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F01 Lateral Dynamics Systems

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Lateral Dynamics Systems

Model: F01/F02

Production: From Start of Production

OBJECTIVES

After completion of this module you will be able to:

- Understand the operation new Integrated Active Steering
- Locate and identify components of the Integrated Active Steering
- Understand the interaction of IAL with Integrated Chassis Management

Introduction

BMW Steering Systems - Innovative and technically always something special!

Since the introduction of the first EPS electric power steering system on the E85 in 2002, the variety of technical innovations on steering systems has rapidly expanded. Before then the following systems were used:

- Hydraulic power steering
- Speed-sensitive power steering (Servotronic)

The next major step with steering systems then came with the E60 and the revolutionary Active Steering system, which not only had the Servotronic function but also incorporated speed-sensitive modulation of the steering angle.

BMW also improved the electric power steering (EPS) system and used it in a variety of forms.

The main difference between hydraulic and electric power steering is in the method of generating the power assistance force that reduces the amount of force that the driver has to apply to the steering wheel.

In order to further inventively optimize the advantages of Active Steering on the new 7 Series, **Integrated Active Steering** has now been developed and is described in this document.

Current BMW Steering Systems

Model Series	Standard steering systems	Optional steering systems
1-Series (E8X)	Hydraulic power steering	Active Steering
3-Series (E9X)	Servotronic	Active Steering
5-Series (E60)	Servotronic	Active Steering
6-Series (E63/E64)	Servotronic	Active Steering
7-Series (E65/E66)	Servotronic	N/A
X3 (E83)	Hydraulic power steering	Servotronic
X5/X6 (E70/E71)	Hydraulic power steering	Active Steering
Z4 (E85/E86)	C-EPS	N/A
Z4M (E85/E86)	Hydraulic power steering	N/A

EPS = Electric Power Steering
C-EPS = Column mounted EPS

System Overview

Integrated Active Steering

General Details
Integrated Active Steering is an innovative and logical development of the Active Steering system developed by BMW.

With Active Steering, a steering angle amplification factor reduces the steering effort on the part of the driver and combines the capabilities of “steer by wire” systems with authentic steering feedback.

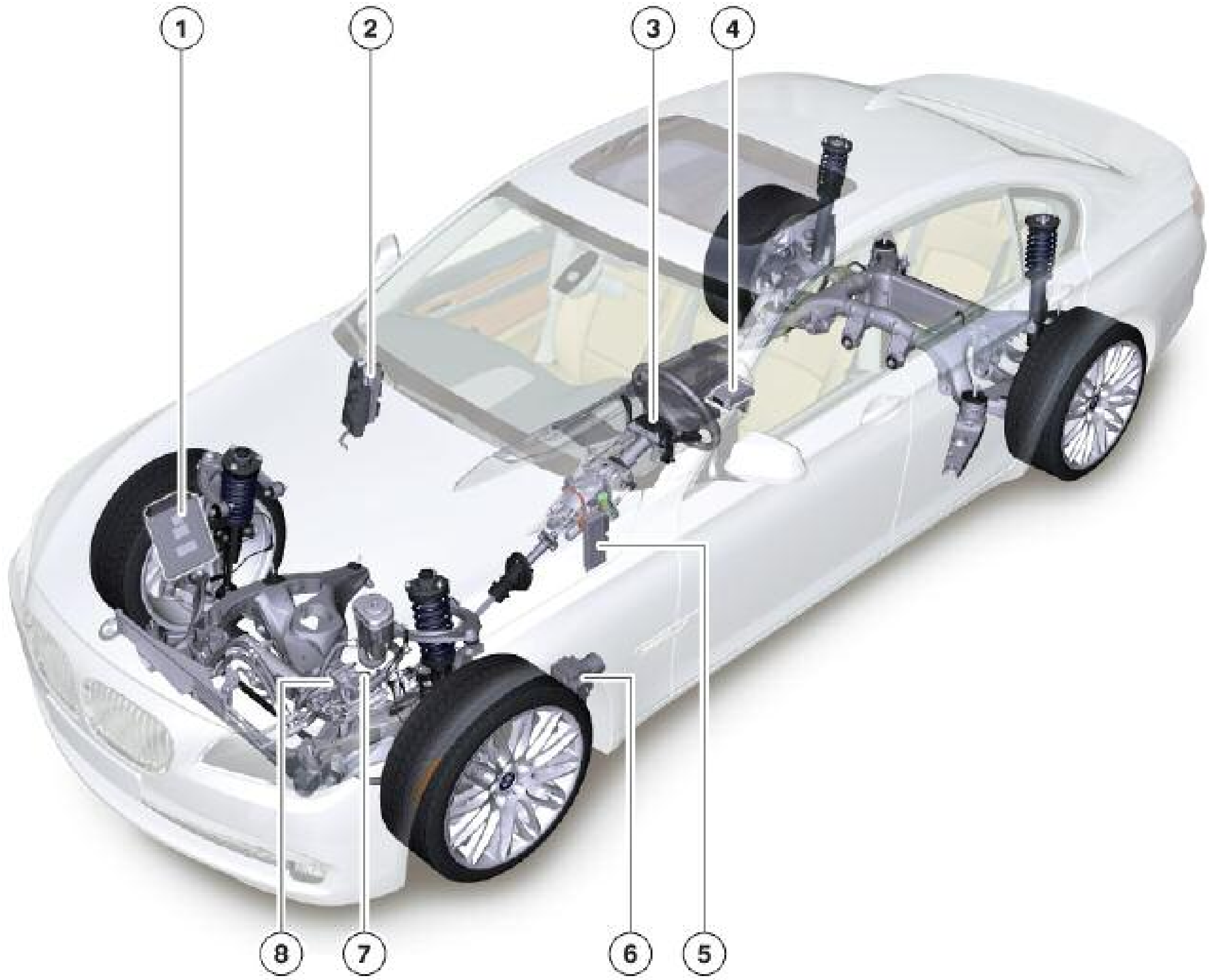
By intervening in the steering independently of the driver’s actions, it is also able to perform a stabilizing function in terms of vehicle handling.

In order to move further ahead in terms of handling dynamics, the familiar Active Steering has now been logically extended by the addition of active rear-wheel steering on the new BMW 7 Series.

Active Steering of the rear wheels is a logical extension of Active Steering and the two are now combined as an all-in one system referred to as Integrated Active Steering.

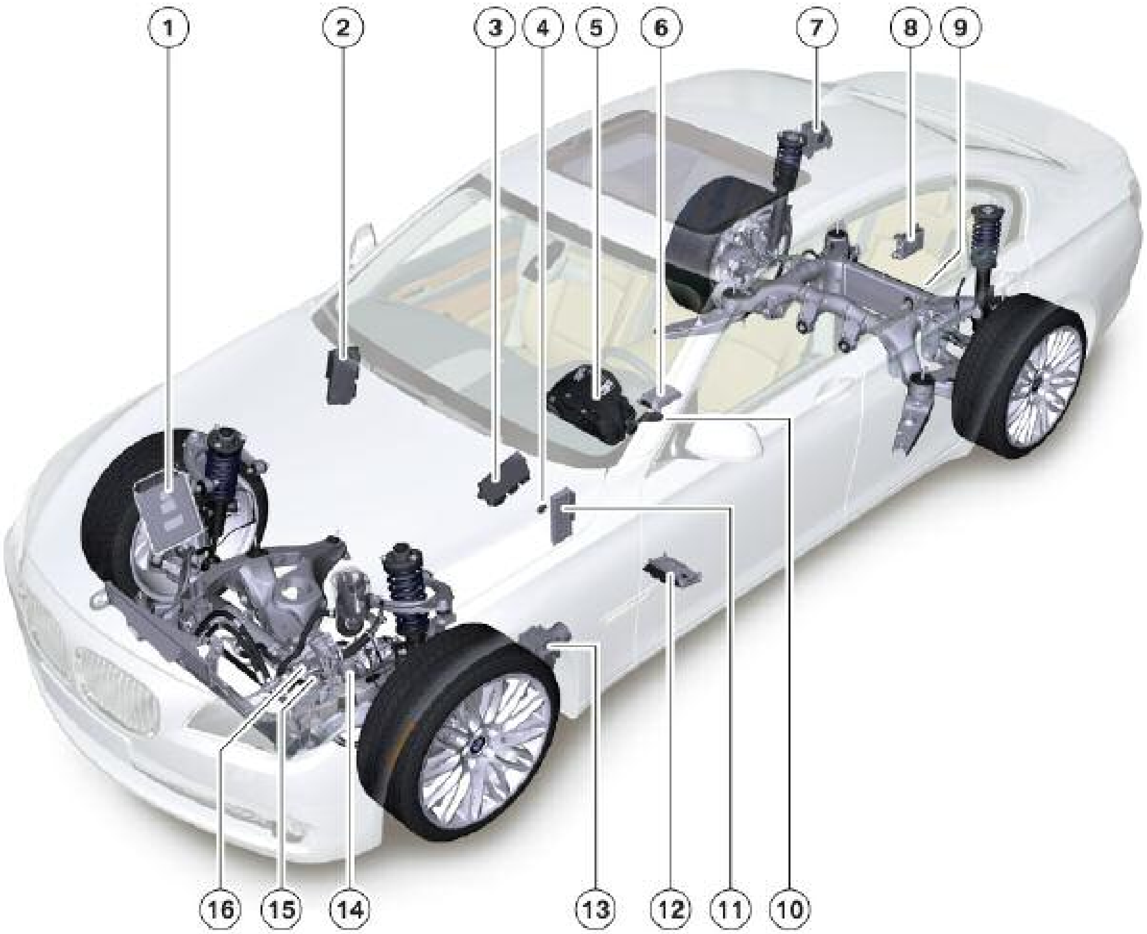
Integrated Active Steering is available as an option on the F01/F02 because the standard steering system is the Servotronic.

Components of Servotronic Steering (standard)



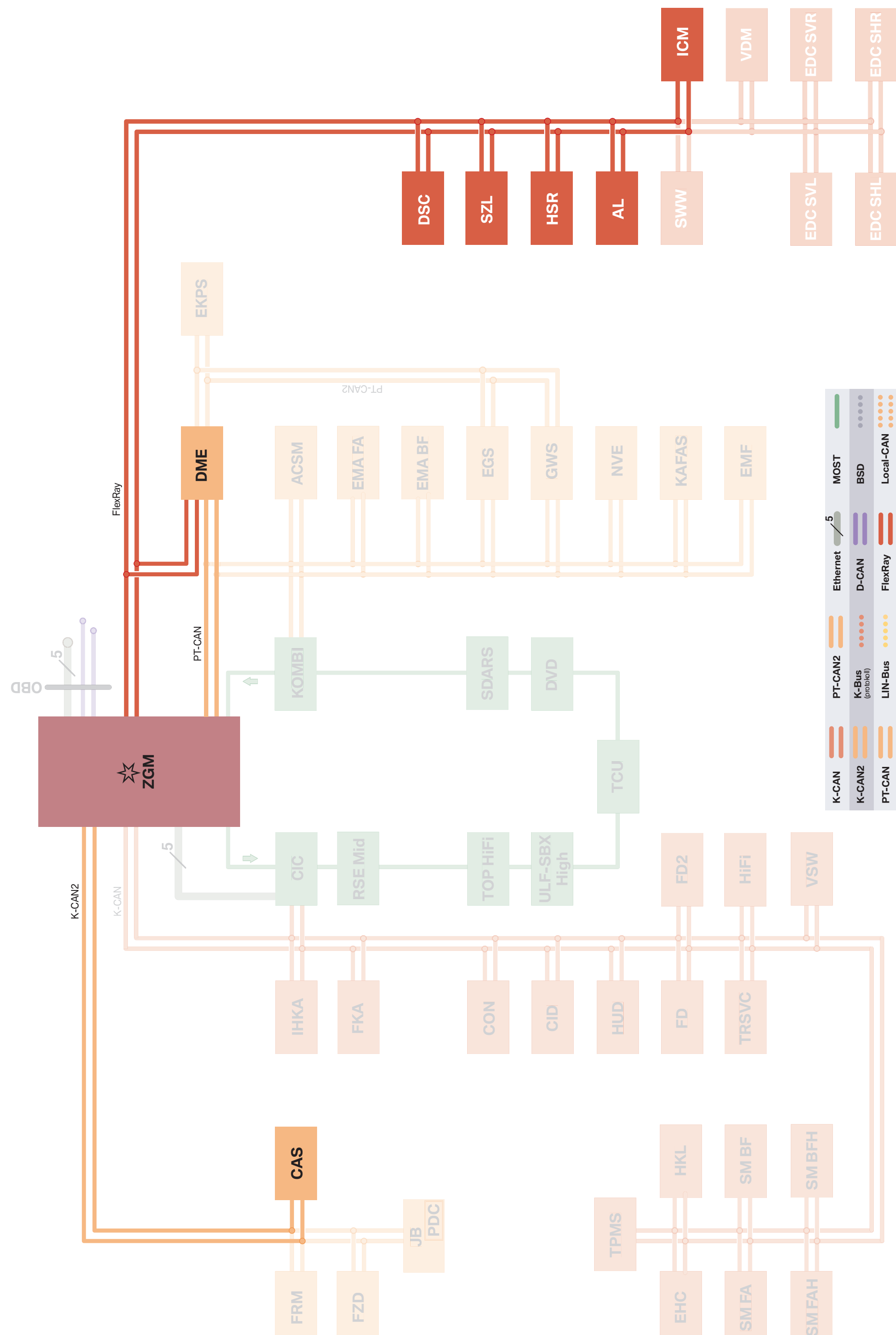
Index	Explanation	Index	Explanation
1	DME	5	ZGM
2	Front power distribution box	6	DSC
3	SZL	7	Servotronic valve
4	ICM	8	Electronic volumetric flow control (EVV) valve

Components of Integrated Active Steering



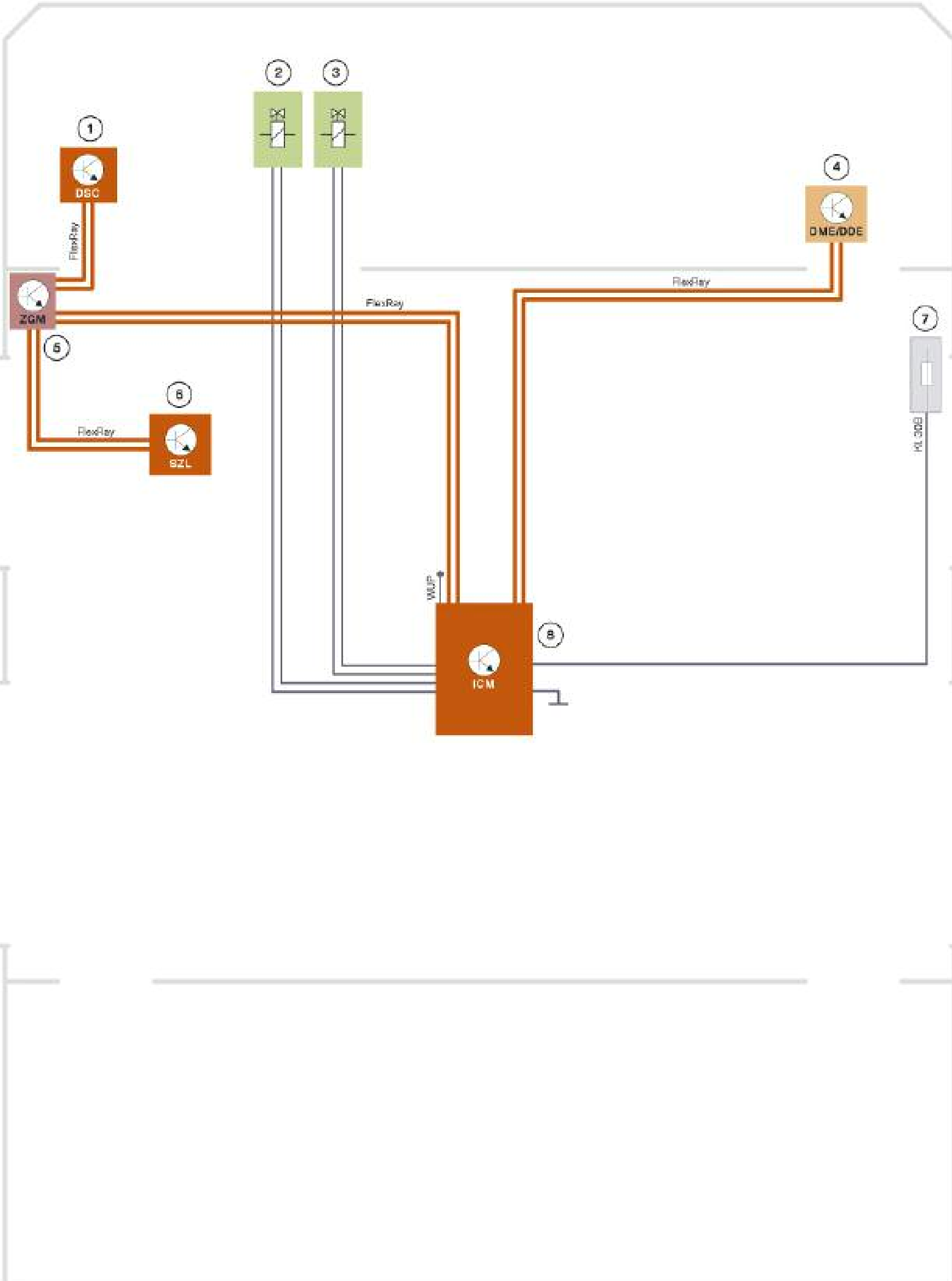
Index	Explanation	Index	Explanation
1	DME	9	Rear-wheel steering actuator (HSR)
2	Front power distribution box	10	SZL
3	CAS	11	ZGM
4	Brake light switch	12	Active Steering actuator control unit
5	Instrument cluster	13	DSC
6	Integrated Chassis Management (ICM)	14	Active Steering actuator motor with motor angular position sensor and lock
7	Rear power distribution box	15	Electronic volumetric flow control (EVV) valve
8	HSR control unit	16	Servotronic valve

Bus Diagram for Lateral Dynamics Systems



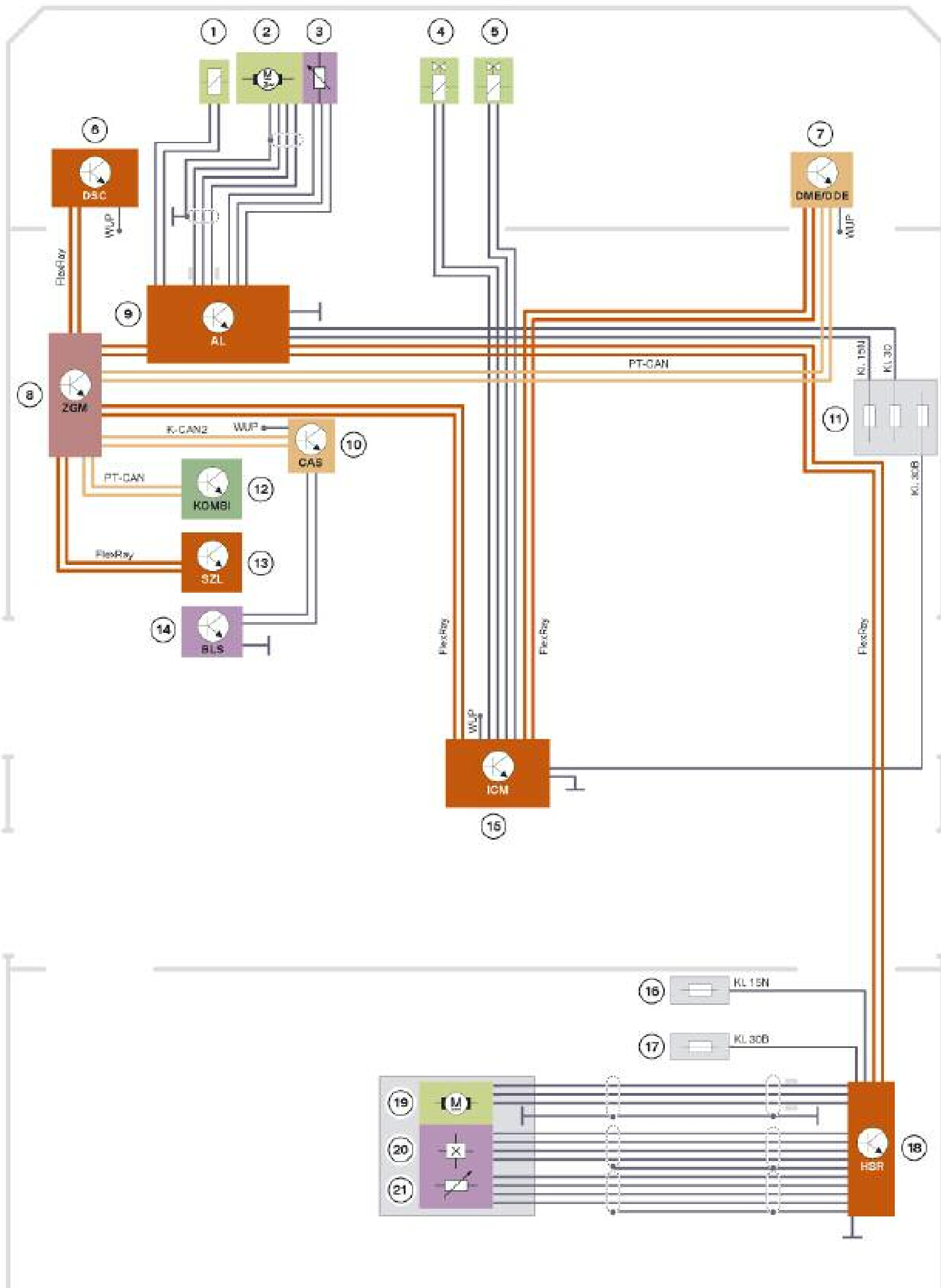
Index	Explanation	Index	Explanation
CAS	Car Access System	SZL	Steering column switch cluster
ZGM	Central Gateway Module	HSR	Rear-wheel steering control unit
DME	Digital Motor Electronics	AL	Active Steering
DSC	Dynamic stability control	ICM	Integrated Chassis Management

System Circuit Diagram for Servotronic System



Index	Explanation	Index	Explanation
1	Dynamic stability control	5	Central Gateway Module
2	Electronic volumetric flow control (EVV) valve	6	Steering column switch cluster
3	Servotronic valve	7	Front power distribution box
4	Digital Motor Electronics	8	Integrated Chassis Management

System Circuit Diagram for Integrated Active Steering



Index	Explanation	Index	Explanation
1	Active Steering lock	12	Instrument cluster
2	Active Steering electric motor	13	Steering column switch cluster
3	Active Steering motor angular position sensor	14	Brake light switch
4	Electronic volumetric flow control (EVV) valve	15	Integrated Chassis Management
5	Servotronic valve	16	Right rear power distribution box
6	Dynamic stability control	17	Battery power distribution box
7	Digital Motor Electronics	18	Rear suspension slip angle control
8	Central Gateway Module	19	HSR electric motor
9	Active Steering	20	Hall-effect sensor
10	Car Access System	21	Track-rod position sensor
11	Front power distribution box		

Functions

Steering Systems

Implementation of the Integrated Active Steering function has essentially been made possible by the new ICM system complex on the F01/F02.

The Servotronic function including valve control is also taken over by the ICM control unit. That steering control function is also influenced by the Driving Dynamics Control function.

Advantages of Integrated Active Steering:

- Extension of Active Steering (AL) by the addition of rear-wheel steering (HSR)
- Variable steering-gear ratio (steering angle amplification factor)
- Independent control of rear-wheel steering angle (steer by wire)
- Servotronic
- Handling stabilization functions
- Reduction of braking distance under split surface braking conditions.

Supply of Signals

Signals from external sensors

The ICM control unit reads the following signals that are essential to the Integrated Active Steering from external sensors:

- Four wheel-speed signals sent via Flexray by the DSC
- Steering angle sent via Flexray by steering column switch cluster
- Status of AL and HSR actuators transmitted via Flexray.

However, because the rear-wheels are steerable, the steering angle of the front wheels alone is not definitive for dynamic handling control purposes. Therefore, the ICM control unit also takes the steering angle of the rear wheels into account. Ultimately, the effective steering angle is calculated from the two steering angles (front and rear wheels). The effective steering angle indicates the angle to which the front wheels would have to be turned to bring about the same vehicle response without steerable rear wheels. That variable is the easiest for all vehicle systems to use to analyse the steering action.

Control and Modulation of Steering

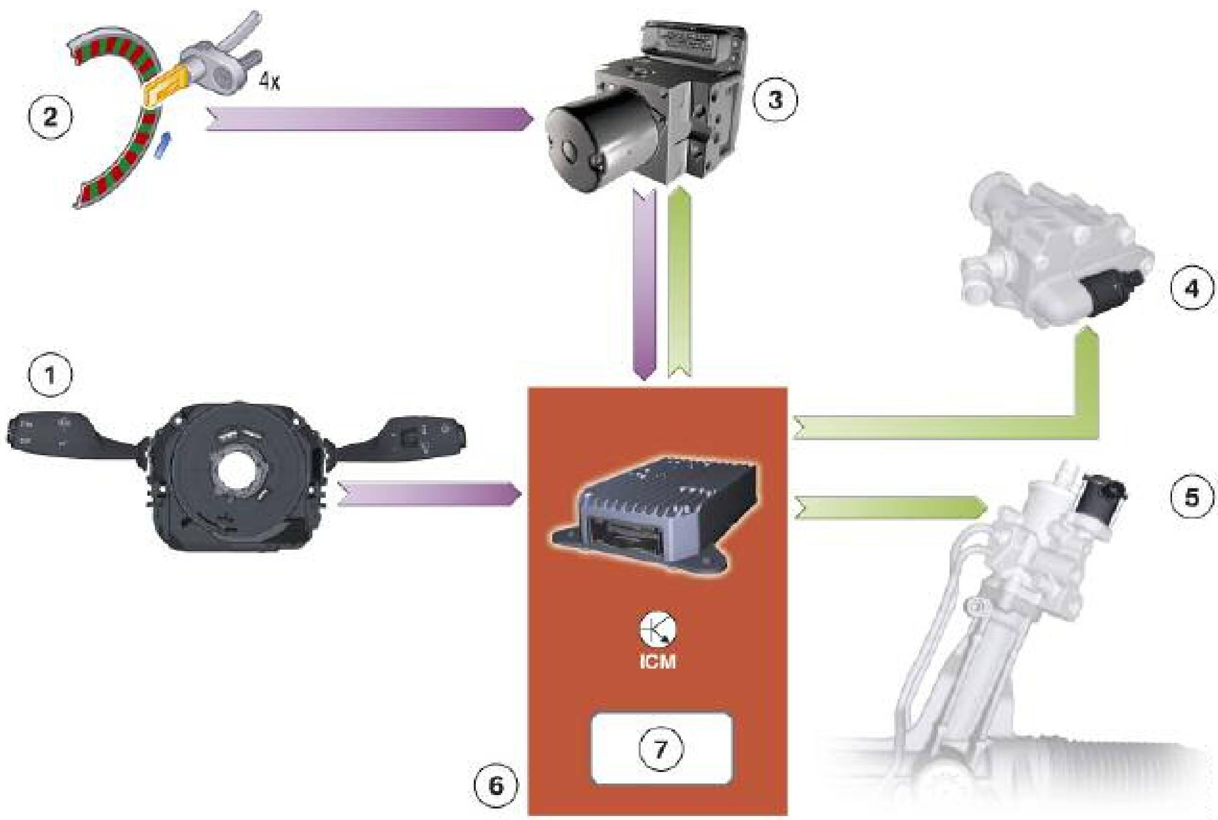
Both the basic steering system and the optional Integrated Active Steering on the F01/F02 incorporate the **Servotronic** function. That speed-sensitive power assistance function is effected by way of the Servotronic valve on the steering gear.

The Servotronic valve is always controlled by the ICM control unit regardless of the equipment options fitted. Accordingly, the Servotronic function algorithm is stored on the ICM control unit.

Similarly regardless of equipment options, the steering system also always incorporates a proportional control valve which is controlled by the ICM control unit. With the aid of that valve, the power steering pump's volumetric flow rate can be electronically adjusted. For that reason it is also referred to as the **"electronic volumetric flow control"** valve (EVV valve).

That valve too is controlled by the ICM control unit. Depending on the degree of power assistance demanded at the time, the volumetric flow rate delivered by the power steering pump is split between the steering valve and a bypass circuit. The ratio of that split can be infinitely varied. The less power assistance is required, the more hydraulic fluid is diverted into the bypass circuit. As the hydraulic fluid does not have to do any work in the bypass circuit, less power is required to drive the power steering pump. Consequently, the proportional control valve helps to **reduce** fuel consumption and **CO_2 emissions**.

Inputs/outputs: control of steering by ICM



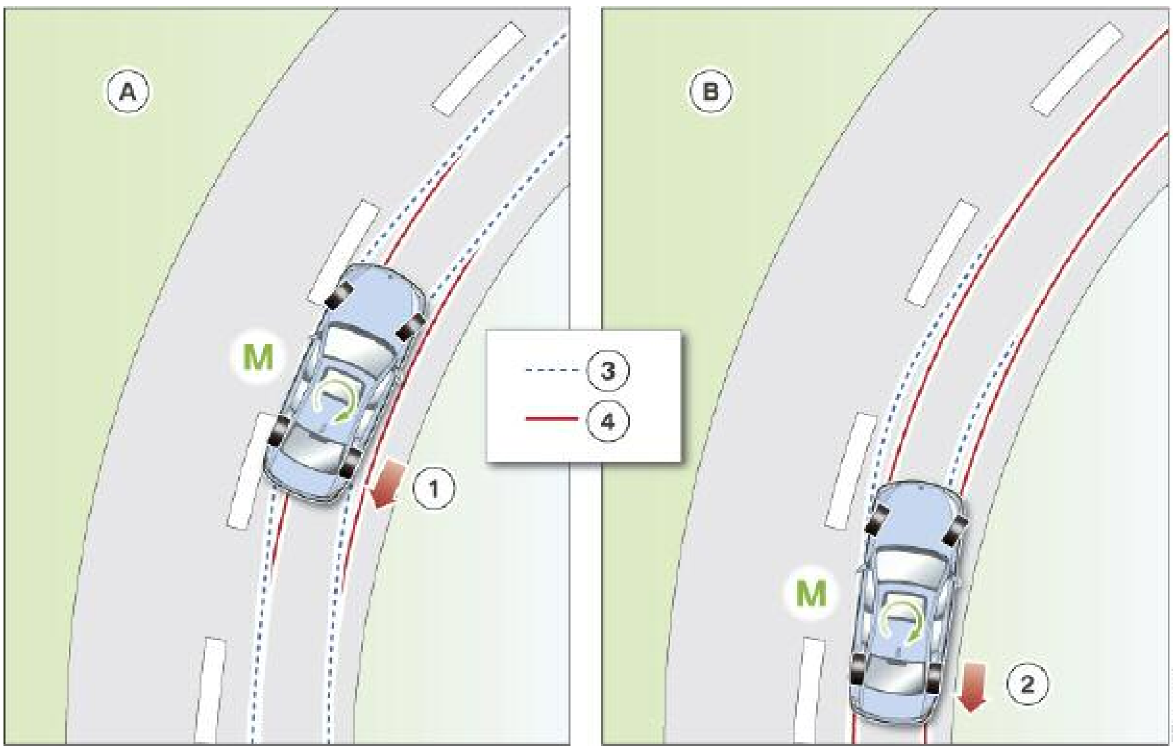
Index	Explanation	Index	Explanation
1	Steering column switch cluster	5	Servotronic valve
2	Wheel speed sensor	6	Integrated Chassis Management
3	Dynamic stability control	7	"Steering control" function on ICM
4	Electronic volumetric flow control (EVV) valve		

Higher-level Dynamic Handling Control

Centralized Dynamic Handling Control

The interventions by the dynamic handling control systems are performed with the aim of improving agility and traction. Quite obviously, they also re-stabilize the vehicle when required. On previous vehicles the various functions were performed by a number of discrete systems which, although they communicated with one another, nevertheless had strictly defined limits to their spheres of operation. Accordingly, the interaction of all systems which ultimately determines the overall handling response, was difficult to harmonize.

Influence on handling characteristics by dynamic handling control system



Index	Explanation
A	Correction of unstable handling
B	Early intervention to bring about neutral handling
1	Individual modulation of brakes to correct understeer
2	Individual modulation of brakes to prevent understeer
3	Course of an understeering vehicle
4	Course of a vehicle with neutral handling
M	Yaw force acting on the vehicle as a result of individual modulation of brakes

The Integrated Chassis Management system on the F01/F02 employs centralized dynamic handling control. It compares the vehicle response desired by the driver with the actual motion of the vehicle at that moment. By so doing, it is able to determine whether and in what way intervention in the dynamic handling systems is required.

The output variable of the centralized dynamic handling control system is a yaw force. It brings about a yawing motion on the part of the vehicle that is superimposed over the existing movement of the vehicle. In that way, the behavior of the vehicle can be “corrected” if a difference from what is desired by the driver is detected. The classic examples of that are vehicle understeer or oversteer.

A new feature of the ICM on the F01/F02, however, is that the dynamic handling systems are brought into action even before such a discrepancy is detected. Thus, the interventions by the dynamic handling systems take place long before the vehicle becomes unstable. As a result, the vehicle feels much better balanced than would be achievable with a conventional suspension and steering set-up. The vehicle displays neutral handling characteristics in many more situations and does not even begin to under or oversteer. This new function is made possible by very precise computation models and new control strategies by which the handling characteristics can be assessed and influenced.

Co-ordinated Intervention by the Dynamic Handling Systems

The possibilities for intervention available in the past (and, of course, still available now) in order to generate the required yaw force calculated by the central dynamic handling controller are listed below. In brackets in each case are the dynamic handling systems concerned.

- Modulation of individual brakes (DSC)
- Adjustment of engine torque (ASC+T, DSC, MSR)
- Adjustment of front-wheel steering angle independently of driver input (Active Steering).

Subordinate to the centralized dynamic handling control system is an “actuator coordination” function. It decides which dynamic handling system can be used to produce the yaw force in the particular situation concerned.

For example, if the vehicle is exhibiting significant understeer, it can be counteracted by controlled braking of the rear wheel on the inside of the bend. If the vehicle has Integrated Active Steering, the same effect can be brought about even more harmoniously by steering the rear wheels to an appropriate degree.

As both means of intervention are limited in their degree, it can also be useful to use them both simultaneously. Avoidance of understeer is noticeable to the driver in the shape of a significant gain in agility.

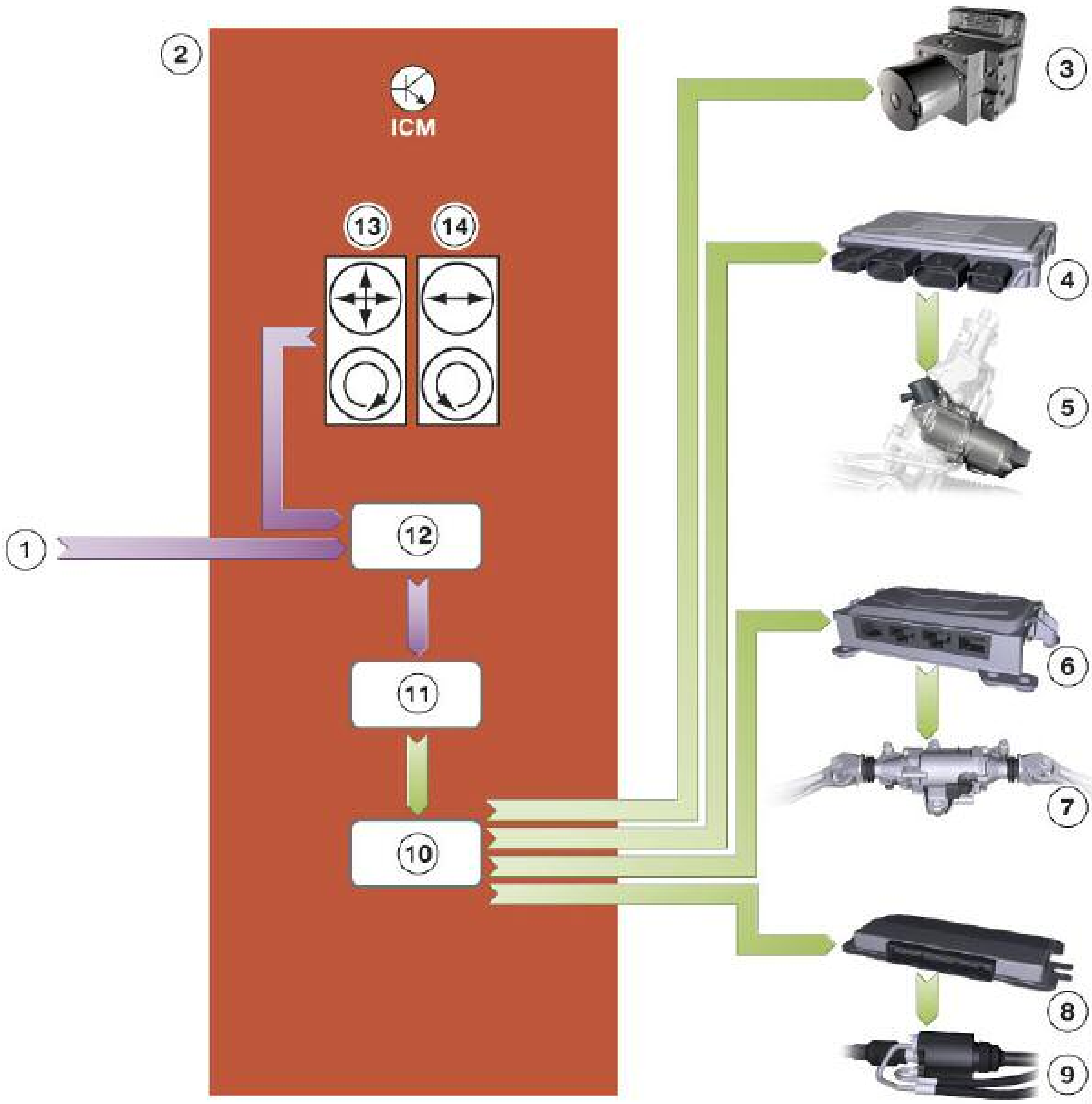
The F01/F02 is also the first model on which there is true functional networking between the Integrated Chassis Management and vertical dynamics management functions. But that doesn’t simply mean that the ICM registers the ride height data, processes it and passes to the VDM.

An integral component of the dynamic handling control system is that the ICM also actively initiates the Dynamic Drive function in order to affect the self-steering characteristics. As is familiar from conventional suspension and steering designs, a stiffer anti-roll bar results in a lower achievable overall lateral friction force at the pair of wheels concerned. The actuator motors in the Dynamic Drive anti-roll bars can be used to simulate the effect of stiffer and more flexible anti-roll bars.

Thus the ICM centralized dynamic handling control system can use the Dynamic Drive’s active anti-roll bars to selectively control the available lateral friction force at a pair of wheels. If the vehicle is oversteering, that means there is too little lateral friction force on the rear wheels. In that case, it is better to reduce the roll limiting force on the rear suspension. In return, there is a gain in lateral friction force on the rear wheels which helps to stabilize the vehicle.

The input/output diagram on the following page summarizes the effect of the centralized dynamic handling control functions on the ICM control unit.

Centralized dynamic handling control on ICM

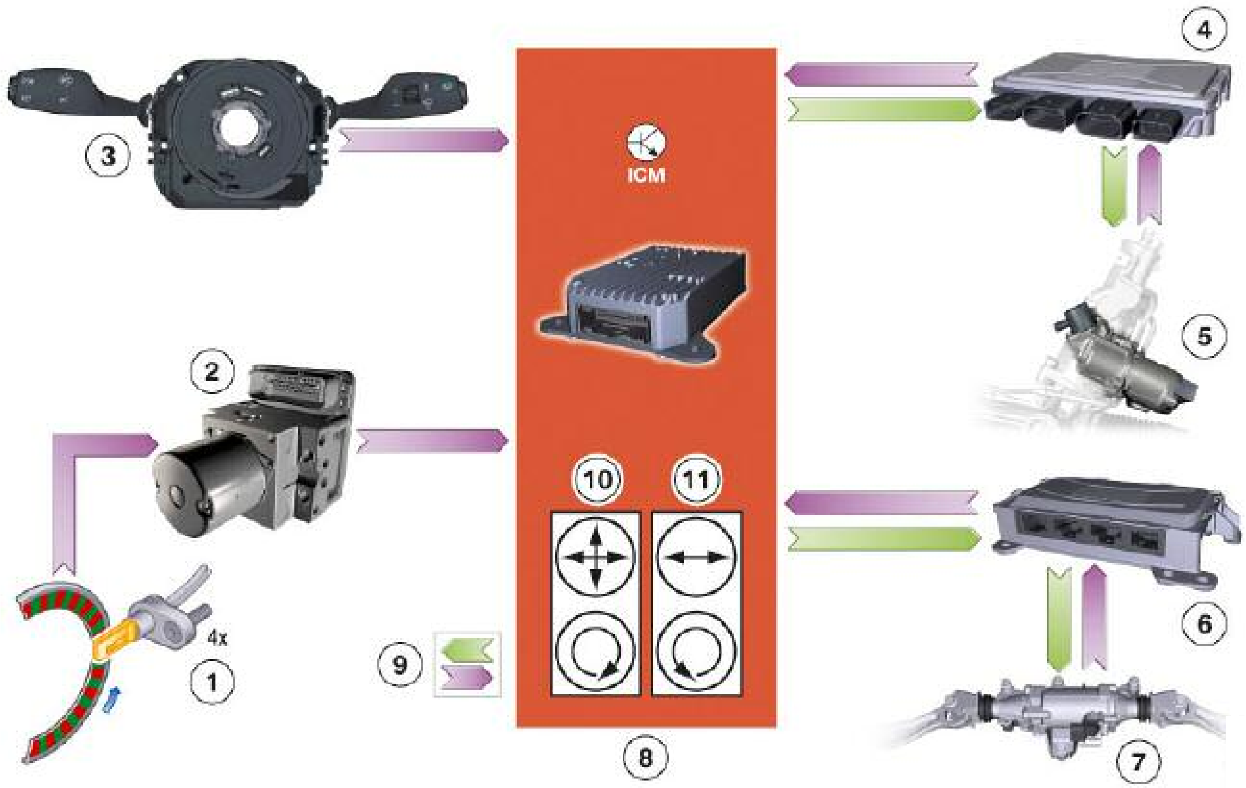


Index	Explanation	Index	Explanation
1	Input signals from external sensors	8	VDM control unit
2	Integrated Chassis Management (ICM)	9	Active stabilizer bar
3	Dynamic stability control	10	"Actuator co-ordination" function on ICM
4	Active Steering control unit	11	"Centralized dynamic handling control" function
5	AS actuating unit	12	"Sensor signal processing" function
6	HSR control unit	13	Integrated DSC sensor (combined linear acceleration, lateral acceleration and yaw rate sensor)
7	HSR actuator unit	14	Integrated DSC sensor (additional combined lateral acceleration and yaw rate sensor)

Distributed Functions: ICM and Actuator Control Units

The distribution of functions between the ICM and the other dynamic handling control units in the case of Integrated Active Steering is described below.

ICM and actuator control units AL and HSR



Index	Explanation	Index	Explanation
1	Wheel speed sensors	7	HSR actuator unit
2	Dynamic stability control	8	Integrated Chassis Management (ICM)
3	Steering column switch cluster with steering-angle sensor	9	Other input and output signals*
4	Active Steering control unit	10	Integrated DSC sensor (combined linear acceleration, lateral acceleration and yaw rate sensor)
5	AS actuating unit	11	Integrated DSC sensor (additional combined lateral acceleration and yaw rate sensor)
6	HSR control unit		

* Instrument cluster failure BLS-CAS braking DME engine torque increase.

The Integrated Chassis Management is the control unit which computes the higher-level dynamic handling control functions for the Integrated Active Steering.

From the current vehicle handling status and the desired course indicated by the driver, the Integrated Chassis Management calculates individual settings for the variable steering-gear ratio and the superimposed yaw rate. Once they have been prioritized, the ICM provides a required setting in each case for the AL and HSR control units. The setting specified is a required steering angle to be applied to the front and rear wheels respectively.

The AL control unit receives the required setting and has the main job of controlling the actuators so as to correctly apply the specified setting. Thus the AL Active Steering control unit is purely an actuator control unit. The same applies to the HSR control unit. It too is an actuator control unit. Like the AL control unit, it is responsible only for implementing the required steering angle specified by the ICM.

With the introduction of the ICM on the E71, this type of function distribution was used for the first time. On the F01/F02, it has been expanded to the extent that

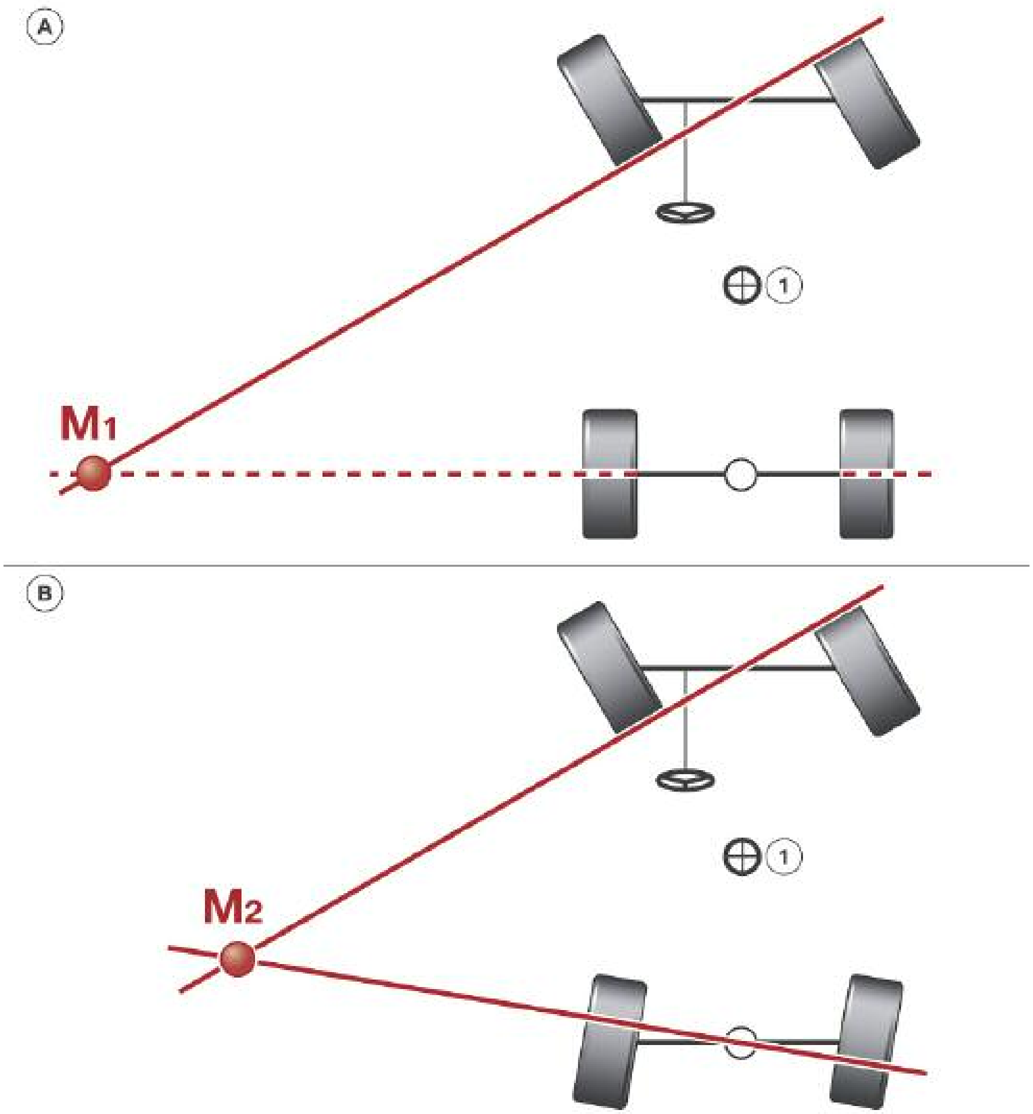
- the ICM now controls all linear and lateral dynamics systems (AL, HSR and also DSC) and
- the ICM is the master control unit both for linear dynamics and unstable handling situations.

The interface between the Integrated Chassis Management and the Dynamic Stability Control (DSC) represents a special case.

Functional Areas of Integrated Active Steering

Low Speed Range

The variable steering-gear ratio of the Active Steering component reduces steering effort to approximately 2 turns of the steering wheel from lock to lock. In the low speed range up to approximately 37 mph, the variable steering-gear ratio for the front wheels is combined with a degree of opposite rear-wheel steer. The effect is to increase vehicle agility.

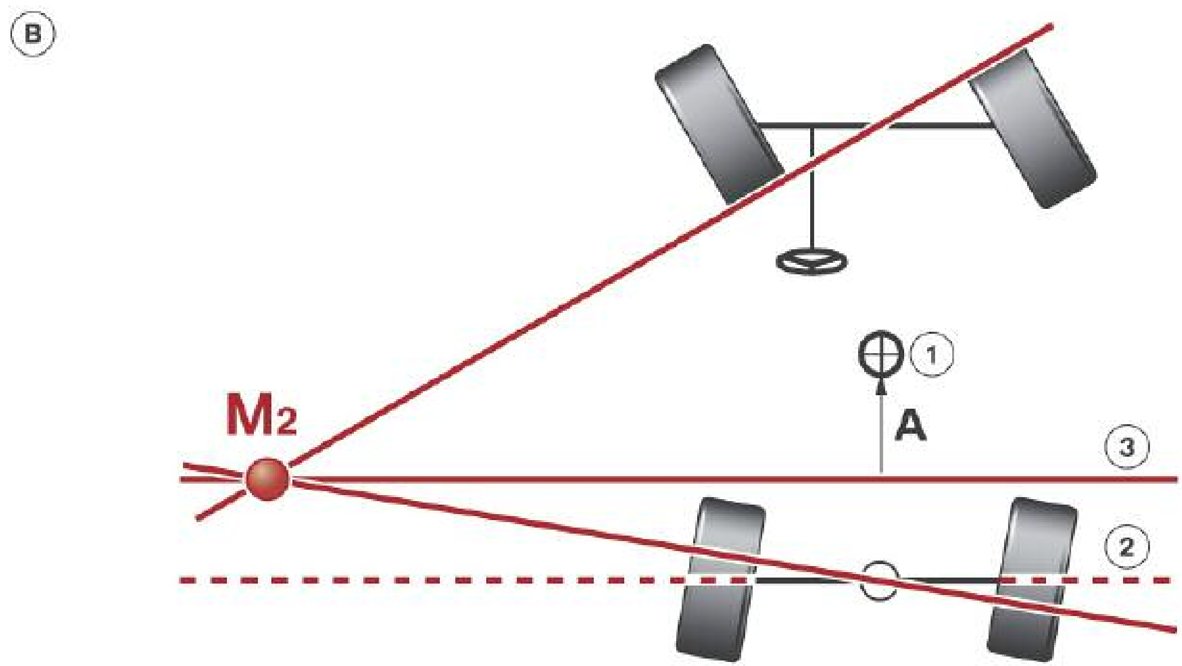


Index	Explanation	Index	Explanation
A	Conventional steering system	M2	Momentary axis 2
B	Integrated Active Steering	1	Center of vehicle
M1	Momentary axis 1		

When the steering wheels of a vehicle are turned, it follows a curved path around what is called the momentary axis “M”.

In the case of conventional vehicles, that momentary axis is positioned at a point along the extension of a line passing through the center of the rear wheels.

Active Steering intervention turns the rear wheels in the opposite direction at speeds up approximately 37 mph.



Index	Explanation	Index	Explanation
A	Effective wheelbase reduction	1	Center of vehicle
B	Integrated Active Steering	2	Straight line through Center of rear wheels
M2	Momentary axis 2	3	Axis of rotation closer to center of vehicle

The consequence of the rear-wheel steering intervention is that the axis of rotation moves closer to the center of the vehicle with the same amount of steering effort.

In terms of agility and dynamic handling, that is equivalent to a vehicle with a shorter wheelbase.

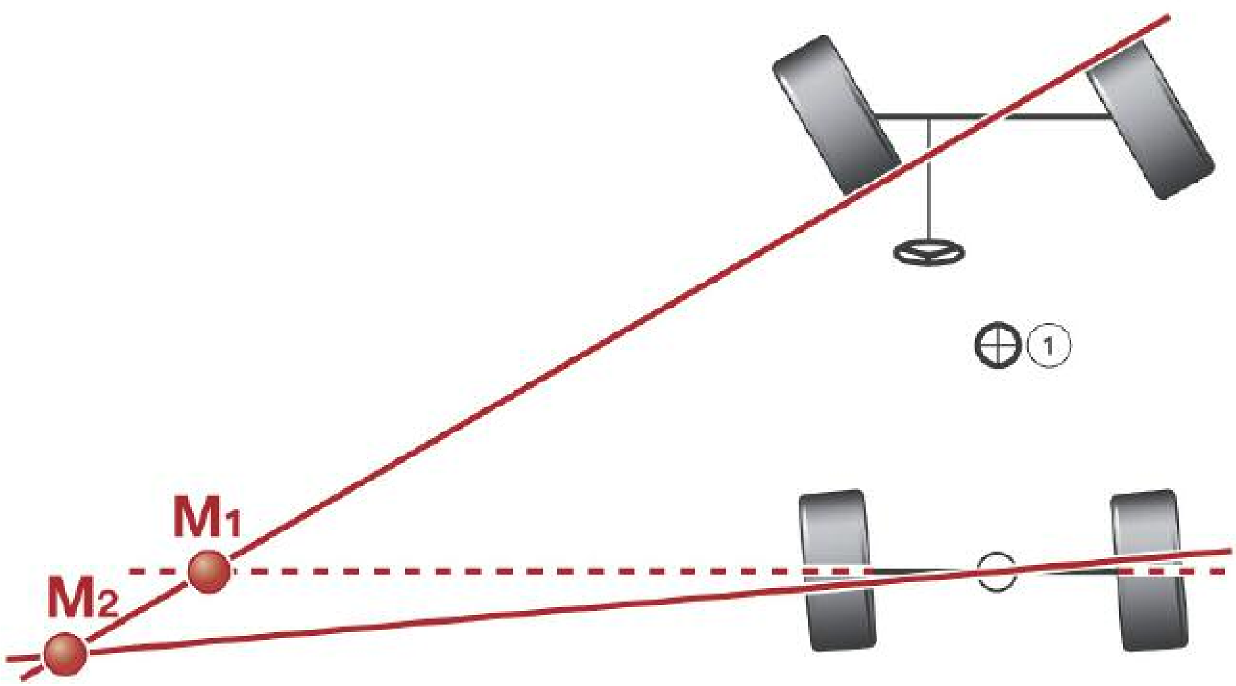
High Speed Range

As the vehicle speed increases, the degree of steering angle amplification by the Active Steering component is reduced. The steering-gear ratio becomes less direct.

At the same time, the steering strategy adopted by the Integrated Active Steering changes. Whereas, at low speeds, the rear wheels are steered in the opposite direction to the front wheels, at higher speeds the rear wheels are steered in the same direction as the front.

The momentary axis moves further back, equivalent to a vehicle with a longer wheelbase, producing more stable straight-line handling. The radius of the curve becomes longer.

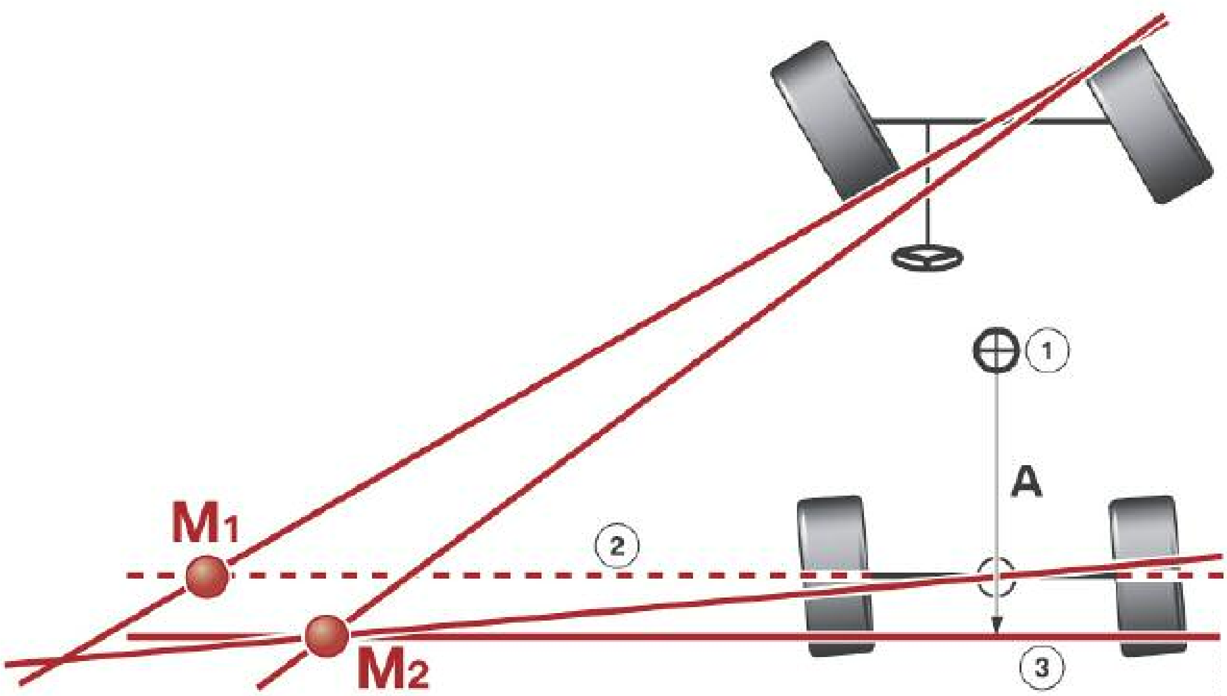
By the combination with the Active Steering, an additional amount is added to the steering angle of the front wheels so that the radius of the curve and the required amount of steering lock remain at the familiar level.



Index	Explanation	Index	Explanation
M1	Momentary axis 1	1	Center of vehicle
M2	Momentary axis 2		

All in all, co-ordination of the steering interventions at front and rear makes lane changes and steering maneuvers considerably easier to negotiate without sacrificing agility or balance.

Combination of the Active Steering with the new rear-wheel steering system offers benefits for the driver at all speeds.



Index	Explanation	Index	Explanation
M1	Momentary axis 1	1	Center of vehicle
M2	Momentary axis 2	2	Straight line through center of rear wheels
A	Effective wheelbase increase	3	Axis of rotation further from center of vehicle

Handling Stabilization by Integrated Active Steering When Understeering

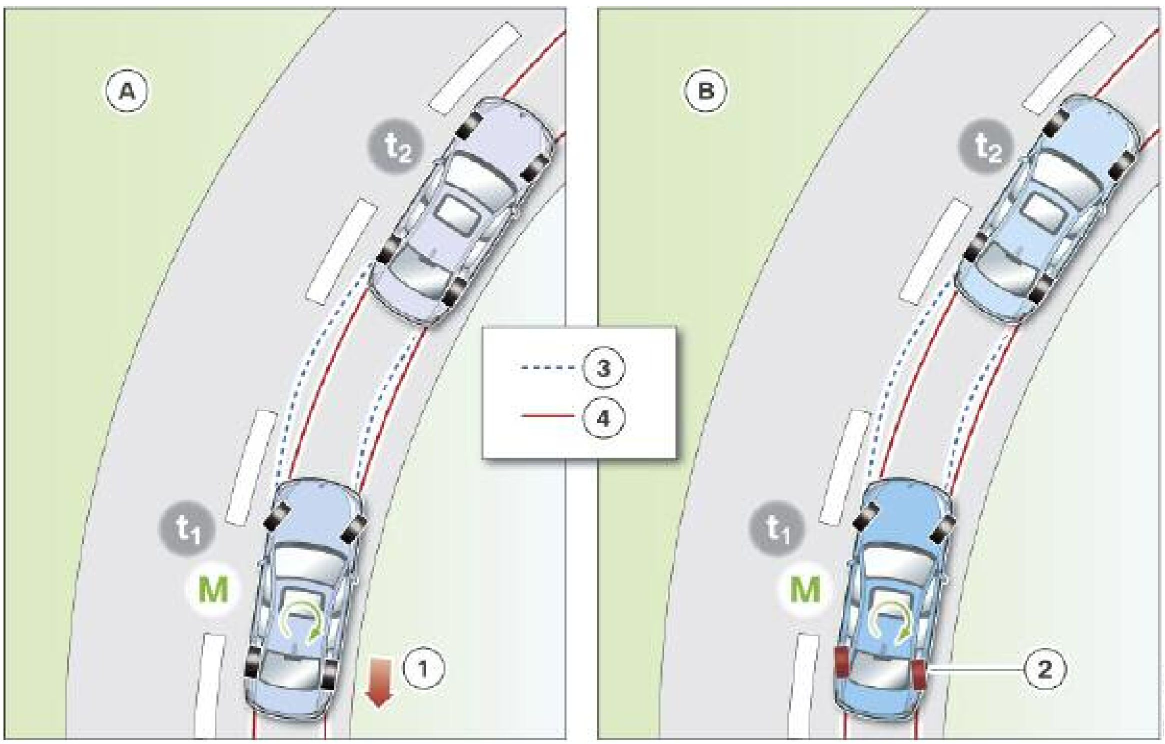
When changing lanes quickly, all vehicles have a tendency to produce a significant yaw response and can sometimes start to oversteer.

If the ICM dynamic handling controller detects a difference between the response desired by the driver and the reaction of the vehicle, it initiates co-ordinated steering interventions on the front and rear wheels. The speed of the stabilizing intervention is such that it is hardly discernible by the driver.

Braking interventions by the DSC, which have a decelerating effect, can be largely dispensed with.

The end result is that the vehicle is more stable and more effectively damped.

Possible dynamic handling interventions when understeering



Index	Explanation
A	Prevention of understeer by individual brake modulation (DSC)
B	Prevention of understeer by rear-wheel steering intervention (IAL)
1	Individual brake modulation (DSC)
2	Rear-wheel steering intervention (IAL)
3	Course of an understeering vehicle
4	Course of a vehicle with neutral handling
M	Yaw force acting on the vehicle as a result of dynamic handling system intervention

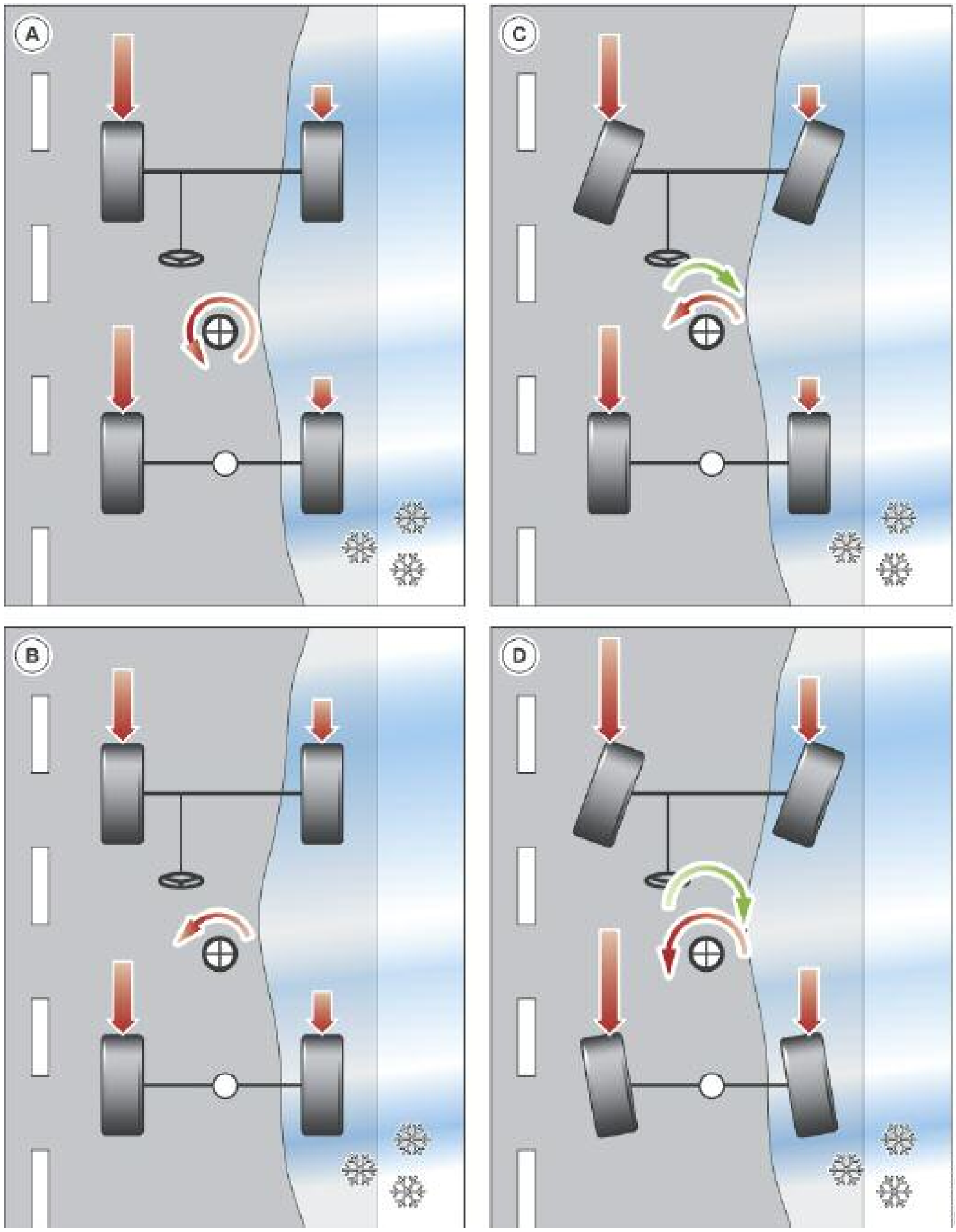
If the driver underestimates how sharp a bend is when driving quickly on a country road, he/ she can be caught out by sudden understeer.

By virtue of its inherent features, Active Steering was only able to react to vehicle oversteer.

Integrated Active Steering incorporating active rear-wheel steering is now also able to make corrective interventions when the vehicle is oversteering and thus further increases active safety.

Handling Stabilization by Integrated Active Steering Under Split Surface Braking Conditions

Hard braking on road surfaces which provide less grip for the wheels on one side of the vehicle than on the other causes the vehicle to yaw towards the side with more grip.



Index	Explanation	Index	Explanation
A	Vehicle without DSC	C	Vehicle with DSC and AL (yaw force compensation on E90)
B	Vehicle with DSC	D	Vehicle with DSC and Integrated Active Steering

Under emergency braking, the driver of a conventional vehicle then has to correct the vehicle's course.

Under such split surface braking conditions, the dynamic handling controller generates a stabilizing yaw force by opposite steering interventions on the front and rear wheels.

A) Without DSC
In the case of a vehicle without DSC, maximum braking effect is achieved by the wheels on the dry side of the road, while those on the wet or icy side produce very little retardation.

As a result, a very substantial yaw force acting in an counterclockwise direction is produced, causing the vehicle to swerve to the right.

B) With DSC
A vehicle equipped with DSC brakes the individual wheels more sensitively in order to keep the yaw force within manageable limits for the driver, which however, slightly increases the braking distance.

C) With DSC and AL
The additional "yaw force compensation" function represents a significant safety feature.

When braking on road surfaces with differences in frictional coefficient between one side of the vehicle and the other (tarmac, ice or snow), a turning force is generated around the vehicle's vertical axis (yaw force) rendering the vehicle unstable. In such cases, the DSC calculates the required steering angle for the front wheels and the Active Steering implements it by actively applying opposite lock.

As a result, an opposing yaw force around the vertical axis is generated, "compensating" for the original yaw force (cancelling it out, i.e. the vehicle is stabilized by intelligent co-ordination of DSC brake modulation and AL steering, constituting a safety feature unique in this class of vehicle).

D) With DSC, dynamic handling controller and Integrated Active Steering
Under such split surface braking conditions, the dynamic handling controller generates a stabilizing yaw force by opposite steering interventions on the front and rear wheels.

That counteracts the slewing of the vehicle caused by the uneven braking forces.

At the same time, maximum braking force can be applied in order to achieve a short braking distance.

Integrated Active Steering is a logical development from the Active Steering systems. The functions of the systems complement each other perfectly, taking the driving experience to a new dimension.

Integrated Active Steering Special Function

Quite obviously, Active Steering systems must not be capable of being switched on or off by the driver.

In the case of Integrated Active Steering, there is a special feature in that regard because if snow chains are fitted to the rear wheels, Active Steering of the rear wheels must be disabled.

When snow chains are fitted, the rear-wheel steering is deactivated in order to ensure that the wheels are always free to rotate.

Automatic snow-chain detection assists the driver and indicates the detected status on the Control Display. This does not remove the responsibility for manually changing the setting.

Control display message

When show chains are used, the setting on the iDrive Settings menu must be changed to “Show chains fitted”.

If the maximum speed of 50 kph (31mph) for driving with snow chains is exceeded, the rear-wheel steering is reactivated regardless of the “Snow chains fitted” setting.

Automatic snow chain detection

It is possible to detect from the wheel-speed sensor signals a characteristic pattern produced by the motion of the wheel when show chains are fitted (only with BMW-approved show chains). From that characteristics signal pattern, the control unit is able to detect whether show chains are fitted on each individual wheel.

System Components

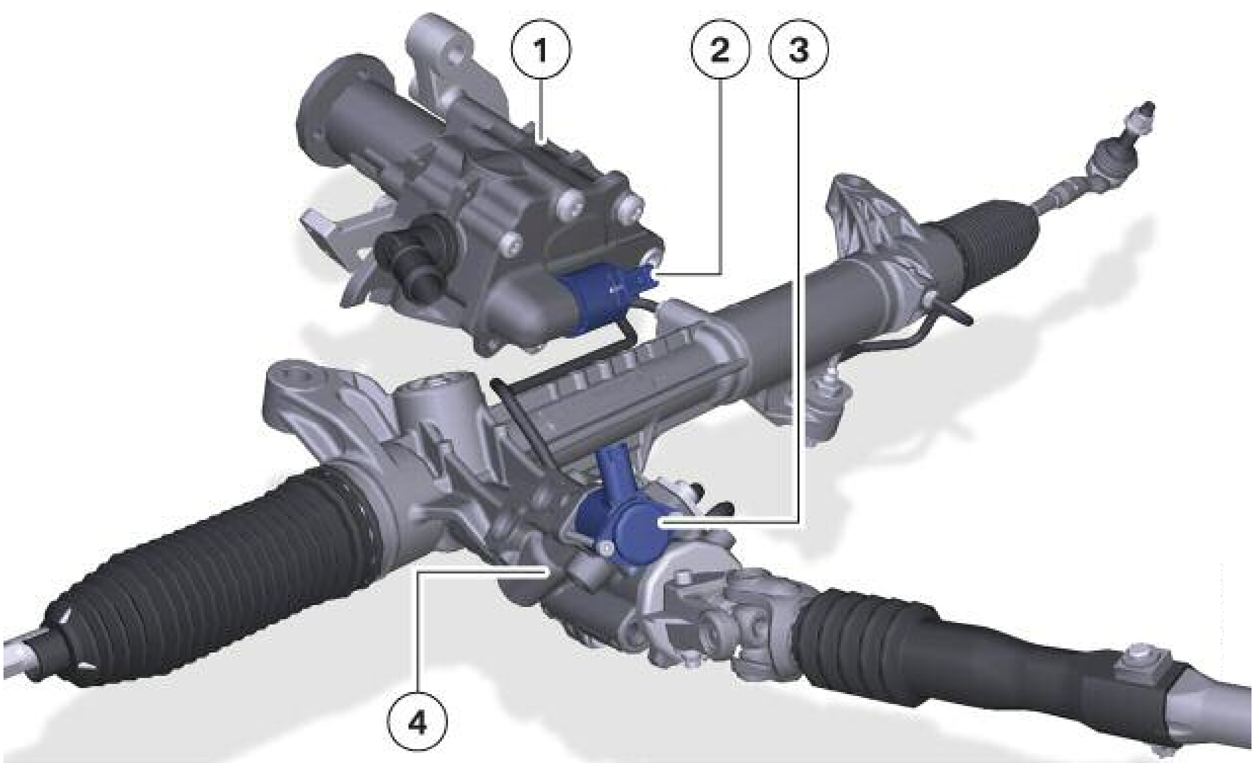
Steering Systems

There are two lateral dynamics systems available on the F01/F02:

- Servotronic
- Integrated Active Steering

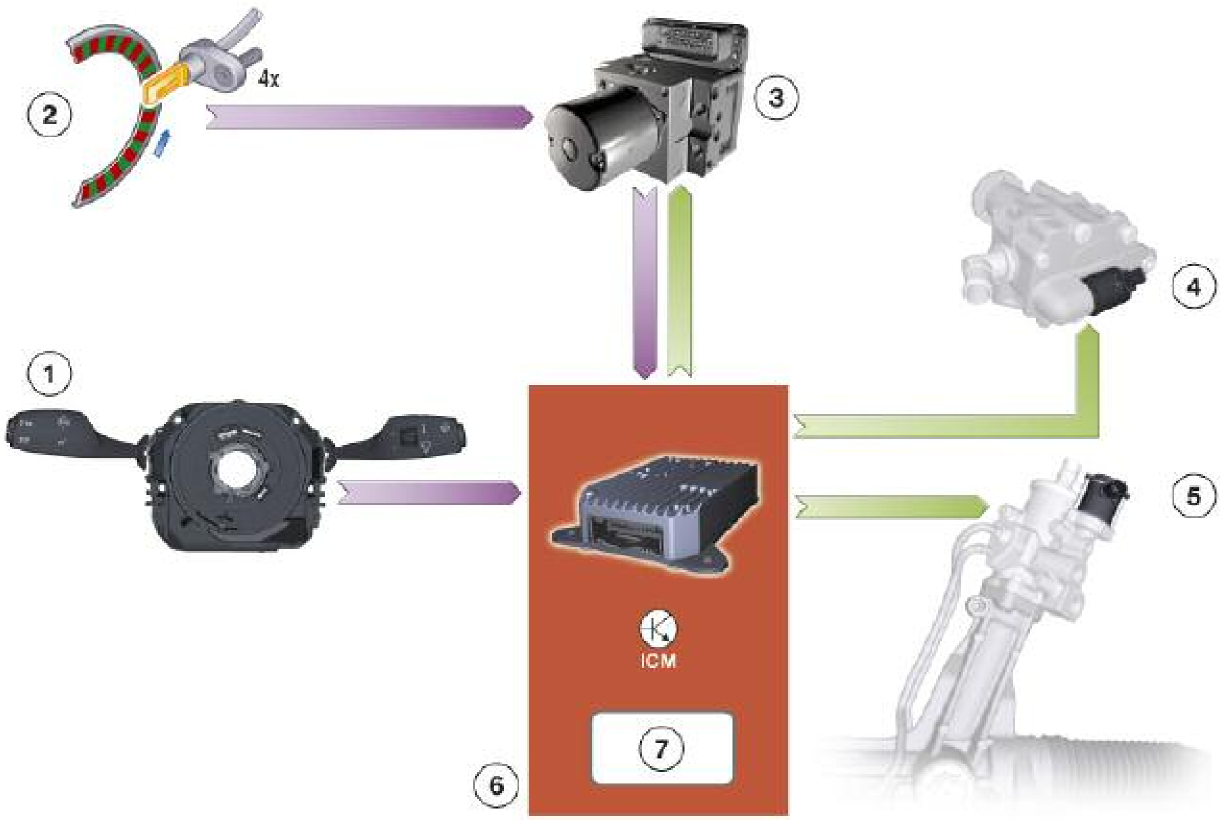
Servotronic Components

The proportional valve for electronic volumetric flow control (EVV valve) and the Servotronic valve are directly controlled by the ICM regardless of whether the Servotronic or Integrated Active Steering is fitted.



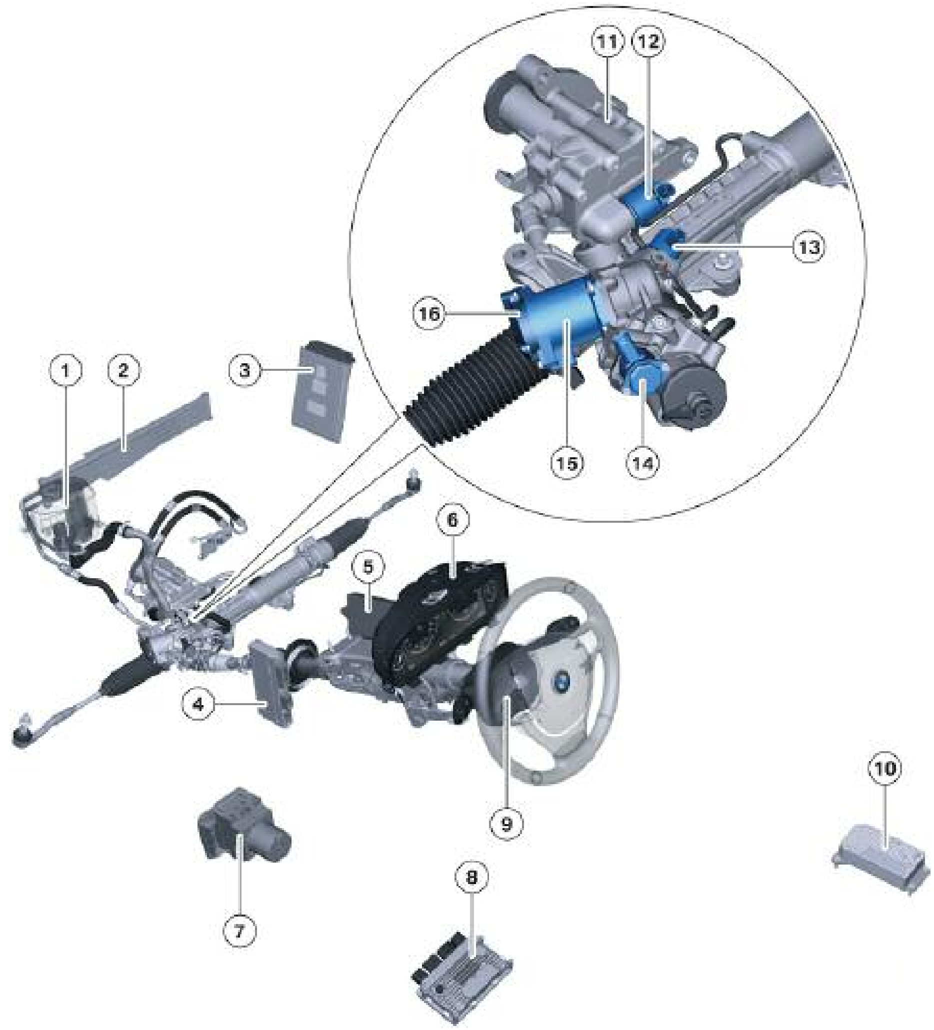
Index	Explanation	Index	Explanation
1	Hydraulic pump	3	Servotronic valve
2	Electronic volumetric flow control valve (EVV valve)	4	Hydraulic power steering control valve body

Inputs/outputs: control of steering by ICM



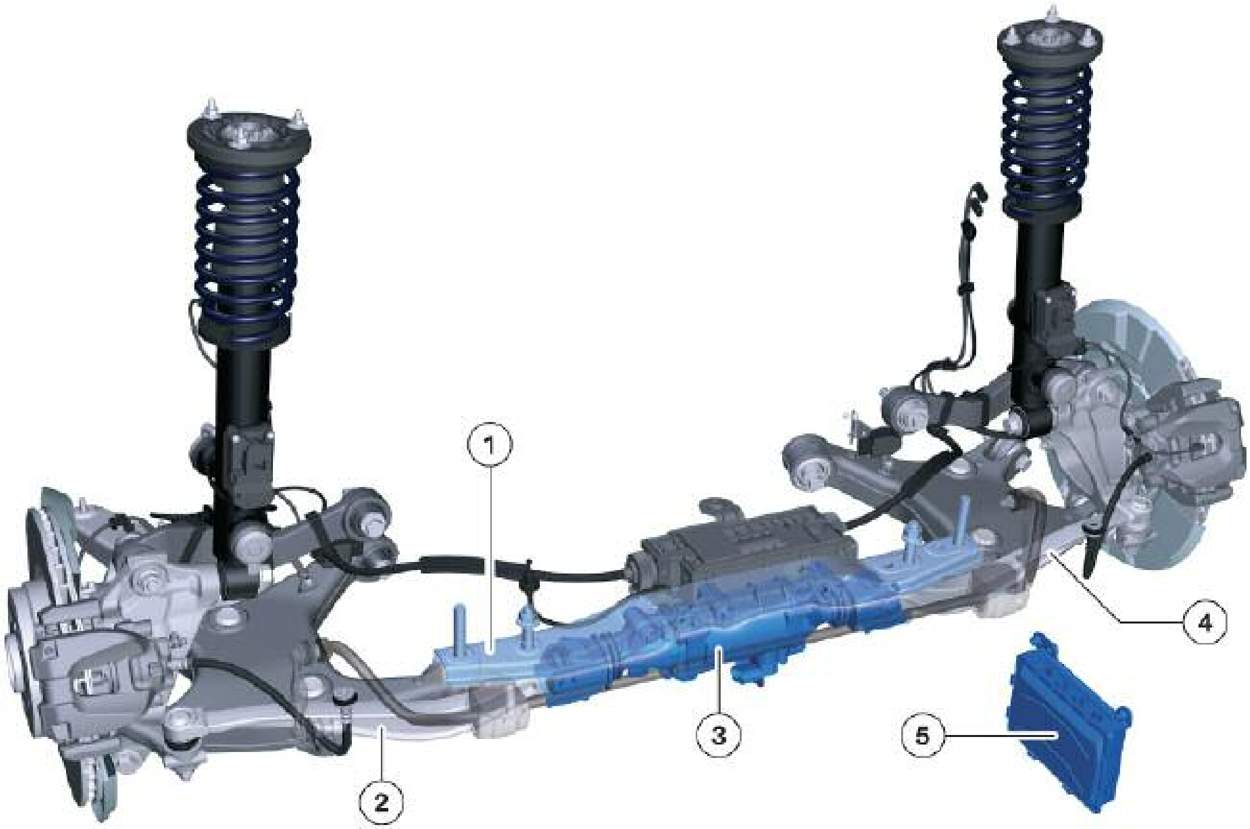
Index	Explanation	Index	Explanation
1	Steering column switch cluster (SZL)	5	Servotronic valve
2	Wheel speed sensor	6	Integrated Chassis Management (ICM)
3	Dynamic stability control (DSC)	7	"Steering control" function
4	Electronic volumetric flow control (EVV) valve		

Components of Integrated Active Steering



Index	Explanation	Index	Explanation
1	Hydraulic fluid reservoir	9	SZL
2	Power steering cooler	10	ICM
3	DME	11	Hydraulic pump
4	ZGM	12	Electronic volumetric flow control (EVV) valve
5	CAS	13	Lock
6	Instrument cluster	14	Servotronic valve
7	DSC	15	Actuator unit electric motor
8	AL	16	Motor angular position sensor

Location of HSR actuator on rear suspension



Index	Explanation	Index	Explanation
1	Mounting plate	4	Right track rod
2	Left track rod	5	HSR control unit
3	HSR actuator		

The special actuator on the rear suspension is fixed underneath a mounting plate on the rear suspension subframe.

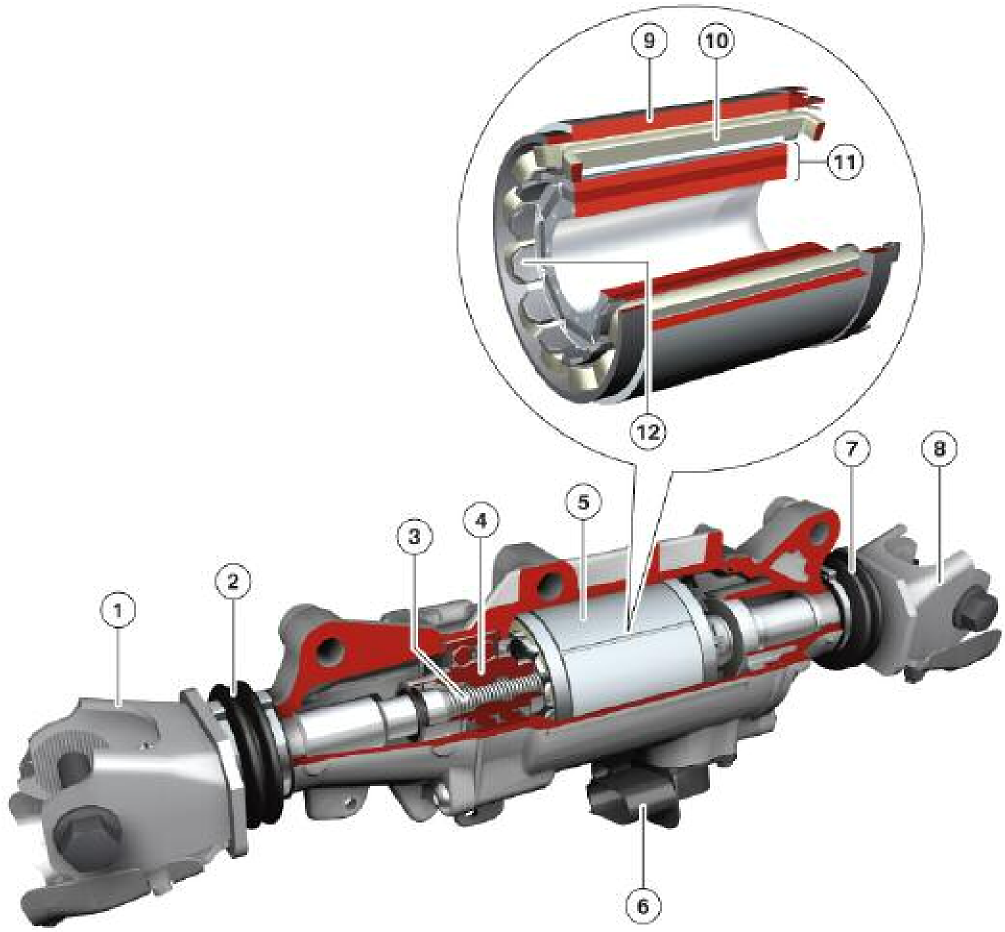
The electromechanical actuator is positioned between the two new track rods of the Integral V rear suspension. The rear-wheel steering system has its own actuator control unit which is responsible for controlling and monitoring the actuator.

It was previously the state of the art that control systems were largely independent of one another.

On the F01/F02, the Integrated Chassis Management (ICM) system brings the separate systems together.

A central ICM control unit in the ICM architecture replaces the previous dynamic handling sensors and forms a central dynamic handling controller.

HSR actuator



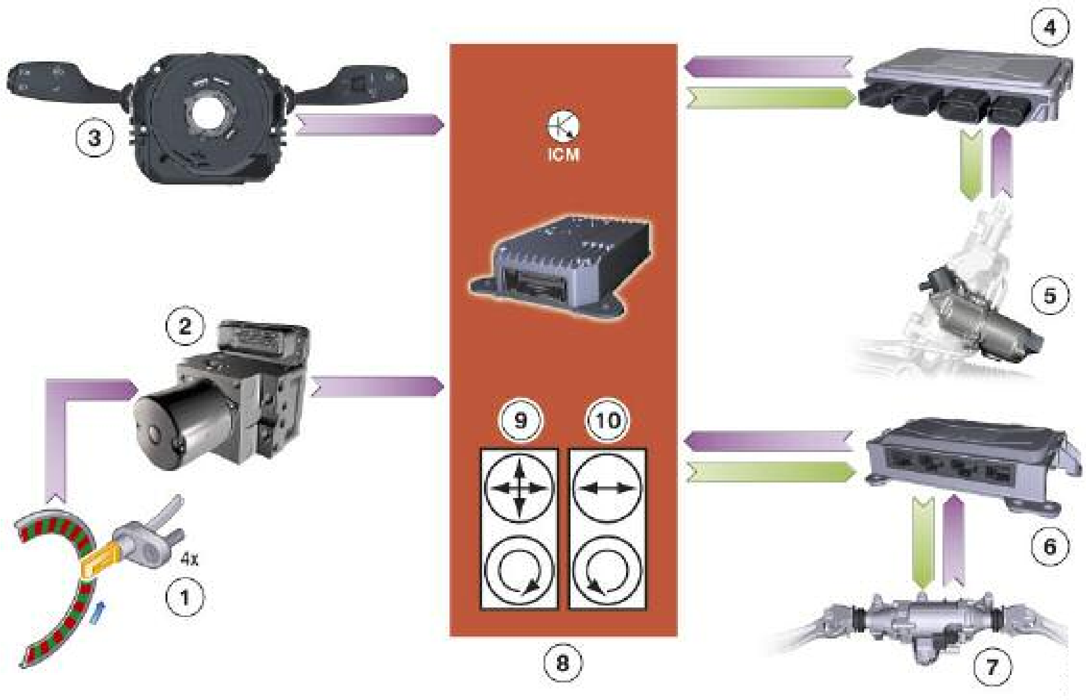
Index	Explanation	Index	Explanation
1	Left track rod joint	7	Right shaft gaiter
2	Left shaft gaiter	8	Right track rod joint
3	Worm shaft	9	Iron jacket
4	Worm nut	10	Winding stator
5	Electric motor	11	Permanent magnet
6	Electrical connector	12	Carrier/armature winding iron core

The electromechanical actuator essentially consists of an electric motor which moves the two track rods by means of a worm-and-nut steering gear.

The actuator is designed for a maximum travel of ±8 mm, which brings about a maximum steering angle of ±3 ° at the roadwheel.

The worm-and-nut rear-wheel steering gear is self-inhibiting. That means that if the system fails, the vehicle adopts exactly the same handling characteristics as a vehicle without rear-wheel steering.

Components and system complex for Integrated Active Steering



Index	Explanation	Index	Explanation
1	Wheel speed sensors	6	HSR control unit
2	DSC	7	HSR actuator unit
3	SZL with steering-angle sensor	8	ICM
4	Active Steering control unit	9	DSC sensor in ICM (linear acceleration, lateral acceleration and yaw rate sensor)
5	AS actuating unit	10	Back-up DSC sensor in ICM (lateral acceleration and yaw rate sensor)