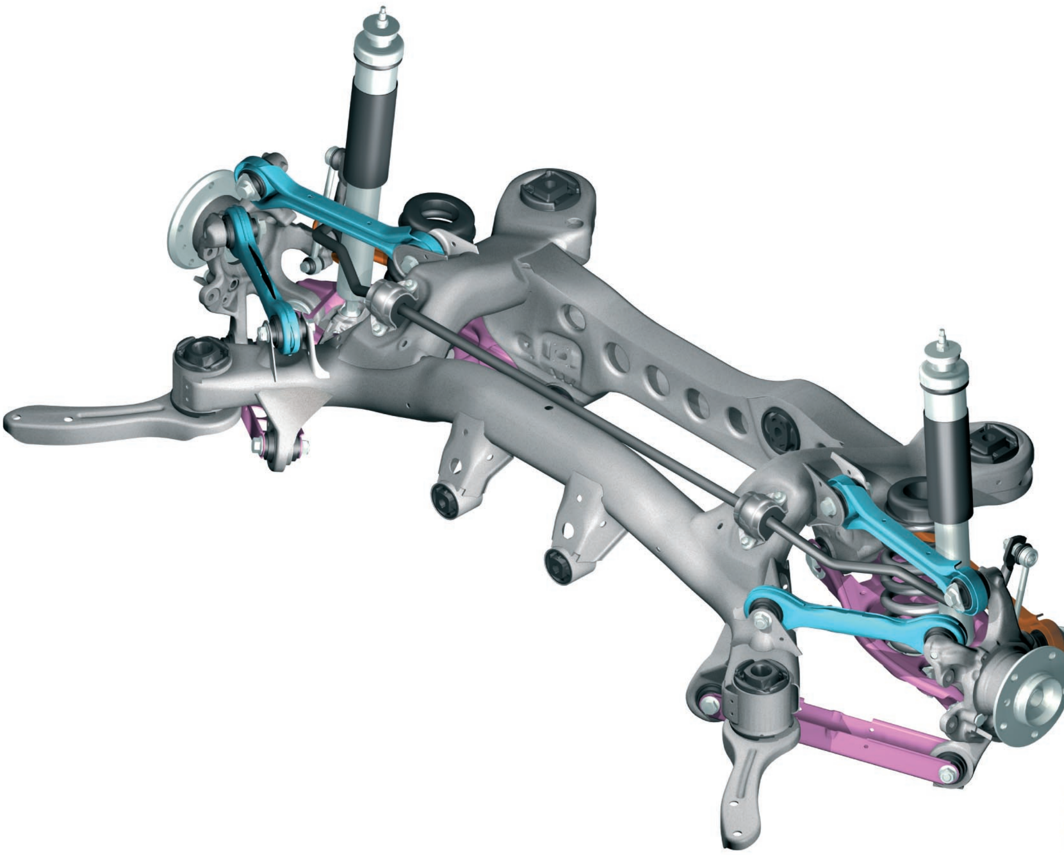
6 - Rear axle from rear left (top) and from front left (bottom)



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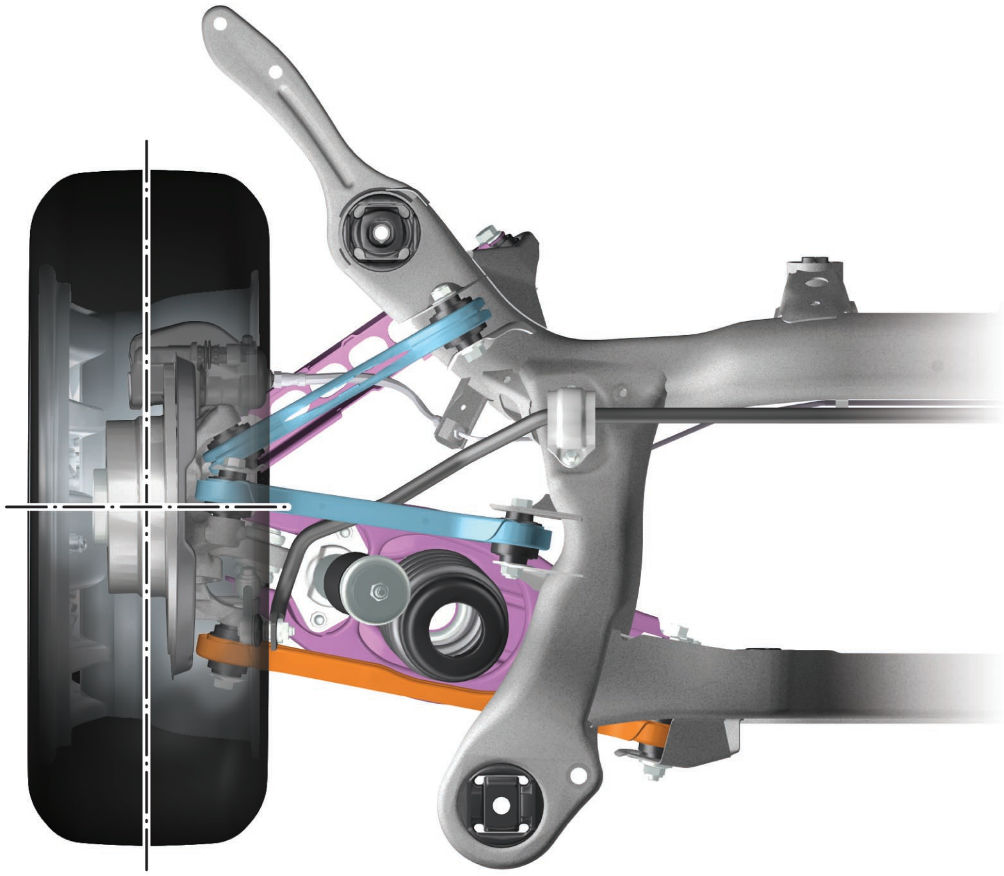
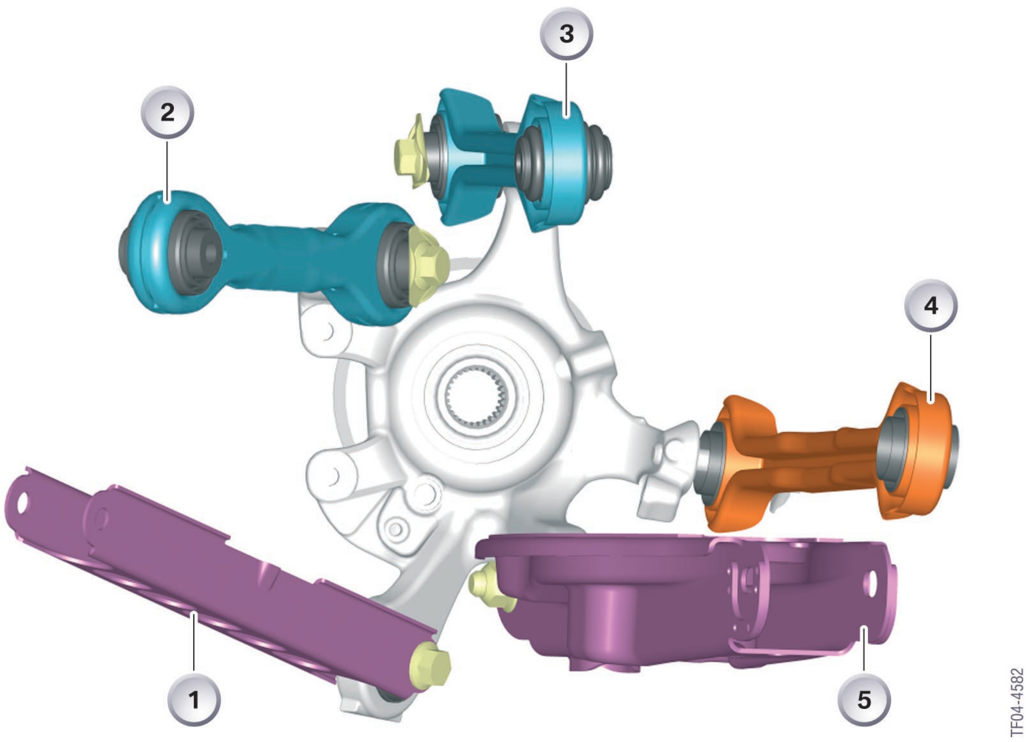


7 - Top view of rear axle, left

Various links of HA 5

The top view of the two upper links (blue in the illustration) form a triangle as do the two lower links (purple in the illustration).

The rear link (orange in the illustration) represents the track rod.



8 - Rear axle carrier from right

Index	Description	Index	Description
1	Semi-trailing arm	4	Track link
2	Traction strut	5	Camber link
3	Control arm		

Advantages of the new rear axle

The right-hand wheel carrier with the five different links of the HA 5 is shown in forward direction.

The rear axle carrier and the links are made from high strength steel. The wheel carrier is cast from GGG 40.

Compared to the previous rear axles, the HA 5 offers the following advantages:

- Manufacturing costs

The lower costs are attributed to the fact that the use of high strength steel has made it possible to reduce the wall thicknesses of the rear axle carrier and of the links.

Compared to the integral IV, a considerable saving potential has been exploited by manufacturing the entire axle from high strength steel and the HA 5 rear axle does not have an excessively high weight.

- Lightweight design

A bending moment occurs only in the camber link as the spring and damper are supported on this link. The remaining four links are not subjected to moments of force thus enabling a lightweight and rigid design.

Thanks to the straight design of the links and the connection by means of ball joints, apart from the camber link, all links transmit only tensile and compressive forces. Consequently, the wheel control with this axle is subject to only minimal elasticity and is very precise.

- Production

The HA 5 rear axle can be completely preassembled and adjusted with the brake system as well as the suspension and damping. This is a particular advantage for the production plants as it reduces cycle times.

- Kinematics

The very small positive kingpin offset guarantees insensitivity to longitudinal forces even in connection with wide tyres.

The relatively large caster ensures a defined degree of lateral force understeering and therefore obliging vehicle handling. This method of vehicle stabilization offers the fastest response and is therefore also the best.

The change in toe (see Fig. 6) as part of the suspension action enables outstanding directional stability with a relatively short wheelbase and exceptional self-steering characteristics while cornering.

The change in camber as part of the suspension action is selected such that an optimum camber with respect to the road surface is always established while cornering. Nevertheless, the change in camber during spring compression due to load is not too great as to cause increased tyre wear. As a result, new lateral force potentials are utilized together with RSC tyres.

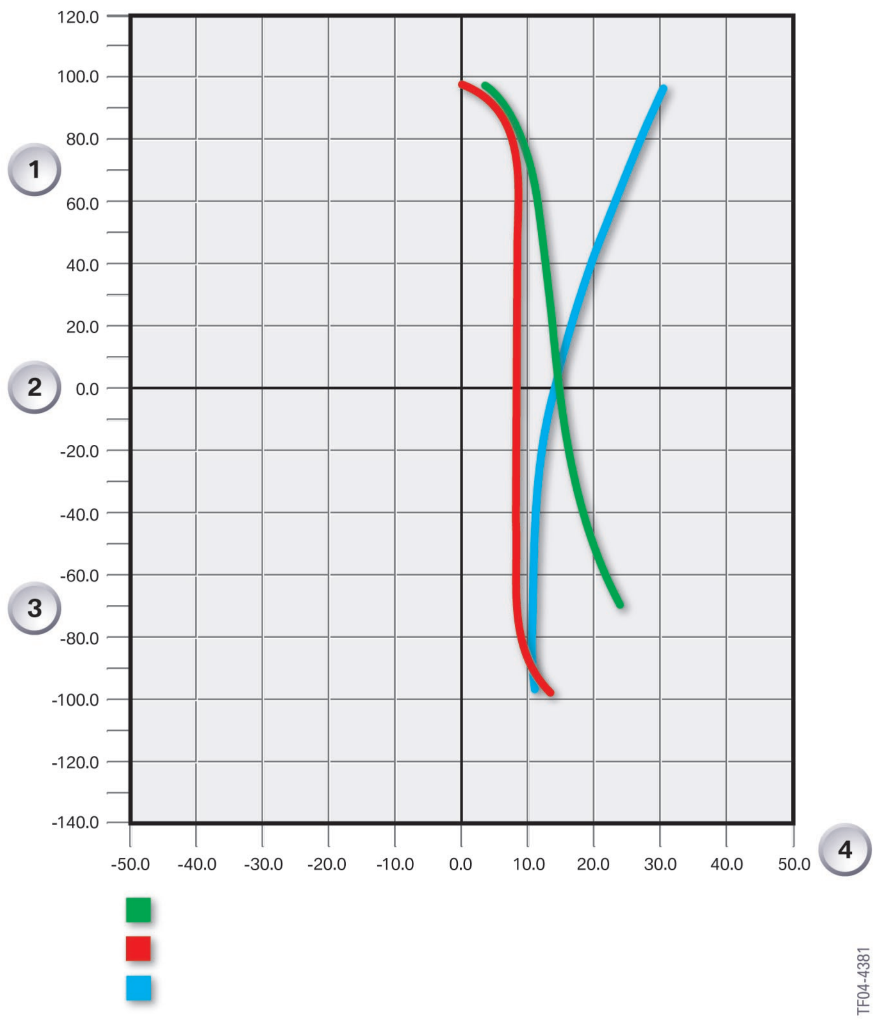
The long design of the track link makes for outstanding length tolerance insensitivity. The long track link also has a positive effect on the toe-in characteristics over the spring travel range.

The low roll centre has a particularly beneficial effect on the rolling motion.

The "propping" effect while cornering has been largely minimized by improving the roll centre change rate.

The braking support has been set to 70 %. Racing cars generally have a support angle of 0 % in order to constantly achieve maximum contact force. On these vehicles, the disadvantage of a dive motion while braking and starting off is compensated by the taut suspension. The braking support (anti-dive) realized on the E87 represents an optimum compromise between comfort, safety and driving dynamics requirements.

The use of five links enables free selection of the pivot axle for the design layout. This means that the movement of the wheel in interaction with the suspension can be optimized without compromise under braking, acceleration and lateral forces. This largely determines all important variables such as toe, camber, brake support (anti-dive) angle, roll centre and roll centre change rate.



9 - Toe characteristics over the rear axle spring range

Index	Description	Index	Description
1	Spring compression	3	Spring deflection
2	Spring travel range [mm]	4	Track [min.]
	Toe-in change over spring travel range under braking force		Toe-in change under spring compression and deflection without force
	Toe-in change over spring travel range under lateral force		

- Crash requirements

The body side member had to be cranked to a relatively large extent in connection with the semi-trailing arm and central link axle. This brought about disadvantages in connection with a rear end impact. In contract, the HA 5 rear axle permits a considerably more favourable progression of the side member, resulting in specific advantages particularly at low impact speeds.

Added to this, the large rear axle carrier is connected directly t the rigid frame side member, allowing it to transmit the applied crash forces more favourable.

The semi-trailing arm features crash beading (in the semi-trailing arm of the HA 5 rear axle, see Fig. 5) to ensure the fuel tank is not damaged under any circumstances.

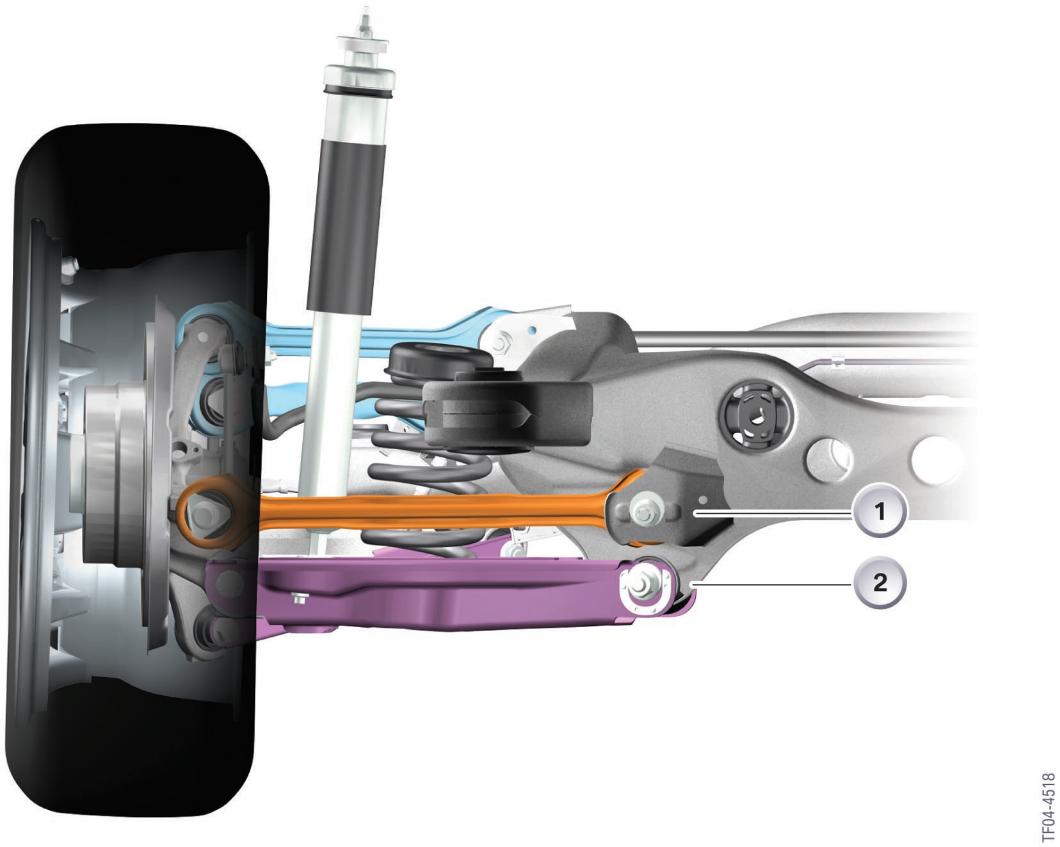
- Rigidity/acoustics

The rear axle carrier of the HA 5 rear axle extends up to the rigid frame side members of the body with its axle mounting points and even up to the sill with its thrust rods. This provides a very large support face for the applied forces and moments. The resulting advantages include, on the one hand, considerably lower stress and strain on the body (rear axle break-away) and, on the other hand, the option of designing the rear axle bearing mounts, which are wide apart, relatively soft. This arrangement and the double flexible mounting provide outstanding insulation against road noise and tyre rolling noise.

Technical data

Description	
Wheelbase	2660 mm
Track width	1507 mm
Press-in depth	37 mm
Tyre radius (static)	291 mm
Total toe-in	18’
Camber	-1° 30’

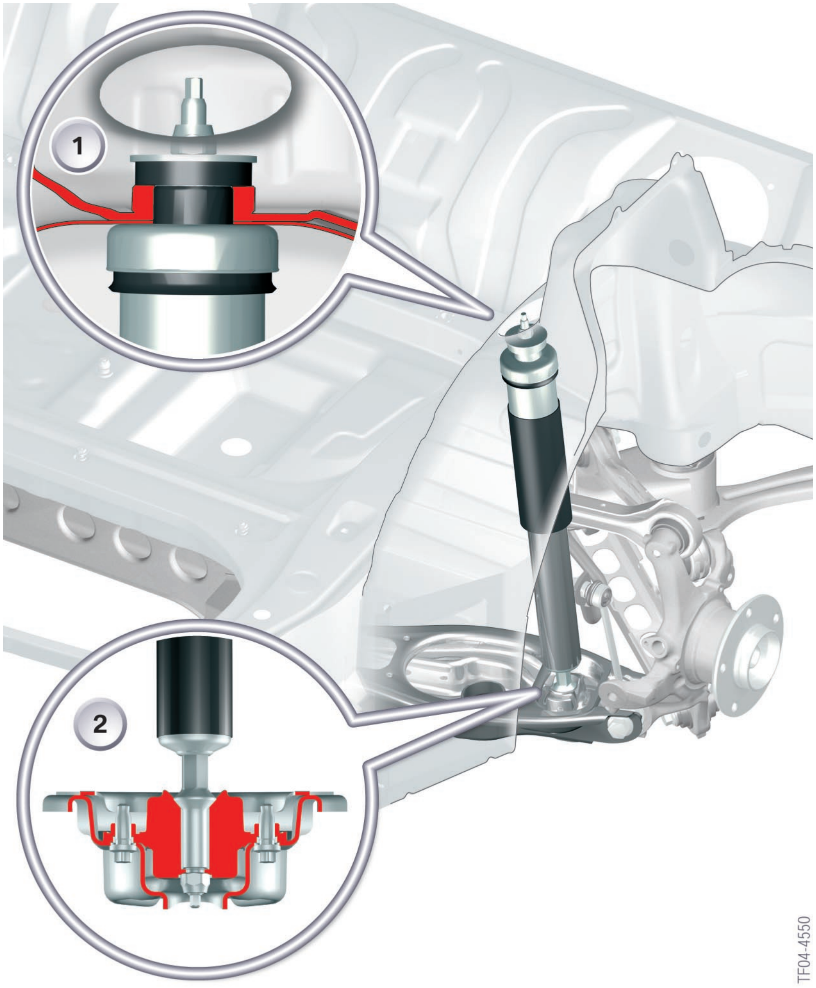
Setting



10 - Track and camber settings (rear view)

Index	Description
1	Track adjusting screw
2	Camber adjusting screw

Suspension and damping



11 - Damper

Index	Description
1	Mount
2	Pin joint

The rear damper (shock absorber) on the E87 is connected in a new way to the chassis. The mount (1) has a central nut and the lower pin joint represents a new design at BMW. This arrangement provides great advantages in assembly (only one nut) and in production.

The E87 will also be offered with the option SA 226 "Sports suspension settings" as well as SA 8SD "Sump guard" (in certain country-specific variants).

Electric steering lock

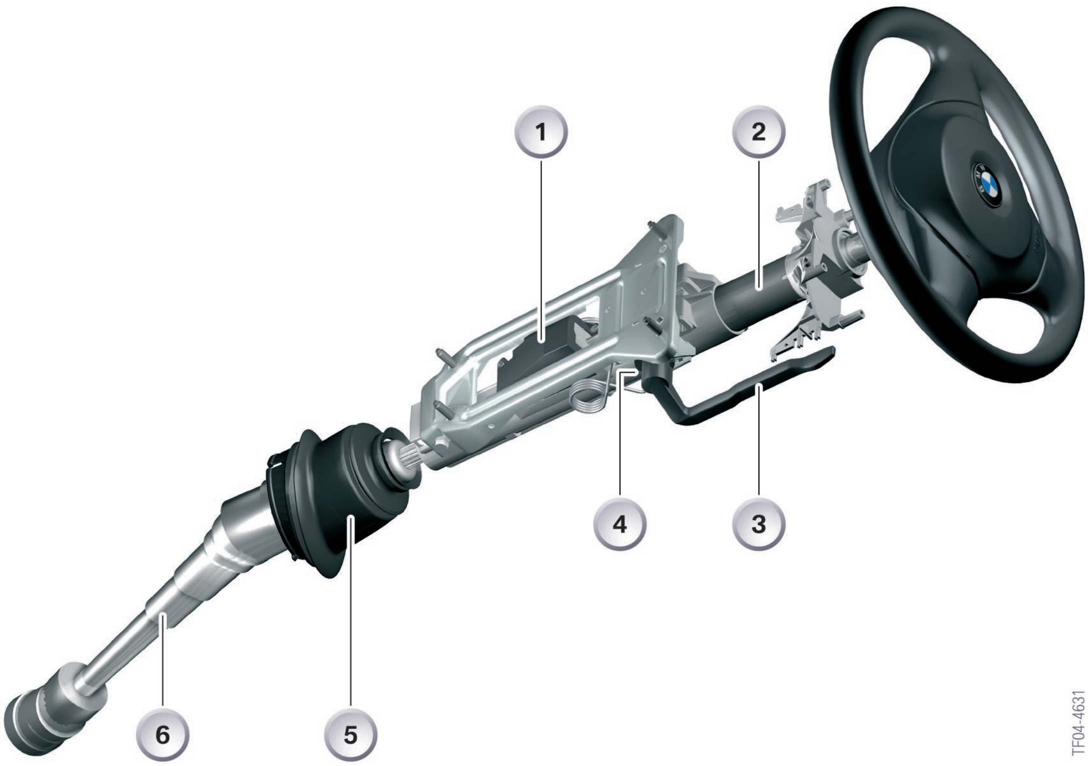
History

Electric steering lock (ELV)

Differing from the E65 that is not equipped with a conventional steering wheel lock, for the first time, the "steering wheel lock function" will be realized by an electric steering lock (ELV) on the E87. The E65 is equipped exclusively with automatic transmission and electromechanical parking brake and therefore sufficiently protected against theft. The complete system in the E87 consists of a start-stop button, remote control, the comfort access control unit (CAS) and the electric steering lock (ELV).

System and functional description

Together with the electric steering lock facility (ELV), the steering column forms one component and may only be replaced as a complete unit. The ELV in turn consists of an electronic and a mechanical part.



12 - Steering column assy

Index	Description	Index	Description
1	ELV	4	Catch for steering wheel adjustment
2	Crash element	5	Steering sleeve
3	Adjusting lever	6	Steering shaft

Electronic part of the ELV

Both ground and a 12 Volt voltage are applied to the 3-pin plug connection. A K-bus line from the CAS supplies the necessary communication telegram to the ELV. The CAS monitors the various driving or standstill situations of the vehicle and is therefore also the control unit that triggers the unlocking (release) or locking action in the ELV. Generally, no power is applied to the ELV when the vehicle is not stationary.

Mechanical part of the ELV

A locking lever with its position monitored by a sensor and a locking pin are the main components of the mechanical part designed to lock or unlock the steering column at the correct moment. The entire internal kinematic structure is designed such that a mechanical lock (locking lever) keeps the unlocked locking pin in position when no power is applied to the ELV.

Advantages of the ELV:

- Remote control as on the E65 in the form of a "bitless key"
- High 2-fault security (an electronic and mechanical fault must occur simultaneously) in accordance with DIN Standard SIL3
- No steering wheel lock in knee impact area.
- The E87 can also be equipped with the comfort access option.

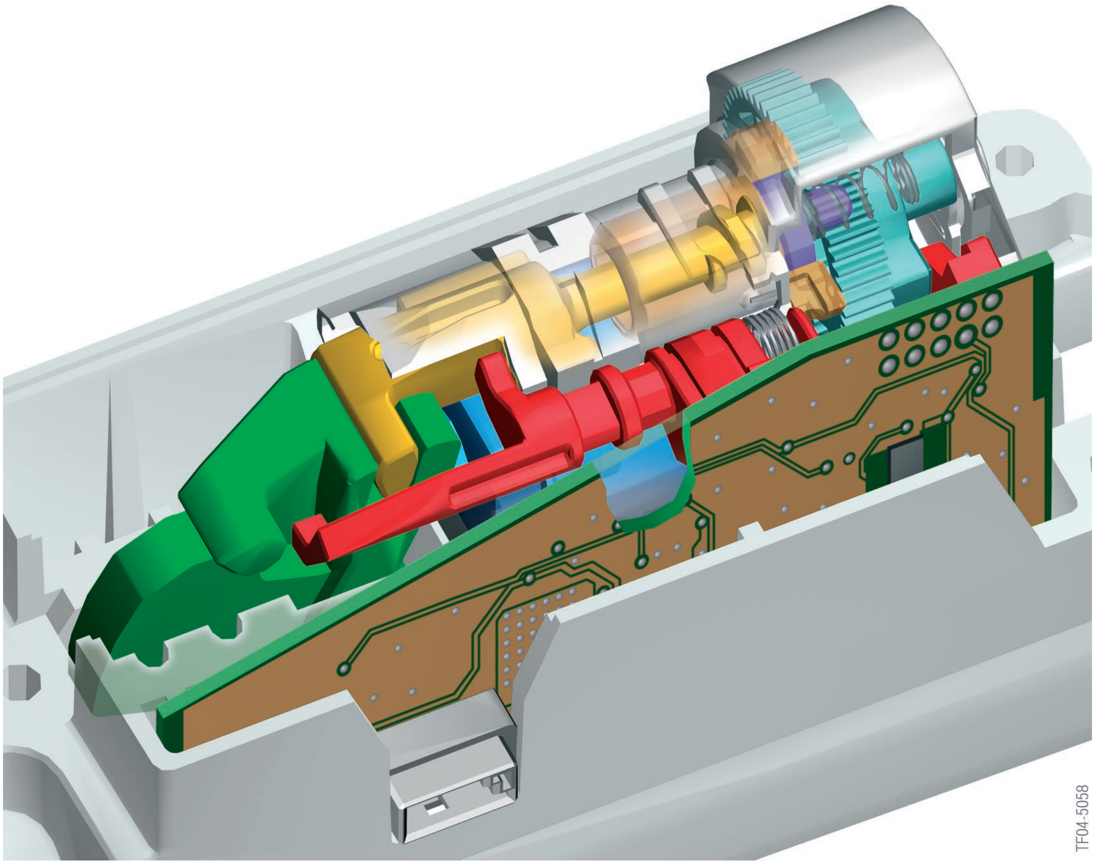
The 46 featured an infinitely variable clamp connection for the steering wheel up/down and in/out adjustment. An extremely closely-stepped catch connection is used on the E87.

The adjustment range has been extended and the user friendliness increased. The new adjustment unit now supports the airbag and the steering column. The upper area of the steering column and an integrated crash element (metal tube) are designed as load-bearing parts.

The metal tube is pre-perforated in a defined longitudinal area at the upper end of the steering column. In the event of an impact, this metal tube begins to crack at the predefined points. This perforation is required for the purpose of converting energy in the event of an impact.

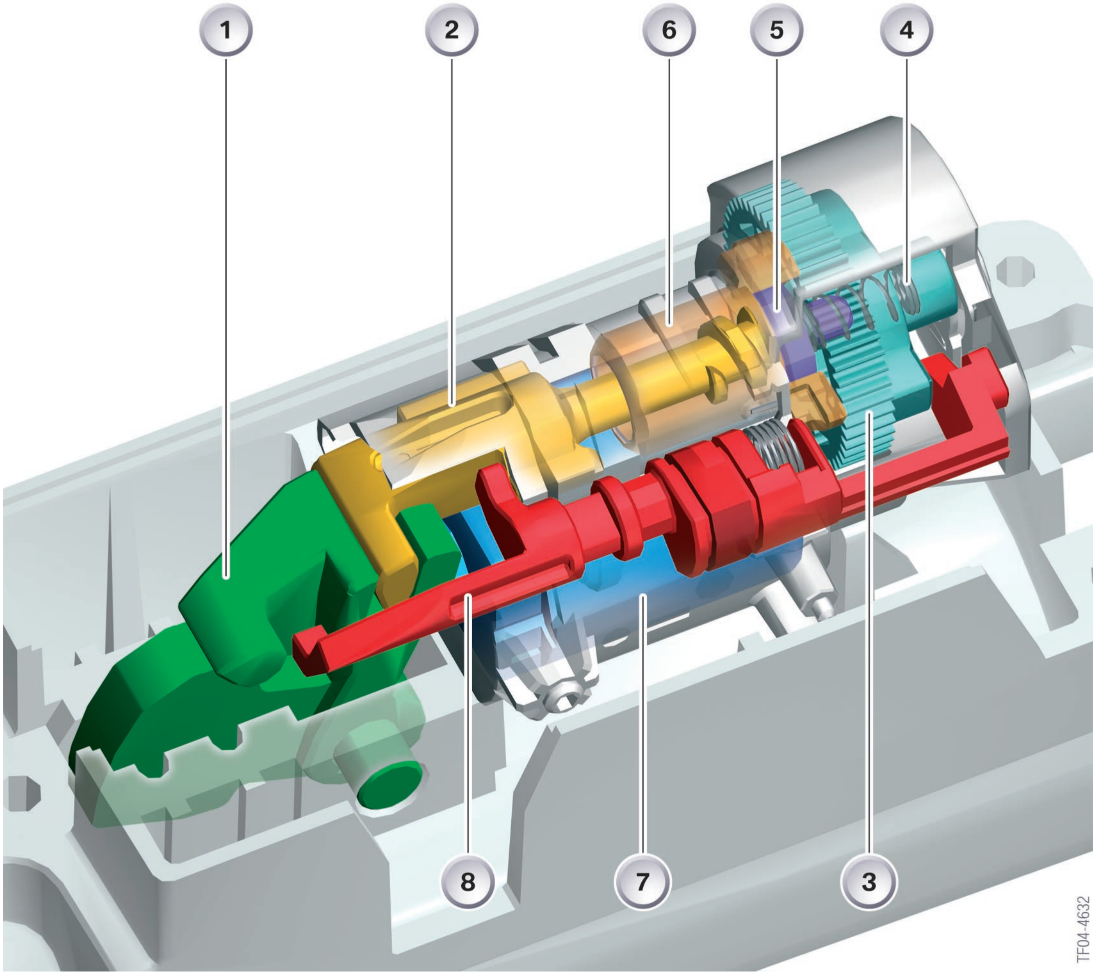
The steering column must always be replaced after an airbag has triggered or the steering shaft is replaced!

The steering shaft sleeve or collar is also new on the E87. On the E46, this collar was held in position by the pedal assembly. The new collar is connected in the bulkhead and is double-sided. This arrangement results in a lower reset force for the steering column height adjustment.



13 - ELV assy without cover (opened)

In the following, the ELV is shown without the electronics and only the mechanism is explained.

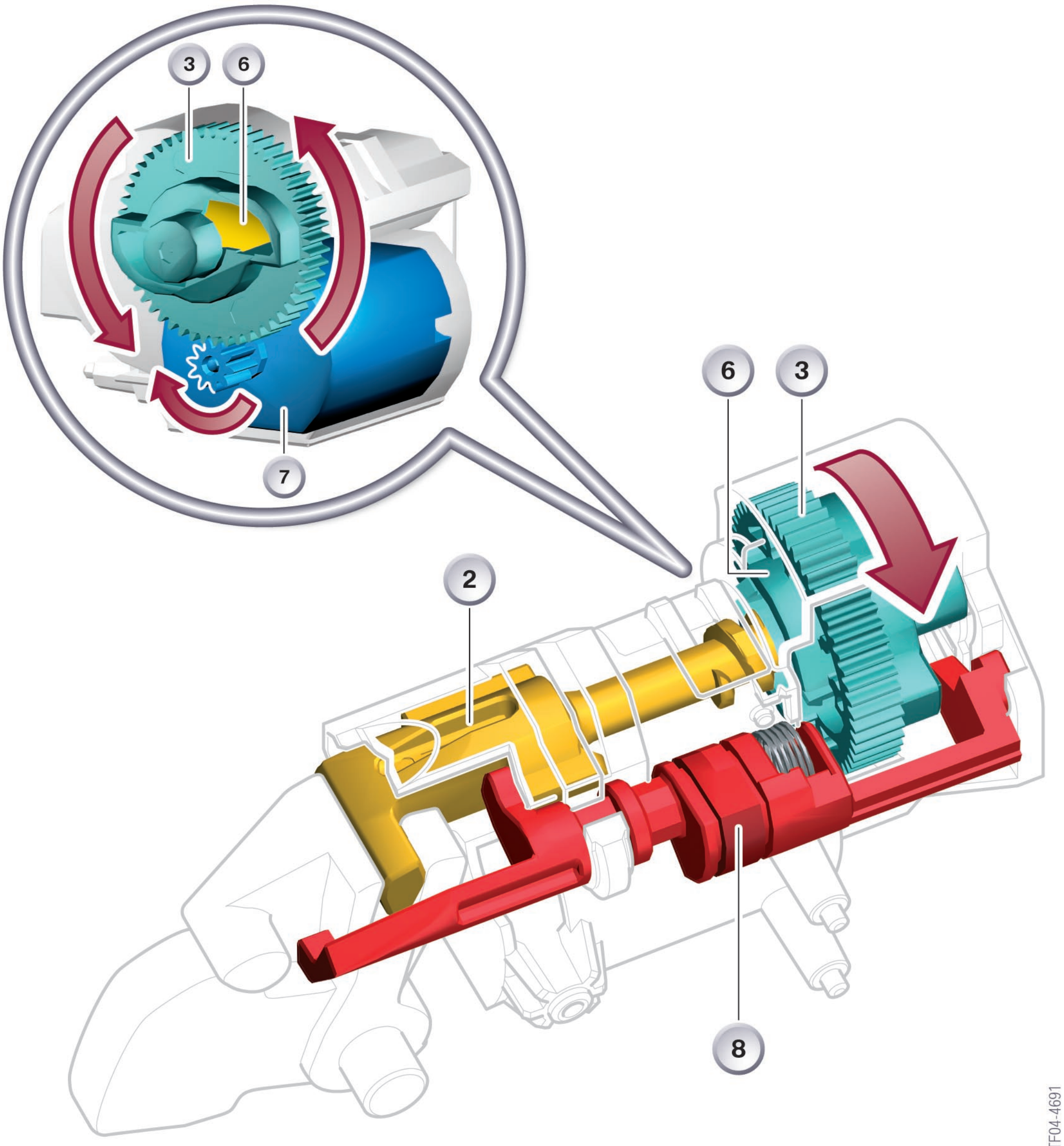


14 - ELV mechanism

Index	Description	Index	Description
1	Locking pin	5	Pressure plate
2	Driver with worm	6	Nut
3	Gearwheel with control contour	7	Electric motor with pinion
4	Spring	8	Locking lever

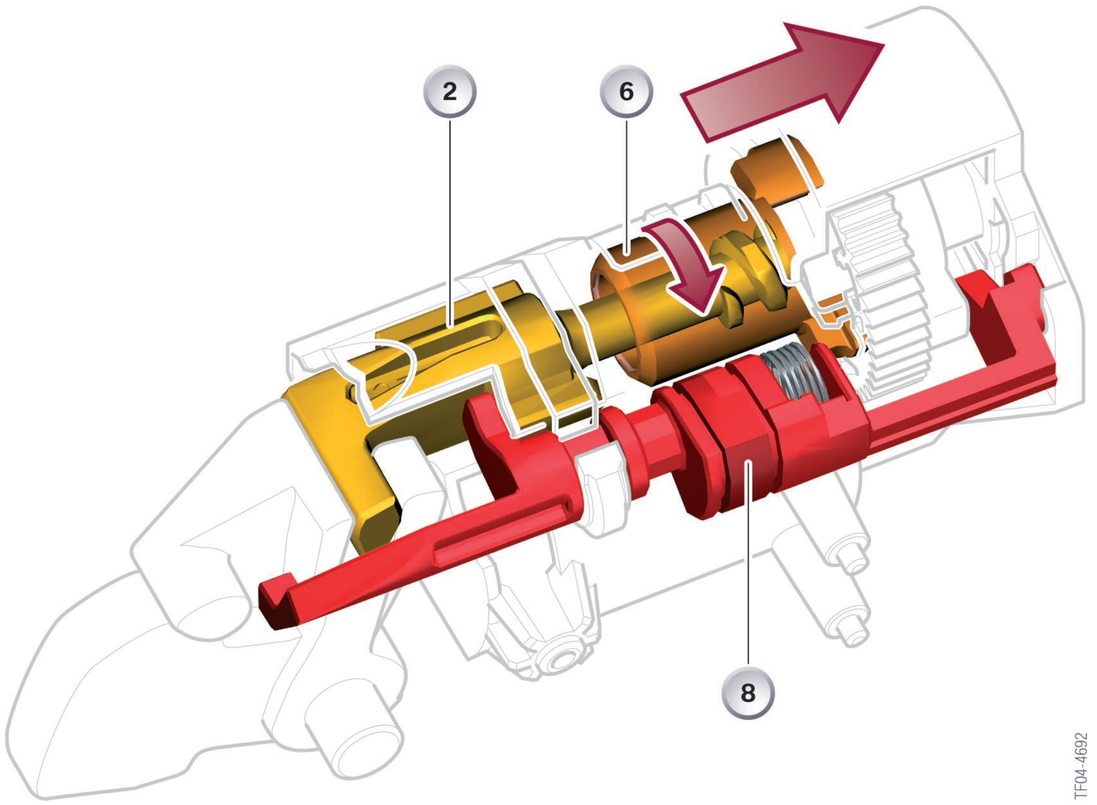
As on the E60, the steering wheel is coded to avoid confusion. The steering shaft no longer has a flexible coupling and is available in a right-hand drive version (stainless steel corrugated tube) and left-hand drive version (aluminium/steel telescopic tube).

Locking procedure



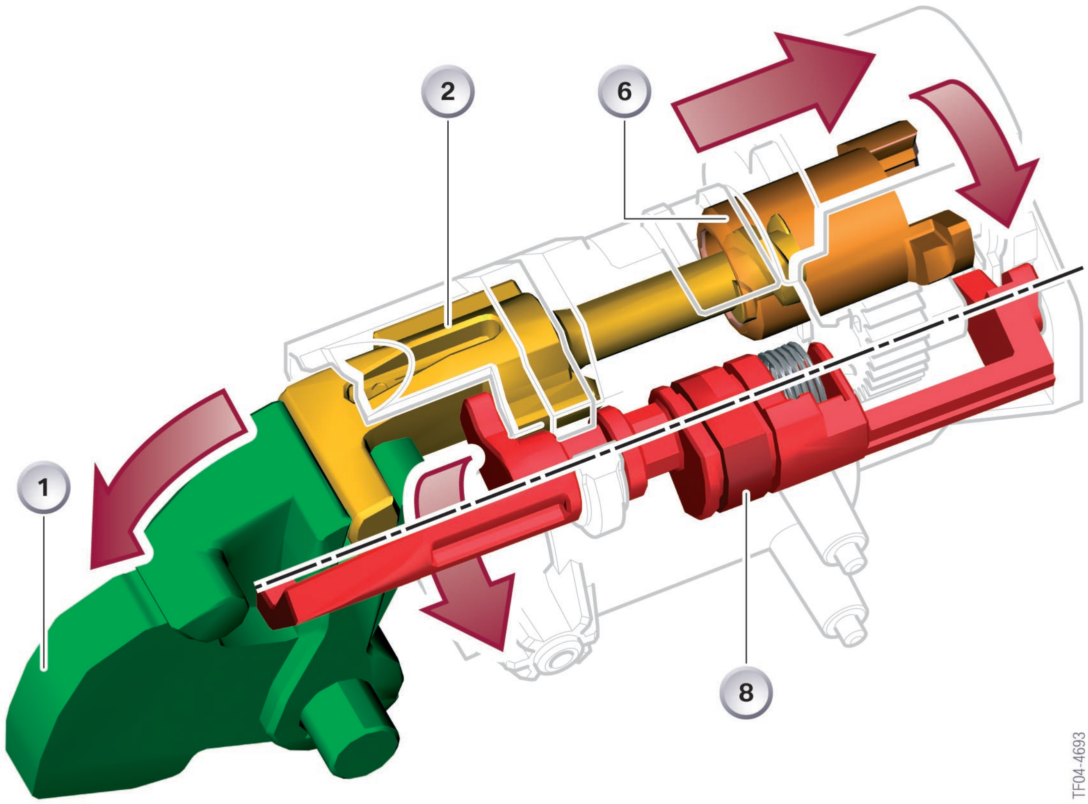
15 - ELV mechanism

From the "unlocked" position, the electric motor (7) begins to turn the gearwheel with control contour (3) and the reclined mechanism. The drive carrier with worm gear (2) is blocked by the locking lever (8). The reclined nut (6) now begins to rotate.



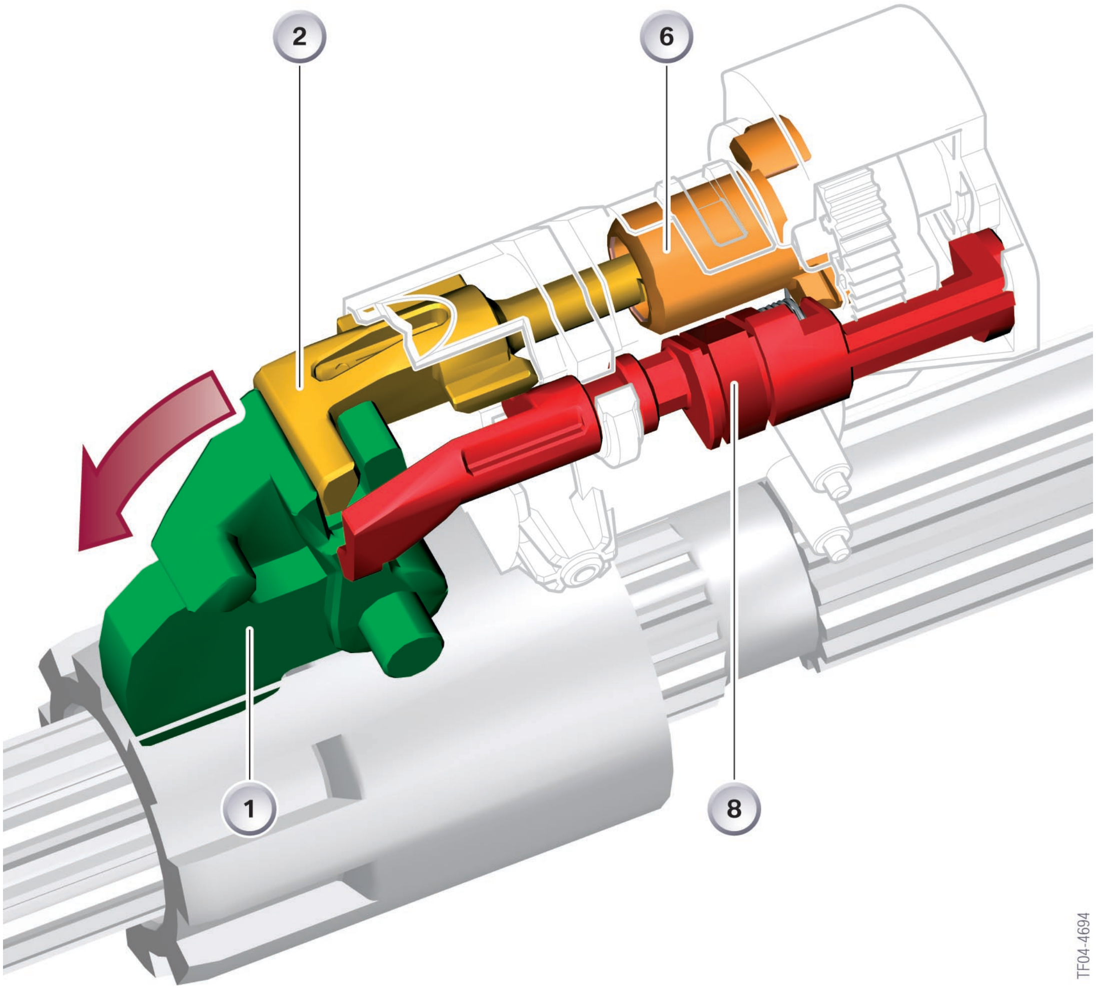
16 - ELV mechanism

The nut (6) moves on the worm towards the locking lever (8).



17 - ELV mechanism

The locking lever (8) is now rotated by the control contour so that the drive carrier with worm (2) and locking pin (1) snap in position.



18 - ELV mechanism

The locking pin (1) is snapped in with the mechanism in the locked position. The locking lever (8) rests on the drive carrier.

Adaptation of the dynamic driving systems

Introduction

DSC MK 60 PSI

The well-known MK 60 PSI supplied by Continental Teves is used on the E87. On the E46 and E85, two pressure sensors are installed on the master brake cylinder. The DSC PSI in the E87 features a double sensor with plausibility monitoring in the hydraulic unit. Consequently, it has been possible to dispense with the two pressure sensors on the master brake cylinder that provide the DSC with a signal relating to the brake pressure exerted at the pedal.

Traction control systems

Basis ABS/ASC Kamm's circuit

Traction control systems

DSC General

ABS		Anti-lock braking system
	EBV	Electronic brake power distribution
	CBC	Cornering brake control (counteracts drift)
	DBC	Dynamic brake control (MBC/DBC)
ASC		Automatic stability control
	MMR	Engine torque control
	MSR	Engine drag torque control
	BMR	Braking torque control
DSC		Dynamic stability control
	GMR	Yaw moment control
	SDR	Overrun differential control (in E46 since 09/01)
	DTC	Dynamic traction control

Both pressure sensors on the master brake cylinder of the E87 have been dispensed with.

The sensor in this system (in the DSC module, not replaceable) is designed as a double sensor and operates on the basis of plausibility monitoring.

The yaw rate sensor is located under the driver's seat!

On the E87, the wheel speed sensor consists of: a multipole wheel - (behind a stainless steel cover) - magnets in the pole wheel - i.e. larger air gap. It operates in accordance with the magnetoresistive principle.

A brake wear indicator is integrated in the DSC MK60PSI, i.e. same as on the E65, E60 DSC 8.0

The DSC sends a standstill signal and a reverse identifier signal to the electric steering lock (ELV) and the CAS. The bus protocol and the PT-CAN and F-CAN structure are identical. A second bus connection (F-CAN) was necessary as the PT-CAN no longer had spare capacity.

In contrast to the E60, the wheel sensors on the E87 provide no standstill identification and no direction of rotation identification.

The ELV and CAS, however, require this information that is therefore made available by the DSC in the form of a frequency:
10 Hz = Stationary (standstill)
50 - 55 Hz = Not stationary (not standstill) [as from 4 km/h]

You will find further information on the steering column switch cluster with steering angle sensor under: "General Vehicle Electrical System Part 2".

Summary

Electric steering lock

► Together with the electric steering lock (ELV), the steering column forms one component and may only be replaced as a complete unit. ◄

Abbreviations

ABS	Anti-lock braking system
ELV	Electric steering lock
LDS	Torsional steering wheel vibrations

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